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Maurice Loewy
1833–1907

Popular Astronomy.

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MAURICE LOEWY.

French astronomy having already suffered great losses has just met with one more, one of the most irreparable that could occur. Monsieur Loewy, director of the Paris Observatory, fell a victim to a sudden illness from which he did not recover. He died at the height of his activity, in full possession of his powers, without his arduous zeal ever having slackened. It is, no doubt, the death he would have wished, one which allowed him to work up to the last minute; for enforced repose would have been for that indefatigable worker a dreadful punishment.

Maurice Loewy was born at Vienna, April 15, 1833; it is there that he studied, that he began to observe, that he had his first works printed. His first publications have for their subject the calculation of the orbits of comets and of small planets; he calculated the ephemerides of several comets, among others of the celebrated comet of Donati. The work in this line to which he devoted the most time is the theory of the planet Eugenia to which he returned several times and for which he finally obtained very exact elements by using three normal places corresponding to three consecutive oppositions and by taking account of the perturbations.

These first researches had attracted the attention of Le Verrier; in Austria at this time the Jews were not treated on an equal footing, and Loewy feared lest his career be trammelled on that account. Le Verrier made offers to him and he accepted them. He entered the Observatory of Paris August 15, 1860, and one year later he was appointed associate astronomer. Le Verrier knew how to discover young talents, to encourage them and to attract them; perhaps having once attracted them he did not continue his encouragement with enough perseverance.

In France Loewy continued his researches in the orbits and introduced improvements in the method of Olbers so as to make it more easily applicable when the three observations are not very near together. In collaboration with Tisserand he also calculated the orbit of the planet Dike, which had been lost for four years. But the field of his activity was quickly enlarged, and he turned his attention to the detailed study of the instruments. It was he who was appointed to draw up for the *Annales de l'Observatoire* instructions about the use of the equatorials; one finds in this statement the same care for exactness and precision which was to distinguish him later.

He had been serving France for nine years when he was admitted to the great naturalization of 1869. Our country has always known how to attach to herself her adopted sons, who were not the least devoted of her children. Scarcely a year later Paris was invaded by the enemy, and Loewy had to defend his new country upon the ramparts of the capital. The dangers braved for France finished the work of making him a Frenchman. Since then he has liberally paid his debt to France in giving to her forty-seven years of persistent labor and in giving her also valiant sons who, following the example of his life, should become useful workers and good citizens. His writings and especially his work of observation have won for him the esteem of all the scholars, and they proved it to him by making him a member of the Academy of Sciences in 1873. The preceding year he had been appointed a member of the Bureau of Longitudes. These new functions would cause him much work; but an increase of work had never frightened him. For fifteen years with Admiral Mouchez, he was busy with the direction of the observatory of the Bureau of Longitudes, which was installed in the Park Montsouris for the astronomical instruction of sailors and explorers. During thirty years he directed the computers of the Bureau of Longitudes, a work which demands incessant verifications and constant supervisions. He took the interests of these modest co-laborers to heart and defended them valiantly, sometimes at the risk of getting into a quarrel with the managers of the administration who no less legitimately, were preoccupied in managing our finances.

It was thus that he edited more than thirty volumes of the *Connaissance des Temps*; he wanted this ephemeris to remain superior to all similar publications and he continually introduced improvements in it; planned far many more and he was restrained only by the narrow limits of the meagre budget of the Bureau, importunate hindrances which he endured with impatience. And that was not all; it was he who took charge of the astronomical part of the *Annuaire du Bureau des Longitudes* and who unceasingly revised it; it was he who edited the ephemerides of the stars of lunar culmination which this Bureau published every year as long as its financial resources permitted and finally it was he who almost entirely filled the first volume of the *Annales* with original articles. We see in how many different ways and with what perseverance he co-operated with the learned body which had just called him into its circle.

In 1871 Loewy proposed a new form of equatorial which he was to realize later and from which he was to derive great advantage. It is well-known how laborious is the use of the ordinary equatorial, what continual gymnastics it demands of astronomers. Without doubt their devotion to science is great, and they would not mind the fatigue of it were it not to detract from the value of their observations; but it is clear that this is not the case and that a tired observer will do less satisfactory work. It was these considerations which determined Loewy to invent the equatorial coudé. By means of two reflections by plane mirrors, a luminous ray starting from any point whatever in the heavens he turned into a fixed direction, that of the polar axis. Comfortably seated in an arm-chair and without moving, the astronomer can successively bring into his field of vision any star whatever by operating two little hand-levers placed within his reach. He can even warm himself, which for an astronomer is an unheard-of comfort. To these advantages are added those which result from the great focal distance.

There are also some drawbacks; one may fear lest the plane mirrors cause a loss of light, lest they get out of shape on account of the deflection or the temperature; lest in this double tube, unequally heated, there be produced currents of air or undulations. In fact, at certain times the images may appear a little wavy; but by taking certain precautions learned from experience, astronomers have succeeded in decreasing these disadvantages, and in practice they have proved to be less serious than was feared at first. Two instruments of this kind have been set up in the gardens of the Observatory; it is one of these which was used for the photograph of the Moon with the results already known. The bent equatorial also lends itself readily to the adaptation of the spectroscopes which when they are somewhat heavy it is often difficult to arrange suitably in the awkward position at the end of a long tube.

Monsieur Loewy did not confine himself to having the instrument constructed, he established the theory of it and determined, in collaboration with M. Puiseux, the effects of flexure on this complicated system.

The flexure in the meridian instruments also attracted his attention; it exerts a perceptible influence in the measures of declination, and its effects are not to be overlooked even in the measures of right ascension if one wishes to carry precision to its extreme limits; for one can never be assured that the symmetry of the apparatus is perfect and that there is no lateral flexure. Hence the necessity of a direct determination of these flexures. But this determination was difficult; Loewy devised an ingenious apparatus for this purpose and, with the collaboration of Périgand, he applied it to the Bischoffsheim meridian circle. A glass disk cut on four faces is placed inside the tube at the intersection of the optical axis and the axis of pivots; this makes it possible to bring upon the reticule three images at will: the reflected image of the threads of the reticule, that of the marks written on the objective and that of the divisions of a plate adjusted in the axis of the pivots.

The comparison of these numerous images permits of many verifications which are a valuable proof of exactness; it also gives the longitudinal and lateral flexures in the different positions of the telescope. It gives something more still; in the theory of the meridian telescope it is supposed that the pivots are perfect cylinders of revolution, and in fact the makers accomplished this with great exactness. But in sciences of observation the postulates should be submitted to constant revision, for they cease to be acceptable in proportion as people become more exacting and demand more precision. It became necessary to determine the exact form of the pivots. The apparatus of Loewy furnished the means for it several years before M. Hamy had given the splendid solution of this problem which is now known.

I will add to these works those that he did more recently on this same circle in collaboration with M. Renan. Inexplicable anomalies had been noted; the readings made on the right circle and on the left gave different results and the differences had a systematic character. Studies were undertaken to discover the cause; the differences were attributed successively to a flexure of the radii of the circles, and to a torsion of the axis; but these different explanations had to be given up and the real cause was finally found in the manner in which the lines of the division were illuminated; then this fact, which might have passed unnoticed for a long time, could be remedied. Loewy did not neglect the slightest detail in his study of the instruments; he knew how small a thing it takes to alter their readings.

I now come to a very ingenious method which may be used to determine on the one hand the constant of refraction, on the other that of aberration. These two phenomena both have the effect of varying the apparent angular distance between two fixed stars. The problem then in both cases is to measure the small variations of this angular distance.

But until recent times this measure had not been made directly and one was limited to determining the positions of the two stars to be compared by using meridian observations. The result was, for instance, that one must take account of the uncertainty in the nutation, and in general of every error in the position of the equator and of the ecliptic which serve as planes of reference. One was deprived also of all the advantages of differential processes. Unfortunately, it seemed that these processes could not he applied, since the two stars whose distance was in question were always so far separated the one from the other. Loewy conceived the idea of bringing the two images nearer together by having them reflected upon the two faces of a prism placed before the objective. What was most remarkable was, that errors which might have arisen from a lot of different causes eliminated themselves of their own accord. There was no need of knowing the angle of the prism provided it remained constant; the variations of temperature acted only upon the linear dimensions without affecting this angle; small changes in the orientation of the prism introduced only errors that might be considered as infinitely small of the second order. These are the advantages common to all the differential methods.

Why has this method not yet given all the results that were expected of it? I can not tell; the success was at first encouraging; the difficulties at first experienced in obtaining good images had been surmounted. It seems that Loewy let himself be turned aside from his researches by other ideas which soon demanded all his attention and occupied all his time; it is to be regretted that he did not intrust its continuation to some one of his co-laborers. I believe that we may yet expect much from it.

The principal difficulty in the meridian observations is the determination of the instrumental constants; the position of the instrumental equator must be compared with that of the real equator. This comparison is made by the observation of stars near the pole. But in the classic method one was content with observing the two passages of the same circumpolar star at a twelve hours interval. The inconveniences of this method of procedure are evident, since the stars observable in the daytime are rare, and since, in a period of twelve hours, the position of the instrument may have varied as well as the rate of the clock. Loewy sought a means of avoiding these difficulties by directing his telescope toward the pole and by determining at each instant, by the aid of a micrometer, the coördinates of different polar stars. Thus one may see in a single night a hundred stars pass by, all included between the second and tenth magnitudes, on which one can effect a series of pointings without waiting for their passage across the meridian. By properly grouping these pointings, by judiciously choosing the time, by re-dividing the stars into couples or groups of four, one can eliminate the causes of systematic error, and can get rid, for instance, of those which might come from the rate of the clock or from the shifting of the instrument during the time of observations. Loewy made numerous notes of this discussion; he left no point obscure, and he found co-laborers who have applied his method with success.

The method may take different forms, where the measurements of the two coördinates of each star combine in different ways: this is not the place to dwell upon the variations which the inventor studied in detail. We will simply call attention to the fact that the advantages are still greater as regards the absolute declination than for the right ascensions, since these measures are subject to a special error, refraction, and the systematic variations of this refraction between day and night, between summer and winter. The method of M. Loewy permits of eliminating it.

In these later days Loewy busied himself with the study of the circle divisions; this study always represents a long and difficult work which can be shortened without the exactness suffering, if the measures are intelligently directed in such a way that the determination of the different lines of the same order are given the same weight. Much time and trouble can be economized by following a judicious course in this work; how to choose this course is the problem which Loewy had proposed to himself and which he had happily solved.

I cannot speak of the daily tasks at the Observatory, but simply recall the part which he took in the determination of the differences of longitude between Paris and Marseilles, Marseilles and Algiers, Algiers and Paris, Paris and Berlin, Paris and Bonn, Paris and Bregenz, Paris and Vienna.

But that which occupied him almost exclusively in his last years, and which will remain one of his best titles to renown, is the photographic atlas of the Moon which he executed in collaboration with M. Puiseux. He had created the instrument; it was the great bent coudé telescope; this apparatus, thanks to its great focal length, gave a direct image of unusual dimensions. This image was further enlarged afterwards. Before reaching the perfection which we admire in the plates of his atlas he had to overcome many difficulties.

However numerous may be the published plates, they can give no idea of the immensity of the work accomplished. Without doubt they observed only when the images seemed good so as not to spoil the plates; but nevertheless they were obliged to throw away nine out of every ten photographic plates, so as to keep only those whose sharpness was perfect. The two authors allowed themselves absolutely no retouching. It is only at this price that a document having scientific value can be obtained; hence, what a precious source of information are these perfectly true photographs, taken at all phases and consequently under all degrees of illumination. A few years from now we shall be able to know without doubt whether our satellite is congealed in positive immobility, or whether rare changes take place there, as has been sometimes affirmed without any proof other than the fancy of a draughtsman.

Messrs. Loewy and Puiseux tried to get from their plates all the information possible; they wished to know what they teach us about the history of the Moon. This heavenly body, today reduced to silence and the repose of death, has in fact had a history; it was once alive and it is impossible not to recognize the traces of the great cataclysms of which it was formerly the theater. Deprived now of atmosphere, it may have had one formerly; and Messrs. Loewy and Puiseux are disposed to think so, for they believe they can see the effects of the winds which blew about it at some anterior epoch.

In 1878, after the death of LeVerrier, Admiral Mouchez appointed director of the Observatory, had Loewy join him as assistant director; he held the same position under the direction of Tisserand. In 1896 after the death of Tisserand, so premature and so lamented, it was to him that the minister intrusted the direction of our great astronomical establishment. He had to divide his time between personal research and the duties of administration. These constant cares took a part of his days while his nights remained devoted to scientific work. His directorship was fruitful and, to confine myself here to material progress and to that which has a direct scientific interest, I will remind you that he helped to have introduced into the observatory the printing chronograph and the self-registering micrometer, constructed by Gautier for meridian observations.

His authority among the French scholars went on increasing from day to day, but it was no less recognized abroad than at home. It became more firmly established on the occasion of two great international enterprises. The first had begun before him. I mean the Catalogue and Photographic Chart of the Heavens. It was Admiral Mouchez who had conceived the first idea of it, and Tisserand had continued the work of his predecessor. But fortunately his death caused no delay in the work, and thanks to Loewy, France retained in the international collaboration, the place which was due to its initiative· In the councils which meet periodically, the influence of Loewy was very great, and thanks to the authority which he was able to gain, it made itself felt very usefully in the intervals of the sessions.

The success, henceforth assured, has shown in a striking manner what can be expected of an international coöperation well directed. So when the discovery of Eros caused astronomers to forsee the possibility of a more exact determination of the solar parallax, appeal was again made to this coöperation; for the task seemed to exceed the forces of a single nation. Loewy conceived the idea and knew how to get it adopted; a congress brought about a prompt understanding and this fine conception became practical; a plan of work was decided upon and it was Loewy who was intrusted to write up the instructions about it which appeared in this publication; the greater number of the observatories of the world responded to this call and they have furnished us with a rich material from the observations which it remains to work up; in a few years we shall know whether they come up to the hopes that we had entertained of them.

The role that Loewy played in these two enterprises witnessed to his authority in foreign countries and at the same time developed it. The Royal Astronomical Society of London, the Academies of Vienna, St. Petersburg, Berlin, Rome, Washington admitted him among their fellows and their correspondents.

Loewy was good, he knew no malice. An intense worker himself, he liked great workers; they alone could count upon his support.

Sometimes he made mistakes in his valuation of men; but he could always recognize his error and he always did it without mental reservation and without fake pride. But a few minutes before his death at the Council of the Observatories he was energetically defending an astronomer whom he had once mistrusted, and a member of the Council called his attention to it and congratulated him on this proof of impartiality.

For two or three years past his health had been impaired, but his zeal for work, his scientific activity, had not slackened. And so his co-workers, even his family, did not believe his end was so near. On October 15, 1907, he went to the Council of Observatories which was to present for the choice of the minister a list of candidates for the directorship of the observatories of Algiers and of Marseilles. He began to speak, giving a remarkably clear exposition of the claims of the different candidates. He was speaking with some animation when all at once he grew weak and immediately lost consciousness. In a few moments he ceased to breathe; this fine intellect had been suddenly extinguished. French Science had received one more sorrowful blow.

Translated by Miss Isabella Watson, Northfield, Minnesota.

BULLETIN ASTRONOMIQUE, November 1907.

THE PLANET NEPTUNE.*

EDWIN HOLMES.

Numbers of people who, like myself, use a telescope as a hobby or a recreation, are troubled to recognize the planet Neptune, and have vague or erroneous ideas as to his appearance and dimensions. I have thought it might be an

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advantage to collect in one place such data and information as I could find bearing upon the subject.

I fear vain expectations have been raised in many minds by the perusal of Mr. Proctor's statement in his "Half Hours with the Telescope" that he was certain no observer could mistake him for a fixed star with a 2-inch aperture and a few minutes' patient scrutiny in favorable weather. It is unnecessary to say anything more of this than our first President said he was afraid his late lamented friend must have drawn on his imagination with reference to what could be perceived upon this planet with a 2-inch telescope. I have seen a telescope on Parliament Hill which might show something extraordinary upon Neptune, since I heard its exhibitor state that it showed hundreds of stars with rings like Saturn, and that Capella had thirteen, all of different colors, which he would show after dark when Capella would be rising in the north. This was on the 28th of April, when I thought Capella was in another direction, but that is no matter.

Another statement that has misled many is that when Dr. Galle picked up Neptune he ejaculated "My God in heaven, this is a big fellow!" When I some years ago applied the word apocryphal to this anecdote, the late Mr. Sadler was very indignant, and said he had the story from one who was present. I am willing to qualify my expression and call it ridiculous instead, for what are the facts? Grant's history tells us that Dr. Galle compared the indicated part of the sky with a star map and found the latter did not contain an eighth-magnitude star, which was very near the position indicated by Le Verrier. The observation of the following evening showed the star had moved, and thus decided that this was the Trans-Uranian planet. There is nothing about its big disk. If the detection had been by means of its disk, it is plain its identification would not have had to wait for a second comparison with the map. Professor Challis also had recorded the position of Neptune as a star on the 30th of July and 12th of August, 1846 without his recognizing that it was anything other than a fixed star. It was not till September 29, after receiving other information, that he found one star among 300 examined presented some appearance of a disk. And as these observations were made with two of the largest telescopes then in existence, one being 9$\frac{6}{10}$-inch, and the other 11½-inch, it is certain Neptune presented no very striking appearance.

There is another story told by Mitchel in his "Orbs of Heaven," not of his discovery, but of his first recognition of the planet. After relating that Dr. Galle found an eighth-magnitude star which was not present on an accurate map of the Heavens, he says the following evening was awaited with the deepest interest to decide by actual motion of the suspected star whether it was indeed the planet. He relates that having obtained from Le Verrier the computed place of the planet, although he had no star chart to guide him and no meridian instrument, he hoped the power of his great telescope, 11-inch, might be sufficient to select it by the magnitude of its disk. He then says: "On placing my eye to the finder, four stars of the eighth magnitude occupied its field. One of them was brought into the field of the large telescope and critically examined by my assistant and rejected. A second star was in like manner examined and rejected. A third star rather smaller and whiter than either of the others was now brought to the center of the field of the great telescope, when my assistant exclaimed: 'There it is! there is the planet! with a disk as round, bright, and beautiful as that of Jupiter!' There, indeed, was the planet, throwing its light back to us from the enormous distance of more than 3000 millions of miles, and yet so clear and distinct, that in a few minutes its diameter was measured and its magnitude computed."

This is definite enough, but curiously in contrast with the other accounts of first night's performances, except Mr. Sadler's. I suspect both these stories have a common origin. Certainly, with a disk as round and bright as that of Jupiter, there could have been no hesitation at all as to differentiating the planet from a star, and with so many indefatigable searchers of the Heavens it must have been discovered long before.

But in addition, the first human eye to see the planet appears to have been that of Lalande on the 8th and 10th of May 1795. The planet had moved in the two days, and Lalande supposed his first observation to have been an error and thus missed. Professor Newcomb says: "A discovery which would have made his name immortal." I presume he has made his name so far immortal on other grounds that it will never be missing from astronomical literature, but the point I wish to emphasize is that Lalande evidently saw nothing in its aspect to distinguish the planet from a fixed star.

Before citing the observations of various eminent astronomers I will just refer to the very various determinations of the diameter of Neptune. I shall append a list of all I have found to my paper but do not propose to read it. The diameters vary in arc from 2″ to 3″.12, or in miles from 27,000 to 38,265. When we note the great variations and reflect that one-tenth of a second at the distance of Neptune is equal to 1,370 miles, we feel some of the computations are a little wire-drawn.

I begin with observations made with the smaller instruments. "A Fellow of the Royal Astronomical Society" wrote that he had never been able to make anything of Neptune as a telescopic object, but that a power of 400 on an 8½-inch mirror *ought* to raise a small bluish disk, and that a 4-inch with 300 suffices to show it is not a star, and that is all. A 12-inch mirror ought to show a good disk, but to measure its diameter would require a large amount of skill and practice. I infer from his language he had not personally seen Neptune with either of the larger apertures, so that his remarks thereon are of the nature of pious opinions.

Mr. Herbert Sadler, with 430 on 6½-inch, saw a disk clearly. Kaiser, with 6½-inch refractor, measured the diameter to one hundredth of a second. Hind, with 320 on 7-inch, measured to the same accuracy. Dr. Terby, in 1889, wrote (in French): "With my 8-inch Grubb refractor, Neptune shows as a very little sharp disk, with powers of 150 and 250, but I have never succeeded yet in seeing it neatly with higher powers. These, however, show it very differently to a star." Mr. George Hunt says: "I have frequently examined Neptune with my equatorial of 8-inch aperture, but I have never satisfied myself that I saw a disk, though the planet shone with a steady light different from the constant flicker of a star." Mr. Gaudibert says: "I looked at the planet last night, January 6th. I saw at once it was not a star. Its appearance was like the preceding star, slightly out of focus, but not quite so bright. On the other hand, it was more steady, but the border was not sharp." This was with a 10¼ "With," and power 600 and 750. In another place, he says a star is a minute dot, and with the same focus the planet has so sensible a disk that it is at once seen it is not a star of any magnitude whatever. Vogel, with the 11½-inch Bothkamp and 620, says: "Edge was not distinct; Neptune was exactly like a faint planetary nebula."

Dr. C. W. Wirtz, of Strassburg Observatory, obtained a determination of the diameter of Neptune with the 18-inch refractor of the Imperial University. He thinks it necessary to add that, with his instrument, the disk of the planet was not sharply defined, but was apparently surrounded by a faint nebulous aureola, the breadth of which was about one-seventh the diameter of Neptune.

A writer in the "English Mechanic" declared his 12¼-inch was not large enough to get a disk sharp enough to measure. No more trace of a disk than an 8½-magnitude star in the field.

Lassell, with a 24-inch mirror and power of 1,027, remarks that the feeble light of the disk, and its minuteness, renders its accurate measurement a work of great difficulty.

I have been unable to find any description of the appearance of Neptune in the Greenwich 28-inch, but I infer it appears as a very sharp disk, because with 670 the difference betwixt the equatorial and polar diameters has been measured as 0″.004, and it must be very well seen to permit of such accuracy. With the Lick 36-inch the disk seemed to be perfectly round in all the observations, and no markings seen with a power of 1,000. The Concise Knowledge Library says that with this instrument and power it looks like a planetary nebula.

We have a fairly general agreement that the planet does not present a distinct disk, but is nebulous; that its diameter is betwixt 2″ and 3″, with a preponderance for the smaller figure, and that it is useless to expect to see a disk with small instruments or with less power than 500.

Against the statements that a clear disk was visible with 430 on 6½-inch and the exact measures with 6⅛-inch we have to contrast the fact that in 11½-inch it looks like a planetary nebula, in 18½-inch has no sharp outline, that it was minute in 2 ft., and a planetary nebula with 1,000 on 36-inch. When such a power as 430 was used on 6½-inch, it is obvious that a spurious disk would be formed by every star bright enough. This may account for the visibility of a disk to Neptune with such an instrument.

I have known an observer to try for years with a 4-inch to distinguish Neptune from a star without success, except by its motion. In my own experience I have often observed very carefully, and with 300 on 12-inch. I can in no way distinguish Neptune from a fixed star of equal magnitude. With 500 I have no certainty of a disk. A 700 shows a looseness about it, and 900 brings out a nebulous appearance without definite edge, not unlike Σ 5, but less brilliant and far less well defined. I am quite prepared to accept Mr. Arthur Mee's statement "that no physical detail whatever has been observed on Neptune, and so far no marvel-monger has ventured to canalize his surface" although Professor See believes he has remarked faint equatorial bands on the disk of Neptune. The expression used is not quite satisfactory, for Professor See does not profess to have seen but "only believes he has remarked" the bands. He says also that "the diameter of the planet has shrunk with the increased perfection of astronomical measurement, and that it scarcely, if at all, exceeds 2″." I do not think it can exceed this.

For if a disk of 2″ diameter is viewed with a power of 900 it should look nearly as large as the full Moon seen with the naked eye, and if 2″.433 as the Lick measures make it, it should show considerably larger and ought to be seen easily instead of appearing minute.

But the question of light affects our appreciation. Neptune is 30 times more distant from the Sun than our Moon is. and, therefore, 900 times less brilliantly illuminated. Flammarion in his "Marvels of the Heavens," says, "the light and heat which it receives are 1,300 times less than that with which the Earth is enriched, so that no great difference can be noticed betwixt the day and the night of this distant planet." "The stars of the heavens remain visible day and night and the Sun is only a more brilliant star than the others." I do not understand his calculation, but the light being reduced to $\frac{1}{900}$ is still equal to that of 686 full moons, a rather respectable difference betwixt the day and the night. If we examine the planet with a power of 500, we spread the same light over 250,000 times the surface, and with a 12-inch telescope, which has sixty times the aperture of the eye, the light is increased 3,600 times *if* all the light reaches the eye, but no telescope transmits more than 80 per cent, so that 3,000 times is an outside estimate. Then multiplying 900 by 250,000 and dividing by 3,000 we find that viewed under these conditions the disk of Neptune is 75,000 times less brilliant than the Moon to the unaided eye, and is only a feebly luminous object. With 700 the illumination is reduced to $\frac{1}{150000}$. Now, I have a little contrivance which loses light by four reflections at surfaces of plane glass, which I calculate reduces brilliancy to about the same proportion, and I find the Moon thus seen is a very indefinite object and looks small in consequence. I conclude the want of light accounts for the smallness of Neptune as seen in a telescope, but it also disposes of the "big fellow" idea.

Referring again to Professor See's measures, the BULLETIN OF THE ASTRONOMICAL SOCIETY of France for 1901 says, "this diameter and this density are less than has been previously admitted." There seems some error in implying that density and diameter decrease together, but the various densities are given evidently of little value, since with the same mass, with a diameter of 2″ the density must be 2½ times greater than with a density of 3″.12.

While on this point of possible printers' errors, I may mention that, in an old edition of Chambers' "Astronomy," there is an illustration of the perturbations of Uranus by Neptune, which shows both planets traveling in their orbits the reverse way to the other planets and to that we see in the northern hemisphere. This might hardly be worth mentioning but for a passage in the same author's "Solar System," which states that "great differences exist in the inclinations of the orbits of the different planets to the plane of the ecliptic, a fact which is better shown by a diagram than a table of mere figures. The orbit of Uranus is, indeed, so much inclined that its motion is really retrograde compared with the general run of the planets, and the same remark applies, though much more forcibly, to the case of Neptune;" and the diagram shows the Earth's orbit inclined 23½° to the ecliptic, and that of Neptune 146°.

It does not appear to me sufficient notice is given to the fact that Alexis and Eugène Bouvard had the idea, not only of an outer planet, but of its position and distance, before Adams and Le Verrier. They had even pointed out that the planets must have been in conjunction about 1822, and that the disturbing planet "must be at a distance from the Sun of less than 32 times that of the Earth from the Sun, and not less than 28 radii of the Earth's orbit;" and therefore the longitude of the planet January 1, 1847, would be betwixt 323° and 328^{c}. The Bouvards were therefore very much nearer the real distance than either Adams or Le Verrier.

I have come across a recipe for the identification of planets in an old "Leisure Hour" which may interest: "First, planets are generally lower in the horizon than stars, and they generally rise and south in localities where stars are not numerous; second, that, if due in the evening, planets rise before stars, and that, in the morning, they shine after stars become invisible; third, that planets are larger and more luminous than stars." I do not know who was the writer, but he goes on to say: "Everything has its season, and star-, or rather, planet-gazing must also be prosecuted at proper times. Improper times are during the day and at midnight. During the day planets cannot be seen, owing to the superior light of the Sun. At midnight they can be seen, but it is wrong to encroach on the hours dedicated to repose."

Authority	Aperture of Telescope in inches	Power.	Diameter in Seconds	Diameter in Miles	Remarks.
F. R. A.S.	4	—	—	38,138	No disk.
Sadler.	$6\frac{1}{2}$	430	—	—	Net disk.
Kaiser	$6\frac{1}{2}$	200	2.87	—	
Hind	7	320	2.47	31,000	
Terby	8	150–250	—	—	Little, very sharp disk.
Hunt	8	—	—	—	Never sure of disk.
Gaudibert	$10\frac{1}{4}$	600–750	3	—	Like star out of focus.
Encke	$9\frac{6}{10}$	264	2.82	—	Bright line micrometer.
Galle	$9\frac{6}{10}$	264	2.62	—	Bright line micrometer.
Encke	$9\frac{6}{10}$	264	3.12	—	Bright field.
Galle	$9\frac{6}{10}$	264	2.12	—	Bright field.
Madler	$9\frac{6}{10}$	532	2.40	—	
Mitchell	$11\frac{1}{4}$	—	—	—	Diameter stated to be equal to eight times that of the Earth.
Vogel	$11\frac{1}{2}$	620	2.66	—	Exactly like a faint planetary nebula.
Wirtz	18	—	2.303	31,506	Disk not sharp.
See	26	—	2.008	27,000	
Lassell	24	1,027	2.71	—	
Lassell and Marth	48	872	2.24	—	
Grenwich	28	670	2.096 2.1	—	
Lick	36	1,000	2.433	32,900	
Lockyer	—	—	—	36,620	
Chambers	—	—	2.7	37,500	An old Edition.
Neison	—	—	—	27,000	
Beckett	—	—	—	38,265	
Newcomb	—	—	2.56	34,500	

PLANET LAUNCHING.

THOMAS CURRAN RYAN.

FOR POPULAR ASTRONOMY.

The launching of a planet (or, the same thing, a planet's nucleus) in such a system as ours, which, Sun and all, is being translated through space, upon a highway as wide as the diameter of Neptune's orbit, and with a velocity of translation *along* that highway of about twelve and one-half miles per second, is a problem that was not involved in the cosmogony of Laplace. He assumed that the entire original mass possessed axial revolution, for which he did not account. If we accept this assumption, and if the whole mass had then the same translatory motion through space that it now has, it is easy enough to see that each particle in its equatorial zone, from center to circumference, extending beyond the orbit of Neptune, was occupying and pursuing just the *sort* of orbit in which the planets are now moving. So far as Laplace dealt with the orbits, his task was the simple one of gathering up bundles of these primeval orbits and binding them into sheaves, in his "rings." Thus everything was already launched into the present planetary orbits at the point where Laplace began his study which related only to the subsequent evolution. The assumed motions were not disturbed by the change from a revolving mass to revolving "rings."

But the new cosmogony, suggested by Messrs. Chamberlin and Moulton, begins farther back, and takes upon itself the task of explaining the phenomenon of planet launching, *a profound and curious problem, never before broached in astronomy.* When a longer and sustained inspection of it shall disclose to our minds some conception of its real immensity, perhaps we, like Laplace, may have to invoke chance. Dame Tyche was rather kind to Laplace. She gave him the revolving nebular mass that he needed, once out of half a billion of chances. At least we have his word for it. Agnes M. Clerke says, "human credulity is nowhere more conspicuous than in what it is prepared to attribute to chance." A wise and witty saying this—a thought well worth pondering. Chance is merely chaos. To invoke it is to acknowledge ourselves baffled. Chance and science are diametrically opposed thoughts. If the new cosmogony is to explain how the planets were launched, it must do it upon scientific grounds. Otherwise it will be no improvement upon the "nebular hypothesis."

The fundamental idea of this new cosmogony (Chamberlin's "Geology" pages 1-81; Moulton's "Introduction to Astronomy" pages 440-448) is that the matter now constituting a planet was at one time a portion of the Sun's mass, and began its evolution into an independent globe through being ejected into space by the force of explosive eruptions, such as are now seen taking place in the Sun, only upon a vastly larger scale. Tentative preference is given to the supposition that the disturbances which caused these eruptions took place while another Sun was passing near enough to cause disruptive tidal protuberances in ours. The result is supposed to be a spiral nebula the nucleus of which later recondensed into our present Sun, leaving the "arms", "knots", and diffused materials of the nebula to be gathered up in the meantime into planets, their satellites, comets and asteroids.

The authors of this hypothesis make no dogmatic claims for it. They are testing it mathematically and mechanically, to determine its adequacy as a solution of the phenomena taking place in our solar system. A few tests of this sort have been made, with results which Mr. Chamberlin says are, upon the whole, encouraging. But, as I study the conditions opened up by the theory, they impress me more and more as involving an interminable range of inquiry.

It is, of course, assumed that the force used in the case did not "*scatter.*" It fired its charges in certain *directions.* The ejected sun-lava was not sent forth in *spray*, but mostly in *streams.* Hence the "arms" and "knots" of the spiral nebulae. Quite naturally the "knots" are supposed to represent the *nuclei* of planets in this scheme. Nor is it difficult to account for them. Indeed, if we knew that the "arms" of the nebulae were caused by powerful explosions proceeding from the body of a Sun, we should be disappointed if the "knots" were not there. We should not know how to account for their absence. For, as the most forcibly ejected portion of this matter receded from the Sun it would exhibit a steady decrease in velocity, and this would result in an overtaking process, crowding the more rapid rear upon the slowing front which would thus become a sort of dam, impeding the stream. The less forcibly ejected matter thrown out by the dying explosion would string out behind, forming the "arms."

No system of cosmogony is complete unless it will account for *all* the phenomena of our solar system—for all that the bodies belonging to it are now doing. And, so, the first thing to be considered is their present movements. We see a very nice balancing of antagonistic forces in our solar system. As an instance of this, all the planets are moving with greater velocity than the Sun, yet they do not out-run him. The Sun moves through space at the rate of about twelve and one-half miles per second. It is said in text-books that Mars moves about 15 miles per second, and the outer planets are given velocities that gradually decrease with distance, until we get to Neptune which we are told moves only about three and a half miles per second. But these velocities were ascribed before the Sun's motion was discovered. They are the velocities that would carry the planets around the Sun in their periods, if the Sun were a stationary body. Planets moving at less than the Sun's velocity could not keep up with him as ours do. The slowest of them must have a speed considerably greater than the Sun, inasmuch as they have to keep pace with him though they all travel very winding paths while his path is comparatively straight. The planets are moving in the same direction as the Sun, but they progress forward upon this road by swinging around the Sun's path, so that their orbits are shaped like cylindrical spirals,—i. e. like corkscrews. *They move ever forward upon a spiral curve.*

In examining the problem of "launching" a planet, under the "planetesimal hypothesis," (as Mr. Chamberlin calls it) it will simplify the discussion to confine ourselves to one planet. They are all governed by the same laws: all their movements teach the same lesson. What is our planet doing? It turns upon its axis, but it is not assumed *here* that this motion affects the question of launching, inasmuch as several bodies of the system are able to hold their orbits though they have no true axial motion. We only need to inquire: Could our planet have been driven out *from the Sun* to a distance of 93,000,000 miles, into its present orbit? If that could have been done, state *how*. Show that the two motions—the 12½ miles per second motion, toward the north inherited from the Sun, and the added motion it received as a projectile shot away from the Sun (of which it would seem it retained the large excess over and above the Sun's velocity, which it now has) could in some way be combined to give that nucleus the Earth's present impulse of simple motion—i. e: to give us that straight line of motion we should now have if the Sun were to stop attracting us. This is what I mean by "launching." The planet pursues its course: it has its orbit. It was launched into that orbit some time. How?

And, right here, I beg the pardon of better men than myself, for making a suggestion. Shall we ever begin to think quite clearly about celestial mechanics so long as we persist in saying that a planet has *two* motions, one forward with the Sun, the other a circle around the Sun? No thing can have two simultaneous motions, for it cannot occupy two parts of space at the same moment. The two-motion idea seems to represent the fading inertia of the old "ring-orbit" around a *fixed* Sun. Our orbit is undoubtedly a compound of initial motions; but, whatever diverse impulses were involved in its initiation, the result could not have transcended the laws of motion, consequently, the initiatory impulse must have been a straight line. *It must have been a tangent of the orbit.* It was that straight line which the Sun's attraction is *now* constantly bending into the series of infinitesimal straight lines which in the aggregate make the curve our planet moves in. Could the Sun's attraction combine with our velocity to *put us into* that orbit, and *keep us there,* if our planet, or the nucleus of it, had been expelled from the body of the Sun? In other words, does that straight line which now represents the tangent of the Earth's orbit proceed from the body of the Sun? Obviously it does not.

It may be found that the "planetesimal hypothesis" makes it necessary to assume that prior to planetary initiation the Sun must have been much more massive than now, for the process seems to me to involve a vast amount of waste. But this, if true, would not appear to alter the launching problem. It could only affect the space *dimensions,* not the space *form,* of the problem, nor the laws invoked into effect by the conditions, any more than a geometrical figure can be changed by simply increasing or decreasing the length of its lines without altering their geometrical relations or proportions.

In examining the mechanical features of the launching problem, let us, for simplicity, call that face of the Sun toward the solar apex, the "front", the opposite face the "rear", and the plane midway between these the "flank". Suppose, then, that the nucleus of our planet was ejected straight from the front. If this mass was thrown off with anything less than a "velocity of escape", must not the Sun eventually, aided by attraction, overtake and re-absorb it? On the other hand, suppose this mass to have been ejected from the rear. Should we not have the same two alternatives? Again, if the supposed "nucleus" were expelled from the Sun's flank, upon a line perpendicular to his path and intersecting his center, the ejected mass would inherit the Sun's motion assuredly, so that, however forcibly it was expelled, it would always occupy a line perpendicular to the Sun's path and intersecting his center. If it had a velocity of escape, it would escape on this line. If it had not such velocity it would gradually approach the Sun upon this line and be reabsorbed by him. Must it not be so with all masses of matter ejected from the body of the Sun, no matter in what direction? Ever and always, however their direction of flight may be affected, by attraction of, or collision with, other bodies similarly ejected and flying from the Sun, they are affected by only these two forces, the force driving them directly away from the Sun, and the Sun's attraction pulling them directly toward him. The stronger of these forces they must obey. *The angle upon which they move outward is the only road they can possibly travel.* With a velocity of escape they will escape from the Sun upon that road; with a less velocity they must return to the Sun upon the same road. A planetary orbit does not seem to me to be a possible result in such a case.

What would be the Earth's motion now if the Sun were to stop attracting us? The Sun is not going to stop attracting us, but the question, what would our motion be if that attraction should cease, is relevant, because his attraction is responsible for the fact that we move through space in a spiral instead of a straight line. The straight line in which the Earth would now move if it were released from the Sun's attraction, is a tangent of the present orbit, and so, it is not a line proceeding from the body of the Sun. How then can we conceive it as evolved from a force proceeding outward from the Sun? How are we to account for a straight line of motion outward from the Sun being changed into our present simple impulse of motion from no cause but the Sun's attraction? Could attraction do that? Obviously, attraction is not exhibiting any force *now* that would be competent for such a task. Did it once do a thing which it could not do now? If not, then we must eliminate as impossible for evolution into planetary orbits, all motions derived from explosions sending the ejected matter in any direction whatever outward *from the Sun.* In other words, our planet, or its nucleus, could not have been launched by this means *alone.* It may have been thus driven to a point from which it could be launched. But the real launching must have taken place somewhere near the planet's present mean distance from the Sun. As the Sun's attraction, at this distance, is only strong enough to *hold* our planet in its present orbit, it seems that the process of launching the planet involved such a change in the angle of direction of simple motion as would task the Sun's attractive energy with just this *holding* of the planet, this being *the limit of its power.* It is an interesting inquiry—what angle of direction from the Sun's motion would do this. But if we knew precisely the distances, velocities and respective masses of Sun and Earth we could locate the line. Let us content ourselves, for the time being, with the fact that this angle, whatever it is, was found, since the Earth is doing what it could not do otherwise. What force can the new cosmogony invoke to join with those already mentioned in such manner as to impart this essential change of direction to our planet's motion, after its nucleus was expelled from the Sun's mass? Could it have been caused by the attraction of a "stranger" Sun, supposed to have been instrumental in increasing the violence of the explosions? The change needed is not to move the first line of motion of its nucleus to a line proceeding in some other direction, but still from the Sun. Impact with or attraction from other outgoing masses could only do that. What we need, is a line of motion for the "nucleus" that shall cross in a diagonal direction a line running parallel with the Sun's path and about 93,000,000 miles distant from that path. If the direction of the Earth's simple impulse of motion, i. e., the motion it would have if released from the Sun's attraction, were turned to a larger angle from the Sun's path than the present tangent of our orbit, we could not have a planetary orbit, for our speed is too great. If it were turned to a lesser angle with the Sun's path, we could have no planetary orbit, for our speed is not enough. Our speed is sufficient to give us a planetary orbit, only at our present distance from the Sun, not at a greater or less distance. This is evident from the fact that the velocities of all the planets decrease with increasing distance and increase as they are located nearer to the Sun.

Is gravity the sort of force that could perform the task of launching into a planetary orbit a volume of matter ejected from the body of the Sun? If our Sun or masses of matter flying away from it could not do this, could the supposed "stranger" Sun, by its attraction, do it for us? That attraction would bend our first line of motion toward that Sun. This means that ejected streams of matter upon the side nearest that Sun would be bent farther away from our Sun's path. This would only increase the difficulty. But streams upon the opposite side would be bent toward our Sun's path. It would be possible, therefore, that the necessary change of direction might be thus given to some of these latter, were it not for the fact that attraction never stops pulling. *The proper direction once imparted to the planet's nucleus must be thereafter left undisturbed.* But if the attraction of another body pulled the Earth or its nucleus into the right path, it would keep on pulling, and *immediately* take it out of that path again. Here we meet with a task which it seems such a power as attraction is not fitted for. The sort of help needed to launch into a planetary orbit, matter thus ejected from the Sun, would seem to be a sudden impact that does all it can do *in a moment* and has no further efficiency. Such help might come from the "carom" of an outgoing mass upon an infalling mass. To suppose a case: if the nucleus of our Earth were ejected from the Sun, but when it reached the present distance, or a little more, it collided, at the proper angle, with an infalling mass from the "stranger" Sun, or with one from our own Sun which had met with no obstruction, and had consequently traveled farther before the Sun's gravity overcame its outward impulse, such an impact might be competent not only to change direction but to give to the masses thus united a new impulse of velocity in the new path. If the two suns passed near enough to each other so that the streams of matter ejected from both became intermingled with each other, and if there were "A succession of more or less irregular outbursts", as Mr. Chamberlin suggests, and as it seems there would certainly be, the sort of "caroms" that would be required to impart the needed change of direction would occur much more frequently. For, as these suns must move either in different directions, or upon parallel lines, and, for the time being, presumably upon curved paths, on account of their mutual attractions, no two of these "successive outbursts" would be projected at the same angle. Here we should have, in great profusion, the multitudinous diversity of angles of motion needed for *attempts* at launching. And if these favorable conditions lasted long enough to call forth from the "womb of time", the number of successful efforts our solar system proves to have taken place some time, and in some way, we could thus account for what we see.

As to the length of time such favorable proximity of suns might last, all would depend upon their respective courses and velocities. Three assumed cases will illustrate this: suppose two suns each having a velocity of thirteen miles per second to be passing each other moving in opposite directions, upon parallel paths. Suppose their nearest approach to each other to be seven billions of miles and that they could cause eruptions of the required force in each other at a distance of nine billions of miles. They would remain within this disruptive influence about ten years. Suppose, again, that they were moving upon parallel paths and in the same direction, one at thirteen miles per second, the other at twelve and a half, they might be together long enough to disrupt each other entirely. Suppose again that their paths crossed at right angles; they might not remain long enough in each other's company to give birth to planets. If we should assume that our Sun was, in ante-planet times, much more massive than now,—that the forces which now expel eruptions of matter from him, sometimes with an initial velocity of 500 miles per second, and to a distance of 300,000 miles, were then much stronger, our Sun might do work of this kind without help, and time would not be an important factor in the problem. In either case the myriad probabilities of failure against success in launching the nucleus of a planet, and the certainty that the failures would result fairly often in expelling masses of matter with a velocity of escape, would, if we accept the new cosmogony, lead us to look for evidence, in our present solar system, of the former existence of a large amount of mass and energy which has been lost in abortive efforts at planet launching.

Wausau, Wisconsin.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTFR.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

Part II.

SPECIFIC STATEMENTS OF FUNDAMENTAL CONCEPTS CONCERNING THE CONSTITUTION OF MATTER.

It is a matter of common observation, as well as a scientific fact, that all known matter exists in one or other of, at least, three conditions, or states; viz., the solid, the liquid and the gaseous, and that these three are transmutable *inter se*. Solid matter can, by the application thereto of heat to a certain degree of temperature proper to each substance and termed the "point of fusion", or the "melting point," be converted into the liquid state, as ice into water at 32 degrees Fahrenheit, steel at from 2400° to 2600° and platinum at about 3650°, while even that most refractory element, *carbon*, becomes plastic, and shows signs of melting in the heat of the voltaic-arc the temperature whereof is between 6000° and 7000° of the Fahrenheit scale. By the further application of heat to the liquids so formed from solid substances, up to the temperature of ebullition, or the "boiling-point", as it is commonly called—which for water is 212° Fahrenheit under the normal conditions—all these liquids can be transformed into vapors, or gases, the temperatures of ebullition ranging from far below zero, as in the case of liquid air, up to the temperature of the electric arc between 6000° and 7000° as aforesaid, while carbon itself may be vaporized at about 7500° Fahr. Conversely, all gaseous matter, even the gases once regarded as inconvertible and hence called permanent gases—oxygen, nitrogen and the mechanical mixture thereof known as "atmospheric air," and hydrogen, have all been within comparatively recent times, reduced by increase of pressure and decrease of temperature, not only to the condition of liquids but also to the solid state, by a further abstraction of heat from the liquids under pressure, by the sudden expansion of a portion of the compressed fluid into the atmosphere, whereby *work* is performed by the expanding mass, and a definite equivalent of the correlated energy-heat abstracted therefrom.

Scattered over the expanse of the heavens above us are to be seen faintly luminous, hazy objects—mere wisps, or patches, of nebulous light—many of which, as the telescope has demonstrated, are simply clusters or groupings of distant stars *apparently* so close together that the light of each individual star of a cluster, overlaps that of its immediate neighbors in the group, the really widely separated stellar points of light being thereby blended into the nebulous object aforesaid, this effect being caused by "irradiation," an optical phenomenon whereby a very small surface heated to incandescence *appears* much larger than it is *in reality*, as is well illustrated by the incandescent electric lamp, the extremely thin filament whereof appears very much thicker while the electric current is coursing through it, than it does when the light is extinguished, and if two such filaments—or portions of the same filament—were set parallel, at a very small distance apart, (less than one-twentieth-inch) the light of one would so overlap, or blend with, that of the other, that the two would appear as a single luminous thread.

This phenomenon has no objective existence, it being a purely physiological effect or sensation, caused by the action of very bright light upon the organs of vision, and when a sufficiently high magnifying power is used, these nebulous objects are resolved into separate stars, a notable group of this kind, distinctly visible to the naked eye—and sometimes mistaken for a comet—being that known as *Præsepe* in the constellation Cancer, but many other of these nebulosities cannot be thus resolved into discrete stellar points, even by the highest power of the greatest telescopes, nor can they ever be resolved by telescopic or other means because when viewed through the spectroscope, they exhibit spectra consisting of bright lines, which are the distinctive spectra of incandescent gases, and these objects are therefore, to be regarded as enormous volumes of gaseous matter—the true *nebulæ*—posited in space at vast distances from the Earth and from the whole solar system. These nebulæ are of various shapes and dimensions but some of them present a more or less distinct central condensation, or stellar nucleus, a fact which logically leads to the conclusion that these volumes of gaseous matter for ages have been—and now are—undergoing, under the action of the force of gravity inherent in the mass, a gradual process of compression resulting in the generation of heat in the condensing matter, a portion at least of which heat is continually radiated into surrounding space, thereby permitting the process of condensation to continue. This generation of heat by the compression of a gas is a matter of common observation as in the case of ordinary air compressors, the quantity of heat developed being proportional to the mechanical work done in the compression, and rigorously determinable by means of an algebraic expression of the thermodynamics of gases.

There is considerable—even quite sufficient—evidence in favor of the hypothesis that our own particular star—the Sun—is the result of such a process of compression or condensation (productive of the intrinsic heat of that body) whereby it has been brought to its present dimensions, density and temperature, from a vastly extended volume of gaseous matter primarily in equilibrium, as to density, temperature and pressure, with the superlatively tenuous, and extremely cold, matter called the "luminiferous ether" which fills all interstellar space and of which, indeed—for reasons to be stated subsequently,—this solar nebula may be regarded as a derivative. In order that this process of condensation should continue—or even begin—it is necessary that a portion at least of the heat developed by the compression due to gravity, be simultaneously radiated from the surface of the gaseous nebula into surrounding space, otherwise the expansive effect of the heat so developed would counteract the compressive force in such a mass of tenuous gaseous matter. If *all* the heat were radiated from the surface of the mass, as soon as generated, the condensation would proceed *pari-passu*, but if—as seems to be the case—compression and the consequent generation of heat, operate more rapidly than does radiation, the condensation of the nebulous mass will be checked at certain definite and—as will be shown subsequently—definable intervals and a force antagonistic to gravitation be developed so that when radiation has had time to operate sufficiently, and the process of compression is resumed, a portion of the superficial matter of the nebula, particularly that in the region of greatest angular velocity (all such condensing masses must ordinarily be endowed with some motion of rotation around an axis) will be separated from the main mass, and be left behind, the aforesaid force opposed to gravitation acting conjointly with the centrifugal force due to rotation, in effecting the fission, and the diffused gaseous matter, thus separated, will be suspended in space above, and en-circling, the surface of the parent mass around which it will revolve in the direction of the rotation of the nebula whence it has been derived.

As this matter is obviously not of equal density throughout, minor centers of condensation toward which surrounding gases will gravitate must be the result, each forming a nucleus toward which compressive action will be exerted by the force of gravity resident therein—just as in the case of the main mass of the nebula that is now the Sun—these secondary centers, or nuclei, being the embryos which have developed into the planetary bodies which must revolve around the Sun in the direction disclosed by astronomical observations.

The detached masses consisting as they do of very tenuous diffused matter, may be roughly annular, but it is quite unlikely that, if viewed from a very distant standpoint, they would appear as well defined luminous rings like those of the planet Saturn, and it would seem that a quite perfect analogue is to be found in the great nebula in the constellation Andromeda, clearly visible to the naked eye and known from the earliest historical times, with its central condensation, or nucleus, and extended oval surrounding nebulosity divided by dark rifts into several nebulous belts wherein appear a number of minor centers of condensation, or nuclei, as shown in Robert's fine photograph of this nebulous object. While the character of this nebula as viewed spectroscopically, is somewhat dubious—its spectrum being, as remarked by an eminent astronomer, "perfectly expressionless—and while it *appears* to have been partially resolved into stars, it certainly presents the aspect of a vast gaseous nebula condensing toward the stellar or the sunlike condition, in the manner above described. The stars into which a portion of this nebula *seems* to have been resolved may in *reality* be extraneous to, and far beyond the nebula itself through the tenuous matter whereof they are visible—just as far distant stars have been seen to shine through the diaphanous "tail" of a comet—while the degree of condensation of the nebulous mass and the intrinsic physical conditions, may operate to prevent the exhibition, thereby, of a distinctive nebular spectrum or of a decidedly stellar one; but, in any case, this nebula serves well as an illustration of the appearance of the solar system in the early stages of its development, and in this connection a pertinent fact may be adduced. In the course of an investigation concerning the development of the solar system from the primitive nebula, by means of analytical methods and formulæ based upon the principles of my general theory of gases, I found that, when this nebula began to differentiate from the ether, its radius—regarding the mass as spherical—was 11,600 times the mean distance of the Sun from the Earth, or nearly 400 times the mean distance of the planet Neptune, while if we regard it as an ellipsoid similar to the Andromeda nebula, its semi-major axis would be about 40,000 times the mean distance of the Sun. Now it can be demonstrated that if the Andromeda nebula is at a distance from us, equal to that of the nearest fixed star, α Centauri—so far as known—the annual parallax whereof is nine-tenths of a second of arc, and distance therefore very approximately 21 trillions of miles, its longer diameter must be more—probably much more—than 30,000 times the mean distance of the Sun from the Earth, which fact makes the analogy between that nebula and the primitive solar nebulous mass the more striking; this fact furthermore, indicates roughly the distance of that beautiful and wonderful celestial object that has been called Queen of the Nebulæ. To some readers it may appear that the foregoing paragraphs concerning the development of the solar system are tantamount to a re-statement of the Nebular Theory advanced by Laplace and other men of science, long ago, but such is not the case; there are several important points of difference, one of them being that said nebular theory postulates a primitive mass of *fiery* matter, whereas, according to the hypothesis that I have set forth, the matter of the gaseous nebula, when it began to differentiate from the ether and to condense toward its present state, was at the temperature of the ether or as it is sometimes called improperly the "temperature of space" of which several estimates have been made, differing among themselves, but to which physicists are generally agreed in assigning very low values—a determination based upon the principles of my theory, and which will be discussed subsequently, giving only a very small fraction of one degree above what is known as "absolute zero" which is nearly 460° *below* the zero of the Fahrenheit scale. The nebulous matter became heated only after a very considerable compression, the augmentation of temperature being very small until the volume of the nebula had contracted to nearly the present dimensions of the Sun the maximum internal temperature whereof, obtained by my method, being 13,400 degrees of the absolute scale, which temperature is only one-third of that to which the matter would have been raised by *adiabatic* compression of the whole nebula from its outer limit at the distance of 11,600 times the mean distance of the Sun from the Earth (which mean distance is in round numbers 93 millions of miles) down to the present semi-diameter of the solar globe—432,200 miles—the other two-thirds having been lost by radiation into surrounding space, during the process of contraction, agreeably to a certain law that will be set forth in another part of this paper. Even when at the mean distance of the Earth, the matter that was to condense in like manner to form our globe, was at a temperature of only about four-tenths of a degree above absolute zero, and it did not rise to even one degree above, until the radius of the solar nebula had contracted to nearly the mean distance of the planet Venus.

For the absolute surface temperature of the Sun, at the present time, I have obtained a value of very nearly 6700 degrees Fahrenheit by means of four independent methods, the first employing as a *known* quantity the radiation of *heat* as indicated by the "solar constant" determined by the pyrheliometer; the second using the radiation of *light*, as measured by the candle-power of the luminous radiance emitted from unit surface of the Sun's disk, as the photometrically observed quantity; the third method is by means of the observed difference between the length of the solar spectrum and the length of the spectrum given by the voltaic arc as measured in the direction of the ultra-violet end, this involving the question of the physical properties of the luminiferous ether and its function in the propagation of radiance according to the principles of the "wave theory;" while in the fourth method, what is known as the "strength of pole" in the case of terrestrial magnetism is used as the known or observed quantity, terrestrial magnetism, for reasons to be stated subsequently in full, being regarded as due wholly to the radiant energy of the Sun, which has heretofore been regarded merely as a perturbing factor in the terrestrial magnetic field.

The analytical expressions for the law of radiation of both heat and light, whence I have obtained the aforesaid value of the surface temperature of the Sun—and also the density of the luminiferous ether relative to that of atmospheric air under the normal conditions—have been rigorously derived from the principles of my general theory, and involve the molecular and atomic weights or masses, dimensions and motions of the atoms in their orbits in the surface of each molecule of which they are the constituent parts, in *absolute measure*, and those expressions have been crucially tested by comparison with radiation actually observed, and directly measured in *absolute units*, from divers material surfaces the temperature-excesses whereof above the temperature of the inclosure, or surroundings, ranged from comparatively low values—as from 10° to 200° for cast-iron and wrought-iron heating pipes—up to nearly 3300° Fahrenheit in the case of radiation from the carbon filament of an incandescent electric lamp, the quantity of heat or thermal energy, radiated from the iron, in thermal-units, per unit surface, per second, for the temperature differences, and also the number of thermal units and the corresponding number of electrical units (watts) radiated from the carbon filament, being in exact agreement with the values observed or measured and, in so far as I have been able to learn, no other "law of radiation" or algebraic expression therefor has heretofore been found competent.

The solar surface temperature that I have thus obtained is considerably lower than the experimentally determined value as found by Le Chatelier, which is about 13,700 degrees Fahrenheit, with a possibility of its being as low as 11,900 degrees, and also lower than that by Wilson and Gray—11,200° Fahrenheit—but the difference in each case is mainly, if not wholly, attributable to the fact that the deduction of temperatures as high as that of the Sun, by these experimental methods, is necessarily made through an extrapolation that requires the use of an adequate algebraic expression for the true "law of radiation," while this law itself, for the case of very high temperatures, has not been regarded as well determined, and purely empirical formulæ have necessarily been used, Le Chatelier employing an expression devised by himself while Wilson and Gray used Stefan's "law of the 4th power of the absolute temperature," which while analytically derived and answering in some cases of radiation quite well, depends upon certain fundamental assumptions not fully proven to be true. Le Chatelier employed the observed or measured intensity of the Sun's *light* in his investigation, and by using his observed values in connection with my analytically derived expression of the "law of radiation," I have found a value of the Sun's surface temperature *substantially the same* as that derived by me through the four independent methods as stated in a preceding paragraph, viz, 6700° Fahrenheit; in any case it is quite apparent that the enormous temperatures (some several millions of degrees) once assigned to the Sun by physicists, and which were based upon laws of radiation such as Newton's "law of cooling" as it is called–which are true for only comparatively few degrees of temperature of a heated surface above its surroundings, can no longer be regarded as even approximately true. It should be noted that this solar radiating temperature—6700°—is the arithmetical mean between the maximum internal temperature —13,400° Fahrenheit,—according to my determination—and the temperature of the ether outside the solar globe, which temperature may in this case be regarded as "absolute zero."

The radiating temperature aforesaid is that of the surface of the photosphere or rather the upper portions thereof since we cannot well conceive that a volume of gaseous matter, such as the Sun, possesses a strictly *geometric* surface, this portion of the photosphere being immediately overlaid by the so-called "reversing layer" that comparatively thin stratum of glowing gases which, itself giving a spectrum of bright lines, strikes down, or absorbs, corresponding vibrations, or wave-lengths in the solar spectrum thus causing a portion, at least, of the dark lines exhibited by the latter.

In a paper published in the *Sitzungsberichte* of the Berlin Academy of Science, a translation of which was printed in No. 127 of Astronomy and Astro-Physics (August 1894), Professor J. Scheiner of Potsdam, Germany, in discussing the behavior of a certain line in the arc-spectrum of magnesium, in comparison with a corresponding line in the case of several classes of stars, states, as his conclusion, that in stars of Class II—with which the Sun is comparable—the temperature of the "reversing layer" is about that of the electric-arc, or between 5400° Eahrenheit and 7200° Fahrenheit, a mean value being 6760 degrees, of the absolute scale, which is almost exactly the value of my determination of the surface temperature of the Sun, by the several methods aforesaid, the difference being less than one per cent.

By means of an analytical method based upon the principles of my theory, and which will be fully set forth in a subsequent part of this paper, I have found that when the secondary "center of condensation," which formed the nucleus of the Earth, began to differentiate from the parent nebula, the temperature of its matter was only four-tenths of a degree above absolute zero, and its density only the 10-thousandth part of that of atmospheric air, under the normal conditions, and the radius of the volume of this fully expanded "terrestrial nebula"—as it may be called—regarded as a sphere, was approximately 336 times the present semidiameter of our globe, or nearly 1⅛ millions of miles.

It appears that the development of heat in this secondary nebula by its compression or contraction under the action of its own force of gravity, in the same manner as in the case of the primary nebulous mass, was such that when contraction had proceeded to nearly the present dimensions of our globe, and the greater part of the condensing mass had become viscid or plastic, the temperature thereof was approximately 6300 degrees Fahrenheit, which temperature is still, according to my determination, that of the internal matter of the Earth at a depth of about sixty-five miles below the surface, the temperature increasing downward at the mean rate of about one degree for each fifty-five feet which is not only the value derived from many actual measurements, but also a theoretical value that I have obtained through an equation based on my theory, as will be shown hereafter. Notwithstanding the fact that the matter of the Earth below a depth of sixty-five miles is at a temperature of 6300 degrees Fahrenheit (nearly equal to that of the Sun's surface) throughout, it is demonstrable, for reasons to be stated, that this matter is *solid* and of very great rigidity, and we may regard it as a *nucleus* enclosed by a solid envelope sixty-five miles in depth, the temperature whereof gradually decreases upward to the surface, and if this envelope which is less than one-sixtieth of the radius of the Earth in thickness, were to be removed—like the rind from an orange,—the highly heated nucleus would glow with a radiance approximating that of the Sun's disk.

While it may seem reasonable to connect this high temperature of the interior mass of the Earth with seismic perturbations—earthquakes and volcanic eruptions—that during all historic ages have been known to manifest themselves upon the surface of the globe, and of which we have had very recently appallingly violent exhibitions throughout the world, it can be demonstrated that, while there is, to a certain degree, such a connection, it is not *direct* but quite *remote*. The matter of the envelope aforesaid having a thickness of sixty-five miles and which, for convenience, may be called the "crust" of the Earth—although there is no very great mass of liquid matter in the interior of our globe necessitating the idea of a superincumbent solid crust—is of very low thermal conductivity and the flux of heat from the internal highly heated mass, or nucleus, to the comparatively cool surface, and its radiation therefrom into outer space are very *slow*, as well as very *uniform*, processes, as will be demonstrated when I have set forth my development of an analytical expression for the "law of radiation", and some other all-important factors in this connection. We must, according to my hypothesis, regard the cooling of the *uniformly heated* nucleus as being effected only in what we may call the "interface" between it and the superincumbent envelope, or "crust," whereof the temperature is *variable*—decreasing toward the surface—a thin layer being thus as it were, *very slowly* taken from the nucleus and added to the "crust" above it, the former therefore decreasing in volume and the latter increasing. Geologists generally regard earthquake shocks as caused by the rupture or slipping of underground strata at a point—or along an axis—where the regular order of deposition thereof has been altered, and a condition of stress brought about, by the secular cooling of the globe or its loss of heat during long ages of geological history, this causing what are called "faults" in the rocky strata. But, according to the view advanced above, the contraction of the volume of the Earth by reason of the secular cooling of its mass, is confined to the superficial envelope that may be called the "crust" as aforesaid, and it proceeds slowly and uniformly *pari-passu* with the processes of conduction of heat from the interior of the Earth and its radiation from the surface thereof, so that seismic phenomena might well be expected to recur but rarely, at indefinite intervals, whereas their occurrence is comparatively frequent and of a quite well marked periodicity —as will be shown,—a fact which is antagonistic to the hypothesis that these phenomena are due *immediately* to the stresses caused by contraction of the matter of our globe, consequent upon the secular cooling thereof and which fact, in conjunction with certain theoretical determinations that I have made has indicated to me a more probable *immediate* cause of these phenomena, a knowledge of which may lead to ability to *predict* concerning them; but a discussion of this matter must be deferred to a subsequent part.

Another point of difference between the nebular hypothesis of Laplace and the one that I have set forth above, is that the former regards the separation of rings of matter from the surface of the contracting nebulous mass, as due to "centrifugal force" alone, whereas, according to the latter view, the fission is effected not only by that force but mainly by one developed by the heating of this mass of tenuous gases, and operating directly against the force of gravity, especially at the surface of the nebula. The probable existence of such a force was pointed out by me, in an article concerning an apparent connection between the relative densities of the planets, and the relative times of their rotation upon their axes, which article was published in No. 75 of the SIDEREAL MESSENGER (May, 1889 and further referred to in a paper of mine that appeared in No. 105 of ASTRONOMY AND ASTRO-PHYSICS (May 1892) under the title Radiant Energy as a Probable Cause of the Solar Corona, the Comæ and Tails of Comets and the Aurora Borealis, this repellent force being the same that urges the carbon particles from the filament of an incandescent electric lamp, and deposits them upon the interior surface of the inclosing bulb—a phenomenon that may be termed the "radiation of matter"—finely divided particles of matter being radiated outward from the Sun's surface in all directions, and to vast distances therefrom to the Earth's orbit and even beyond it—this tenuous, but probably solid, matter giving the faint, continuous, part of the spectrum of the "corona," and being also a factor in the causation of the "zodiacal light" and that peculiar phenomenon, the faint luminosity sometimes seen in the midnight sky, "shining in opposition, to the Sun, wherefore it has received its appropriate German appellation, *Gegenschein.*

In regard to the "tails" of comets, the *modus operandi* of the Sun's radiant energy in repelling the tenuous cometary matter in a direction away from that of the solar globe, is quite obvious but, as to the aurora, certain developments along the line of my theory with respect to "terrestrial magnetism" and the part that the Sun plays in its causation give another demonstrable and more satisfactory explanation carrying with it some important disclosures concerning electricity and magnetism and the distinctive spectra of comets and auroræ but a discussion thereof must be deferred to a subsequent part of this paper.

In addition to the matter thus radiated outward from the Sun there is most probably, scattered in space throughout the original volume of the solar nebula, some *residual* gaseous matter in the primitive, roughly annular, conformations, portions whereof instead of condensing into the planetary masses and revolving in approximately *circular* orbits around the Sun, have formed into very much smaller masses, and fallen quite directly toward the center of gravity of the solar system, which lies within the present volume of the Sun—revolving around it in extremely *elliptical* orbits,—in most cases apparently parabolic, these masses of the residual matter of the primitive nebula constituting what we now call the "comets."

According to this view, all comets may be regarded as *original* members of the solar system, and constituted from what we may term the "debris" of the primitive solar nebula the boundaries whereof extended, at least, to a distance of 11,600 times the Sun's mean distance from us, or to a distance of a million millions of miles, possibly to three or four times that distance. In this connection it may be well to state that some time ago I found upon examination of the "elements" of all the periodic comets in the catalogues at hand, that the aphelion distance in each case, fell well within one or other, of the many rings or zones of separated nebulous matter between the Earth and the outermost limit of the solar nebula, according to my computations, a very great number, for obvious reasons having their aphelion distance in what we may call the *Jovian zone.*

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To be continued.

PROPOSAL OF A NEW METHOD TO COMPUTE A PLANET'S ANOMALY AND RADIUS VECTOR.

FRANCIS RUST C. E.

FOR POPULAR ASTRONOMY.

By Kepler's first law a planet's orbit is an ellipse, in the one focus of which stands the Sun and the first step in computing a planet's ephemeris is to determine its location in its orbit by polar coördinates as functions of time.

For this purpose a fictitious planet, moving in a circle with constant velocity, a "mean" planet, is introduced, its anomaly, the *mean amomaly*

$$m = \zeta t$$

is directly proportional to time. From this mean anomaly an auxiliary angle u the *eccentric anomaly* is derived by the equation

$$m = u - e \sin u \qquad (1)$$

and from u follows the true anomaly θ by the equation

$$\operatorname{tang}\frac{\theta}{2} = \operatorname{tang}\frac{u}{2}\cdot\sqrt{\frac{1+e}{1-e}}. \qquad (2)$$

The radius vector is determined by the equation

$$\rho = a\,(1 - e\cos u). \qquad (3)$$

To solve the equation (1) for u has been the cause for Lagrange to invent his famous method of reversing series and by the most elegant methods of calculation he deduces further θ and ρ directly as functions of the mean anomaly, that is as functions of time:

$$\left.\begin{aligned} \frac{\zeta}{a} &= D_0 + D_1\cos m + D_2\cos 2\,m + D_3\cos 3\,m + \ldots \\ \theta &= m + E_1,\sin m + E_2\sin 2\,m + E_3\sin 3\,m + \ldots \end{aligned}\right\} \qquad (I)$$

In these series the coefficients D and E are depending on the numeric eccentricity e only and have to be calculated for each planet.*

Unfortunately the convergence of series (I) is but very weak, the computing of θ and ρ by same consequently a tiresome task. So offering an easier method, I dare to ask the question: "*Why not rather this way?*"

By the second of Kepler's laws, the motion of a planet in its orbit is such, that the area swept over by the planet's radius vector is proportional to time. The total area of an ellipse is:

$$S = ab\,\pi$$

or for

$$b = a\cos\kappa$$

$$S = a^2\,\pi\cos\kappa$$

consequently if we consider the semimajor axis of the planet's orbit units of lengths

$$S = \pi\cos\kappa.$$

Supposed now the planet's period be t units of time, the area covered by the radius during one unit of time is:

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* Besel has deduced formulas for ζ and θ, introducing his function

$$I_n\,(x) = \frac{1}{\pi}\int_0^{\pi}\cos\,(n\,\phi - x\sin\phi)\,d\phi$$

for n a positive integer and x positive fraction or integer. Here is no room for further explanation. See Todhunter's, Laplace's, Lame's and Bessel's functions.

$$\Delta S = \frac{\pi \cos \kappa}{t} \tag{4}$$

and if we construct a table, which gives the area, covered by the radius vector as functions of θ, we may from such a table find θ by interpolation with no more labor than it requires to find for a given logarithm the corresponding number from the tables.

The construction of such a table requires the squaring of an ellipse, referred to polar coördinates, one focus the pole and the major axis the polar axis. The vertex next to the pole corresponds to the planet's perihelion and the equation is:

$$\rho = \frac{a(1-e^2)}{1+e\cos\theta}\cdot$$

From this we derive by the general expression of the area in polar coördinates:

$$S = \tfrac{1}{2} \int \rho^2 d\theta$$

counting the area from the perihelion and taking the semimajor axis for units of lengths:

$$S = \frac{(1-e^2)^2}{2} \cdot \int_0^\theta \frac{d\theta}{(1+e\cos\theta)^2} \tag{5}^*$$

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[*] The evaluation of the integral

$$I = \int \frac{d\theta}{(1+e\cos\theta)^2}$$

necessitates a complicated operation, which we arrange here, in order not to interrupt the text with it.

Substituting

$$e\cos\theta = u,$$

results

$$-e\sin\theta\, d\theta = du$$

and

$$\sin\theta = \sqrt{1-\left(\frac{u}{e}\right)^2}$$

consequently

$$d\theta = -\frac{du}{\sqrt{e^2-u^2}}$$

and transforms our integral to

$$I = \int \frac{-du}{(1+u)^2\sqrt{e^2-u^2}}\cdot$$

from which is derived, performing the integration

$$S = \chi . \cos\kappa - \tfrac{1}{4}\sin 2\kappa \sin 2\chi \qquad (6)$$

sin $k = e$ and for the auxiliary angle is

$$\text{tang}\,\chi = \sqrt{\frac{1-e}{1+e}}\,\text{tang}\,\frac{\theta}{2}\Big\} \quad \text{(g) in foot note} \qquad (7)$$

This last equation for tang χ permits a simplification. Making

$$e = \sin\kappa = \cos\mu, \quad \text{or} \quad \mu = 90^\circ - \kappa$$

makes

$$\sqrt{\frac{1-e}{1+e}} = \text{tang}\,\frac{\mu}{2} = \text{tang}\left(45^\circ - \frac{\kappa}{2}\right)$$

consequently .

$$\text{tang}\,\chi = \text{tang}\left(45^\circ - \frac{\kappa}{2}\right).\,\text{tang}\,\frac{\theta}{2}. \qquad (8)$$

Formulas (6) and (8) are excellently adapted for computing the area swept over by the radius vector as a function of the anomaly θ, the calculation to be carried tabularly as shown below:

For rationalization we make

$$\frac{e-u}{e+u} = \frac{1-\cos\theta}{1+\cos\theta} = \text{tg}\,\frac{\theta^2}{2} = z^2 \qquad \text{(a)}$$

which brings as its consequences:

$$(e-u)(e+u) = e^2 - u^2 = (e+u)^2 z^2$$

or

$$\sqrt{e^2 - u^2} = (e+u)\,z \qquad \text{(b)}$$

and also

$$e - u = (e+u)\,z^2$$

or

$$u = e\,\frac{1-z^2}{1+z^2}\,; \qquad \text{(c)}$$

lastly from (c) by differentiation

$$du = -\frac{4\,e\,z\,d\,z}{(1+z^2)^2}\,. \qquad \text{(d)}$$

From equation (c) results

$$1 + u = \frac{(1+e) + (1-e)\,z^2}{1+z^2} \qquad \text{(e)}$$

and from (b) and (c) we derive

$$\sqrt{e^2 - u^2} = e\,z\left(1 + \frac{1-z^2}{1+z^2}\right) = \frac{2\,e\,z}{1+z^2} \qquad \text{(f)}$$

1 θ	2 $\log \text{tang} \frac{\theta}{2}$ $\log \text{tang}\, \chi$	3 χ $\text{arc}\, \chi$ 2χ	4 $\log \text{arc}\, \chi$ $\log A$	5 $\log \sin 2\chi^2$ $\log B$	6 $A - B = S$
	$\log \text{tang} \frac{\theta}{2} + \log \text{tang}\left(45^\circ - \frac{\kappa}{2}\right) = \log \text{tg}\, \chi$		$\log \text{arc}\, \chi + \log \cos \kappa = \log A$	$\log \sin 2\chi + \log \frac{\sin 2\kappa}{4} = \log B$	

The calculation in column (2) (4) and (5) demands in each case the addition of one constant logarithm to the logarithm of a certain function of θ, which is done by a "*movable logarithm*", namely, the constant logarithm is written on a slip to be held in place over the other sum and only the result written below it.

Here is a sample of the calculation for the Earth's orbit:

$$\kappa = \text{arc} \sin e = 0^\circ\, 57'\, 34''.48$$

80°	9.9238135 9.9165397	39° 31′ 41″.468 0.6898970 79° 3′ 22″.93	9.8387842 9.8387233	9.9920294 7.9148755	0.6898002 0.0082200 0.6815802

By the method explained above the values of S were computed for an interval of θ five degrees and the attached fragment of a table composed by interpolation.

Introducing the expressions from (e) and (f) transforms our integral to

$$I = 2 \int \frac{(1 + z^2)\, dz}{[(1 + e) + (1 - e) z^2]^2}$$

or extracting the factor $(1 + e)^2$ in denominator

$$I = \frac{2}{(1 + e)^2} \cdot \int \frac{(1 + z^2)\, dz}{\left(1 + \frac{1 - e}{1 + e} z^2\right)^2} \cdot$$

For abbreviation introduced

$$c^2 = \frac{1 - e}{1 + e}$$

our last equation, combined with equation (5) in the text results in

$$S = (1 - e)^2 \int \frac{(1 + z^2)\, dz}{(1 + c^2 z^2)^2} \cdot \tag{A}$$

In this equation (A), the new integral

$$K = \int \frac{(1 + z^2)}{(1 + c^2 z^2)^2} = \int \frac{dz}{(1 + c^2 z^2)^2} + \int \frac{z^2\, dz}{(1 + c^2 z^2)^2}$$

θ	S	θ	S
75° — ′	0.638286	80° — ′	0.681580
10′	0.639727	10′	0.683025
20′	0.641168	20′	0.684471
30′	0.642610	30′	0.685916
40′	0.644051	40′	0.687362
50′	0.645493	50′	0.688808
76° — ′	0.646935	81° — ′	0.690254
10′	0.648377	10′	0.691700
20′	0.649819	20′	0.693146
30′	0.651261	30′	0.694592
40′	0.652703	40′	0.696039
50′	0.654146	50′	0.697486
77° — ′	0.655589	82° — ′	0.698933
10′	0.657031	10′	0.700380
20′	0.658474	20′	0.701827
30′	0.659917	30′	0.703234
40′	0.661361	40′	0.704721
50′	0.662804	50′	0.706169
78° — ′	0.664247	83° — ′	0.707616
10′	0.665691	10′	0.709064
20′	0.667135	20′	0.710512
30′	0.668579	30′	0.711960
40′	0.670023	40′	0.713408
50′	0.671467	50′	0.714856
79° — ′	0.672911	84° — ′	0.716305
10′	0.674355	10′	0.717754
20′	0.675800	20′	0.719202
30′	0.677245	30′	0.720651
40′	0.678690	40′	0.722100
50′	0.680135	50′	0.743549
80° — ′	0.681580	85° — ′	0.724999

and the first of these integrals to the right

$$\int \frac{dz}{(1+c^2z^2)^2} = \int \frac{(1+c^2z^2-c^2z^2)\,dz}{(1+c^2z^2)^2}$$

$$= \int \frac{dz}{1+c^2z^2} - c^2\int \frac{z^2\,dz}{(1+c^2z^2)^2}$$

consequently we get:

$$K = \int \frac{dz}{1+c^2z^2} + (1-c^2)\int \frac{z^2dz}{(1+c^2z^2)^2}\,. \qquad \text{(B)}$$

Upon the second integral in (B) we apply the formula of reduction

$$\int \frac{x^p\,dx}{X^q} = \frac{p-1}{2c\,(q-1)}\int \frac{x^{p-2}\,dx}{X^{q-1}} - \frac{b}{c}\int \frac{x^{p-1}\,dx}{X^q} - \frac{x^{p-1}}{2c\,(q-1)X^{q-1}} \qquad \text{(C)}$$

for $X = a + 2\,bx + cx^2$

the deducement of which will be shown below and which reads for our special case, that is with

$$X = 1 + c^2x^2$$

consequently with 1 for a, nought for b, c^2 for c, $p = q = 2$:

An example may illustrate the use of such a table, which depending on e only, will remain useful for many years after being once properly computed.

Whereas the Earth and the Sun always stand opposite each other in the ecliptic, the Sun's longitude exceeds the heliocentric longitude of our Earth for 180°, consequently the sum of the longitude of Earth's perihelion plus the true anomaly θ, as taken from our tables, increased for 180° must result in the Sun's geocentric longitude. From different sources* I could compile: Epoch 1901, January 1, $0.^h$ Greenwich M. T. (the beginning of the XXth Century.)

Heliocentric longitude of ⊕'s perihelion 101° 14′; annual tropic motion + 61″.7 [composed of proper motion (11″.46)

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* The astronomical data are anything but harmonious. The layman mathematician becomes puzzled as to "Why compute for fractions of seconds if you differ for minutes?"

$$\int \frac{z^2\,dz}{1 + c^2 z^2)^2} = \frac{1}{2\,c^2} \int \frac{dz}{1 + c^2 z^2} - \frac{z}{2\,c^2(1 + c^2 z^2)}$$

which transforms equation (B)

$$K = \frac{1 + c^2}{2\,c^2} \int \frac{dz}{1 + c^2 z^2} + \frac{1 - c^2}{2\,c^2} \cdot \frac{z}{1 + c^2 z^2}$$

or integration performed:

$$K = \frac{1 + c^2}{2\,c^3} \text{ arc tang } cz + \frac{1 - c^2}{2\,c^3} \cdot \frac{cz}{1 + c^2 z^2} + C \tag{D}$$

By equation (a)

$$z = \text{tg}\,\frac{\theta}{2}$$

consequently z vanishes if θ is zero and no constant is to be added in (D). Resubstituting this value for z and introducing an auxiliary angle χ:

$$\text{tang}\,\chi = \sqrt{\frac{1 - e}{1 + e}} \cdot \text{tang}\,\frac{\theta}{2} = cz \tag{g}$$

brings equation (A) to the form

$$F = \frac{1 + c^2}{2\,c^3}(1 - e)^2.\,\chi - \frac{1 - c^2}{2\,c^3}(1 - e)^2 \frac{\text{tang}\,\chi}{1 + \text{tang}\,\chi^2}$$

and from this, the coefficients properly simplified with

$$c^2 = \frac{1 - e}{1 + e} \text{ and } \quad e = \sin \kappa$$

results in equation (6) in the text.

and precession]; length of anomalistic year $365^d.25948$ M. T.
$e = \sin \kappa = 0.016747$, annual decrease in 7th decimal;

$$de = -4.244$$

⊕ in perihelion 1901, I, $0 + 0^d.80758$ Greenwich M. T.

For equation (4) the area covered by the Earth's radius vector during one mean solar day is

$$\Delta S = \frac{\pi . \cos (57' \, 34''.48)}{365.25636} \quad \text{or} \quad \log \Delta S = 7.9344912 - 10.$$

Find the Sun's longitude for 1906, March 18, 0^h Greenwich M. T. The Earth passed through its perihelion in 1906, 5 anomalistic years after its passage in 1901, consequently 1906, I, 0, + $0^\circ.10498$ up to March 18, 0^h have elapsed, 74^d, 89502 M. T., to which corresponds $\Delta S = 0.644086$, for which we interpolate from our table $\theta = 75^\circ \, 40' \, 14''.6$.

The longitude of perihelion 1906, I, 0 is $101^\circ \, 19' \, 8''.5$ consequently the Sun's longitude March 18, 0^h

$$X = 180^\circ + 75^\circ \, 40' \, 14''.6 + 101^\circ \, 19' \, 8''.5 = 356^\circ \, 59' \, 23''.1$$

This calculation however is to be regarded only as an example to demonstrate the simplicity of my method, compared with that one, expressed in equations (I). The result should

---

The deducement of the formula of reduction, used above is:
Differentiating

$$U = \frac{x^m}{X^n}$$

results

$$dU = \frac{m x^{m-1} dx}{X^n} - \frac{n x^m \, dX}{X^{n+1}}$$

consequently for

$$X = a + 2\,bx + cx^2$$

and

$$dX = (2\,b + 2\,cx)\,dx$$

$$dU = \frac{m x^{m-1} dx}{X^n} - \frac{2\,bn\,x^m \, dx}{X^{n+1}} - \frac{2\,cn\,X^{m+1} dx}{X^{n+1}}$$

from which by integration results—

$$\int \frac{x^{m+1} dx}{X^{n+1}} = \frac{m}{2\,cn} \cdot \int \frac{x^{m-1} dx}{X^n} - \frac{b}{c} \int \frac{x^m dx}{X^{n+1}} - \frac{x^m}{2\,cn\,X^n} .$$

Substituting

$$m + 1 = p, \quad n + 1 = q$$

results formula above.

be corrected for planetary perturbations etc., the same as if derived by the other method.*

Having determined θ by interpolation, the ratio $\frac{\rho}{a}$ an be deduced also with far greater ease from the polar equation of the ellipse:

$$\frac{\rho}{a} = \frac{1 - e^2}{1 + e\cos\theta} \qquad \text{(E)}$$

than from the series equation (I).
Making

$$e\cos\theta = \sin\kappa\cos\theta = \operatorname{tang}\mu^2$$

or

$$\operatorname{tang}\mu = \sqrt{\sin\kappa\cos\theta}$$

results from (E)

$$\frac{\rho}{a} = \cos\kappa^2\cos\mu^2. \qquad (9)$$

This formula (9) fails on account of the negative cosine for 90° $< \theta <$ 270°. For those values we must substitute

$$\operatorname{tang}\mu^2 = -\sin\kappa\cos\theta$$

which then is positive and the result is

$$\frac{\rho}{a} = \frac{\cos\kappa^2}{1 - \operatorname{tg}\mu^2} = \frac{\cos\kappa^2\cos\mu^2}{\cos 2\mu}. \qquad (10)$$

It is evident, that as $\frac{\rho}{a}$ is only dependent on e and θ, it may be calculated in a table as a function of θ and such a table for interpolation will remain good for as long as the tables for θ itself.

For computing the ephemeris of any planet, the polar coördinates, obtained as shown above, must be transposed upon the plane of the ecliptic and for that purpose must be given: the (heliocentric) longitude of the planet's ascending node to the perihelion, the arc distance from the ascending node to the perihelion measured in the orbit,—the anomaly of the ascending node,— and the dihedral angle intercepted by the planes of the planet's orbit and the ecliptic. With these data given it is a simple problem of spherical trigonometry to compute in the spherical right triangle, formed by the plane of the ecliptic, that of the planet's orbit and

---

* Neither the data for Epoch 1901 I, 0, nor the calculatory correctness of the tables can be guaranteed.

one passed through the planet and the poles of the ecliptic, both sides of the right angle, which are: the difference of the planets heliocentric longitude and the longitude of its ascending node and the slope of its radius vector against the plane of the ecliptic.

By multiplying the radius vector with sine and cosine of its slope against the ecliptic, the projection of the planet upon the plane of the ecliptic is performed, and this done the computing of the planet's geocentric longitude and latitude becomes a task of plane trigonometry.

The formulæ for this calculation become simplest by referring the entire system to a system of rectangular coördinates, the plane of the ecliptic for the plane XY and the axis of X through the vernal equinox.

Let x, y and z be the coördinates of the planet, unit of lengths of course the semimajor axis of the Earth's orbit, the coördinates of Earth to be x_1 and y_1, then

$$\text{tang}\,\lambda = \frac{y - y_1}{x - x_1}$$

the projection of the distance between Earth and the planet, the curtate distance

$$D = \pm \frac{x - x_1}{\cos\lambda}$$

and

$$\text{tang}\,\beta = \frac{z}{D}.$$

The true distance required for computing the parallax is

$$\Delta = \frac{D}{\cos\beta}.$$

Allegheny, Pennsylvania.

ASTRONOMICAL PHENOMENA IN 1908.

Eclipses in 1908.

In the year 1908 there will be three eclipses of the Sun and a Lunar Appulse.

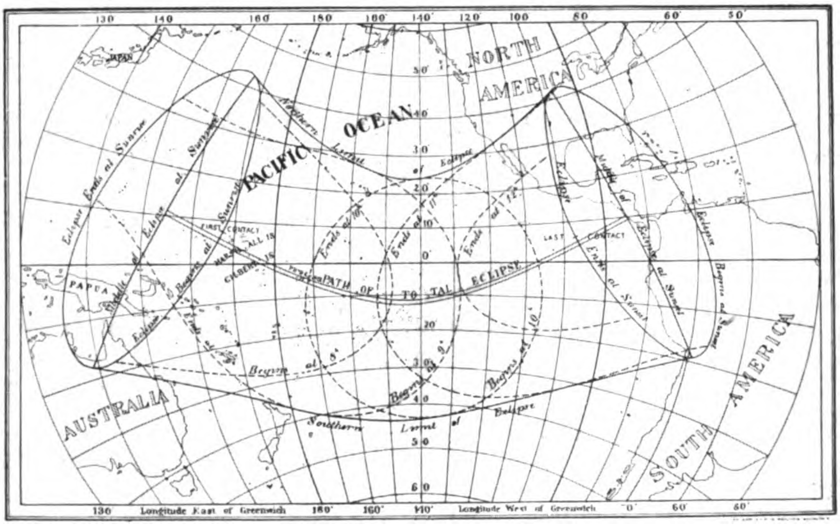
I.—*A Total Eclipse of the Sun*, 1908, January 3, invisible at Washington.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of ☌ in right ascension, January 3 d 9 h 45 m 14.3 s

Sun and Moon's R. A.	18 h 52 m 47.55 s	Hourly motions	11.02 s and 164.96 s
Sun's declination	22° 53′ 44.5″ S.	Hourly motion	0′ 13.9″ N.
Moon's declination	22 41 57.1 S.	Hourly motion	0 3.3 S.
Sun's equa. hor. parallax	8.9	Sun's true semidiameter	16 16.0
Moon's equa. hor. parallax	61 15.7	Moon's true semidamenter	16 40.8

TOTAL ECLIPSE OF JANUARY 3' 1908.



Note.- The hours of beginning and ending are expressed in Greenwich Mean Time

CIRCUMSTANCES OF THE ECLIPSE.

		Greenwich Mean Time. d	h	m	Longitude from Greenwich. °	′	Latitude. °	′
Eclipse begins	January	3	7	7.7	167	10.6 E.	7	8.3 N.
Central eclipse begins		3	8	4.1	154	39.2 E.	10	45.1 N.
Central eclipse at noon		3	9	45.2	145	13.9 W.	10	51.0 S.
Central eclipse ends		3	11	26.7	84	49.1 W.	9	53.4 N.
Eclipse ends		3	12	23.1	97	20.6 W.	6	16.7 N.

II.—*An Annular Eclipse of the Sun*, 1908, June 28, visible at Washington as a partial eclipse.

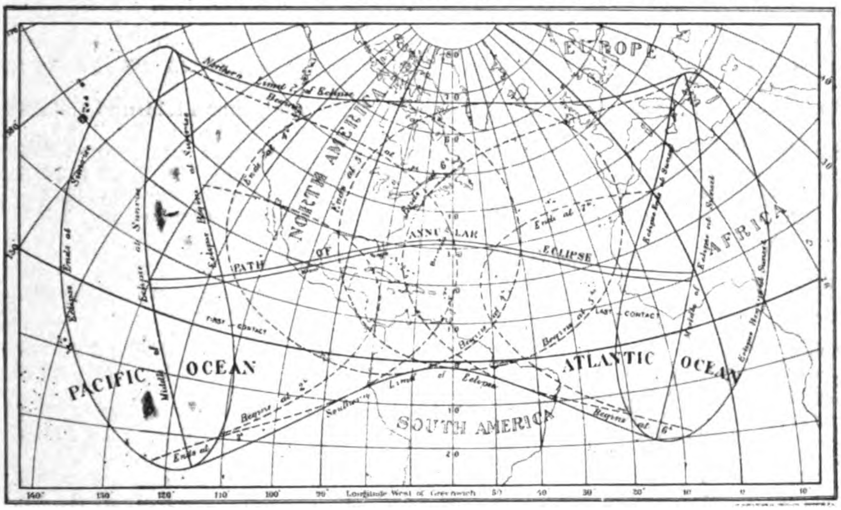
ELEMENTS OF THE ECLIPSE.

		d	h	m	s
Greenwich mean time of ☌ in right ascension,	June	28	4	30	39.4

	h	m	s		s	s
Sun and Moon's R. A.	6	28	25.85	Hourly motions	10.37 and	133.40

	°	′	″		′	″
Sun's declination	23	17	24.0 N.	Hourly motion	0	7.0 S.
Moon's declination	23	25	0 3 N.	Hourly motion	1	19.0 N.
Sun's equa. hor. parallax			8.7	Sun's true semidiameter	15	43.8
Moon's equa. hor. parallax		54	53.7	Moon's true semidiameter	14	56.8

ANNULAR ECLIPSE OF JUNE 28th 1908.



Note.– The hours of beginning and ending are expressed in Greenwich Mean Time

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.				Longitude from Greenwich.		Latitude.	
		d	h	m	°	′	°	′
Eclipse begins	June	28	1	29.2	112	24.8 W.	1	58.4 N.
Central eclipse begins		28	2	34.7	129	56.8 W.	4	39.3 N.
Central eclipse at noon		28	4	30.7	66	55.3 W.	31	27.3 N.
Central eclipse ends		28	6	24.9	1	8.0 W.	10	1.0 N.
Eclipse ends		28	7	30.5	18	42.4 W.	7	21.0 N.

III.—*A Lunar Appulse*, December 7, 1908; the Moon just rising at Washington, and visible generally throughout Europe, Asia, Africa, and the extreme eastern portions of North and South America.

ELEMENTS OF THE APPULSE.

		d	h	m	s
Greenwich mean time of ☍ in right ascension,	December	7	9	31	32.0

	h	m	s		s
Sun's right ascension	16	56	39 50	Hourly motion	10.94
Moon's right ascension	4	56	39.50	Hourly motion	139.80

	°	′	″		′	″
Sun's declination	22	39	9.6 S	Hourly motion	0	16.5 S.
Moon's declination	21	40	28.1 N.	Hourly motion	6	33 6 N.
Sun's equa. hor. parallax			8.9	Sun's true semidiameter	16	14.4
Moon's equa. hor. parrallax		57	5.7	Moon's true semidiameter	15	32.7

CIRCUMSTANCES OF THE APPULSE.

	d	h	m
Nearest approach of Moon to Earth's shadow, December	7	9	55
Computed least distance of Moon's limb from shadow			12″

Angle of position of point of nearest approach, 12° to the west from north point.

IV.—*A Central Eclipse of the Sun*, 1908, December 22-23, invisible at Washington. The central eclipse will be annular at the beginning and end, and will be total in the middle.

ELEMENTS OF THE ECLIPSE.

	d	h	m	s
Greenwich mean time of ☌ in right ascension, December	22	23	49	17.8

	h	m	s		s	s
Sun and Moon's R. A.	18	5	36.19	Hourly motions	11.11 and	154.08
	°	′	″		′	″
Sun's declination	23	26	42.1 S.	Hourly motion	0	1.5 N.
Moon's declination	23	56	10.4 S.	Hourly motion	2	53.7 S.
Sun's equa. hor. parallax			8.9	Sun's true semidiameter	16	15.7
Moon's equa. hor. parallax		58	58.7	Moon's true semidiameter	16	3.5

CIRCUMSTANCES OF THE ECLIPSE.

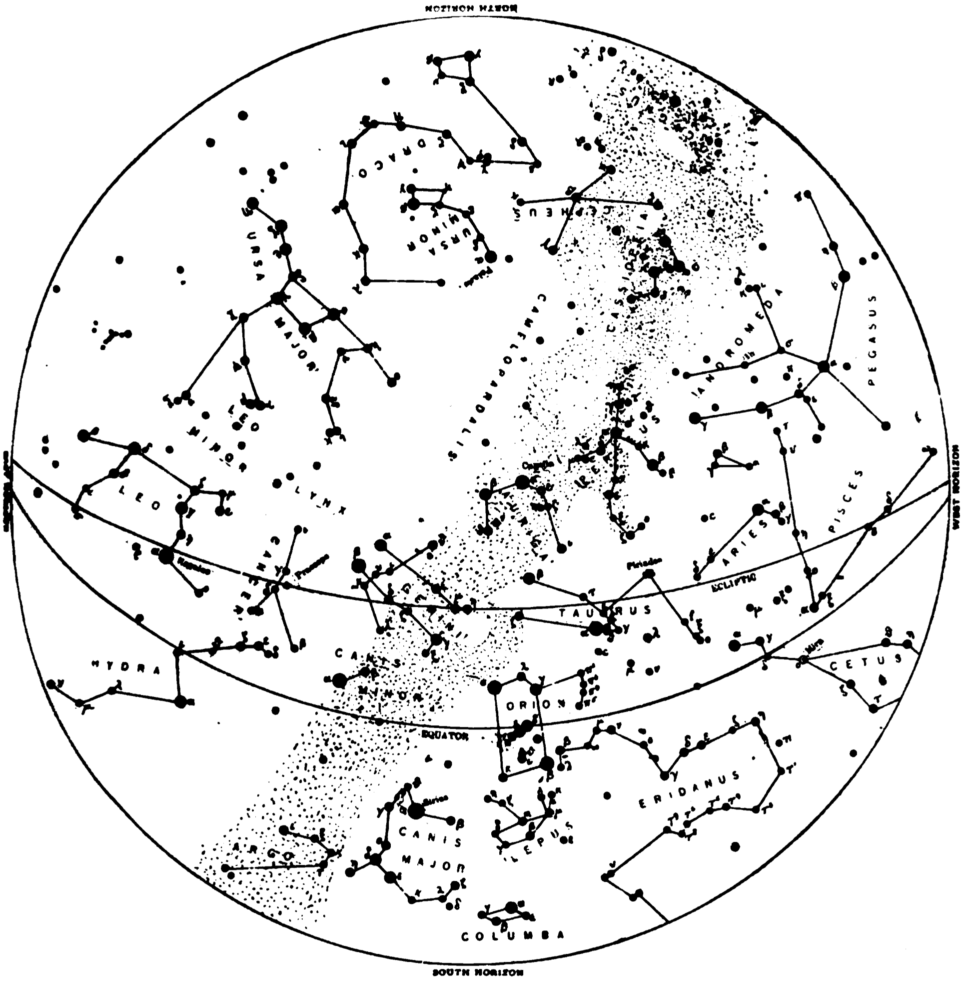
		Greenwich Mean Time.			Longitude from Greenwich.		Latitude.	
		d	h	m	°	′	°	′
Eclipse begins	December	22	21	6.6	52	24.8 W.	12	33.8 S.
Central eclipse begins		22	22	11.3	73	31.7 W.	22	46.1 S.
Central eclipse changes from annular to total		22	22	57.9	28	3.0 W.	46	13.0 S.
Central eclipse at noon		22	23	49.3	2	27.6 E.	53	46.0 S.
Central eclipse changes from total to annular		23	0	37.9	36	18.0 E.	51	24.0 S.
Central eclipse ends		23	1	17.7	86	1.9 E.	31	54.4 S.
Eclipse ends		23	2	22.3	64	14.0 E.	21	52.3 S.

The regions within which the first and second eclipses of the Sun are visible are laid down on the accompanying charts, from which, by means of the dotted lines, the Greenwich times of beginning and ending at any place may be found with an uncertainty which will vary from three or four minutes for a high Sun, to fifteen or twenty minutes when the Sun is near the horizon.

The Planets.

The apparent courses of the planets among the stars during the year 1908 are shown upon the charts, Figures 3 and 4. *Mercury* describes a course quite similar to that of last year, beginning in Sagittarius and running outward to the constellation Aquarius, where in February and March the planet in circling round the Sun will make a large closed loop in its path. Then it will move eastward again until, in June and July, another large closed loop will be formed in the constellation Gemini. Again in October and November the planet retrogrades in movement, forming this time an open Z-shaped loop in its apparent path. Mercury will be at inferior conjunction with the Sun February 28, July 4 and October 28. The following table shows the condition of Mercury as to brightness and distance from the Sun at the several greatest elongations which will occur this year. It will appear from this together with the declination of Mercury as shown on the chart, that the planet will be most easily seen about February 13.

Date.	Elongation.	Distance.	Brightness.
Feb. 13	East	18° 09′	65
Mar. 27	West	27 49	33
June 7	East	23 59	34
July 25	West	19 51	43
Oct. 4	East	25 34	35
Nov. 13	West	19 19	58



THE CONSTELLATIONS AT 9:00 P. M., FEBRUARY 1, 1908.

Venus begins the year in Capricorn and moves eastward along the Zodiac until June, when she makes a large loop in Gemini. The dotted curve on the chart Figure 3 shows the apparent course of Venus for the year. Venus and Mercury will be at inferior conjunction with the Sun at very nearly the same time in July, the conjunction of Mercury July 4 and that of Venus July 5. Venus will be evening star during the first half of the year, increasing in brilliancy until May 30, then decreasing rapidly until the conjunction. After that she will be morning star increasing very rapidly in brightness and remaining very brilliant for the rest of the year.

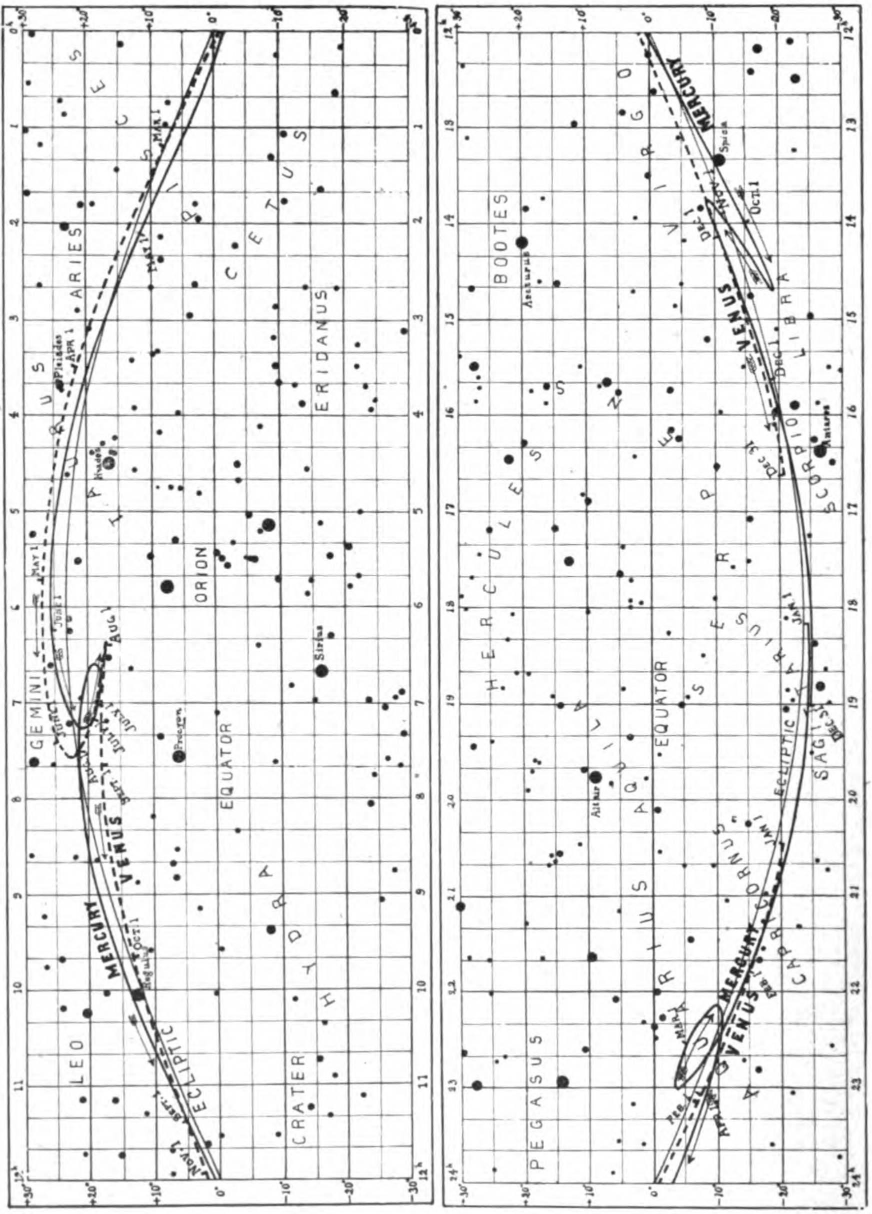


Fig. 3. The Apparent Paths of the Planets Mercury and Venus during the Year 1908.

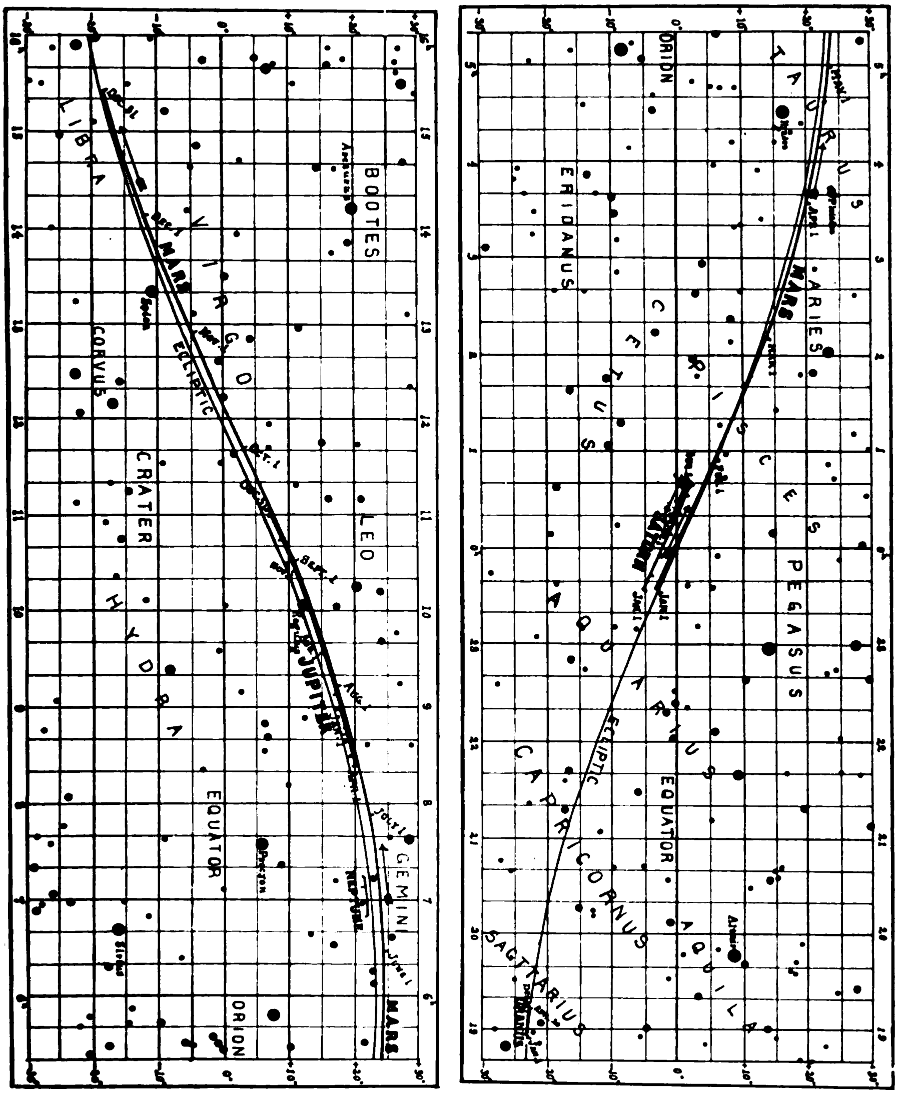


Fig. 4. Apparent Paths of the Planets Mars, Jupiter, Saturn, Uranus and Neptune during the Year 1908.

The path of Mars this year forms no loop, but extends smoothly along the ecliptic from Aquarius to Libra.

Jupiter's course is retrograde in Cancer for the first three months and after that is direct for the rest of the year, extending through Cancer and the greater part of Leo. The planet will be in conjunction with the first magnitude star Regulus on the night of September 4 and will then be only 22′ north of the star.

Saturn's path lies along the boundary between Aquarius, Pisces and Cetus and the motion is direct until the latter part of July, then retrograde until December 1. The angle between the line of sight from Earth to Saturn and the plane of the rings will increase to nearly 8° in July, then decrease to 5° in December.

The path of *Uranus* is a short one in Sagittarius, the movement being direct until April 20, then retrograde until September 21 and direct for the rest of the year.

Neptune describes a very short course in Gemini, retrograding until March 22 and again after October 20.

Phases of the Moon.

Washington Mean Time.

New Moon				First Quarter				Full Moon				Last Quarter			
1908		h	m			h	m			h	m			h	m
Jan.	3	4	35.1	Jan.	9	20	44.6	Jan.	17	20	28.6	Jan.	25	21	53.0
Feb.	1	15	28.2	Feb.	8	11	19.2	Feb.	16	15	57.1	Feb.	24	10	16.0
Mar.	2	1	48.6	Mar.	9	4	33.8	Mar.	17	9	20.2	Mar.	24	19	23.3
Mar.	31	11	53.9	Apr.	7	23	23.2	Apr.	15	23	47.0	Apr.	23	1	58.4
Apr.	29	22	24.8	May	7	18	15.0	May	15	11	24.1	May	22	7	08.9
May	29	10	06.2	June	6	11	47.8	June	13	20	46.9	June	20	12	17.8
June	27	23	23.2	July	6	03	16.7	July	13	4	39.6	July	19	18	53.4
July	27	14	08.5	Aug.	4	16	32.1	Aug.	11	11	50.5	Aug.	18	4	17.2
Aug.	26	5	50.6	Sept.	3	3	42.5	Sept.	9	19	15.0	Sept.	16	17	25.1
Sept.	24	21	51.1	Oct.	2	13	05.4	Oct.	9	3	55.1	Oct.	16	10	27.1
Oct.	24	13	38.3	Oct.	31	21	08.0	Nov.	7	14	49.7	Nov.	15	6	32.8
Nov.	23	4	44.8	Nov.	30	4	36.1	Dec.	7	4	35.8	Dec.	15	4	04.2
Dec.	22	18	41.4	Dec.	29	12	31.6								

Occultations visible at Washington.

The list of occultations given by the *American Ephemeris* as visible at Washington during this year numbers 101. We plan to give the list for each month in POPULAR ASTRONOMY one month ahead of time so that our readers may have ample notice of each. The list for February is as follows:

Date 1908	Star's Name	Magnitude.	IMMERSION.			EMERSION.			Duration.	
			Washington M.T.		Angle f'm N.	Washington M.T.		Angle f'm N		
			h	m	°	h	m	°	h	m
Feb. 10	BD.+19° 811	6.2	11	21	124	12	16	224	0	55
11	ζ Tauri	3.0	5	04	77	6	27	249	1	23
13	δ Geminorum	3.5	4	38	107	5	42	240	1	04
14	Piazzi viii, 42	6.0	10	32	126	11	59	262	1	27
24	B A. C. 5567	6.5	18	41	144	19	48	250	1	07
25	52 Ophiuchi	6.4	16	06	38	16	33	355	0	27
26	Bradley 2335	5.8	16	37	109	17	47	270	1	10
26	26 Sagittarii	6.1	18	59	182	19	04	190	0	05

Comets.

The periodic comets which were due at perihelion in 1907 have thus far none of them been detected. In 1908 four are due, two which have been observed at more than one apparition and two which have been seen but once.

1. The first is Encke's comet which reappears every three and a third years. It is due at perihelion April 30 but will be in best position to be observed in June and July. It will be most easily seen by observers on the Southern Hemisphere.
2. The comet Tempel-Swift will be at perihelion towards the last of September. It will be in favorable position for observation during the autumn months.
3. Brook's comet 1886 IV comes to perihelion in October, when it will be almost behind the Sun and so is not likely to be detected.
4. The comet Denning 1894 I is due at perihelion about the middle of December under fairly favorable conditions. It is most likely to be found in the early part of the winter.

Variable Stars.

The list of variable stars is increasing so rapidly now that the task of predicting the times of minima and maxima is becoming a laborious one. For 1908 we expect to continue the plan of former years of giving the times of all the minima of the Algol type stars, except where the period is less than one day. These predictions are given only to the nearest hour of Greenwich mean time, but the calculations have been carried out to the nearest minute. The computations have been checked independently at the beginning and the end of the year, as well as by a subsidiary check at every tenth minimum, so that we hope that the errors are pretty thoroughly eliminated. For the stars of short period not of the Algol type the times of maxima have been calculated in the same way. For stars whose periods are less than half a day it seems hardly worth while to prepare tables, since observations of these stars will be valuable at any hour.

We are endeavoring to keep our list of elements of short period variables up to date and shall be glad if any observer will send us corrections or new elements which he does not see noted in our monthly notes.

Meteor Showers.

The following is a list of the radiant points of the most brilliant showers in Mr. Denning's list given in the *Companion to the Observatory* for 1907.

Date	Radiant		Remarks
	α	δ	
Jan. 2-3	250°	+53°	Swift; long paths
Apr. 20-22	271	+33	Swift:
May 1-6	338	− 2	Swift; streaks.
July 25-31	339	−11	Slow; long.
Aug. 10-12	45	+57	Swift; streaks.
Oct. 18-20	92	+15	Swift; streaks.
Nov. 14-16	150	+22	Swift; streaks.
Nov. 17-23	25	+43	Very slow; trains.
Dec. 10-12	108	+33	Swift; short.

The Perseids, with maximum on August 11, are visible for a considerable period and their radiant point exhibits a motion to E. N. E. among the stars of about 1° per day. Its position for July 19, is about $\alpha = 19^\circ$, $\delta = +50^\circ$ and for August 16 about $\alpha = 53^\circ$ $\delta = +58^\circ$.

PHENOMENA OF JUPITER'S SATELLITES.

Central Standard Time, reckoning from noon.

	h	m			
Feb. 1	5	35	I	Tr.	In.
	5	39	I	Sh.	In.
	7	55	I	Tr.	Eg.
	7	59	I	Sh.	Eg.
	17	30	III	Oc.	Dis.
2	5	04	I	Ec.	Dis.
	14	04	II	Oc.	Dis.
	17	12	II	Ec.	Re.
4	8	53	II	Tr.	In.
	8	28	II	Sh.	In
	11	05	II	Tr.	Eg.
	11	24	II	Sh.	Eg.
5	5	13	IV	Tr.	Eg.
	6	49	IV	Sh.	Eg.
	7	19	III	Tr.	In.
	8	03	III	Sh.	In.
	11	01	III	Tr.	Eg.
	11	45	III	Sh.	Eg.
	15	33	I	Oc.	Dis.
6	6	29	II	Ec.	Re.
	12	52	I	Tr.	In.
	13	05	I	Sh.	In.
	15	12	I	Tr.	Eg.
	15	25	I	Sh.	Eg.
7	9	59	I	Oc.	Dis.
	12	31	I	Ec.	Re.
8	7	18	I	Tr.	In.
	7	34	I	Sh.	In.
	9	38	I	Tr.	Eg.
	9	54	I	Sh.	Eg.
9	7	00	I	Ec.	Re.
	16	18	II	Oc.	Dis.
11	10	23	II	Tr.	In.
	11	04	II	Sh.	In.
	13	19	II	Tr.	Eg.
	14	00	II	Sh.	Eg.
12	10	35	III	Tr.	In.
	12	02	III	Sh.	In.
	14	17	III	Tr.	Eg.
	15	44	III	Sh.	Eg.
13	5	26	II	Oc.	Dis.
	7	58	IV	Oc.	Dis.
	9	04	II	Ec.	Re.
	14	36	I	Tr.	In.
	14	59	I	Sh.	In.
	16	21	IV	Ec.	Re.
	16	56	I	Tr.	Eg.
	17	19	I	Sh.	Eg.
Feb. 14	11	43	I	Oc.	Dis.
	14	25	I	Ec.	Re.
15	9	02	I	Tr.	In.
	9	28	I	Sh.	In.
	11	23	I	Tr.	Eg.
	11	48	I	Sh.	Eg.
16	5	21	III	Ec.	Re.
	6	09	I	Oc.	Dis.
	8	54	I	Ec.	Re.
17	5	49	I	Tr.	Eg.
	6	17	I	Sh.	Eg.
18	12	39	II	Tr.	In.
	13	40	II	Sh.	In.
	15	35	II	Tr.	Eg.
	16	36	II	Sh.	Eg.
19	13	54	III	Tr.	In.
	16	01	III	Sh.	In.
20	7	42	II	Oc.	Dis.
	11	40	II	Ec.	Re.
	16	21	I	Tr.	In.
	16	54	I	Sh.	In.
21	13	28	I	Oc.	Dis.
	14	44	IV	Tr.	In.
	16	20	I	Ec.	Re.
22	5	54	II	Sh.	Eg.
	10	47	I	Tr.	In.
	11	22	I	Sh.	In.
	13	00	I	Tr.	Eg.
	13	43	I	Sh.	Eg.
23	7	55	I	Oc.	Dis.
	9	28	III	Ec.	Re.
	10	49	I	Ec	Re.
24	5	51	I	Sh.	In.
	7	34	I	Tr.	Eg.
	8	11	I	Sh.	Eg.
25	14	57	II	Tr.	In.
	16	16	II	Sh.	In.
27	9	59	II	Oc.	Dis.
	14	15	II	Ec.	Re.
28	15	14	I	Oc.	Dis.
	18	15	I	Ec.	Re.
29	5	34	II	Sh.	In.
	7	03	II	Tr.	Eg.
	8	31	II	Sh.	Eg.
	12	33	I	Tr.	In.
	13	17	I	Sh.	In.
	14	53	I	Tr.	Eg.
	15	37	I	Sh.	Eg.

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

VARIABLE STARS.

The Variable 136.1907 Andromedæ.—In A.N. 4215 Mr. A. A. Nijland gives observations of this new variable, while together with the previous observations of Blajko, of Moscow, and von Biesbroeck, of Uccle, indicate that the period is perhaps 34.67 days. The fractions one-half, one-third, one-fourth and perhaps one-eighth of this period are possible, but smaller fractions are excluded by Nijland's observations. The three minima observed by the above mentioned observers were:

1907	Aug.	8	8.7^h to 11.5^h	Blajko.
	Sept.	12	8.0 to 16.1	von Biesbroeck and Nijland.
	Oct.	17	5.6 to 11.2	von Biesbroeck and Nijland.

The duration of the minimum is not less than 9 hours nor more than 24 hours.

New Variables 141 and 142.1907.—These are announced in *A. N.* 4213 by Professor W. Ceraski and were discovered by Mme. L. Ceraski on the Moscow photographs. Their positions are

	α 1855	δ 1855	α 1900	δ 1900
	h m s	° ′	h m s	° ′
141.1907 Andromedae	22 52 54.	+ 42 04.	22 54 55	+ 42 18.
142.1907 Cassiopeiae	0 03 08.3	+ 54 05.1	0 05 28.1	+ 54 20.1

The first is probably of long period and on fourteen photographs taken in the years 1900-07 ranges from 9.6 to <11 magnitude.

The second is probably of the Algol type or perhaps irregular. It is the star BD + 54° 7, noted in the BD. as of magnitude 8.3. On 34 photographs taken in the interval 1895-1907 it appears of almost constant brightness, $8^m.7$ to $8.^m9$ but upon two of the dates September 18, 1905 and August 13, 1907 its magnitude is estimated at 9.2 and 9.4.

New Variables 143 and 144.1907.—Two more new variables are announced by Professor Ceraski in *A. N.* 4215. They were discovered on the Moscow photographs by Mme. L. Ceraski, and their positions are

	α 1855	δ 1855	α 1900	δ 1900
	h m s	° ′	h m s	° ′
143.1907 Andromedae	23 06 40	+ 45 21	23 08 44	+ 45 36
144.1907 Cassiopeiae	0 07 26.1	+ 57 37.2	0 09 47.9	+ 57 52.2

The first is probably of the Algol type, ranging from about 10.5 to 11.2 magnitude. The second is of short period and varies between 9.2 and 10.0 magnitude. It is star BD + 57° 42.

Sixteen New Variable Stars.—In the Circular No. 132 of the Harvard College Observatory, is a list of 23 stars having peculiar spectra, sixteen of which are noted as variable. The Variable Star Committee of the Astronomische Gesellschaft have given these the numbers 147 to 162.1907.

No.	Constellation	DM		R.A. 1900		Dec. 1900		Mag.
		°		h	m	°	′	
147.1907	Arietes	+11	305	2	09.6	+11	46	8.2 - 8.8
148.1907	Aurigae	+45	1324	6	28.2	+45	43	8.5 - 9.4
149.1907	Monocerotis	— 4	1708	6	48.3	− 4	27	9.2 - 10.4
150.1907	Canis Major	−22	1850	7	19.4	—22	47	11.0 - 11.9
151.1907	Cancri	+15	1808	8	16.8	+15	19	9.4 - 10.3
	Ursa Major	...		9	44.4	+53	07	...
	Vela	—49	5234	10	21.0	−49	54	9.6
152.1907	Carinae	−72	1048	10	48.7	—72	14	9.8 - 11.5
153.1987	Muscae	R		11	35.0	−72	00	8.6 - 10.0
154.1907	Virginis	...		12	00.0	+12	56	8.5 - 12.5
155.1907	Muscae	R		12	17.4	−74	57	8.8 - 10.6
156.1907	Corvi	−16	3503	12	32.3	−16	43	8.8 - 10.5

No.	Constellation	DM.	R.A. 1900	Dec. 1900	Mag.
		°	h m	° ′	
157.1907	Centauri	−63 2720	13 15.5	−63 42	9.0 - 10.5
	Centaurus	−56 5891	13 36.4	−56 16	6.8
	Circinus	−67 2622	14 30.9	−67 46	7.0
158.1907	Coronae Bor.	+39 2901	15 37.8	+38 53	7.0 - 8.3
159.1907	Draconis	+57 1786	17 35.4	+57 48	8.0 - 9.7
	Ophiuchus	+ 6 3898	18 37.1	+ 6 43	9.0
	Aquila	...	20 07.1	+11 35	...
160.1907	Draconis	+74 861	20 25.9	+64 56	8.3 - 10.5
161.1907	Cygni	+32 3850	20 27.6	+32 14	8.5 - 9.5
162.1907	Pegasi	+34 4597	22 01.4	+34 52	8.2 - 9.2
	Aquarius	−21 6376	23 06.3	−21 32	9.0

Fifteen New Variable Stars.—Circular No. 133 of the Harvard College Observatory contains a list of fifteen more new variables found by Miss Leavitt in examining the chart plates for bright variable stars. These have been given the numbers 163 to 177.1906 by the Variable Star Committee of the Astronomische Gesellschaft.

No.	Constellation	DM.	R.A. 1900	Dec. 1900	Mag.
		°	h m s	° ′	
163.1907	Hydrae	− 7 2715	9 00 48	− 7 51.5	9.0 - 11.5
164.1907	Hydrae	...	8 19 53	− 6 21.8	10.0 -<11.5
165.1907	Leonis	+26 1981	9 31 05	+26 41.4	9.0 - 10.6
166.1907	Leo. Minor	...	9 42 33	+33 45.2	9.5 - 11.5
167.1907	Leonis	+27 1818	9 46 25	+27 22.3	9.8 - 10.4
168.1907	Sextantis	+ 2 2264	9 48 16	+ 2 31.6	8.9 - 9.6
169.1907	Leo. Minor	...	10 00 07	+39 51.4	11.0 - 11.8
170.1907	Leonis	+24 2183	10 02 08	+24 28.9	9.0 - 9.8
171.1907	Hydrae	− 9 3017	10 07 24	− 9 49.5	9.1 - 9.8
172.1907	Bootes	...	15 26 47	+36 08.1	10.2 - 11.0
173.1907	Coron. Cor.	+36 2672	15 54 47	+36 17.9	9.6 - 10.6
174.1907	Herculis	+25 3031	16 03 14	+25 10.3	8.8 - 9.7
175.1907	Herculis	+38 2803	16 32 28	+28 10.1	8.4 - 9.7
176.1907	Herculis	+17 3117	16 49 54	+17 00.0	10.0 - 10.8
177.1907	Herculis	+22 3048	16 57 15	+22 36.7	10.0 -<11.0

Nos. 163, 165 and 166 appear to be of the Algol type.

The Variable Star Z Ceti.—In *A. N.* 4215 Mr. Wilhelm Luther gives the results of his observations in 1907 of this long period variable, and finds from these combined with earlier observations the formula

$$\text{Maximum} = 2417838 + 185^{d}.8\ E.$$

Error in Predicted Minima of Algol.—In computing the minima of Algol for 1907 our computer managed to make an error of one day in both the direct computation and the check, which makes the dates all one day too large after March 13. The computations for 1908 have all been subjected to a second independent check at the end of the year as well as an intermediate check every tenth minimum, so that we hope that no errors remain undetected.

Observations of Nine Algol Type Variables.—In *A.N.* 4211 A. A. Nijland of Utrecht, finds that the error of the ephemeris of ALGOL according to Chandler's elements, from the average of four observed minima in 1907 is 36^{m}. The minima occur 36^{m} earlier than predicted in our tables.

U SAGITTÆ.—Mr. Nijland gives the following corrected elements of U Sagittæ:

$$\text{Minimum} = 2415690.276 + 3.^{d}380603\ E.$$

According to these the minima should occur about an hour earlier than the times given in our tables. The entire duration of minimum is about 11 hours; the star remains stationary at minimum for two hours, at magnitude 9.2 while at full brightness it is 6.85^{m}.

Z PERSEI.—Mr. Nijland also finds the observations of this star to be departing from the ephemerides, the minimum coming $2^{h}\ 27^{m}$ earlier than predicted on July 31, 1907. From the comparison of nine minima in 1905-07 he finds the following corrected elements:

$$\text{Minimum} = 2416009.693 + 3.056463\ \text{E}.$$

According to these elements the correction to our tables for January will be $-\ 2^{h}\ 30^{m}$. The light change occupies about 9 hours; the star is stationary at minimum for $2^{h}.4$, the magnitude being 12.4 while its normal brightness is 9.6.

Y CAMELOPARDI.—For this star also the correction is approximately $-\ 1^{h}\ 15^{m}$ and the new elements according to Mr. Nijland are

$$\text{Minimum} = 2417615.382 + 3^{d}.305461\ \text{E}.$$

Our tables of this star for February have been corrected. The duration of the light change is about 12 hours and the range of brightness from 9.7^{m} to $11^{m}.8$.

Z DRACONIS.—The corrected period given by Nijland is printed as $1^{d}.374145$, but this must be in error and probably should be $1^{d}.3574145$, the new formula becoming

$$\text{Minimum} = 2416177.399 + 1^{d}.3574145\ \text{E}.$$

The correction to our tables for 1908 is about $-\ 1^{h}$. The minimum is very sharp, the entire duration of the light change being only 5 hours, and the range of brightness from $10^{m}.1$ to $12^{m}.3$.

RW GEMINORUM.—The observations of this star by Nijland do not indicate any certain correction to the elements used. The minimum lasts about 12 hours and the magnitude is 12.1 at minimum and 9.75 at normal.

RZ CASSIOPEIÆ.—For this star Nijland finds the following formula to satisfy the observations up to August 27, 1907;

$$\text{Minimum} = 2417649.455 + 1^{d}.19526\ \text{E}.$$

This makes the error of the table for January about 3^{h}. The minima occur three hours later than the times given in the table. The duration of the change of light at minimum is about 5.4^{h} and the range of magnitude from 6.5 to 8.1 magnitude.

RR DELPHINI.—This star is also departing widely from the ephemerides, the correction being now about -4^{h}. Mr. Nijland finds for the corrected formula

$$\text{Minimum} = 2417424.514 + 4^{d}.5993\ \text{E}.$$

The normal magnitude is 10.5 and at minimum it descends to 11.8. The minimum lasts about 14 hours.

RY PERSEI.—From his own observations together with those of Mr. Ichinohe (A. N. 4172), Nijland finds these corrected elements:

$$\text{Minimum} = 2417523.475 + 6^{d}.8640\ \text{E}.$$

The minimum lasts about 23 hours and the range of magnitude is from 8.1 to 10.6. The times in our table for this star for January, 1908, should be diminished by 2 hours.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
Feb.	2	0
	4	12
	7	0
	9	12
	12	0
	14	11
	16	23
	19	11
	21	23
	24	11
	26	23
	29	10

Z Persei

Feb.	3	0
	6	2
	9	3
	12	5
	15	6
	18	7
	21	9
	24	10
	27	11

RY Persei

Feb.	4	12
	11	9
	18	5
	25	2

RZ Cassiop.

Feb.	1	9
	2	14
	3	18
	5	0
	6	4
	7	8
	8	13
	9	18
	10	22
	12	3
	13	8
	14	12
	15	17
	16	22
	18	3
	19	7
	20	12
	21	17
	22	21
	24	2
	25	7
	26	11
	27	16
	28	21

RX Cephei

Feb.	23	22

Algol

	d	h
Feb.	2	20
	5	17
Feb.	8	14
	11	10
	14	7
	17	4
	20	1
	22	22
	25	19
	28	16

RT Persei

Feb.	1	8
	2	15
	3	11
	4	8
	5	4
	6	0
	6	21
	7	17
	8	13
	9	10
	10	6
	11	3
	11	23
	12	19
	13	16
	14	12
	15	9
	16	5
	17	1
	17	22
	18	18
	19	15
	20	11
	21	7
	22	4
	23	0
	23	20
	24	17
	25	13
	26	10
	27	6
	28	2
	28	23
	29	19

λ Tauri

Feb.	4	19
	8	18
	12	17
	16	15
	20	14
	24	13
	28	12

RW Tauri

	d	h
Feb.	1	17
	4	11
	7	6
	10	0
	12	19
Feb.	15	13
	18	18
	21	2
	23	21
	26	15
	29	9

RV Persei

Feb.	2	8
	4	7
	6	6
	8	6
	10	5
	12	5
	14	4
	16	3
	18	3
	20	2
	22	1
	24	1
	26	0
	28	23
	29	23

RW Persei

Feb.	13	11
	26	16

RS Cephei

Feb.	13	1
	25	11

RW Geminorum

Feb.	1	3
	4	0
	9	21
	9	18
	12	14
	15	11
	18	9
	21	5
	24	1
	26	2
	29	19

RW Monoc.
(24.1907)

Feb.	2	7
	4	5
	6	3
	8	1
	9	22
	11	20
	13	18
	15	16
	17	14
	19	11
	21	9
	23	7
	25	5
	27	2
	29	0

RU Monoc.

	d	h
Feb.	1	21
	2	19
	3	17
	4	14
	5	12
	6	9
	7	7
	8	4
	9	2
	9	23
	10	21
	11	18
	12	16
	13	13
	14	11
	15	8
	16	6
	17	3
	18	1
	18	22
	19	20
	20	17
	21	15
	22	12
	23	10
	24	7
	25	5
	26	2
	27	0
	27	21
	28	19
	29	16

R Canis Maj.

	d	h
Feb.	1	1
	2	4
	3	7
	4	11
	5	14
	6	17
	7	20
	9	0
	10	3
	11	6
	12	9
	13	13
	14	16
	15	19
	16	22
	18	2
	19	5
	20	8
	21	12
	22	15
	23	18
	24	21
	26	1
	27	4
Feb.	28	7
	29	10

Y Camelopardi

Feb.	3	16
	7	0
	10	7
	13	14
	16	22
	20	5
	23	12
	26	20

R Puppis

Feb.	1	3
	7	14
	14	0
	20	10
	26	21

V Puppis

Feb.	1	19
	3	6
	4	17
	6	4
	7	15
	9	2
	10	13
	11	23
	13	10
	14	21
	16	8
	17	19
	19	6
	20	17
	22	4
	23	15
	25	2
	26	13
	27	23
	29	10

X Carinæ

Feb.	1	11
	2	13
	3	15
	4	17
	5	19
	6	21
	7	23
	9	1
	10	3
	11	5
	12	7
	13	9
	14	11
	15	13
	16	15
	17	17
	18	19
	19	21

Minima of Variable Stars of the Algol Type.—Continued.

X Carinæ

	d	h
Feb.	20	23
	22	1
	23	3
	24	5
	25	7
	26	9
	27	11
	28	13
	29	15

S Cancri

Feb.	6	1
	15	12
	25	0

S Velorum

Feb.	4	2
	10	0
	15	23
	21	21
	27	19

RR Velorum

Feb.	1	16
	3	13
	5	9
	7	6
	9	2
	10	23
	12	19
	14	16
	16	12
	18	9
	20	5
	22	2
	23	22
	25	19
	27	15
	29	12

SS Carinae

Feb.	4	0
	7	8
	10	15
	13	22
	17	5
	20	13
	23	20
	27	3

Z Draconis

	d	h
Feb.	1	6
	2	15
	3	23
	5	8
	6	16
	8	1
	9	10
	10	18
	12	3
	13	11
	14	20
	16	5
	17	13
	18	22
Feb.	20	6
	21	15
	22	23
	24	8
	25	17
	27	1
	28	10
	29	18

RZ Centauri

Feb.	1	18
	2	16
	3	15
	4	13
	5	12
	6	10
	7	9
	8	8
	9	6
	10	5
	11	3
	12	2
	13	0
	13	23
	14	21
	15	20
	16	18
	17	17
	18	15
	19	14
	20	12
	21	11
	22	9
	23	8
	24	6
	25	5
	26	3
	27	2
	28	0
	28	23

SS Centauri

Feb.	2	9
	4	20
	7	8
	9	19
	12	7
	14	18
	17	6
	19	17
	22	5
	24	16
	27	4
	29	15

δ Libræ

	d	h
Feb.	2	5
	4	13
	6	21
	9	5
	11	13
	13	21
	16	4
Feb.	18	12
	20	20
	23	4
	25	12
	27	20

U Coronæ

Feb.	1	12
	4	23
	8	10
	11	20
	15	7
	18	18
	22	5
	25	16
	29	3

R Aræ

Feb.	4	20
	9	7
	13	17
	18	3
	22	13
	26	23

U Ophiuchi

Feb.	1	2
	1	22
	2	18
	3	14
	4	10
	5	7
	6	3
	6	23
	7	19
	8	15
	9	11
	10	7
	11	3
	12	0
	12	20
	13	16
	14	12
	15	8
	16	4
	17	0
	17	20
	18	17
	19	13
	20	9
	21	5
	22	1
	22	21
	23	17
	24	14
	25	10
	26	6
	27	2
	27	22
	28	18
	29	14

Z Herculis

	d	h
Feb.	1	12
	3	9
	5	12
	7	9
	9	11
	11	8
	13	11
	15	8
	17	11
	19	8
	21	11
	23	8
	25	11
	27	8
	29	11

RS Sagittarii

Feb.	3	2
	5	11
	7	21
	10	7
	12	17
	15	3
	17	13
	19	23
	22	9
	24	19
	27	5
	29	15

V Serpentis

Feb.	1	7
	4	18
	8	5
	11	16
	15	3
	18	14
	22	1
	25	12
	28	22

RZ Draconis

	d	h
Feb.	2	1
	3	3
	4	6
	5	8
	6	10
	7	13
	8	15
	9	18
	10	20
	11	23
	13	1
	14	3
	15	6
	16	8
	17	11
	18	13
	19	16
	20	18
	21	21
	22	23
	24	1
Feb.	25	4
	26	6
	27	9
	28	11
	29	14

RX Herculis

Feb.	1	9
	2	7
	3	4
	4	1
	4	23
	5	20
	6	17
	7	15
	8	12
	9	10
	10	7
	11	4
	12	2
	12	23
	13	20
	14	18
	15	15
	16	12
	17	10
	18	7
	19	4
	20	2
	20	23
	21	20
	22	18
	23	15
	24	12
	25	10
	26	7
	27	4
	28	2
	28	23
	29	20

SX Sagittarii

Feb.	1	7
	3	8
	5	10
	7	12
	9	14
	11	16
	13	18
	15	20
	17	21
	19	23
	22	1
	24	3
	26	5
	28	7

RR Draconis

Feb.	3	2
	5	22
	8	18
	11	14
	14	10

Minima of Variable Stars of the Algol Type.—Continued.

RR Draconis

	d	h
Feb.	17	6
	20	2
	22	22
	25	18
	28	14

RZ Ophiuchi

Feb.	11	14

U Scuti

Feb.	1	4
	2	3
	3	2
	4	1
	4	23
	5	22
	6	21
	7	20
	8	19
	9	18
	10	17

U Scuti

	d	h
Feb.	11	16
	12	15
	13	14
	14	13
	15	12
	16	10
	17	9
	18	8
	19	7
	20	6
	21	5
	22	4
	23	3
	24	2
	25	1
	26	0
	26	23
	27	22
	28	20
	29	19

RX Draconis

	d	h
Feb.	2	0
	3	22
	5	19
	7	16
	9	14
	11	11
	13	9
	15	6
	17	4
	19	1
	20	23
	22	20
	24	18
	26	15
	28	13

RV Lyræ

Feb.	3	23
	7	13
	11	4
	14	18

RV Lyræ

	d	h
Feb.	18	8
	21	23
	25	13
	29	4

U Sagittæ

Feb.	3	14
	7	0
	10	9
	13	18
	17	2
	20	11
	23	20
	27	5

SY Cygni

Feb.	6	5
	12	5
	18	5
	24	5

WW Cygni

Feb.	1	7

WW Cygni

	d	h
Feb.	4	15
	7	23
	11	6
	14	14
	17	21
	21	5
	14	13
	27	20

SW Cygni

Feb.	2	9
	6	23
	11	12
	16	2
	20	16
	25	6

VW Cygni

Feb.	3	17
	12	3
	20	14
	29	0

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(—5	19)
Feb.	8	2
	22	22

RX Aurigæ

	(—4	0)
Feb.	6	9
	18	0
	29	15

Y Aurigæ

	(—0	18)
Feb.	3	7
	7	4
	11	0
	14	21
	18	18
	22	14
	26	11

T Monoc.

	(—7	23)
Feb.	8	10

W Geminorum

	(—2	22)
Feb.	4	9
	12	7
	20	5
	28	3

ζ Geminorum

	(—5	0)
Feb.	9	19
	19	23

RU Camelop.

	(—9	12)
Feb.	4	8
	26	14

RR Geminorum

	d	h
	Period 9.5h	
	(—0	2)
Feb.	1	9
	2	13
	3	18
	4	23
	6	3
	7	8
	8	12
	9	17
	10	22
	12	2
	13	7
	14	11
	15	16
	16	21
	18	1
	19	6
	20	10
	21	15
	22	20
	24	0
	25	5
	26	9
	27	14
	28	19
	29	23

V Carinæ

	(—2	4)
Feb.	7	8
	14	0
	20	17
	27	10

T Velorum

	d	h
	(—1	10)
Feb.	1	7
	5	23
	10	14
	15	5
	19	21
	24	12
	29	3

W Carinæ

	(—1	0)
Feb.	4	9
	8	18
	13	3
	17	12
	21	20
	26	5

S Muscæ

	(—3	11)
Feb.	2	14
	12	5
	21	21

T Crucis

	(—2	2)
Feb.	5	1
	11	18
	18	12
	25	5

R Crucis

	(—1	10)
Feb.	2	18
	8	14
	14	10
	20	6
	26	2

S Crucis

	d	h
	(—1	12)
Feb.	4	21
	9	13
	14	6
	18	22
	23	15
	28	7

W Virginis

	(—8	5)
Feb.	3	22
	21	5

V Centauri

	(—1	11)
Feb.	3	18
	9	6
	14	18
	20	6
	25	17

R Triang. Austr.

	(—1	0)
Feb.	1	20
	5	6
	8	15
	12	0
	15	10
	18	19
	22	5
	25	14
	28	23

S Triang. Austr.

	(—2	2)
Feb.	4	7
	10	15

S Triang. Austr.

	d	h
Feb.	16	23
	23	6
	29	14

S Normæ

	(—4	10)
Feb.	2	17
	12	11
	22	5

RW Draconis.

	Period 10.6h	
	(—0	3)
Feb.	1	9
	2	7
	3	4
	4	1
	4	22
	5	20
	6	17
	7	14
	8	11
	9	9
	10	6
	11	3
	12	0
	12	22
	13	19
	14	16
	15	13
	16	11
	17	8
	18	5
	19	3
	20	0

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

RW Draconis

	d	h
Feb.	20	21
	21	18
	22	16
	23	13
	24	10
	25	7
	26	5
	27	2
	27	23
	28	20
	29	18

RV Scorpii

	d	h
	(—1	10)
Feb.	6	8
	12	9
	18	11
	24	12

RV Ophiuchi minimum.

	d	h
Feb.	4	9
	8	2
	11	18
	15	11
	19	3
	22	20
	26	12

X Sagittarii

	d	h
	(—2	22)
Feb.	6	22
	13	22
	20	22
	27	23

Y Ophiuchi

	d	h
	(—6	5)
Feb.	1	16
	18	19

W Sagittarii

	d	h
	(—3	0)
Feb.	5	21
	13	12
	21	2
	28	16

Y Sagittarii

	d	h
	(—2	2)
Feb.	2	23
	8	18
	14	12
	20	7
	26	1

U Sagittarii

	d	h
	(—2	23)
Feb.	5	0
	11	18
	18	12
	25	6

β Lyræ

	d	h
	(—3	2)
	(—3	7)
Feb.	9	20
	16	7
	22	18
	29	5

κ Pavonis

	d	h
	(—1	7)
Feb.	3	2
	12	5
	21	7

U Aquilæ

	d	h
	(—2	4)
Feb.	1	20
	8	20
	15	21
	22	21
	29	22

XZ Cygni
Period 11.2^h

	d	h
	(—0	4)
Feb.	1	20
	2	19
	3	17
	4	15
	5	14
	6	12
	7	11
	8	9

XZ Cygni

	d	h
Feb.	9	7
	10	6
	11	4
	12	3
	13	1
	13	23
	14	22
	15	20
	16	19
	17	17
	18	15
	19	14
	20	12
	21	11
	22	9
	23	7
	24	6
	25	4
	26	3
	27	1
	28	22
	29	20

V Vulpeculæ

	d	h
	(—1	8)
Feb.	2	20
	10	20
	18	19
	26	19

SW Cygni

	d	h
	(—1	7)
Feb.	3	9
	7	5
	11	2
	14	22
	18	18
	22	14
	26	11

η Aquilæ

	d	h
	(—2	6)
Feb.	5	16
	12	20
	20	0
	27	4

S Sagittæ

	d	h
	(—3	10)
Feb.	6	14
	15	0
	23	9

X Vulpeculæ

	d	h
	(—2	1)
Feb.	3	22
	10	6
	16	14
	22	21
	29	5

GENERAL NOTES.

Different Explanations of the Canals of Mars. In *Harper's Magazine*, December 1907, Professor William H. Pickering gives a brief statement of the different explanations of the Canals of Mars.

First that they are artificial water courses. Objection to this is the extent of them over nearly level surfaces would require gigantic pumping machinery to force the water rapidly so far. Also in so thin an atmosphere water would evaporate rapidly.

Second, if Mars is inhabited and its vegetation is cultivated, Professor Pickering suggests how its shrubbery might have the line-like look we see by the aid of the telescope. This view is illustrated by photographs taken while on a visit at the Azores Islands recently.

Other explanations are the same as those published in this magazine Vol. XII, p. 439; *Science* 1888 vol. XII. p. 82.

No explanation of these singular markings on the surface of Mars is yet given that well satisfies all the conditions.

Request Concerning the Transit of Mercury, Nov. 14, 1907. As far as the unfavorable conditions will permit, the writer desires that certain special physical observations be attempted upon the Planet Mercury at its transit, November 14, 1907. The writer had most interesting experiences in observing the transit of Mercury in 1878, and the transit of Venus in 1882. During these transits he tested a delicate method for successfully observing the physical appearances of the planets, and he now desires this method, described in Washington observations for 1876, article "Transit of Mercury," to be applied to the determinations of at least one particular point.

In 1878, when the planet Mercury was projected about midway upon the limb of the Sun between first contact and second contact, the writer, with rested eye, glanced into the telescope and was surprised to find that the *entire disk* of Mercury, including that part *off the solar edge* showed in a faint, grayish illumination. The writer has good reasons for believing that this appearance can only be seen at a *critical time* midway between third and fourth contacts on the 14th, and then only seen under good conditions of observation. Adjust accurately to focus, use a rested eye, try the method of glimpsing at image so as to use full sensitivity, and all retinal rods and cones. Swing telescope back and forth so as to move solar-planetary image over *all* retinal rods and cones.

Use these processes *before* and *after* midway position, so as to eliminate "physiological" effect. Especially use this method *at midway position*, because entire disk very likely shows *only then.*

Far best, and latest, observations of fourth contact rapidly move image by swinging telescope. Mercury as *complete disk* MAY thus be seen projected on Chromosphere of Sun.

MONROE B. SNYDER.

Philadelphia Observatory,
Nov. 9, 1907.

If this note had been received in time for the November number of this magazine, doubtless observers of this interesting phenomenon, would have given particular attention to the requests made. As it is, if any observers can give Professor Snyder the information he wishes from the observations of the transit as they were made, the same will be very gratefully received. [Ed.]

Transit of Mercury. Professor M. Moye, of Montpellier, France, writes, November 14, that the transit of Mercury was seen by him in a very fine sky. At ingress and egress no luminous ring was observed outside of the Sun, but the black ligament was conspicuous for fully a minute. He says:

"At no time did I see the faintest suspicion of a halo or ring around Mercury, or any luminous spot on its disk. The planet was black and without any abnormal feature in any form. In short, it was a perfect geometrical transit."

3 rue Achille-Bégé, Montpellier, France.

The Transit of Mercury at Goodsell Observatory.—The Sun was near the horizon and the seeing was very poor, the image boiling badly, but the times of egress of Mercury are probably not more than five or six seconds in error. The observations were made with the 16-inch refractor and and polarizing eyepiece, with magnifying power 225. The times were noted by means of a watch which was compared with the Central Standard Time clock both before and after the observations. The reduced times of the two contacts are:

	h	m	s	
Contact III (interior)	1	48	28 ±	Greenwich mean time.
Contact IV (exterior)	1	50	48 ±	" " "

I could at no time see illumination of the edge of Mercury off the Sun, although at times between the two contacts I could imagine that I saw the whole outline of the black disk.

H. C. WILSON.

Transit of Mercury, Detroit Observatory. Observations of the Transit of Mercury, November 14, were made at Ann Arbor by Professor Hussey, with the 12-inch refractor, and by the writer, with a 4-inch. The atmospheric conditions were very poor, because of the Sun's low altitude.

The table gives the Greenwich Mean Times of contact observed here, and also those published in POPULAR ASTRONOMY for December. It also shows the geocentric times of the American Ephemeris, corrected for the positions of the observers, (which was not done in all of the published times): and the difference between computed and observed times.

It will be seen that the observed times of third contact, (which are naturally more accurate than fourth), range on both sides of American Ephemeris times, showing that the errors are in the observations.

That all observed values of fourth contact are too early, is doubtless due to the fact that Mercury was lost before it was really tangent, because of irregularities in Sun's limb.

Transit of Mercury November 14.

Observer	Place	3rd. Contact			4th Contact		
		Observed	Am Cph.	Dif.	Observed	Am. Cph.	Dif.
		h m s	h m s	s	h m s	h m s	s
Pickering	Cambridge	1 48 9	1 48 18 8	+ 10	1 50 37	1 50 57.5	+ 20
Upton	Providence	1 48 26	1 48 18.5	— 8	1 50 48	1 50 57.2	+ 9
Doolittle	Philadelphia	1 48 26.8	1 48 17.5	— 9	1 50 39.9	1 50 56.3	+ 16
Hussey	Ann Arbor	1 48 20	1 48 18.4	— 2	1 50 23	1 50 57.3	+ 34
Vinton	Ann Arbor	1 48 20	1 48 18.4	— 2	1 50 35	1 50 57.3	+ 22

WARREN J. VINTON.

Detroit Observatory,
Ann Arbor, Mich.
Dec. 12, 1907.

Group of Red Stars near Nova Velorum. In a cursory examination of Draper Memorial spectrum plates, recently received from Peru, a new gaseous nebula was found, by Mrs. Fleming, on Plate A 8341, taken with the 24-inch Bruce Telescope, on June 6, 1907, with an exposure of 120^m. On further examination this object proved to be the spectrum of Nova Velorum, the new star discovered by Miss H. S. Leavitt, and announced in H. C. 121. The region covered by Plate A 8431, R. A. 10^h 36^m to 11^h 23^m, Dec. $-51°.0$ to $-57°.0$ (1875) shows so many interesting spectra that a list of them has been prepared, and is given in Table I. All of these are here announced for the first time, unless otherwise stated in the Remarks. The designation and magnitude taken from the Cape Photographic Durchmusterung are given in the first and fourth columns. The class of spectrum is given in the fifth column. Two of these stars have been found to be variable, and one other, suspected of variability, proved to be the known variable, RW Centauri.

REMARKS.

10^h 47^m $35.^s2$. H. V. 2990. An examination of ten chart plates, taken between June 20, 1900 and May 13, 1905, shows a variation of about 0.9 magn. Estimates from these plates, give the approximate limiting magnitudes, 10.0 to 10.9. A plate taken on April 12, 1898, gives the estimated magnitude 12.0, and increases the amount of variation to about 2.0 magnitudes.

10^h 57^m $15.^s9$. H. V. 1268. Nova Velorum. Seven bright lines appear in this spectrum, having the approximate wave-lengths, 5013, 4926, 4862 4643, 4611, 4340, and 4101. Their estimated intensities are 7, 3, 2, 4, 4, 10, and 1, respectively. All of these lines appear to coincide with bright lines in the later spectra of Nova Persei, No. 2, except the fifth, 4611, which perhaps coincides with a bright line at 4608 in the spectrum of H. P. 1311. The strong helium line, 4472, however, which was bright in Nova Persei, No. 2, is absent.

11^h 1^m $50^s.8$. The known variable star, RW Centauri. Rediscovered independently in this examination. This star is Z. C. 11^h 129.

11^h 15^m $42^s.2$. H. V. 2991. An examination of 11 chart plates, taken between April 12, 1898 and May 13, 1905, shows a variation of about 0.7 magn. Estimates from these plates give the approximate limiting magnitudes, 9.7 to 10.4.

The variable stars, *104055* = H 1275, and 110551 = H 1281, found by Miss Leavitt, and announced in H. C. 122, have spectra of classes K and A 5 F, respectively, on Plate A 8341.

EDWARD C. PICKERING.

Harvard College Observatory. Circular 131.
October 3, 1907.

TABLE I.

RED STARS IN REGION OF NOVA VELORUM.

C. P. D.		R. A. 1875.			Dec. 1875.		Mag.	Spectrum.
		h	m	s	°	′		
−53°	4086	10	37	2.2	−53	4.1	9.8	Mb5c
−52°	3863	10	38	59.6	−52	26.2	9.2	Mb5c
−52°	3887	10	40	33.6	−52	58.3	8.7	Ma
−54°	4020	10	40	44.3	−54	4.2	9.6	Mb
−52°	3915	10	42	21.6	−52	41.8	10.0	Mb
−55°	3855	10	42	47.7	−55	0.0	10.0	Mb
−55°	3876	10	43	55.2	−55	56.6	9.6	Mb5c
−54°	4080	10	44	42.3	−54	11.8	9.6	Ma
−52°	3964	10	45	59.5	−52	54.8	10.0	Mb
−55°	3919	10	46	25.1	−55	3.5	10.1	Mb
−56°	3935	10	47	1.7	−56	15.6	9.6	Mb
..	..	10	47	35.2	−52	45.6	..	Na
..	..	10	49	45.7	−53	26.2	..	Ma
−52°	4048	10	52	0.0	−52	26.7	10.2	Mc
−56°	4069	10	54	11.2	−56	5.3	9.4	Mb
−55°	4046	10	55	1.0	−55	10.5	9.2	Ma
−55°	4075	10	56	50.6	−55	14.4	9.3	Mb
−53°	4299	10	57	11.7	−53	53.6	10.0	Mb
−51°	3819	10	58	40.5	−51	48.0	9.6	Ma5b
..	..	10	57	15.9	−53	42.8	..	Br. lines
−55°	4114	10	59	39.8	−55	25.2	9.5	Mb
..	..	11	1	45.3	−53	45.8	..	Mb
−53°	4358	11	1	54.8	−53	11.6	9.4	Mb
R		11	1	50.8	−54	26.8	9.0	Na
−52°	4239	11	2	27.7	−52	7.7	8.9	Ma
−55°	4157	11	3	3.8	−55	19.8	9.8	Mb
−55°	4176	11	4	18.3	−55	20.8	10.0	Mb
−52°	4310	11	6	2.2	−52	49.4	9.4	Ma
−55°	4207	11	6	45.8	−55	32.1	9.6	Mb
−54°	4389	11	7	12.5	−54	17.4	9.6	Ma
−54°	4405	11	8	30.8	−54	10.7	9.8	Ma5b
−53°	4500	11	15	43.0	−53	26.9	9.6	Ma?
..	..	11	15	42.2	−55	4.8	..	Na
−54°	4516	11	18	39.9	−54	27.1	9.4	Ma5b

The Synodic Period of Jupiter and Saturn. The mean motions in days, from Hill's Tables are,—Jupiter, 4332.5880; Saturn, 10759.2009.

From these the converging portions may be found

$$\frac{5}{2},\ \frac{72}{29},\ \frac{149}{60},\ \frac{2456}{989},\ \frac{7517}{6027},\ \text{revolutions}$$

and also the synodic period in years;—

19.85888 or 20 years less 51.5 days.

And the planets are together distant from their starting point. $242^\circ.69 = 242^\circ\ 41'.4$

It is thus seen while the period in time is considerably less than twenty years, the points of conjunction vary but little from the meridians 240° apart.

ROBERDEAU BUCHANAN.

High School Algebra by Slaught and Lennes. This new text-book is published by Allyn and Bacon, Boston, Mass. It is an elementary course in Algebra designed for use in secondary schools. In it the authors treat of number relations fully, by example and precept, of the solution of problems, of simultaneous equations, of special products and factors, of quotients and square roots and of fractions with literal denominators.

The important features which the authors emphasize in this drill book for class work are

1 Algebra is constantly connected with arithmetic.

2 The principles of Algebra are given in eighteen short statements.

3 The purpose of this course is to learn how to solve problems,—not to examine the truths of Algebra for their own sake.

4 The course has been planned with these thoughts in mind in choosing the matter and in shaping its treatment.

It appears to us that this book would do good service in the school room in the hands of a teacher whose ability to teach is in keeping with its spirit and purpose.

Auroral Arches. I was very much interested in reading in your August-September issue, the two references, under General Notes, to "Auroral Arches."

It has been my good fortune while spending my vacations in Canada, to observe some magnificent auroral displays, but the most interesting I think was the one seen by our party at Maple Lake, Ontario, Canada, during the evening of August 8th, 1896. The following notes which I made describe the general appearance:

"About 8 P. M. there appeared in the East a white column or band of smoke which we first believed came from a forest fire. Slowly the column ascended to the zenith and short radial streamers came from a small corona but did not last long—as the white column moved slowly toward the western horizon and gradually disappeared. While the radial streamers were seen in the zenith, rolls of light were also ascending from the northern horizon toward the zenith."

From my notes of the following evening, I find:

"A faint aurora appeared in the northern sky about 9 o'clock; at 10 o'clock the dark segment was quite plainly seen. The light seemed brightest on the upper edge. Streamers appeared at 11 o'clock but there was no recurrence of the east to west band."

This was my first observation of this form of the Aurora and although I have watched for it each summer during my stay in Canada we were not rewarded until last summer, August 7th, 1906, while we were encamped at the mouth of the Moon River, Georgian Bay and just ten years after the former appearance.

Last year's aurora appeared about 8 o'clock and the band seemed to be about 8° wide, and as in 1896, rose in the east, passed slightly south of the zenith and extended almost to the western horizon.

The luminous matter forming the band or arch was very dense at times although it did not prevent our seeing the brighter stars through it. We could also plainly see a pulsating movement in the band, this movement, as nearly as I could estimate, was about 5° a second.

Between 9 and 10 o'clock beautiful waves or curtains of pale yellow light swept across the northern horizon from east to west, the eastern portion seemed much brighter and higher than the western end.

About 10 o'clock the band or arch became very attenuated and finally disappeared. The streamers from the northern horizon, however, continued some time after the disappearance of the band or arch.

The next evening we again saw the band but it appeared segmental and the luminosity had very much diminished and soon disappeared. We also saw streamers in the north but these were very faint compared with the display of the previous evening.

It is interesting to note the coincidence of the occurrence of the displays of 1871 and 1903 recorded by Mr. Campbell, and those of 1904 and 1907 observed by Mr. Hervey, with the years of Maximum Solar Activity.

If we add thirty-five years, the mean length of the secular period of variation, deduced by Dr. W. S. Lockyer, to the year 1871, we obtain 1906 as the year of recurrence of great solar activity and associated phenomena as aurora, etc.

There is also a close agreement when we add the well-known "mean length" deduced by Dr. Wolf of eleven years to 1896 and obtain 1907 as time of recurrence of activity of 1896 referred to above.

While it is probable that the form of the aurora we have been considering is observed more frequently in higher latitudes where the conditions are more favorable, it does not seem to be of rare occurrence in latitudes south of 45°, and a record of future occurrences will undoubtedly assist in the solution of one of nature's sublime phenomena.

Irwin, Pa. J. WALTER MILES.

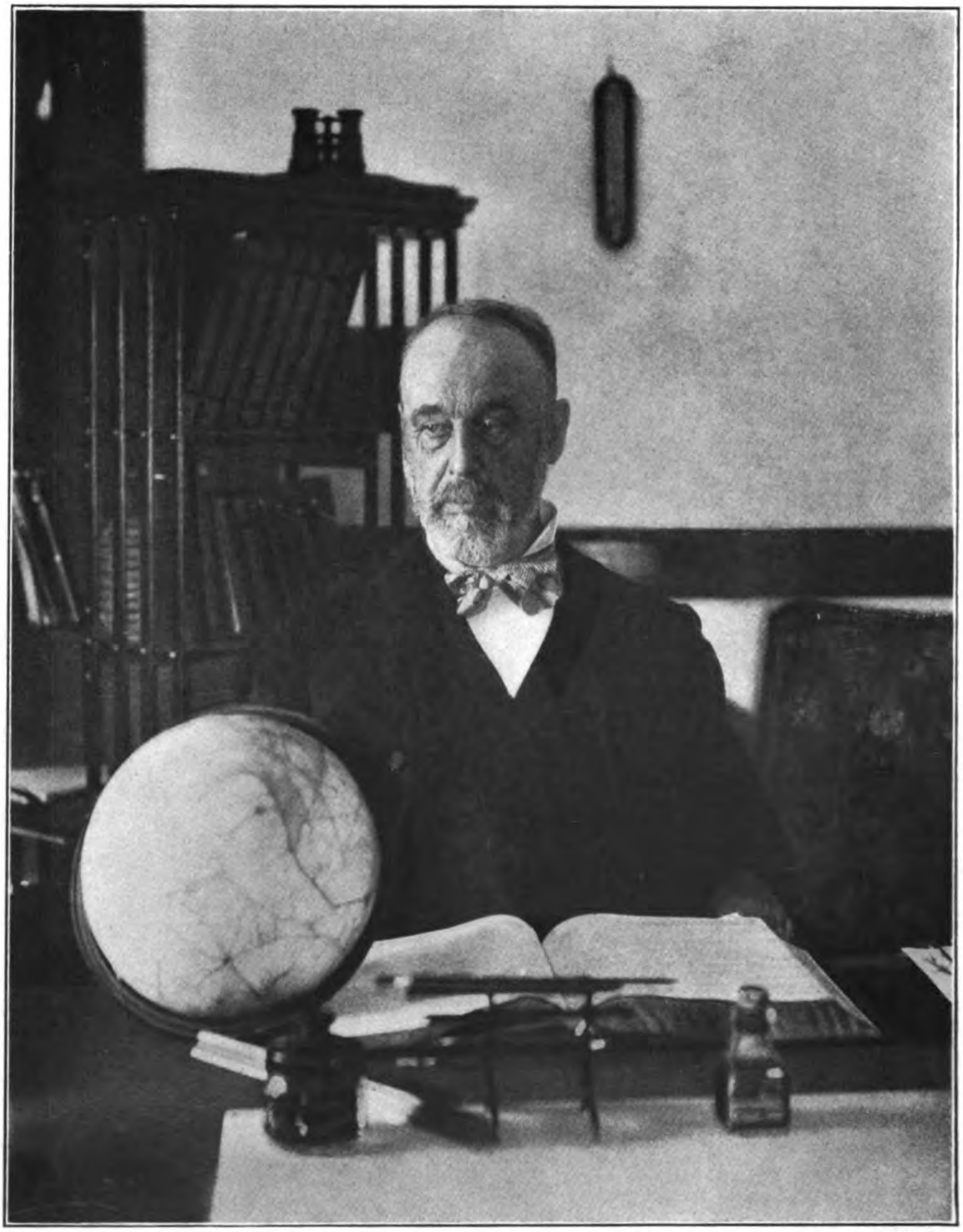
Parallax of the Andromeda Nebula.—In A.N. 4213 Mr. Karl Bohlin, of Stockholm, gives the results of three determinations of the parallax of the nucleus of the Andromeda Nebula, from measurement of photographic plates. In the measurement of the different plates he states that some 41,000 single pointings were made. The results of the three determinations are respectively +0″.08, +0″.20 and +0″.19, the mean of the three giving +0″.17 as the final result. This places the nebula at only a moderate stellar distance, about 19 light years.

Annular Eclipse.—Under the head of Astronomical Phenomena for 1908, readers will find mention of an annular eclipse in June. Requests have come for a detailed map of the path of this eclipse, and we are glad to say that such a map will appear in the May number.

Errata.—In December, 1907, on page 394, line 6 from the bottom, for "Mitchell's Pass" read *Marshall's Pass*, and same page, line 5 from the bottom. for "18,000 feet" read *10,846 feet*, in J. F. Lanneau's article.

Through an oversight the directorship of Detroit Observatory, Ann Arbor, Michigan, was credited to J. M. Schaeberle in our last number. Professor W. J. Hussey, formerly of Lick Observatory, as most readers of POPULAR ASTRONOMY know is still director at Ann Arbor.

PLATE II.



ASAPH HALL

1829–1907

Popular Astronomy.

Vol. XVI, No. 2. FEBRUARY, 1908. Whole No. 152

ASAPH HALL.

H. S. PRITCHETT.

Professor Asaph Hall, one of the most noted of American astronomers, died on November 22 at the home of his son, Professor Angelo Hall, at Annapolis, Maryland, and was buried at Goshen, Connecticut, in the family cemetery on November 25.

Asaph Hall was born in Goshen, Connecticut, October 15, 1829. His ancestors were among the early English settlers of New England and their names appear in the records of the colonial wars and of the revolution. His grandfather, Asaph Hall, was a captain of the company organized at Cornwall, Connecticut, which assisted in the defense of Ticonderoga. His father, Asaph Hall, married Hannah Palmer, of Goshen, Connnecticut, and Professor Asaph Hall, who has just died was the eldest of six children by this marriage.

He received such early education as the youth of his time had access to in the country and at Norfolk Academy and, after he had become of age, attended College at McGrawville, N. Y. There he met Angeline Stickney, a student and teacher of mathematics at that college, whom he subsequently married and who, throughout her life, gave herself devotedly to him and to his scientific work. Professor Hall's choice of astronomy was largely due to her suggestion and she was the first perhaps to recognize his unusual mathematical ability. After their marriage, they went to Ann Arbor, Michigan, where Mr. Hall studied under Brünnow, the well-known astronomer, at that time director of the Ann Arbor Observatory.

Professor Hall's career as an astronomer began at the Harvard Observatory, under William Bond, in 1857. His work there consisted mainly in the routine observatory work, but he quickly became an expert in the computation of the orbits of comets and began to show the admirable grasp of mathematical relations which later on made him an authority in problems of gravitational astronomy.

In 1862 he entered the Naval Observatory as assistant astronomer and in 1863 was appointed professor of mathematics in the United States Navy by President Lincoln, a position which he retained until retired, under the regulations, in 1891, on the completion of his sixty-second year.

The thirty years which Professor Hall spent at the Naval Observatory were full of fruitful work, both as an observer and in the higher sphere of mathematical investigation of astronomical phenomena. From 1862 to 1866 his work was that of assistant observer with the 9½-inch equatorial, then considered a very large instrument, and consisted in the main of observations of asteroids and comets. In 1867 he was in charge of the meridian circle; from 1868 to 1875 in charge of the 9½-inch equatorial; and from 1875 to 1891 in charge of the 26-inch equatorial, at the time of its erection the largest refracting telescope in the world. During these years he was the leader in many expeditions to distant parts of the world to conduct observations of special interest. In 1869 he went to Bering Strait to observe an eclipse of the Sun; in 1870 to Sicily to observe an eclipse; in 1874 to Vladivostock to observe the transit of Venus, the voyage being made on the *Kearsarge*. In 1878 he had charge of an expedition to Colorado to observe the eclipse of the Sun in that year; and in 1882 he went to Texas to observe the transit of Venus.

The contributions of Professor Hall to astronomy were so numerous that a mere enumeration of them would fill a long catalogue. Working astronomers have been familiar with his papers in the *Astronomische Nachrichten*, that universal journal of astronomical communication, for half a century.

His first discovery with the 26-inch equatorial, which was of great interest, was a white spot on the planet Saturn in 1876, by means of which a new and accurate determination of the rotation period of the planet was made.

In the summer of 1877, at the time of the near approach of the planet Mars, he made a systematic search for new satellites, which was rewarded by the most interesting discovery with which his name is connected, that of the two satellites Deimos and Phobos. Up to that time it had been believed that Mars had no moons and the discovery of two companions of this comparatively well-known planet in a period less than one-third of the revolution time of the planet itself, came to astronomers almost as an unwarranted innovation in the solar system. The investigation of the inner satellite has led to the most interesting results in the study of the evolution of planets and their satellites.

Next to these brilliant telescopic discoveries, the discovery of the motion of the line of the apsides of the orbit of Hyperion, one of Saturn's satellites, was perhaps Mr. Hall's most remarkable piece of work.

His long and systematic observations with the great equatorial at Washington were of special value, not only for the great accuracy with which they were made, but also for the admirable way in which they were joined to the work of other observers and made as nearly as possible comparable with them. Perhaps no observer in any nation, unless it be Otto Struve, has contributed so long and valuable a series of observations with a single equatorial as is embraced in the work of Professor Hall.

This work lay mainly in three directions: first, planetary observations, consisting in the main of determinations of the positions of the satellites, with the consequent investigations of their orbits;.second, observations of double stars with numerous investigations of the double star orbits; third, determinations of the stellar parallax. In each of these fields of astronomical activity Mr. Hall's work was of the highest value and led not only to interesting observational results, but to most elegant discussions of gravitational problems in the solar and stellar systems. His observations, in particular, of the system of the planet Saturn, including those of the rings, have been of primary importance in bettering our knowledge of that interesting planet.

In all this work Professor Hall showed not only a high order of skill as an observer, but he also developed a very high order of ability in his grasp of those mathematical relations involved in the treatment of the gravitational problems of our system of planets and satellites. His papers concerning the various problems arising out of the motions of planets and satellites brought him his highest recognition and showed him to be a man possessing an order of intellectual ability of exceptional character. It is not too much to say that he is one of a group of Americans of not more than a half dozen men at most who have attained high rank as mathematical astronomers.

The recognition of Professor Hall's work by various societies and governments is most significant of the character of the work itself. He received the gold medal of the Royal Astronomical Society of London, the Lalande prize of France, the Arago medal from the French Academy of Sciences, and was made a knight of the Legion of Honor. He was a member of the more important scientific societies in this country and abroad, being an honorary member of the Royal Society in England as well as of the French Academy and of the Royal Academies of Russia and Germany. As a member of the National Academy of Sciences of America he served for many years as secretary and later as its vice-president. He received honorary degrees from many colleges and universities amongst others the degree of LL.D. from Yale and the same degree from Harvard at the celebration of its two hundred and fiftieth anniversary.

Retiring from the Naval Observatory at the age of sixty-two, in accordance with naval regulations, Professor Hall continued his work for some years at the observatory in order to complete those matters upon which he was particularly engaged. For some years after he was in charge of the observatory at Madison, Wisconsin, and in 1896 became a member of the faculty of Harvard University with the title of professor of mathematics, which he retained until 1901.

Professor Hall's first wife, Angeline Stickney Hall, died in July, 1892. Of this marriage four sons survive. In October, 1901, he married Mary B. Gothier, of Goshen, Connecticut, who survives him.

Professor Hall numbered amongst his friends the leading scientific men of Europe and of America. His correspondence, running back for more than fifty years, would form of itself an interesting account of the astronomy of his day. He was in temperament, in devotion, in the simplicity and single-mindedness of his life, a true man of science. For him no distractions of social recognition or money-making served to withdraw his attention from the science to which he had given his life. No man in our generation and in our country has given a better example of that true simplicity and sincerity which are the distinguishing characteristics of the highest type of the scientific life. Those of us who worked with him as students, as assistants, as colleagues, revere his memory not less for the simplicity and sincerity of his personal life than for the work he wrought for astronomy. His career is an illustration of the possibilities open to an American boy, and his life has shed luster upon his country and upon his science.

SCIENCE, December 13, 1907.

HALLEY'S COMET.

O. C. WENDELL.

FOR POPULAR ASTRONOMY.

On account of the importance attaching to Halley's comet and its approaching return to perihelion in 1910, it seems to be a matter of interest at the present time to know its general course of approach to the Earth and Sun. Accordingly I have computed the following ephemeris from Pontécoulant's elements, given in the *Connaissance des Temps* for 1908, for intervals of three months, except those in 1910 which are for somewhat shorter intervals. The last date in the table, May 16, 1910, is Pontécoulant's computed time of perihelion passage. As a result of the admirable work of Messrs. Cowell and Cromelin in computing anew the orbit and perturbations, as well as the work of others yet to come in the same line, Pontécoulant's elements will, possibly, be somewhat changed, but while the ephemeris computed from those elements and given below, cannot perhaps be assumed to *rigorously* represent the places of the comet on the different dates, yet these places and distances may be regarded, at least as approximately indicating its apparent path.

	HALLEY'S COMET								SUN			
Date	R. A.			Dec.			Millions of miles from		R. A.		Dec.	
							Sun	Earth				
	h	m	s	°	′	″			h	m	°	′
1907 Oct. 1.5	6	53	32.6	+ 11	14	14	872	876	12	27	— 2	55
1808 Jan. 1.5	6	21	17.6	+ 10	35	24	815	726	18	43	— 23	5
" Apr. 1.5	5	50	1.0	+ 12	40	42	757	774	0	43	+ 4	35
" July 1.5	6	14	46.7	+ 14	4	38	696	788	6	41	+ 23	7
" Oct. 1.5	6	37	52.8	+ 12	59	51	630	625	12	30	— 3	13
1909 Jan. 1.5	5	42	56.5	+ 12	14	24	561	473	18	46	— 23	1
" Apr. 1.5	4	59	8.1	+ 14	41	38	488	522	0	42	+ 4	29
" July 1.5	5	35	53.5	+ 17	21	23	408	498	6	40	+ 23	8
" Oct. 1.5	6	3	42.3	+ 17	41	6	319	294	12	29	— 3	7
1910 Jan. 1.5	2	33	21.7	+ 13	0	23	218	158	18	45	— 23	2
" Mar. 1.5	1	8	51.5	+ 10	32	22	144	202	22	47	— 7	44
" May 16.5	0	44	28.3	+ 16	51	31	64	94	3	30	+ 19	1

Cambridge, Mass.

PIERRE JULES CESAR JANSSEN.

HECTOR MACPHERSON JR.

FOR POPULAR ASTRONOMY.

Astronomical science has been heavily hit during the past year by the hand of death. Early in January, there died Miss Agnes Clerke, the astronomical historian who left a place which has not been filled. She was followed in June by Professor Alexander Herschel, the Son of Sir John and grandson of Sir William Herschel. In August there passed away Professor Vogel, of Potsdam, one of the most original men of his time; and now France has lost its oldest astronomer, one of its veterans of science, and is mourning the death on December 23 last of Professor Janssen, the director of the Meudon Observatory, near Paris.

M. Janssen had a long active and brilliant scientific career and his astronomical work was of lasting value. Born in Paris on February 22, 1824, Pierre Jules Cèsar Janssen was in his eighty-fourth year. He was well educated and devoted himself in his youth to Chemistry, Mathematics, Physics and Architecture. It was not until 1864, when he was forty years of age that he became definitely an astronomer. In that year the French Academy of Sciences sent him to Nyon, on Lake Geneva, to study spectroscopic astronomy. Here he threw himself into this branch of the science with vigor and energy. In 1869 he ascended Etna and spectroscopically observed the planets from the summit, detecting water vapor in the atmosphere of Saturn.

But his greatest work was accomplished in 1868. On August 18th of that year there occurred a great total eclipse of the Sun, visible in India. The French Academy sent Janssen to Guntoor to observe the phenomenon. At that time the interest in a total solar eclipses centered round the prominences or "red flames" which had, in 1860 been definitely ascertained to belong to the Sun.

The problem of 1868 was to get more knowledge regarding the prominences. The morning of the eclipse was not perfectly clear, but Janssen succeeded in observing the spectrum of the red flames, which his instrument showed to be one of the bright lines, proving conclusively that they were composed of glowing gas. A brilliant idea struck the French astronomer. He was impressed with the brilliance of the bright lines from the prominences, and it occurred to him that the spectrum might be observed without an eclipse. As Proctor pointed out in his work on the Sun: "The light of the prominences, when dispersed by the spectroscope forms a few lines; that of the illuminated terrestrial atmosphere is spread out into the rainbow-tinted solar spectrum. Therefore, if we only use adequate dispersive power, we can cause the prominence lines to show conspicuously on the background of observed atmospheric light." After the eclipse was over, clouds gathered, so Janssen was prevented from trying the experiment of observing the prominence-spectrum in full daylight; but at ten o'clock on the following morning he turned his instrument on the Sun and observed all day. "I have experienced today a continuous eclipse" he remarked. He had succeeded in observing the prominence spectrum in full daylight and had made possible continued and systematic observations of the red flames of the Sun.

On September 19, 1868 Janssen announced his discovery to the French Academy, but the news took two months to reach Europe. By that time Sir Norman Lockyer had made the same discovery in England and a short time before Janssen's result arrived, Lockyer had sent to the Academy a communication to a similar effect. To commemorate the discovery the Academy caused a medal to be struck in 1892, on which Janssen and Lockyer appeared as co-discoverers.

Since 1895 Janssen has been director of the Astro-Physical Observatory at Meudon, near Paris, in connection with the Paris Observatory. He secured many remarkable observations of the Sun and published his results in January 1904 in his great solar atlas, which comprises six thousand photographic representations of the solar surface.

That an astronomer's life is not necessarily a dry uninteresting one is illustrated by the career of Janssen, for his adventures in connection with his scientific expeditions bordered on the romantic. At the time of the eclipse of December 22, 1870 he was in Paris and of course the French capital was at that time besieged by the German army; but so determined was Janssen to see the eclipse visible in Algeria that he escaped from the city in a balloon. But his hopes were disappointed, for at Otan clouds obscured his view of the eclipse. In 1894 he observed the transit of Venus at Nayasaki and narrowly escaped destruction by a typhoon in the China seas. In 1888 he traveled about 11,000 miles to observe a total eclipse at Caroline Island a coral reef in the Pacific, and on this occasion he was very fortunate.

In 1890 Mr. Janssen ascended Mont Blanc to arrange for the erection of an observatory on the top of the ice-cap and three years later at the age of sixty-nine he made another ascent to observe the oxygen-lines in the Sun's spectrum. Latterly he lived quietly in France, but was active to the last.

Janssen was a knight of the Legion of Honor and of the Brazillian order of the Rose, and a Foreign Member of the Royal Society of London. A few years ago France could boast of a group of eminent astronomers whose fame was world wide. Janssen, Tisserand, the brothers Henry, Perrotin, Callandreau, Loewy and Flammarion, within a few years death has sadly depleted their numbers, and now Flammarion reigns alone, the undisputed chief of French astronomy.

Johnsburn, Balerno,
Midlothian, Scotland.

SOME OPPORTUNITIES FOR ASTRONOMICAL WORK WITH INEXPENSIVE APPARATUS.*

GEORGE E. HALE.

I have sometimes heard it said that the great cost of modern observatories tends to discourage workers with small instruments—observers who are no less interested in the pursuit of astronomical research than the astronomers in the large institutions. It seems to me that if there is any serious discouragement, due to this cause, of men who are engaged in original research with small telescopes and inexpensive apparatus, it is a question whether large observatories should be established. For at any period in the progress of observational astronomy there are two most important subjects for consideration. One relates to the accomplishment of a great amount of routine observation and the discussion of results, and the other relates to the introduction of new ideas and to the beginnings of the new methods which will make the astronomy of the future. I think we will all admit that the introduction of new ideas is quite as important as the prosecution of routine research; and that if any cause whatsoever

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* A Lecture delivered by Professor Hale, Director of the Mount Wilson Solar Observatory of the Carnegie Institution of Washington, at the Royal Astronomical Society, Burlington House, London, W., on Wednesday evening, June 26, 1907.

tends to discourage the men from whom the new ideas might be likely to proceed, that cause of discouragement should be set aside if possible. And therefore I say, with all seriousness, that it is a fair question whether large observatories, with powerful instrumental equipment, should be established if they tend to keep back the man who is pursuing the subject with less expensive appliances, and is introducing, through his careful consideration of the possibilities of research, the new methods which in the process of time will take the place of the old ones. I think it can be shown, however, that the large observatories should be a help rather than a hindrance, at least by suggesting new possibilities of research, in which most valuable results can be obtained by simple means.

I am talking tonight, in purpose at least, to the amateur; but my definition of the amateur is perhaps a broader one than is generally accepted. According to my view, the amateur is the man who works in astronomy because he cannot help it, because he would rather do such work than anything else in the world, and who therefore cares little for hampering traditions or for difficulties of any kind. The "amateur," then, is the person to whom I wish to address my remarks, whether he be connected with a small observatory in the capacity of professional astronomer, or working by himself with very simple instrumental means. But in speaking to the amateur I do not wish to deal with work that shall be satisfactory merely from the standpoint of instruction or amusement. That is not my purpose. If it is possible to carry on research by simple means that shall really be important and useful, it is my hope to point out some such possibilities. But I do not wish to speak of any work except that of the first class, nor to recommend that any investigation should be undertaken with simple instruments that are not quite as important as other investigations which can be better undertaken with more expensive instruments.

The problem then becomes one of this character—to determine the relative advantages of large and small telescopes for different classes of research, and the possibility of constructing really powerful instruments at moderate expense. I cannot pretend to discuss all phases of this large problem; I shall mention only a few of them, and approach it from a single direction. But before taking up the details of this discussion, perhaps I may be permitted to say that the conception that is sometimes formed of the newer observatories, the idea that vast sums of money are expended, perhaps without the fullest sense of economy, is not always well-founded. For I am quite sure that if you would visit us (to take a single concrete case) in California, you would agree that we have considered the economical side of the question, that we have perhaps in some instances gone almost too far in our desire to save money for instruments of research, and to economize in certain directions where money can be saved. For example, you would find that our offices, our buildings, are of the simplest and least expensive character, while our instruments and machinery are as effective as we can make them. The great expense of such an observatory as the Solar Observatory on Mount Wilson does not depend in large degree on the cost of the instruments used for investigations of the Sun, but in surmounting the difficulties encountered in utilizing a mountain site, deprived of the ordinary means of transportation, and in the construction of large equatorial reflecting telescopes for stellar work, which cannot be built cheaply if they are to be really efficient.

I wish now to come to the question before us, and to illustrate some of the advantages and some of the disadvantages of large and small instruments. Perhaps you will permit me, in showing the first slide on the screen, to say that I have some right to undertake a discussion of this sort, because I have viewed the subject from the standpoint of the man using small and inexpensive apparatus. In my first spectroscopic work, which was done in a room in my father's house, the instruments were of the simplest character, and largely of my own construction. Later, a small building was constructed for a concave grating of ten feet focal length, and the apparatus, although powerful, was not expensive. Subsequently a tower and dome were added, and a 12-inch telescope was erected for photographic work upon the Sun. After the preliminary experiments had been completed, and the spectroheliograph had begun to take form, the possibility that its results could be greatly improved through the use of a larger telescope suggested itself, and for this reason I made many efforts to acquire a large instrument for these solar investigations. The result, through the generosity of Mr. Yerkes, was the 40-inch Yerkes telescope, which proved to be very useful for the extension of the spectroheliograph work. The next slide shows the instrument, which you will see is a large and expensive machine. The question, then, comes right down to this point: What are the advantages of such a telescope compared with, let us say, a 6-inch equatorial or possibly a 4-inch equatorial? It is possible with a 6-inch equatorial to do the work comparable in importance with the work that can be done with a 40-inch equatorial?

The next slide will show that there was an advantage in passing from the Kenwood 12-inch to the Yerkes 40-inch, at least for the photography of the Sun. Very minute details of the flocculi were brought out which had not previously been known. But it may easily be shown that the advantages of the 40-inch telescope for most classes of solar work are due more particularly to its great focal length than to its large aperture.*

Let us take another illustration. Here we have a picture of the Moon made by Professor Ritchey with the 12-inch Kenwood telescope. You will notice that near the terminator is the crater Theophilus, which you will see again in the next slide as photographed with the 40-inch telescope. This photograph taken by Professor Ritchey is probably as good a photograph of the Moon's surface as has yet been made, and in this case the advantages of the 40-inch telescope is apparent.† But if we take another case, as illustrated in the next slide, it becomes obvious enough that for certain classes of work the Yerkes telescope is not well suited. Here is a picture made with the 40-inch of the Andromeda Nebula. You see how little it shows, since a long-focus telescope, unless of very great aperture, is not well adapted for the photography of faint nebulæ. When we compare this picture with the next one, made by Professor Ritchey, with the 2-foot reflector (of 8 feet focal length), we appreciate immediately that the 40-inch, in spite of its great advantages for certain classes of work, is wholly unadapted for other investigations. As you know, a refractor of much smaller aperture and of shorter focal length would also give a pho-

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* So far as resolving power is concerned, an aperture of eight inches would be sufficient to permit the smallest known details of the flocculi to be photographed.

† Here, again, the full visual resolving power is not utilized, but the great aperture is of advantage in permitting the large image to be photographed with very short exposures.

tograph of the Andromeda Nebula far superior to anything that could be taken with the 40-inch.

If we look at the next slide, which shows Professor Barnard's 10-inch Bruce telescope when it was mounted on Mount Wilson, where he was using it to photograph the Milky Way, you will see an instrument that is very small and inexpensive as compared with the Yerkes telescope. It has a 10-inch Brashear lens of 50 inches focal length and certain smaller cameras attached to the side of the tube. With such an instrument as this, superb photographs of the Milky Way, like the one, illustrated in the next slide, can be taken, which are indispensable for investigations on the distribution of stars in this part of the heavens. Excellent work can also be done with a much smaller lens, provided with a very simple mounting.* A fine instance of systematic work with a portrait-lens is afforded by Mr. Franklin-Adams's photographic map of the northern and southern heavens.

It is hardly necessary to recall the fact that the 40-inch could not do this work at all. If we attempted to photograph the Milky Way with it, we might get a very small region on a very great scale, but to give us any notion as to the general distribution of stars in the Milky Way the 40-inch would be a total failure. However, if it were a question of studying some star cluster like the one shown in this slide, which would occupy a very small region indeed of the Milky Way, the 40-inch would enable us to pick out the separate stars, to study their individual phenomena, their changes in light and position, while such work could not be done on photographs taken with a portrait-lens.

I have shown these miscellaneous illustrations for the purpose of emphasizing, what is perfectly well-known to all of you, that each instrument has its particular fields of work, in which it can accomplish, or permit to be accomplished, various investigations which are not within the reach of other kinds of telescopes. But I now wish to discuss the question somewhat more specifically, and in doing so I shall confine myself almost entirely to observations of the Sun, although one might attack the subject from many other directions. The first point is this. Suppose one has a small

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* Professor Barnard has illustrated in the *Astrophysical Journal* some of the admirable results he has himself obtained with a cheap "lantern lens" belonging to an ordinary stereopticon.

telescope of four inches or six inches aperture and wishes to observe the Sun with it; and let us assume at the outset that he has no attachments whatever in the form of spectroscopes, but that he wishes simply to make direct observations of the Sun: Is there work for such an instrument at the present time? If you will examine the literature of the subject you may perhaps be surprised to find that many years have elapsed since very careful and extensive investigations have been made similar to those of Langley, which may be almost forgotten by many astronomers, but certainly are not forgotten by those of us who follow the Sun and are accustomed to the appearance of the spots when the definition is good. The next slide shows the well-known drawing of Langley's typical sun-spot. You will remember, if you have systematically observed the Sun, that every time the conditions become extremely good, the structure of sun-spots more and more closely resembles this drawing. This is a typical drawing; it does not represent any particular spot; it brings together observations of various spots; but in general the details of a sun-spot look very much indeed like that drawing when the definition is good enough to show them properly. This subject has been greatly neglected for a long time, and it would well repay observers with large or small instruments to observe sun-spots, and to study many of the details of their structure which still remain obscure and difficult to understand.* Of course the question of the resolving power of the instrument must then be considered. A 4-inch telescope, capable of separating objects one second of arc apart, would not do for the very finest details in a sun-spot. According to Langley, the penumbral filaments sometimes exhibit structure considerably smaller than such a telescope would show; but a 10-inch or 12-inch telescope would show everything that has ever been recorded in a sun-spot, and there are many instruments of that size available for such observations.† Even a much smaller telescope, if carefully and systematically used, would contribute largely to our knowledge of sun-spots and of

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* For example, it would be of great interest to study the structure of the umbra, as seen through a minute pin-hole in the focal plane of a positive eyepiece, as Dawes did many years ago.

† It must not be forgotten that photography is still far behind visual observations in revealing the minute structure of sun-spots. It can hardly be doubted, however, that if only the umbra and penumbra were permitted to fall on the plate, and the exposure properly regulated, new and valuable results would be obtained. The amateur will readily find many opportunities for work in this field.

the structure of the solar surface. One might enlarge upon this subject, but time is hardly sufficient to permit me to do so.

To be concluded.

BRYANT'S HISTORY OF ASTRONOMY.*

The announcement of the appearance of a book entitled 'A History of Astronomy' not unnaturally suggests the question whether there is in our shelves a gap which this book can be expected to fill. *A priori* we should answer in the negative; *a posteriori* we frankly modify that answer into the advice to make a gap for it. We do not for a moment suggest that Mr. Bryant's book should displace Delambre or Grant nor even Miss Clerke; those are in a different category. Perhaps Mr. Berry's 'History of Astronomy' enters more nearly into competition with the book before us; but there is a clearly marked divergence in the aims of the two books, inasmuch as the former has compiled a book of reference for students, while Mr. Bryant has aimed at a lightly written history for the delectation of amateurs.

And to the amateur the book can be cordially recommended. He cannot fail to feel that he is listening to a man who is in possession of full and practical experience of his subject. And perhaps it is just the practical details which will be found the most interesting, such as the chapter on Adjustment of Instruments, in which some account is given of the inevitable difficulties connected with personality, or in such *obiter dicta* as the following:—"Herschel was probably the first astronomer who considered his eye as part of the observing instrument, and was careful to adjust the position of his head in order to view such an object as a band on a planet in the same direction relative to the position of the retina." We hear so much about the science of astronomy that these references to the art are refreshing.

The illustrations naturally catch the attention as one opens the book; the selection is made with determination; the one or two old friends are welcome, while the four from Hevelius are well worth reproduction. It seems a pity to have omitted that one of Hevelius' comets of which the tail is discontinuous; such an anticipation of Barnard's photographic discov-

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* By W. W. Bryant, B. A., F. R. A. S., F. R. Met. Soc., of the Royal Observatory, Greenwich. Methuen & Co. Price 7s. 6d.

ery of shattered tails deserves attention. A word of praise is due to the careful account given of the origin of each illustration; the "Newton" by Kneller must surely be well-known. We believe it is now hanging at Petworth. It is annoying, however, to find the photographs of nebulæ indiscriminate in their orientation. The Pleiades have the north at the top, the Ring Nebula has the west at the top, and the rest have the south uppermost.

The style of the whole book is light and pleasant and induces one to forgive an occasional obscure passage. Sometimes, however, the obscurity is such as to baffle all attempts at comprehension. There is a sentence on p. 163 in which "the axial rotation effect" in the Sun is apparently made to account for "well-marked frequency zones for spots," and another on p. 31 containing reference to "the practically infinite distance of the point to which the Earth's axis is directed." We confess that these defeated us.

Perhaps the greatest difficulty that the critic finds in estimating the success of the book consists in arriving at any idea as to the class of audience that is being addressed. On p. 15 the obliquity of the ecliptic is carefully explained, while on p. 59 an argument such as (5S—2J) is lightly referred to and seems to call for no enlightening footnote. One cannot help sympathizing with an author who is full of information; it costs a pang to omit anything, but there can be no question that there is too much in this book. With p. 125 open before us we find that there might have been eleven footnotes, all giving reference to first class papers. Such a page cannot leave any useful impression on the mind. Difficult subjects like the interpretation of spectra are treated so sketchily that the account can scarcely be useful to the unenlightened, while it is superfluous for others.

The biographical part, covering the first 96 pages, suffers least from the congestion which mars so many chapters. Surely Copernicus did think that the stars were all the same distance from the Earth; and ought not a special reference to be made to Tycho's initiation of the important practice of repeating observations? "Tycho next married a plebian girl on his own account," which is called a "descensus Averno." In passing we cannot omit to note with satisfaction that both in the case of "Averno" and of the "smaller fleas" later in the book, common misquotations have been avoided. Hevelius should have the credit of the optical libra-tion, while Galileo claims the diurnal. Can Mercury have been seen in transit before Kepler's time, that is without a telescope? We must test this on the 14 inst.

Three chapters on the Sun are full to overflowing, but the interest is well maintained in spite of several exceedingly cryptic passages.

In the five chapters on the stars the impossible task has been attempted of covering the whole ground from Fundamental Astronomy to Spectroscopy in 70 pages. But when once we have asserted the impossibility, we must admit that the reader finds it difficult to put down the book, the matter is so clearly sound, and the manner is cautious and philosophical. There is a pleasant absence of dogmatic statement; in fact the fault is rather in the opposite direction. Such phrases as "it is hinted that" might often be replaced by a more direct assertion. We are, for instance, told that it is doubtful whether the lunar rills are or are not dried-up water-courses, when the negative has been asserted by more than one competent authority. Dr. Rambaut has done more than "hint" that he can produce the green flash before sunset. Again, we read that the case stated by Kapteyn and Eddington might be "met by assuming for our system a position well outside the center of a single universe, so that a fair proportion of its members by virtue of their position, like planets at inferior conjunction, would appear to be moving in a different direction to the rest." This suggestion has been disposed of by Mr. Eddington as ignoring the whole principle of his discussion.

The index is well compiled, and the marginal cross-references if continued throughout the book would have greatly added to its usefulness as a book of reference. The pages on bibliography and current periodical literature are useful, and would have been more useful still to the uninitiated had some guidance been given as to which of the periodicals might perhaps have been suited to him.

The proof-reading has been exceptionally careful; we find one hyphen displaced on p. 342!

For an extremely ignorant and for the extremely learned in Astronomy the book is not suited, but for that very reason it will probably meet the requirements of many among that larger public who fall between those two extremes.

J. A. H. in *The Observatory*, November 1907.

THE "AUTOCHROM" PLATE.

ROBERT JAMES WALLACE.

FOR POPULAR ASTRONOMY.

It is difficult to introduce this subject without a prelude upon the happy realization of the many hopes which have been entertained since the advent of photography, regarding the registration of objects in their natural colors. It may be, however, sufficient to state, that hope sustained by many promises has at last been realized, if not in a manner thoroughly complete, yet sufficiently perfect to warrant high commendation.

During the past few years there has been great activity in the direction of "color photography;" an activity, which not confined to any one country, has produced many processes and methods possessing in the main undoubted merit, yet they have but rarely advanced beyond the position of interesting laboratory experiments.

It has been reserved however, for Messrs. Lumière, of Lyons, France to produce and place upon the market, a one plate method which places in the hands of even the ordinary amateur the means of reproducing in full color, and with a single exposure, a record of the object photographed, in all its varied tints and tones, and with a fidelity truly marvelous. That the Messrs. Lumière should have brought the plate and method to such a point of perfection before its public introduction, is an achievement deserving of much praise.

The "autochrom" plate consists of a plate of glass of fairly even quality, upon which is spread a layer of colored potato starch granules. These transparent granules are colored respectively red, green and blue-violet, and are then mixed together in quantity, in proper proportion; and spread over the cleaned and varnished plate, and then rolled to flatten the granules. The interstices between the circular colored disks are then filled by a black pigment, thus preventing the passage of any light other than that which passes through the colored starch grains.

After again varnishing, this colored mosaic filter layer is coated with a film of "panchromatic" emulsion, and the plate is complete.

Exposure must be made through the "back", so that the light is compelled to pass through the colored granules before reaching the sensitive film. It is necessary also, that the light must pass through a yellow compensation-filter placed in front of, or behind the lens, its purpose being to absorb the ultra-violet, and reduce the action in the visible blue and violet.

After exposure the plate is developed with pyro-ammonia, and after a brief washing, the reduced silver, i. e., the negative image, is dissolved out by means of acid permanganate of potass, and redeveloped, thus obtaining a positive image in place of the former negative. The plate now shows clear film proportionate to the amount of silver reduced, and through which regions may be seen the color of the starch granules. Intensification, clearing, fixing, washing, drying and varnishing, follow in rapid succession, details of which are supplied by the Lumiere company together with the plates, and which need find no place here.

Taking up first the colored layer, a microscopic examination gives the granules a mean diameter of 0.014mm.,* and which with polarized light, show the characteristic black cross. With the aid of the spectroscopic eyepiece the absorption spectra of the individual colors may be observed. Photography of the spectrum, however, supplies all the information necessary upon this point, and to which further reference will be made presently.

By counting the colored granules contained in various selected areas, one may reach a conclusion as to the relative distribution. From this observation it results that the red, (or blue) granules are about equal in number, while the green are in excess in the ratio of about four green to three red and blue. Treatment of the color film with hot water (temp. 90° C.), and occasional examination under the microscope, shows that the blue color is the most soluble, next the red, while the green granules retain their color for a considerable length of time. Evidence of the greater solubility of the blue-violet is shown by the general yellow tint which the plate acquires after but a very brief immersion in the hot water, which indicates the removal of the blue-violet color in quantity too small to be indicated by examination of the individual granules. Upon treatment with cold water the green granules appear to be the first to discharge their color, followed by the red, while the blue appears to be quite persistent. No difference could be observed in the mass tint after soaking in cold water for thirty minutes. Ether dissolves the varnish

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* This is in practical agreement with Wall who gives a mean of 1.5 mm., Brit. Jour. Photo. Sup. p. 57, 1907.

of the starch layer so that isolated granules may be observed individually; there is no influence, however, upon the color. In alcohol the green color is slowly discharged and the color film frills away from the glass support in one continuous sheet. Dilute ammonia discharges the color slowly in the order of red, green and blue. In acid permanganate of potass all colors are equally (but slowly) discharged.

Measurements to determine the absorption coefficient of the color-film and glass, made in the polarizing spectrophotometer,* gave a mean value of 16.6° which equals a H. & D. density of 1.0882. Measurement of the thickness of this colored starch layer gives a value of $\frac{6}{10,000}$ inch $= 15.24\mu$.

The sensitive film which is coated upon the color filter-layer is of extreme tenuity measuring in thickness slightly less than 4.0μ ($= .00015$ inch). With the ordinary dry plate film of Seed "27" there is a measured thickness of about 31μ ($= .0012$ inch). This extreme thinness of film precludes the consideration of much latitude in exposure, and this is borne out in practice. The sensitive film itself is not entirely soluble in hot water, nor does it dissolve in an ether alcohol mixture. Stenger† is of opinion that the sensitive film is composed of a combination of gelatine and collodion, which, from the observations of the writer, is considered as probable, even although the further treatment with ether-alcohol failed to dissolve it. The reduced "silver grain" of this film is of exceptional fineness for a fast emulsion, giving upon measurement a mean of 0.5 to 0.8μ for individual "grain" particles, while mean "group particles"‡ measure 1.6μ to 2.0μ; these measurements were of course made prior to intensification.

Tests for determination of selective sensitiveness were made by exposing an "autochrom" plate with the film side towards the lens, to a series of nine differently timed exposures to the spectrum of diffused daylight, in the "standard" spectrograph, ¶ the sky effect remaining apparently constant throughout. Examination of the resultant negative (devel-

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* See *Astrophysical Journal* 25, 124. 1907. Studies in Sensitometry I. by the author.

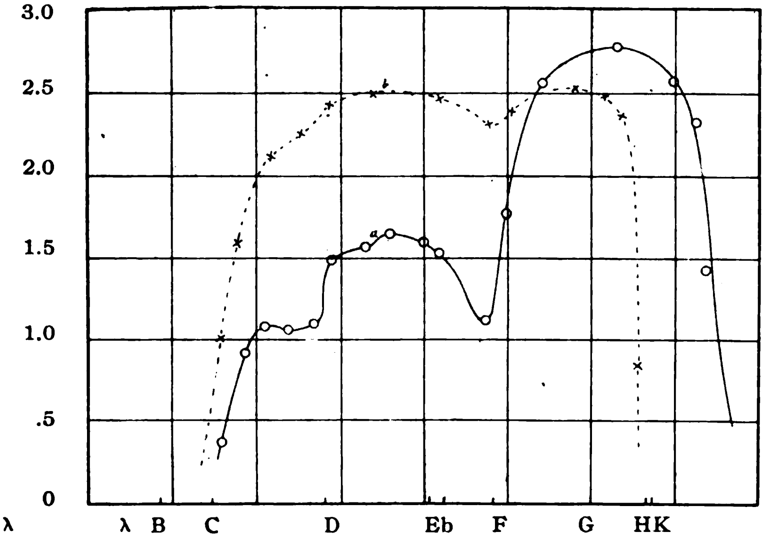
† Zeitschrift für wissenschaftliche photographie. Band 5. p. 374, 1907.

‡ *Astrophysical Jour.* XX p. 113. 1904.

¶ For description of this and other instruments for sensitometry see former paper *Astrophysical Jour.* vol. 25. p. 122. also vol. 26. p. 12. 1907.

oped in pyro-ammonia) shows a heavy drop in the blue-green sensitiveness, which extends from λ 4860 to nearly λ 5180, (F—*b*). A second drop is apparent from λ5890 (D) to λ6200, the sensitiveness ending (with normal exposure) at about λ 6500 *minus*.

FIGURE 1



[The vertical of G lay so near to the line "4300" that it coincides in the reproduction.]

From measurements on this plate, the accompanying curve figure 1 (*a*) was plotted, and examination of which shows that regarded from a "panchromatic" standpoint the emulsion leaves much to be desired. The sensitiveness-curves shown herewith are not in agreement with those plotted by Stenger who shows a much higher χ value $\left(=\frac{\lambda\,4100}{\lambda\,5600}\right)$ than does the present writer. In Stenger's sensitiveness-curves the density value of the red at λ 6100 is almost identical with the density of his blue at λ 4200. The lack of accordance arises from the fact that Stenger made use of an artificial light source (Nernstprojektionslamp) which gives a false intensity to the red, while the present curves are from negatives exposed to a gray foggy north sky.*

Exposures were also made upon the film side through the Lumière compensation-filter, and the effect obtained is shown

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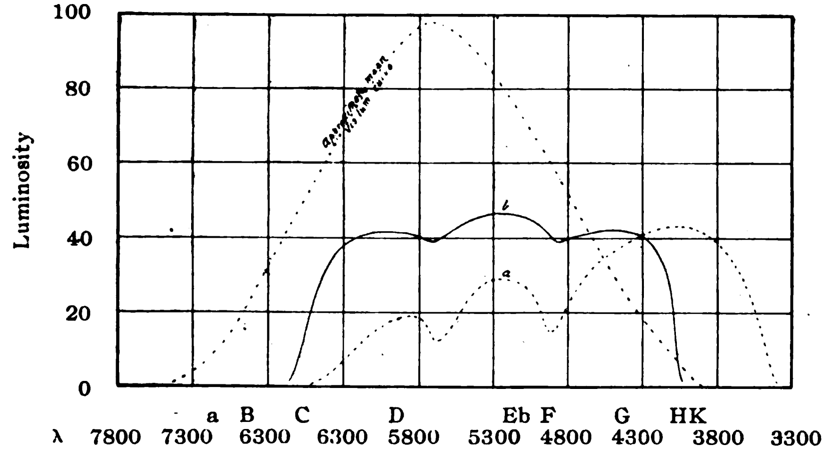
* (Die Autochromplatte. Erich Stenger. Zeitschrift für wissenschaftliche photographie. 5. 376. 1907.)

by the dotted line (*b*) in the same figure. The rather abrupt drop in the blue-violet, and the general improvement in the orange and blue-green will be readily noted. The adjustment of this filter evidences much care, and it would be indeed difficult to improve upon, either in individual or commercial manufacture.

A series of spectrum exposures were now made with the light passing through the color film but *without* the interposition of the compensation-filter. The plate was handled throughout according to the instructions by Messrs. Lumière. With under-exposure the action is first visible in the violet at λ 4100, which, as it is to be expected, is shown as a bright blue, while with increased exposure the green at λ 5270 is the next color to show, followed almost immediately after by an action at λ 5850, which region is shown as a deep red instead of a bright yellow. With increased exposure the blue-violet from λ 4300 to λ 3900 becomes diluted with white, while the green and red regions are extended and brightened, but showing at what may be termed "normal exposure," two distinct absorptions in the blue-green and yellow as indicated in *a*, figure 2. The ultra-violet region to λ 3400 is of course evident throughout, and is shown as a bright blue.

FIGURE 2



There is difficulty in depicting graphically the "autochrom" reproduction of the spectrum, inasmuch as the colors do not correspond correctly to the wavelength. For example, taking the blue region from λ 4860 (F), to λ 3933 (K) in the ultra-violet, visual observation of the spectrum show that the hues embraced are pure blue, indigo blue and violet. In the "autochrom" reproduction on the contrary, we have first a drop in the blue at F, just where it should show the purest, which is due, first, to the insensitiveness of the emulsion for that region and second; to the lack of overlap (with normal exposure) in the green and blue filter transmissions, which results in the introduction of black at this point, hence a lowering of the luminosity curve. The change in hue with the wavelength which gives the delicate blend to indigo blue and then to the spectral violet, is absent in the reproduction, being represented instead, (after recovery from the insensitive band at F) as a blue of even hue throughout. The same criticism applies to the green and red regions. That delicacy and charm of graduated color which makes the solar spectrum the most magnificent phenomenon in the domain of science is utterly lacking in the reproduction, which appears crude by comparison. Hence in the graphical representation of the colored spectra, be it understood that approximate luminosity alone, is estimated, and not hue.

A second series of exposures made through the color film of the plate, but with the interposition of the compensation filter, presents particular interest, as not only fulfilling the requirements demanded by the inventors, but as supplying authoritative information relative to the selective transmission of the color granules. With underexposure the region at λ 5850 is the first to show action but instead of being represented as a pure yellow is again depicted as a deep red. This is to be expected when we consider that the additive formation of yellow is accomplished by the mixture of red and green, and that therefore yellow can only be represented when there has been sufficient exposure to extend and unite the action of the red and green regions.

The initial action in the red is closely followed by that in the green at λ 5270 and then by the blue at λ 4500. Increase in exposure results in a widening of the color bands but without perceptible change in hue or purity (although the luminosity is increased), until at "normal exposure," that is to say, at the exposure which represents the maximum allowable, without the introduction of white to the colors there is formed by the mixture of the green and red bands, a rather dingy orange-yellow, in place of a pure yellow of high luminosity. In the opposite direction the admixture of the green and blue color bands results in the formation of an "indigo" of low luminosity in place of a pure blue-green, together with a faint trace of overexposure in the blue at λ 4400 — 4500. As a reproduction of the spectrum the result is not good, and can be considered as a rough approximation while the size of the color particles (which in this consideration is equal in effect to coarseness of "grain,") precludes the registration of all but the more prominent Fraunhofer lines which are therefore to a large degree, independent of the slit-width; for, when it is remembered that the action throughout either of the three color regions is composed of (almost solely) color particles of one hue, occupying therefore less than one-third of the area,* we see that practically we are reduced to the necessity of considering the result as formed by "group particles" of "grain," of about sixteen times the size of the "grain" particles of an ordinary fast plate.

Even with extreme overexposure it does not appear possible to obtain a pure yellow and this is corroborated by results in ordinary copying where the yellows lack luminosity. From the curve shown in *b* figure 2, it will be seen that the limits of the visible spectrum are much restricted, being cut off rather abruptly (with normal exposure) at λ 4150 and λ 6500. The effect of increased exposure is the formation of a pinkish white, showing first in the regions corresponding to the primary, action with underexposure, and, with increase of exposure, extending in the same manner as does the color effect.

The spectrum result obtained by the action of the light through both the compensation-filter and color-film, is, of course, a record of the transmission of the individual color filters which form the mosaic layer. As has been pointed out by Abney† the filters show isolated transmissions, with decided overlap as exposure is increased, and occupying a position midway between the theoretically perfect "taking" and "viewing" filters. As a reproduction of the spectrum the "autochrom" is ridiculous, while in practice, in the copying of multicolored objects, the results are truly marvelous in their fidelity.

Copies of various color-charts were also made, and when the exposure was such that white was reproduced with the closest approximation, examination of the individual color patches show the great difference in results dependent upon

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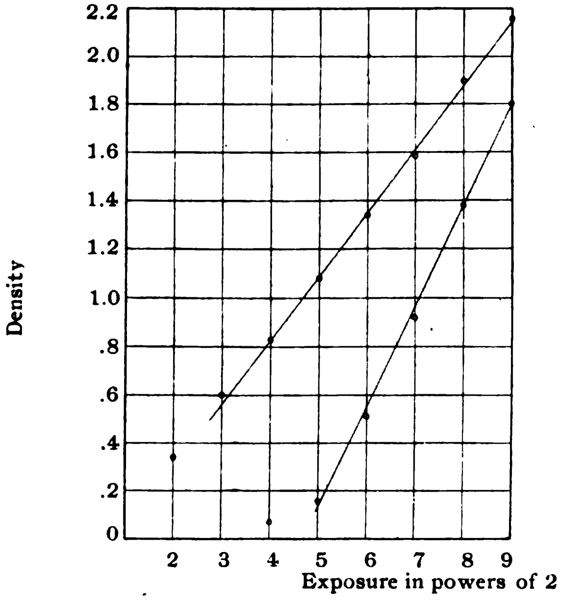
* The black blocking out pigment must also be considered.

† Autochrome. Sir W. de W. Abney. Jour. Royal Photo. Soc. 37, 252, 1907

the photography of *pigment* colors as against *spectral* colors. Under the microscope the yellow region of the spectrum reproduction shows the action confined entirely to the red and green granules, the blue granules being represented by black, while in the case of the reproduction of the yellow pigment patches, the blue granules are also easily visible. The result is a strong uplift to the luminosity of the yellows by the introduction of white.

Inasmuch as the highest light obtainable upon the plate is represented by the admixture of the three colors plus the black pigment it will be seen that white is existent (in reproduction) simply as an effect of contrast. The reproduction, therefore, of any colored object is equivalent in truth, to viewing that object through a light neutral gray glass.

FIGURE 4



Simultaneous exposure of two "autochrom" plates in the revolving sector-disk machine to diffused daylight, (a) upon the face of the sensitive film, and (b), through the color film, give upon measurement, practically identical gradation curves.* While the exposure of an "autochrom" plate (film side) and a Seed "27", give measurements, which being plotted, result in the curves shown in figure 4. Duplicate

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* Development of both plates was with pyro-ammonia for two and one half minutes at 20° C.

plates supply confirmation of the higher density factor of the "autochrom" plate for short development, although with lengthened development these conditions are reversed. The extraction of the relative speed difference gives a value of $2^{2.2}$ (= 4.49 times) in favor of the "27". For the total speed difference however, there must be added the absorption-coefficient of the colored layer and glass, and also the multiplying factor of the compensation-filter which reduces the total speed value of the plate to one-sixtieth of the Seed "27".

To one who has worked with the problem of color reproduction by means of superposed films the first view of an "autochrom" is somewhat disappointing in so far as brilliancy is concerned, but when allowance is made for the reduction in luminosity, (which practically amounts to a lowering of the entire tonal scale) the charm of the result in the delicacy of portrayal is a source of growing enthusiasm.

One is led at first sight to rather dread the somewhat extended operations necessary to the production of the finished result, and this fear is rather enhanced by the amount that has been written regarding the tendency of the film to "frill" and thus ruin the result. Personal experience, however, leads emphatically to the statement that the process is really absurd in its simplicity when compared with other methods, and in the hands of the writer, absolutely no trouble was experienced with "frilling", and that although all of the exposures handled, (about fifty), were upon plates which had been cut from larger sizes. It takes in the neighborhood of from twenty to twenty-five minutes (from the time of the completion of the exposure), to produce the finished result.

The value of the plate to the astronomer or spectroscopist is at present not apparent to the writer, but, to the student of photographic science, and to that great body known as "general workers" there has been placed ready to hand, a means of reproducing the many hues of art or nature, by a method whose exquisite beauty calls forth nothing but the highest enconiums.

Time will, of course, bring many improvements, but the process even as it stands now, is a lasting monument to the capability, perseverance, and commercial enterprise of *M. Lumière & ses fils.*

Yerkes Observatory.
December 30, 1907.

METEOROLOGY ON THE PACIFIC SLOPE.

JEROME S. RICARD.

FOR POPULAR ASTRONOMY.

We have of late been engaged in a study of absorbing interest trying to put together the results of our helio-meteorological observations during June, July and August of the present year. In publishing these results, it is not our intention to influence any one this way or that way, much less to descend into the arena of controversy. We are indulging in no theory, but solely looking for and stating facts when we have found them; and if any theorizing there be, it must be a necessary deduction from scientifically ascertained fact. In the sphere of the contingent where meteorology lies, the inductive process takes the lead and the deductive follows.

When this observatory was established, we placed it at the service of the Weather Bureau authorities, under whose fostering care it has remained ever since. Far from being opposed, it has always received from the same authorities not only valuable material help, but also kind encouragement and wise direction. But it was understood, at the very outset, that the great desideratum was not so much a further accumulation of weather records, as philosophical investigation into the origins of meteorological change.

A directive principle along that line of study was that in every system, the primary rules the secondary. The solar system was to be no exception until that exception was proved. The problem had to be faced, not in part but in whole. The meteorologist had so far been mostly concerned with the atmosphere, its temperature, its moisture, its weight, its movement, its electrical loads and discharges. The astronomer, on the other hand, was studying the phenomena of the heavenly bodies, direction, distance, position, interdependence through gravitational agency, physical changes and chemical composition. But the two sets of students kept, on the whole, entirely separate from each other and never thought earnestly of bringing their forces together; and so the link between system and system and, what is worse, the very links by which one system hangs together, were ignored and lost sight of.

But now how changed is the scene! Astrophysics including solar physics has stepped to the front and the high fence between meteorology and astronomy is torn down. The work so happily initiated by Sir Norman Lockyer in 1871 is taken up to-day by such savants as form a nucleus of the International Society for Solar Research of which Professor Hale of Mount Wilson is the President. The interdict so gratuitously put on the sun-spot is lifted and the suspected link between solar condition and weather condition is one of the fundamental subjects of study adopted by that society. Henceforth the air man and the star man can occupy the same chair and their respective offices be combined.

In the presence of this welcome change, one should naturally expect that the masterly minds of our Weather Bureau would collect their forces and their lights and focus them where there is a hope of snatching her secret from nature—the cause behind the cause. There is a groan heard everywhere that our system of Isobars and Isotherms, as figured forth in that international institution called the Weather Map, is nearly exhausted and barren of ultimate progress. The perspicacity of the well drilled mind is not yet able, by an inspection of the map, to tell whether a low that has appeared over Alberta or Washington will travel southward and bring refreshment to a parched vegetation, and far less is the same mind able to foretell the appearance of that low, and far less again whether it will move north, or south, or centrally.

When beset with such difficulties, who is there who would not sigh after superior methods of forecasting? This is precisely what the representative men of our Weather Bureau are striving with might and main to do. They have installed a great observatory on Mount Weather, Virginia, where the study of solar change, as the cause of weather change, is the main study and the prime consideration.

At the Santa Clara College Observatory, too, and at the suggestion of a prominent Weather Bureau authority, similar work has been in progess. The plan of the work and the method of observation were entirely left to our own choice. So we naturally fell in line with the astrophysicists. With recording instruments checked by non-recorders, we have these six years taken a continuous record of weather change and, with an equatorially mounted 9-inch glass by the elder Clarke, a practically continuous record of solar change.

By juxtaposing and correlating these records, it becomes impossible not to notice certain coincidences that excited curiosity and formed the basis for further, and more accurate observation. It was not, however, until the beginning of last, spring that we, hesitatively, formulated the following laws:—

1) When a solar spot is within 2, 3 or, at the most, 4 days from the western limb, it produces a warm wave which expands the air somewhere over the Pacific slope or rather west of it over the Pacific Ocean, thereby originating a low; and by referring to the weather map, you will see the area of that low, generally over the northwest during the winter, generally over the valley of the Colorado during the summer. A central low is the exception and that exception baffles the forecaster for tomorrow's weather. He said fair, and behold it rains.

2) If when a solar spot is thus nearing the western limb, other spots rise anywhere on the visible solar surface, the effect is to swell the actual pulse of the temperature, and the swelling is proportional to the size and intensity of the disturbed solar area.

3) When a solar spot is passing or about to pass off the western limb, it produces a cool wave or fall of the temperature pulse. This wave contracts the expanded air somewhere over the Pacific slope or rather west of it over the Pacific Ocean, thus originating a high that the next weather map will register in the proper place. Following the approach of the cool wave, there will be condensation and precipitation. It is plain, however, that the mere cold of a night or the mere cold of the air in the upper regions can do that, whenever the saturation point is reached. But as watery vapors abound especially over and about the area of the low, as the result of the warm pulse, hence whenever and wherever it is cold enough, rains or other forms of precipitation accompany the passage of the low and vanish soon after the coming in of the high by a sheer process of exhaustion.

4) The cool wave occasioned by the disappearance of a solar spot behind the western limb can be, and often is, tempered or neutralized by the near approach of another solar spot to the same limb. This is a mere corollary of laws 1 and 3. Another corollary is that, contrary to a prevailing opinion, solar spots are an index of an excess of solar heat, whether it be that they are hotter in themselves or there is that about them which is intensely hotter than the rest of the photosphere. A great Irish specialist has it that in the sun-spot the carbon is vaporized and incandescent, whereas in the other parts of the Sun the carbon is incandescent, but not vaporized. So, too, thinks another great specialist on the

Sun, Professor T. J. J. See of the Mare Island observatory. Sir Norman Lockyer admits the fact that the sun-spot is hotter, but explains it in a somewhat different way. In that case, the deep violet-blue color of the umbra must be due to carbon vapors.

Since the time when these laws were formulating themselves in our own mind, they have been subjected to a severe scrutiny. But the search for an exception has been in vain, so the reader may rest assured that these new tenets of solar physics are not the offspring of a morbid imagination, but rest on the solid rock of observed fact. We are told: Beware of coincidences. To which we reply: Beware of asking too much. All that a strict scientific induction requires is a sufficient enumeration of observed particulars backed by an axiom or principle that shall lend universality to the conclusion. For as nothing can give nothing, so no particular, as such, can give the universal. Hence no enumeration of particulars, howsoever far produced, can, if incomplete, yield a universal conclusion. Induction that does not go on a universal principle is as bad as a cork leg or a wooden horse.

To illustrate:—By what right do you hold that fire burns? You say all the fires you have seen did burn. But you have not seen all fires, nor will you, nor can you. How can you hold that all fire burns? You say: howsoever that may be, I am positive all fire burns. But again, what makes you so positive. Possibly you can not tell and possibly I can. If you think of the matter at all, you might reason somewhat like this: If every fire I have seen and every fire I have touched, did burn, this thing cannot be accidental; it cannot be mere chance or ill-luck: it cannot be an independent sequence or mere coincidence in point of time, without any internal nexus whatever. Whatever happens by chance, whatever is a mere sequence with no causal nexus, follows no rule; you can never depend on it; it may happen, it may not happen: you are always at a loss to tell whether it will or whether it will not. If you say it will happen or it will not happen, you knowing only too well you are indulging in absolute guesswork.

So the golden principle to go by in these perplexing matters, is the constancy and uniformity of nature. If an event constantly and uniformly follows upon another, this other must be the cause and the two events must go together as cause and effect. Hence it is manifest that for a valid scientific induction, we have only to know a certain number of particulars, this number being of its nature indefinite, and then apply a universal principle to the point of which there may be question, and, that way, we obtain a universal inference that a strong-headed one may howl against, but can not logically deny.

Such is the train of reasoning that has been followed at this observatory touching the matter of helio-meteorology. We have had cases innumerable of coincidences between approaches of solar maculæ to the western limb and warm waves over the Pacific Slope; and again cases innumerable of coincidences between disappearances of solar maculæ off the western limb and cool waves over the Pacific Slope. We ask any reasonable man what was to be our conclusion, according to the logic of Lord Bacon, or that of Aristotle, or that of any other great thinker? Would he cry out, as some have done: "All mere chance happening—undiluted moonshine—the work of an advanced scholar in noodledom—all humbug!"

But far otherwise have we been taught philosophy; and if that philosophy is wrong, we dare submit there is very little known truth in this world and we are wallowing in the mire of partial or universal skepticism. So we argue that if this whole thing is mere chance happening, and the forecast based upon this thing is mere guesswork, howsoever lucky it may be, the unbroken thread of coincidences must break asunder and there must be a big smash-up somewhere. But this has not been; therefore it shall not be. Therefore there is a causal nexus.

If we are asked to produce our records, we may quote the following for June, July and August of this year—the three most unfavorable months for salient weather features over the Pacific Slope—those very same months about which we were told the solar markings were hors de combat in their hospital home. We have had disappearances of solar spots on June 3, 9, 13, 21, 22, 25; July 2, 6, 12, 14, 19, 23, 26, 30; August 5, 6, 13, 16, 20, 23, 27, 30. On these same dates, cool waves invariably made their appearance over the Pacific Slope, as appears both from the monthly records of temperature even in the Santa Clara Valley, but much more so by referring to the weather map of those dates, when you will see a predominating high lording it somewhere over the Pacific Slope. Well, but what about the warm waves? We can aver that these have invariably inserted themselves between the cool waves preceding and following them according to the laws herein above mentioned. Back of the twenty-three successful cases of our enumeration, where a marvelous order prevails and no break intervenes, lie the like happenings of the previous months and the experiments of about five years before that. And we may add that even up to the present date no exception has as yet appeared.

Our contention, however, is only for the Pacific Slope in general. Not every warm or hot wave or the opposite that enters upon the coast is making itself felt at every single station throughout the length and breadth of the Pacific States. In that case by consulting the weather map, one can see at a glance that the wave has indeed entered and covers a vast amount of territory. Cases of this kind can be quoted on demand. On the whole, however, a disturbance up north and down south sends its messengers even to us here and then people do marvel. asking what's the matter with the weather? The answer is there is an abnormal high or low in the north or the south and we stand within the sphere of its mighty influence.

Let these remarks suffice to justify the scientific value of the study of solar physics in its bearings upon things meteorological here below. It has been found that the meteorology of the Sun runs hand in hand with the meteorology of the Earth —Cfr. Sir Norman Lockyer in North American Review, June 1901, pages 827 et seqq.—and because the Earth is a planet, there is no room left to doubt that the meteorology of the Sun likewise affects the meteorology of the other planets. But secondaries always react on their primaries. Hence there is an avenue open for thinking that the solar spots may, at least in some measure, have a planetary origin.

This may account for the wonderful and undeniable fact to which the writer can bear ample witness—a fact, too, which is based upon the physical basis of observations taken by the most competent men of our weather bureau—that distinguished planetologists have invariably offered the same dates as ourselves, who have depended on solar markings only, for the entrance of warm and cool waves on the Pacific Slope. (By the way, the Professor of Meteorology at Harvard is a planetologist and other distinguished men might be named.)

As to the Moon in particular, we have no special information to offer, unless it be that a long series of experiments conducted under the auspices of the Greenwich Observatory, England, and the Royal Observatory of Belgium, tends to show that it has an effect on the circulation of the atmosphere. Cfr. *Bulletin de la Société Belge d' Astronomie, Revue des Sciences d' observation, Astronomie, Météorologie, Géodésie et Physique du Globe* for the year 1907.

Santa Clara College Observatory,
Santa Clara, California.

P. S. Since the above was written, much corroboration evidence has been accumulating. Long-range forecasts based on solar spots have been verified, as it were to order. But much matter of detail remains to be explained and the objections of the "man from Kansas" to be answered—which will be attended to in our next article. J. S. R.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

Part II. (Continued.)

SPECIFIC STATEMENTS OF FUNDAMENTAL CONCEPTS CONCERNING THE CONSTITUTION OF MATTER.

FOR POPULAR ASTRONOMY.

Some very significant facts, pointing directly to the primitive condition and fundamental nature of all matter, will now be adduced in this connection. Under the condition that the, very approximately, spherical mass of the Sun is the result of the compression, or contraction, of a vastly extended volume of nebulous matter which was, at the very beginning of the process, in equilibrium, as to density, pressure and temperature, with the luminiferous ether whence it has been derived, it is easy to find the radius of the spherical volume of the gaseous mass when it began to differentiate from the ether, and to contract toward the present dimensions of the Sun. If we designate the present semidiameter of the solar globe by *s*, its mean density by D_s and the density of the ether by D_e, and reduce the former density to the latter by assuming the present volume of the Sun to be sufficiently expanded, it is obvious that the maximum radius (R_s) of the expanded spherical volumes in terms of the radius of the solar globe at the present time, will be given by the equation $R_s = s \,.\, \sqrt[3]{\frac{D_s}{D_e}}$; (a) and if the present mean distance of the Earth from the Sun be denoted by S, the maximum radius (R_n) of the primitive spherical nebula, in terms of the Earth's mean distance which is taken as unity, is expressed by the equation; $R_n = \frac{s}{S} \cdot \sqrt[3]{\frac{D_s}{D_e}}$; (b).

The mean distance (S), corresponding to the solar parallax of very nearly 8.″80, is 92,891,300 miles, and the present mean radius of the Sun, for the *apparent* semidiameter 15′: 59″.63. is 432,175 miles, while the mean density (D_s) of the solar mass 1.414 times that of the water standard, or unit. From the observed value of the "solar constant," or measure of the thermal radiation from the Sun, and from the photometrically determined intensity of the luminous radiation from unit surface of the solar disk, I have found by means of two algebraic expressions for the "law of radiation" in each case, analytically derived,—in a manner to be subsequently set forth—from the fundamental concepts of my "astronomical theory of the molecule," that the density of the luminiferous ether, relative to the normal density of atmospheric air, is $\frac{1}{19{,}263{,}000{,}000{,}000{,}000}$, and since the density, or weight per unit volume, of water is 773.4 times that of air, that the density (D_e) of the ether, relative to the normal density of water, is $\frac{1}{14{,}898{,}000{,}000{,}000{,}000{,}000}$ which, as numerical quantities of such magnitude are more conveniently expressed in powers of 10, may be written $\frac{1}{14898 \times 10^{15}}$ or as a decimal fraction, 6712×10^{-28}, and the same value for the density I have found by means of two other independent methods, based upon my theory, which furnish checks upon the accuracy of the determination above set forth. Substituting this value of D_e, together with those of s and D_s above given in equation (a). the value of the maximum radius (R_s) of the primitive solar nebula—considered as a sphere—is found to be 2,761,920 times the semidiameter of the Sun, and therefore 1,193,632,776,000 miles, while, if all the aforesaid known values be introduced into the right-hand member of equation (b), the maximum radius (R_n) referred to the mean-distance of the Earth from the Sun as the unit, is found to be 12,850, a value about 10 per cent greater than that stated in the preceding part of this paper, and which was taken from a preliminary, or provisional, computation, while the result just given has been derived from a more correct and exact value of the relative density of the ether.

The absolute temperature (T_e) of the luminiferous ether is determinable from the density (D) thereof, relative to that of atmospheric air under the normal conditions, through the following equation of my theory; $T_e = T_a . D^{3/8}$; (c) in which T_a represents the normal absolute temperature of atmospheric air, freed from the augmentation due to the solar thermal radiation which raises the atmospheric temperature, materially, only in the lower strata, while not affecting the temperature of the ether beyond. Thus taking the temperature of the "freezing-point" of water, or 32 degrees Fahrenheit, as the standard, we have $32° + 459.°65 = 491.°65$ as the corresponding absolute temperature, and deducting therefrom 112.87 degrees which I have found to represent, well, the augmentation due to solar heat, there results, as the value of T_a in this case, 378.78 degrees, or 80.87 degrees below the zero of the Fahrenheit scale, and this is, very nearly, the lowest terrestrial atmospheric temperature ever observed near the Siberian "magnetic pole"—a very significant fact, as will be subsequently shown. Substituting this value of T_a, together with that of $D^{3/8}$, in equation (c), the absolute temperature of the ether is found to be 0.°000000005271, or only a little more than the two-hundred-millionth part of a degree (Fahrenheit) above absolute zero, and thus we have both the temperature and the density of the ether, which are also the temperature and density of the matter of the incipient solar nebula at the time of its differentiation, or derivation, from that fundamental, superlatively tenuous and extremely cold, substance.

The absolute temperature (T_s) generated by the compression of this vastly extended, gaseous mass, down to the present dimensions of the Sun, is determinable through the following equations of my theory: $T_s = T_e R_s^2 = T_e . \left(\frac{R_n S}{s}\right)^2$; (d), the resulting value of T_s being 40,200 degrees Fahrenheit *absolute*. This temperature has been derived under the condition that the whole compression of the gaseous matter of the nebula has been *adiabatic* or in other words, that no heat has been gained by the mass, from sources other than compression, and that none has been lost therefrom, but, in order that there should be any compression under the action of the force of gravity inherent in such a gaseous mass, there must have been loss by radiation from the surface thereof, otherwise, since the force of gravity at the surface varies inversely as the square of the mean radius of the contracting volume of the nebula while the generation of heat by the process of compression, and the consequent development, thereby, of a force directly antagonistic to that of gravity, as has been pointed out on a preceding page, varies also inversely as the square of said radius, the process of compression could not be carried on—or even have its inception—unless there were a loss of heat from the gaseous mass.

By a differentiation of that equation of my theory, connecting temperature and density in such a mass, I have found that in the process of compression from the original volume to the present dimensions of the Sun, two-thirds of the heat that would have been generated by *adiabatic* compression—were such possible—must have been radiated into space, and one-third retained in the contracted mass, this third part being the measure of the present maximum *internal* temperature of the Sun, which is to be found at a comparatively short distance below the apparent surface of the solar globe, at a depth of probably not more than 5000 miles, or just below the roots of the brilliant filaments constituting the highly luminous portions of the photosphere, and prominently visible in the penumbra of a sun-spot. The temperature due to *adiabatic* compression being, as above stated in round numbers, 40,200 degrees it follows that the present maximum absolute temperature of the internal matter of the Sun is 13,400 degrees. Furthermore, what may be called the "surface temperature" of the Sun, or, since that body does not possess a real, geometric surface (its superficial matter consisting of gases and vapors of varying densities) that of a mean level, or "interface," between the depth at which the internal temperature is a maximum, and the cold ether outside the solar globe, being the arithmetical mean between the absolute temperature of the ether, which is so small that it may be regarded as zero in this connection, and the maximum internal temperature aforesaid, is one-half the latter, or 6700 degrees, a value substantially the same as that derived by means of the several independent methods referred to in the preceding part of this paper. The results above stated in this connection are summarized as follows:

TABLE I

	R_s	R_n	Absolute Temperature	Density
The Ether and the Incipient Solar Nebula	2,761,920	12,850	0.°000000005271	6712×10^{-23} (water) 5191×10^{-20} (air)
The Sun	1	0.004652	13,400°(Internal) 6,700°(Surface)	1.414 (water) 1094.6 (air)

In the first column of Table I is set forth the maximum radius of the incipient solar nebula, in terms of the present semidiameter of the Sun, which is also set forth therein as 1, and in the second column are these quantities referred to the Earth's mean-distance as the unit.

In the third column are given the initial absolute temperature of the nebula (which is also that of the luminiferous ether) and the absolute temperature of the nebulous mass after its condensation into what we call the Sun—both the internal and the surface, or effective radiating temperature of that body being given—while the last column contains the relative density with respect to both the water unit and the normal density of atmospheric air, the density relative to air being that found, directly, from observational data, through the several methods and equations of my theory (which regards the ether as being, fundamentally, of the same nature and constitution as that of the atmospheric, and other, gases) the value of the density relative to the water standard being found simply by dividing the densities relative to air by the constant number 773.4.

Furthermore, it should be remarked that this density does not, necessarily, represent *mass*, or *weight*, per unit volume, but only the *volume* of each hollow, spherical shell, or molecule, of the ether, relative to the normal volume of the standard molecule of atmospheric air, this volume being inversely proportional to the density the expression whereof, in this case, is $D = \frac{1}{V}$ instead of $D = \frac{M}{V}$, the mass (M) being, in this connection, considered as unity for both substances, the volume (V), only being variable.

If the radiation of heat from the contracting nebula, and its generation by reason of the compression due to the nebular force of gravity, were to proceed *pari-passu*, the process of contraction would go on uniformly, but such is not the case, the heat being developed at a rate greater than that of radiation, so that, as has been stated, there results an accumulation of thermal energy which, at certain definite—and definable—intervals, overcomes the compressive force of gravity and by reason of this fact, combined with the effect of centrifugal force due to the rotation of the nebula, superficial portions of the matter of the tenuous gaseous mass are severed therefrom, and left behind in the process of contraction.

From the relation between density and temperature, as expressed by certain equations of my theory, I have found that whenever the absolute temperature is increased three times by the compression, the force of gravity at the surface is thus overcome, and fission occurs.

The relation between the temperature (T) generated by the compression, and the radius (R_n) of the contracting sphere, is expressed by the equation: $T_n = \frac{1}{R_n^2}$; whence, $R_n = \sqrt{\frac{1}{T_n}}$, the temperature denoted by T_n being a proportional quantity, in this case, the value whereof is 3, so that, beginning with the maximum value of R_n, which is 12,850, and dividing this by $\sqrt{3}$ we obtain 7,420 as the mean radius at which the temperature of the mass will be tripled and fission result, and by continuing this process downward until the present surface of the Sun is reached at the relative radius $R_n = 0.004652$, we obtain a series of intervals at which, roughly annular, portions of the superficial matter of the nebula are detached, and also the mean absolute temperature and density of the matter of these severed portions whence the planets and comets have been, subsequently, formed. The following table contains, in the first column, the values of n, or the number of intervals, counting from the outermost, downward, in the second column the values of the radius (R_n) of the contracted sphere at the numbered interval; in the third column, the corresponding absolute temperatures, and in the fourth, the density relative to that of the water unit.

The temperature corresponding to $n = 1$ in this table, is that of the luminiferous ether, and three times this value would be the temperature of the matter separated at the radius 7,420, corresponding to $n = 2$, but under the condition that two-thirds of the heat generated has been radiated into space during the interval, and one-third retained in the nebulous mass, the *actual* temperature at $n = 2$, must have been the same as the fundamental temperature or that of the ether, as aforesaid, so that all the temperatures set forth in the third column, below $n = 1$, are *actual* temperatures due to heat retained in the condensing mass, and by multiplying these by three, we obtain the absolute temperatures which would have been produced by the compression to each value of the mean radius of the nebula, had there been no loss by radiation–the compression being considered as *adiabatic.* As a matter of convenience, the densities, relative to the water unit, in the fourth column are expressed in terms of the powers of 10, down to, and including, $n = 11$, and thence, downward to the Sun they are written as decimal fractions in the ordinary way.

TABLE II

n	R_n	Absolute Temperature	Density	
1	12.850	0°.000000005271	6512×10^{-23}	The Ether
2	7,420	0°.000000005271	3488×10^{-22}	
3	4,284	0 .0000000158	1812×10^{-21}	
4	2,474	0 .0000000474	9417×10^{-21}	
5	1,428	0 .000000142	9893×10^{-20}	
6	824	0 .000000427	2543×10^{-19}	
7	476	0 .00000128	1321×10^{-18}	
8	275	0 .00000384	6865×10^{-17}	
9	159	0 .0000115	3567×10^{-16}	
10	92	0 .0000345	1832×10^{-15}	
11	53	0 .000104	9631×10^{-15}	
12	31.00	0 .000312	0.000000000000050	Orbit of Neptune
13	18.00	0 .000936	0.00000000000260	" " Uranus
14	10.00	0 .00281	0.000000000135	" " Saturn
15	5.89	0 .00842	0.000000000702	" " Jupiter
16	3.39	0 .0252	0.00000000360	" " Asteroids
17	1.96	0 .0756	0.0000000190	" " Mars
18	1.13	0 .227	0.0000000985	" " Earth
19	0.65	0 681	0.000000512	" " Venus
20	0.38	2 .043	0.00000266	" " Mercury
21	0.2171	6°.128	0.0000138	
22	0.1256	18 .38	0.0000718	
23	0.0725	55 .14	0.000373	
24	0.0418	165 .42	0.00194	
25	0.0241	496 .3	0.0100	
26	0.0140	1,488 .9	0.0524	
27	0.0081	4,466 .7	0.272	
28	0.004652	13,400 .1	1.414	The Sun

The process of development of the Sun, from the primitive nebula, is clearly indicated in Table II, and if this nebula were drawn from the numerical data thus tabulated, the ideal depiction would be an almost perfect similitude of the great nebula in Andromeda.

In the determination of these tabulated values, the nebula has been considered as a sphere, but further evidence, from both theory and observation, will be presently introduced to show that it must have been of a roughly oval shape, with its longest diameter between three and four times the shortest.

It will be shown also that the rings, or belts, of separated matter were of great width, as were also the spaces, comparatively devoid of nebulous matter, between them; these void spaces constituting the dark rifts, or "lanes," such as those in the great nebula in Andromeda, to which attention was first called by Professor G. P. Bond, of the Harvard College Observatory—of which he was director, about the middle of the last century—these rifts, so observed, being two in number and known as "Bonds dark lanes" from their discoverer.

The process of derivation of the members of the solar system—the planets with their satellites, and the comets as well—the nuclei whereof were formed by secondary and tertiary condensations in the matter cast off from the primary solar nebula, in the manner above described, can be traced by means of the same analytical method, based upon the principles of my theory, that I have employed in the case of the derivation of the Sun from the primitive nebulous mass.

Designating the relative density of any planetary body by D_p, and that of the separated matter in, and from, which it has condensed by reason of compression due to its intrinsic force of gravity, down to its present dimensions and density, by D_n, the initial radius (R_p) of the planetary nebulous matter, at the time of beginning of this secondary process of condensation, is determinable through the equation: $R_p = \sqrt[3]{\frac{D_p}{D_n}}$; (d_1) in terms of the mean radius of the planet at the present time, this radius being taken as 1—and from the equation: $T_p = \frac{T_n}{3} . R_p$: ($e_1$) the maximum absolute temperature of the mass, at the time of its formation into an approximately solid body, can be found, T_p, representing also the maximum internal absolute temperature of any planet, at the present time. In these equations, T_n which represents the absolute temperature of the gaseous matter in any belt or ring, at the time of beginning of the planetary condensation, is to be taken directly from the third column of Table II, and the density D_n of this matter from the fourth column thereof, while D_p represents the density—relative to the water-unit—of the planet at the time when the compressed mass passed from the gaseous state into the *viscous* (it will be shown that the chemical constitution of the greatest part of the known matter of the Earth precludes the idea that, in the transition period from the gaseous to the solid state, it was *liquid* in the same sense as water is regarded; it indicates rather, that, at that time, the terrestrial matter, was in a condition similar to that of *molten glass*) after which the contraction due to loss of heat did not, of course, follow the thermodynamical laws governing the compression of gases.

In the case of the Earth, its mean density—relative to the water-unit—is known to be very approximately, 5.52, while that of the superficial strata, is only about one-half this, the greater density of the internal matter being due, principally, to the enormous pressure of the superincumbent strata of the so-called "crust," and therefore, the density (D_p) to be used in the equation (d_1) is 2.66, or that of the most abundant, superficial solid matter.

Substituting this value, and that of D_n taken from Table II, for $n = 18$, the initial radius (R_p) of what may be called the "terrestrial nebula," in its most expanded state, is found to be 300 times the mean radius of the terrestrial spheroid at the present time, or nearly 1,189,000 miles.

Squaring this value of R_p, and substituting the result, together with one-third the value of T_n (since, in the process of planetary compression, two-thirds of the heat that would result from *adiabatic* compression is radiated away just as in the case of the primitive solar nebula) taken from Table II, for $n = 18$, in equation (e_1), we obtain 6,800 degrees Fahrenheit as the maximum absolute temperature of the internal matter of the Earth, which is equivalent to 6,340 degrees when referred to the zero of the ordinary scale. Therefore, if we take the mean temperature of the whole surface of the Earth at forty degrees, the excess of temperature between the surface and the internal matter, is 6,300 degrees, so that, if the increase of temperature downward from the surface, be at an average rate of 55 feet per degree, Fahrenheit, which is the mean value derived from a number of the best determinations in the case of mines, wells and borings of great depth, and also the value, as found through an equation derived from my theory, in a manner to be subsequently shown, this equation being $p = \frac{k}{R}$, (t) (in which k

represents the mean conductivity of the the matter of the "crust", and R, the rate of radiation from the Earth's surface, or the quantity of heat radiated from unit surface, in unit time, the algebraic formula for which furnishes a crucial test of my theory) the maximum internal temperature is reached at a depth of 66 miles. This superficial "envelope"—as it may be regarded—the temperature whereof increases downward to the maximum, at the depth aforesaid, may be called the "crust" of the Earth although, as has been stated there is abundant reason for the statement that the whole mass of our globe is, substantially, a *solid* of great rigidity, notwithstanding the fact that it is exceedingly hot not very far below the surface. This temperature is, of course, far above that of the melting-points of the metals and of many of the substances entering into the composition of the Earth, but it is *barely* the temperature of the melting point of the element "carbon" and its chemical congener "silicon", under the ordinary conditions of *pressure*, and it is very obvious that, under the enormous pressure of the 66 miles of depth of the "crust" aforesaid, even these two, most highly refractory, substances must be in the *solid* state and, under this condition, would constitute a very rigid mass such as that which is, evidently, the nucleus of our globe which is practically of the same density and temperature throughout its whole extent below the comparatively thin "crust" the depth whereof is 66 miles or only the one-sixtieth part of the present mean semidiameter of the Earth.

The aforesaid thickness of the so-called "crust" is only a *mean* value dependent upon the *mean* thermal conductivity of the matter of the crust, so that in some regions this crust may be considerably thicker than the average of 66 miles, and in others thinner; moreover, the surface matter of the Earth is never at absolute rest but is always yielding, more or less, to divers stresses brought to bear upon it by extraneous forces traceable ultimately to the action of the Sun and having a rough periodicity, as will be demonstrated, and the kinetic energy due to even very minute movements of the matter of the crust at a depth of only a few miles, as in the case of the more violent movements known as "earthquakes" (the seismic foci being generally located at depths of from three to five miles, although in some cases the focus has been found at a depth of thirty miles below the surface) may generate, in portions of the distributed strata triturated by the movement, heat, to a degree quite as great, or even greater, than the maximum internal temperature at the lower depth aforesaid, and to this superficial, and local, action, according to my hypothesis, is to be attributed seismic phenomena, the earthquakes and volcanoes. In this view, the maximum internal heat of our globe, generated by the original gaseous compression, is only a remote factor in the causation of said phenomena, the slow and uniform contraction of the Earth by reason of the secular cooling of its internal matter, resulting in the corrugation of the previously comparatively smooth surface into elevations and mountain ranges in proximity to correlated ocean depths, thereby producing axes of weakness, or "faults," in the rocky strata of later deposition, portions of these strata giving way at intervals, to the stresses put upon them by extraneous forces aforesaid, the amount of the development and the amplitude of the vibration, or "shock," caused thereby, being comparatively, small but productive frequently, of violent swayings and disastrous results on the surface of the Earth by reason of the great velocity of the vibrations in the strata affected by the "earthquake waves." While we do not possess positive knowledge, derived from actual observation, as to the nature and condition of the terrestrial matter at considerable depths below the surface, we do know quite accurately, the relative proportions and chemical constitution of the superficial matter, and from this fact, in connection with spectroscopic evidence presented by the Sun, stars, gaseous nebulæ and comets, when viewed in the light of the nebular hypothesis as conceived by my theory, we can deduce conclusions in regard to the internal matter of our globe, which possess a degree of probability so great that they approach what may be rationally regarded as a very close approximation to positive knowledge in this respect, and more than this is not to be anticipated until some mechanical means of reaching the internal matter at the depth of 66 miles—by borings or otherwise,—can be devised and this, pre-requisite while, in the light of what has been accomplished in engineering achievements, it cannot be regarded as an absolute impossibility, is practically, a very remote contingency, in all probability.

The chemical element *silicon* in combination with the gas *oxygen*, in the form of the solid substance known as "silica" (of which pure quartz, rock crystal, sand and other minerals are specimens) the silicates of alumina, etc., constitute by far the greater portion of the superficial matter of the Earth, the metals—even iron—abundant as they are, being inconsiderable in quantity when viewed in this connection, they constituting only about one-tenth, by weight, of the whole superficial matter, so far as known. At the time when the terrestrial matter was transformed from the gaseous into the *viscous* state, the temperature thereof was far above that at which oxygen could combine, chemically, with silicon to form the solid silica and the silicates aforesaid, and when said matter had cooled to a degree sufficient to permit this combination, the transformation was effected only upon, and to a small distance below, the surface of the crust, by reason of the fact that the internal temperature continued to be above that of "dissociation," and that the gas oxygen which is a light superficial element, incapable of penetrating to very great distances below the surface, could not reach and combine with the silicon at considerable depths. In view of these facts, it is most reasonable to conclude that, while the surface matter is thus chiefly composed of chemical combinations of silicon with oxygen and other elements, one substance, at least, in its elementary form enters into the constitution of the nucleus of the Earth, at an average depth of 66 miles and even into that of the crust at a considerably higher level, and that this is the element *silicon*.

One of the best attested of all the many important disclosures made by the spectroscope in the hands of skillful and eminent physicists, is that of the presence of carbon in some form—notably in that of a combination of carbon with the gas hydrogen as a hydro-carbon—in the Sun and many of the stars, comets and gaseous nebulæ, and it is also well-known that the principal part of the light radiated by the Sun is emitted from incandescent solid matter in a state of fine division, suspended in an atmosphere of highly heated, but much less luminous gases.—hydrogen etc.,—this light-giving portion of the solar globe being known as the "photosphere" the temperature whereof must be as high—or even higher—than the effective surface temperature of the Sun, which is 6,700 Fahrenheit (absolute) according to my determinations as stated on preceding pages, and the only *known* substance that can remain in the solid state at so high a temperature, is the element *carbon* and we might therefore expect to find this substance in abundance in the superficial matter of our globe, but aside from the carbon found in the "coal-measures," and which is known to be of vegetable origin, there is only a comparatively small quantity of this element, in approximately pure condition, and known as "graphite", existing in the older geological rocks, but its absence from the superficial matter can be accounted for very easily. It is very evident, from what has been remarked above concerning the chemical combinations of silicon and oxygen aforesaid, that even had carbon existed in great quantity on, and just below the surface of the Earth, when the temperature had fallen sufficiently to allow chemical combination with oxygen to take place, the resultant could not have been a solid, or solids, as in the case of silicon and oxygen, but must have been invisible. gases, ether in the form of carbon-dioxide, or carbonic-acid gas, the former gas, subsequently entering into the composition of plant and animal life, as one of the chief constituents thereof, and also combining with oxygen and calcium and like elementary matter to form the great system of rocks known as carbonates of lime etc., while the monoxide was occluded in the lower depth where the supply of oxygen was deficient.

A portion of the carbon thus coverted into vegetable matter was subsequently, deeply buried under earth and water, and slowly coverted into that combination of carbon with other matter, which is called "coal."

The pure primitive solid carbon must therefore have quite wholly disappeared from the superficial matter of the Earth at small depths, but the heavy hydro-carbon gases that are ejected from the craters of volcanoes in violent eruption, and which cover the volcanic mountain and the surrounding country with a heavy pall of black smoke when they have come into contact with the oxygen of the atmosphere and flashed into flame; the gaseous and liquid hydro-carbons that swell up so abundantly from the depths of the Earth in many regions and which have proved so useful to man in many ways, all bear testimony to prove the existence of abundant quantities of primitive carbon at considerable depths, and lead directly, and rationally to the conclusion that it, as well as its chemical congener silicon, is one of the chief constituents of the solid nucleus of our globe.

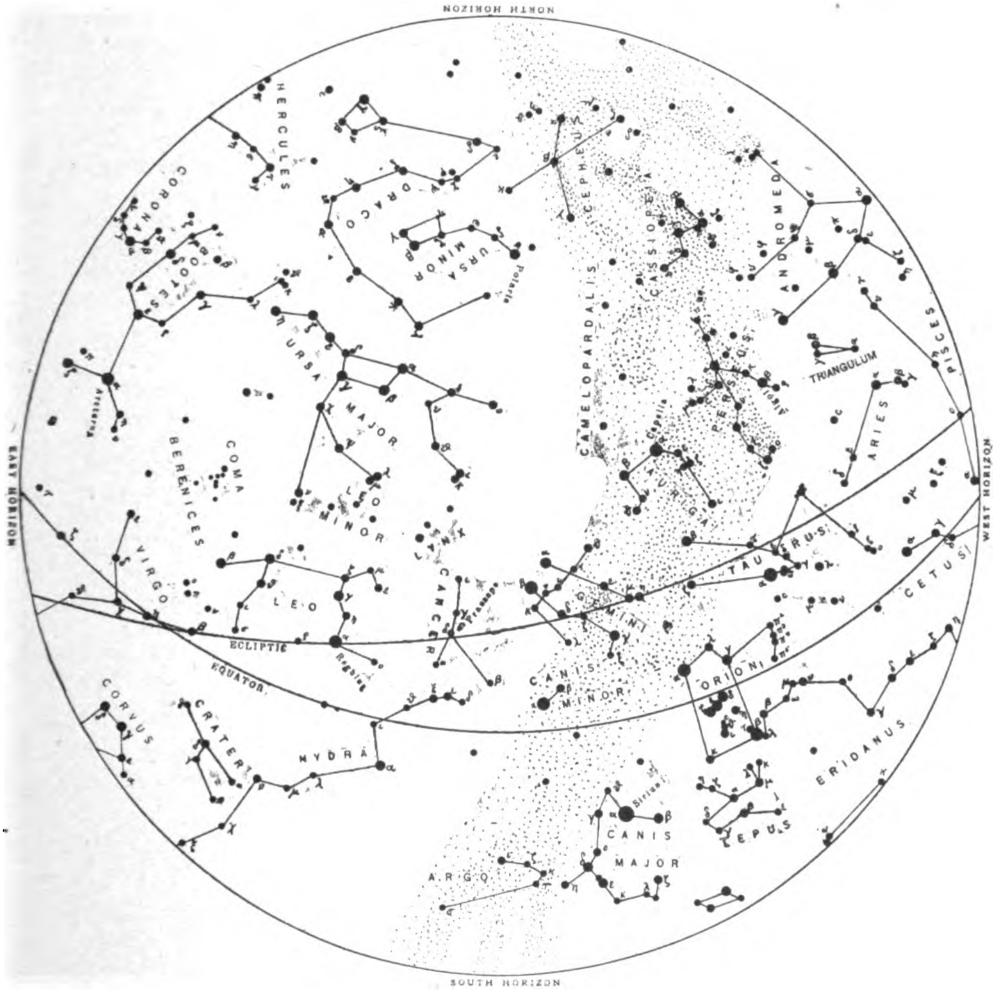
St. Paul, Minn.

To be continued.

PLANET NOTES FOR MARCH 1908.

H. C. WILSON.

Mercury is morning star and will be at greatest elongation, west from the Sun 27° 49′, on the morning of March 26. The planet at this time will be only half as bright as it is under the most favorable conditions. Mercury will be at aphelion March 28.



THE CONSTELLATIONS AT 9:00 P. M., MARCH 1, 1908.

Venus is evening star, very brilliant in the west soon after sunset. The planet will soon be visible to the naked eye in full sunlight in the afternoon to those who know just where to look for it. Venus will be at perihelion on March 31.

Mars having passed Saturn in January, is moving westward and northward away from the latter and during March will journey through Aries into Taurus. The apparent diameter of the planet is now under 6″ so that the markings of its surface are not easily seen.

Jupiter is the brilliant planet seen nearly overhead in the early part of the night. The ruddy "belts" are easily seen with a small telescope and with a large instrument are full of fine details. The four bright satellites are seen at a glance with the smallest telescope. Their orbits this year are nearly in the plane with the Earth and so each one exhibits all the "phenomena," transit of the satellite, transit of the shadow, eclipse and occultation by the planet.

Saturn will be in conjunction with the Sun March 20 and so will not be in position for study this month.

Uranus may be found with a telescope in the morning but it is not in good position for study.

Neptune may be studied with a good telescope in the early evening, a little way west and north of the star ζ Geminorum. There has been quite a little discussion among some of the English students of astronomy as to whether Neptune is really easily distinguishable by its disk. With a large telescope and good seeing there is never any question about this. The disk of the planet is very plainly different from the spurious disk of a star of the same brightness.

Occultations visible at Washington.

			IMMERSION.		EMERSION.		
Date 1908	Star's Name	Magnitude.	Washington M.T.	Angle f'm N.	Washington M.T.	Angle f'm N	Duration.
			h m	°	h m	°	h m
Mar. 7	Mayer 121	6.4	6 10	44	7 25	275	1 15
10	η Geminorum	3.5	6 26	25	7 16	320	0 50
11	44 Geminorum	5.9	4 54	46	6 01	303	1 07
11	δ Geminorum	3.5	14 9	117	15 02	262	0 53
19	n Virginis	6.5	16 50	109	18 02	303	1 12
22	B.A.C. 5408	6.4	11 35	73	12 24	335	0 49

Phenomena of Jupiter's Satellites.

Central Standard Time, reckoning from noon.

	h	m			
Mar. 1	5	42	IV	Ec.	Dis.
	6	48	III	Oc.	Dis.
	9	41	I	Oc.	Dis.
	10	25	IV	Ec.	Re.
	12	44	I	Ec.	Re
	13	28	III	Ec.	Re.
2	7	00	I	Tr.	In.
	7	46	I	Sh.	In.
	9	20	I	Tr.	Eg.
	10	06	I	Sh.	Eg.
3	7	13	I	Ec	Re.
5	12	18	II	Oc.	Dis.
7	6	26	II	Tr.	In.
	8	11	II	Sh.	In
	9	23	II	Tr.	Eg.
	11	07	II	Sh.	Eg.
	14	20	I	Tr.	In.
	15	12	I	Sh.	In.
8	10	16	III	Oc.	Dis.
	11	28	I	Oc.	Dis.
	14	39	I	Ec.	Re.
Mar. 9	5	43	IV	Tr.	In.
	6	07	II	Ec.	Re.
	8	47	I	Tr.	In.
	9	40	I	Sh.	In.
	10	31	IV	Tr.	Eg.
	11	07	I	Tr.	Eg.
	12	00	I	Sh.	Eg
	15	02	IV	Sh.	In.
10	5	55	I	Oc.	Dis.
	9	03	I	Ec.	Re
11	6	29	I	Sh.	Eg.
12	7	42	III	Sh.	Eg.
	14	39	II	Oc.	Dis.
14	8	49	II	Tr.	In.
	10	48	II	Sh.	In.
	11	45	II	Tr.	Eg.
	13	44	II	Sh.	Eg.
15	13	16	I	Oc.	Dis.
	13	48	III	Oc.	Dis.
16	8	42	II	Ec.	Re.
	10	35	I	Tr.	In.

	h	m			
Mar.16	11	35	I	Sh.	In.
	12	55	I	Tr.	Eg.
	13	55	I	Sh.	Eg.
17	7	44	I	Oc.	Dis.
	11	03	I	Ec	Re.
	13	55	IV	Oc.	Dis.
18	6	4	I	Sh.	In.
	7	22	I	Tr	Eg.
	8	24	I	Sh.	Eg.
19	7	27	III	Tr.	Eg.
	7	59	III	Sh.	In.
	11	41	III	Sh.	Eg.
21	11	14	II	Tr.	In.
	13	25	II	Sh.	In.
	14	10	II	Tr.	Eg.
23	6	14	II	Oc.	Dis.
	11	17	II	Ec	Re.
	12	24	I	Tr.	In.
Mar.23	13	30	I	Sh.	In.
	14	44	I	Tr.	Eg.
24	9	33	I	Oc.	Dis.
	12	58	I	Ec.	Re.
25	6	52	II	Tr.	In.
	7	58	I	Sh.	In.
	9	12	I	Tr.	Eg.
	10	19	I	Sh.	Eg.
26	7	24	III	Tr.	In.
	7	27	I	Ec.	Re.
	8	03	IV	Sh.	In.
	11	06	III	Tr.	Eg.
	11	58	III	Sh.	In
	12	55	IV	Sh.	Eg.
28	13	41	II	Tr.	In.
30	8	40	I	Oc.	Dis.
31	11	24	II	Oc.	Dis.

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

COMET NOTES.

Encke's Comet Rediscovered.—A cablegram received at Harvard College Observatory January 3, from Kiel, Germany, states that Encke's comet was photographed by Professor Max Wolf on January 2. Its position was

Jan. 2.2358 Gr. M. T. R. A. $23^h\ 03^m\ 16^s$ Decl. $+1^\circ\ 19'$.

This indicates that the ephemeris, calculated from the elements given below, required a correction of about $+3^m$ in R. A. and $-15'$ in Decl. The comet is visible in a large telescope.

Elements and Ephemeris of Encke's Comet for 1908.—In *A.N.* 4222 are given elements of this periodic comet, computed for the epoch 1908.0 by Mr. M. Kamensky and Miss E. Korolikov. They are taken from the *Bulletin de l'Acad. Imp. des Sciences de St Pétersbourg.* 1907.

ELEMENTS.

Epoch and Occultation Feb. 22.0 (Berlin.)

$$\begin{array}{l}
M = 339^\circ\ 36'\ 34.''86 \\
\left.\begin{array}{l}\pi = 159\ \ 05\ \ 39.\ 00 \\ \Omega = 334\ \ 30\ \ 17.\ 77 \\ i = 12\ \ 36\ \ 40.\ 54\end{array}\right\}\ 1908.8 \\
\phi = 57\ \ 56\ \ 57.\ 17 - 2.''394\,\tau \qquad \tau = \dfrac{t - t_0}{1200} \\
\mu = 1076.''45733 + 0.''067715\,\tau \\
T = 1908 \text{ April } 30.1913 \text{ (Berlin)}
\end{array}$$

Ephemeris of Encke's Comet.

Berlin 0^h	α			δ		log *r*	log Δ	Aberration Time.	
1908	h	m	s	°	′			m	s
Feb. 4	23	38	07	+ 5	07.5	0.2130	0.3435	18	19
8		44	04	5	43.1	1992	3408		12
12		50	20	6	21.0	1846	3373	18	04
16	23	56	55	7	01.1	1692	3329	17	55
20	0	03	51	7	43.7	1528	3278		42
24		11	09	8	28.3	1354	3219		28
28		18	51	9	15.3	1168	3151		11

Berlin 0h	α			δ		log *r*	log Δ	Aberration Time.	
1908	h	m	s	°	′			m	s
Mar. 1	0	22	53	+ 9	39.6	0.1069	0.3113	17	01
3		27	00	10	04.5	0967	3074	16	52
5		31	14	10	30.0	0861	3031		41
7		35	35	10	56.1	0752	2985		31
9		40	06	11	22.6	0638	2938		20
11		44	43	11	49.6	0520	2888	16	09
13		49	27	12	17.3	0396	2834	15	57
15		54	24	12	45.7	0267	2776		45
17	0	59	29	13	14.5	0.0133	2716		31
19	1	04	44	13	43.7	9.9992	2652		18
21		10	10	14	13.4	9843	2586	15	4
23		15	49	14	43.5	9689	2515	14	50
25		21	40	15	13.9	9526	2440		34
27		27	44	15	44.7	9355	2360		19
29		34	02	16	15.7	9175	2276	14	02
31	1	40	36	+ 16	46.7	9.8984	0.2186	13	45

VARIABLE STARS.

Approximate Magnitudes of Variable Stars on Jan. 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A 1900		Decl. 1900		Magn.
	h	m	°	′			h	m	°	′	
X Androm.	0	10.8	+46	27	13.3*d*	R Persei	3	23.7	+35	20	13.4*d*
T Androm.		17.2	+26	26	10.0 *i*	Nov. Per. 2		24.4	+43	34	13.3*d*
T Cassiop.		17.8	+55	14	10.0*d*	S Fornacis		41.9	−24	42	8.5
R Androm.		18.8	+38	1	13.2*d*	T Tauri	4	16.2	+19	18	10.4
S Ceti		19.0	− 9	53	9.7 *i*	R Tauri		22.8	+ 9	56	<13
Y Cephei		31.3	+79	48	13.0*d*	W Tauri		22.2	+15	49	8.4 *i*
U Cassiop.		40.8	+47	43	13.5 *i*	S Tauri		23.7	+ 9	44	<12
RW Androm.		41.9	+32	8	13.3	T Camelop.		30.4	+65	57	8.8 *i*
V Androm.		44.6	+35	6	12.2 *i*	RX Tauri		32.8	+ 8	9	<13
RR Androm.		45.9	+33	50	<13.5	X Camelop.		32.6	+74	56	9.0 *i*
W Cassiop.		49.0	+58	1	10.6*d*	V Tauri		46.2	+17	22	12.0 *i*
RX Androm.		58.9	+40	46	13.0	R Orionis		53.6	+ 7	59	9.8*d*
U Androm.	1	9.8	+40	11	<13.5	R Leporis		55.0	−14	57	10.0
S Piscium		12.4	+ 8	24	11.0 *i*	V Orionis	5	0.8	+ 3	54	9.7*d*
S Cassiop.		12.3	+72	5	13.2 *i*	T Leporis		0.6	−22	2	10.2
U Piscium		17.7	+12	21	11.8	R Aurigae		9.2	+53	28	9.2*d*
R Piscium		25.5	+ 2	22	14 *d*	S Aurigae		20.5	+34	4	11.0
RU Androm.		32.8	+38	10	10.0*d*	W Aurigae		20.1	+36	49	10.0
Y Androm.		33.7	+38	50	9.0*d*	S Orionis		24.1	− 4	46	10.5*d*
X Cassiop.		49.8	+58	46	10.0	T Orionis		30.9	− 5	32	10.0
U Persei		53.0	+54	20	9.0 *i*	S Camelop.		30.2	+68	45	11.0*d*
S Arietis		59.3	+12	3	11.5 *i*	RR Tauri		33.3	+26	19	12.0
R Arietis	2	10.4	+24	35	8.4 *i*	U Aurigae		35.6	+31	59	10.0*d*
W Androm.		11.2	+43	50	13.8*d*	U Orionis		49.9	+20	10	12.0
Z Cephei		12.8	+81	13	13.5*d*	V Camelop.		49.4	+74	30	<13.5
o Ceti		14.3	− 3	26	5.2*d*	Z Aurigæ		53.6	+54	18	9.0
S Persei		15.7	+58	8	8.6 *i*	X Aurigae	6	4.4	+50	15	10.6*d*
R Ceti		20.9	− 0	38	13.5*d*	V Aurigae		16.5	+47	45	12.6
U Ceti		28.9	−13	35	10.0 *i*	V Monoc.		17.7	− 2	9	9.7*d*
RR Cephei		30.4	+80	42	13.6*d*	R Monoc.		33.7	+ 8	49	13.0
R Trianguli		31.0	+33	50	10 0 *i*	S Lyncis		35.9	+58	0	13.5*d*
T Arietis		42.8	+17	6	8.8	W Monoc.		47 5	− 7	2	10.4*d*
W Persei		43.2	+56	34	10.0*d*	Y Monoc.		51.3	+11	22	13.2*d*
U Arietis	3	5.5	+14	25	8.4 *i*	X Monoc.		52.4	− 8	56	8.4*d*
X Ceti		14.3	− 1	26	13.4*d*	R Lyncis		53.0	+55	28	9.3*d*
Y Persei		20.9	+43	50	10.0*d*	V Can. Min.	7	1.5	+ 9	2	12.8*d*

Approximate Magnitudes of Variable Stars on Jan. 1, 1908—Con.

Name.		R. A. 1900.	Decl. 1900.		Magn.	Name.		R.A. 1900.	Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
R Gemin.	6	1.3	+22	52	12.0*d*	U Cygni	20	16.5	+47	35	8.0 *i*
R Can. Min.		3.2	+10	11	9.6 *i*	RW Cygni		25.2	+39	39	8.6*d*
RR Monoc.		12.4	− 1	17	10.6*d*	Z Delphini		28.1	+17	7	8.5 *i*
V Gemin.		17.6	+13	17	9.0 *i*	ST Cygni		29.9	+54	38	13.2*d*
S Can Min.		27.3	+ 8	32	11.8*d*	Y Delphini		36.9	+11	31	10.8*d*
T Can. Min.		28.4	+11	58	11.0*d*	S Delphini		38.5	+16	44	10.8*d*
U Can. Min.		35.9	+ 8	37	13.5*d*	V Cygni		38.1	+47	47	11.6*d*
S Gemin.		37.0	+23	41	<13.5	Y Aquarii		39.2	− 5	12	10.4*d*
T Gemin.		43.3	+23	59	9.0 *i*	U Capricorni		42.6	−15	9	<13.5
U Puppis		56.1	−12	34	11.4	T Delphini		40.7	−16	2	13.5 *i*
R Cancri	8	11.0	+12	2	9.4*d*	W Aquarii		41.2	− 4	27	<13.5
V Cancri		16.0	+17	36	8.0 *i*	V Delphini		43.2	+18	58	<13.8
U Cancri		30.0	+19	14	12.0	T Aquarii		44.7	− 5	31	8.0*d*
X Urs. Maj.		33.7	+50	30	<12	RZ Cygni		48.5	+46	59	11.7 *i*
S Hydrae		48.4	+ 3	27	11.4 *i*	X Delphini		50.3	+17	16	13.0
W Cancri	9	4.0	+25	39	10.8	— Delphini		50.3	+17	20	9.5
Y Draconis		31.1	+78	18	13.5	R Vulpeculae		59.9	+23	26	8.6 *i*
R Leo. Min.		39.6	+34	58	8.3 *i*	X Cephei	21	3.6	+82	40	<13.5
R Leonis		42.2	+11	54	7.0 *i*	RS Aquarii		5.8	− 4	27	11.6*d*
V Leonis		54.5	+21	44	<1.15	Z Capricorni		5.0	−16	35	13.6*d*
R Urs. Maj.	10	37.6	+69	18	9.9*d*	R Equulei		8.4	+12	23	8.4 *i*
T Urs. Maj.	12	31.8	+60	2	7.0 *i*	T Cephei		8.2	+68	5	10.0*d*
RS Urs. Maj.		34.4	+59	2	12.0 *i*	RR Aquarii		9.8	− 3	19	<13
S Urs. Maj.		39.6	+61	38	8.6 *i*	X Pegasi		16.3	+14	2	9.8*d*
T Urs. Min.	13	32.6	+73	56	9.0*d*	T Capricorni		16.5	−15	35	10.4 *i*
R Can. Ven.		44.6	+40	2	8.0*d*	Y Capricorni		28.9	−14	25	<13.5
U Urs. Min.	14	15.1	+67	15	10.0*d*	S Cephei		36.5	+78	10	9.2*d*
S Bootis		19.5	+54	16	13.0 *i*	RU Cygni		37.3	+53	52	9.0
R Camelop.		25.1	+84	17	12.0 *i*	RR Pegasi		40.0	+24	33	12.2*d*
S Urs. Min.	15	33.4	+78	58	11.2*d*	V Pegasi		56.0	+ 5	38	10.0*d*
RR Herculis	16	1.5	+50	46	8.0	U Aquarii		57.9	+17	6	13.4*d*
W Herculis		31.7	+37	32	7.6 *i*	RT Pegasi		59.8	+34	38	13.4*d*
R Draconis		32.4	+66	58	12.6	T Pegasi	22	4.0	+12	3	13.5*d*
V Draconis	17	56.3	+54	53	<13.5	Y Pegasi		6.8	+13	52	<12
T Herculis	18	5.3	+31	0	9.0*d*	RS Pegasi		7.4	+14	4	9.0 *i*
W Draconis		5.4	+65	56	12.0 *i*	X Aquarii		13.2	−21	24	<13.5
X Draconis		6.8	+66	8	11.6*d*	RT Aquarii		17.7	−22	34	10.4 *i*
W Lyrae		11.5	+36	38	8.5	RV Pegasi		21.0	+29	58	12.0*d*
SV Herculis		22.3	+24	58	8.5 *i*	S Lacertae		24.6	+39	48	11.4*d*
RY Lyrae		41.2	+34	34	9.0 *i*	R Lacertae		38.8	+41	51	13.0*d*
RW Lyrae		42.1	+43	32	13.6*d*	S Aquarii		51.8	−20	53	<13.2
Z Lyrae		56.0	+34	49	11.8*d*	RW Pegasi		59.2	+14	46	8.8 *i*
RX Lyrae		50.4	+32	42	<13.5	R Pegasi	23	1.6	+10	0	11.5*d*
U Draconis	19	9.9	+67	7	13.4	V Cassiop.		7.4	+59	8	12.0*d*
U Lyrae		16.6	+37	42	9.4*d*	W Pegasi		14.8	+25	44	8.0 *i*
R Cygni		34.1	+49	58	13.4*d*	S Pegasi		15.5	+ 8	22	13.4*d*
RT Cygni		40.8	+48	32	8.4d	Z Androm.		28.8	+48	16	11.0 *i*
TU Cygni		43.3	+48	49	<13	— Androm.		33.8	+35	13	10.0 *i*
χ Cygni		46.7	+32	40	12.0 *i*	R Aquarii		38.6	−15	50	9.5
Z Cygni		58.6	+49	46	9.0 *i*	Z Cassiop.		39.7	+56	2	<13.6
S Cygni	20	3.4	+57	42	12.0 *i*	RR Cassiop.		50.7	+53	8	<13.5
S Aquilae		7.0	+15	19	9.2 *i*	Z Aquarii		47.1	−16	24	8.6
RS Cygni		9.8	+38	28	7.8	V Ceti		52.8	− 9	31	10.2 *i*
R Delphini		10.1	+ 8	47	13.2*d*	Z Pegasi		55.0	+25	21	8.6 *i*
SX Cygni		11.6	+30	46	13.8*d*	W Ceti		57.0	−15	14	9.5*d*
WX Cygni		14.8	+37	8	10.6	Y Cassiop.		58.2	+55	7	<13.5
V Sagittae		15.8	+20	47	13.0 *i*	R Cassiop.		53.3	+50	50	10.0*d*

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Vassar College, Mt. Holyoke, Whitin and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
Mar.	2	22
	5	10
	7	22
	10	10
	12	22
	15	9
	17	21
	20	9
	22	21
	25	9
	27	20
	30	8

Z Persei

Mar.	1	12
	4	14
	7	15
	10	16
	13	18
	16	19
	19	21
	22	22
	25	23
	29	0

RY Persei

Mar.	2	23
	9	19
	16	16
	23	13
	30	10

RZ Cassiop.

Mar.	2	6
	3	11
	4	15
	5	20
	7	1
	8	5
	9	10
	10	15
	11	20
	13	0
	14	5
	15	10
	16	14
	17	19
	19	0
	20	4
	21	9
	22	14
	23	18
	24	23
	26	4
	27	8
	28	13
	29	18
	30	23

RX Cephei

Mar.	27	5

Algol

	d	h
Mar.	2	12
	5	9
	8	6
	11	3
	14	0
	16	20
	19	17
	22	14
	25	11
	28	8
	31	4

RT Persei

Mar.	1	16
	2	12
	3	8
	4	5
	5	1
	5	21
	6	18
	7	14
	8	11
	9	7
	10	3
	11	0
	11	20
	12	17
	13	13
	14	9
	15	6
	16	2
	16	22
	17	19
	18	15
	19	12
	20	8
	21	4
	22	1
	22	21
	23	18
	24	14
	25	10
	26	7
	27	3
	27	23
	28	20
	29	16
	30	13
	31	9

λ Tauri

Mar.	3	11
	7	10
	11	9
	15	7
	19	6
	23	5
	27	4
	31	3

RW Tauri

	d	h
Mar.	3	4
	5	22
	8	17
	11	11
	14	6
	17	0
	19	19
	22	13
	25	8
	28	2
	30	20

RV Persei

Mar.	2	22
	4	22
	6	21
	8	20
	10	20
	12	19
	14	18
	16	18
	18	17
	20	16
	22	16
	24	15
	26	15
	28	14
	30	13

RW Persei

Mar.	9	21
	23	2

RS Cephei

Mar.	8	21
	21	7

RW Geminorum

Mar.	3	16
	6	13
	9	9
	12	6
	15	3
	18	0
	20	20
	23	17
	26	14
	29	11

RW Monoc.

Mar.	1	22
	3	20
	5	17
	7	15
	9	13
	11	11
	13	8
	15	6
	17	4
	19	2
	21	0
	22	21

RW Monoc.

	d	h
Mar.	24	19
	26	17
	28	15
	30	12

RU Monoc.

Mar.	1	14
	2	11
	3	9
	4	6
	5	4
	6	1
	6	23
	7	20
	8	18
	9	15
	10	13
	11	10
	12	8
	13	5
	14	3
	15	0
	15	22
	16	19
	17	17
	18	14
	19	12
	20	9
	21	7
	22	4
	23	2
	23	23
	24	21
	25	18
	26	16
	27	13
	28	11
	29	8
	30	6
	31	4

R Canis Maj.

Mar.	1	14
	2	17
	3	20
	4	23
	6	3
	7	6
	8	9
	9	12
	10	16
	11	19
	12	22
	14	1
	15	5
	16	8
	17	11
	18	15
	19	18

R Canis Maj.

	d	h
Mar.	20	21
	22	0
	23	4
	24	7
	25	10
	26	13
	27	17
	28	20
	29	23
	31	2

Y Camelop.

Mar.	1	3
	4	10
	7	18
	11	1
	14	8
	17	16
	20	23
	24	6
	27	14
	30	21

RR Puppis

Mar.	4	7
	10	17
	17	3
	23	14
	30	0

V Puppis

Mar.	1	21
	3	8
	4	19
	6	6
	7	17
	9	4
	10	15
	12	2
	13	13
	14	23
	16	10
	17	21
	19	8
	20	19
	22	6
	23	17
	25	4
	26	15
	28	2
	29	12
	30	23

X Carinæ

Mar.	1	17
	2	19
	3	21
	4	23
	6	1
	7	3
	8	5

Continued.

X Carinæ

	d	h
Mar.	9	7
	10	9
	11	10
	12	12
	13	14
	14	16
	15	18
	16	20
	17	22
	19	0
	20	2
	21	4
	22	6
	23	8
	24	10
	25	12
	26	14
	27	16
	28	18
	29	20
	30	22

S Cancri

Mar.	5	11
	14	23
	24	11

S Velorum

Mar.	4	18
	10	16
	16	15
	22	13
	28	11

RR Velorum

Mar.	2	8
	4	5
	6	2
	7	22
	9	19
	11	15
	13	12
	15	8
	17	5
	19	1
	20	22
	22	18
	24	15
	26	11
	28	8
	30	4

SS Carinae

Mar.	1	10
	4	17
	8	1
	11	8
	14	15
	17	22
	21	6
	24	13
	27	20
	31	3

Z Draconis

	d	h
Mar.	2	3
	3	11
	4	20
	6	5
	7	13
	8	22
	10	6
	11	15
	12	23
	14	8
	15	17
	17	1
	18	10
	19	18
	23	3
	22	12
	23	20
	25	5
	26	13
	27	21
	29	6
	30	15

RZ Centauri

Mar.	1	20
	2	18
	3	17
	4	15
	5	14
	6	12
	7	11
	8	9
	9	8
	10	6
	11	5
	12	3
	13	2
	14	0
	14	23
	15	21
	16	20
	17	18
	18	17
	19	15
	20	14
	21	13
	22	11
	23	10
	24	8
	25	7
	26	5
	27	4
	28	2
	29	1
	29	23
	30	22
	31	20

SS Centauri

Mar.	3	3
	5	14
	8	1
	10	13

SS Centauri

	d	h
Mar.	13	0
	15	12
	17	23
	20	11
	22	22
	25	10
	27	21
	30	9

δ Libræ

Mar.	1	4
	3	11
	5	19
	8	3
	10	11
	12	19
	15	3
	17	11
	19	18
	22	2
	24	10
	26	18
	29	2
	31	10

U Coronæ

Mar.	3	14
	7	0
	10	11
	13	22
	17	9
	20	20
	24	7
	27	18
	31	4

R Aræ

Mar.	2	10
	6	20
	11	6
	15	16
	20	2
	28	23

U Ophiuchi

Mar.	1	19
	2	7
	3	3
	3	23
	4	19
	5	15
	6	11
	7	7
	8	3
	9	0
	9	20
	10	16
	11	12
	12	8
	13	4
	14	0
	14	21
	15	17
	16	13

U Ophiuchi

	d	h
Mar.	17	9
	18	5
	19	1
	19	21
	20	17
	21	14
	22	10
	23	6
	24	2
	24	22
	25	18
	26	14
	27	10
	28	7
	29	3
	30	19
	31	15

Z Herculis

Mar.	4	10
	8	10
	12	10
	16	10
	20	10
	24	9
	28	9

RS Sagittarii

Mar.	3	1
	5	11
	7	21
	10	7
	12	17
	15	3
	17	13
	19	23
	22	9
	24	19
	27	5
	29	15

V Serpentis

Mar.	3	9
	6	20
	10	5
	13	18
	10	5
	13	18
	17	5
	20	16
	24	3
	27	14
	31	0

RZ Draconis
Period 13^h.2

Mar.	1	16
	2	19
	3	21
	4	23
	6	2
	7	4
	8	7
	9	9

RZ Draconis

	d	h
Mar.	10	12
	11	14
	12	17
	13	19
	14	21
	16	0
	17	2
	18	5
	19	7
	20	10
	21	12
	22	15
	23	17
	24	19
	25	22
	27	0
	28	3
	29	5
	30	8
	31	10

RX Herculis

Mar.	1	18
	2	15
	3	12
	4	10
	5	7
	6	4
	7	2
	8	20
	9	18
	10	15
	11	12
	12	10
	13	7
	14	5
	15	2
	15	23
	16	21
	17	18
	18	15
	19	13
	20	10
	21	7
	22	5
	23	2
	23	23
	24	21
	25	18
	26	15
	27	13
	28	10
	29	7
	30	5
	31	2
	31	23

SX Sagittarii

Mar.	1	8
	3	10
	5	12
	7	14

Continued.

SX Sagittarii

	d	h
Mar.	9	16
	11	18
	13	20
	15	21
	17	23
	20	1
	22	3
	24	5
	26	7
	28	8
	30	10

RR Draconis

Mar.	2	10
	5	6
	8	2
	10	22
	13	17
	16	13
	19	9
	22	5
	25	1
	27	21
	30	17

U Scuti

Mar.	1	18
	2	17
	3	16
	4	15
	5	14
	6	13
	7	12
	8	11
	9	10
	10	9

U Scuti

	d	h
Mar.	11	7
	12	6
	13	5
	14	4
	15	3
	16	2
	17	1
	18	0
	18	23
	19	22
	20	21
	21	20
	22	18
	23	17
	24	16
	25	15
	26	14
	27	13
	28	12
	29	11
	30	10
	31	9

RX Draconis

Mar.	1	10
	3	7
	5	5
	7	2
	9	0
	10	21
	12	19
	14	16
	16	14
	18	11
	20	9
	22	6

RX Draconis

	d	h
Mar.	24	3
	26	1
	27	22
	29	20
	31	17

RV Lyræ

Mar.	3	28
	7	8
	10	23
	14	13
	18	3
	21	18
	25	8
	28	23

U Sagittæ

Mar.	1	15
	5	0
	8	9
	11	18
	15	3
	18	12
	21	21
	25	7
	28	16

SY Cygni

Mar.	1	5
	7	6
	13	6
	19	6
	25	6
	31	6

WW Cygni

	d	h
Mar.	2	4
	5	12
	8	19
	12	3
	15	10
	18	18
	22	2
	25	9
	28	17

SW Cygni

Mar.	5	9
	9	23
	14	13
	19	2
	23	16
	28	6

VW Cygni

Mar.	8	10
	16	21
	25	7

UW Cygni

Mar.	1	16
	5	3
	8	14
	12	1
	15	11
	18	22
	22	9
	25	20
	29	7

W Delphini

Mar.	4	16
	9	12
	14	7

W Delphini

	d	h
Mar.	19	2
	23	22
	28	17

RR Delphini

Mar.	3	6
	7	21
	12	11
	17	1
	21	16
	26	6
	30	21

VV Cygni

Mar.	2	5
	3	16
	5	4
	6	15
	8	2
	9	14
	11	1
	12	13
	14	0
	15	12
	16	23
	18	11
	19	22
	21	9
	22	21
	25	8
	25	20
	27	7
	28	19
	30	6
	31	18

UZ Cygni

Mar.	27	21

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
Mar.	8	17
	23	12

RX Aurigæ

	(−4	0)
Mar.	12	6
	23	21

Y Aurigæ

	(−0	18)
Mar.	1	7
	5	4
	9	1
	12	21
	16	18
	20	15
	24	11
	28	8

T Monoc.

	d	h
	(−7	23)
Mar.	6	10
Apr.	2	10

W Geminorum

	(−2	22)
Mar.	7	1
	14	23
	22	21
	30	19

ζ Geminorum

	(−5	0)
Mar.	1	3
	11	7
	21	10
	31	14

RU Camelop.

	d	h
	(−9	12)
Mar.	19	21

RR Geminorum
Period 9.5^h

	(−0	2)
Mar.	2	4
	3	8
	4	13
	5	18
	6	22
	8	3
	9	8
	10	12
	11	17
	12	21
	14	2

RR Geminorum

	d	h
Mar.	15	7
	16	11
	17	16
	18	20
	20	1
	21	6
	22	10
	23	15
	24	19
	26	0
	27	5
	28	9
	29	14
	30	18
	31	23

V Carinæ

	d	h
	(−2	4)
Mar.	5	2
	11	19
	18	12
	25	4
	31	21

T Velorum

	(−1	10)
Mar.	4	19
	9	10
	14	2
	18	17
	23	8
	28	0

W Carinæ

	(−1	0)
Mar.	1	14

Continued.

W Carinæ

	d	h
Mar.	5	23
	10	8
	14	17
	19	2
	23	11
	27	20

S Muscæ

	(−3	11)
Mar.	2	13
	12	5
	21	20
	31	12

T Crucis

	(−2	2)
Mar.	2	23
	9	16
	16	10
	23	4
	29	21

R Crucis

	(−1	10)
Mar.	2	21
	8	17
	14	13
	20	9
	26	5

S Crucis

	(−1	12)
Mar.	4	0
	8	17
	13	9
	18	2
	22	18
	27	11

W Virginis

	(−8	5)
Mar.	9	11
	26	18

V Centauri

	(−1	11)
Mar.	2	6
	7	17
	13	5
	18	17
	24	5
	29	17

R Triang. Austr.

	(−1	0)
Mar.	3	8
	6	18
	10	3
	13	12
	16	22
	20	7
	23	16
	27	2
	30	11

S Triang. Austr.

	(−2	2)
Mar.	6	22
	13	6
	19	13
	25	21

S Normæ

	d	h
	(−4	10)
Mar.	2	23
	12	17
	22	11

RW Draconis.
Period 10.6^h

	(−0	3)
Mar.	1	15
	2	12
	3	9
	4	7
	5	4
	6	1
	6	22
	7	20
	8	17
	9	14
	10	11
	11	9
	12	6
	13	3
	14	1
	14	22
	15	19
	16	16
	17	14
	18	11
	19	8
	20	5
	21	3
	22	0
	22	21
	23	18
	24	16
	25	13
	26	10
	27	7
	28	5
	29	2
	29	23
	30	21
	31	18

RV Scorpii

	(−1	10)
Mar.	1	14
	7	15
	13	17
	19	18
	25	20
	31	21

RV Ophiuchi
Minimum.

Mar.	4	21
	8	13
	12	6
	15	22
	19	15
	23	7
	27	0
	30	16

X Sagittarii

	(−2	22)
Mar.	5	23

X Sagittarii

	d	h
Mar.	12	23
	20	0
	27	0

Y Ophiuchi

	(−6	5)
Mar.	6	22
	24	1

W Sagittarii

	(−3	0)
Mar.	7	7
	14	21
	22	11
	30	1

Y Sagittarii

	(−2	2)
Mar.	2	20
	8	14
	14	9
	20	4
	25	22
	30	17

U Sagittarii

	(−2	23)
Mar.	3	0
	9	17
	16	11
	23	5
	29	23

β Lyræ

	(−3	2)
	(−3	7)
Mar.	6	8
	13	0
	19	4
	25	22

κ Pavonis

	(−1	7)
Mar.	1	9
	10	11
	19	13
	28	16

U Aquilæ

	(−2	4)
Mar.	7	22
	14	23
	22	0
	29	0

XZ Cygni
Period 11.2^h

	(−0	4)
Mar.	1	18
	2	17
	3	15
	4	14
	5	12
	6	10
	7	9
	8	7
	9	6
	10	4
	11	2
	12	1
	12	23
	13	22

XZ Cygni

	d	h
Mar.	14	20
	15	18
	16	17
	18	14
	19	12
	20	10
	21	9
	22	7
	23	6
	24	4
	25	2
	26	1
	26	23
	27	22
	28	20
	29	18
	30	17
	31	15

U Vulpeculæ

	(−2	3)
Mar.	5	18
	13	18
	21	17
	29	17

SU Cygni

	(−1	7)
Mar.	1	7
	5	3
	9	0
	12	20
	16	16
	20	12
	24	9
	28	5

η Aquilæ

	(−2	6)
Mar.	5	8
	12	13
	19	17
	26	21

S Sagittæ

	(−3	10)
Mar.	2	18
	11	3
	19	12
	27	22

X Vulpeculæ

	(−2	1)
Mar.	6	13
	12	20
	19	4
	25	12
	31	19

X Cygni

	(−6	19)
Mar.	5	19
	22	4

T Vulpeculae

	(−1	10)
Mar.	5	10
	9	20
	14	17
	18	17

T Vulpeculae

	d	h
Mar.	23	3
	27	14

WZ Cygni
Minimum
Period 14^h

Mar.	1	16
	2	20
	4	0
	5	4
	6	8
	7	12
	8	16
	9	20
	11	0
	12	4
	13	8
	14	12
	15	16
	16	20
	18	0
	19	4
	20	8
	21	12
	22	16
	23	21
	25	1
	26	5
	27	9
	28	13
	29	17
	30	21

RV Capricorni
Period 10.7^h

Mar.	1	15
	2	13
	3	10
	4	8
	5	5
	6	3
	7	0
	7	22
	8	19
	9	17
	10	14
	11	12
	12	9
	13	7
	14	4
	15	2
	15	23
	16	21
	17	18
	18	15
	19	13
	20	10
	21	8
	22	5
	23	3
	24	0
	24	22
	25	19
	26	17

Continued.

RV Capricorni			RV Capricorni			VY Cygni			VZ Cygni			VZ Cygni		
	d	h		d	h		d	h		d	h		d	h
Mar.	27	14	Mar.	31	4		(—2	14)		(—2	12)	Mar.	17	8
	28	12				Mar.	4	16		(—8	6)		22	2
			TX Cygni				12	13	Mar.	2	15		27	2
	29	9	Mar.	13	20		20	9		7	15		31	19
	30	7		28	14		28	6		12	8	Apr.	5	19

Nomenclature of Recently Discovered Variable Stars.

Provis. Notation A. N.	Name	Position for 1900.0 R. A.			Decl.		Prec. 1900 R. A.	Decl.
		h	m	s	°	′	s	′
64.1905	SS Cassiopeiae	0	4	24	+51	0.6	+3.10	+0.33
65.1905	ST Cassiopeiae	0	12	14	49	43.9	3.16	0.33
5.1907	SW Andromedae	0	18	29	+28	50.8	3.13	0.33
—	U Tucanae	0	54	9	—75	32.4	1.86	0.32
156.1906	RZ Persei	1	23	35	+50	20.3	3.65	0.31
51.1907	SX Andromedae	1	27	34	46	0.4	3.59	0.31
33.1907	SS Persei	1	49	34	49	59.6	3.80	0.30
120.1906	RY Persei	2	38	59	47	43.3	4.01	0.26
155.1906	ST Cassiopeiae	2	43	3	68	28.5	5.28	0.25
7.1907	RV Camelopardalis	4	22	24	57	11.5	4.96	0.14
27.1907	RY Aurigae	5	11	32	+38	13.1	4.10	0.07
—	T Pictoris	5	12	19	—47	1.8	1.67	+0.07
24.1907	RW Monocerotis	6	29	18	+ 8	54.2	3.28	—0.04
3.1902	RV Monocerotis	6	53	0	6	18.0	3.22	0.08
2.1907	RU Camelopardalis	7	10	54	69	51.2	6.54	0.10
66.1907	X Leonis	9	45	40	+12	20.3	3.23	0.28
158.1906	ST Carinae	10	12	30	—59	42.9	2.04	0.30
42.1906	S Sextantis	40	29	49	+ 0	10.5	3.07	0.31
169.1906	ST Centauri	11	5	29	—51	56.8	2.67	0.32
170.1906	SU Centauri	11	6	34	47	18.0	2.74	0.33
177.1906	SV Centauri	11	43	5	60	0.5	2.90	0.33
180.1906	W Crucis	12	6	42	58	13.6	3.14	0.33
182.1906	SW Centauri	12	12	30	49	10.6	3.16	0.33
183.1906	SX Centauri	12	15	52	—48	39.4	3.18	0.33
54.1906	RV Draconis	12	33	11	+66	8.7	2.64	0.33
186.1906	X Crucis	12	40	32	—58	34.6	3·46	0.33
10.1907	RY Draconis	12	52	30	+66	32.2	2.37	0.33
141.1906	RZ Centauri	12	55	37	64	5.4	3.73	0.32
149.1906	SS Centauri	13	7	9	63	37.1	3.85	0.32
11.1907	TT Centauri	13	13.2		60	15	3.81	0.32
153.1906	U Muscae	13	18	16	64	8.4	4.00	0.31
190.1906	SY Centauri	13	35	3	61	15.8	4.05	0.31
191.1906	SZ Centauri	13	43	51	58	0.2	4.01	0.30
12.1907	ST Virginis	14	22	31	+ 0	27.1	3.07	0.27
13.1907	TU Centauri	14	28	4	—31	14.9	3.56	0.27
14.1907	RS Bootis	14	29	16	+32	11.4	2.56	0.27
86.1906	RR Bootis	14	43	15	+39	43.7	2.35	0.25
69.1905	X Lupi	14	46	45	—46	12.4	4.00	0.25
15.1907	Y Lupi	14	52.3		—54	33	4.35	0.24
67.1907	RT Bootis	15	13	22	+36	43.5	2.33	0.22
16.1907	Y Coronae	15	43	4	38	33.9	2.19	0.19
17.1907	Z Coronae	15	52.2		29	32	2.43	0.18
87.1906	RW Draconis	16	33	43	+58	2.6	1.08	0.12
50.1907	SS Ophiuchi	16	52	40	— 2	36	3.13	0.10
3.1907	SW Herculis	16	54	11	+21	42	2.56	0.09
52.1907	ST Ophiuchi	17	28	50	— 1	0.4	3.09	0.04
53.1907	SU Ophiuchi	17	34	22	+ 1	39.8	3.03	0.04
54.1907	SV Ophiuchi	17	51	25	+ 3	24.1	2.99	—0.01
55.1907	W Serpentis	18	4	6	—15	34.0	+3.44	+0.01

Provis. Notation A. N.	Name	Position for 1900.0 R. A.			Decl.		Prec. 1900 R. A.	Decl.
		h	m	s	°	′	s	′
56.1907	W Scuti	18	18	54	—13	42.5	3.40	0.03
26.1907	RZ Draconis	18	21	49	+58	50.1	0.87	0.03
57.1907	X Scuti	18	25	41	—13	10.8	3.38	0.04
58.1907	Y Scuti	18	32	36	— 8	27.2	3.27	0.05
30.1904	SY Lyrae	18	37	33	+28	43.2	2.35	0.05
61.1907	Z Scuti	18	37	36	— 5	55.1	3.21	0.05
63 1907	SZ Aquilae	18	59	35	+ 1	9.4	3.05	0.09
4.1907	Y Vulpeculae	19	0	8	24	38.3	2.48	0.09
121.1906	RX Draconis	19	1	8	58	35.2	0.96	0.09
64.1907	TT Aquilae	19	3	9	1	8.5	3.05	0.09
—	AA Cygni	20	0	46	36	32.0	2.22	0.17
193.1906	ZZ Cygni	20	20	40	46	35.7	1.92	0.19
20.1907	RS Delphini	20	24	33	15	56.5	2.76	0.20
33.1904	YZ Cygni	20	58	55	+40	53.5	2.25	0.24
48.1907	RV Aquarii	21	0	44	— 0	36.6	3.08	0.24
70.1905	RX Pegasi	21	51	44	+22	23.2	2.78	0.28
50.1906	RY Pegasi	22	1	27	33	1.2	2.64	0.29
51.1906	RZ Pegasi	22	1	29	33	1.3	2.64	0.29
23.1907	Y Lacertae	22	5	13	50	33.3	2.29	0.29
88.1906	X Lacertae	22	44	58	55	54.0	2.44	0.32
65.1907	SW Cassiopeiae	23	2	53	58	1.0	2.54	0.32
52.1906	ST Andromedae	23	43	47	35	12.5	2.96	0.33
194.1906	SV Cassiopeiae	23	34	12	51	42.5	2.88	0.33
1.1907	SV Andromedae	23	59	14	39	33.1	3.07	0 33
53.1906	SU Andromedae	23	59	28	42	59.7	3.07	0.33
154.1906	Nova Velorum	10	58	20	+53	50.9	+2.59	+0.32

Nomenclature of Recently Discovered Variable Stars—Continued

Provis. Notation A. N.	Name	Chart Place R. A.			Decl.		Magnitude Max.	Min.
		h	m	s	°	′	m	m
64.1905	SS Cassiopeiae	0	2	5	+50	45.6	9	12 v
65.1905	ST Cassiopeiae	0	9	53	49	28.9	7.5	9.0 ph
5.1907	SW Andromedae	0	16	8	+28	35.8	8.7	9.9 ph
—	U Tucanae	0	53	22	−75	40.5	9.1	13.0 ph
156.1906	RZ Persei	1	20	51	+50	6.3	8.5	9.7 v
51.1907	SX Andromedae	1	24	53	45	46.3	9.2	<11.5 ph
33.1907	SS Persei	1	46	44	49	46.1	10.7	11.2 ph
120.1906	RY Persei	2	35	58	47	31.7	8.0	10.3 v
155.1906	SU Cassiopeiae	2	39	7	68	17.0	5.9	6.3 v
7.1907	MV Camelopardalis	4	18	41	57	5.1	7.8	9.5 ph
27.1907	RY Aurigae	5	8	28	38	9.8	10.7	11.7 v
—	T Pictoris	5	11	37	—47	3.5	8.4	12.4 ph
24.1907	RW Monocerotis	6	26	50	+ 8	56.0	9.0	10.8 v
3.1902	RV Monocerotis	6	50	35	6	21.4	7	8 v
2.1907	RU Camelopardalis	7	5	59	69	55.6	8.5	9.8 ph
66.1907	X Leonis	9	43	14	+12	32.8	11.5	13.5 ph
158.1906	ST Carinae	10	11	39	—55	35.5	9.2	10.3 ph
42.1906	S Sextantis	10	27	31	+ 0	24.4	8.9	10.5 ph
169.1906	ST Centauri	11	4	23	—51	48.7	9.8	10.7 ph
170.1906	SU Centauri	11	5	26	47	9.9	8.7	9.6 ph
177.1906	SV Centauri	11	41	53	59	52.2	8.8	9.8 ph
180.1906	W Crucis	12	5	24	58	5.3	8.7	9.3 ph
182.1906	SW Centauri	12	11	11	49	2.3	8.8	11.4 ph
183 1906	SX Centauri	12	14	33	—48	31.1	8.3	10.2 ph
54.1906	RV Draconis	12	31	12	+66	23.6	9.7	<12.5 ph
186.1906	X Crucis	12	39	6	—58	26.4	8.5	9.0 ph
10.1907	RY Draconis	12	50	43	+66	46.8	6.1	7.0 v
141.1906	RZ Centauri	12	54	5	−63	57.2	8.5	8.9 ph
149.1906	SS Centauri	13	5	33	—63	29.1	8.8	10.4 ph

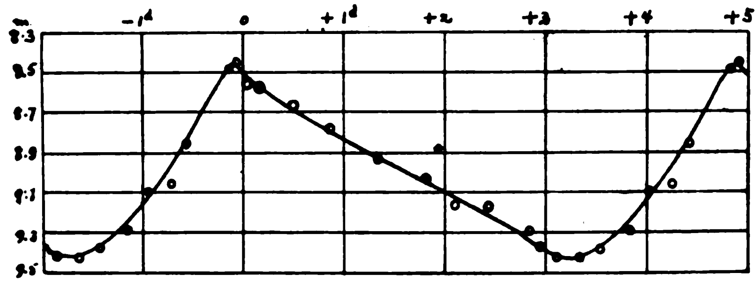
Provis. Notation A. N.	Name	Chart Place R. A.			Decl.		Magnitude Max.	Min.
		h	m	s	°	′	m	m
11.1907	TT Centauri	13	11.6		−60	7	10.5	13.5 ph
153.1906	U Muscae	13	16	36	64	0.5	10.5	<14.0 ph
190.1906	SY Centauri	13	33	22	61	8.1	9.8	10.8 ph
191.1906	SZ Centauri	13	42	11	57	52.7	8.0	8.9 ph
12.1907	ST Virginis	14	20	12	0	14.9	9.1	<10.5 ph
13.1007	TU Centauri	14	26	35	−31	8.2	9.0	14.0 ph
14.1907	RS Bootis	14	27	21	+32	23.4	8.9	10.0 ph
86.1906	RR Bootis	14	41	29	+39	55.1	8.9	<12 v
69.1905	X Lupi	14	45	5	−46	6.1	10.4	12.8 ph
15 1907	V Lupi	14	50.5		−54	27	8.5	13.5 ph
67.1907	RT Bootis	15	11	37	+36	53.5	9	<11 v
16.1907	Y Coronae	15	41	25	38	42.4	8.5	10.5 ph
17.1007	Z Coronae	15	50.4		29	40	8.0	<11.0 —
87.1906	RW Draconis	16	32	55	+58	8.1	9.6	10.8 ph
50.1907	SS Ophiuchi	16	50	19	− 2	32	8.1	12 v
3.1907	SW Herculis	16	52	16	+21	46.3	12.5	14.5 ph
52.1907	ST Ophiuchi	17	26	31	− 0	58.3	10.0	11.1 ph
53.1907	SU Ophiuchi	17	32	6	+ 1	41.5	10.0	11.0 ph
54.1907	SV Ophiuchi	17	49	10	+ 3	24.7	9.7	<12.0 ph
55.1907	W Serpentis	18	1	31	−15	34.2	8.5	10.0 ph
56.1907	W Scuti	18	16	21	−13	43.7	9.3	10.4 ph
26.1907	RZ Draconis	18	21	10	+48	48.6	9.5	10.2 ph
57.1997	X Scuti	18	23	9	−13	12.4	9.5	11.0 ph
58.1907	Y Scuti	18	30	9	− 8	29.3	8.9	10.2 ph
30.1904	SY Lyrae	18	35	47	+28	40.8	10.2	11.0 ph
61.1907	Z Scuti	18	35	12	− 5	57.5	9.0	10.3 ph
63.1907	SZ Aquilae	18	57	18	+ 1	5.6	8.8	10.5 ph
4.1907	Y Vulpeculae	18	58	17	24	34.5	13.5	14.5 ph
121.1906	RX Draconis	19	0	25	58	31.3	9.3	10.2 v
64.1907	TT Aquilae	19	0	52	1	4.5	7.6	9.0 ph
—	AA Cygni	19	59	6	36	24.5	8.0	9.2 v
193.1906	ZZ Cygni	20	19	14	46	27.1	10.4	11.5 v
20.1907	RS Delphini	20	22	28	15	47.6	8.9	9·8 ph
33.1904	YZ Cygni	20	57	13	+40	42.9	—	— —
48.1907	RV Aquarii	20	58	25	− 0	47.2	8.5	<12 v
70.1905	RX Pegasi	21	49	39	+22	10.5	8.1	9.4 ph
50.1906	RY Pegasi	21	59	28	32	48.1	10.0	10.6 ph
51.1906	RZ Pegasi	21	59	30	32	48.2	10.0	12.4 ph
23.1907	Y Lacertae	22	3	30	50	20.1	8.5	9.2 v
88.1906	X Lacertae	22	43	9	55	39.8	8.2	8.6 v
65.1907	SW Cassiopeiae	23	0	59	58	46.4	9.2	10.2 ph
52.1906	ST Andromedae	23	31	33	34	57.6	8.2	<10.5 ph
194.1906	SV Cassiopeiae	23	32	2	51	27.6	7	< 9.5 v
1.1907	ST Andromedae	23	56	56	39	18.1	9	<12.5 ph
53.1906	SU Andromedae	23	57	10	+42	44.6	8.3	9.8 ph
154.1906	Nova Velorum	10	57	15	−53	42.9	—	— —

New Variable Star 178.1907 Tauri.—This was discovered by Rev. Joel H. Metcalf of Taunton, Massachusetts, on a photograph taken November 11, with two exposures of 47 and 40 minutes respectively. The plate was moved during the exposure so that the star images are lengthened out into trails. Toward the last part of the first exposure the star shows a slight increase in brilliancy and during the second exposure it increased about 0.6 magnitude. The position of the variable is approximately

1900 R. A. 3^h 31^m $24.^s1$ Decl. + 5° 2.′5

The nearest BD star is + 4° 560 from which it is (north following) + $12.^s4$ in R. A. and + 0.′7 in Decl. Its magnitude is 11-12.

Variable Star V Lacertæ 110.1904.—In the Bulletin No. 13 of the Laws Observatory Mr. Seares gives observations of this variable extending through the interval June 30, 1904 to August 11, 1907 and derives new elements as follows:



LIGHT CURVE OF V LACERTÆ 110.1904.

Maximum = J. D. 2416666.76 + $4.^d98269$ E, (Gr. M. T.).

The light curve shows a sharp maximum with slow descent and rapid rise.

Variable Star X Lacertæ (88.1906).—In Bulletin No. 13 of the Laws Observatory Mr. Seares gives the following new elements of this variable star, depending upon a long series of photometric observations during the period September 7, 1906 to August 11, 1907.

Minimum = J. D. 2416672.45 + $5.^d44269$ E (Gr. M. T.).

New Variable Star 179.1907 Cassiopeiæ.—This is announced in *A. N.* 4222 by Professor W. Ceraski as discovered by M. S. Blajko upon his photographs taken at the Moscow Observatory. Its position is

$\alpha = 0^h\ 44^m\ 32^s \qquad \delta = +46^\circ\ 41.'4$ (1855.0).

$ = 0\ \ 47\ \ 03 \qquad = \ \ 46\ \ 56.1$ (1900.0)

About 0.'5 north of this there is a star of about magnitude 12. From the study of 25 plates it appears that the variable changes from 10.5 to 11.2 magnitude and that its period is short.

New Variable 180.1907 Aurigæ. In *A. N.* 4222 Mr. L. Pračka, of Bamberg, calls attention to the star BD 46° 1088 which appears to vary between the magnitudes 8.9 and 9.6 in a period of from 18 to 28 days. The position of the star is

$\alpha = 5^h\ 52^m\ 46.^s6 \qquad \delta = +46^\circ\ 27.'0$ (1855.0)

$ = 5\ \ 56\ \ 08.1 \qquad +46\ \ 27.4$ (1900.0).

New Variable Star 181.1907 Aurigæ.—This is announced by Professor W. Ceraski in *A. N.* 4225 as discovered by Mme. L. Ceraski upon the Moscow photographs. It appears to vary between the magnitudes 11 and 12.5 or fainter. Its position is

$\alpha = 4^h\ 29.^m8 \qquad \delta = +31^\circ\ 03'$ (1855.0)

$ = 4\ \ 32\ 0 \qquad +31\ \ 09$ (1900.0)

Variable Star Notes.

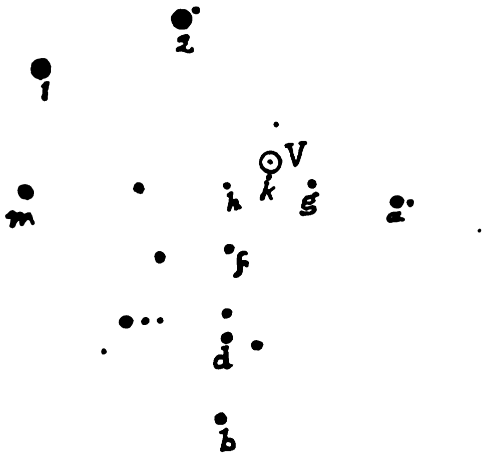
MIRA *o* CETI.

The unusually bright maximum of this star in the end of 1906 was not equalled this year as the highest range was but little beyond the lustre of Gamma Ceti of 3.4 magnitude. Its customary uneven increase and decrease are noticeable in the following record.

1907 Aug.	19	8.8	magnitude.
Sept.	5	8.3	"
	12	7.5	"
	18	7.2	"
	28	7.0	Nearly equal to 71 Ceti.
Oct.	7		At low altitude, visible to naked eye. Equal to Nu Ceti.
	28		About .2 brighter than Gamma Ceti, but half a magnitude less than Alpha Ceti.
Nov.	1, 3, 7, 19, 24.		Equal to Gamma; less than Alpha: brighter than Delta.
	29		Less than Gamma; brighter than Delta.
Dec.	7		Equal to Delta, but in opera glass seems brighter than that star. Brighter than Nu Piscium.
	12		About .2 dimmer than Delta.

V CASSIOPEIÆ.

This variable may be found about half a degree northeast of the sixth magnitude star numbered 2 in Flamsteed's catalogue. A recent maximum, in which it attained to nearly seventh magnitude was observed as follows:



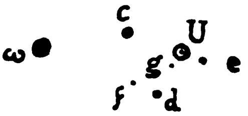
VICINITY OF V CASSIOPEIÆ.

1907 Aug.	9	Equal to f.
	25	Equal to a and to b.
Sept.	1	Brighter than a or b. Less than m.
	4, 12, 15	The same.
	23	Slightly brighter than a or b.
	27, 29	Distinctly brighter than a or b.
Oct.	3, 7	The same.
	14	Equal to a and b.
	28	Less than b. Equal to f.
Nov.	2	Less than f. Equal to g.
	9, 21	Dimmer than g. Equal to n.

Some maxima of two other variables in this constellation were also observed as follows:

U Cassiopeiæ.

1906	Aug.	12	Equal to g.
		19	Brighter than g; less than e.
	Sept.	16	Brighter than d; equal to c.
		26	Brighter than e or d; less than c.
		29	Nearer to c than to d.
	Oct.	3	Midway between c and d.
		6	Nearer to d than to c.
		7, 12	The same.



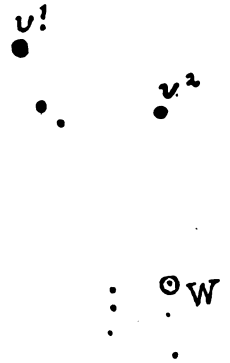
Vicinity of U Cassiopeiæ.

	Nov.	4, 11	Equal to d; brighter than e.
		14	Equal to e; less than d.
		20	Between d and e.
1907	Aug.	8	Brighter than g; less than d: equal to e.
		25	It seems equal to e and to g. Altitude low.
	Sept.	1	Less than e or g.
		4	Invisible. Night dim.

During the following three months, including some nights of more than ordinary clearness, 19 observations were taken of the vicinity of the variable but it was not discernible in a four-inch lens. As shown in the chart, it is adjacent to the star of fifth magnitude, Omicron Cassiopeiæ.

W Cassiopeiæ.

1905	May	27	Between a and c; brighter than d. Morning very clear.
	June	26	Between a and c.
	July	6	The same.
	Sept.	17	Equal to n; Less than d.
		24	The same.
	Oct.	15	Between d and n.
		23, 26	Equal to n, less than e or f.
	Nov.	3	The same.
		14	Between n and k.
		28, 20, 30	The same.
	Dec.	3	Dimmer than n or k.
1906	Aug.	12, 19	Equal to c.
	Sept.	16, 26	Equal to d; less than c.
	Oct.	3, 6, 12	Equal to d; brighter than n.
	Nov.	4. 20	Less than e or F. Equal to n.
1907	Aug.	8, 25	Brighter than d or c; less than a.
	Sept.	1, 4, 12	The same.
		15	Equal to a.
		23	Less than a, brighter than c.
	Sept.	29	Slightly brighter than c or d. Night clear.



VICINITY OF W CASSIOPEIÆ.

Oct.	2, 7, 14	Equals d brighter than e.
	28, 30	Less than than d. Equals e.
Nov.	2, 7, 21	The same.
	24	Less than e.

The coördinates of this variable are:
R. A. $0^h\ 48^m\ 59^s$ Decl. + 58° 09′.

ROSE O'HALLORAN

San Francisco,
December 14, 1907.

GENERAL NOTES.

β 208 in Periastron. Please call attention to the periastron passage of β 208, which will occur early in 1908. The orbit is highly inclined and very eccentric like that of γ Andromedæ B. C., and the angle will soon change by 180°. The minimum distance will not exceed 0.″05, and it will probably be beyond the reach of any telescope in the world, but it will soon widen out again. Observations are needed just before and just after periastron passage. The orbit will then be accurately defined, while if this opportunity is neglected another will not recur for almost forty years.

T. J. J. SEE.

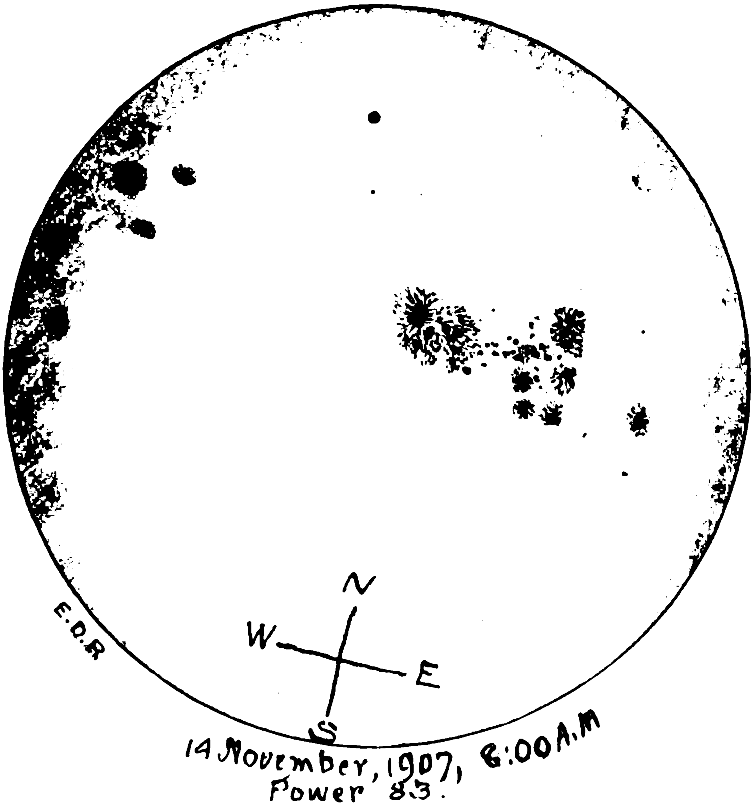
Naval Observatory.
Mare Island, California.

Bulletins of Harvard College Observatory. On page 517 of the October number of POPULAR ASTRONOMY, is given a list of different Observatory publications, prepared by Mr. Severance. Permit me to correct the list of publications credited to this observatory. The Report of the Henry Draper Memorial has been discontinued. The present publications of the observatory are:—

Annals
Annual Report of the Director
Bulletins
Circulars.

EDWARD C. PICKERING.

Sun Observations at Syracuse University. Though the morning of November 14 was somewhat cloudy here, the Transit of Mercury was visible most of the time after 7:45 A. M. to near its finish. I watched the planet until it was within about five seconds of arc of third contact. The time of third and fourth contacts could not be accurately noted as clouds prevented. During the observation I had time to make a careful and deliberate drawing of all that was to be seen on the Sun's disk. Mercury is shown in transit as a solitary black disk slightly west of north. The drawing also shows the great sun-spot and several others. The objects on the Sun's disk are shown in approximate position on the disk as they individually appeared magnified 83 times, but the disk of the Sun is not magnified on the same scale.



E. D. Roe, Jr.

Syracuse University,
November 8, 1907.

Disappearance of Saturn's Rings Seen at Chabot Observatory—Merely to confirm reports you will probably receive, I write to say that Saturn's ring is an easy object in the 8-inch Clark equatorial of this observatory.

When the ring disappeared in the early part of October, I believed, of course, that it would remain completely invisible until January following, and took no interest in it except the novelty of seeing Saturn without the ring. My surprise was very great then, when on Oct. 29th, the ring flashed out distinctly as a row of dots, again as a broken line, and then as a very fine but continuous line.

I made careful notes and watched carefully on succeeding nights, and soon found that I could see the ring any time when the seeing permitted the belts to be well seen. In fact, the ring could be rather more easily seen than any but the most prominent belts. Several visitors saw it without trouble. One evening when a satellite was apparently in the middle of the fine line, a visitor described it as "a piece of string with a knot in it."

The intervals when it can be distinctly seen vary from (say) a tenth of a second to two seconds.

CHARLES BURCKHALTER.

Chabot Observatory,
Oakland, Cal.,
Dec. 16, 1907.

Observations of the Transit of Mercury were made at the Harvard College Observatory this morning, under favorable atmospheric conditions. The observed times of third and fourth contact are given below in Greenwich mean time:

Date	Third Contact			Fourth Contact			Instrument	Observer
1907	h	m	s	h	m	s		
Nov. 14,	1	48	16	1	50	47	15-in. Equatorial	O. C. Wendell
	1	48	16	1	50	26	6-in. Equatorial	L. Campbell
	1	48	9	1	50	37	5-in. Clacey	W.H.Pickering
	1	48	11	1	50	30	4-in. Caswell	J. R. Edmonds

Twenty-three photographs were obtained by Mr. E. S. King, with the 11-inch Draper Telescope.

EDWARD C. PICKERING.

Transit of Mercury, Nov. 13-14, 1907—The transit of Mercury was observed with the 12 in. equatorial stopped down to 8 in. with polarizing eyepiece magnifying 144 diameters. Clouds covered the Sun during most of the passage but broke at time of contacts which were recorded by chronograph as follows-

Seeing bad. Longitude E, $2^h\ 21^m\ 52^s.7$
I Contact G. M. T. $22^h\ 24^m\ 2.^s5$ (5^s late)
II " (Geometrical) 22 25 41.1
III " " 1 47 44.7
IV " 1 49 51.1

The black drop was noted for 7 seconds after II contact and before III contact. The sun's limb was very unsteady so that the internal contacts are probably the more accurate.

ALFRED H. JOY.

Syrian Protestant College Observatory,
Beirut, Syria.

A Bright Meteor—Thinking that it might possibly interest you, I am writing this to tell you that I observed a meteor of considerable brightness yesterday. It was 5:45 p. m. (This was the time by my watch, and as I was in some doubt as to the exactness of its running, I called up the telephone office a few minutes later, and found that the watch was correct according to their time, which is considered quite accurate.) I was in the yard and was stooping to pick up some object, when I noticed that it became light about me, and faint shadows were moving past me. I looked to the North and saw a meteor which then had come into view past the corner of a building. It moved quite slowly and thus gave me time to make my observations with some leisure. I should say that it appeared to have an elevation of 20 degrees, moved eastward and disappeared at an elevation of, I judged, five degrees; but am inclined to think that was too low an estimate, and should think seven or eight degrees possible. I have not the means of making sure instrumentally; but could get the elevation of its disappearance accurately to one degree, with a transit. It was, as stated, bright enough to cast shadows of trees and fenceposts; but decreased in brightness as it moved on. There were at least three periods at which it gave off a considerable shower of sparks; and its disappearance took place in the midst of such a shower. In this last action the sparks flew in all directions in considerable numbers. I noted well the point at which it disappeared; and have this morning made measurements and find the angle to be about 59 degrees east of north. On the map this would be somewhere in line with New Richmond, Barron, Butternut, and Mercer, Wis., and Gogebic, Brotherton, Boraga, and Keeweenaw Bay, Mich. I hardly suppose this is of any importance, except as reports might come in from other points. I suspect that no large fragments reached earth. It probably was pretty well dissipated before it could fall. Still, as it was an unusually large meteor, or bright one, (the largest but one that I have seen), possibly it may have left some trace somewhere in the way of fragments. I saw it through an arc of at least 55 degrees in its motion. How long it took it to make this distance I can not say. I had time to shift my position gradually so as to keep it directly over a post which I fixed on as a point of reference.

A. A. VEBLEN.

Stillwater, Minnesota.
Nov. 24, 1907.

Mars as the Abode of Life is the title of a carefully written paper in the November *Century Magazine* by Dr. Percival Lowell. This is the first paper of a series on "Mars as the Abode of Life," which is being prepared by Mr. Lowell. The particular theme of this paper is "The Genesis of a World," its origin, the typical meteorite, its history and meaning in world genesis, the various stages of crust formation in planet growth until advanced age ensues.

The cataclasm of which the author speaks in the early processes of world formation, is pretty strongly emphasized, as if it might be the only, or the main way, in which world existence begins. We do not think Mr. Lowell means to convey that impression, but probably, only to say that this appears to be one method in which planet life begins in its early history.

Mr. Lowell has set this introductory part in popular phrase easily to be understood, though embracing a wide range of scientific thought well related to the theme in hand.

The article is finely and fully illustrated, and, as a whole, will lead its readers to expect more with increasing interest as the series goes on. This ought to be so for no other astronomer living has studied the planet Mars more thoroughly or caused it to be studied more favorably by others than has Mr. Lowell. Astronomy owes him much for his long, earnest and patient work for the science.

Photographic Chart of the Sky—We have recently received two fasciculi of prints from the chart plates taken at the observatory of Tacubaya, Mexico. These charts are beautifully printed by the heliogravure process upon heavy plate paper, which ought to be very durable. The star images are black and distinct, each image being triple, the result of three half-hour exposures. The components of the triple image of stars brighter than the tenth magnitude encroach upon each other but in those of the eleventh magnitude and fainter the components of the image are separated so that quite accurate positions could be measured from the prints. The faintest stars shown are of the fourteenth magnitude as indicated by a scale of magnitude printed upon the margin of the chart.

The *reseau* or reticle which was imprinted upon the original plate before its development has very distinct sharp lines. In the reproduction the squares are approximately one centimeter on a side, and the scale of the prints is noted as 1′ in declination=2 millimeters, and 1^m in right ascension=28.8 millimeters at the center of the plate. All of these charts are in the zone having as its center—16° of declination. The charts are 8^m apart in right ascension and are numbered successively in the order of right ascension. Some of the numbers are missing and will we suppose be supplied later. The numbers now at hand are: 1, 3, 9, 10, 11, 12, 13, 14, 17, 23, 24, 30, 32, 33, 34, 35, 36, 37, 38, 39, 40, 43, 44.

These charts in this way made accessible to astronomers in general will certainly be of very great value, their form is convenient for use and it seems as if doubt of the preservation of the star images was largely removed by this process.

The photographs were taken under the direction of Mr. Felipe Valle, Director of the Observatory of Tacubaya, and the printing was done by L. Schutzenberger, Paris.

Dr. Charles. A. Young, Hanover, N. H., departed this life Jan. 2, 1908. His many friends the world over, will feel the loss in the rank of great astronomers keenly. A biographical sketch of this great scholar will appear in this journal soon.

Dr. T. D. Simonton, of St. Paul, was known to many of the readers of this magazine who will regret his death which occurred late in December. Fuller notice of his interest and work in astronomy will be given later.

Jupiter's Satellites VI and VII. These diagrams are a graphical representation of the observations of Jupiter's Satellites VI and VII from photographs taken at the Royal Observatory with the 30-inch Reflector during the oppositions of 1905-6 and 1906-7, printed in the MONTHLY NOTICES vol. lxvi. p. 438 and vol. lxvii. p. 479.

During the 1905-6 opposition eighty-six photographs of J. VI were secured on thirty-six nights from 1905 August 23 to 1906 February 15—a period of 177 days. Of J. VII nineteen photographs were secured on fifteen nights from 1905 October 22 to 1906 January 26—a period of 97 days.

The opposition 1906-7 was not so favorable as regards weather conditions, but fifty-six photographs of J. VI were obtained on twenty-eight nights over a period of 222 days, and twelve photographs of J. VII on seven nights over a period of 87 days.

The positions plotted in the diagrams are the mean when more than one photograph was taken on any night. The curves were drawn through these points, but in the case of 1906-7 observations of J. VII the curve is continued beyond the observations to indicate the apparent form.

For comparison, the orbits of the four larger satellites are shown, the major axes being plotted to scale, but the minor axes intentionally exaggerated.

ASTRONOMER ROYAL.

From MONTHLY NOTICES, LXVII, No. 9.

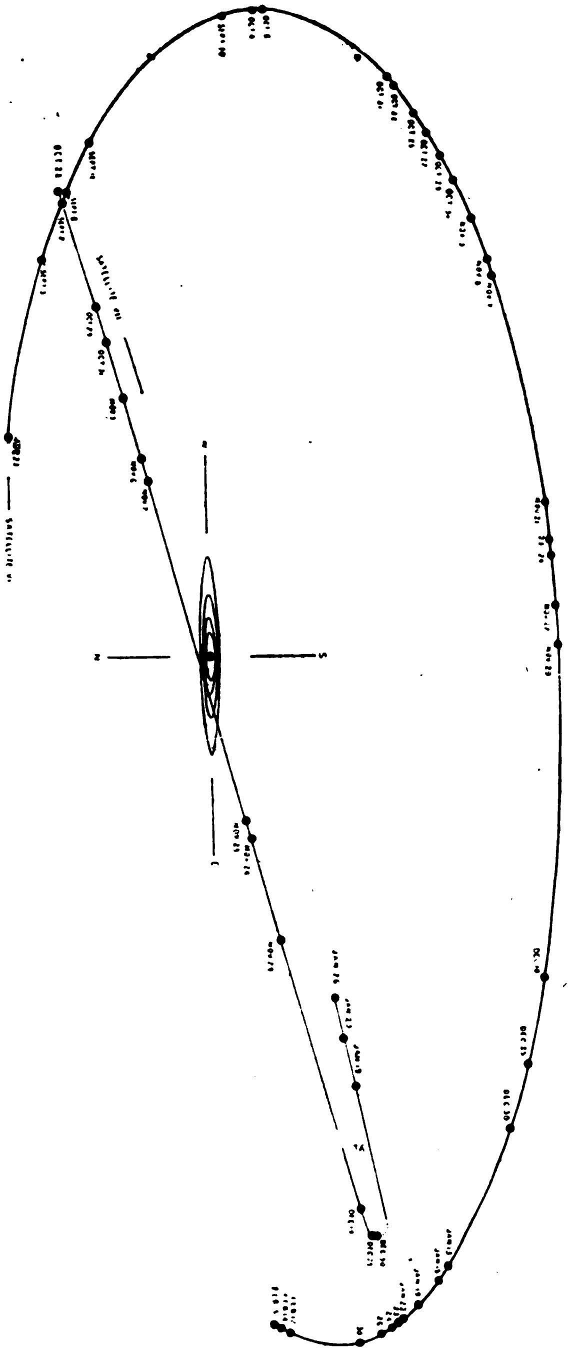


Diagram showing the positions of Jupiter's Satellites VI. and VII., from photographs taken at the Royal Observatory, Greenwich, during the Opposition 1905-6.

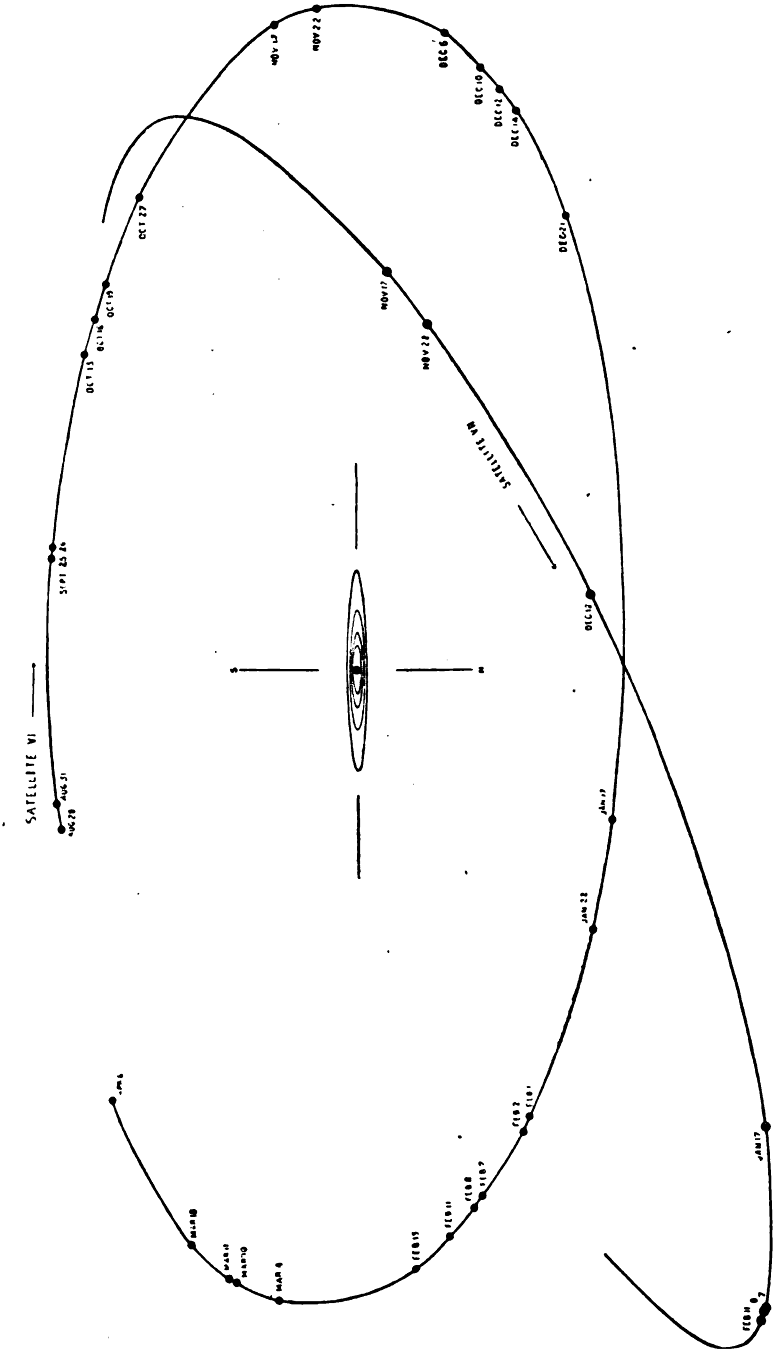
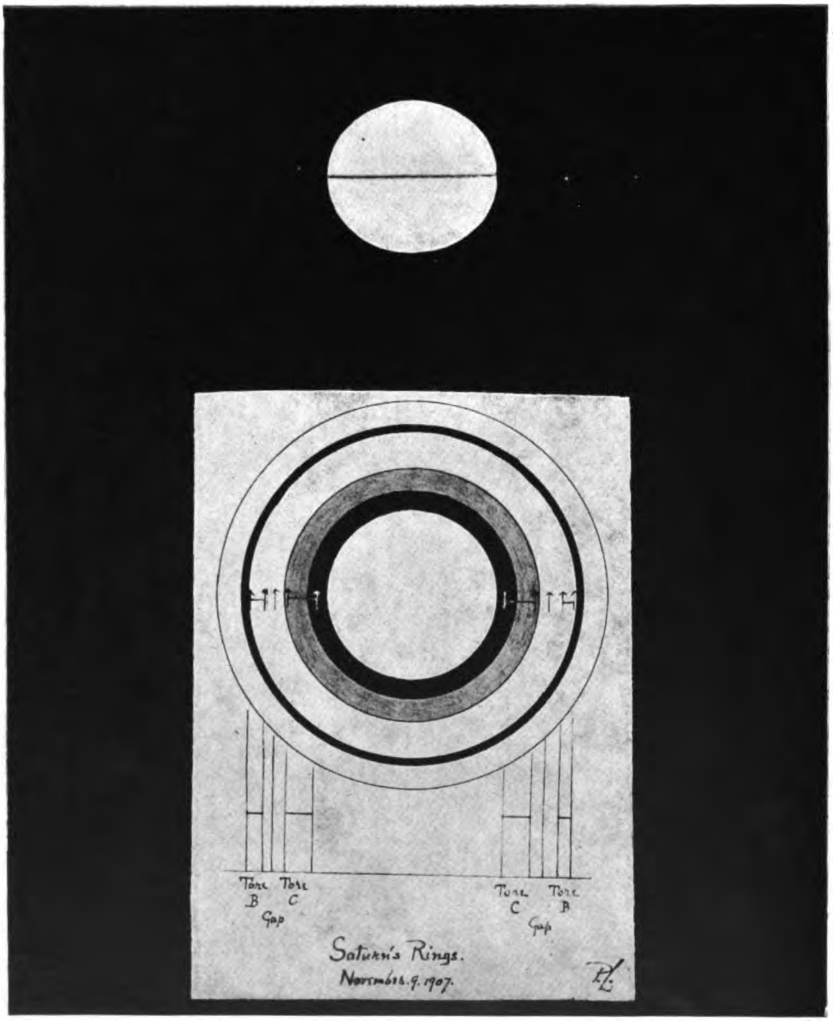


Diagram showing the positions of Jupiter's Satellites VI. and VII., from photographs taken at the Royal Observatory, Greenwich, during the Opposition 1906-7.

PLATE III.



SATURN'S RINGS.

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THE TORES OF SATURN.

PERCIVAL LOWELL.

FOR POPULAR ASTRONOMY.

A little before sunrise on June 19th (1907), a new phenomenon was detected at Flagstaff in the saturnian ring system. The date was the first occasion that Saturn had been looked at there at this opposition. The planet was morning star at the time, raised just above the dimming of the dawn in the Eastern sky, having but recently passed quadrature and was in that curious phase of its aspect when it seems to have lost its ring. Next to the singularly Jupiter-like appearance it presented in consequence and the striking oblateness of figure it revealed the most conspicuous feature of the disk was the dark band which then belted the planet's equator. In this band which first caught and then kept attention for the detail it disclosed, centered the interest. For the band, which was in truth the shadow of the rings upon the ball, suggested rather one of the planet's belts and at the same time exhibited features of a peculiar character. The shadow, far from being dark, was only moderately dusky and furthermore presented when first looked at a curious tripartite appearance. On more careful scrutiny its lack of uniformity proved to be due to a narrow black line that threaded it medially throughout its length, the black core being perhaps one-fourth as wide as the less dense background upon which it stood. At the same time the rings themselves could with attention be made out as the finest knife-edges of light cutting the blue of space on either side the planet's disk. As the Sun was at the moment 32′ north of the plane of the ring-system, while the Earth was 2 degrees 16′ south of it, the two were on opposite sides of the system, which fact combined with its then visibility shows that the rings are never wholly lost in the Flagstaff glass. This black core to the shadow of the rings upon the ball is a phenomenon which has not previously been observed, nor has it yet been seen elsewhere, although evident to all the observers at Flagstaff.

The planet was not looked at again until October 31, other work occupying the observatory in the meantime. In November, however, it was critically studied. The dusky band was evident as in June and the black line made core to it as before, being plainly perceptible to all the observers. On the 12th and 13th of the month I measured both with the filar micrometer, the measures on the latter date being the more numerous and exact, for the band was then measured between the micrometer threads, outside them and from center to center of the same, while the pencil-like core was estimated in terms of the thread itself. The mean of the measures with the suitable corrections applied gave:'

for the whole shadow, 0″.46
and for its black core, 0″.10.

The band was tinged a faint cherry red (Nov. 5); rather more strongly so than the planet's own belts which could be seen both north and south of it two; on either hand, the temperate the fainter, and the tropical fainter in the center than on the sides.

The black medial line running through it was by no means even. It both undulated slightly and showed irregularities of outline, one black bead in especial being noticeable upon it about halfway from the planet's center to its (the planet's) eastern limb (Nov. 13 — 7^h). The line also seemed not quite central in the belt but a little nearer its northern edge. The Sun was now 1° 39′.5 south of the ring-plane while the Earth was 50′ north of it, so that both bodies were now again on opposite sides of it, having respectively shifted across.

The rings themselves were equally visible, in fact, were now easy objects, although as before only the edge of their plane was presented to the eye. But in addition to the general line of their light, agglomerations were plainly discernible on them. The condensations, puffs of light upon a golden thread, were symmetrically placed, two on either side the ball, and continued observation showed them to be permanent in position. Micrometric measures were made upon them by both Mr. Lampland and by me from November 3rd to November 9th. Before seeing to what they commit us we will review what had previously been done on the subject.

Apparent agglomerations or thickenings of the rings have been noticed by several observers since the time of Herschel; by Bond, Wray and Struve in especial.

At the last occasion when the rings were presented edgewise to the Earth they vanished as observed with the Lick telescope by Barnard, not becoming visible till October 30, 1901. When they did appear he noticed that the ring could first be seen at a distance of about $2''$ from the edge of the disk; also that the two halves on either side were not the same; and lastly he perceived two bright knots on the western one. In explanation of the knots Barnard assumed that he saw two of the inner satellites; but as Seeliger from whom the above account is quoted quaintly remarks "Mimas only could be in question and it might raise difficulties to explain both knots by it."

Seeliger then goes on to give his own explanation of the knots first propounded by Olbers to wit: that they are due to ansal forelengthening of the brightest portions of the ring from traverse of them by the line of sight. From his study of the relative lustre of different parts of the ring system, both observational and theoretic, he deduced for their apparent maxima:

$$\left.\begin{matrix}1.60\\ +\ 1.98\end{matrix}\right\} \text{ in radii of Saturn from the planet's center.}$$

Barnard published no measures of the positions of the knots but from his drawings Seeliger deduced for them =

$$\left.\begin{matrix}1.60\\ +\ 1.94\end{matrix}\right\} \text{ in radii of Saturn from the planet's center}$$

while the outer edge of ring A from Barnard lay at 2.22
radii and Seeliger's calculated value at 2.30.

Bond's earlier explanation seems to have been that the knots were caused by the seeing of the outer edge of the ring reinforced by the inner edge of its neighbor where the two turned at their ansae, the rings being slightly opened to the line of sight.

Now at Flagstaff this last November, the positions of the thickenings in the rings were as I have said not only observed but measured so that we have quantitive data to go on. These data from my measures, with which those of Mr. Lampland substantially agree, are—

November 9. 1907. $8^h\ 25^m$ to $8^h\ 50^m$

		In seconds of arc from the nearer limb	In equat. radii of Saturn from the planet's center	Corr. for irradiation
RIGHT mean of				
3 measures	Inner edge of inner thickening	1″.00	1.11	
2 “	Outer “ “ “ “	3″.94	1.43	
2 “	Gap (most conspicuously vacant spot)	5″.36	1.58	
3 “	Inner edge of outer thickening	6″.92	1.75	
4 “	Outer “ “ “ “	8″.51	1.92	
LEFT				
2 measures	Inner edge of inner thickening	1″.15	1.12	1.13
2 “	Outer “ “ “ “	4″.22	1.46	1.47
5 “	Gap (most conspicuously vacant spot)	5.58	1.60	1.61
3 “	Inner edge of outer thickening	6.53	1.71	1.72
2 “	Outer “ “ “ “	8.46	1.91	1.92

At the same time measures of the span of the whole ring gave:

Mean of			Cor. for irradiation
2 measures	On the right, measured from the nearest limb, reduced to equat. radii from the planet's center.	2.164	2.16
1 “	On the left, measured from the nearest limb, reduced to equat. radii from the planet's center.	2.145	2.16
4 “	From W. end to E. end visible; double measures, reduced as above	2.191	2.20

The equatorial radius, also measured, came out:

Mean of
2 measures Nov. 9. 9″.245
corresponding to a diameter of 17″.38 at distance 9.5389
Nov. 3. 9″.388
corresponding to a diameter of 17″.49 at distance 5.5389
giving a mean diameter of 17″.44 “ “ “

Compare now with these distances from Saturn those of the latest measures of the ring-system (See 1901).

From Saturn's center in radii of the planet.

Outer radius of the outer ring, A.		2.32
Encke's division.		2.19
Inner radius of outer ring A.		2.01
Cassini's division.		
Outer radius of ring B.		1.95
Inner radius of ring B.		1.50
Outer radius of ring C.		1.50
Inner radius of ring C.		1.19
Planet's radius.	(17.″24)	1.00

Measures by other observers of the system give for our present purpose substantially the same result.

From the known dimensions of the ring-system, several interesting points are at once deducible from the Flagstaff measures. First it is evident that the rings in November could not be followed quite to the outer limit of ring A as that stretches to 2.25 or 2.30 radii from the center of the planet according to whose measures of the system we adopt, while the measured breadth now was at most 2.20. This implies that the outer part of ring A has less thickness than the rest, for we cannot refer the effect to the less breadth of ring it traverses there being intersected by the line of sight, since the Earth was on the opposite side of the ring-system from the Sun. The average width of the thread of light upon which the agglomerations were strung was by comparison with the black core of the shadow not over eighty miles.

Secondly: The present measures indicate that the rings approach the body of the planet closer than they have been measured before.

Thirdly: The measures of the positions of the agglomeration show that Olber's explanation of them, endorsed by Seeliger, fails to account for the appearances.

Fourthly: These positions point to another explanation of some interest; and

Fifthly: This latter explanation proves also to account for the phenomena of the shadow and incidentally to answer a query propounded by Seeliger on previous observations of it.

To make this clear we will begin by quoting Seeliger upon the observations and deductions on the last occasion when the rings were presented as now edgewise to the Earth.

"Before the ring begins to be visible, it must disclose itself as a dark stripe across Saturn's disk. This was a fact seen and drawn by Mr. Barnard. He found on October 22, (1891) for the breadth of the dark band 0″.51 and for the position of its middle point from the north limb (of the planet) 7″.40′; from the south one, 6″.56. Mr. Barnard asserts that the measured breadth entirely agrees with the ephemeris data. I find, however, for an elevation of 1° 41′ for the Earth above the plane of the ring's width to be 0″.16 or 0″.24 according as the bright ring alone is considered or the dark ring is included as well; [This quantity being the breadth of the ring-system into the sine of the angle of elevation of the Sun above the plane of the rings.] On the contrary I find very good agreement between the observations and the data for the position of the dark band of 7″.64 and 6″.72 from the north and south limits respectively, and of 7″.60 and 6″.76 if the dark ring be also comprised. The above remarked divergence between observation and theory demands explanation, since Mr. Barnard on October 29 found an even greater breadth of the dark band of 0″.65."

Now taking up first the shadow phenomena seen at Flagstaff, calculation shows that the shadow of the whole ring-system including the crepe ring, with the Sun as on November 9 (1907), 1° 39′.5 above the ring-plane, would be 0″.26 wide only. The position of the Earth does not sensibly change this. Now the shadow was nearly twice as wide as this, being 0″.46. Such then, as Seeliger rightly concluded, cannot be its cause. Nor can the dusky band be the penumbra of the dark umbral core as that would be only 0″.05 in width, a quantity indistinguishable in fact by the eye. Neither projection nor penumbra then can account for the effect and we must look out of the plane of the rings for an explanation. The only supposition to tally with the facts is that in the black core we are looking at the shadow of such parts of the ring-system as are practically plane, chiefly ring A, and in the dusky shadow about it through particles situated above and below that plane lying in the other rings. In other words, that ring B and ring C are for the most part not flat rings but tores.

Turning now to the phenomena of the rings themselves, the agglomerations on the Olbers-Seeliger theory of their showing should, as computed in the same memoir by Seeliger be found at 1.60 and 1.98 radii of Saturn from the planet's center, for these are the points where the line of sight from the Earth traverses the greatest ansal breadth of the rings at their densest.

Instead, however, of being so found the present thickenings occur in striking contrast to this, the maxima showing where the minima should and the minima where the maxima would be; since their centers are situated at 1.27 and 1.83 with a conspicuous gap at 1.60 and another falling-off at 1.92 outward. It is not, then, to line of sight massing from particles in one plane that the observed effect is due.

But the moment we let our thought wander out of the plane we light upon an explanation which satisfies the phenomena. For suppose portions of the rings to be not flat rings but tores, that is, rings after the manner of anchor-rings, encircling the planet. Then, viewed edgewise, such a tore would make its presence perceptible by humps of light in two patches symmetrically placed on either side of the planet, to wit, at its ansae where the sight-line would penetrate the greatest amount of it. The agglomerations, then, can represent tores, but cannot represent flat rings.

Thus we are led by the phenomena presented by the rings to the same explanation to which those of the shadow conducted us. Furthermore, it is to be remarked that the line of argument in each case is independent of the other. For in the one case, in the shadow, we are reasoning on what we note from a transverse viewing of the tores, in the other, the rings themselves, from a longitudinal aspect of them in the bright agglomerations. As the two deductions lead to the same result each gains corroboration from the other.

The rings of Saturn, then, are not flat rings but for the most part tores, some hundreds of miles across, thus many times exceeding in thickness the portions approximately plane for which the Flagstaff observations indicate a cross section of eighty miles. They are only to be seen in their true character on the occasions of edgewise presentation to the Earth for as the ring opens the increased apparent breadth of the of the whole system masks the slight difference between the tores and the plane sections still further obliterated by the greater irradiation of the last.

It seems necessary to suppose that we see through the tore to its partially illuminated side, for from observations made or published since this article was written it appears that the agglomerations disappear when either the Sun or the Earth passes through the plane of the rings.

Thus Mr. Lampland's observations of the rings gave,—

December 31,	Agglomerations visible.
January 1,	Ansae too faint to detect structure.
January 3 and 4,	Ansae continuous.
January 7,	No agglomerations. Rings easily seen.

Earlier observations by Aitken at the Lick July 23—October 12, show that no agglomerations were seen between those dates. See Barnard to the same affect.

Since this article was written Barnard has published his observations with his explanations. His explanations, however—for he gives two,—one that the eye sees through the underside of the rings and that such light is greatest where the rings are densest, the other the exact opposite, that the light is most where the ring is least crowded—are self-condemning on several counts, one for instance that the inner condensation does not fall by his own showing on the ansal position of any part of ring A, but wholly on the crape ring. Each explanation might account for one agglomeration alone but for that very reason fails for both.. The presence of the gaps is another fatal objection to them.

As seen at Flagstaff, under the same seeing that disclosed the dark core to the ring's dusky shadow, the agglomerations were fairly continuous, though uneven, for the whole length of them measured on November 9th. Their vertical width was about 0″.20 while that of the continuous ring was about 0″.02 giving for the width in the main plane of the rings some 80 miles or 130 kilometers.

The appearance of these tores was at times exquisitely beautiful. Particles on them would shine out like diamonds in flashes of light to fade the next moment, while others farther along twinkled in turn. Nor did the satellites in the least conflict with them; for the divergence of the line to the Earth from the ring-system's plane, slight as it was, sufficed to throw the satellites above or below it against the background of the sky.

Such are the facts of observation. Interesting as they are in themselves they gain both in import and in cogency when the system is considered from the point of view of celestial mechanics.

Mechanically considered, knowledge of the character and constitution of the rings has had an eventful history. Although Cassini had suggested that they might not be solid, they were universally so deemed until Laplace took up the subject. He first showed that the rings could not be, as they appear, wide solid rings, inasmuch as the strains due to the differing attraction of Saturn for the several parts must disrupt them. Peirce then proved that even a series of very narrow solid rings could not subsist and that the rings must be fluid. Finally Clerk-Maxwell demonstrated that even this was not enough and that the rings to be stable must be made up of discrete particles, a swarm of meteorites, in fact. But, if my memory serves me right, Clerk-Maxwell himself pointed out that even such a system could not eternally endure but was bound eventually to be forced both out and in, a part falling upon the surface of the planet, a part going to form a satellite farther away.

Even before Clerk-Maxwell's time Edward Roche in 1848 had shown that the rings must be composed of discrete particles,—mere dust and ashes. He drew this conclusion from investigations on the minimum distance at which a fluid satellite, or even a solid one of sufficient size, could revolve around its primary without being disrupted by tidal strains.

The dissolution which Clerk-Maxwell foresaw can easily be proved to be inevitable if the particles composing the swarm are not at considerable distances from one another. For a swarm of particles revolving round a primary are in stable equilibrium *only in the absence of collisions.* From the light rings A and B send us, it is evident that they must be pretty closely packed, even allowing for the comminuted form of their constituents. In so crowded a company collisions, due either to the mutual pulls of the particles or to the perturbations of the satellites, must occur. At each collision, although the total moment of momentum of the two particles remains the same, energy is lost unless the bodies be perfectly elastic, a condition not found in nature, the lost energy being converted into heat. In consequence some particles will be forced in toward the planet while others are driven out; the greater number falling in until at last they are brought down upon the body of the planet.

Now the interest of the observations at Flagstaff consists in their showing us this disintegration of the rings in process of taking place. For a mechanical discussion of the problem proves that tores would be raised and that these would lie where the actual tores are observed to be.

One of the chief causes of collision among the particles composing the ring system would be the perturbing action they must suffer at the hands of the satellites. For the disturbing pull of the latter is different for particles at different distances from Saturn and diverse for the same particle in varying positions of its orbit. Even if the bodies constituting the ring were all originally revolving in approximate circles they must from this cause speedily be thrown into ellipses of differing major axes and differently positioned so that collisions would be greatly increased both in number and force. Such collisions would be most frequent and disastrous where the perturbative action of the satellites was greatest. The first thing, then, in our inquiry is to discover where the satellites' action would be most potent.

To evaluate the disturbing action of a body upon a second revolving round a third, the most effective analytic treatment for our present purpose the discovery of perturbations of long period is by the method of variation of the arbitrary constants. By this artifice first developed by Lagrange the undisturbed elliptic form of the equations expressing the motion is preserved but the elliptic constants are now regarded as variables whose values are determined from the perturbative function, subject to the condition that they shall represent in form both the unperturbed function and its first derivatives or in other words the place and the velocity of the particle as if they were invariable, differing from the actual motion only in their second derivatives or in the change of the velocity brought about by perturbation. The resulting equations are then solved by expansion in a converging series of terms of which enough may be taken to attain any desired accuracy.

The points germaine to our present inquiry are the perturbations in the radius vector. For those alter the mean distance of the disturbed particle from Saturn and therefore its mean motion about the planet,

$$\text{since} \quad n^2 = \frac{\mu}{a^3}.$$

Now, put analytically, by the method above outlined of variation of parameters, the radius vector of the perturbed body —the disturbed particle in the present case—may be denoted, following Airy's excellent exposition of the subject, by

$$r_1 = \frac{a_1 (1 - e_1^2)}{1 + e_1 \cos. \ (\theta_1 - \omega_1)}$$

where the subscripts refer to the variable elements which must then be evaluated in terms of the supposed invariable ones for a given moment. The perturbed longitude is expressed by

$$\theta_1 = n_1 t + e_1 + (2e_1 - \frac{e_1^3}{4} + \text{etc.}) \sin (n_1 t + e_1 - \omega_1) + \text{etc.}$$

The variable elements are found in terms of the invariable by means of the equations,

$$\frac{da_1}{dt} = - \frac{2na^2}{\mu} \frac{dR}{de}, \qquad \frac{dn_1}{dt} = \frac{3n^2 a}{\mu} \quad \frac{dR}{de},$$

and so on, deduced from the general equations of motion, on the above understanding in which R, the perturbative function =

$$\frac{m^1 r \cos. \ (\theta^1 - \theta)}{{r^1}^3} - \frac{m^1}{\sqrt{\ }[{r^1}^2 - 2r^1 r \cos. \ (\theta^1 - \theta) + r^2)]}$$

m^1 denoting the mass of the satellite, and μ that of Saturn and the particle. The equations when integrated give a_1, n_1, etc. Substituting these, the radius may then be expanded in an ascending series of terms according to powers of the eccentricities and of cosines of multiple arcs of the mean motions of perturber and perturbed by Fourier's series. The resulting expression is composed of terms similar to those in the undisturbed orbit and of others denoting the effect of the perturbation has $a_1 = a +$ etc. The latter are of the typical form:

$$\frac{cn}{\mu} \quad \frac{Pe^{x}e^{x_1}}{pn - qn^1} \cos. \overline{(pn - qn^1)\ t - M}$$

or

$$\frac{cn}{\mu} \quad \frac{Pe^{x}e^{x_1}}{pn - qn^1} \cos. \overline{((p-1)\,n - (q-1)\,n^1)t - N}$$

where P is a function of a and a^1, the radii vectores of the perturber and perturbed.

The form of these terms shows that they will become considerable in proportion as $pn - qn^1$ is small, since their coefficients are divided by this quantity. Now as nt and n^1t are the mean motions of perturber and perturbed, if these are nearly commensurate there will always be terms of the sort which will be large, namely those in which $\frac{q}{p} = \frac{n^1}{n}$; for p and q are always integers, in consequence of the method of expansion.

The various terms with the argument $(pn - qn^1)\ t$ will have coefficients of different powers of the eccentricities. The lowest of these which can occur in the expressions will be of the order $p - q$. The term therefore, in which $x + x_1 = p - q$ is the term least diminished by the eccentricity coefficient and therefore the most potent in its effect.

From this it is evident that two bodies will mutually disturb each other in their revolutions about a third according as their periods are,

1st — Commensurate.
2nd — Differ by the smallest integer.

The most disturbing ratio is when the periods are

1 : 2 ; 2 : 3 etc.
the next, 1 : 3 ; 3 : 5 etc.
then, 1 : 4 ; 2 : 5 etc.
and so on.

The initial ratio in each line will be the most effective in that line because the cycle of the disturbance will be repeated in the time it takes the outer body to come again into conjunction with the inner and this for the ratio 3 : 5 for instance will be three times as long as for that of 1 : 3.

The thing can be seen geometrically by considering that the two bodies have their greatest perturbing effect on one another when in conjunction and that if the periods of the two be commensurate they will come to conjunction over and over in the same points of the orbit and thus the disturbance produced by one on the other be cumulative. If the periods are not commensurate the conjunctions will take place in ever shifting positions and a certain compensation be effected in the outstanding results. In proportion as the ratio of periods is simple will the perturbation be potent. Thus with the ratio 1 : 2 the two bodies will approach closest only at one spot, and always there, until the perturbations thus induced themselves destroy the commensurability of period. With 1 : 3 they will approach at two different spots recurrently; with 1 : 4 at three, and so on. The number of points round the orbit at which they will meet is in fact as the sum of the powers of the eccentricities in the lowest coefficient of the terms with the commensurable argument.

We see, then, that perturbations, which in this case will result in collisions, must be greatest on the particles having periods commensurate with those of the satellites. But inasmuch as there are many particles in any cross-section of the ring there must be a component of motion in any collision tending to throw the colliding particles out of the plane of the ring, either above or below it. Such extra-plane particles would, therefore, be most numerous just inside the points of commensurability, because though the moment of momentum is preserved and particles are thus thrown outward from the point as well as in, owing to the loss of energy the waifs must be more numerous on the inside.

Considering, now, the commensurate ratios between the periods of particle and satellite which can enter into the problem, we find these in the order of their potency to be:

With Mimas,	1 : 2,
	1 : 3,
	1 : 4,
With Enceladus,	1 : 3,
With Tethys,	1 : 4.

Such periods of commensurability as 2 : 3 of Mimas and 1 :2, 2 : 3, of Enceladus, do not come into question as they take place practically outside the ring-system. Now calculation shows that the distances corresponding to a period of 1 : 2 of Mimas, 1 : 3 of Enceladus, and 1 : 4 of Tethys, fall in Cassini's division, which separates ring A from ring B. The first or outer tore should therefore occur just inside that division or in the outer part of ring B. Now when we turn to the observations and compare them with the plan of the ring-system we note that this is precisely where it occurs; for the inner edge of Cassini's division lies at 1.92 radii of Saturn from the center of the planet and the outer tore begins at 1.92, thence to stretch inward toward the disk.

Pursuing our inquiry with the next most effective ratio, that of 1 : 3 of Mimas' period, we note that its corresponding distance falls at the boundary of ring B and ring C at 1.50 radii of Saturn from the center. Now it is inside this, to wit, at 1.46 and 1.42, that the inner tore begins. But this is not all. The inner tore is much longer than the outer one. We turn, therefore, to the next most potent ratio, that of 1 : 4 of Mimas' period, to find that its distance falls at 1.24. So that here a second perturbation prolongs the action of the first. The two together thus account for the greater length of the inner tore.

The remarkable way in which theory thus explains observation is of interest and the more so from involving a case of celestial mechanics interesting in itself.

Thus the rings are falling in upon the planet under the action of the satellites, of Mimas and Enceladus in particular. But there is nothing catastrophic about the occurrence. The moons of Saturn have been busied disintegrating the rings since that appendage was formed. The far fact can be sounded by the plummet of our analysis though the action fail of certain record in our telescopes for the length of the period involved in its working out. To penetrate time is so much harder than to see through space.

Yet even so there are comparative observations which seem to point to it. If we tabulate Jacobs' measures made in 1856 with those of Barnard and of See we detect an apparent encroachment of the dark ring toward the body of the planet. Thus—

Distance from Saturn in radii of the planet.

		Jacobs.	Reduced to same diameter as later ones and cor. for irradiation.	See.	As measured at Flagstaff 1907.
Outer	A	(40″) 2.23	2.28	2.32	[2.28
Encke	"	2.12	2.17	2.19	2.17
Inner	"	2.00	2.03	2.01	1.99
Outer	B	1.94	1.97	1.95	1.92
Inner	"	1.47	1.51	1.50	1.48
Outer	C	1.47	1.51	1.50	1.48]
Inner	"	1.26	1.30	1.19	1.12
Radius		(17″.94) 1.00	1.00	(17″.2.4) 1.00	(17.44) 1.00

But this though suggestive is inconclusive because the greater power of modern objectives would produce the same seeming stretching in of the crepe ring toward Saturn's limb. But the fact stands as securely proved mathematically as if its advance had already been recorded.

But there is another outcome to the analysis beside the end to which it eventually leads and that is the disclosure of the method by which that end is brought about. This is that the Flagstaff observations exemplify and in this that their importance lies. They show the action of disintegration in process of taking place. To him who appreciates the analysis by which man's mind stretches out beyond the now and here to the then and there, the tores speak of the rings' decay and dissolution as prophetically as if time were so shortened for him that he could mark the very particles tumbling in to rest forever upon the planet's self. For that beautiful appendage that now diadems Saturn making him by far the most immediately impressive object in the heavens he is destined eventually to lose. Robbed of it by his own retinue, the satellites, he will circle round the Sun a discrowned orb. The condition that makes him at present so superb a sight has for its characteristic instability and this trait dooms it to pass away. Though there is nothing catastrophic about the changes now going on, their slowness of action clothes them with all the greater import. For the very stateliness of the process renders its inevitableness the grander to the mind of man.

Lowell Observatory,
Flagstaff Arizona.

A PRACTICAL METHOD OF DRAWING ELLIPSES.

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY.

In POPULAR ASTRONOMY 1894 I 248 Professor Burnham states that in his opinion the best method of drawing ellipses is by the old method using a thread or wire and two needles. In this I quite agree with him. In order to vary the major axis he employs a sewing machine needle varying the length of the thread by drawing it through the eye. I have found another simple method which involves the use of a pin and two needles. In this case the thread is tied into a loop which is thrown over the needles, and given a single turn about each one. If we wish to draw the upper half of an ellipse, the major axis being horizontal, the pin is placed inside the loop between the needles and slightly below them. By simply varying the distance between the pin and the line joining the needles we can vary the major axis of the ellipse by as small or large a quantity as we choose. This arrangement is very convenient, as it enables us to allow for the slight stretching of the thread which almost always occurs in practice. I usually use one pencil to draw the ellipse, and another to carry the thread down to the bottom of the needles. By holding the drawing pencil at the proper angle the thread maintains itself upon it at a constant height of one or two millimeters.

In constructing an ellipse it is more accurate to determine the length of the thread by the minor rather than by the major axis. The former should therefore always be laid off before the curve is drawn. The semi-minor axis $b = a\sqrt{1 - e^2}$ where a is the semi-major axis, and e the eccentricity, or the distance from the focus to the center divided by the semi-major axis.

Harvard College Observatory,
January 17, 1908.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

Part II. (Continued.)

SPECIFIC STATEMENTS OF FUNDAMENTAL CONCEPTS CONCERNING THE CONSTITUTION OF MATTER.

FOR POPULAR ASTRONOMY.

It is reasonable to infer, therefrom, that some of the gaseous matter ejected from volcanoes consists of pure carbon vapor pressed upward from great depths, and that what are commonly considered as "flashes of lightning," playing in the clouds overhanging the craters, are simply the results of the sudden oxidation, and flashing into flame, of this carbon vapor, the solid and liquid, or viscous, matter—ashes, lava etc.—being forced upward to the crater, through the ducts of the volcano, by the pressure of the gases confined in the depths below.

The black cloud that suddenly descended from the riven side of Mont Pelée, in Martinique, W. I., on that awful day in May 1902, and fell upon the populous city of St. Pierre, near the base of the mountain, most probably contained within itself, or was partly composed of, pure carbon vapor together with divers hydrocarbon gases which, when mixed with the proper proportion of atmospheric oxygen, flashed into flame with the rapidity of an explosion, and in a moment, not only killed, practically, all the population of that city of more than 30,000 people, but also destroyed the city itself, shattering even its most substantial edifices; such also was, undoubtedly, the cause of the historic catastrophe that befell the cities of Pompeii and Herculaneum in that memorable year 79 A. D. when the pent up gases within the depths of Vesuvius burst their bonds and overwhelmed the people of those cities while engaged in their daily occupations, burying all under many feet of the solid matter ejected from the crater.

Certain of the physical properties of silicon, carbon and possibly *boron*, indicate the fitness of these elementary substances for service as the matter of *solid*, and *very rigid*, nucleus of the Earth: A form of pure silicon is a dark-brown, amorphous powder which *when heated to redness in the absence of air becomes denser* and assumes a *graphitic* appear-

PLATE IV.

GREAT NEBULA IN ANDROMEDA.

[Scale: 1mm=27.″5]

ance, and much the same statement, except as to color, may be made concerning pure carbon. Now, if these substances, in pulverized form, become *denser* when heated to *redness*, or at a temperature of 1000°—1200°, Fahrenheit, under ordinary pressures, we may say, with almost absolute certainty, that, at the internal temperature of 6,340°, which is about that of the electric arc, and under the enormous pressure of the 66 miles of matter above it, and in the obvious absence of air, the density of both silicon and carbon,—assuming these to constitute the nucleus of the Earth below the "crust" thereof,—would easily be about double that of the same matter at the surface and under the ordinary conditions of pressure and temperature, and therefore equal to the present mean density of the Earth which is 5.52.

Taking the mean surface density as 3.25, if we assume that it increases regularly with the depth, the condition that the mean density of the whole Earth is 5.50 would imply a maximum density of 7.75 for the internal matter, or nucleus, and this is the density of *iron*, a fact which, of late, has led some physicists to assert that this metal is the chief constituent of the *nucleus*, and that the Earth is an "iron globe," but we know that iron constitutes only a small percentage of the superficial matter and there is no reason to assume that conditions in this respect are materially different in the interior, while, from what has been stated above concerning silicon and carbon, particularly in regard to density, quantity, solidity and rigidity under extremely high temperature and pressure, all necessity for assuming a *metallic* nucleus is obviated. We know that the approximately pure species of carbon called the "diamond" is of considerable density (about 3.5) and of the *greatest hardness*, and that it has been artificially produced from carbonaceous matter, *under conditions of great pressure and high temperature, in the absence of air*, in the electric furnace the temperature whereof is practically the same as that of the Earth's internal matter, as above determined. Pure silicon, under the same conditions, would also constitute a substance of probably vitreous nature and extreme hardness, and it is also known that the somewhat similar element *boron* is chemically obtainable as a very hard substance called "adamantine boron."

Therefore, in such substances under said conditions of temperature and pressure, we have materials well fitted to constitute the *solid*, and *extremely rigid*, nucleus of the Earth, which, as the late Lord Kelvin many years ago pointed out, must be a solid *more rigid than steel*, in order to resist the distorting stresses brought to bear upon it continually, by the tidal forces of the Moon and the Sun.

I have also computed the initial radius (R_p) of each of the secondary condensations in the primitive solar nebula, which formed the nuclei of the other planetary members of the solar system, and the maximum temperature (T_p) generated by the compression of these gaseous nuclei to the dimensions of the planets at the present time, by the same methods employed in the case of the Earth, through the equations (d_1) and (e_1) derived from my theory, and the results are tabulated as follows:

TABLE II a.

Planet	Density	Initial Radius	Internal Absolute Temperature
Neptune	0.88	5,604	3,266°
Uranus	0·94	3,307	3,411
Saturn	0.72	1,747	2,864
Jupiter	1.32	1,234	4,281
Mars	1.93	472	5,640
Earth	2.66	300	6,800
Venus	2.84	177	7,120
Mercury	3.09	180	7,934

In the first column of numbers are set forth the densities (D_p), and in the second, the radii (R_p) of the secondary nebulous masses—now the planets,— at the time of beginning of condensation, the present semidiameter of each planet being referred to as 1, while in the third column are the maximum absolute temperatures (T_p), generated by the compression of each planet down to its dimensions at the present time, and these are also the maximum internal temperatures at certain depths below the surface in each case, while the temperatures referred to the "zero" of the ordinary Fahrenheit scale are deducible therefrom by subtracting 460° from each tabulated temperature.

An inspection of this table discloses some interesting and striking facts from which some important conclusions concerning mooted astronomical questions may be deduced.

Thus it is noticeable that the density and the temperatures in the case of each of the four great outer planets, Jupiter, Saturn, Uranus and Neptune are *low* when compared with the similar quantities in the case of the four inner, and smaller, planets Mars, Earth, Venus and Mercury, the densities in all the former cases being less than that of the Sun which is known to be a gaseous body still undergoing compression according to the laws of the thermodynamics of gases and, therefore, still heating at an *increasing* rate. Now the reason for this marked difference between the two sets of planets becomes apparent when we consider the values of the initial radii, (R_p) set forth in the second column of numbers, because the values therein given are very *large* for the great planets aforesaid, as compared with those of the four smaller planetary bodies of which the Earth is one; in other words, the volumes of the secondary nebulous masses, at the beginning of the process of formation of the greater planets, were vastly greater than those forming the four smaller bodies, and therefore *more time has been required* for the former to condense to their present dimensions, and as result they are yet in the gaseous state and still compressing and heating as is the Sun, a fact to which both photometric and spectroscopic observations bear witness.

While the spectroscope shows that these planets shine, principally, by reflected sunlight, the photometric comparisons indicate that the intensity of their light is distinctly greater than can be attributed to reflected solar radiance alone, whence it is inferred that they shine partly by their own intrinsic light and are therefore, still in the gaseous, compressive and *sunlike* stage of development, and increasing in temperature; but, as the spectroscope indicates, they are enveloped by very deep, vapor-laden atmospheres that obscure the actual conditions on their surfaces, which conditions are considered to be somewhat similar to those now existent upon the Sun's surface,–the "belts" "redspot" etc,, on the disk of Jupiter being very significant on this point.

A number of the most eminent observers have noted abnormalities in the light of the planet Uranus, and also the fact that the outermost known planet, Neptune, does not exhibit a clearly defined, planetary disk, it appearing more like a small planetary nebula.

The fission of the several masses of the surface matter of the primitive solar nebula in, and from, which the secondary condensations forming the nuclei of the four great outer planets were developed, quite obviously occurred long ages before that of the matter whence the Earth, Mars, Venus and Mercury were formed, and therefore it has been commonly inferred that the four greater planets aforesaid are much older, and in a more advanced state of development, than the Earth and the three smaller planets just named; but this does not necessarily follow. It may well be that the beginning of the process of planetary condensation, or formation, was not in the same order, as to time, as that of the fission of the belts of matter in which they had their origin, from the parent solar nebula, but may have varied greatly; the beginning of the formation of the nuclei of the four outer planets may have been about at the same time, or *even later* than that in the case of the Earth and the three other inner planets. Moreover, the *mass*, or the quantity of matter, of each of the four larger planets is much greater than that in the case of the Earth and the three other bodies, as was also the original volume and the initial radius thereof, or the distance through which they have contracted to their present dimensions, and all these factors must have operated to prolong the period of formation relative to that in the case of the Earth, while, on the other hand, the relative surfaces of each of the four outer planets is much greater than that of our globe, and the radiation of heat and the rate of contraction therefore greater, and the time of reduction of said planetary bodies to their present dimensions, consequently *relatively less* than in the case of the Earth.

The *masses* of Jupiter, Saturn, Uranus and Neptune are respectively, 300; 90; 13 and 17 times that of the Earth, and their initial radii, set forth in the second column of Table IIa, are respectively 4.1; 5.7; 11.0 and 18.7 times the initial radius in the case of our globe, while, on the other hand, the respective surfaces relative to that of the Earth are 114; 79; 18 and 22.

These relative masses and initial-radii may be regarded as *plus* factors with respect to the time, or duration, of the process of planetary formation, and the relative surfaces as *minus* factors; therefore by taking the product of the *plus* factors in each case and dividing it by the corresponding *minus* factors there result, in whole numbers, 11; 7; 8 and 14 which, *ceteris-paribus*, may be regarded as the times required for the formation of the four greater planets relative to the time in the case of the Earth; in other words, these planets are respectively, only $\frac{1}{11}$; $\frac{1}{17}$; $\frac{1}{8}$ and $\frac{1}{14}$ as far advanced in the stage of development, as the Earth. The relative time of *beginning* in each case is, as stated above, *problematical*, but if we take, empirically, the arithmetical series 2; 3; 4 and 5 as representing, approximately, the relative times of beginning of planetary formation in each cast-off belt of matter, and multiply by the fractional quantities set forth just above, the products $\frac{1}{5}$; $\frac{1}{2}$; $\frac{1}{2}$ and $\frac{1}{8}$ will indicate, in some wise, the stages of development with respect to the Earth. In any case it is quite evident, from what has been stated, that both observation and my theory indicate that the planets Jupiter, Saturn, Uranus and Neptune are still in the gaseous, or formative, stage of development, or, as we may term them, "unfinished worlds". As yet, these planets,—particularly Jupiter and Saturn with their systems of satellites—are comparable to miniature solar-systems, and, as has been done in the case of the Sun, the absolute surface temperature may be taken as one-half the maximum internal temperature in each case set forth in Table IIa, this absolute surface temperature being, in the case of Jupiter 2140 degrees; Saturn, 1335 degrees; Uranus 1705 degrees and Neptune 1633 degrees and by deducting 460 degrees from these values there result for the respective surface temperatures, referred to the zero of the Fahrenheit scale, in the ordinary manner; Jupiter 1680 degrees; Saturn 975 degrees; Uranus 1245 degrees Neptune 1173 degrees.

Now, the wave-length (λ) at the more refrangible end of the spectrum of a surface heated to the absolute temperatures above set forth, is given by the following, analytically derived, equation of my theory: $\lambda = 7886 \times \frac{1438^\circ}{T}$; (*g*), the wave-length so found marking the upper limit of the spectrum, in each case. Taking the values of the absolute surface temperature (T), given above, and substituting it in equation (*g*) for each planet, there results, as the wave-length, in the case of Jupiter; 5300 tenth metres; in that of Saturn 7900; for Uranus 6650 and for Neptune 6946; from which it appears that if the true surface of Jupiter could be observed through the spectroscope, the spectrum exhibited would have its upper-limit near the E line in the "yellow," the predominating color being "reddish-yellow," or "orange," and I think that the observations upon the "red-spot" and other surface phenomena only dimly disclosed through the heavy superficial clouds or vapors enveloping the "giant planet," bear testimony to the truth of my theoretical deductions in this connection. Under the same conditions of visibility, the upper limit of the spectrum in the case of Saturn would be nearly at the A line, or at about the beginning of the "red," and in the case of Uranus near the C line, and in that of Neptune near the B line—both the latter spectra being therefore confined to the "red" also.

We must therefore, conclude that, since the surfaces of these planets are so hot, and are still increasing in temperature, no form of life, either animal or plant, can possibly exist upon these four great members of the solar system but may be developed thereon, in the far distant future, after these planets shall have attained their maximum temperatures, and have subsequently gone through all the processes that have brought the Earth to its present habitable condition. Of the three other companions of the Earth, the planet Venus which is almost identical, in dimensions, with our globe, appears to possess a considerable extent of atmosphere laden heavily with vapors, or clouds, which, while they obscure the real surface, reflect the sunlight most brilliantly when Venus is in proper position relative to the Sun and the Earth.

While observing the "transit of Venus," with my 3-inch refractor at Washington, D. C. on December 6, 1882, I noticed that shortly after the time of "first contact" when the greater portion of the disk of the planet was outside the Sun's limb, it was distinctly outlined by a narrow, pearly aureole which, if not caused by light from the coronal background, must have been due to refraction and reflection of the Sun's light, by an atmospheric envelope, of considerable density and extent, surrounding the planet. This phenomenon was seen by other observers, not only on that occasion, but also in previous "transits," when conditions were favorable, and from certain thereof observations of this phenomenon it has been quite well determined that the atmosphere of Venus is very similar to that of our globe.

The internal, and surface, temperature and the vapor-laden atmosphere, taken in connection with the dimensions and *mass* of the planet Venus with respect to the Earth, all lead to the conclusion that the surface conditions on Venus are much the same as those that existed upon the Earth in the Palæozoic, or Primary Age of geological history, when the surface of our globe had cooled sufficiently to allow precipitation of the aqueous vapor of the atmosphere thereupon and the existence of the most primitive elementary forms of plant and animal life thereon, at or about the ending of the Huronian-Cambrian period, or the, beginning of the Silurian, as is evidenced by the fossil fauna and flora of that remote epoch which (according to computations based upon the "law of radiation" derived from the principles of my general theory) was, very approximately, 50 millions of years ago at which time the surface temperature, due to the internal heat of our globe, was about 150 degrees Fahrenheit, a temperature adapted to the, existence and propagation of certain forms of vegetable and animal life, particularly in the waters that then covered the surface of the Earth more extensively than at the present time, or before "the waters were gathered together in one place, and the dry land appeared"—to quote the words of Genesis.

Much the same course of reasoning, and conclusions therefrom, are applicable to the case of the planet Mercury, so that, of all the eight known planets of the solar system, only the Earth can be regarded as fitted by reason of its physical condition, both internal and superficial, to be the abode of living organisms such as now exist upon it, the question as to the planet Mars being still an open one which has, of late years, been receiving considerable attention—both scientific and pseudo-scientific—and we must await further observational developments; in fact this question concerning the habitability of Mars is more of popular, than of scientific, interest in this connection.

If the process of contraction of each of the four great planets, Jupiter, Saturn, Uranus and Neptune were to continue from the density (D_p) at the present time, until the density (2.66) of the principal part of the superficial matter of the Earth is reached and the planetary matter passes from the *gaseous* to the *viscous*, or approximately solid, state, the final radius (r) of each planet aforesaid may be found from the expression $r = \left(\frac{2.66}{D_p}\right)^{-\frac{1}{3}}$, derived from equation (d_1) set forth in the preceding part of this paper, the numerical value of r being in terms of the respective planetary semidiameters which, in each case, are taken as 1, while the final maximum absolute temperature (T_m) will be given by the following expression; $T_m = T_p + \frac{T_p}{3}(r^{-2} - 1)$ derived from the equation (e_1) of said part.

The density (D_p) of each of the four planets is given in Table IIa, as is also the maximum temperature (T_p) at the present time, a solution of the two equations, set forth just above, giving the following results:

Jupiter	Final Radius	0.7893	Max. Temperature	6571°	Increase	2290°
Saturn	" "	0.6469	" "	5154	"	2285
Uranus	" "	0.7070	" "	5686	"	2275
Neptune	" "	0.6916	" "	5543	"	2277

Taking average values for these four planets, it is apparent that the intrinsic absolute temperatures should increase by 2280 degrees, reaching finally a maximum of 5800 degrees, whereas the present maximum absolute temperature, in the case of the Earth, is 6800 degrees, as stated in the preceding part. This former temperature is about that at which pure *silicon* would pass from the *gaseous* to the *viscous* state, while the latter temperature is about that at which pure *carbon* would undergo the same change of state, a mean of the two temperatures, or 6300 degrees, would therefore represent that at which a combination of silicon and carbon, in equal proportions by weight, would be at the transition point, and this temperature does not differ materially from that which I have obtained in the manner described in the preceding part of this paper, the depth at which this maximum internal temperature is reached being, under the conditions just stated, 61 miles, whereas in the former case it was stated as 66 miles, so that, when everything is taken into consideration, with regard to the peculiar and complex conditions involved in the problem, the determinations in this connection may be regarded as quite definitive and sufficient.

Regarding each of the four great planets as similar to the Sun, in respect to the development of heat therein by the compression of its gaseous mass, the surface temperatures, when each planet will have reached the limit of gaseous compression, in the far distant future, will be one-half the maximum internal temperatures attained at that time, as set forth above, the absolute temperature of the surface of Jupiter becoming then 3285 degrees Fahrenheit; that of the surface of Saturn 2577 degrees; that in the case of Uranus 2843 degrees and that of the surface of Neptune 2772 degrees. Introducing these values of T in the equation connecting temperature (T) and wave-length (λ), set forth in a preceding paragraph, there results λ 3452 as the shortest wave-length (in tenth-meters) in the case of Jupiter; λ 4400 in that of Saturn; λ 3989 in that of Uranus, and λ 4091 in the case of Neptune; that is these would be the limiting wave-lengths at the more refrangible end of the spectrum, in each case, for a solid surface heated to the temperatures aforesaid and radiating in the atmosphere under the normal conditions, provided there were no absorption by surrounding gaseous matter, or in the transmitting medium itself, and they would mark the extent of the spectrum in each case. Under these conditions the spectrum of Jupiter would be lengthened to beyond the H line, or to the ultra-violet part; that of Saturn to approximately the G line in the "indigo," while in the case of Uranus and Neptune the upper end of the spectrum would be found in the vicinity of the H line, or at about the end of the "violet."

Following the same course of reasoning, and applying the same method, in the case of the Sun as that used to determine the final radius and corresponding maximum absolute temperature for the four great planets, by substituting D_s or the density of the Sun at the present time, for D_p the planetary density, and T_s instead of T_p for the maximum absolute temperature of the internal matter of the solar globe, instead of the planetary temperature, D_s being 1.4 and T_s 13,400—the following results are found. The Sun should undergo gaseous compression until its semidiameter will have contracted to 0.8074 of its present length, or from 432,170 miles to 348,930 miles—through a distance of 83,240 miles,—and until its internal absolute temperature has become 15,790 degrees Fahrenheit, an increase of 2390 degrees, and since the absolute temperature of the solar surface matter, under such conditions, is one-half the internal, its value would then be 7,895 degrees, or about 1,195 degrees greater than at the present time, according to my determinations. Finally, since in the process of contraction two-thirds of the heat that would be generated by *adiabatic* compression must be radiated, and lost, from the mass, only one-third, or 2390 degrees being retained, the temperature loss (T_e) must be 4780 degrees.

These conditions in the case of the Sun are fraught with great, and practical, import not only to solar physics, and astro-physics, but also preëminently to meteorology, and may lead to a modification of some views now held by physicists working in these particular fields of research. In the first place, the loss of heat, (T_u) measured in thermal units of any system, such as the "pound degree, Fahrenheit" (which is represented by one pound avoirdupois of water heated through one degree of the Fahrenheit scale), is expressed by the equation; $T_u = W.s.\ T_e$; (1) in which W represents the weight of the Sun (lbs. avoir.) and s, the specific heat of the solar matter, T_e representing the temperature loss which is 4780 degrees as aforesaid. Regarding the Sun as a gaseous mass, the specific heat (s) may be taken at 0.20 which is about a mean between the value of the specific heat of a gas at "constant pressure," and the specific heat thereof at "constant volume," so that sT_e, in equation (1), is equal to 956°, while the weight (W) of the Sun, (which is easily found since we know the volume of the solar globe (in cubic feet) and the density, or weight per cubic foot, is 4351×10^{27} lbs, and therefore, the product of this number by the value of sT_e, stated just above, is 4160×10^{30} thermal units this being the value of T_u which represents the quantity of heat lost by the Sun in contracting, from its present dimensions, down to the limit of greatest compression, through the distance of 83.240 miles of its radius.

Now, the quantity of heat, measured in thermal units as in the case just stated, received from the Sun, on unit surface (one square foot for instance) at the Earth, has been very accurately determined by means of pyrheliometric instruments, and this quantity multiplied by the square of the distance from the Earth to the Sun's surface, measured in terms of the radius of the solar globe—taken as 1—gives the number of thermal units radiated from one square foot of the Sun's surface, in any given time—one year for instance—and since the total area of said surface, (in square feet) is known, we will have by multiplying it by the radiation, per square foot, the total radiation of solar thermal energy, per annum, which is 1455×10^{28} thermal units and since the total loss of heat during the compression through the 83,240 miles of the radius would be, as aforesaid, 4160×10^{30} units, it follows that the number of years required for the consummation of the process of compression through the distance of 83,240 miles of the Sun's semi-diameter, which number is obtainable by a division of the total heat loss,—4160×10^{30} thermal units—by the total radiation per annum, which is, as above stated, 1455×10^{28} thermal units, would be 286 years, *provided that the radiation of heat proceed uniformly from every portion of the Sun's surface.*

Since the diameter of the solar globe would be thus reduced by 166,480 miles in 286 years, *under the aforesaid condition*, the rate of contraction would be 582 miles per annum, or nearly the $\frac{1}{150}$ part of the diameter in a century, a conclusion so at variance with known facts of solar physics that it amounts to a veritable *reductio ad absurdum*, but one that leads directly to certain concepts which I regard as among the most important ones of my general theory, viz: those that have reference to terrestrial atmospheric conditions as affected by correlated solar and planetary influences, and which are, therefore, of great practical importance as they serve to elucidate some heretofore suspected, but obscure, relationships between solar and planetary conditions and certain phenomena of meteorology, directly affecting the comfort and welfare—if not the very existence—of mankind.

Saint Paul, Minnesota.

To be continued.

A NOTE ON THE RELATION OF ASTRONOMICAL SECONDARY NEGATIVES TO THEIR ORIGINALS.

ROBERT JAMES WALLACE.

FOR POPULAR ASTRONOMY.

The use of glass positives is a matter of every day practice in the preparation of plates recording astronomical (and physical) data. These positives are in many instances made directly from the original negatives, and, where the object is to direct attention to fine filamentous structure or detail, such as the outlying nebulosity farthest removed from a nucleus, or other detail, of low relative contrast, then it is the general practice to resort to local (chemical) reduction on the film of the positive.

There are, however, negatives of certain subjects in which it is not possible by this single remove to introduce sufficient contrast to clearly show the structure which can be traced with a practiced eye, upon the original negative. In this event, it is necessary to make from the original a secondary negative, in which, by the minimum of exposure and the maximum of development, (together with judicious chemical reduction), the relative contrasts are exaggerated. By such means one is enabled to render visible in the positive, or subsequent engraving, those particular characteristics which would otherwise remain merely records apparent to the eye of the individual privileged to examine the original negative.

It must, however, be evident, that no matter what care is taken, or how expert an individual may become in the handling of copying processes or reducing solutions, used either locally or in "flat" reduction, the resultant positive can not but (under the circumstances) be utterly false in its relative photographic light values. The result is, that except for "form", the new negative or positive is neither a record of visual or photographic relative intensity.

Further advance along the line of photographic plates does not promise a betterment of these conditions, because no matter how much they may be improved, or rendered more adaptable, there will always be nebulous structure, or faint lines, which lie at the extreme limit of the underexposure portion of the characteristic plate curve, while astronomical negatives continue to be made.

Under the assumption then, that conditions in this direction indicate a fair degree of stability, it is advisable that some method of estimating the change in the photographic light value between the later illustration and the original negative be suggested. This is more particularly the case where the photograph purports to be a record of scientific accuracy, and in which relative photographic intensity holds a prominent place.

The alteration in the ratios existing between the densities of a photographic negative due to chemical reduction, was first pointed out definitely in the classical research of Hurter and Driffield;* it is desirable however, that a record be obtained embracing the gradual action of the reducer upon the plate under conditions approximating actual use in astronomical work. A negative was therefore made by development of an exposure in the revolving sector-disk machine, and after measurement in the spectrophotometer its curve was plotted. A standard reducing solution† being then made up, the plate was placed therein, and rocked for 2 min. 30 sec., it was then washed, dried, and again measured and plotted. Subsequent reductions and measurements were now given in three steps of 2 min. each, followed by two further reductions for 3 min. each, and one action for 5 min. The reducing solutions were made up fresh for each operation, and the film was always washed and dried before measurement. The resultant curves are shown in Figure 1 where the heavy continuous line indi-

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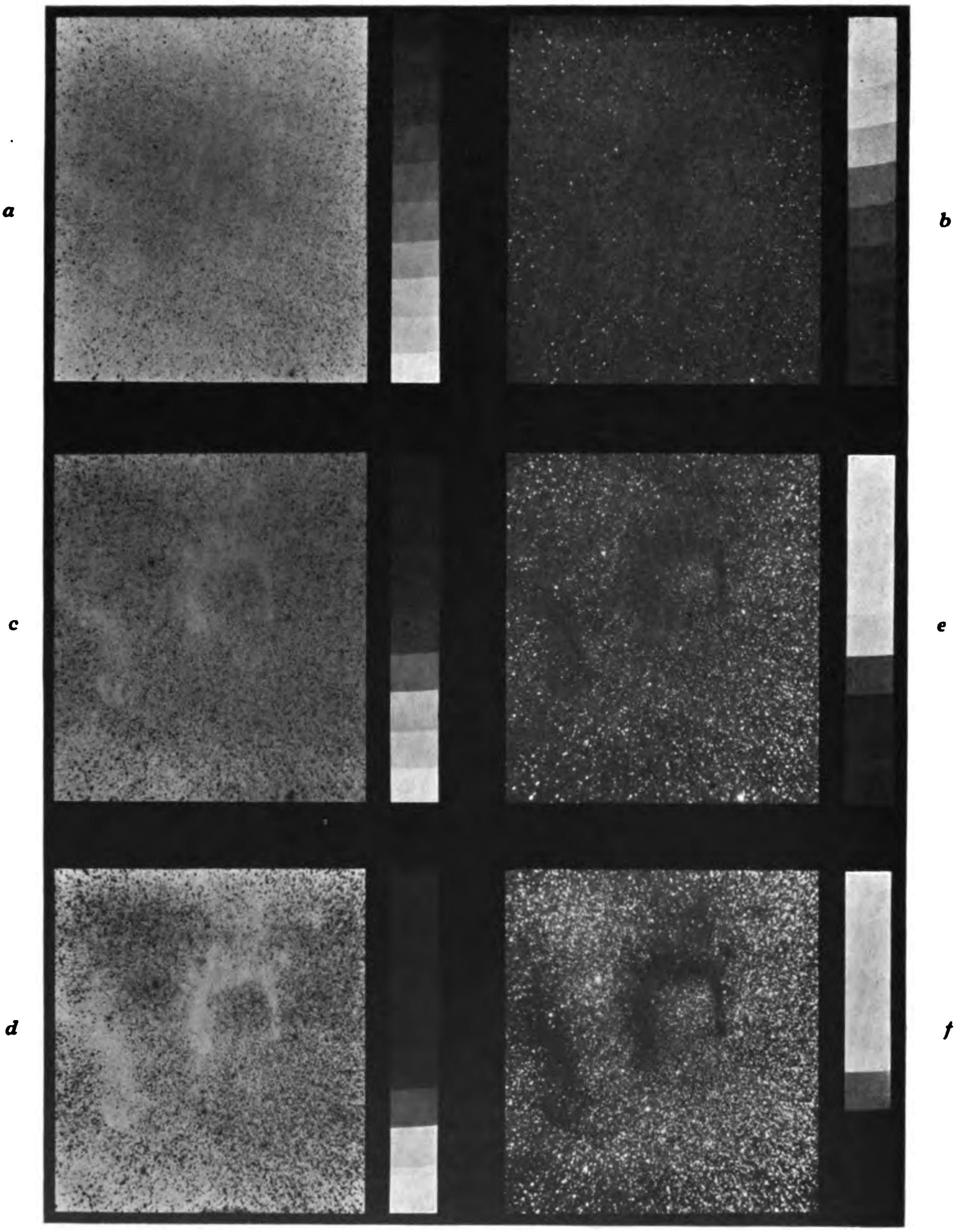
* Jour. Soc. Chem. Industry. May 31, 1890. p. 462.

† Potassium ferricyanide and sodium hyposulphite in proportion of 1:10· 200 cc. combined solution used at a time; size of plate 3¼x1½ inches.

PLATE I.



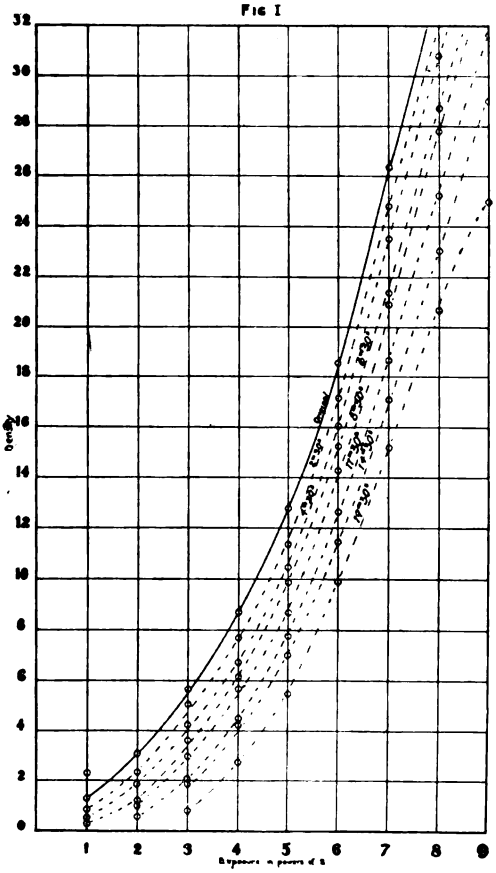
BLACK HOLE IN MILKY WAY.
(R. A. $19^h\ 38^m$ δ 10°46.5)

CHANGE IN RELATIVE LIGHT-VALUES
WITH INCREASE IN CONTRAST.

cates the original negative, and the dotted lines show the action of the reducing solution for the times indicated. The disappearance of the lower densities will be readily marked.

If there should be placed in position adjoining the original, a supplementary small negative containing a scale of densities, and this scale-plate be impressed on all subsequent copies, negative or positive, undergoing precisely the same treatment as does the body of the plate, then the measurement of the scale upon the last plate of the series, will, in conjunction with its original, give a difference which represents the value of the photographic light change.

FIG I



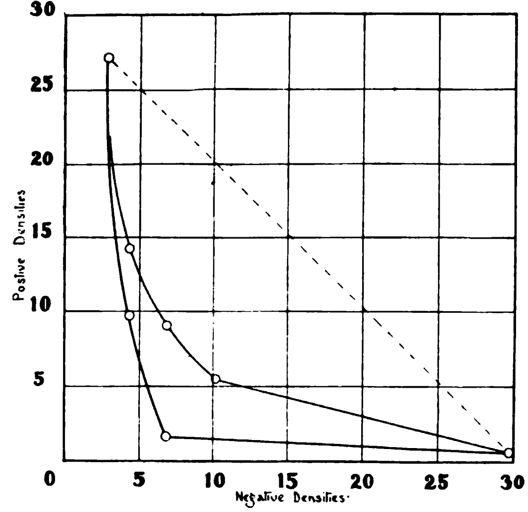
Calling the densities of the original D_1, and those of the same negative after reduction D_2, then the change in the ratios is tabulated thus:

Expos.	D_1	Ratio	D_2	Ratios
1	.1318			
2	.3086			
3	.5624	1.0	.0780	1.0
4	.8720	1.55	.2736	3.51
5	1.2800	2.27	.5454	6.99
6	1.8554	3.30	.9906	12.7
7	2.6354	4.69	1.5184	19.5
8	5.3956 (?)	9.57	2.0644	26.5
9			2.4954	32.0

Were the densities of the reduced negative proportional to the original, then the *ratios* would be similar no matter what the values of the densities.

Referring to the actual employment of the method, there is shown in Plate I (*a*), the original negative* and the original scale plate, together with a positive reproduction of the same

FIG II



(*b*). From this positive was made the secondary negatives *c*, and *d*. For the production of negative *c* a Seed "23" plate was made use of while negative *d* was made upon a Cramer "Transparency" plate, which possesses a higher development factor than the "23". Both plates were developed in a hydrochinone contrast developer, the "Transparency" plate being pushed to the practical limit of chemical action.

Examination of these resulting negatives showed a wide difference in relative contrast and density, which was further

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* My thanks are due to Mr. F. W. Jordan for the use of this negative.

accentuated by reduction with ferricyanide and hypo. Absolutely no local reduction was given, but the action of the solution was allowed to proceed evenly upon the respective plates and which, of course, acted equally upon the adjoining scale-plates. The inclusion of positive plates *e*, *f*, (which are exposed and developed to reproduce as exactly as possible, tones truly the inverse of those in their accompanying negatives) merely serve to illustrate the values obtained.

From measurement of the original scale-plate, and also of that resulting in the secondary and tertiary positives, the accompanying curves were plotted, Figure 2. This method of plotting was first suggested by Hurter & Driffield,* wherein the ordinates represent densities of the *positive*, while the abscissæ correspond to the *negative* densities. As is obvious, (and pointed out by these investigators), if the positive densities be truly the inverse of the negative, then the curve would be represented as a straight line. The amount of departure from the straight line condition indicates the value of the difference.

So long as this method of reproduction is utilized then tremendous shortening of the tone-scale will inevitably follow. Making use of a different type of reducing solution (ammonium persulphate for example) is not allowable on work of this class, because one should then undo a very considerable amount of the effect which was striven for in the exposure and development of the subsequent plates from the original, viz: increase in the underexposure portion of the characteristic curve of the plate. We are purposely and intentionally altering the tone-values because it is just that alteration which is desired. It remains, however, that it would seem advisable that there should be some means of indicating just what change has taken place in the light values, and it follows that such change should be capable of expression, and further, that every illustration serving as a record of scientific data which is printed from, other than the original negative, should bear in such reproduction, a copy of a tone-scale showing both the "before and after" effects, and thus point the way for correction to true values when the knowledge of such values is needful.

Yerkes Observatory.
January 17, 1908.

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* Relation between photographic negatives and their positives. Jour. Soc. Chem. Indust 1891. p. 100.

A NIGHT MIRAGE.

WILLIAM B. SPERRA.

FOR POPULAR ASTRONOMY.

While engaged in the observation of variable stars on the evening of April 3, 1907, a most peculiar and interesting atmospheric phenomenon was noticed by me at 8h 15m. While observing the field U Geminorum, a patch of light in the constellation of Hydra was seen by averted vision, appearing something like a comet or as the Praesepe cluster does to the naked eye. There was a slight haze in the air, plainly perceptible to the eye but which did not interfere with the definition only to blot out the fainter stars.

When first seen it was about a degree due east of δ Hydra. It soon became evident that the star and patch of light were separating, the nebulous light drifting east of the star. or rather, as a few minutes showed it to be stationary, and that it was the diurnal motion of the star that caused the separation. At first it was only nebulous with a somewhat brighter center, but soon became elongated about 2° to 3°, and about 15′ wide. At times it would almost disappear and then suddenly get much brighter, generally with a rift in the center. In the telescope it appeared with two distinct condensations or nebulous knots with nebulosity extending outward in opposite directions, appearing like two comets with tails extending in opposite directions.

As already stated it soon became apparent that this strange light was stationary nearly in the meridian and about the height of the equatorial circle. Settings were made with the telescopes for position. The first setting at 8h 20m showed an approximate position: 3° 18′ E. of meridian and 2° 30′ N. declination. A later setting showed a decrease in the altitude of 2°. At about 9h 17m, a second light (which for convenience we will call B and the first A) appeared 8° 15′ to the W. and 4° 15′ to the S. of the first setting for A, giving for the position of B, 5° 0′ W. of meridian and 2° 15′ declination; but as the declination of A had decreased 2°, the relative difference in declination was only 2° 45′. These equatorial measures reduced to altitude, give for the zenith distances 39° 41′ for A, and 43° 45′ for B.

At first it was puzzling how to account for the apparitions, but they were no doubt reflections of the blast furnaces connected with the rolling mills at Newburg. Usually the light from these furnaces shows as red illumination on the clouds or sky, generally flashing, lighting the southern sky, sometimes half way to the zenith. But not a trace of this was to be seen now.

At 10h 10m the haze had become so dense as to obscure all but the very brightest stars, and when A made its appearance—which occurred at intervals of about twenty-five minutes—it was fully five degrees in length, and the flashes were visible emanating from it. Unfortunately no settings were made at this time, as I had removed the telescope to the house, and so cannot tell which way from the observed position the extention occurred. At 10h 45m it was about ten degrees in length, with many bright patches, but mostly brighter near bottom with sharp central line extending toward the zenith.

There was also a round patch of nebulous light SW. of the zenith. At 9h 45m it was just west and below the Praesepe Cluster. At 10h 25m it was east and above. This was continually visible, and no doubt was due to a similar cause.

While having under consideration a discussion as to the probable cause of the phenomenon, I was favored with a second apparition under slightly different conditions on the night of April 18. There was a dense haze all the evening so that only the very brightest of the stars were visible, thus being different from the night of April 3, except for the concluding observations of that evening. First observation at 8h 20m with Regulus on the meridian, and instrument was oriented by means of this star. First setting gave for A's Dec. 8¾ degrees south, and the hour angle as 3½ degrees east. At first it appeared as a nebulous patch of light, as on the evening of April 3. At 9h two distinct centers appeared four degrees apart, with an extreme elongation of 5½ degrees. The upper half was nearly twice as long as the lower half. Settings gave for the positions of upper and lower centers as —5° and —9° respectively.

At 9h 15m light A appeared triple, extreme length being now 9°. Lower image appears essentially the same at each apparition, and settings show its center to be fixed at about —9°, and all elongations being upward. The upper images appear more linear and run into one another. At 9h 40m A is double and its lower image is quite linear, being two degrees long, measuring one degree on either side of located center. Light B appeared several times, but for an instant only, so no measures could be made of it.

Presuming that this phenomena was a reflection from the lower surface of an air stratum, a preliminary determination for the height of the reflecting surface was made. The furnace A (the origin of light A) is about 4.26 miles south from here. Using the first determination of the zenith distance of A, viz., 39°, the height of the stratum was 2.63 miles. Using the second determination, viz., 41°, the height of the stratum was 2.45 miles, showing that the reflecting stratum fell .18 of a mile between the two observations. Using A's measures on the night of April 18, the height of the reflecting surface was 1.76 miles.

What now was the cause or the conditions that produced these reflections, if such they were. Were they of the order of a mirage, or was the cause similar to that which produces halos? If of the former nature, was the reflection from the under surface of a denser or rarer stratum? That it was from the surface of a denser stratum seems to be indicated from the fact that astronomical definition was good, there being but the slightest scintillation of the stars, and that followed to the zenith. But if so why should the elongations of as much as ten degrees occur? If we suppose this surface to become ruffled in any way, then the elongations are a result of the disturbed surface, for who has not noticed the line of light resulting from the reflection of the Sun on the surface of disturbed water, then again where there was a series of bright patches, each one may have represented a distinct image of the furnace fire, being reflections from an undulatory surface.

A fact that may have an important bearing as to the cause, is that the lowermost image always appeared first, and as it increased in brightness, the others would appear. Then as evidenced from the night of April 18, the lowermost image was stationary, all elongations or multiplications starting from this point, were extended upwards. The elongations and multiplications thus invariably appearing as a function of the increasing brightness and density of the haze. Now if this was a true mirage, though of a compound nature, the upper images should appear similar to the lower, though with relative features reversed; but the fact is they had but little resemblance to the first or lower one, except when it would first appear. When first seen on April 3, while the haze was very light, the image at its brightest with the rift in the center, appeared not unlike a mirrored picture of what was actually taking place at the furnace mouth, flames made up of innumerable incandescent particles pouring forth, usually in two opposite directions.

The conclusion seems to be that the lower image was a true mirage, but that the upper images and extensions were the result of reflections or refractions from ice crystals of which the haze, no doubt, was composed. And, as the haze deepened or became lower, its modifications of the mirage became more intensified so as to alter the character of the reflections, and the lineal effect was the result, as noted in the last observation of the first night.

Cleveland, Ohio.
January 27, 1908.

SOME OPPORTUNITIES FOR ASTRONOMICAL WORK WITH INEXPENSIVE APPARATUS. II.*

GEORGE E. HALE.

Now let us consider the case of the prominences. If we have available a small spectroscope like that admirable little instrument designed by Evershed, or one made by Thorp,† or a still simpler home-made instrument, and attach such a spectroscope to a 4-inch or 6-inch telescope, we have an almost ideal equipment for the observation of the solar prominences. As a matter of fact, an instrument like the 40-inch is wholly unsuited for work of this kind. You will easily see why. If you wish to observe the entire prominence, its image in the focal plane of the 40-inch telescope is usually so large that the slit cannot be opened wide enough to include the prominence without admitting too much light of the sky. Therefore for a study of the general characteristics of prominences, the small instrument has a great advantage over the large one. It was practically out of the question with the 40-inch for us to do systematic visual work on prominences. When the conditions were pecu-

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* A lecture delivered by Professor Hale, Director of the Mount Wilson Solar Observatory of the Carnegie Institution of Washington, at the Royal Astronomical Society, Burlington House, London, W., on Wednesday evening June 26, 1907.

† I wish to call special attention to the solar spectroscopes and other inexpensive instruments made by Mr. Thomas Thorp of Manchester. One of these, a polarizing helioscope, has done excellent service on Mount Wilson.

liarly fine we could study the structure of certain prominences, and I never saw anything more remarkable than such details when they came out under the best seeing. But with the spectroscope available, and under ordinary atmospheric conditions, we could not make records of the general form and distribution of prominences that would compare in value with the records obtainable with small telescopes.

It has remained for certain amateurs here in England very recently to show that objects upon the surface of the Sun which escaped many of the earlier solar observers can be observed at any time when the conditions are favorable with a very small instrument indeed. For example, Mr. Buss and Captain Daunt, and, I believe, some others, have been observing the Sun with such instruments, and have been able to see upon the disk dark regions in which the D_3 line is strengthened, which I think have never been recorded before in any systematic way. Observations of the dark D_3 line upon the face of the Sun were formerly mentioned as unusual and rather remarkable phenomena, and certainly, so far as I have ever seen in the literature of the subject, the dark hydrogen flocculi were never recognized upon the Sun by the earlier spectroscopists; but they are seen, at times at least, by those gentlemen to whom I have referred. This I can make quite certain from my own knowledge, because on one occasion, when Mr. Buss had described one of the very peculiar dark hydrogen flocculi—flocculi of this type appear very much darker than the ordinary ones photographed daily with the spectroheliograph—I looked up our photographs of that date, and there was the image recorded by the spectroheliograph precisely as it had been described. So that if I had previously been a little doubtful as to the possibility of seeing these objects with such an equipment, I gave up all doubt after having made that comparison.* One might say that it would hardly be practicable to observe such phenomena in any satisfactory way with a large telescope. A small one is very much more advantageous for work of this kind. As soon as possible we are going to set up a small equatorial for the purpose of seeing these objects and comparing them with our photographs, after having derived the knowledge of the possibility of observing them from the work done by these men in England. But we will not undertake systematic work in this field, as I hope the valuable ob-

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* As I understand the matter, only the more conspicuous dark flocculi can be observed visually.

servations now in progress here will be continued. No records are made with the spectroheliograph of the D_3 image of the Sun at present. We have tried experiments, but so far they have not been successful. We ought to be able to photograph the Sun through the D_3 line, but we have not done it yet. The only existing records are those made by the members of the British Astronomical Association. These observations should be made in conjunction with other solar observations, as in fact is being done at the present time. The characteristics of the hydrogen lines are being observed at the same time that these D_3 images are being recorded, so that any relationship between the two may be discovered. I cannot dwell upon this very interesting subject. There is a great opportunity here for further work of high importance.

I must now pass to the question of sun-spot spectra. I need hardly tell those who are present that observations of sun-spot spectra made visually are sometimes far more valuable than those which can be made by photographic methods. Take, for example, the lines in the green region of the spectrum. This photograph will suffice to show them. Here is the *b* group in the spectrum of a sun-spot and also in the spectrum of the photosphere. We see in the spot a large number of fine lines, long ago observed by Young and Maunder, and now being studied with great care. All of these fine lines shown by a powerful instrument photographically can be seen visually with a spectroscope attached to a 6-inch or probably a 4-inch telescope, and many other phenomena which cannot be photographed at all can be seen with a similar equipment. There is a certain advantage in observing such spectra with a larger telescope, provided that the spot under consideration is a small one. But if the spot is a fairly large one (and hitherto no one has had time to observe the spectra of small spots systematically) I think there is no advantage whatever in having a telescope to form the image of the Sun on the slit of the spectroscope; it is merely a question of having an image of moderate dimensions upon the slit, and after that the spectroscope does the work. So that, so far as the spots actually under observation are concerned, a small telescope is quite as satisfactory as a large one for *visual* work on their spectra.

I will return in a moment to the question of the relative advantages of the photographic and the visual method of observing spot spectra; but I want to point out in passing that the 40-inch telescope has certain very definite advantages for work on the Sun. If one wishes to observe the spectrum of the chromosphere, for example, the advantages of great focal length immediately become apparent. The width of the spectroscope slit is essentially constant; the chromospheric arc must have a certain linear width on the slit in order to permit the base of the chromosphere to be observed, and consequently the spectrum of the chromosphere, as seen with the 40-inch telescope, is a remarkable sight, showing thousands of lines which do not come out with a small focal image of the Sun.

Here we have, then, an illustration of the advantages for certain purposes of considerable focal length. I think it is not so much a question of the telescope's aperture here, because we must not forget, in thinking of the optics of this question, that the brightness of the spectrum (for constant purity) is quite independent of the linear or the angular aperture of the object-glass that forms the image of the Sun, on the slit of the spectroscope.* Perhaps it is well to bear in mind that the brightest solar spectrum one can get is obtained without any telescope whatever to form an image on the slit, but merely with a collimator of suitable angular aperture. But a large solar image is frequently advantageous, and an equatorial telescope of great focal length is necessarily an expensive instrument. The aperture in the case just mentioned is less important than the focal length; but even if the aperture were only 6 inches the focal length unchanged, the tube must still be 64 feet long, and the mounting would cost no less than the mounting of the Yerkes telescope. So if we wish to have an instrument of great focal length, and yet keep down the expense to a reasonable figure, we must use a telescope of a different type. There are many other reasons why we should wish to use a fixed telescope for certain kinds of solar work, although I should be the last to admit that the 40-inch telescope is not an almost perfectly satisfactory machine of its kind. It has, as we have seen, inconveniences and disadvantages for some classes of work, but in other fields its superior qualities become more and more striking day after day as the observer learns to appreciate them. I only wish

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* When the focal length of the collimator is limited (as is usually the case in a spectroscope attached to an equatorial telescope), an increase in the angular aperture of the telescope permits the linear aperture of the spectroscope, and consequently the resolving power and the brightness of the spectrum, to be increased up to a limit fixed by the size of the grating available. With a cœlostat telescope, however, the same conditions do not obtain, since the aperture of the spectroscope can be increased by merely increasing the focal length of the collimator.

we could afford to have such a telescope (or even a much smaller equatorial refractor) on Mount Wilson, as it would be of great service for many purposes.

Now let us consider some of the possibilities of the fixed telescope; and let me show, for purposes of comparison, a picture on the screen of the Snow telescope and which is now employed at Mount Wilson. Here is a cœlostat, with mirror 30 inches in diameter. After passing to a second mirror the light is reflected to a concave mirror of 60 feet focal length, which sends it back and forms a large image of the Sun within a laboratory. This is a very simple instrument indeed. The first cœlostat we set up on Mount Wilson was a small one used by the Yerkes Observatory party at the eclipse of 1900, and it was not originally arranged for work of this kind; so we simply built a wooden support for a second mirror, and with the aid of a 6-inch objective of 60 feet focal length we made a telescope which served admirably for our solar work until this one was put on the mountain.

The next photograph shows the spectrograph used with the Snow telescope. It is of the Littrow or auto-collimating type, with slit and plate-holder at one end of a long tube and lens and grating at the other. Light from the solar image, after passing through the slit, falls on the lens 18 feet (its focal length) distant. The rays, thus rendered parallel, then strike the grating and are returned to the lens, which forms an image of the spectrum on the photographic plate, just above the slit (the grating being tipped back a little). Such an outfit (fixed telescope and spectrograph) is an extremely simple thing to build in inexpensive form. Cœlostats, for example, are common nowadays for eclipse work. One might have a cœlostat with a mirror only six inches in diameter and a second mirror about four inches in diameter, and then perhaps a telescope lens of four inches aperture and 40 feet focal length. Such an instrument as that, which could be very cheaply built indeed, would give a large solar image, adapted for many kinds of solar work.

Let me show you in the next slide how we build our spectrographs in actual practice. This is the most powerful spectrograph in use in the laboratories of the Solar Observatory. Here is a little slit I bought from Hilger, the last time I was in London, for a few shillings. All other parts of the spectrograph, except a lens and grating, are of wood, built in a few hours by a carpenter.* The wooden support for slit and plate-holder stand on a concrete pier, and close an opening through a partition which forms one end of a narrow dark room. Eighteen feet from the slit, within the dark room, is another concrete pier. A sliding wooden support, carrying a lens, and a simple wooden mounting for the grating, stand on this pier, and complete the spectrograph. Owing to the scarcity of gratings, we are fortunate in being able to use one loaned by Professor Ames, of Johns Hopkins University. If we had no reflecting grating, we could buy a replica very cheaply from Thorp, or Wallace, or Ives,† which would give quite as good photographs as we obtain now (though the exposures would be longer, because of the smaller aperture). They might even be better, because our photographs of spot-spectra (made with the similar spectrograph of the Snow telescope) are not what they ought to be, or what I hope they will subsequently become. They would not stand comparison for a moment, so far as perfection of definition is concerned, with those magnificent photographs of the solar spectrum made by Mr. Higgs in the center of Liverpool, under conditions which would ordinarily be called very bad even for a crowded city, with tram-cars constantly passing in front of the house. With a spectrograph of his own construction (except the grating), Higgs made the finest photographs of the solar spectrum ever produced; superior, as Rowland would have said, to the best photographs made by himself at the Johns Hopkins University. It is obvious that something other than an expensive instrument is required to make a good photograph. Mr. Higgs has the ability, which others may acquire, to obtain superb definition and exquisite photographs with very simple apparatus indeed.

With a spectrograph of one-inch aperture and ten feet focal length, used with a fixed telescope of four inches aperture and 40 feet focal length, one would be in a position to make good photographs of the spectra of sun-spots.

What, then, are the relative advantages of visual and of photographic work? The next slide shows some photographs.

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* Except the plate-holder which is of a standard make.

† As these are not reflecting gratings the auto-collimating spectrograph might in this case give way to one in which a separate camera lens is used. With the angular aperture here considered, well-made simple lenses would obviously serve perfectly well for collimator and camera, the photographic plate being set at the angle required to bring a sufficient range of spectrum into focus.

The upper one is the spectrum of the Sun and the lower one is that of a spot. These photographs are better than visual observations for the determination of the wave-lengths of unknown lines in spot spectra, simply because you can measure the position of a line on the photograph to much better advantage than you can do it visually at the telescope. They are also better for the determination of the relative intensities of the lines, especially the fainter ones. But when you have said that, you have said almost everything that can be said for the photographs, and you have left out of account many of the very important advantages of visual observation. These photographs represent the integrated spot spectrum, as it were. Even with a large image of the spot on the slit of the spectrograph (and you realize here that the principal point of our great focal length is to have a large image of the spot on the slit), we cannot as yet satisfactorily record minute differences in the spectrum corresponding to small details in the spot. If we wish to study these very important differences in the spot, we must do so, at present at any rate, by visual means. For example, Mr. Newall, your President, told me the other day that he had found the spectrum of the outer edge of the penumbra of a spot to have the same characteristic strengthening of the lines that is observed to the umbra, which is a very difficult thing to explain from the standpoint of the hypothesis I have been favoring of late, viz., that the principal cause of the change of the relative intensities of lines in a spot is reduced temperature of the vapors in the umbra. I knew nothing about that; I had not been observing the spot spectrum visually for many years, and in our photographs this phenomenon is not recorded. You see, then, in such a case the decided advantage of visual observations. I might go on to speak of other advantages. For example, suppose there were a sudden change in the spectrum due to an eruption; the chances that one would get a photograph just at that time are small, whereas visual observations necessarily occupy a considerable period of time, during which eruptions might be detected*. Even a few results might be of extreme importance, and would probably be wholly missed in the photographs. Again, the extension of certain lines outside of the

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* It is, of course, desirable to take photographs as often as possible, since a photographic record of a marked change in the spectrum, if fortunately obtained, may be much more valuable than the results of a few visual observations made hastily.

spot, upon the photosphere is not recorded at all in our photographs, because of the method we usually employ of excluding from the plate all light except that which comes from the umbra, and perhaps part of the penumbra. We ordinarily get no trace of these extensions, but perhaps the conclusions drawn from the study of such phenomena may have much to do with the final views as to the nature of the spots themselves.

To mention only one other thing, the reversals of spot lines which have been seen by some observers have not been photographed with our present apparatus. Whether they can be photographed in the future remains to be seen. But, without going into this subject of spot spectra any more in detail, you will certainly agree that the visual observer has a superb opportunity, which the photographic observer cannot by any possibility take away from him.

To be continued.

ASTRONOMY IN 1907.

"Accurate and scientific measurement," observed Sir David Gill, in his Presidential Address to the British Association at Leicester, "seems to the non-scientific imagination a less lofty and dignified work than looking for something new. But nearly all the greatest discoveries of Science have been the reward of accurate measurement and patience, long-continued labor in the minute sifting of numerical results." To the astronomer who spends little time in looking for something new, and a great deal of labor in mathematical reductions, these words will appear a truism; but they would be his apology if he felt it necessary to offer one, for the unsensational character of the year's work in 1907, or in most years. The year was marked by the appearance of five comets, the popular test of astronomical research; by a rich crop of sun-spots; and by an opposition of Mars, which enabled Professor Lowell to assert once again his belief in the objectivity of the doubled Martian Canals. Saturn showed the edge of its rings; and Jupiter was well placed for observation; but otherwise, if we except the opportunities afforded by Sir David Gill's address, the astronomer was not much before the public. A few sentences must be spared for a summary of the address of the Cape Astronomer. He supported his thesis of the importance of accurate measurement, by a reference to the recent measurement, of the wave-length of the red line in the spectrum of cadmium; and by showing its importance in furnishing a unit of measurement which appeared to be trustworthy within the one ten-millionth of a metre. He showed the importance of an accuracy of this order when dealing with the problem of measuring a great arc of meridian, such as that which is now drawing to completion in Africa, and which may sometime be joined to Struve's great arc. Other instances which he supplied, had reference to the measurement of the Sun's distance; of observations of Eros; and to the measurement of the speeds of the Sun and of the stars in space. With regard to the Eros observations, it should be noted that the last "circular" (grown to a bulky volume of 150 pages) was circulated in July. The thanks of all astronomers are due to the late M. Loewy (M. Loewy died suddenly in October, immediately after attending a scientific meeting) and the French Government, for their energy and generosity in this matter. From the circular it appeared that fifty-eight observatories took part in the observations. The number of reference stars was 671, and the observations of these numbered in all 35,398; the observations of Eros numbered 6,642. If to these are added the photographic observations of Eros, as well as of the 671 reference stars, and of the 962 comparative stars, we arrive at a grand aggregate of 76,186 observations.

"By patient, long-continued labor in the minute sifting of numerical results the grand discovery has been made that a great part of space, so far as we have any visible knowledge of it, is occupied by two majestic streams of stars traveling in opposite directions. Accurate and minute measurement has given us some certain knowledge as to the distances of the stars within a certain limited portion of space, and in the cryptograms of their spectra has been deciphered the amazing truth that the stars of both streams are alike in design, alike in chemical constitution, alike in process of development." The long-continued labor was not only that of the two astronomers we have named, but also that of the eighteenth and nineteenth century astronomers, Bradley and Groombridge, whose star atlases have furnished the means of comparison with star positions in the twentieth century. The astronomical discoveries of next century, perhaps incomparably greater than those of today, will depend similarly on the faithfulness and painful accuracy of the astronomers now living. It remains to add only that some of Kapteyn's earlier deductions regarding the movements of the stars have not been confirmed (as is remarked by Mr. W. Bryant, in his "History of Astronomy", published in October), but that the hypothesis of the intersecting streams of the stellar universe has found wide acceptance.

The solar eclipse of January 14th has added little to astronomical knowledge because the points at which it could be profitably observed were too difficult of access to encourage expeditions, but several reports of it have come in. The New Year began with a legacy of sun-spot activity from the previous year. Another great group followed an extensive Northern group, and January ended with a larger extent of spotted area than when it began. February opened with seven groups, bequeathed from January, and from the 4th to the 11th-12th there were four great groups separately visible to the naked eye. There was another group on February 19th, March showed a falling off from the great activity of January and February, and an epoch of recovered solar activity, which had begun in November, 1906, may be said to have ended in this month. There were in March, numerous groups during the first four or five days, and there were six returns of other spots. In April the Sun was on no day free from spots, and there were three groups, inherited from March on the Northern Hemisphere. May was freer than April, as April had been freer than March, but two returning groups of spots were large enough to be visible with the naked eye. June's record was practically the history of a single group, which was, however, one of the finest groups of the contemporary maximum. It consisted of a straight and almost continuous stream made up of three very large spots, nearly equal in size, and close to each other, followed by a multitude of small attendants. The leader was the best defined, and was nearly circular. The last was barred by bright bridges. In July the area of sun-spots greatly decreased, though the June spot returned in much diminished magnificence. Mrs. E. W. Maunder followed up Mr. Maunder's researches on the magnetic influence of sun-spots and its causes, by a paper which appeared to suggest that the Earth itself exerted some reciprocal influence on sun-spots, and the data which led to this conclusion are still under consideration. Father Cortie, in an article in the *Astrophysical Journal*, discussing the variability in the light of Mira Ceti in relation to the evidence which it affords respecting the relative temperature of sun-spot vapors, came to the conclusion that the temperature of sun-spots was lower than that of the solar photosphere.

Five comets were noted during the year. Giacobini's, noted by Giacobini, at Nice on March 9th, as of about the 11th magnitude; Grigg's, noted by Mr. John Grigg, of Thoms, New Zealand, on April 9th; another comet noted by Giacobini, as about the 13th magnitude, on June 1st; Daniel's comet, the most important of the year, which was first seen by Professor Daniel, of Princeton Observatory, U. S. A., on June 10th, and which was nearest to the Earth on August 1st, and brightest on August 21st; and Mellish's comet, discovered by Mrs. Mellish, on October 13th. Mellish's comet had several points of interest, approaching within twenty million miles of the Earth on November 11th, and being then visible in small telescopes.

Mars occupied the post of observational honor during 1907 though the opportunities of examining the Great Red Spot of Jupiter, the rings of Saturn, and the transit of Mercury were of great astronomical interest. A beaded appearance of Saturn's rings was remarked. As usual, Mars was the arena of controversy as to the nature and implications of its canals. Professor Simon Newcomb wrote an elaborate article to show that if all the 380 canals which have been charted on Mars were real, they would occupy a disproportionately large portion of the surface of Mars. He also made some interesting mathematical calculations as to the width which a Martian canal would have to be in order to be visible to observers with terrestrial telescopes, and suggested new tests of observation.

Professor Lowell, in an answer in the *Astrophysical Journal* to Professor S. Newcomb's criticisms, contended that the Martian canals needed a width of only fifteen miles for visibility, and that in the aggregate they need occupy, therefore, only one-tenth the planet's area.

Professor Lowell supplemented his rejoinder by the publication of the report of the expedition which was sent out during the year at his expense to Alianza, near Iquique, in Northern Chili, where it was believed that better conditions of vision would be secured. The expedition was equipped with a new 18-inch Clark refractor, and Professor Todd reported that with excellent conditions of seeing from June 18th to August 1st, many valuable photographs were obtained, which showed as many as twenty canals in one photograph. Numerous "double canals" were also photographed, including Euphrates, Thoth, Eumenthes, Gihon, Astabour, Phison, and Nilokeras. Apart from this aspect of Mars, Professor Lowell, in addition to an interesting popular work on the planet, published an essay on the climate of Mars, in which he demonstrated with considerable plausibility that the temperature was not too low to support animal life. Among other papers and essays published during the year, which claim attention, were those of W. W. Coblenz and F. W. Very, on the temperature of the Moon (—225 C.); some new spectroheliograph work by Professor Hale, in the direction of solar photography with sun-spot lines; J. J. Lunt, on the presence of tin in stellar atmospheres; W. L. Elkin of Yale, on stellar parallaxes of ten stars of the 1st magnitude in the northern sky. We may also note the extension of Solon I. Bailey's catalogue, now including 1,173 stars in all, and a paper by E. Strongren and V. Heinrich, on the 2nd and 3rd Asteroids near Jupiter.

Professor Trowbridge, on a consideration of the reputed instances of the so-called meteor trains, came to the conclusion that the phosphorescence was dependent on the gas pressure of the strata where incandescence takes place. Professor Trowbridge also wrote an interesting essay on the character of "ball lightning."

Professor Seeliger having called attention to the absence on the photographs taken at the last eclipse of any indication of the existence of an intra-Mercurial planet, concludes that the mass of meteorites and meteoric dust in the solar system is sufficient to account for some unexplained planetary perturbations.

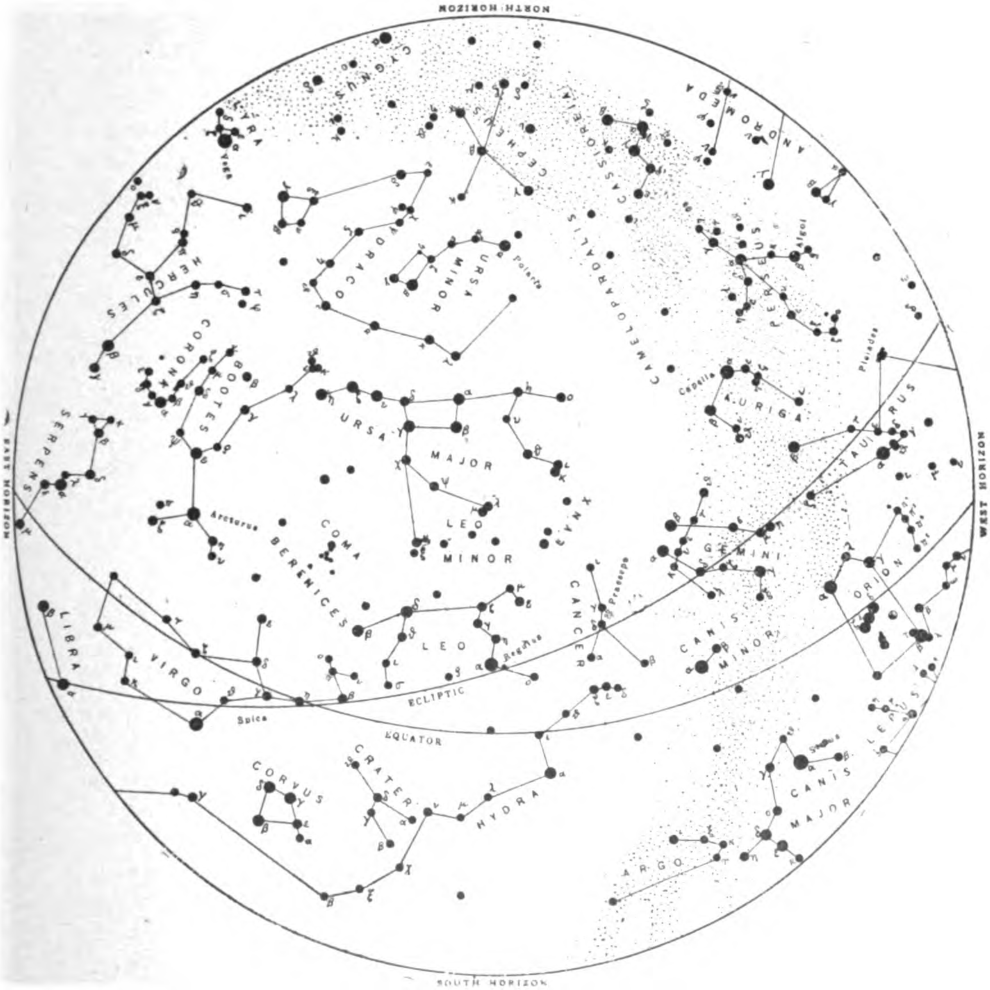
We may note also Professor Barnard's examination of a new theory on the cause of lanes and striations of blackness among the stars; Professor Pickering's investigations of the volcanoes of Hawaii, and his deductions as to the methods of formation of the craters of the Moon; and another paper by the same author, in which he suggested that the Moon before it was torn away from the Earth was in touch with the space now occupied by the South Pacific Ocean. Professor Poynting's suggestion, that Saturn's rings may represent the capture of a comet or cometary trains; and Professor Simon Newcomb's investigations of the irregularities of the movement of the Moon were of first-class importance.

SCIENCE YEAR BOOK 1908.

PLANET NOTES FOR APRIL 1908.

H. C. WILSON.

Mercury will be morning star during April but will be invisible to the naked eye except on the first three or four days. Mercury and Saturn will be in conjunction on April 14, Mercury being 28′ south of Saturn at 3 P. M., Central Standard Time.



THE CONSTELLATIONS AT 9:00 P. M., APRIL 1, 1908.

Venus during February has been very brilliant in the western sky in the early evening, and will increase rapidly in brightness during March and April. The phase of the planet will be slightly gibbous at the first of the month but will decrease to a little less than half full during the month Venus and Mars will be in conjunction on April 4 at 9 A. M., Central Standard Time, the former being then 1° 37′ north of the latter. Venus will be at greatest elongation, east from the Sun 45° 37′ on April 26. The planet will then be over 26° north of the equator, so that the position will be most favorable for the study of the surface markings. Little is known of the surface of this most brilliant of all the planets which seems to be enveloped in almost perpetual clouds, so that only the vaguest of markings can be detected. The present opportunity for study is one that should not be neglected by those who have the best of telescopes at their disposal and suitable atmospheric conditions.

Mars is way past the best position for observation for this year but may still be seen in the early evening. Its course for this month lies through Taurus. The conjunction with Venus has been mentioned in the preceding paragraph.

Jupiter vies with Venus in brilliancy on these clear winter nights but cannot equal his fair neighbor. Jupiter is nearly overhead at 8 P. M., while Venus is then well down toward the west Jupiter will be stationary on March 30, having finished his retrograde motion, and during the spring and summer will move eastward through Cancer into Leo. The planet will be at quadrature, 90° east from the Sun, April 24.

Saturn having just passed conjunction with the Sun is not in position for observation during April.

Uranus will be at quadrature 90° west from the Sun, April 6 and will be stationary in right ascension in Sagittarius April 21.

Neptune will be at quadrature, 90° east from the Sun, April 1 and may be found with the aid of a good telescope in the constellation Gemini in the early evening. Its position April 1 will be in right ascension $6^h\ 52^m\ 11^s$, declination north 22° 6′.

Occultations visible at Washington.

Date 1908		Star's Name	Magnitude.	IMMERSION. Washington M.T. h	m	Angle f'm N. °	EMERSION. Washington M.T. h	m	Angle f'm N °	Duration h	m
Apr.	5	*l* Tauri	5.2	9	25	129	10	10	224	0	45
	6	141 Tauri	6.3	9	54	34	10	27	332	0	33
	8	B.A.C. 2544	6.3	7	26	64	8	36	320	1	10
	9	39 Cancri	6.5	11	34	157	12	20	241	0	46
	9	40 Cancri	6.5	11	44	168	12	19	231	0	35
	13	ν Virginis	4.2	6	46	110	8	4	306	1	18
	23	27 Capricorni	6.1	17	6	112	18	1	208	0	55
	24	29 Aquarii	6.5	14	18	80	15	20	256	1	2

Phenomena of Jupiter's Satellites.

Central Standard Time, reckoning from noon.

		h	m			
Apr.	1	8	18	II	Sh.	Eg.
		8	42	I	Tr.	In.
		9	53	I	Sh.	In.
		11	2	I	Tr	Eg.
		12	14	I	Sh	Eg.
	2	9	22	I	Ec	Re.
		11	7	III	Tr.	In.
	3	6	15	IV	Oc.	Dis.
		6	42	I	Sh.	Eg.
		11	2	IV	Oc.	Re.
Apr.	6	9	27	III	Ec.	Re.
		11	8	II	Oc.	Dis.
	8	7	59	II	Sh.	In
		8	24	II	Tr.	Eg.
		10	34	I	Tr.	In.
		10	55	II	Sh.	Eg.
		11	48	I	Sh.	In
		12	54	I	Tr.	Eg.
	9	11	18	I	Ec.	Re
	10	6	17	I	Sh.	In

Phenomena of Jupiter's Satellites.—Continued.

	h	m					h	m			
Apr. 10	7	22	I	Tr.	Eg.	Apr. 18	7	42	I	Ec.	Re.
	8	37	I	Sh.	Eg.	20	8	38	III	Oc.	Dis.
12	6	58	IV	Sh.	Eg.		11	52	IV	Ec.	Dis.
13	8	24	III	Oc.	Re.		12	19	III	Oc.	Re.
	9	53	III	Ec.	Dis.	22	10	34	II	Tr.	In.
15	8	1	II	Tr.	In.	24	7	39	III	Sh.	Eg.
	10	37	II	Sh.	In.		8	49	I	Tr.	In.
	10	57	II	Tr.	Eg.		10	6	I	Sh.	In.
	12	27	I	Tr.	In.		10	54	II	Ec.	Re.
16	9	38	I	Oc.	Dis.		11	10	I	Tr.	Eg.
17	6	55	I	Tr.	In.		12	27	I	Sh.	Eg.
	8	12	I	Sh.	In.	25	9	37	I	Ec.	Re.
	8	19	II	Ec.	Re.	26	6	56	I	Sh.	Eg.
	9	15	I	Tr.	Eg.	28	8	10	IV	Tr.	In.
	10	32	I	Sh.	Eg.						

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

COMET NOTES.

Ephemeris of Encke's Comet.

[Continued from page 113.]

1908	α app. h	m	s	δ app. °	′	log r	log Δ	Aber. Time m	s
April 1	1	43	59	+17	2.2	9.8884	0.2139	13	36
2		46	27	17	18.0	8782	2090		27
3		50	59	17	33.3	8677	2041		17
4		54	36	17	49.0	8568	1989	13	8
5	1	58	18	18	5.2	8456	1936	12	59
6	2	2	1	18	21.2	8341	1882		49
7		5	52	18	35.4	8222	1826		39
8		9	49	18	49.3	8100	1767		28
9		13	50	19	3.7	7975	1705		18
10		17	56	19	18.0	7845	1641	12	7
11		22	7	19	31.8	7711	1577	11	57
12		26	24	19	45.2	7573	1508		46
13		30	47	19	58.1	7432	1436		34
14		35	15	20	10.4	7288	1361		22
15		39	48	20	21.5	7139	1284	11	10
16		44	25	20	32.1	6987	1204	10	58
17		49	6	20	41.8	6833	1119		45
18		53	53	20	50.5	6675	1029		32
19	2	58	46	20	57.9	6516	0935		18
20	3	3	41	21	3.7	6358	0837	10	5
21		8	33	21	7.5	6201	0735	9	51
22		13	24	21	9.2	6047	0628		36
23		18	16	21	8.8	5899	0514		21
24		23	3	21	6.1	5759	0393	9	6
25		27	42	21	0.4	5631	0266	8	50
26		32	14	20	51.8	5517	0.0133		34
27		36	31	20	40.1	5423	9.9994		18
28		40	32	20	24.2	5350	9850	8	2
29		44	12	20	4.7	5304	9699	7	45
30	3	47	28	+19	41.4	9.5284	9.9543	7	29

VARIABLE STARS.

The Variable 136.1907 Andromedæ.—This variable appears to have a period of about 35 days.

In *A.N.* 4229 Mr. A. A. Nijland of Utrecht gives the following ephemerides of minima in the first part of 1908:

Period $34^{d}.79$		Period $34^{d}.95$		
1908 Jan. 29	7^{h}	1908 Jan. 29	11^{h}	Gr. M. T.
Mar. 4	2	Mar. 4	10	
Apr. 7	21	Apr. 8	9	
May 12	16	May 13	7	

Mr. Nijland gives the normal brightness as $10^{m}.7$ ($0^{m}.5$ fainter than BD 42°29) and the minimum $12^{m}.2$ or $0^{m}.2$ fainter than a star which is $1'.3$ north of the variable.

New Variable 182.1907 Draconis.—In the study of his observations of RW Draconis Dr. Hartwig finds that one of the comparison stars used is a long period variable. The star is missing from the Bonn DM but in December 1907 had a magnitude of 8.7. Its place is

	h	m	s	°	′	″
1855	16	32	59.15	+ 57	53	48.5
1900	16	33	47.59	+ 57	48	15.4

RW Tauri.—In *A. N.* 4229 Professor E. Hartwig gives the following elements of this antalgol variable, which completely satisfy his observations on December 17, 1907.

$$\text{Max.} = 2417407.27917 + 0^{d}.442938\ E.$$

Approximate Elements of Seven Variable Stars.—In *A. N.* 4223 Mr. Sigurd Enebo of Dombaas, Norway, gives the following approximate elements of seven of the variable stars discovered in 1907.

						Mag.
65.1907 Cassiop.	Max.	=1907 Aug. 20	21^{h}	Gr.M.T.	$+5^{h}\ 13^{m}$ E	9.0 — 9.7
		=2417808.88		"	$+5^{d}.54$ E	
68.1907 Persei	Min.	=1907 Oct. 8	7^{h}	"	$+2^{d}15^{h}31^{m}$E	9.1—<10.5
		=2417857.29		"	$+2^{d}.648$ E	
132.1907 Lacertae	Max.	=1907 Sept. 4	9^{h}	"	$+10^{d}\ 17^{h}$ E	8.2 — 9.0
		=2417823.38		"	$+10^{h}.7$ E	
133.1907 Lacertae	Max.	=1907 Sept. 17	8^{h}	"	$+6^{d}\ 12^{h}$ E	8.5 — 9.2
		=2417836.33		"	$+6^{d}.5$ E	
39.1907 Camelop.	Max.	=1907 Oct. 8 (2417857)			$+16.^{d}$ E	8.2 — 9.4
43.1907 Draconis	Max.	=1907 Sept. 26	$6^{h}\ 30^{m}$	"	$+0^{d}\ 9^{h}\ 33^{m}$ E	8.9 — 9.6
		=2417845.27		"	$+0^{d}.3978$ E	
73.1907 Persei	Max.	=1907 Sept. 11 (2417830)			$+11^{d}.2$ E	8.8 — 9.6

(65.1907 = SW Cassiop.)

Two New Variable Stars 1 and 2.1908.—These were discovered by Mr. Sigurd Enebo of Dombaas, Norway, and are announced in *A. N.* 4229. Their positions for 1855 are

	h	m	s	°	′	″
1.1908 Geminorum	$\alpha = 6$	31	14.9	$\delta = +31$	19.0	
2.1908 Persei	4	00	53.06	41	49	27.9

The first is BD + 31°1380 ($9.^{m}2$). From March to December 1906 it was invisible with a telescope of 70^{mm} aperture. On Dec. 24 1906 it was about 9.5 magnitude. On April 12, 1907 in was again invisible with a telescope of 108^{mm} aperture and has not been visible since that time. The period is long, possibly about 20 months. The next maximum will be expected about August 1908.

The second star is BD + 41°824 ($8^m.5$) and varies between 8.4 and 9.6 magnitude. The period is about 160 days, approximate elements being:

Max = 1905 Dec. 9 (2417189) + 160^d E.

The color of the star is yellowish red.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei		
	d	h
Apr.	1	20
	4	8
	6	20
	9	8
	11	19
	14	7
	16	19
	19	7
	21	19
	24	7
	26	18
	29	6
RZ Cassiop.		
Apr.	2	8
	3	13
	4	17
	5	22
	7	3
	8	7
	9	12
	10	17
	11	21
	13	2
	14	7
	15	11
	16	16
	17	21
	19	2
	20	6
	21	11
	22	15
	23	20
	25	1
	26	6
	27	10
	28	15
	29	20
	31	0
RX Cephei		
Apr.	28	13
Algol		
Apr.	3	1
	5	22
	8	19
	11	16
	14	12
	17	9
	20	6
	23	3
	26	0
	28	20

RT Persei		
	d	h
Apr.	1	5
	2	2
	2	22
	3	19
	4	15
	5	11
	6	8
	7	4
	8	1
	8	21
	9	17
	10	14
	11	10
	12	6
	13	3
	13	23
	14	20
	15	16
	16	12
	17	9
	18	5
	19	2
	19	22
	20	18
	21	15
	22	11
	23	8
	24	4
	25	0
	25	21
	26	17
	27	13
	28	10
	29	6
	30	3
	30	23
λ Tauri		
Apr.	4	2
	8	1
	12	0
	15	22
	19	21
	23	20
	27	19
RW Tauri		
Apr.	2	15
	5	9
	8	4
	10	22
	13	17

RW Tauri		
	d	h
Apr.	16	11
	19	6
	22	0
	24	19
	27	13
	30	7
RV Persei		
Apr.	1	13
	3	12
	5	11
	7	11
	9	10
	11	10
	13	9
	15	8
	17	8
	19	7
	21	6
	23	6
	25	5
	27	4
	29	4
RW Persei		
Apr.	5	6
	18	11
RS Cephei		
Apr.	2	17
	15	3
	27	13
RW Geminorum		
Apr.	1	7
	4	4
	7	1
	9	22
	12	19
	15	16
	18	12
	21	9
	24	6
	27	2
	29	23
RW Monoc.		
Apr.	1	10
	3	8
	5	6
	7	3
	9	1
	10	23
	12	21
	14	18

RW Monoc.		
	d	h
Apr.	16	16
	18	14
	20	12
	22	10
	24	7
	26	5
	28	3
	30	1
RU Monoc.		
Apr.	1	1
	1	23
	2	20
	3	18
	4	15
	5	13
	6	10
	7	8
	8	5
	9	3
	10	0
	10	22
	11	19
	12	17
	13	14
	14	12
	15	9
	16	7
	17	4
	18	2
	18	23
	19	21
	20	18
	21	16
	22	13
	23	11
	24	8
	25	6
	24	3
	27	1
	27	22
	28	20
	29	17
	30	15
R Canis Maj.		
Apr.	1	6
	2	9
	3	12
	4	15
	5	19
	6	22
	8	1

R Canis Maj.		
	d	h
Apr.	9	5
	10	8
	11	11
	12	14
	13	18
	14	21
	16	0
	17	3
	18	7
	19	10
	20	13
	21	16
	22	20
	23	23
	25	2
	26	6
	27	9
	28	12
	29	15
	30	19
Y Camelop.		
Apr.	3	4
	6	11
	9	19
	13	2
	16	10
	19	17
	23	0
	26	8
	29	15
RR Puppis		
Apr.	5	10
	11	21
	18	7
	24	17
V Puppis		
Apr.	1	10
	2	21
	4	8
	5	19
	7	6
	8	17
	10	4
	11	15
	13	2
	14	12
	15	23
	17	10
	18	21
	20	8

Minima of Variable Stars of the Algol Type.—Continued.

V Puppis

	d	h
Apr.	21	19
	23	6
	24	17
	26	4
	27	15
	29	2
	30	12

X Carinæ

	d	h
Apr.	1	0
	2	2
	3	4
	4	6
	5	8
	6	10
	7	12
	8	14
	9	16
	10	18
	11	20
	12	22
	14	0
	15	2
	16	4
	17	6
	18	8
	19	10
	20	12
	21	14
	22	16
	23	18
	24	20
	25	22
	27	0
	28	2
	29	4
	30	6

S Cancri

	d	h
Apr.	2	22
	12	10
	21	22

S Velorum

	d	h
Apr.	3	10
	9	8
	15	7
	21	5
	27	4

RR Velorum

	d	h
Apr.	1	1
	2	21
	4	18
	6	14
	8	11
	10	7
	12	4
	14	0
	15	21
	17	17
	19	14
	21	10
	23	7
Apr.	25	3
	27	0
	28	20
	30	17

Z Draconis

	d	h
Apr.	1	0
	2	8
	3	17
	5	1
	6	10
	7	18
	9	3
	10	12
	11	20
	13	5
	14	13
	15	22
	17	6
	18	15
	20	0
	21	8
	22	17
	24	1
	25	10
	26	19
	28	3
	29	12
	30	20

RZ Centauri

	d	h
Apr.	1	19
	2	17
	3	16
	4	14
	5	13
	6	11
	7	10
	8	8
	9	7
	10	5
	11	4
	12	2
	13	1
	14	22
	15	20
	16	19
	17	17
	18	16
	19	14
	20	13
	21	11
	22	10
	23	8
	24	7
	25	5
	26	4
	27	2
	28	1
	28	23
	29	22
	30	20

SS Centauri

	d	h
Apr.	1	20
	4	8
	6	19
	9	7
	11	18
	14	6
	16	17
	19	5
	21	16
	24	4
	26	15
	29	3

δ Libræ

	d	h
Apr.	2	18
	5	1
	7	9
	9	17
	12	1
	14	9
	16	17
	19	1
	21	8
	23	16
	26	0
	28	8
	30	16

U Coronæ

	d	h
Apr.	3	15
	7	3
	10	13
	14	0
	17	11
	20	22
	24	8
	27	19

R Aræ

	d	h
Apr.	2	9
	6	19
	11	5
	15	16
	20	2
	24	12
	28	22

U Ophiuchi

	d	h
Apr.	1	11
	2	7
	3	4
	4	0
	4	20
	5	16
	6	12
	7	8
	8	4
	9	0
	9	21
	10	17
	11	13
	12	9
	13	5
	14	1
Apr.	14	21
	15	17
	16	14
	17	10
	18	6
	19	2
	19	22
	20	18
	21	14
	22	10
	23	6
	24	3
	24	23
	25	19
	26	15
	27	11
	28	7
	29	3
	30	0
	30	20

Z Herculis

	d	h
Apr.	1	9
	3	6
	5	9
	7	6
	9	9
	11	6
	13	9
	15	6
	17	8
	19	5
	21	8
	23	5
	25	8
	27	5
	29	8

RS Sagittarii

	d	h
Apr.	1	1
	3	11
	5	21
	8	7
	10	17
	13	3
	15	13
	17	23
	20	9
	22	19
	25	5
	27	15
	30	0

V Serpentis

	d	h
Apr.	3	11
	6	22
	10	9
	13	20
	17	7
	20	18
	24	5
	27	15

RZ Draconis

Period $13^h.2$

	d	h
Apr.	1	12
	2	15
	3	17
	4	20
	5	22
	7	1
	8	3
	9	6
	10	8
	11	10
	12	13
	13	15
	14	18
	15	20
	16	23
	18	1
	19	4
	20	6
	21	8
	22	11
	23	13
	24	16
	25	18
	26	21
	27	23
	29	2
	30	4

RX Herculis

	d	h
Apr.	1	21
	2	18
	3	15
	4	13
	5	10
	6	7
	7	5
	8	2
	8	23
	9	21
	10	18
	11	15
	12	13
	13	10
	14	8
	15	5
	16	2
	17	0
	17	21
	18	18
	19	16
	20	13
	21	10
	22	8
	23	5
	24	2
	25	0
	25	21
	26	18
	27	16
	28	13
	29	10

Minima of Variable Stars of the Algol Type.—Continued.

RX Herculis
d h
Apr. 30 8

SX Sagittarii
Apr. 1 12
3 14
5 16
7 18
9 20
11 21
13 23
16 1
18 3
20 5
22 7
24 8
26 10
28 12
30 14

RR Draconis
Apr. 2 13
5 9
8 5
11 1
13 21
16 17
19 13
22 9
25 5
28 1
30 21

U Scuti
Apr. 1 8
2 7
3 6
4 4
5 3

U Scuti
d h
Apr. 6 2
7 1
8 0
8 23
9 22
10 21
11 20
12 19
13 18
14 17
15 15
16 14
17 13
18 12
19 11
20 10
21 9
22 8
23 7
24 6
25 5
26 4
27 3
28 1
29 0
29 23
30 22

RX Draconis
Apr. 2 15
4 12
6 10
8 7
10 5
12 2
13 23

RX Draconis
d h
Apr. 15 21
17 18
19 16
21 13
23 11
25 8
27 6
29 3

RV Lyræ
Apr. 1 13
5 3
8 18
12 8
15 22
19 13
23 3
26 18
30 18

U Sagittæ
Apr. 1 1
4 10
7 19
11 4
14 13
17 22
21 8
24 17
28 2

SY Cygni
Apr. 6 6
12 7
18 7
24 7
30 7

WW Cygni
d h
Apr. 1 1
4 8
7 16
10 23
14 7
17 15
20 22
24 6
27 14
30 21

SW Cygni
Apr. 1 20
6 9
10 23
15 13
20 3
24 16
29 6

VW Cygni
Apr. 2 17
11 4
19 14
28 0

UW Cygni
Apr. 1 18
5 4
8 15
12 2
15 13
19 0
22 10
25 21
29 8

W Delphini
d h
Apr. 2 12
8 8
12 3
16 22
22 18
26 13

RR Delphini
Apr. 4 5
8 20
13 10
18 0
22 15
27 5

VV Cygni
Apr. 2 5
3 16
5 4
6 15
8 3
9 14
11 2
12 13
14 1
15 12
17 0
18 11
19 22
21 10
22 21
24 9
25 20
27 8
28 19
30 7

UZ Cygni
Apr. 28 4

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.
d h
(−5 19)
Apr. 7 7
21 2

RX Aurigæ
(−4 0)
Apr. 4 12
16 3
27 18

Y Aurigæ
(−0 18)
Apr. 1 4
5 1
8 22
12 18
16 15
20 11

Y Aurigæ
d h
Apr. 24 8
28 5

T Monoc.
(−7 23)
Apr. 2 10
29 10

W Geminorum
(−2 22)
Apr. 7 17
15 15
23 13

ζ Geminorum
(−5 0)
Apr. 10 18
20 21

RU Camelop.
d h
(−9 12)
Apr. 11 3
May 3 10

V Carinæ
(−2 4)
Apr. 7 14
14 6
20 23
27 16

T Velorum
(−1 10)
Apr. 1 15
6 6
10 22
15 13
20 4

T Velorum
d h
Apr. 24 20
29 11

W Carinæ
(−1 0)
Apr. 1 5
5 13
9 22
14 7
18 16
23 1
27 10

S Muscæ
(−3 11)
Apr. 10 4
19 20
29 11

T Crucis
d h
(−2 2)
Apr. 5 15
12 8
19 2
25 19

R Crucis
(−1 10)
Apr. 1 0
6 20
12 16
18 12
24 7
30 3

S Crucis
(−1 12)
Apr. 1 3

S Crucis

	d	h
Apr.	5	20
	10	12
	15	5
	19	22
	24	14
	29	7

W Virginis

(—8 5)

	d	h
Apr.	13	0
	30	7

V Centauri

(—1 11)

	d	h
Apr.	4	5
	9	17
	15	4
	20	16
	26	2

R Triang. Austr.

(—1 0)

	d	h
Apr.	2	21
	6	6
	9	15
	13	0
	16	10
	19	19
	23	5
	26	14
	29	23

S Triang. Austr.

(—2 2)

	d	h
Apr.	1	5
	7	13
	13	20
	20	4
	26	12

S Normæ

(—4 10)

	d	h
Apr.	1	5
	10	23
	20	17
	30	11

RV Scorpii

(—1 10)

	d	h
Apr.	6	23
	13	0
	19	2
	25	3

RV Ophiuchi

Minimum.

	d	h
Apr.	3	9
	7	1
	10	18
	14	10
	18	3
	21	19
	25	12
	29	4

X Sagittarii

(—2 22)

	d	h
Apr.	3	0
	10	0
	17	1
	24	1

Y Ophiuchi

(—6 5)

	d	h
Apr.	10	4
	27	7

W Sagittarii

(—3 0)

	d	h
Apr.	6	16
	14	6
	21	20
	29	10

Y Sagittarii

(—2 2)

	d	h
Apr.	6	11
	12	6
	18	0
	23	19
	29	14

U Sagittarii

(—2 23)

	d	h
Apr.	5	17
	12	11
	19	5
	25	23

β Lyræ

(—3 7)

(—3 2)

	d	h
Apr.	8	4
	14	10
	21	2
	27	7

κ Pavonis

(—1 7)

	d	h
Apr.	6	18
	15	20
	24	22

U Aquilæ

(—2 4)

	d	h
Apr.	5	1
	12	1
	19	2
	26	2

U Vulpeculæ

(—2 3)

	d	h
Apr.	6	16
	14	16
	22	15
	30	15

SU Cygni

(—1 7)

	d	h
Apr.	1	1
	4	22
	8	18
	12	14
	16	10
	20	7
	24	3
	27	23

X Vulpeculæ

(—2 1)

	d	h
Apr.	7	3
	13	11
	19	18
	26	2

V Vulpeculae

Minimum

	d	h
Apr.	4	9

X Cygni

(—6 19)

	d	h
Apr.	7	13
	23	23

T Vulpeculae

(—1 10)

	d	h
Apr.	1	1
	5	11
	9	21
	14	8
	18	18

T Vulpeculae

	d	h
Apr.	23	5
	27	15

WZ Cygni

Period 14h

Minimum

	d	h
Apr.	1	1
	2	5
	3	9
	4	13
	5	17
	6	21
	8	1
	9	5
	10	9
	11	13
	12	17
	13	22
	15	2
	16	6
	17	10
	18	14
	19	18
	20	22
	22	2
	23	6
	24	10
	25	14
	26	18
	27	22
	29	2
	30	6

TX Cygni

	d	h
Apr.	12	7
	27	1

VY Cygni

(—2 14)

	d	h
Apr.	5	3
	12	23
	20	20
	28	16

VZ Cygni

(—2 12)

(—3 6)

	d	h
Apr.	10	13
	15	13

VZ Cygni

	d	h
Apr.	20	6
	25	6
	30	0

δ Cephei

(—1 10)

	d	h
Apr.	2	4
	7	13
	12	22
	18	7
	23	16
	29	0

Y Lacertae

(—1 10)

	d	h
Apr.	2	10
	6	18
	11	1
	15	9
	19	16
	24	0
	28	7

V Lacertae

(—0 17)

	d	h
Apr.	5	5
	10	5
	15	4
	20	4
	25	4
	30	3

X Lacertae

Minimum

	d	h
Apr.	6	10
	11	20
	17	7
	22	17
	28	4

RS Cassiop.

(—1 19)

	d	h
Apr.	5	18
	12	1
	18	8
	24	15
	30	22

RY Cassiop.

(—7 10)

	d	h
Apr.	2	10
	14	14
	26	17

Approximate Magnitudes of Variable Stars on Feb. 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A 1900		Decl. 1900		Magn.
	h	m	°	′			h	m	°	′	
X Androm.	0	10.8	+46	27	<13.5	W Cassiop.	0	49.0	+58	1	10.5*d*
T Androm.		17.2	+26	26	7.8 *i*	RX Androm.		58.9	+40	46	12.8*d*
T Cassiop.		17.8	+55	14	11.0*d*	U Androm.	1	9.8	+40	11	<13.5
R Androm.		18.8	+38	1	13.8*d*	S Piscium		12.4	+ 8	24	11.2 *i*
S Ceti		19.0	− 9	53	8.2 *i*	S Cassiop.		12.3	+72	5	13.0 *i*
Y Cephei		31.3	+79	48	13.4*d*	U Piscium		17.7	+12	21	13.0 *i*
U Cassiop.		40.8	+47	43	11.0 *i*	R Piscium		25.5	+ 2	22	14.0
RW Androm.		41.9	+32	8	13.0 *i*	RU Androm.		32.8	+38	10	11.6*d*
V Androm.		44.6	+35	6	11.3 *i*	Y Androm.		33.7	+38	50	10.0*d*
RR Androm.		45.9	+33	50	<13	X Cassiop.		49.8	+58	46	10.5

Approximate Magnitudes of Variable Stars on Feb. 1, 1908—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
U Persei	1	53.0	+54	50	7.8 *i*
S Arietis		59.3	+12	3	13.6
R Arietis	2	10.4	+24	35	7.8 *i*
W Androm.		11.2	+43	50	<13.5
Z Cephei		12.8	+81	13	14.0
o Ceti		14.3	— 3	26	6.2*d*
S Persei		15.7	+58	8	8.5
R Ceti		20.9	— 0	38	12.8 *i*
U Ceti		28.9	—13	35	8.0 *i*
RR Cephei		30.4	+80	42	<13
R Trianguli		31.0	+33	50	8 4 *i*
T Arietis		42.8	+17	6	9.4
W Persei		43.2	+56	34	9.5
U Arietis	3	5.5	+14	55	7.7 *i*
X Ceti		14.3	— 1	26	9.0 *i*
Y Persei		20.9	+43	50	9.0
R Persei		23 7	+35	20	12.0 *i*
Nov. Per. 2		24.4	+43	34	13.3*d*
T Tauri	4	16.2	+19	18	11.4*d*
R Tauri		22.8	+ 9	56	13.5*d*
W Tauri		22.2	+15	49	9.0*d*
S Tauri		23.7	+ 9	44	11.0
T Camelop.		30.4	+65	57	8.2 *i*
RX Tauri		32.8	+ 8	9	14.0
X Camelop.		32.6	+74	56	8.0
V Tauri		46.2	+17	22	9.5 *i*
R Orionis		53.6	+ 7	59	10.0*d*
V Orionis	5	0.8	+ 3	58	11.8*d*
T Leporis		0.6	—22	2	11.2*d*
R Aurigae		9.2	+53	28	9.5*d*
S Aurigae		20.5	+34	4	10.4
W Aurigae		20.1	+36	49	9.0 *i*
S Orionis		24.1	— 4	46	11.4*d*
T Orionis		30.9	— 5	32	9.5
S Camelop.		30.2	+68	45	10.0
U Aurigae		35.6	+31	59	11.5*d*
U Orionis		49.9	+20	10	11.0 *i*
V Camelop.		49.4	+74	30	<13
Z Aurigæ		53.6	+53	18	10.0
V Monoc.	6	17.7	— 2	9	11.0*d*
R Monoc.		33.7	+ 8	49	11.5 *i*
X Gemin.		40.7	+30	23	11.5
W Monoc.		47.5	— 7	2	9.5 *i*
Y Monoc.		51.3	+11	22	<13
X Monoc.		52.4	— 8	56	7.5
R Lyncis		53.0	+55	28	9.8*d*
R Gemin.	7	1.3	+22	52	13.0*d*
V Can. Min.		1.5	+ 9	2	13.5*d*
R Can. Min.		3.2	+10	11	8.8 *i*
RR Monoc.		12.4	+ 1	17	12.4*d*
V Gemin.		17.6	+13	17	8.8
S Can Min.		27.3	+ 8	32	12.0*d*
T Can. Min.		28.4	+11	58	13.0*d*
U Can. Min.		35.9	+ 8	37	9.5 *i*
S Gemin.		37.0	+23	41	<13.5
T Gemin.		43.3	+23	59	8.8 *i*
U Puppis		56.1	—12	34	12.2*d*
R Cancri	8	11.0	+12	2	10.0*d*
V Cancri		16.0	+17	36	8.0
RT Hydrae		24.7	— 5	59	8.4
S Hydrae		48.4	+ 3	27	9.2 *i*
T Hydrae		50.8	— 8	46	8.4 *i*
W Cancri	9	4.0	+25	39	11.5*d*
Y Draconis	9	31.1	+78	18	12.8 *i*
R Leo. Min.		39.6	+34	58	9.0*d*
R Leonis		42.2	+11	54	6.3 *i*
V Leonis		54.5	+21	44	<13
R Urs. Maj.	10	37.6	+69	18	11.2*d*
T Urs. Maj.	12	31.8	+60	2	8.2*d*
RS Urs. Maj.		34.4	+59	2	10.0 *i*
S Urs. Maj.		39.6	+61	38	7.5 *i*
U Urs. Min.	14	15.1	+67	15	11.0*d*
S Bootis		19.5	+54	16	11.5 *i*
R Camelop.		25.1	+84	17	8.5 *i*
R Bootis		32.8	+27	10	9.0*d*
S Urs. Min.	15	33.4	+78	58	11.3
U Draconis	19	9.9	+67	7	<13
U Lyrae		16.6	+37	42	11.5*d*
R Cygni		34.1	+49	58	13.6*d*
RT Cygni		40.8	+48	32	9.4d
TU Cygni		43.3	+48	49	<13.5
χ Cygni		46.7	+32	40	11.0 *i*
Z Cygni		58.6	+49	46	8:0 *i*
S Cygni	20	3.4	+57	42	10.0 *i*
RS Cygni		9.8	+38	28	8.3 *i*
WX Cygni		14.8	+37	8	10.0 *i*
U Cygni		16.5	+47	35	7.6 *i*
RW Cygni		25.2	+39	39	8.6*d*
Z Delphini		28.1	+17	7	7.8 *i*
ST Cygni		29.9	+54	38	13.4
Y Delphini		36.9	+11	31	12.6*d*
S Delphini		38.5	+16	44	11.4*d*
V Cygni		38.1	+47	47	12.6*d*
T Delphini		40.7	+16	2	12.5 *i*
V Delphini		43.2	+18	58	<13.5
X Delphini		50.3	+17	16	10.5*d*
R Vulpeculae		59.9	+23	26	8.0 *i*
TW Cygni	21	1.8	+29	0	10.6 *i*
X Cephei		3.6	+82	40	<13.5
T Cephei		8.2	+68	5	10.2*d*
S Cephei		36.5	+78	10	8.5 *i*
RU Cygni		37.3	+53	52	8.0 *i*
RR Pegasi		40.0	+24	33	12.7*d*
V Pegasi		56.0	+ 5	38	10.5*d*
RT Pegasi		59.8	+34	38	9.6 *i*
T Pegasi	22	4.0	+12	3	13.5*d*
Y Pegasi		6.8	+13	52	13.5
RS Pegasi		7.4	+14	4	8.0 *i*
RV Pegasi		21.0	+29	58	13.0*d*
S Lacertae		24.6	+39	48	12.7*d*
R Lacertae		38.8	+41	51	13.8*d*
RW Pegasi		59.2	+14	46	7.8*d*
R Pegasi	23	1.6	+10	0	12.4*d*
V Cassiop.		7.4	+59	8	13.2*d*
W Pegasi		14.8	+25	44	9.6*d*
S Pegasi		15.5	+ 8	22	13.2*d*
Z Androm.		28.8	+48	16	11.0
— Androm.		33.8	+35	13	9.0 *i*
Z Cassiop.		39.7	+56	2	13.8*d*
RR Cassiop.		50.7	+53	8	<13
V Ceti		52.8	— 9	31	8.5 *i*
R Cassiop.		53.3	+50	50	10.8*d*
Z Pegasi		55.0	+25	21	8.0 *i*
W Ceti		57.0	—15	14	10.0*d*
Y Cassiop.		58.2	+55	7	<14

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whitin, Mt. Holyoke, and Harvard Observatories.

GENERAL NOTES.

Transit of Mercury. In answer to Professor Snyder's request I can give from a layman's standpoint the experience we had.

Our observation was with an almost perfect atmosphere and with but one or two small passing clouds. The half hour preceding the third contact was as nearly perfect as I have ever seen, there being a minimum of "boiling."

Between third and fourth contact a very small cloud passed over but gave no trouble but rather acted as a rest for the eye.

During the transit the image of Mercury appeared raised from the Sun so that Mrs. Merritt expressed it as looking as though a card could be passed between it and the Sun.

To observe the third and fourth contacts I projected the image using an undeveloped photograph plate as this gives me the best surface I have ever found upon which to throw projections. Just after third contact our view was interrupted by the cloud referred to but only for a few seconds and on the re-appearance we unmistakably saw the whole disk of Mercury and continued to see it till three or four seconds after the fourth contact.

The instrument used was a 4″ Alvan Clark Equatorial.

M. G. MERRITT.

Rome, New York.
January 20, 1908.

Resume of Sun-Spot Observations, 1907.

Month	No. of Obs.	N. of Equator No. Groups	N. of Equator Av. Lat.	S. of Equator No. Groups	S. of Equator Av. Lat.	Av. No. at each Obs.	New Groups
			°		°		
January	12	14	+ 9.6	7	—11.2	4.3	21
February	17	11	10.0	9	12.7	6.0	17
March	16	8	10.2	14	12.6	4.8	17
April	9	4	9.8	4	18.9	2.0	8
May	13	6	6.6	6	13.0	2.7	12
June	12	2	10.2	4	17.5	2.2	5
October	26	6	5.8	11	16.4	3.2	17
November	16	6	7.7	5	13.0	3.0	9
December	7	3	8.1	7	15.6	4.4	10
Total	128	60		67			116

Average number at each observation	3.61
Average latitude of spots north of equator	+9°.0
Average latitude of spots south of equator	—14°.6

The Sun was observed only once when no spots were seen, November 29th.

In the résumé a group appearing upon the eastern limb was counted as "new", even though the same area had been disturbed when upon the western limb a few days earlier.

Observations were made with the eight-inch equatorial. The image of the Sun was projected upon Thomson's Disks, for which approximate latitude and distance from the center can be read at once for each group. The record from January to June was made by Miss Elizabeth Schindler, that for October to December by Miss Anna Oathout.

ANNE SEWELL YOUNG.

Mount Holyoke College Observatory.

Richard Hinckley Allen. At 4:00 A. M., Tuesday January 14, at Northampton, Mass., passed from this life Mr. Richard Hinckley Allen of Chatham, N. J. Mr. Allen was the author of "*Star Names and Their Meanings*,"—a work of wide research and of classical value in astronomical literature, with which most of the readers of POPULAR ASTRONOMY must be familiar. He was also a member of the Astronomical Society of the Pacific and the American Association for the Advancement of Science.

A brief sketch of his career as man of business and as an author appeared about a year ago in POPULAR ASTRONOMY (Vol 14 Page 592) accompanied by his portrait.

Although Mr. Allen had not enjoyed excellent health during recent years, yet he was actively engaged in a careful revision of his book, ever having the greatest regard for absolute accuracy in every portion of its contents. On Thursday preceding his death, while suffering from a severe attack of the grippe, he left his New Jersey home to attend the funeral of his sister in Massachusetts. The exposure induced pneumonia to which he succumbed. He is survived by his widow, who was Miss Mary C. Wallace of Chatham, N. J., and a brother Rev. Arthur H. Allen and a niece Miss Agnes G. C. Allen. Interment was made in Mount Pleasant Cemetary.

By all those who were acquainted with Mr. Allen, he was considered a most highly respected gentleman; by his friends, affectionately loved for his kindly courteous manner and whole-souled cordiality. He was a Christian who could see in the stars whose names he had enrolled and explained, the work of a Divine Artificer, and his activity was evidenced by his election to an eldership and trusteeship of the Presbyterian Church at Chatham, and in that church on January 26th was held a special Memorial Service in his honor.

H. S. D.

A Reply to Francis Rust's Paper (January 1908.) The January number of this Journal contains an article by Mr. Francis Rust, which calls for a reply and criticism. The author presents what he calls "a new method to compute a planet's anomaly and radius vector" but fails to recognize that his equation (6) is nothing but Kepler's equation. That this is indeed the outcome of his rather uselessly laborious mode of integrating $r^2 \frac{d\theta}{dt} = c$ will be evident from his equation (7) which defines his auxiliary angle χ. This equation (7) is as follows

$$\tan \chi = \sqrt{\frac{1-e}{1+e}} \operatorname{tg} \frac{\theta}{2},$$

but everybody knows that the eccentric anomaly u is defined by

$$\operatorname{tg} u/2 = \sqrt{\frac{1-e}{1+e}} \operatorname{tg} \frac{\theta}{2}$$

$$\therefore \quad u = 2\chi \qquad \dots (a)$$

Equation (6) reads as follows:

$$S = \chi \cos \kappa - \frac{1}{4} \sin 2\kappa \sin 2\chi \tag{6}$$

where $\sin \kappa = e$, by making use of (a) we obtain

$$S = \frac{u}{2}\sqrt{1-e^2} - \frac{1}{2} e\sqrt{1-e^2} \sin u \qquad \text{or}$$

$$\frac{2S}{\sqrt{1-e^2}} = u - e \sin u.$$

We would have Kepler's equation if we were to express the left side as a linear function of t, but this our author does not clearly indicate although he actually carries it out in his example. He simply looks upon the right side of (6) as an expression for the area S between $\theta = 0$ and $\theta = \theta$. Then he proposes to construct a table for S with the argument θ. This done he solves the problem: given a time t to find the angle θ, by first computing S as a linear function of time and then interpolates the value of θ by his table. It is hardly necessary to point out that the astronomer in solving the same problem turns too to Kepler's equation to find the value of the eccentric anomaly and then obtains by $\operatorname{tg} \theta/2 = \sqrt{\frac{1-e}{1+e}} \operatorname{tg} u/2$ the value of θ. To construct a table in the way Mr. Rust proposes would hardly repay the great labor spent in computing it, since even for the orbit of the Earth the eccentricity is constantly undergoing changes. To take account of these an additional table for $\frac{d\theta}{de}$ would be necessary. Astronomers since the days of Kepler have not been entirely unsuccessful in devising modes of computation for this ever recurring and fundamental problem of Astronomy. A careful perusal of a textbook on theoretical astronomy and a study of astronomical tables like those of Bauschinger will reveal to the reader most valuable stores of information of which he should eagerly avail himself before he attempts an improvement in this course of study. The knowledge so gained will enable the reader to use astronomical ephemerides intelligently without which some astronomical data could easily appear "not harmonious to the layman" (see remark on page 42 of this journal).

KURT LAVES.

Chicago, Ill.
February 1908.

Ephemeris for Physical Observations of the Sun.

	Greenwich Mean Noon.							Greenwich Mean Noon.					
1908	P.		D.		L.		1908	P.		D.		L.	
	°	′	°	′	°	′		°	′	°	′	°	′
Jan. 1	+ 2	23	—3	5	0	22	Feb.20	—18	55	—7	2	61	59
6	— 0	3	3	39	294	31	25	20	24	7	10	356	8
11	2	28	4	11	228	40	Mar.1	21	44	7	14	290	17
16	4	51	4	42	162	50	6	22	55	7	15	224	25
21	7	10	5	10	97	0	11	23	56	7	13	158	31
26	9	25	5	36	31	10	16	24	47	7	7	92	37
31	11	33	5	59	325	20	21	25	27	6	58	26	42
Feb. 5	13	35	6	20	259	31	26	25	58	6	46	320	46
10	15	30	6	37	193	41	31	26	17	6	31	254	49
15	—17	16	—6	51	127	50	Apr. 5	—26	26	—9	13	188	50

	Greenwich Mean Noon.					
1908	P.		D.		L.	
	°	′	°	′	°	′
Apr. 10	−26	24	−5	53	122	50
15	26	11	5	30	56	50
20	25	47	5	4	350	47
25	25	11	4	37	284	44
30	24	25	4	7	218	40
May 5	23	28	3	37	152	34
10	22	20	3	4	86	28
15	21	2	2	30	20	20
20	19	34	1	55	314	11
25	17	57	1	20	348	2
30	16	11	0	44	181	52
June 4	14	18	−0	8	115	43
9	12	18	+0	28	49	32
14	10	12	1	4	343	21
19	8	2	1	40	277	10
24	5	48	2	16	210	59
29	3	32	2	48	144	48
July 4	−1	15	3	21	78	37
9	+1	2	3	52	12	26
14	3	17	4	22	306	17
18	5	30	4	50	240	7
24	7	39	5	16	173	58
29	9	46	5	40	107	50
Aug. 3	11	45	6	1	41	42
8	13	40	6	20	335	35
13	15	28	6	37	269	29
18	+17	10	+6	50	203	24
Aug. 23	+18	44	+7	1	137	20
28	20	11	7	8	71	16
Sept. 2	21	30	7	13	5	13
7	22	40	7	15	299	11
12	23	42	7	13	233	10
17	24	34	7	9	167	9
22	25	17	7	1	101	10
27	25	50	6	50	35	10
Oct. 2	26	13	6	36	329	12
7	26	25	6	19	263	14
12	26	26	5	59	197	16
17	26	16	5	37	141	19
22	25	54	5	11	65	22
27	25	21	4	44	359	26
Nov. 1	24	36	4	14	293	30
6	23	39	3	43	227	34
11	23	31	3	9	161	40
16	21	10	2	34	95	44
21	19	39	1	58	29	50
26	17	57	1	20	323	56
Dec. 1	16	5	0	42	258	2
6	14	4	+0	4	192	9
11	11	56	−0	35	126	16
16	9	40	1	13	60	23
21	7	20	1	50	354	32
26	4	56	2	28	288	40
31	+2	31	−3	3	222	49

The position-angle of the Sun's axis, P, is the position-angle of the N. end of the axis from the N. point of the Sun, read in the direction N., E., S., W. In computing D (the heliographic latitude of the center of the Sun's disk), the inclination of the Sun's axis to the ecliptic has been assumed to be 82° 45′ and the longitude of the ascending node for 1908.0 to be 74° 28′.6. In computing L (the heliographic longitude of the center of the Sun's disk), the Sun's period of rotation has been assumed to be 25.38 days, and the meridian which passed through the ascending node at the epoch 1854.0 has been taken as the zero meridian.

Companion to the Observatory, No. 391.

Carnegie Solar Observatory on Mount Wilson California. In a recent lecture, Professor George E. Hale gave a description of the new tower telescope and the tests already made with it.

This telescope consists of a vertical steel tower, sixty-five feet in height, on the summit of which are mounted two plane mirrors, which receive the rays of the Sun and reflect them vertically downward to an object glass twelve inches in diameter lying horizontally just below the mirrors. This glass has a focal length of sixty feet, and forms an image of the Sun sixty feet below, six and one-half inches in diameter, in a laboratory at the base of the tower. In connection with these mirrors is a spectroscope over thirty feet long, which extends down into a deep well, with concrete walls beneath the floor of the laboratory.

Any of the peculiar disturbances on the Sun, such as the flames at its edge and the sun-spots, may be investigated by means of this spectroscope. The tower telescope embodies many new features, and the preliminary tests show that it will prove superior to the Snow telescope, which is horizontal. It will be used exclusively for work on the Sun.

Besides the tower and Snow telescopes, Professor Ritchie has completed the work on a great sixty-inch mirror, which is expected to be more powerful than any optical instrument now in use. Professor Hale then explained to his audience the work on the Hooker telescope, of which the mirror is 100 inches, or more than eight feet across. The glass disk is now being cast in France, and when completed will weigh more than four and one-half tons. The sixty-inch glass, will be in place next summer, but it will be several years after this when the Hooker lens will be in place and ready for work.

Rev. Tilton C. H. Bouton, Henniker, N. H., writes of the interest awakened in the high school of that place on account of his setting up a 5-inch telescope for personal study in the elements of practical astronomy. In a letter of the fourth ult. he says:—"I give to the local High School the use of my equipment. As a result astronomy has been reinstated in the course of study in the English department, and a class is now receiving instruction. I wish the subject were taught in an elementary way in every High School and Academy. While on a vacation in August I was surprised to find the interest I was able to awaken, in a score of people, where I was stopping, and the wonder and pleasure which they showed in viewing a few celestial objects by the aid of a spy-glass with an objective one and seven-eighths inches aperture, using a power of about fifty diameters."

This is only one of many testimonials that might be cited to the same effect, regarding elementary astronomy and the way to teach it in secondary schools. The reason why this, the noblest, the most inspiring branch in all natural science is thrown out of nearly all high schools in this country, is the shameful fact that teachers do not know how to teach it, if they know anything at all about the subject.

Harvard College Catalogue of Variable Stars. In answering some queries for information concerning variable star catalogues, made of us recently by a correspondent, we omitted to mention the *Second Catalogue of Variable Stars* prepared by Miss Cannon, which forms Part I of Volume LV of the Annals of Harvard College Observatory. Probably Professor E. C. Pickering, Director of the Observatory could supply that Catalogue separately to any one in need of it.

Perth Catalogue of 420 Standard Stars. We have undertaken the zone 32° — 40° South declination for the International Photo Durchmusterung. Nearly all the necessary photographs (for the catalogue portion) have been taken, but the measurement is only now being commenced.

In all probability we shall not be able to take the long exposure photographs for mechanical reproduction.

In order to obtain the plate constants three stars have been selected, where practicable, in every square degree, and these are being observed with the transit circle. This work was commenced on October 6th 1901. Each observation consists of transits over seven vertical wires and readings of four microscopes. The instrument is a modern one of Messrs. Troughton & Simms, having a clear aperture of six inches. The "seeing" is usually good and the definition excellent.

The old method, which was first adopted, of determining clock error from equatorial stars of the Nautical Almanac, and the nadir point from reflections over the mercury trough, was not considered satisfactory and was definitely abandoned on 1905, July 28th., after we had completed zones 32°, 33°, 39°, and 40°, and part of 33° — 34°. It was then determined to obtain both clock error and equator point from standard stars situated within or close to the zone of observation. Auwer's "Fundamental Catalog für Zonenbeobachtungen an Südhimmel" was accepted as the basis of the system but since at least three reference stars per hour are required for each zone of 2° it was necessary to choose a number of stars to act as Secondary Standards, and to observe these a considerable number of times. This has been done and the present catalogue is the result. It will be adopted as fundamental in the zone reductions until the whole zone 31° — 41° is completed and the results previously obtained between 1901, October 6 and 1905, July 28 will be reduced as well as possible to the present system.

In a few years a satisfactory determination (three complete observations) of the positions of some eight to ten thousand stars fairly well distributed over the region 31° to 41° will be obtained, and these will be used for the determination of the plate constants in the astrographic catalogue.

And now a few words as to the future of transit work. I have adopted a plan which I hope to see copied by a number of other observatories. I propose that the Perth Observatory shall confine its transit observations to this particular region and prepare a catalogue of exactly the *same stars* every ten or twelve years, or as frequently as possible, including each time a redetermination of the 420 secondary standards. Thus in course of time the worker in this part of the sky will turn to the Perth catalogues with the certainty of finding a number of stars in any ordinary sized field all of whose positions have been regularly determined from time to time and can therefore be brought reliably up to date.

Notwithstanding the millions of observations which have been taken and the hundreds of existing catalogues there are very few parts of the sky in which the above conditions exist. It is earnestly hoped that this attempt to place meridian work upon a more satisfactory basis may be followed by others, so that the output of energy may be concentrated upon some systematic measuring of the sky instead of being squandered as it has to some extent been in the past. In particular I hope that when their present program is finished the four Australian observatories will co-operate in order to maintain a systematic survey of the region 20° to 60° South declination.

W. ERNEST COOKE.
Government Astronomer for West Australia.

New Photographic Meridian Telescope of the Paris Observatory. A new instrument for the determination of right ascension has been provided by Professors Ebert and Mascart for the Paris Observatory. It was designed by Professor Lippmann and it was constructed by Gautier, the new feature, in the main, being to use photography for getting meridian transits of stars to determine their right ascensions fundamentally.

The principle on which this new photographic telescope works for meridian results can be readily understood with a brief explanation.

A collimator is directed in the plane of the meridian and a cylindrical mirror with its axis normal to that plane is placed in front of the lens of the telescope. The rays from the illuminated vertical slit in the other end of the collimator will be spread out by the mirror into a plane sheet which will intersect the celestial sphere in a meridian circle. If these rays fall on an object-glass of a telescope, visual or photographic, which at the same time receives the light from a star, the image of the latter will be formed in the focal plane together with the line which represents the image of the great circle of the heavens (the circle of reference) traced by the luminous sheet reflected from the cylindrical mirror.

The telescope is mounted equatorially, in order to make long photographic exposures when desired. The diameter of the object-glass of this instrument is 6.3 inches. The slit of the collimator is provided with an instantaneous slit worked by clock-work once each minute. The field of view of the instrument is 180 degrees, and stars of the ninth magnitude can be photographed in twelve minutes. The plates show the star images and the black meridian lines for each minute. These data are said to be sufficient to give the star places with reference to the meridian within $\frac{1}{10}$ of a second of arc, or less than $\frac{1}{100}$ of a second of time, bringing out about 30 stars on each photographic plate.

The amount of electric light falling on the slit is regulated by hand, and that from the electric arc is used because it is more steady, all other light being shut out from the sensitive plate.

Professors Mascart and Ebert are now planning some improvements for this new method of star photography in order to give it wider application in several ways in the broad field of work opening before them. The advantages of this new instrument seem to be many, and meridian star places are likely to be improved and soon to be greatly extended.

The Zeigler Polar Expedition. The scientific results of the Zeigler Polar Expedition have been published in a fine volume of 630 pages under the auspices of the National Geographical Society by the estate of William Zeigler, Washington, D. C. The contents of this volume are an introduction by Anthony Fiala, magnetic observations and reductions, notes and sketches in colors of the Aurora Borealis, meteorological observations and compilations, tidal observations and reductions, astronomical observations and reductions, and map constructions and survey work.

A large part of this volume is given up to the magnetic observations and notes and finely colored sketches of the Aurora Borealis. The report is unique and valuable in this respect. The meteorological work in tabular form and graphical representation is full and useful for reference in high northern latitudes. The tidal observations and results also form an interesting feature.

On the inside of the right hand cover of the book is a large pocket containing three beautiful maps which will be highly prized by any one interested in a study of the north polar regions. It is named a Map of the North Polar Regions. It is 18 inches square and printed in delicate tints. It contains a multitude of historical and other references and geographical explanations which make it a most valuable reference map for almost all kinds of scientific knowledge as far as ascertained in this field of inquiry. The other two maps are of Franz Joseph Archipelago and locally interesting. The officers of this expedition are to be heartily congratulated on the success of this piece of work.

Report of W. F. King, Chief Astronomer of the Dominion Observatory at Ottawa, Canada. A bound volume of 283 pages is the report of Chief Astronomer, W. F. King for the year 1905. It is an interesting publication for it contains more information about the astronomical work recently done in Canada than has appeared in print before so far as we know. The names of the men on the working staff are known to many of our readers, for most of them have been referred to in this publication from time to time, especially Otto J. Klotz, J. S. Plaskett and Chief Astronomer King.

The report of Mr. Klotz on the transpacific longitudes which has been carried on under his direction is a paper of special interest. A general account of this longitude work across the Pacific Ocean with some illustrations of the island stations on the way would make a very useful article for the general reader as well as those more particularly interested in such astronomical work.

Mr. Plaskett's illustrated and descriptive report of the Observatory and its instrumental equipment, and his account of the observations of total solar eclipse of August 30, 1905 give clear and concise ideas of the important fields covered by the same. Mr. Stewart's description of the Time Service maintained by the Observatory gave us just the information desired in this line, because it was full enough to indicate a good and healthy existence although so near to the United States. Over here observatories generally have given up the public time service in which they were formerly engaged because the Western Union Telegraph Company has driven them from the field.

This report is a credit to those making it and to the observatory from which it comes.

Astronomical Papers for the Nautical Almanac. We are pleased to get the catalogues of zodiacal stars for 1900 and 1902, reduced to an absolute system, which is Pt. III, Vol. VII of the Astronomical Papers which are being prepared from time to time for the American Ephemeris and Nautical Almanac, and published by the authority of Congress.

This paper was prepared by Henry B. Hendrick, an assistant on the American Ephemeris, who commenced the work in 1899 by the authority of the late William Harkness, then Director of the Nautical Almanac. It was carried on by Henry D. Todd, S. J. Brown and Walter S. Harshmann, respectively, of the Nautical Almanac, as fast as the routine work of the office would permit. This catalogue contains 1098 standard clock and zodiacal stars which will be useful also in observing occultations in the future. In making this catalogue the following classes of stars were examined for sufficient observations:

1. All the stars within eight degrees of the ecliptic in the *Catalogue of 1098 Standard Clock and Zodiacal Stars* compiled under the direction of Professor Simon Newcomb and published as *Astronomical Papers of the American Ephemeris*, Volume I, Part IV.
2. All the stars in Dr. Downing's list *834 Zodiacal Stars selected for use in the Nautical Almanac* and published as an appendix to the British Nautical Almanac for 1897.
3. All the stars of the 7.5 magnitude and brighter within eight degrees of the ecliptic in the *Catalogue of 2798 Zodiacal Stars for the epoch 1900* selected and compiled under the direction of Dr. David Gill, at the Cape of Good Hope, in accordance with resolution 9 of the *Conférence Internationale des Étoiles Fundamentales* held at Paris in 1896.
4. All the stars of the 7.0 magnitude and brighter within eight degrees

of the ecliptic contained in Argelander's and Schönfield's *Bonn Durchmusterung* and in Thome's *Cordoba Durchmusterung*.

After examination of the adopted catalogues all the stars of which there were sufficient observations were included in the final list.

Also some stars, although not well observed, were included for one or more of the following reasons:

(*a*) If the star was contained in the first or second class given above.

(*b*) If it was a bright star and near the ecliptic.

(*c*) If it was contained in the older catalogues and needed modern observations, especially in the case of stars contained in Gill's Catalogue, as these will, in the immediate future at least, be more observed.

In all, more than 2500 stars were examined, of which about 900 were excluded for insufficient observations, and of the remainder at least 1000 are so well determined as to be regarded as fundamental.

The catalogues employed in the work were reduced to the same absolute system as that of Newcomb's *Catalogue of Fundamental Stars*, and all available positions in that catalogue are given in the present catalogue for 1900 without change.

The final solutions that were computed in this office and the computations of all the proper motions, secular variations, and star constants were done in duplicate. The copy for the printer was prepared from one set and the first type proof read from the other. In every particular the utmost care has been exercised to render the completed work free from error.

Dr. A. M. W. Downing, Superintendent of the British Nautical Almanac, upon notification of the commencement of the work, volunteered his assistance, and the final solutions of the equations of condition for all stars in classes 1 and 2 were performed under his direction with great efficiency.

Acknowledgments are due also to Professor E. C. Pickering, Director of Harvard Observatory, who kindly communicated photometric magnitudes of stars not contained in Volume XLV of the *Annals of Astronomical Observatory of Harvard College*, from which the magnitudes in this catalogue are taken, and to W. H. M. Christie, Astronomer Royal, who furnished advance sheets of the *Greenwich Second Ten-year Catalogue of Stars* for 1890.

Terrestrial Magnetism during the Total Solar Eclipse. In October *Knowledge*, some interesting conclusions have been reported regarding the effect of a total solar eclipse on terrestrial magnetism by C. P. Butler. Three are named which closely correspond with observations of this kind taken at different places. They are:

(1) The elongation of the needle to the west of the equilibrium position during the whole course of the eclipse was considerably less than the mean elongation; (2) none of the other curves recorded at one place (on other days) during the above period show this peculiarity; (3) at the exact moment of totality, corresponding to the usual maximum elongation to the west, there is shown a well accentuated minimum.

From this it will be seen that the effect of the eclipse is to cause a deflection of the needle to the east. The symmetry of the minimum and maximum of the curve proves that the magnetic effect accompanying the eclipse was of practically equal magnitude at the two stations at the moment of their respective totalities. The deflection at one place amounted to about 3′ to the east, whereas normally the needle at eclipse time should be about 5′ to the west of its mean position. M. Nordmann proposes to explain this phenomena by the direct action of the Sun's heat on the Earth's atmosphere. The upper air currents will be altered in electrical conductivity when they are immersed in the shadow, and this variation crossing the Earth's magnetic field may induce sufficient electromotive force to influence the declination needle. In support of this view is cited the fact that the daily variation does follow the insolation almost exactly. On this idea the effect of the eclipse is not to produce an actual deflection to the east, but to diminish the action of whatever factor produces the westerly daily variation.

The Dimensions of the Andromeda Nebula. Assuming the parallax 0″.7 determined for the Andromeda Nebula by Mr. Carl Bohlin of Stockholm (See P.A. No. 151 p. 96), to be correct, I have been interested in a rough calculation of the dimensions of the nebula. Using the ordinary formula for the distance of a star,

$$D = \frac{R}{\sin p''} = R \times \frac{206265}{p''}$$

and assuming R to be 93,000,000 miles, we have for the distance of the center of the nebula from the Sun roughly

$$D = \frac{93{,}000{,}000 \times 206{,}265}{0.17} = 113{,}000{,}000{,}000{,}000 \text{ miles.}$$

From measurement of my 12 hour photograph of the nebula I find the length to be approximately 1° 49′ and the width to be 29′. Assuming that the longest line through the nebula is perpendicular to the line of sight, from the Earth to the center of the nebula, we have for its longer dimensions

$$L = 113{,}000{,}000{,}000{,}000 \times 2 \tan 54.'5 = 3{,}600{,}000{,}000{,}000 \text{ miles.}$$

That is, the extent of the Andromeda Nebula is more than 600 times that of the orbit of the Neptune.

If the spirals of the Nebula are nearly symmetrical, lying in the same plane and the elongation is merely due to the foreshortening of one dimension by perspective, then the inclination of the plane of the spirals is about 15.°5.

The parallax used in the above calculations must be regarded as extremely uncertain, and the conclusions drawn therefrom should be given little weight, but they may help to give the reader a slight conception of the enormous extent of one of the most wonderful objects in the heavens.

The Crookston Meteorite—On the evening of Jan. 4, at 7:45 p. m., the people of Crookston, Minn., were terrified by the great brilliancy and sudden bursting into many fragments of what appeared to be a great meteorite, not far away. The dazzling light continued for more than 30 seconds. It was so bright as to frighten horses and make them unmanageable. We can not yet learn that any sounds of a detonating kind were detected in the terrific roar accompanying the display. Though searched for, no fragments have yet been found.

Meteoric Shower. On 1907 August 15 I saw five meteors during a watch of forty minutes from a radiant at 288° + 61°. One of them was stationary at that point. On August 26 at $9^h\ 18^m$ I observed a brilliant member of the same shower falling from 231° + 57° to 213° + 50°, and showing some curious fluctuations in its light. On August 28, during a short period of clear sky, I recorded two other meteors from the same radiant. On August 15, Mr. H. Corder saw a Draconid equal to Mars flashing out with an orange color at 288° — 10°, and falling 8° further in a vertical path directed from a point one degree west of β Cygni.

The shower is evidently active between August 15 and 28, and I recognized it between these dates in the years 1887, 1899, and 1900. Mr. Corder had also seen it pretty richly manifested on 1879 August 16 from 286° + 61° (10 meteors).

This display of Draconids, coming, as it does, concurrently with the rapidly declining stages of the great Perseid shower, deserves special mention, and particular efforts should be made in future years to re-observe it. In 1879 August 21 to 25, of 225 meteors which I recorded, no less than 56 were Draconids, and nearly all of them were bright, slow-moving objects with yellow trains. During the twenty-eight years which have passed since 1879 I have never seen the shower richly exhibited until last month, when, however, my observations were very imperfect on account of ill-health. Particulars of this evidently prominent and periodically visible system of meteors, as it appeared in 1879, will be found in the Monthly Notices vol. xl. pp. 127-8, and in The Observatory, vol. iii. pp. 172-3.

W. F. Denning.

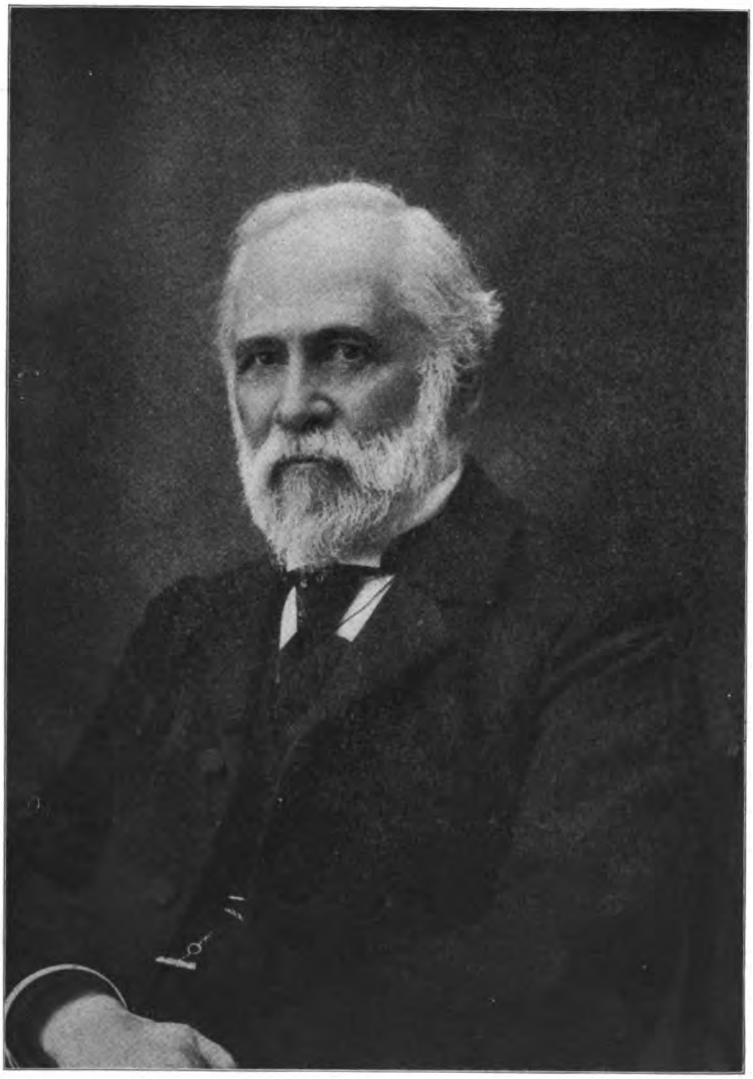
From Monthly Notices, LXVII, No. 9.

Solar and Planetary Physics and Motion—We have received a neatly printed pamphlet of more than 50 pages, titled: "Solar and Planetary Physics and Motion," by Edward Lynch, of Alameda, California. We notice that the pamphlet is dedicated to the memory of John M. Gregory first president of the University of Illinois, which at once brings to our minds, very freshly, the noble record that Dr. Gregory made in Michigan before going to Illinois.

The pamphlet is one of very unusual interest because of the research work in it on lines of study that have taxed able scholars for many years past and probably will continue to do so for many years to come. We are glad the author has titled these chapters as preliminary, because the suggestions they bring out can not be thought of as more than that, for the problem to be solved, and herein hinted at, is by far too difficult for more than plausible inference from the data that science has yet collected and helpfully arranged. To predict terrestrial meteorology for months and years to come from solar and planetary physics and motion, or from any other sources, is a thing to be sought after very earnestly, wisely and diligently.

In this direction the author has gathered much information, tabulated a mass of it, as well as he could, done a lot of interesting graph work in which he is plainly at home, and then based on all this information the supposition that the planets have influence enough in the Sun possibly to cause weather changes, electrical storms, earthquakes, and other phenomena of a similar kind. The many and interesting facts that the author has collected, arranged and tabulated, doubtless have a place and important meaning in terrestrial meteorology, but we fear no one can certainly claim for them yet quite so much as the author seems to see in them as the cause or causes of terrestrial influence for time predictions, for the reason that it is not yet proved that such things show sufficient cause.

PLATE VI.



CHARLES A. YOUNG,
1834-1908.

Popular Astronomy.

Vol. XVI, No. 4. APRIL, 1908. Whole No. 154

OUTLINE OF THE NEW THEORY OF EARTHQUAKES.*

T. J. J. SEE

FOR POPULAR ASTRONOMY.

Among all the varied natural phenomena witnessed upon our planet nothing so excites the dread and terror of mankind as an earthquake, which is at once violent and so sudden and unexpected as to alarm the calmest mind. That this direful feeling has prevailed in all ages we are amply assured by the comparisons made in the Bible and other venerable works of antiquity, which make known the consternation inspired among the people by these terrible natural commotions. Thus we read in history that some of the Emperors of Rome, especially Trajan and Hadrian, while witnessing the chariot races at Antioch and other places, found it advisable to withdraw from the amphitheatre and retire into the open spaces, in order to avoid the danger of falling walls. And the history of Greece and Rome abounds in stories of the religious anxiety excited among the people by earthquakes, which were believed to be signs of evil omen, sent from the infernal and marine divinities, but especially Poseidon, "the earthshaker," to whom so many temples were dedicated on isthmuses, promontories and other regions in the neighborhood of the sea.

When a great earthquake took place, and was followed by a series of after-shocks, impressively recalling both the terror and the disaster of the principal disturbance, which may have laid waste cities and devastated whole countries, it is not wonderful that the people who had sustained such losses were troubled and wrought up to a high pitch of excitement. In such emergencies the god Poseidon above all others called forth the veneration of the people; and he was generally held to be the most important of the infernal and marine divinities, because he held both the power of earthquakes and of those dreadful inundations by the sea, which were so often noticed

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* Address delivered at the University of Missouri, May 30, 1907, being Lecture No. 2 of a general course in Natural Philosophy.

to accompany violent seismic disturbances in the Peloponnesus and elsewhere.

The wide-spread alarm and religious affliction of the inhabitants of the Peloponnesus after the great Achaian earthquake of 373 B. C. is especially remarked by Diodorus Siculus, and other historians. At the same time it is stated that the natural philosophers explain these phenomena by natural and necessary causes, rather than by the wrath of the gods. But during the ages of Greek Polytheism, and even during the earlier centuries of Christianity, such disasters were always believed by the multitude to be a sign of the divine displeasure. Sometimes they were attributed to the wickedness of an emperor, or to the sins of factional opponents; the heathens charging them upon the Christians and the Christians laying them to the idolatrous conduct of the heathens.

In view of the undeveloped state of science in former times a modern student can easily understand the great perplexity of the ancients, in the midst of such terrible calamities. The Senate of Rome on more than one occasion did what it could to alleviate the sufferings of the people, which were partly real and partly imaginary. We find several accounts of the sending of formal embassies for the offering of public sacrifices to the angry divinities. If these sacrifices did not quiet the agitating forces of nature, they at least calmed the people and thus allayed their imaginary afflictions, and were therefore of service to the state.

It is well known that both the ablest statesmen and generals of antiquity regarded earthquakes as proceeding from natural causes; and I have recently been at some pains to translate the theories held by Aristotle and other leading Greek philosophers. Aristotle gives the views of those who preceded him, and his own theory was generally adopted by his successors. We may infer this by the way in which it was followed by such writers as Strabo and Pliny.

Aristotle placed his discussion of earthquakes in the book on *Meteorology*, because he ascribed the shaking of the Earth to vapor confined within the crust, and agitating to effect an escape so as to diffuse itself in the atmosphere. He recognized the high internal temperature of the Earth from the warm springs observed to break forth in many places, and from the eruptions of volcanoes which he had witnessed in the Aeolian Islands and elsewhere. Both he and Strabo mention eruptions occurring in the bed of the sea, and they also notice the great seismic sea waves which frequently accompany violent earthquakes originating near the sea shores.

Aristotle and Pliny distinctly remark that earthquakes are especially prevalent in maritime districts; and they attribute this phenomenon to submarine passages, conceived as deep conduits, by which air and water obtain access to the heated matter in the bowels of the Earth. They held that earthquakes are due to the agitation of imprisoned vapors even when none of it escapes to the surface, but all remains hidden beneath the Earth's crust. That the cause is the same when a volcanic outbreak occurs and when only an earthquake takes place without eruption, Aristotle affirmed on the ground of the similarity of the movement in the two cases.

To an unbiased naturalist like Aristotle it did not seem strange that in the one case the vapor should break through and diffuse itself in the atmosphere, while in the other it continued to agitate till movements occurred which gave more space beneath the Earth's crust, and was then followed by a cessation of the shocks. Aristotle's view was thus consistent with Newton's rule of philosophy, that the same effects are to be ascribed so far as possible to the same causes; and in marked contrast with the modern method of dividing earthquakes into two arbitrary classes, volcanic and tectonic, according as they are accompanied by eruption, or only by a surface's dislocation of the Earth's crust along a fault line.

While Aristotle's theory is imperfect in many respects, the general ideas underlying it are essentially sound, and in reading this work written more than twenty-two centuries ago, one cannot but be impressed both by his penetration into the nature of things, and by the vast extent of his knowledge. With characteristic independence he refused to accept the views of his predecessors, but examined *de novo* all questions upon their merits, so far as the existing state of science would permit. He is thus led to many interesting remarks, and the criticisms which he offers are often as good as can be made today.

In view of the great afflictions due to earthquakes suffered by so many countries from the earliest ages, it seems to the modern student truly remarkable that our understanding of the cause of these disturbances has remained so unsatisfactory. Whether we read in Strabo or Pliny that a great earthquake in Syria had laid waste twelve cities in a single night, or turn to the current books and press dispatches, which tell of widespread devastation by modern earthquakes, we are left equally in the dark as to the cause of these calamities. In current discussions we often see it stated that earthquakes may occur anywhere, and that no place is free from the dreadful ravages which they inflict upon large portions of mankind. This statement obviously is not correct, yet it shows that heretofore science has not reached the true laws of these phenomena.

The main object of science is the illumination of the human mind, and much of it scarcely admits of application to practical affairs, so as to alleviate human suffering; but if we had a true science of earthquakes it ought to be indeed of the highest humane as well as scientific interest. Shall our cities continue to be devasted and rebuilt without an understanding of the disturbing cause? If so what advance has our boasted civilization made over that of the Greeks and Romans? Nay, shall we not know even the regions especially afflicted by earthquakes? We could indeed have learned this from the study of Aristotle; but in our time we claim, though not always justly, to have improved on the knowledge of the ancients. If we do not find out the regions especially subject to earthquakes, so as to forewarn the people as to what kind of houses to build, and how to protect their cities from fire in the case of an earthquake, of what practical use is science to the community? Some branches of science might be very excellent indeed and still be of no use to the multitude of people; yet this obviously is not true of a science which deals with earthquakes imperiling the lives and property of thousands of our fellow citizens.

We must confess that heretofore this knowledge of the cause of earthquakes has not been forthcoming. But as a physicist believing in the existence of natural laws, which, if known, would be of the greatest service to mankind both now and throughout coming ages, I am going to treat of earthquakes and kindred phenomenon connected with the physics of the Earth. The theory of which I shall treat has been recently presented to the American Philosophical Society in Philadelphia, and I take this occasion to acknowledge my indebtedness to this illustrious society for the publication of lengthy arguments which can be mentioned here only with the utmost brevity.*

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* 1. The Cause of Earthquakes, Mountain Formation and Kindred Phenomena connected with the Physics of the Earth. Proc. Am. Philos. Society, 1906, issued March, 1907.

2. On the Temperature, Secular Cooling and Contraction of the Earth

At the time of the great earthquake at San Francisco, I had just finished the researches on the Physical Constitution of the heavenly bodies which have been recently published in the *Astronomische Nachrichten*; and as the explanations of the earthquake then made public by men of science did not seem to me to be well founded, I temporarily laid aside astronomical work in order to take up this problem of the Physics of the Earth. It is not too much to say that the papers which the American Philosophical Society did me the honor to publish have awakened a lively interest in the scientific world; and while one can scarcely hope that every difficulty has been overcome, it is evident that at least a good foundation has been laid for the true theory of earthquakes, mountain formation and kindred phenomena connected with the physics of the globe.

Since the processes involved in earthquakes are forever hidden from mortal view, the discovery of the cause involved naturally has been very difficult. But as the effects would become most sensible in earthquakes of the world-shaking class, it was felt at the outset that the investigation should be restricted to the study of these great phenomena. If the study of the greatest earthquakes enabled us to reach the underlying cause, the inquiry could later be made to include the smaller disturbances, many of which are after-shocks of the great earthquakes.

In speaking of earthquakes therefore we shall have in mind primarily earthquakes of the world-shaking class. If we had attempted to study all earthquakes together, the results could only have been hopeless confusion; for we should have been unable to discover the processes even of the greatest earthquakes.

One of the most remarkable results of these inquiries is the conclusion that the Earth is not shrinking, as commonly held in all the physical sciences for the past 80 years; but that it may indeed be slightly expanding. Another is that there is a progressive secular desiccation of the oceans, which are becoming narrower and also deeper in many places, so that as the world grows older the intensity of the earthquakes is slowly increasing, not diminishing. But obviously there has been no sensible change within the historical period.

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and on the Theory of Earthquakes held by the Ancients. Proc. Am. Philos. Society, 1907.

3. The New Theory of Earthquakes and Mountain Formation as illustrated by Processes now at work in the Depths of the Sea. Proc. Am. Philos. Society, 1907, issued in March 1908.

We shall now proceed to state the cause of earthquakes and related phenomena, and after so doing shall resume the consideration of the other questions connected with the physics of the globe.

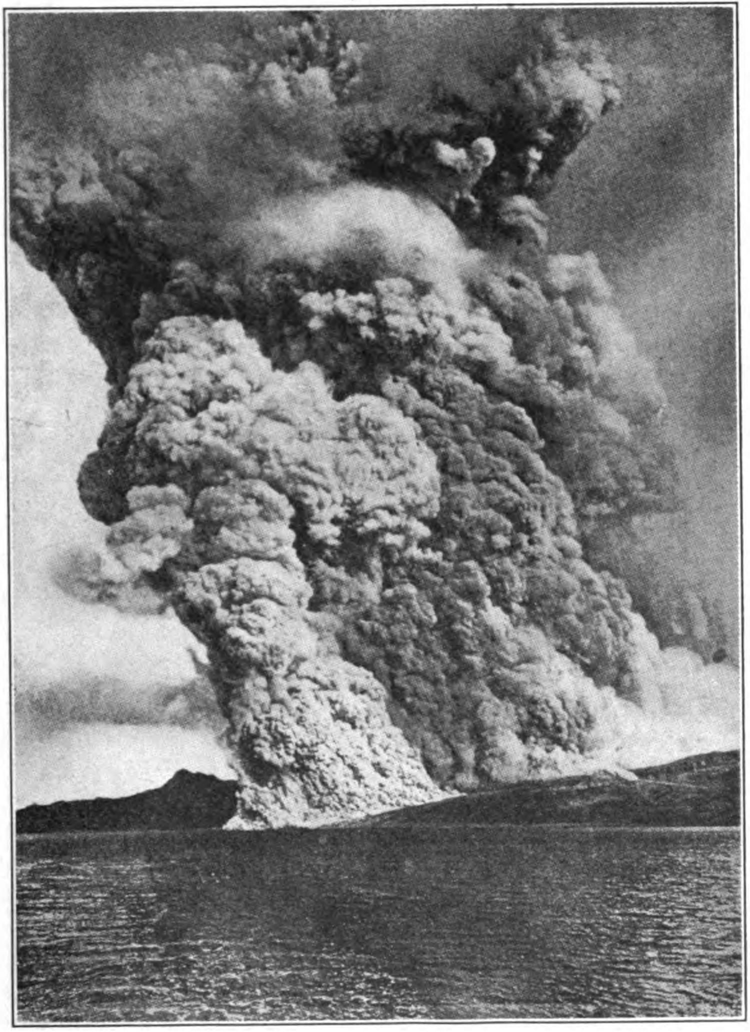
1. It is shown that the principal cause of world-shaking earthquakes is the secular leakage of the ocean bottoms, which produces steam beneath the Earth's crust. When the pressure has sufficiently accumulated the movement of the underlying molten rock shakes the Earth, lays waste cities and devastes whole countries. Much steam is formed under the ocean, but scarcely any under the land, and hence the usual process of movement consists in the expulsion of lava from beneath the sea, and the pushing of it under the land. The crust is thus pushed up and broken along the seashore, and thus forms mountains parallel to the coast.

2. The mountain systems of the world have been formed by this expulsion of lava from under the sea, and not at all by the shrinkage of the globe. Taking account of the mere lay of the mountains relatively to the sea, it is proved by the theory of probability that the chances are at least a decillion decillions to one that they were formed so exactly parallel to the coast by a true physical cause depending on the oceans. Moreover there are other phenomena to be considered of such weight that it becomes an absolute certainty that the mountains are formed by the sea.

3. The coast frequently is noticed to be upheaved during earthquakes, and the adjacent sea bottom is shown to sink, from the way in which the water retires before the inrush of the accompanying seismic sea wave. The sea does not withdraw from the land by the violence of the agitation of the ground during the earthquake, but slowly drains off afterwards, as in the ebbing of a tide, only the withdrawal is more rapid in the case of the movement before the sea wave; and as the sea level near the shore is thus lowered sometimes by forty or fifty feet, so that vessels at anchor in seven fathoms of water are left resting on the ground, it follows that the sea bottom sinks some distance from the shore, and the water rushes in from all sides to fill up the depression. When the currents meet at the center the water is forced up into a corresponding elevation, above the normal sea level, and the collapse of this aqueous ridge sends a great wave ashore, to add to the horror of the earthquake.

4. If then the sea bottom frequently sinks and the coast is

PLATE VII.



MOUNT PELÉE.

The Burning Cloud of December 6, 1902, seen from the sea.

PLATE VIII.


MAP SHOWING SEISMIC AND VOLCANIC AREAS OF THE EARTH'S SURFACE.
Seismic Areas in position and relative intensity
Volcanoes, Fumaroles, Solfataras now active or presumed as within historic or recent Geologic periods
Areas of supposed subsidence now proceeding
The number of "World Shaking" Earthquakes originating in districts A B C &c. 1899 to 1903 inclusive are given by large numbers. The Earthquakes from H I J & L were small.
J. Milne
NORTH AMERICA
SOUTH AMERICA
ATLANTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
AUSTRALIA
ASIA
Japan Islands
A 27
B 22
C
D 15
E 38
F 58
G 18
H 22
J 3
K 36
L 2
San Francisco
Longitude 80° East
Longitude 80° West
0
40°
80°
120°
160°

simultaneously upraised, it follows that lava is expelled from under the sea and pushed under the land. For in the regular order of nature the sea bottom could not sink unless it was in some way undermined, and the coast could not be uplifted unless something was pushed under it, and as one sinks while the other rises it follows that lava is expelled from under the sea and pushed under the land. Not only is this process now going on along the west coast of South America, and elsewhere, as repeatedly observed within historical times, but we may also affirm that the long continuation of this undermining in the past has sunk the sea bottom down into a deep trough and at the same time pushed such vast quantities of lava under the adjacent mountains that the lofty peaks in the Andes with snow-capped summits now seem to near the stars. There is thus direct continuity between the small movements observed within the historical period and the vastly greater effect of these forces operating over immense periods of time.

5. The process by which mountains and deep ocean troughs are formed is even better illustrated in the Aleutian and Kurile Islands, where the mountains under water are just rising out of the sea and the adjacent ocean trench is very narrow, and runs exactly parallel to them for great distances (see Manual of Tides, Coast Survey Reports, 1900, Part IV, A, by Rollin A. Harris, including maps of the depths of the ocean). This chain is also one of the worst earthquake belts in the world, and many of the mountains have burst open and become volcanoes. The earthquakes are frequently accompanied by great seismic sea waves, showing that the bed of the ocean sinks after lava has been expelled from under it in the formation of mountains. If the process thus made out is a true law of nature it follows that all the great mountain chains of the globe were formed by this same process, though in some cases the recession of the sea coast due to the movement of the crust by earthquakes, has changed the original shapes of the troughs, and consequently can now be make out only by careful investigation.

6. Our present knowledge of the Earth's surface does not enable us to decide just what movement of the land has taken place in each case, but the parallelism of the mountains to the sea coast is sufficiently remarkable to attract universal attention. Heretofore the cause of this phenomenon has been quite obscure, and some have inferred that it is a "coincidence which is only in part causal." It is shown, however, as already

remarked, that the chances are at least a decillion decillions to one that the parallelism depends on a true physical cause connected with the sea. It is absolutely unthinkable that the Pacific ocean could be so effectively walled in by great mountain chains all around, unless the mountains were formed about the ocean itself, by the expulsion of lava, in the way we have described.

7. In 1899, September 3-20, a terrible earthquake took place at Yakutat Bay, Alaska, during which the coast was elevated for more than a hundred miles, and at the maximum the elevation amounted to 47⅓ feet. Elevations of from 7 to 20 teet were common, while small depressions also occurred in a few places. This case was carefully investigated by Professor R. S. Tarr of Cornell University and Mr. Lawrence Martin of the National Geographical Society; and their memoir in the Bulletin of the Geological Society of America, Vol. 17, May, 1906, is illustrated by photographs of the most convincing kind, showing the uplifted coasts, with barnacles still adhering to the rocks. Their investigation is classic and absolutely conclusive. In the confused state of scientific opinion heretofore prevailing geologists could deny the bodily uplift of the solid land; but after the publication of this memoir they could no longer legitimately maintain this attitude. And if one instance of elevation by a powerful earthquake could be clearly established, it naturally followed that others could arise from similar causes. Last year the earthquake at Valparaiso, August 16, 1906, is said to have raised the Chilian coast about ten feet; and many similar movements at other places both in ancient and modern times can be certainly established.

8. The fact that no active volcano exists over about 100 miles from the sea or other large body of water, and the further fact that according to Geikie 999 in 1000 parts of the escaping vapor is steam, shows the dependence of volcanoes on the sea. The activity of 105 volcanoes in the Andes within historical time shows that volcanoes are nothing but ordinary mountains broken through by the pressure of subterranean steam. Hence it follows that the same forces which raise the mountain chains and peaks also cause the eruption of some of them.

9. The vapor of steam and no other is the cause of both mountain building and of volcanic outbreaks; for mountain building always takes place in or near the sea, and volcanoes

throughout the world develop near the center of the earthquake belts. Volcanoes emit chiefly vapor of steam, and eruptions generally cease when the vapor has escaped into the atmosphere. Thus earthquakes, volcanoes, mountain formation, and seismic sea waves are all due to a common cause.

10. As the expulsion of lava from under the sea causes the earthquakes and seismic sea waves, it follows also that all mountains are underlaid with pumice of various degrees of density, which is simply molten rock inflated with steam and then cooled and dried. The expulsion of such vast quantities of pumice from volcanoes shows that there must be a process for its abundant manufacture in nature, and that it must have been formed under all mountains when they were originally upheaved. The prevalence of pumice in volcanic regions is therefore accounted for in a perfectly simple manner. The grinding up of pumice makes volcanic ashes, and hence arise the vast quantities of this dust blown out of many volcanoes. Pumice and its disintegrated product in the form of ashes, result from the diminished pressure exerted on steam-saturated lava, when it is pushed under the mountains where the crust is broken, and increased expansion of the molten rock takes place.

11. The formation of islands in the sea and of plateaus on land, is to be explained by elevation of a portion of the Earth's crust by the injection of lava beneath. This lava comes from neighboring areas, which are thus undermined, unless the partial cavity is again filled up by an additional supply of molten rock. Hence plateaus such as those of Titicaca and Tibet are closely associated with the expulsion of lava, which originally caused the uplift of the Andes and Himalayas. In many cases islands in the sea have depressions near them, showing that the sea bottom was undermined in the elevation of the islands, and afterwards sank down to secure stability.

12. As all mountains and plateaus exhibit a feeble attraction when measured in geodetic operations, it follows that the cause of this phenomenon is the pumice underlying these elevated portions of the crust, which makes them attract as if they were hollow, or filled with caverns. This was noted by Bouguer and LaCandamine in their observations on Chimborazo as early as 1738.

13. When the subterranean pressure becomes great enough to shake the Earth's crust, it naturally moves at the nearest

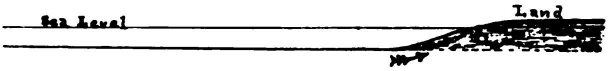
fault line, where the rocks are broken, and the resistance is least *but the movement observed is the result, not the cause of the earthquake.* It has been customary heretofore to explain earthquakes by the movement of faults, without assigning the cause of the fault movement, or by vague references to the supposed secular cooling of the Earth. Such procedure is altogether illogical, for it does not account for the origin of faults, nor even point out the correct cause of their movement.

14. If faults were due to the secular cooling of the Earth they ought to originate and move in the interior of continents as well as along the ocean shores; for acre for acre as much heat is being lost by Kansas, or Sahara, as by any sea coast or ocean bed in the world. Yet no important movements occur inland, while the sea coast is repeatedly shaken. The constant shaking of the Andes compared to the general quiescence of the Rocky mountains shows the effect of proximity to the sea, and proves that the secular cooling of the Earth is not a true cause of earthquake movements.

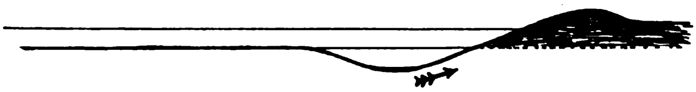
15. In the papers published by the American Philosophical Society at Philadelphia it is shown that the effects of secular cooling are wholly inappreciable, and that the Earth is not really contracting; but in all probability slightly expanding, owing to the predominant effects of elevations of the land by world-shaking earthquakes, 120,000 of which have occurred since the beginning of the Christian Era. And it is calculated that the effects of elevation may exceed the effects of contraction from 10 to 100 times, so that in all probability the globe is really expanding.

16. It turns out therefore that the doctrine of mountain formation based on the theory of contraction and now held for some 80 years is quite devoid of real foundation. If the Earth is not shrinking another cause must be sought to account for the observed elevations of the crust as seen in mountain folds; and it should explain mountain ranges in the sea as well as on the land. The present theory meets this severe test perfectly, and is beautifully illustrated by the phenomena exhibited near the Aleutian and Kurile Islands. Here the earthquakes are raising islands and at the same time sinking down the adjacent sea bottom, as may be confidently inferred from the accompanying seismic sea waves. These long narrow trenches have been dug out by the expulsion process, and it is still going on at the present time. No other interpretation of the observed phenomena is really possible.

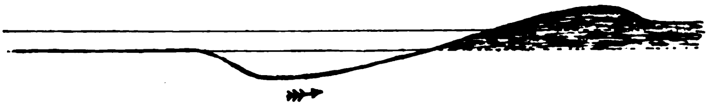
PLATE IX.



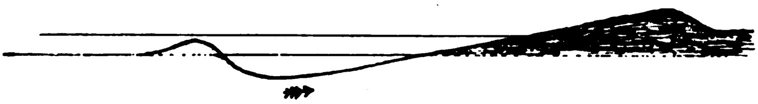
a. Mountain formation just beginning.



b. Mountain formation in the middle stages.



c. Mountain formation in the later stages.



d. New range rising from the sea.

17. The whole Plateau west of the Rocky Mountains has been raised from the sea in recent geological time. This is shown by the abundant beds of fossils, and by the numerous parallel mountain ranges nearer the Pacific Coast. The San Joaquin and Sacramento Valleys have been recently raised from the sea, and the great earthquake at San Francisco, April 18, 1906, was but one of an infinite number which have raised the coast range little by little and finally lifted California above the ocean level. Earthquakes obviously will recur in California, but no important disturbance is to be expected at San Francisco for at least a generation. This is inferred from the study of other places similarly disturbed during the historical period, and from the nature of the process of ocean leakage, which is very slow and gradual.

18. The cause of the terrible earthquakes in Japan is now perfectly clear, namely the leakage of the deep sea just to the East of Nipon, known as the Tuscarora Deep. By the expulsion of lava from under this area the whole island of Nipon has been lifted above the sea, and the process still continues with increasing violence. The east coast of Japan has risen considerably within the historical period, and naturally a movement of this kind confirms the theory here developed.

19. The present theory of mountain formation enables us to account for all the principal mountain ranges of the globe, and the more gradual slopes which they exhibit towards the sea from which the lava has been expelled in the process of elevation. In the case of islands the mountains run lengthwise, right through their centers like veritable backbones. In other cases lava escapes under larger submarine areas which will eventually be raised above the sea and formed into larger islands or continents. The principal cause of the movement of the Earth's crust is everywhere the same, but we do not yet know the details of all parts of the globe, because most of it is under water, and even that above sea level is very imperfectly surveyed.

20. As land is raised above the sea by earthquakes, it follows that the chief effect of seismic activity is the formation of more land. Since this narrows the oceans, and water is also constantly sinking down into the Earth, and only a small part of it again escapes through the vents of volcanoes, it follows that there is a secular desiccation of the oceans, but the process is excessively slow, and not certainly recognizable within the historical period. Yet a portion of the lowering

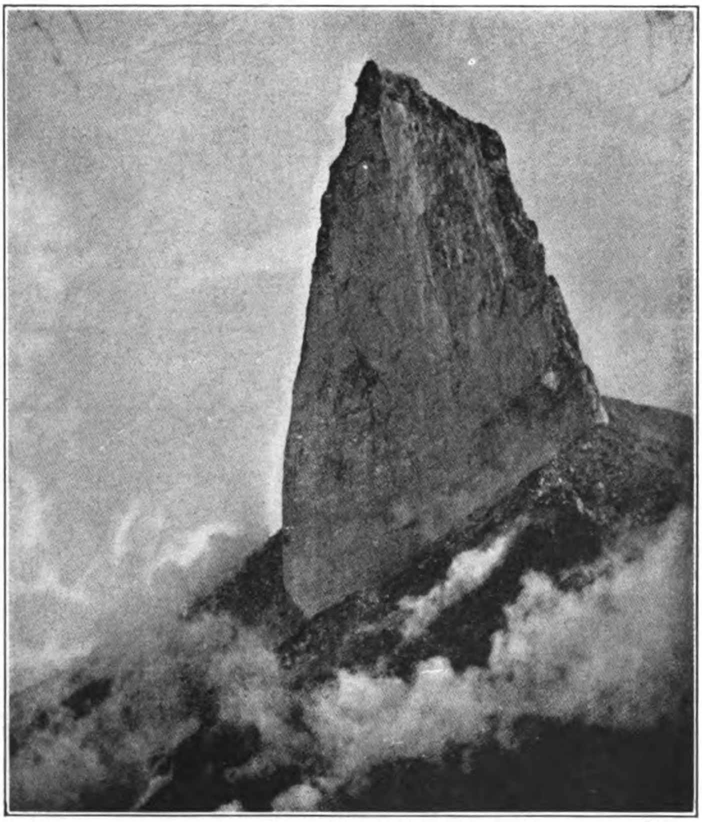
of the strand line noticed in later geological ages may be due to this cause.

21. In studying the sinking of the sea bottoms in connection with the expulsion of lava for the elevation of coasts and the formation of mountains, the writer took up the problem of the sinking of the Homeric City of Helike, after the great earthquake in Achaia, in 373 B. C., which occurred during the lifetime of Aristotle and Plato. And it was possible to prove from historical authorities that the subsidence amounted to about 100 feet, which shows that after that earthquake had pushed lava under the mountains in Arcadia, the bed of the Gulf of Corinth gave down, and carried the shore on which Helike stood down with it, so that, as Pausanias says, only the tops of the trees about the temple of Poseidon remained above the water. This famous disaster, which happened when Plato was 54 and thus at the head of the Academy in Athens, and Aristotle was a boy eleven years old, was therefore due to the expulsion of lava from under the Gulf of Corinth. Is it not remarkable that after the lapse of so many centuries we should be able to explain by simple principles a calamity which so disturbed the Greek world, and completely bewildered even the wisest of the Athenian sages?

22. As the result of his researches Aristotle held that earthquakes are due to vapors in the Earth, seeking to escape and diffuse themselves in the atmosphere. This view was generally adopted by the ancients, for we find it clearly stated by Strabo and Pliny, who studied the writings of Aristotle. Strabo also holds the theory that the land is uplifted and depressed by earthquakes. He seems to have held that not only islands and continents but also mountains are thus produced, which essentially accords with the theory of Aristotle, who had carefully studied volcanic and earthquake phenomena, including several eruptions observed to occur in the sea. Aristotle had observed that maritime districts are especially subject to earthquakes. In view of the results of modern observations and the theory now established, may we not justly consider this to be one of the most remarkable inductions of antiquity?

23. The theory now developed was therefore vaguely outlined by the leading Greek philosophers, especially by Aristotle, who associated the causes producing earthquakes and volcanoes, islands and seismic sea waves, all of which were attributed to the accumulation of vapors in the Earth. This natural order of thought as developed by the Greeks presents a strik-

PLATE X.



THE SHATTERED OBELISK OF MOUNT PELÉE.

Photographed by Professor Angelo Heilprin.

ing contrast to the disconnected and anachronous views on these subjects still current in our own time, and admonishes us to give ample heed to the independent conceptions of the Greeks who were not so much swayed as some moderns are by contemporary opinion.

24. The theory recently current that great seismic disturbances of the Earth's crust are due to unequal loading of different areas arising in erosion, denundation and deposits of sediment is, to say the least, unworthy of modern science, because such forces could produce no uplifts whatever, nor could they produce any serious continuous shaking, even if a slight movement of the ground should occur. It is the movement of molten rock under the Earth's crust, in the process of adjustment of steam pressure, which forms mountains, shakes down cities and lays waste whole countries. The development of the highest mountain ranges about the deepest oceans shows that these great uplifts of the crust depend upon the sea and not at all on the shrinkage of the globe. The indications of nature indeed are as clear as the noon-day Sun, and all we have to do is to apply to these phenomena a little of the saving common sense which has distinguished mankind in the better ages of the human mind.

This summary of the results of these researches is necessarily incomplete, but probably sufficiently extended to afford an idea of the trend of the investigation. Among American geologists Dana approached most nearly to the true views of the physics of the Earth's crust, and we shall therefore quote his statements as they were made over forty years ago. Some of his intuitions are quite remarkable.

VIEWS OF DANA.

In the first edition of his *Manual of Geology*, 1863, J. D. Dana treats of the general Features of the Earth and shows how the continents are walled in by mountains, erected about their borders, and finally adds (p. 29):

(a) "The continents thus exemplify the law laid down, and not merely as to high borders around a depressed interior, a principle stated by many geographers,—but also as to the highest border being on the side of the greatest ocean (first announced in American Jour. Sci. (2) xvii, vols. iii, iv, 1847, and xxii, 335, 1856). The continents then are all built on one model, and in their structure and origin have a relation to the oceans that is of fundamental importance." He also observes that the borders of continents are from

500 to 1000 miles wide, and infers that "a continent can not be less than a thousand miles, (twice five hundred), in width," otherwise it would not have the characteristic basin form with mountain barriers about a low interior.

(b) On page 731 he discusses the evolution of the Earth's great outline reliefs, and of the successive phases in its progress, summarizing his conclusions as follows:

I. "The continents have mountains along their borders, while the interior is relatively low; and these border mountain chains often consist of two or three ranges elevated at different epochs."

II. "The highest mountain-border faces the largest ocean, and conversely."

III. "The continents have their volcanoes mainly on their borders, the interior being almost wholly without them, although they were largely covered with salt water from the Azoic age to the Tertiary. Also metamorphic rocks later than the Azoic are most prevalent near the borders."

IV. "Nearly all of the volcanoes of a continent are on the border which faces the largest ocean."

V. "The strata of the continental borders are for the most part plicated on a grand scale, while those of the interior are relatively but little disturbed."

VI. "The successive changes of level on coasts, even from the Azoic age to the Tertiary, have been in general parallel to the border mountain chains; as those of the eastern United States, parallel to the Appalachians, and those of the Pacific side, as far as now appears, parallel to the Rocky Mountains."

VIII. "The continents and oceans had their general outline or form defined in earliest time. This has been proved with regard to North America from the position and distribution of the first beds of the Lower Silurian,—those of the Potsdam epoch. The facts indicate that the continent of North America had its surface near tide-level, part above and part below it (p. 196), and this will probably be proved to be the conditions in primordial time of the other continents also. And, if the outlines of the continents were marked out, it follows that the outlines of the oceans were no less so."

The three other conclusions announced by Dana are of less interest, and need not be quoted here.

(c) The following deductions (p. 732) regarding the positions of the reliefs are of high interest:

"1. The situation of the great mountain chains, mainly near the borders of the continents, does not indicate whether the elevating pressure acted within the continental or oceanic part of the Earth's crust. But the occurrence between the principal range and the sea coast of the larger part of the volcanoes (and, therefore, of the profound and widely-opened fractures) of these borders, of the most extensive metamorphic areas, and of the closest and most numerous plications of the strata, as so well shown in North America, are sufficient evidence that the force acted most strongly from the oceanic direction."

"2. The relation between the extent of the oceans and the height and volcanic action, etc., of their borders proves that the amount of force in action has some relation to the size and depth of the oceanic basin. The Pacific exhibits its greatness in the lofty mountains and volcanoes which begirt it."

"3. In such a movement, elevation in one part supposes necessarily subsidence in another; and, while the continental was the part of the crust which was elevated, the oceanic was the subsiding part."

In connection with the theory that the mountains are formed by the expulsion of lava from under the sea, through the operation of world-shaking earthquakes, these early views of Dana are of great interest. But in other respects he was led astray by the doctrine of the secular refrigeration of the globe; for he says that "no other cause presents itself that can comprehend in its action the whole globe and all time". He thus speaks as if the entire globe were shrinking, whereas local changes only are occurring, and these always near the sea. Dana's views that "the pressure of the subsiding oceanic portion has acted against the resisting mass of the continents; and thus the border between them has become elevated, plicated, metamorphosed and embossed with volcanoes," is alike misleading and unjustifiable. To produce such an effect the settling of the ocean basin would have to be many miles, and we have shown that no such shrinkage has taken place since the crust was formed; on the contrary there is reason to think that the Earth is expanding at a rate of from 10 to 100 times that of the contraction due to secular cooling. Moreover we have no more right to assume that the continent is squeezed by the settlement of the ocean, than that the ocean is squeezed by the settling of the continent.

(d) We have, however, recalled these views in order to do justice to the most original of the older American geologists, and also to let the student see where he departs from the true line of thought. Many years ago Rev. O. Fisher showed that shrinkage was wholly inadequate to account for the height of the mountains observed upon the Earth, which are hundreds of times higher than the contraction theory will explain. In the paper on the cause of earthquakes it is shown that the contraction theory is also emphatically contradicted by the present distribution of mountains. And in the second paper, "On the Temperature, Secular Cooling and Contraction of the Earth, and on the Theory of Earthquakes held by the Ancients," it is shown that at present the Earth is not contracting at all; so we are compelled to abandon the older theories entirely.

As heretofore developed geology has presented the strange anomaly of offering no theories adequate to account for the uplift of mountains or the deposits of fossil beds thousands of feet above the sea. This is the more remarkable, since in the days of Humboldt, Lyell, and Darwin, the bodily elevation of the land was an accepted item of belief. But subsequently Lord Kelvin, Sir George Darwin and other eminent British physicists, showed from the investigation of tidal and other phenomena that the Earth as a whole behaved as a solid, and under the influence of this line of thought geologists gave up the doctrine of the bodily elevation of the land, and restricted themselves to the collapse of portions of the crust under gravity. Such a line of thought, however, utterly fails to explain mountains and plateaus and islands, as well as shells and other organic remains at great height above the sea level. But it was felt that the argument of the physicists against the bodily yielding of the Earth was unanswerable, and so it was, but this does not exclude the existence of a layer just beneath the crust which in earthquakes behaves as fluid.

In my researches a theory is developed by which these two views may be reconciled, and it is, I think, clearly proved that in earthquakes there is movement of molten rock beneath the crust. It is this movement of molten rock beneath the Earth's crust which produces most of the dislocations, crumpling, folding, and other phenomena studied in geology. If such a view is justifiable, it shows us how cautious we must be in drawing final conclusions, and how incomplete all the sciences still are today.

We must now refer to Daubrée's experiments, and the problem of explaining how the water gets beneath the Earth's crust, to develop the steam power operative in earthquakes. Daubrée's experiments have shown that under pressure of

PLATE XI.


CARIBBEAN SEA
Gulf of Darien
Gulf of Panama
Amazon R.
PACIFIC OCEAN
ATLANTIC OCEAN
Rio de la Plata
Gulf of San Matias
Bay of San Jorge
SOUTH AMERICA
(Relief)
SCALE
Statute Miles to one Inch
Dark Brown indicates highest land
Dark Blue indicates deepest water

its own superincumbent column water may pass through cold and enter hot rocks, by capillary action, and increase the pressure within, notwithstanding the increase of steam pressure on the under side. In this way Daubrée explained volcanic eruptions, by which a column of molten lava is forced up into the vent of a volcano. Though Daubrée's results appear to have a good experimental basis, we may prove our fundamental proposition regarding the leakage of the oceans quite independently of these experiments.

Earthquakes are the processes by which mountains are produced, and observation shows that these forces act at a depth of some fifteen miles, where the pressure is so great that no vacancies exist. When the coast is upheaved by an earthquake it is clear that no real cavity is allowed to form beneath; in the same way we may conclude that when the sea bottom sinks after an earthquake no condensation of the matter of average density takes place beneath the bed of the sea. But matter is expelled from beneath the sea bottom and pushed under the land, so that the coast is upraised and the sea bottom sinks to fill up the partial cavity formed beneath the sea by the expulsion of lava.

These phenomena are repeatedly observed in South America, the Aleutian Islands and elsewhere, and, so far as one can see admit of but one interpretation. Hence we may conclude with certainty that the Andes have been formed by the expulsion of lava from beneath the bed of the adjacent ocean; this is the true meaning of the thundering of the earthquakes under the margin of the sea already witnessed for centuries, but not heretofore understood by men of science. This subterranean thunder is the outward expression of the mighty explosive forces by which the crust along the coast is uplifted into some of the mightiest mountains of the globe.

Since the Earth is not contracting, nor experiencing any sensible changes due to secular cooling, it is evident that this expulsion of lava can only be accomplished by explosive vapor such as is seen to issue from neighboring volcanoes, which often break out into eruption simultaneously with an earthquake noticed to produce an elevation of the coast and a sinking of the sea bottom. This vapor therefore is nothing else than common steam.

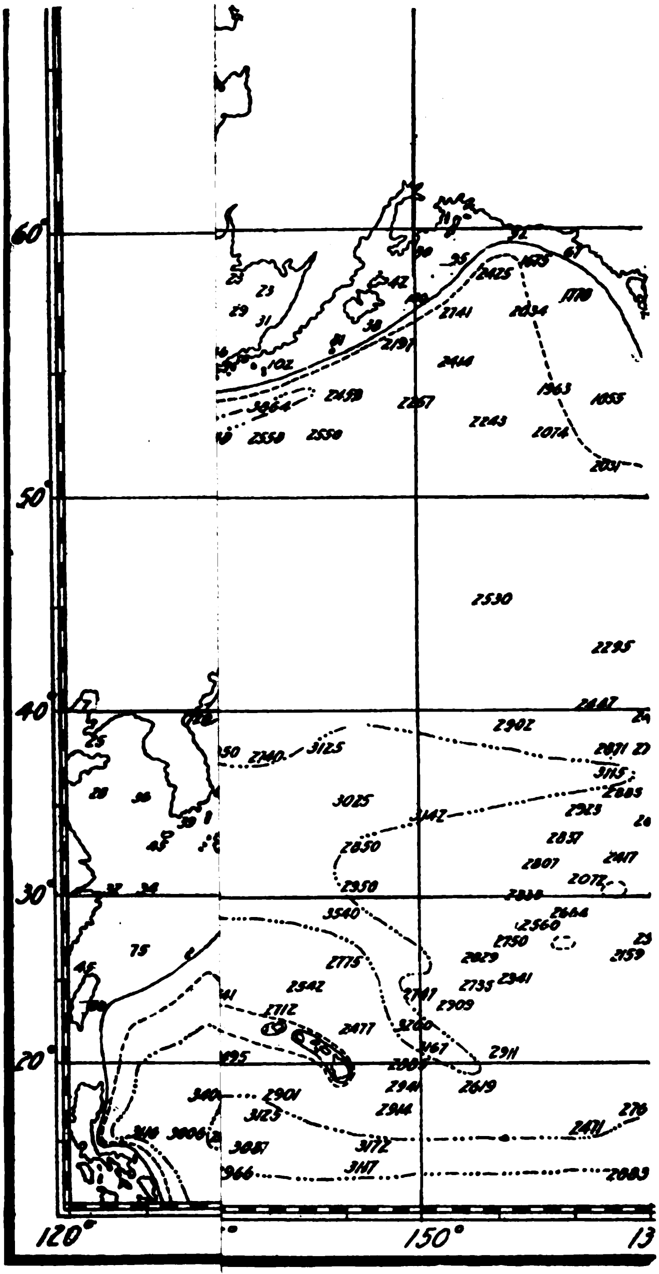
Now the steam developing beneath the Earth's crust and producing earthquakes and volcanic activity can be traced to but two possible sources: First, the original magma of the globe, which, in default of a better explanation, has been frequently invoked by the geologist; Second, the secular leakage of the ocean bottoms, effected through fifteen miles of solid rock like granite, which naturally appeals to the physicist. If the escaping steam, or any sensible part of it, came from the central magma of the globe, volcanoes and earthquakes necessarily would occur in the interior of the continents as well as along the coasts, on islands, and in the depths of the sea. For the continents are large areas, and altogether cover more than one fourth of the total surface of the globe; yet the volcanoes and world-shaking earthquakes are confined to the neighborhood of the oceans or other large bodies of water.

It clearly follows therefore that the agitating vapor does not come from the central magma of the globe, but must come from the secular leakage of the ocean bottoms. This is unmistakably indicated by the most overwhelming evidence of nature, and hence it follows that the secular leakage of the ocean bottoms through fifteen miles of rock like granite is effected by the constant pressure of the water upon the bed of the sea. When we recall that the column of water resting on the sea bottom is often five miles deep, giving a steady pressure theoretically adequate for throwing a jet to that height, it is not at all surprising that the water should work down through fifteen miles of rock like granite.

Accordingly it follows also that Daubrée's experiments are applicable to layers of rock from fifteen to twenty miles thick, and our fundamental proposition regarding the secular leakage of the ocean bottoms is proved quite independently of Daubrée's experiments.

In the case of our thinly encrusted planet so largely covered with water, the natural arrangement between the overlying oceans and the underlying molten globe constitutes a laboratory of the most imposing magnitude, infinitely transcending anything ever conceived by man, with gigantic experiments constantly going on. All that is needed therefore is for the philosopher to interpret nature's stupendous operations, which unfortunately only too often prove disastrous to human life, owing to our ignorance and disregard of natural laws. The highest duty of the philosopher is to discover these laws and make them available to the public, so as to contribute as much as possible to the safety and repose of mankind.

It is often imagined by many that the captains of industry are the principal creators of national wealth and prosperity,



shes, 2,000 fathoms.

and that discoveries of natural laws are of little value compared to material things. Is it necessary to point out the inadequacy of this view? Is not he who discovers how to safeguard and preserve the property of the state as essential to the public well-being as he who merely develops, without knowing how to build so as to preserve, the products of human labor? Would it be extreme to hold that a real discoverer, a true philosopher, is as valuable to the state as any Captain of industry? His worldly possessions, it is true, may be small, but his discoveries are useful to all mankind of the present and future generations; nay they are the one imperishable product of the age, a priceless heritage of civilization, and given *freely* to all the nations of the Earth!

In view of what has been proved in the researches here sketched, there will in the future be no excuse for our cities on the coasts of deep seas being consumed by conflagrations after earthquakes, for it is shown that all places on the coasts of deep seas are liable to earthquake disturbances, and the people should be prepared for such emergencies by extra and independent systems of water works. If San Francisco had possessed such knowledge before the late disaster, and had had the courage to live up to it, she would not have been laid waste by the fire, nor would the earthquake damages have proved very serious. But human frailty is such that we can learn only by experience. Let us hope that the lesson will not soon be forgotten, and that other cities on the coast will be prepared for possible emergencies.

In the same way there is little excuse for damage by seismic sea waves. If ships put promptly to sea on the first sign of the withdrawal of the water from the shore, they will usually be safe, and can ride securely over the waves due to the sinking of the sea bottom; whereas if they remain in the harbor they are almost sure to be stranded and perhaps destroyed, with enormous losses of life and property.

The researches of science therefore have an eminently practical and humane value, in addition to their purely philosophic interest. The preservation and promotion of science has therefore become one of the highest duties of the state; for the discovery of natural laws is really necessary to the protection of the people and the preservation of civilization.

Naval Observatory,
Mare Island, California,

CHARLES AUGUSTUS YOUNG.

JOHN M. POOR.

FOR POPULAR ASTRONOMY.

Charles Augustus Young, Professor Emeritus of Astronomy in Princeton University, one of America's most distinguished astronomers, died at Hanover, New Hampshire, after a brief attack of pneumonia, on January 3, 1908. Though frail of body through disease which had been making its inroad during recent years and though bowed with grief at the death of his wife in 1901 and more recently by that of his daughter, each after long illness, his failing strength prevented him from entering into life about him but a few days before the end came.

His retirement from active service after twenty-eight years as Professor of Astronomy at Princeton in 1905 and his return to Hanover, his native village, the college community of his early years, were made the occasion for placing before the alumni and friends of Dartmouth College substantially the following account of his life, which through personal interests or those of his relatives was for nearly a century closely interwoven with the affairs of the College. It has seemed that this sketch, though written for another purpose, might be of interest at this time to the wider circle of readers of POPULAR ASTRONOMY.

Immediately upon his resignation from Princeton men of science, men of letters and men of affairs, as well as trustees, faculty and students of the University with the townspeople of Princeton, his neighbors, gave expression to their admiration and appreciation for Professor Young, "Twinkle" as he had been fondly nicknamed by the students. One and all tried to show an indebtedness for some good that he had brought into the life of each, for his simple life free from all conceit and ostentation was a lesson to all about him, as they saw him quietly and modestly coming and going, thinking and speaking good of all. As teacher, investigator, adviser, friend and neighbor, Professor Young was loved.

Professor Young's resignation from active service was submitted to the trustees of Princeton University in December 1904 to take effect the following June. It was accepted, and a minute expressing the high regard of the trustees for him and their sincere regret at his departure was entered on their records, while he was made Professor Emeritus with a liberal salary. At once the University began to show its feeling. His class in astronomy called at his home and presented a loving cup. Mr. Robert Bridges of New York, a former student published in the *Sun* the following lines which deeply touched Professor Young:

THE ASTRONOMER.

The destined course of whirling worlds to trace:
To plot the highways of the universe,
And hear the morning stars their songs rehearse,
And find the wandering comet in its place:
This was the triumph written in his face
And in the gleaming eye that read the Sun
Like open book, and from the spectrum won
The secrets of immeasurable space!

But finer was his mission to impart
The joy of learning, the beliet that law
Is but the shadow of the power he saw
Alike in planet and in throbbing heart—
The hope that life breaks through material bars,
The faith in something that outlives the stars!

Members of the faculty and board of trustees joined with some friends in giving at the Princeton Inn a formal dinner, at which Dean Andrew F. West was toast-master and the toasts were responded to by members of the faculty and board of trustees who had been invited to speak.

President Wilson and Ex-President Patton spoke of the fame that Professor Young had brought to Princeton, and of his remarkable scientific attainments, coupled with his extreme modesty and piety. Mr. Cleveland found it impossible at the last moment to attend the dinner, but he sent the following letter, in response to the toast, "He never sold the truth to serve the hour."

Princeton, May 17, 1905.

Professor Andrew F. West,
My dear Professor:

I feel that I am deprived of a great gratification by my inability to personally participate in the occasion which is to voice the affectionate farewell of the Faculty of Princeton University to the most distinguished of their number.

I hope, however, I may be allowed to express to those who love and admire Professor Young, my sure conviction that nothing can be said by them more completely embodying the exalted nobleness of the man they have assembled to honor, or more prophetic of his everlasting fame, than the words: "He never sold the truth to serve the hour." His scientific achievements will during a long future illumine the world of progress and research; thousands whom he has guided to the height of knowledge will remember him and bless him; his kindly nature and beautiful example will bear fruit in the lives and character of all brought within the circle of their ennobling influence; but in the infallible and indelible record of God, and on the hearts of those who in all time to come shall learn his life, there shall be written this clearest and most conclusive testimony to his greatness and goodness: "He never sold the truth to serve the hour."

Yours truly,
GROVER CLEVELAND.

M. Taylor Pyne, speaking for the trustees of Princeton University said in part:

"Professor Young has been with us twenty-eight years, and he is leaving with the esteem and best wishes of every one of us. Never has his name been mentioned in my hearing except with respect, love, and admiration. I hardly think he knows how very fondly he is esteemed by us all, and how much we appreciate him. I hope he will some day realize what it means to the students who have come out from under his instruction and have watched him studying and mastering great problems, keeping always a firm faith in his maker."

Professor W. F. Magie spoke as a former pupil of Professor Young, and paid a high tribute to his skill as a teacher, and Professor Henry Van Dyke recited the following poem which he had written for the occasion:

STARS AND THE SOUL.

TO CHARLES A. YOUNG.

"Two things," the wise man said, "fill me with awe:
"The starry heavens and the moral law."
Nay add another marvel to thy scroll,—
The living marvel of the human soul.

Born in the dust and cradled in the dark,
It feels the fire of an immortal spark,

And learns to read, with patient, fearless eyes,
The splendid secret of the unconscious skies.

For God thought Light before He spoke the word;
The darkness understood not, though it heard:
But man looks up to where the planets swim,
And thinks God's thoughts of glory after Him.

What knows the star that guides the sailor's way,
Or lights the lovers' bower with liquid ray,
Of toil and passion, danger and distress,
Brave hope, true love, and utter faithfulness?

But the frail heart that, bearing good and ill,
Holds fast to virtue with a loyal will,
Lends to the law that rules our mortal life
The star-surpassing victory of life.

So take our thanks, dear reader of the skies,
Devout astronomer, most humbly wise,
For lessons brighter than the stars can give,
And inward light that helps us all to live.

The world has brought the laurel leaves to crown
The star-discoverer's name with high renown;
Accept the flower of love we lay with these,
For influence sweeter than the Pleiades.

For though the hour has come when we must part,
That influence long shall live within our heart,
And we shall know thee travelling on thy way
Into the brightness of a heavenly day.

Professor Cyrus F. Brackett spoke of Professor Young's place in science, and on behalf of the faculty presented to him a handsome silver loving cup. Then the toast of the evening was proposed standing, Professor Young expressing his thanks in a few characteristically modest words, during which he took occasion to pay a graceful compliment to his successor in the chair of astronomy, Dr. Edgar Odell Lovett. The dinner closed with the singing of Auld Lang Syne and Old Nassau, and a triple cheer for Professor Young.

At Commencement in June 1905 the degree Doctor of Laws was conferred by Princeton on Professor Young, who was thus introduced by Dean West:

"Charles Augustus Young, until to-day the Professor of

Astronomy in Princeton University. A pioneer in astronomical spectroscopy and photography; discoverer of the bright line in the spectrum of the corona; observer of the flash-spectrum at the beginning and the end of totality, thus becoming the discoverer of the 'reversing layer' of the solar atmosphere; preparer of a catalogue of bright lines in the chromosphere spectrum; first observer of remarkable solar eruptions; demonstrator of the resolution of Lockyer's 'basic lines' and of the sun-spot spectrum; author of books and many papers, some of them translated into various languages; observer or conductor in eight astronomical expeditions in this and other lands. His work is an enduring part of the history of astronomy;—a great discoverer, a great teacher, our dear and venerated colleague, whose knowledge is inferior only to his gentle modesty. And so, dear friend, hail and farewell! In the old words: *Di tibi dent annos; de te nam cetera sumes*,—'God grant thee many years. All else thou shalt have in thyself.' "

As he came forward to receive the degree, the students in the body of the house arose and gave a triple cheer for Professor Young.

Professor Young used to say that teaching was his vocation and research his avocation. But among the many who were his students or who profited by his encouragment and advice, several of whom hold high positions as directors of observatories, probably very few can hope to contribute more to science by invention and discovery than he to say nothing of his teaching. He taught astronomy to fifty-one classes of college students, and thousands heard his lectures or read his text-books.

It has been said that Professor Young "was to the manor born." His maternal grandfather, Ebenezer Adams, one of nineteen children, was born on a farm at New Ipswich, New Hampshire, in 1765, and because of the moderate circumstances surrounding him delayed until nearly twenty-two years of age his entrance to Dartmouth College, from which he graduated with honor in 1791. After teaching eighteen years, he was in 1809 called to Dartmouth as Professor of Languages, but in the following year was made Professor of Mathematics and Natural Philosophy. This position he held until his resignation in 1833, when he was made Professor Emeritus. He was a faithful, patient, earnest teacher of varied attainments, personally interested in the welfare of his students to whom he imparted information clearly and easily. He in no small way aided in bearing the burdens of administration and for more than two years during the sickness and after the death of President Brown he acted as president of the College. At his resignation in 1833, he was succeeded in the professorship by the father of Professor Charles A. Young, Professor Ira Young, who soon after his appointment married Eliza, youngest daughter of Professor Adams.

Professor Ira Young was born at Lebanon, New Hampshire, in 1801. His want of means and his father's refusal to allow him time before his majority prevented him from entering College before twenty-three years of age. He graduated from Dartmouth with high rank in 1828. In 1830 he became tutor in Dartmouth College and in 1833 he accepted the Professorship of Mathematics and Natural Philosophy. In 1838 his chair was changed to that of Natural Philosophy and Astronomy, a position which he held until his death in 1858. He was a master of the science and literature of his department to which he had given special attention while in College. A thoroughly earnest seeker for truth, he developed a like spirit in his pupils, and like this predecessor he was a born teacher, possessing the power of clearly stating his knowledge and, mindful of his own youthful difficulties, he was habitually patient in presenting his facts after reducing them to their simplest terms.

In 1853 he visited Europe in the interest of Shattuck Observatory, which was built and equipped with funds obtained largely by his own efforts. He was accompanied by his son, Charles A., then in his senior year in Dartmouth. Professor Ira Young died rather suddenly in 1858, and was succeeded by the late James W. Patterson as Professor of Astronomy and Meteorology, who was in turn succeeded by Professor Charles A. Young as Appleton Professor of Natural Philosophy and Professor of Astronomy in 1866.

Professor Charles A. Young was born at Hanover, New Hampshire, December 15, 1834. Unlike his grandfather and his father he was ready for college at fourteen, having been his father's assistant in surveying and in the chemical and and physical laboratories since ten years of age. He entered Dartmouth in 1849 and graduated in 1853 with honor at the head of his class of fifty men. While a student he was not interested in college politics or society matters. His nickname was *Adulescentulus*. He was a member of the Social Friends, the Theological Society, corresponding to our Y. M. C. A., and the Society of Inquiry, which was composed of students interested in missionary work. As before stated he visited Europe with his father during the spring and summer of 1853, thus being absent from the Commencement exercises of his class, but his diploma was granted with the rest as his work had been "made up" in advance. Soon after graduation he made his first contribution to scientific literature by publishing in a volume entitled "New Hampshire As It Is" the article on "Climate" for which he received ten dollars. From 1853 to 1855 Professor Young taught classics at Phillips Academy, Andover, Massachusetts, when he entered Andover Theological Seminary where he spent one year, giving part time for half a year to teaching classics in the Academy. In 1856 came the call to Western Reserve College at Hudson, Ohio, and Professor Young gave up his plans for missionary work to accept the Professorship of Mathematics, Natural Philosophy, and Astronomy, at that institution, beginning his work in January 1857. In the following August he married Miss Augusta Mixer, grand-daughter of Hon. Samuel Morrill of Concord, New Hampshire, with whom she had lived since the death of her father soon after her birth. To Professor and Mrs. Young were born while in Hudson three children, the late Mrs. Clara Y. Hitchcock, wife of the late Hiram A. Hitchcock, who was for eight years until his death in 1895 Associate Professor of Civil Engineering in the Thayer School at Hanover, New Hampshire, Charles I. of Philadelphia, who is an engineer in the Westinghouse Electric and Manufacturing Company, and Frederick A. of Washington, D. C.

At Western Reserve Professor Young furnished time-service for Cleveland, his system being one of the earliest in the country, and during several summers worked in the U. S. Lake Survey in determining telegraphic differences of longitude. For one year he held his only political office as common councilman of Hudson, from a ward composed largely of students. In 1862 in reponse to a call from the governor of Ohio for three months' volunteers, the students' military company offered its services which were accepted, and it became Company B of the 85th O. V. I. with Professor Young as captain. For a time it did duty at Camp Chase in guarding confederate prisoners, and later went as escort for two thousand prisoners to be exchanged at Vicksburg. "Captain" Young returned to academic duties with impaired health.

As early as 1863 he was offered the Professorship of Mathematics in Dartmouth College, which he declined; but in 1866 came the call to become Appleton Professor of Natural Philosophy and Professor ot Astronomy, a position which he accepted and returned to the home of his boyhood to occupy the chair held by his father until 1858. At about this time, that keen mechanical ingenuity so characteristic of all his work manifested itself in the independent invention and publication of plans for a printing chronograph.

At this point begins the conspicuous period of his career. Upon returning to Dartmouth he began at once his investigations in spectroscopy to which he brought enthusiasm, untiring energy and devotion to work, keen powers of observation and analysis, a vigorous active mind, and rare mechanical skill. He saw the opportunity in spectroscopy and advised that the comparatively large Appleton fund, established in 1845, be spent in equipment rather than buildings. His advice was followed, and within a few years there came that series of investigations and discoveries which placed him at once among the most distinguished astro-physicists of the world, and brought upon the observatory and laboratory an international reputation. Though always interested in mathematical astronomy so that he was a master in analyzing and stating complex ideas there involved; and though his "true eye" brought him a high rank as an observer with micrometer and transit instrument, yet it was above all as an astrophysicist and authority on the Sun that Professor Young was celebrated and for which he was most highly honored.

After corresponding with Professor Cooke of Harvard, Professor Young obtained from Alvan Clark a spectroscope and through Professor Alexander, of Princeton gained an opportunity to observe the eclipse of 1869 at Burlington, Iowa. Professor Young's work consisted in spectroscopic observations of the contacts, first made at this eclipse by him, and his discovery of the green line of the corona spectrum—seen also by others with less powerful instruments—which he wrongly but quite naturally identified with Kirchoff's "1474," a line which he had independently discovered not long before in the chromosphere spectrum. This error remained uncorrected until the eclipse of 1898 when Sir Norman Lockyer and Professor W. W. Campbell independently showed that the wave length of the corona line was slightly different from that of "1474."

This success resulted in the immediate construction, according to plans suggested by Professor Young, of a "prominence" spectroscope, and an invitation to observe the eclipse of 1870 at Jeres in Spain, where he observed the "flash" spectrum and discovered the "reversing layer," the most prominent event of the eclipse, thus described in his own words: "As the crescent grew narrower . . . . . . the dark lines of the spectrum, and the spectrum itself, gradually faded away, until all at once, as suddenly as a bursting rocket shoots out its stars, the whole field of view was filled with bright lines more numerous than one could count."

The wholesale reversal of the spectrum was long questioned, and especially by Sir Norman Lockyer, so that for more than a quarter of a century Professor Young waited for confirmation, which finally came from a photograph by Mr. Shackelton, one of Sir Norman Lockyer's assistants at the eclipse of August 9, 1896. Just before the eclipse Sir Norman had said in *Nature*, "To my mind the reversing layer is dead and buried already, but may the fates be propitious on the 9th and enable us to place the wreath on its tomb." After the reversing layer had been established by Mr. Shackelton, Sir William Huggins in writing Professor Young took occasion to quote from "Old Mother Hubbard," how she

"Went to the joiner to get him a coffin
And when she came back the dog was a-laughing."

The same year (1870) also saw the first photograph of a prominence, which was made with the prominence spectroscope of Shattuck Observatory. After his return from the Spanish eclipse of 1870, Professor Young raised the funds necessary for mounting a 9¼-inch lens by Clark in the dome previously occupied by a 6¼-inch Merz lens. In 1871 he published his explanation of the spectrum of the solar corona, and on September 7, 1871, he observed the most remarkable outburst on the Sun which had been seen up to that time. In the following summer he undertook under the auspices of the United States Government an investigation of the advantages of observing stations of high altitude. He visited Sherman, Wyoming, where 170 new chromosphere lines were added to the one hundred already catalogued at Shattuck Observatory, and at this station were also observed those solar disturbances which when compared with the magnetic records at Greenwich did much to establish the probability of some connection between terrestrial magnetism and solar conditions.

The first aplication of the diffraction grating to astronomical work was made by Professor Young in 1873. In 1874 he was asked to take charge of a party which was to visit Kerguelen Island for observations of the transit of Venus, but this he was unable to accept because of the long absence from the college which would be necessary. He was, however, able to join the party of Professor James C. Watson, which successfully observed the transit at Peking, a large number of photographs being secured; but hardly had the observers finished their work when there appeared clouds which together with a dust storm closed in upon them, entirely obscuring the Sun. One possible disaster had been escaped by a narrow margin, but not all dangers had yet been passed, for within a few days the Emperor of China fell ill with smallpox, and the astronomers from America were advised by the American legation that inasmuch as the foreigners who had been dealing with spots on the Sun might be held responsible for the spots on the Emperor's face it was advisable that the party leave as soon as possible. They therefore immediately began their journey homeward in carts in which they travelled seventy miles, for the most part by night, to Tientsin.

While at Peking Professor Young, in observing transits for time with a "broken" transit instrument, detected certain residuals in his results which he finally traced to flexure of the axis of the transit instrument, a matter which has since received theoretical treatment. In 1876 Professor Young first measured the rotation of the Sun by means of the diffraction grating from displacement of lines in the solar spectrum.

Professor Young had been at Dartmouth little more than a decade when he was called to Princeton as Professor of Astronomy, a position which he accepted. During his years at Dartmouth, besides accomplishing what has already been recorded together with teaching, he had written perhaps one hundred papers, for the most part on scientific subjects, and published his first book "The Sun," the reproduction of a lecture delivered at New Haven in 1872. This book is not to be confused with that of the same name published nine years later. He had begun in 1868 his lectures on physics and astronomy (each given in alternate years) at Mount Holyoke Seminary (now College), which were continued until 1883, after which until 1903 he lectured biennially on astronomy. About 1870 he began those public lectures for which he later became so famous. From 1872 until 1898 he lectured biennially at Bradford Academy, Bradford, Massachusetts. In 1873 and again in 1875 he lectured on physics at Williams College, and he lectured at numerous schools for young women both before and after leaving Dartmouth. While at Dartmouth several offers of professorships were received from leading colleges and universities. In 1869 he was elected an associate of the American Academy of Arts and Sciences, and about 1872 he was made an Associate of the Royal Astronomical Society, a member of the National Academy of Sciences and also of the American Philosophical Society, and in 1876 he was Vice-President of Section A of the American Association for the Advancement of Science. He received the degree Doctor of Philosophy from the University of Pennsylvania in 1870, from Hamilton College in 1871, and in 1876 Wesleyan conferred npon him the degree Doctor of Laws.

At the time of his call, Princeton's chief astronomical equipment was the three-inch Fraunhofer lens now used as a collimator, but within a year the students' observatory was built and liberally equipped with the best instruments for teaching, including a telescope by Clark slightly larger and much better than the one left at Dartmouth, together with the necessary spectroscopic apparatus, and in 1882 the large Halsted Observatory was equipped with a telescope of twenty-three inches aperture, by Clark, and the most powerful spectroscopic apparatus then to be procured. From 1878 to 1880 he undertook an examination of Sir Norman Lockyer's "basic lines" and showed that they were double and not to be attributed to the same element. In 1878 he conducted a party of Princeton men to Denver to observe the eclipse of that year. The weather was good but no especially important results were obtained. In 1887 he visited Russia to observe the eclipse near Moscow, but rain entirely prevented observations, and again in 1900 he organized a party which successfully observed the eclipse at Wadesboro, N. C.

Among other investigations which engaged his attention while at Princeton were spectra of sun-spots, formation of of sun-spots, spectra of comets, the spectrum of Venus, the spectrum of Nova Aurigae, revision of his catalogue of chromosphere lines, color correction of certain objectives, polar compression of Mars, polar compression and belts of Uranus, and measurements of double stars (not yet published), and in 1882 the transit of Venus was elaborately observed, both visually and photgraphically, at Princeton in coöperation with the various government parties. Early in his work at Princeton he completed his plans, already begun at Dartmouth, for a clock escapement which should unlock and receive its impulse at that point in its oscillation where disturbances have least effect on its natural period. This escapement has been giving good service in the standard clock at Princeton for twenty-eight years. A modification of a suggestion by Professor Young has been adopted in the driving clocks used on many recent American telescopes. Professor Young's observational work ceased only when his own failing health and that of Mrs. Young made his frequent visits to the observatory impossible.

In 1881 he published in the international Scientific Series his book entitled "The Sun." This book, containing a complete summary of existing knowledge of the subject, has run through numerous editions and has been translated into several languages. In 1889 he published his first text-book "General Astronomy," in 1890 he published "Elements of Astronomy," and "Uranography," in 1891 "Lessons on Astronomy," and in 1901 his "Manual of Astronomy." All except the last have run through numerous editions and the total sales amount to approximately 130,000. He published a large number of scientific papers, with many magazine and newspaper articles, and from 1890 to 1903 he gave perhaps a dozen courses of university extension lectures as well as many single lectures.

He received the degree Doctor of Laws from Columbia in 1887, Western Reserve 1893, Dartmouth 1903, and Princeton 1905. In 1884 he delivered the address of the retiring president at the meeting of the American Association for the Advancement of Science. In 1887 he attended the meeting of the British Association for the Advancement of Science and was made a foreign correspondent, and at about the same time became an honorary member of the Manchester Literary and Philosophical Society. In 1896 he became a member of the Cambridge (England) Philosophical Society; but his greatest honor came in 1891 when he received the Janssen Medal from the French Academy of Sciences for his spectroscopic investigations, and especially for the discovery of the reversing layer.

Upon his return to the scenes of his boyhood he immediately took part as far as health permitted in the activities about him. Though greatly regretting it, he was compelled to give into the hands of others work which he had definitely planned for the years of his retirement. At times confined to the house, his health had during recent months greatly improved so that he was shut in from the Sun he loved and to the knowledge of which he contributed so much but a few days before he gently passed away.

The funeral was held on Sunday afternoon, January 5. Mr. F. L. Janeway, Pastor of the College Church, a former pupil at Princeton, conducted the service, a few friends sang favorite hymns, and Doctor Leeds, Pastor Emeritus of the College Church, spoke most fittingly out of a long and intimate friendship. The bearers were Professor Edgar Odell Lovett, his successor in the chair of Astronomy at Princeton, Professors John K. Lord, Charles F. Emerson and John M. Poor of the Dartmouth faculty. Interment took place in the old cemetery near the house in which he was born.

At the meeting of the faculty of Princeton University immediately following Professor Young's death the following resolutions were passed:

Resolved: That the faculty have heard with profound sorrow of the death of Professor Charles Augustus Young. Alike in gifts and in character he had always seemed to them the ideal man of science. His transparent honesty, his unaffected modesty, his insight into principle, and his achievement in discovery united to give his career not only distinction but also grace and beauty; and his qualities as a man won for him our love as well as our admiration.

He died full of years and of honors, but his death could at no time be less than a great bereavement; and the faculty extends to his sons, his sister and all who have been nearest to him in life their deepest sympathy.

Resolved: That the Clerk of the Faculty be requested to send a copy of these resolutions to Professor Young's family and to *The Princeton Alumni Weekly.*

Professor Young is survived by his two sons, Charles I., of Philadelphia and Frederick A., of Washington, D. C., his grandson Charles Y. Hitchcock of Hanover, N. H., and also by his brother Albert A., of Winona Lake, Ind., and his sister Mrs. Adeline E. Proctor of Hanover, N. H.

Shattuck Observatory,
Hanover, New Hampshire.

PLATE XIII.

HENRY M. PARKHURST,
1825-1908.

HENRY M. PARKHURST.

J. A. PARKHURST.

FOR POPULAR ASTRONOMY.

After a long and exceedingly active life the subject of this sketch passed away at his home in Brooklyn, New York, on January 21, 1908, after a brief illness. Early in life he was attracted to astronomy, and though his versatile mind could not be confined to any one branch of science, astronomy was his favorite, and the amount of solid and useful work which he accomplished entirely as an amateur would be a credit to any professional astronomer. He was a frequent contributor to the *Sidereal Messenger*, and *Astronomy and Astro-Physics*, so that it seems fitting that a sketch of his life and work should be given in *Popular Astronomy* as an inspiration to those amateurs who are taking up the work which has been laid down by the former generation.

Born in New Hampshire March 1st 1825, he became the first American phonographic reporter. From 1848 to 1854 he was Chief Official Reporter for the United States Senate, and as such reported Daniel Webster's speeches. An idea of the far-reaching influence of this young reporter on American business life can be had by considering the fact that he was first to introduce women to the profession of stenography. Later he followed his profession in New York City, being for twenty years official reporter for the Superior Court.

Before describing his astronomical work, brief mention must be made of some of his activities in other directions, as these will help us to appreciate his ingenuity, his alertness of mind, and the broad view which he had of life. As a young man he was interested in music and in 1851 he invented and constructed a new "Harmonic organ" and devised a new musical notation. In 1855 he patented a new form of proportional dividers. He published papers on "A New Currency" (1848), "A New Mode of Minority Representation," many papers in the *Photographic Times*. That he had the spirit and courage of a reformer we have abundant evidence throughout his life. His work as a stenographer early called his attention to the faults of the English language. Not content with half-way measures of reform, as early as 1845 he invented a universal language, and throughout his life he was an earnest and consistent advocate of spelling reform. For nearly forty years he published "*The Plowshare*," putting it in type and printing it with his own hands, using an alphabet in which each character stood for a single sound and each sound was represented by a single character. Similar reform principles appear in his "Duodecimal Metric System" published in 1872, and the "Duodecimal Notation" in 1874. His "Stenophonography," a modification of Pitman's phonography, was put in type and printed by himself. When we consider that these were all products of his "leisure" time, outside his professional duties by which he gained his livelihood, we must admit that his was a busy life. This opinion will be further strengthened when we come to consider his

ASTRONOMICAL WORK.

He became interested in astronomy at the age of six, and at seventeen he invented what he called the "Elongator," a concave lens for lengthening the equivalent focus of the telescope. At eighteen he observed the great comet of 1843 and computed its orbit by a method of his own devising. When this was published in the *American Almanac* of 1844 his name was mentioned among the "eminent astronomers" who had computed the orbit. His close watch on the sky is shown by his independent discovery of Donati's comet in June 1858 while it was still a faint object, and another similar discovery in 1863. His skill in observing is shown by his success with the transit of Mercury in 1868, for which his observations were allowed greater weight than any others in America. Before this time he came to realize the importance of having a regular line of work which should be continued over a term of years. This was an advanced position to be taken by a busy professional man, and was worthy of an astronomer having a fixed position and salary. Appreciating the need of better star-maps as a foundation for any advance in stellar astronomy, he says—"In September or October 1856 I completed the invention and construction of the first Star-Mapper ever devised. A roll of paper being moved as in telegraphing, to represent the right ascension, a pen moving at right angles to the motion of the paper, and connected by levers with a pointer moving in the focus of the eyepiece, marked the position and the estimated magnitude of each star of the zone. In six years I had thus mapped 100,000 stars. I discovered Galatea by finding it on my maps two months before the news of its discovery by Tempel reached this country."* It is a curious coincidence that the invention and use of the "Star-Mapper" synchronized with the first publication by Argelander of a notice of his great project of the *Bonn Durchmusterung*,† which absorbed the energies of the Bonn Observatory for years. The third part of the *Durchmusterung*, completing the northern heavens, was published in 1862. In these three parts the workers at Bonn had mapped 324,000 stars, while our amateur, after office hours, had mapped 100,000! If American astronomy could have had the same support which was given to the science in Germany, it is reasonable to suppose that we might have shared with that country the glory of such great works as the *Durchmusterung*, but in those troublesome times it could not be expected.

From mapping the positions of stars and estimating their magnitudes, the next logical step was to measure their magnitudes; so we find that from the sixties onwards, stellar photometry occupied more and more of his astronomical activities, and after 1883 became his specialty. It is difficult for us to realize the confusion which existed in stellar photometry a generation ago. The scale of the Bonn Durchmusterung was only one of many in use, and that was founded on eye-estimates and the limit of vision of a 3-inch comet seeker. Pogson's ratio, giving the relation between the light of stars of adjacent magnitudes, had been suggested but not generally adopted, consequently there was no guide for the magnitudes of the fainter telescopic stars. Argelander's 13th magnitude corresponded approximately with the 16th of Herschel and Smyth and 11th of Struve. With characteristic good judgment Parkhurst adopted Pogson's ratio (using it after 1863) and proceeded to devise instruments for the accurate measurement of magnitudes. In the *American Journal of Science* for January 1870 he described two photometers: a "Photomapper" which was a combination of wedge photometer and the "Star Mapper" already described, mapping positions and magnitudes at the same time; and a "Disk Photometer" for the brighter stars.

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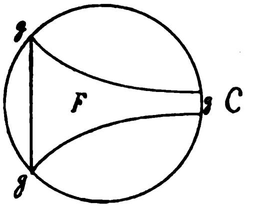
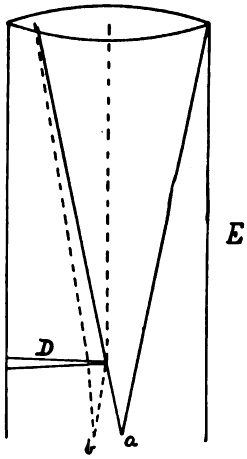
[*] For description of the "Star Mapper" see *American Journal of Science*, September 1869.

[†] *Anzeige* von einer auf der Königlichen Univer. Sternwarte zu Bonn unternommen Durchmusterung des nördlichen Himmels als Grundlage neuer Himmelscarten. Bonn, 1856. See *Bonner Beobactungen*, Bd. III, Einleitung.

He says: "By the latter method I expand the stars into disks by drawing out the eyepiece beyond the focus, until a portion of the disk, shining through an aperture in the field of view, shall be exactly equal to an adjacent luminous disk." During the years 1869-71 he measured with this photometer the light of 82 naked-eye stars, 19 of those most frequently observed having a mean error less than 0.03 and 31 others less than 0.10 magnitude. Constantly experimenting he devised and used; Reduced apertures, 1859; Bar photometer, 1860; Polarization photometer, 1873; Shade photometer, 1873; Immersion photometer, 1876; Variable-aperture photometer, 1878; Deflecting photometer, about 1883. The greater part, and the best, of his photometric work was done with this last instrument, used on a 9-inch Fitz refractor of 112 inches focal-length. For a time this was supplemented by a wedge for the fainter stars. The deflecting photometer is described by him in the *Annals of the Harvard College Observatory* Vol. 18, page 30, and by Müller in his *Photometrie der Gestirne* page 177. It was his favorite apparatus, chosen by a long process of exclusion, because it satisfied two important requirements: First, it was free from the disturbing effects of varying field-illumination, a fatal defect with the extinguishing wedge photometer. Second, it enabled him to make and record his observations without an assistant and without exposing his eye to light. Its principle is shown in Figure 1. The objective (shown in plan at C) is covered by a cap whose opening, F, is bounded by logarithmic curves *ggg*. Inside the telescope tube (shown in section at E) there is supported near the focus a deflector D, a rectangular piece of clear glass whose surfaces make a small angle with each other. Suppose the telescope at rest and pointed south; a star enters the field and until its image reaches the position *a*, the cone of rays, everywhere the shape of the opening F, is not interrupted by the deflector D. But as the image moves from *a*, a portion of the cone passes through the deflector and the rays are refracted, forming a second image of the star, as at *b*. As the image *b* grows brighter, *a* becomes fainter and finally disappears. Since the cone of rays is bounded by logarithmic curves, the change in magnitude is directly proportional to the time elapsed. Since *a* disappears against an unchanged background, there is no error from varying illumination. With this arrangement the diurnal motion causes a change in an equatorial star of one magnitude in about 40 seconds,





so that if the time of disappearance is known within a second, the magnitude is given to 0.025. It is a characteristic of Parkhurst's work that it is carefully guarded against systematic errors, he did not shun the labor necessary to ascertain and allow for them; while his trained skill in observation reduced the accidental errors to small amounts.

RESULTS OF PHOTOMETRIC WORK.

These may be divided into: 1st, Long period variables; 2nd, Asteroids; 3rd, Comparison stars for both.

1st. *Long period variables.* He began this work in 1883 and continued it till the fall of 1907. The results of the first ten years' work were published in the *Annals of the Harvard College Observatory*, Vol. xxix, pages 89 to 170 (including his first catalogue of comparison stars), comprising observations of 96 variables, and measures of nearly 3000 comparison stars. From 1884 to 1890 he colaborated with Mr. John H. Eadie of Bayonne, New Jersey, who observed the variables in their brighter stages with his 3-inch telescope, and some years later with Arthur C. Perry. Standard stars from the Meridian Photometry (*Harvard Annals* xxiv) were used to reduce the results to magnitudes. The tables give concisely the dates and observed magnitudes, and the mean light-curve of each variable, but the separate maxima and minima are not given. Beginning with 1893 he published the results in the *Astronomical Journal* under the title: "Notes on Variable Stars." No. 1 of this series appeared in Vol. xiii, page 167, and No. 41, the last, in Vol. xxiv, page 202. For each star the Julian and calendar dates of maximum or minimum are given, the magnitude, the number of the epoch and the correction to the ephemeris. In a separate table the individual observations are given in a form similar to those in the *Harvard Annals.* As data for the comparison stars accumulated, improved values were given in the "Notes;" and his principal object became the improvement of these standards to the highest possible degree.

2nd. *Asteroids.* Measures of the brightness of a selected list of asteroids were begun in 1887, were very numerous in the years 1887-88-89, and were continued regularly for a smaller list till 1907. His results for 1887, with a complete statement of methods of observation and reduction, were published in the *Harvard Annals* Vol. xviii, pages 29 to 72. The list included 18 asteroids and 598 complete observations were made, nearly all with the Deflecting Photometer. Auxiliary tables for computing the reductions are given, and a thorough discussion of the sources of error, corrections, and significance of the results, make the work a model. After reduction to distance unity, and correction for defect of illuminated disk, his results indicated unmistakably the need of another correction for phase, which was a linear function of the angle at the asteroid between the Sun and the Earth. The correction is pP where P is the angle expressed in degrees, and p a constant for each asteroid, but ranging from 0.02 to 0.05 for the different ones. The values of this coefficient agree closely with those found by Müller at Potsdam* during the years 1881-6. The results for 1887-88 are published in Vol. xxix of the *Harvard Annals*, pages 65 to 88, giving improved values of the mean magnitudes and reduction constants. In all there were 3002 observed extinctions of 36 asteroids.

The importance of these observations (including those by Müller, the only other extended series) can hardly be over-estimated. The light of the asteroids, coming from the Sun, is

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* *Photometrie der Gestirne*, page 377, *Potsdam Pub.* Vol 8, page 355.

dependent only on the solar constancy for its uniformity. (This neglects small changes due to possible rotation, which will be averaged out of even a short series of observations). The uniformity of this solar "constant" can best be tested by comparison of asteroids and stellar standards; or, admitting equal value to the pyrheliometer method, the two will furnish valuable checks on each other.

On the other hand, assuming the solar constancy, the asteroids furnish ideal *standards for stellar magnitude.* This thought was uppermost in Parkhurst's mind for the last twenty years of his life, and he bent every energy to the work of improving the values of his asteroid standard magnitudes. To appreciate the advantages of such standards we must remember that the greatest source of error encountered in the attempt to form a working catalogue of standard magnitude stars scattered over the heavens, is the varying transparency of the sky between regions even a few degrees apart. As an example of attempts to eliminate these errors, Müller and Kempf at Potsdam, selected a list of 144 stars covering the northern sky, compared each repeatedly with six neighboring stars, and by laborious methods formed an excellent standard catalogue. But no sooner was it completed than they found that one of their standards was really variable! As a matter of fact it is as difficult to prove the constancy of each of these stars as it would be to establish the constancy of the light of the Sun, and as a consequence, *all the asteroids.* Furthermore, the motion of the asteroids tends to correct the "local" errors referred to above, since they are traveling standards, and can be compared, not only with stars in different regions, but with each other. Parkhurst's ideas and results cannot be better stated than by an extended quotation from a letter to the writer, dated January 25, 1904.

"We have as yet no standard for star brightness which is reliable except my asteroid standard. Even Müller and Kempf and the Meridian Photometer Catalogues are unreliable, because the stars are all liable to vary, and even if several stars are selected to balance out the errors, we can never tell which ones are most liable to be wrong, or how great the error may be. But I think the asteroids are immutable, except Eros and possibly some others which vary slightly from rotation, and which are safe standards in a series of observations. Hitherto my idea has been that my 24 confirmed asteroids make a combined standard. I have just reached the conclusion that *each* of the 24, excepting Eros, is a standard of itself, and all adjusted in unison; so that all that is needed is to take the nearest of the 24, and using that as a standard the result will be more accurate than any set of catalogue standards can be. For instance using Vesta alone is more reliable than making the same number of comparisons with stars from Harvard or Potsdam, the error being only the error of observation, the error of the standard being inappreciable. That is, I have already reached the point where the error of the standard is less than the error of observation. To illustrate, it is safer to take the diameter of Jupiter from the ephemeris than to take it from the most careful measurement.

I am making small changes in my asteroid constants, but they result from enlarging the number of confirmed stars which underlie the standards, and the changes in the particular stars which happen to come into the list. Instead of a list of 24 I now reduce my list to 12, selecting the 12 most fully observed, each of which is a standard of itself. I shall keep the 24 under observation and use them all in conjunction; but largely in order that I may properly apply the minute changes of the constants and preserve a record of the foundation of such changes.

I will copy my short list of constants, in order that you may preserve it for publication after I have finished work upon it, adding the latest reductions of the other 12, of which I shall make it a point to send you copies for this purpose, in order that finally there shall be no appreciable difference between results from individual asteroids of the list. Please preserve this list and keep with it any changes I may hereafter make in it. I find that I seldom have occasion to modify the last decimal more than 1."

H. M. PARKHURST'S FINAL LIST OF ASTEROID CONSTANTS.

Epoch 1901.

No.	G°	p	No.	G°	p	No.	G°	p
4	4.12	0.023	433	9.78	0.037	16	5.93	0.051
1	3.61	0.043	7	5.84	0.018	3	6.05	0.020
20	6.63	0.035	2	4.32	0.036	5	7.06	0.037
11	6.93	0.022	8	6.63	0.031	12	7.18	0.024

In this table G° stands for the stellar magnitude of the asteroid, in the system of the Harvard Meridian Photometry, reduced to distance unity from the Sun and the Earth. As before stated, *p* is the coefficient of the phase correction, and is to be multiplied by the angle at the asteroid between the Sun and the Earth, expressed in degrees.

This confessedly incomplete sketch cannot do justice to its subject. He possessed a true scientific spirit, combining high ideals, ability and industry. In the opinion of those competent to judge, his results place him in the front rank of workers in stellar photometry. Unfortunately, the writer cannot speak from personal acquaintance, but wishes to acknowledge his indebtedness for much assistance in photometric work, through a correspondence lasting over fourteen years.

Yerkes Observatory,
Williams Bay, Wisconsin.
February 1908.

THE SUN'S MOTION IN SPACE AND THE FIXED STARS.

W. H. S. MONCK.

FOR POPULAR ASTRONOMY.

In 1902 I contributed to POPULAR ASTRONOMY an article in which I contended that our estimates of the Sun's motion in space were influenced by the motion (revolution?) of the Galaxy to which most of the observed stars belonged. I inferred this upon Bossert's Catalogue, chiefly as regards the right ascension of the Stars. I found that the two neutral points which separated the region in which increasing right ascensions prevailed from that in which diminishing right ascensions prevailed, coincided very nearly with the two points where the Galactic Circle crossed the equator—that the neutral point between the sixth and seventh hours of right ascension was sharply defined, the Galaxy being narrow and well-defined at this point, whereas at the other intersection where the Galaxy is ill-defined and double, the neutral point was similarly diffused: and moreover it seemed to lie between the nineteenth and twentieth hours of R. A., the sky being thus divided into two unequal regions of about thirteen hours and eleven hours respectively instead of two equal regions each embracing twelve hours of R. A. On looking over the recent determination of the proper motions of Bradley's stars I noticed somewhat similar features: and the reader will find further information in the writings of Professor Kapteyn and Mr. Eddington though the two authors are not in very close agreement as to the direction of the double star-drift. I think however that their researches confirm the idea of a connection between the observed motions and the motion of the Galaxy though we may not yet be able to state exactly what that connection is. The Catalogue of 1186 Carrington Stars contributed by the astronomer Royal of England to the *Monthly Notices* of the R. A. S. for November 1907 seemed to me calculated to throw additional light on the question, for as they are all situated within 10° of the North Pole it appeared probable that they were little influenced by the Galaxy. I accordingly tabulated them hour by hour as regards their proper motions in R. A., omitting those which had none or whose proper motion was not determined, with the following result:

Hour	Stars with increasing R. A.	Stars with diminishing R. A.
0 to 1	39	15
1 to 2	34	7
2 to 3	26	11
3 to 4	20	18
4 to 5	17	28
5 to 6	20	21
6 to 7	17	24
7 to 8	6	31
8 to 9	8	47
9 to 10	11	34
10 to 11	18	38
11 to 12	13	48
12 to 13	16	41
13 to 14	17	44
14 to 15	14	29
15 to 16	25	27
16 to 17	23	18
17 to 18	23	15
18 to 19	37	17
19 to 20	37	11
20 to 21	35	8
21 to 22	26	8
22 to 23	28	15
23 to 24	30	15
Total	554	571 *

The displacement of the neutral points compared with the results given by Bossert's (or Bradley's) catalogue is here obvious. They here occur about the 4th and 16th hours of R.A., giving about 240° for the R. A. of the Sun's apex which is at least 30° less than that set down in the majority of computations. The neutral points moreover are nearly twelve hours apart thus dividing the part of the sky examined into two

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* These figures may not be strictly accurate, but they are very nearly so.

equal regions in one of which increasing right ascensions preponderate while in the other diminishing Right Ascensions form the majority. The total numbers moreover it will be seen are also very nearly equal, whereas in Bossert's Catalogue there were 1450 stars with diminishing R. A. against 1190 with increasing R. A. These more symmetrical results suggest that this catalogue affords a better representation of the Sun's motion (apart from systematic motions among the fixed stars) than is to be found elsewhere, and I think if any astronomer would compute the position of the Sun's apex from this catalogue of stars it would repay the labor. The reader will notice however that (starting from 0^h) *after passing* the two neutral points there is some unsteadiness and fluctuation, as if there was some cause interfering with the Sun's motion and rendering it less effective than might otherwise be expected. Thus the preponderance of diminishing right ascension is by no means well-marked between the fourth and seventh hours of R. A., and shoots up suddenly between the seventh and eighth. Even the figures arrived at in this article may therefore be influenced by the motions of the Galaxy and the real R. A. of the Sun's apex may be nearer to 230° than 240°.

It would be interesting to know whether the proper motions of the south circumpolar stars present similar features. Those presented by the Carrington stars are at all events sufficiently striking to be worth calling attention to.

Dublin, Ireland.

ERRORS DISCOVERED IN THE KINETIC THEORY OF GASES, ETC.*

LUIGI D'AURIA.

FOR POPULAR ASTRONOMY.

The above paper was written for the purpose of proving the correctness of the theoretical ratio of the two specific heats, $\gamma = 2$, obtained as a result of a previous investigation published in POPULAR ASTRONOMY for April, 1907, under the title: "A new development of the kinetic theory of gases," by a new method quite independent of the expression for the pressure.

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[*] A revision of the paper, "On some serious errors discovered in the kinetic theory of gases and in the application to it of Newton's second law of motion, etc.," published in POPULAR ASTRONOMY for June-July, 1907.

By an examination subsequently made of the paper in question I have found that in the expression (11) for the pressure, page 359, which reads $p = Qm\overline{v}$, I had no right to use the mean square speed $\overline{v}$ of the molecules in a given direction, although its use is in accordance with the expression $p = \rho \overline{v^2} = N\overline{v} \times m\overline{v}$, admitted generally in the kinetic theory, in which ρ is the density of the gas and N the number of molecules contained in unit volume of the gas, and we can see from this same expression that Q, the number of molecules crossing a section of unit area in unit time, is assumed to be equal to $N\overline{v}$. The product $m\overline{v}$ in the above expression is intended to represent the mean normal momentum of each of the Q molecules, but if we examine the problem more closely we find that this momentum should be expressed by mv in which I use v to represent the mean speed of the molecules in a given direction.

In the same paper I pointed out that Q should be independent of the directions of the motions of the molecules while crossing the section, and that instead of putting $Q = N\overline{v}$ we should put $Q = N\bar{u}$, in which $\bar{u}$ is the mean square speed of the molecules irrespective of direction. But here again I had no right to use $\bar{u}$, the proper speed in this expression being u, the mean speed irrespective of direction. Thus the equation (11) referred to above would become

$$p = Nu \times mv = \rho\, u\, v \tag{1}$$

instead of the equation (15) page 360 which reads $p = \rho \bar{u} \overline{v}$ Assuming between v and u the the same relation which is generally assumed to exist between $\overline{v}$ and $\bar{u}$, viz: $\overline{v^2} = \frac{1}{3} \overline{u^2}$, we can put $v = u/\sqrt{3}$ and thus equation (1) becomes

$$p = \frac{\rho}{\sqrt{3}} u^2, \tag{2}$$

instead of which, in the paper under revision, the equation(16) is given which reads $p = \rho/\sqrt{3} . \overline{u^2}$.

Now, in accordance with the well-known law of distribution of velocities found by Maxwell, the relation between u^2 and $\overline{u^2}$ is as follows:

$$u^2 = \frac{8}{3\pi} \overline{u^2}, \tag{3}$$

and if we substitute this in (2) we find

$$p = \frac{8}{3\pi \sqrt{3}} \rho \overline{u^2} = 0.49 . \rho \overline{u^2} \tag{4}$$

Instead of this, in the same paper, the result arrived at was the equation (27) which reads $p = \frac{1}{2} \rho \overline{u^2}$, page 364, and which justifies the ratio $\gamma = 2$. In accordance with the new equation (4) we have $\gamma = 1.98$ which differs from the previous value only by one per cent. But the result $p = \frac{1}{2} \rho \overline{u^2}$ was obtained in spite of the fact that $\overline{v}$ and $\bar{u}$ had been erroneously used instead of v and u in the fundamental equation for the pressure, and by this error the value (4) of p is made, according to (3), $3\pi/8$ times larger. This was however neutralized by two other errors one of which is in the equation (17) giving $\overline{v} = \frac{2}{\pi} \bar{u}$ instead of $\overline{v} = \bar{u}/\sqrt{3}$ which is generally accepted and which is necessary in order to account for a gas being at rest as a whole. By this error the value (4) of p is unnecessarily multiplied by $2\sqrt{3}/\pi$. The remaining error is in my equation (26) page 364 which reads $t\,(\phi) = \frac{\pi}{4} mv$, and in which (ϕ) is the average value of the force ϕ involved during the impact of a molecule. This average value was taken with respect to the path of the force, but by a careful investigation of the problem of the pressure due to the bombardment of elastic molecules upon a surface I have found that the value of (ϕ) should be taken necessarily with respect to the duration of the application of the force, when the above equation will become $t\,(\phi) = mv$. Thus we see that by this last error the value (4) of p is unnecessarily multiplied by $\pi/4$. The combined effect of all the three errors upon this value of p amounts to its being multiplied by

$$\frac{3\pi}{3} \times \frac{2\sqrt{3}}{\pi} \times \frac{\pi}{4} = 1.00325,$$

which shows how nearly the above errors happened to compensate each other, leaving the result $p = \frac{1}{2} \rho \overline{u^2}$ practically the same. Indeed the difference which exists between this value and the new value (4) of p might be accounted for on the ground that the latter involves the relation (3) which may only apply approximately to the case of a gas.

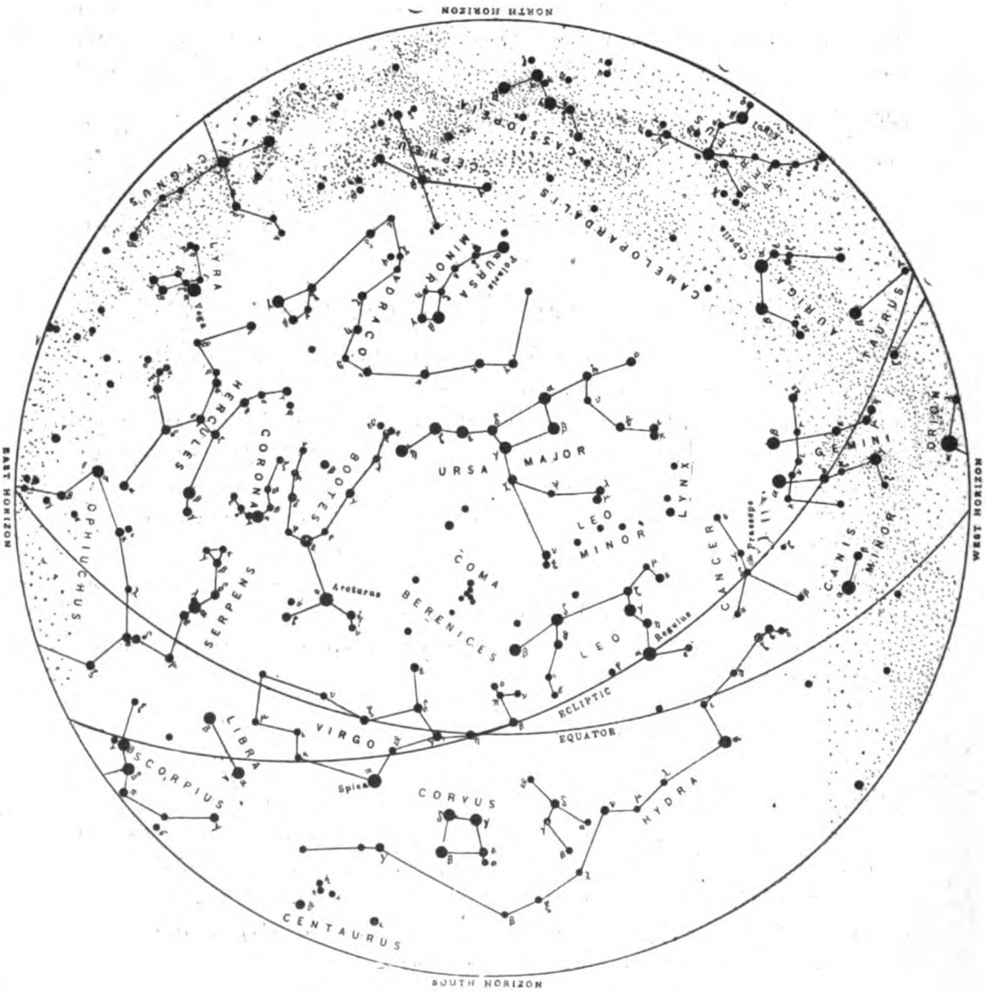
In a paper now in course of preparation the problems of the pressure and of the ratio of the two specific heats in the kinetic theory of gases are being considered more in detail, from a new point of view, and will shortly be submitted for publication.

Philadelphia Pa.

PLANET NOTES FOR MAY 1908.

H. C. WILSON.

Mercury will be at superior conjunction May 7 and so will not be in position favorable to study until near the end of the month, when it will be evening star seen low in the west soon after sunset.



THE CONSTELLATIONS AT 9:00 P. M., MAY 1, 1908.

Venus will attain her greatest brilliancy on May 29 and may be seen in broad daylight during probably all of this month. Of course one must know exactly where to look in order to see the planet in daylight. The best time for study of the planet with a telescope will be in the twilight just after the Sun has set. The phase will be crescent, decreasing from 0.477 on May 1 to 0.259 on May 31.

Mars may still be seen in the west after sunset, but is too low for useful study. The disk of the planet is now only about 4″ in diameter.

Jupiter is brilliant and well up toward the zenith at sunset. It may be studied for several hours each evening. The belts and satellites of Jupiter are well worth one's while to look at on these nights even with a small telescope.

Saturn is yet too close to the Sun for study but may be seen in the morning for a short time before sunrise.

Uranus may be seen in the morning, only with the aid of a telescope, in the constellation Sagittarius.

Neptune may be found with a telescope in the early evening, in Gemini. Its right ascension May 1 is 6^h 53^m 59^s and its declination + 22° 5′. On May 21 at 7^h A. M. Central Standard time Venus will be 4° 8′ directly north of Neptune.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	Angle f'm N. °	EMERSION. Washington M.T. h m	Angle f'm N °	Duration. h m
May 5	58 Geminorum	9.0	6 56	52	7 46	331	0 50
14	BD. 12° 4134	6.4	12 44	151	13 50	263	1 06
20	17 Capricorni	5.8	12 26	53	13 22	297	0 56

Phenomena of Jupiter's Satellites.

Central Standard Time, reckoning from noon.

	h	m					h	m			
May 1	7	55	III	Sh.	In.	May 10	10	45	II	Sh.	Eg.
	8	1	II	Oc.	Dis.		10	45	I	Sh.	Eg.
	10	44	I	Tr.	In.	11	7	57	I	Ec.	Re.
	11	38	III	Sh.	Eg.	15	7	31	IV	Tr.	Eg.
2	7	58	I	Oc.	Dis.	17	7	57	II	Tr.	In.
	11	33	I	Ec.	Re.		9	7	I	Tr.	In.
3	7	34	II	Tr.	Eg.		10	19	I	Sh.	In.
	8	7	II	Sh.	Eg.		10	26	II	Sh.	In
	8	50	I	Sh.	Eg.		10	54	II	Tr.	Eg.
7	10	43	IV	Ec.	Re.		11	27	I	Tr.	Eg.
8	6	50	III	Tr.	In.	18	9	53	I	Ec.	Re.
	10	31	III	Tr.	Eg.	19	7	8	I	Sh.	Eg.
	10	42	II	Oc.	Dis.		7	55	II	Ec.	Re.
	11	55	III	Sh.	In.		9	27	III	Ec	Re.
9	9	55	I	Oc.	Dis.	25	8	20	I	Oc.	Dis.
10	7	10	I	Tr.	In.	26	7	54	I	Tr.	Eg.
	7	49	II	Sh.	In.		8	52	III	Oc.	Re.
	8	12	II	Tr.	Eg.		9	3	I	Sh.	Eg.
	8	25	I	Sh.	In.		9	52	III	Ec.	Dis.
	9	30	II	Tr.	Eg.		10	30	II	Ec.	Re.

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

COMET AND ASTEROID NOTES.

Ephemeris of Comet 1907 *d*.

(For Berlin Midnight, from *A. N.* 4234.)

1908	α 1908.0	δ 1908.0	log *r*	log Δ	Mag.
	h m s	° ′			
April 2	14 42 42	−3 50.0	0.5399	0.4076	
4	40 43	3 37.5			
6	38 43	3 25.1	0.5458	0.4112	10.8
8	36 42	3 12.9			
10	34 39	3 0.9	0.5516	0.4157	
12	32 36	2 49.2			
14	30 32	2 37.7	0.5574	0.4209	10.9
16	28 29	2 26 6			
18	26 26	2 15.8	0.5631	0.4269	
20	24 25	2 5.4			
22	22 23	1 55.3	0.5687	0.4335	11.0
24	20 23	1 45.7			
26	18 25	1 36.5	0.5741	0.4409	
28	16 30	1 27.7			
30	14 36	1 19.4	0.5795	0.4490	11.1
May 2	12 44	1 11.6			
4	10 55	1 4.2	0.5848	0.4577	
6	9 11	0 57.4			
8	14 7 31	−0 51.2	0.5900	0.4670	11.3

New Planet or Satellite of Jupiter.—A cablegram received at this Observatory from Kiel states that a planet has been discovered by Melotte at Greenwich, positions of which are as follows:—

			h	m	s		°	′	″
Jan.	27 5306 Gr. M. T.	R. A.	8	46	7.2	Dec.	+18	03	34
Feb.	28 4782		8	31	32.0		+19	16	13

The object has been observed on eight days and is possibly a satellite. It is visible in a large telescope.

A later telegram, from Professor Campbell states that the object was observed by Albrecht at Lick Observatory March 8.8486 Gr. m. t. in R. A. $8^h\ 28^m\ 33^s.2$, Dec. + 19° 39′ 11″, mean place for the beginning of this year. The object as observed visually by Aitken was of magnitude fifteen.

Astronomical Bulletin, No. 323,
Harvard College Observatory,
March 3, 1905.

VARIABLE STARS.

Variable 31.1907 Aurigæ.—A cablegram has been received at this Observatory from Kiel stating that Hartwig announces that Variable 31.1907 Aurigæ was of the ninth magnitude yesterday and is a U Geminorum type variable.

Note:—A chart of this region showing the position of the variable will be found in the *Astron. Nach.* Vol. 174, p. 363. E. C. P.

Astronomical Bulletin, No. 324,
Harvard College Observatory,
March 7, 1908.

The Variable 136.1907 Andromedæ.—In *A. N.* 4233 Mr. A. A. Nijland of Utrecht, concludes from an observation January 29, in connection with those previously published, that the period, of this star is 34.93 days and that the fractions ½, ⅓, and ¼ of this period are excluded by definite observations. Approximate elements are

Minimum = 2417935.51 + $34^{d}.93$ E.

The stationary minimum lasts at least 22.8 hours.

Elements of the Variable 139.1907 Ursæ Maj.—In *A. N.* 4231 Mr. S. Blažko of the Moscow Observatory announces that this star is of the δ Cephei type and gives the following elements:

Maximum = 1907 Oct. 5 $10^{h}.0$ Gr. m. t. + 11^{h} 14^{m} 24^{s} E.

The range of brightness is from $9^{m}.2$ to $9^{m}.9$ and the change lasts one and one-half hours.

Elements of the Variable 143.1907 Andromedæ.—In *A N.* 4231 Mr. S. Blažko gives elements of this variable star determined from his own observations and photographs:

Minimum = 1907 Dec. 2, $9^{h}.0$ Gr. m. t. + 2^{d} 18^{h} $21^{m}.7$ E.

The star is of the Algol type and the period may possibly be only half of that given. The brightness ranges from $10^{m}.5$ to $11^{m}.3$, the loss and recovery of light occupying eight hours. (For position see P. A. Jan. 1907 p. 55).

Elements of the Variable 144.1907 Cassiopeiæ.—In *A. N.* 4231 Mr. S. Blažko gives the following elements of the variable star 144.1907 Cassiopeiae, determined from five minima in the years 1896 to 1907:

Maximum = 1907 Dec. 1 $11^{h}.5$ Gr. m. t. + 4^{d} 1^{h} $42^{m}.4$ E
= J. D. 2417911.48 + $4^{d}.0711$ E.

The star is of the δ Cephei type and the brightness ranges from $9^{m}.3$ to $9^{m}.9$ (See P. A. Jan. 1908 p. 55).

Two New Variables 3 and 4.1908.—These were discovered by Mme. L. Ceraski upon the Moscow photographs and are announced in *A. N.* 4231. Their positions are:

	α 1855	δ 1855	α 1900	δ 1900
	h m s	° ′ ″	h m s	° ′ ″
3.1908 Aurigae	5 4 51.10	+49 22 23.2	5 8 17.65	+49 25 51.7
4.1908 Aurigae	47 12.3	+48 19.0	4 50 34.9	+48 23.6

No. 3 is BD + 49°.1331 ($8^{m}.9$) and from a study of twenty-four plates obtained in the years 1899 to 1907, it appears that the magnitude varies between 8.6 and 9.3. The period is probably short.

No. 4 is BD. + 48°1187 ($9^{m}.5$). 'Judging from eighteen photographs obtained in 1899-1907, the brightness varies from 10^{m} to about 12^{m}. The period is unknown.

Elements of the Variable RY Aurigæ.—In *A. N.* 4231 Mr. S. Blažko gives elements of this variable star as follows:

Minimum = 1907 Oct. 5 $13^{h}.5$ Gr. m. t. + 2^{d} 17^{h} $24^{m}.3$ E

The star is of the Algol type and the change of light lasts eight hours, the range being about a magnitude, from 11^{m} to 12^{m} (For position see P. A. Feb. p. 120).

Elements of Three Algol Stars.—In *A. N.* 4232 Mr. S. Enebo of Dombaas, Norway gives approximate elements of the variable stars as follows:

RY(27.1907) Aurigæ Minimum = 2417887.24 Gr. m. t. + $2^{d}.728$ E
49.1907 Geminorum " = 2417884.50 " + 12.21 E
143.1907 Andromedæ " = 2417912.426 " + 2.764 E

Elements of Y Camelopardalis.—In *A. N.* 4232 Mr. S. Blažko gives the following elements of this variable and suggests that possibly the period is not constant:

Minimum = 2416306.3887 Gr. m. t. + $3^{d}.305550$ E.

Sixteen New Variable Stars.—Circular No. 134 of the Harvard College Observatory contains a list of sixteen new variables, discovered by Miss Cannon, in the regions of the Harvard Map Nos. 37 and 46. These have been given the numbers 183 to 198.1907 by the Variable Star Committee of the Astronomische Gesellschaft.

No.	Constellation	DM		R.A. 1900			Dec. 100		Mag.
				h	m	s	°	′	
183.1907	Tucanæ	—		0	10	17	—60	46.8	9.4 — 10.2
184.1907	Phoenicis	−50°	118	0	30	19	—50	45.2	9.5 —<11
185.1907	Tucanæ	—72	69	0	48	10	—72	32.6	8.8 — 10.3
186.1907	Tucanæ	—		0	54	09	—63	55.9	9.0 — 10.1
187.1907	Cœli	—33	2018	4	53	12	—33	18.4	9.7 — 10.5
188.1906	Columbæ	—30	2883	6	06	25	—30	43.2	10.4 —<15
189.1907	Canis Maj.	—26	2912	6	14	49	—26	07.9	9.8 —<12
190.1907	Columbæ	—		6	24	35	—40	02.2	9.3 —<11.5
191.1907	Columbæ	—35	2972	6	29	44	—35	14.0	9.8 — 10.4
192.1907	Puppis	—42	2682	6	39	21	—42	16.6	9.1 —<11.5
193.1907	Canis Maj.	—		6	39	44	—31	41.2	10.0 —<12
194.1907	Canis Maj.	—23	4628	6	52	36	—23	50.4	8.9 — 10.1
195.1907	Canis Maj.	—25	3986	7	00	03	—25	38.9	9.5 — 10.2
196.1907	Indi	—70	2860	21	27	41	—70	46.6	9.0 — 10.0
197.1907	Phoenicis	—46	14688	23	27	01	—46	32.2	8.5 —<12
198.1907	Phœnicis	—52	12232	23	51	53	—52	46.9	10.1 — 11.0

Of these Nos. 183, 185, 186, 187, 191, 196 appear to be of short period, 185 and 191 being of the Algol type.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei			RZ Cassiop.			RZ Cassiop.			RX Cephei			RW Geminorum		
	d	h		d	h		d	h		d	h		d	h
May	1	18	May	1	22	May	17	11	May	30	20	May	25	18
	4	6		3	3		18	15	RS Cephei				28	15
	6	18		4	7		19	20	May	10	0		31	12
	9	6		5	12		21	1		22	10	RU Monoc.		
	11	17		6	17		22	5	RW Geminorum			May	1	12
	14	5		7	21		23	10	May	2	20		2	10
	16	17		9	2		24	15		5	17		3	7
	19	5		10	7		25	19		8	13		4	5
	21	17		11	11		27	0		11	10		5	2
	24	5		12	16		28	5		14	7		6	0
	26	16		13	21		29	9		17	4		6	21
	29	4		15	1		20	14		20	1		7	19
	31	16		16	6		31	19		22	21		8	16

Minima of Variable Stars of the Algol Type.—Continued.

RU Monoc.	d	h
May	9	14
	10	11
	11	9
	12	6
	13	4
	14	1
	14	23
	15	20
	16	18
	17	15
	18	13
	19	10
	20	8
	21	5
	22	3
	23	0
	23	22
	24	19
	25	17
	26	14
	27	12
	28	10
	29	7
	30	5
	31	2

R Canis Maj.	d	h
May	1	22
	3	1
	4	4
	5	8
	6	11
	7	14
	8	17
	9	21
	11	0
	12	3
	13	6
	14	10
	15	13
	16	16
	17	19
	18	23
	20	2
	21	5
	22	9
	23	12
	24	15
	25	18
	26	22
	28	1
	29	4
	30	7
	31	11

Y Camelop.	d	h
May	2	22
	6	6
	9	13
	12	20
	16	4
	19	11
	22	18
	26	2
	29	9

RR Puppis	d	h
May	1	4
	7	14
	14	0
	20	11
	26	21

V Puppis	d	h
May	1	23
	3	10
	4	21
	6	8
	7	19
	9	6
	10	17
	12	4
	13	15
	15	2
	16	12
	17	23
	19	10
	20	21
	22	8
	23	19
	25	6
	26	17
	28	4
	29	15
	31	2

S Cancri	d	h
May	1	9
	10	21
	20	9
	29	20

S Velorum	d	h
May	3	2
	9	0
	14	23
	20	21
	26	20

RR Velorum	d	h
May	2	13
	4	10
	6	6
	8	3
	9	23
	11	20
	13	16
	15	13
	17	9
	19	6
	21	2
	22	23
	24	19
	26	16
	28	12
	30	9

SS Cancri	d	h
May	3	3
	6	11
	9	18
	13	1
	16	8
	19	15
	22	23
	26	6
	29	13

Z Draconis	d	h
May	2	5
	3	13
	4	22
	6	7
	7	15
	9	0
	10	8
	11	17
	13	1
	14	10
	15	19
	17	3
	18	12
	19	21
	21	5
	22	14
	23	22
	25	7
	26	15
	28	0
	29	8
	30	17

RZ Centauri	d	h
May	1	19
	2	18
	3	16
	4	15
	5	13
	6	12
	7	10
	8	9
	9	7
	10	6
	11	4
	12	3
	13	1
	14	0
	14	22
	15	21
	16	19
	17	18
	18	16
	19	15
	20	13
	21	12
	22	10
	23	9
	24	7
	25	6
	26	4
May	27	3
	28	1
	29	0
	29	22
	30	21
	31	19

SS Centauri	d	h
May	1	14
	4	2
	6	13
	9	1
	11	12
	14	0
	16	11
	18	23
	21	10
	23	22
	26	9
	28	21
	31	8

δ Libræ	d	h
May	3	0
	5	8
	7	15
	9	23
	12	7
	14	15
	16	23
	19	7
	21	15
	23	22
	26	6
	28	14
	30	22

U Coronæ	d	h
May	1	6
	4	17
	8	4
	11	15
	15	1
	18	12
	21	23
	25	10
	28	21

R Aræ	d	h
May	3	8
	7	19
	12	5
	16	15
	21	1
	25	11
	29	22

U Ophiuchi	d	h
May	1	16
	2	12
	3	8
	4	4
	5	0
	5	20
	6	17
May	7	13
	8	9
	9	5
	10	1
	10	21
	11	17
	12	14
	13	10
	14	6
	15	2
	15	22
	16	18
	17	14
	18	10
	19	7
	20	23
	20	3
	21	19
	22	15
	23	11
	24	7
	25	3
	26	0
	26	20
	27	16
	28	12
	29	8
	30	4
	31	0
	31	20

Z Herculis	d	h
May	3	8
	5	5
	7	8
	9	5
	11	7
	13	4
	15	7
	17	4
	19	7
	21	4
	23	7
	25	4
	27	7
	29	4
	30	7

RS Sagittarii	d	h
May	2	11
	4	21
	7	7
	9	17
	12	3
	14	13
	16	23
	19	9
	21	19
	24	4
	26	14
	29	0
	31	10

Minima of Variable Stars of the Algol Type.—Continued.

V Serpentis

	d	h
May	1	2
	4	13
	8	0
	11	11
	14	22
	18	9
	21	20
	25	7
	28	17

RZ Herculis

May	1	6
	2	9
	3	11
	4	14
	5	16
	6	19
	7	21
	9	0
	10	2
	11	4
	12	7
	13	9
	14	12
	15	14
	16	17
	17	19
	18	22
	20	0
	21	2
	22	5
	23	7
	24	10
	25	12
	26	15
	27	17
	28	20
	29	22
	31	0

RX Herculis

May	1	5
	2	2
	3	0
	3	21
	4	18
	5	16
	6	13
	7	10
	8	8
	9	5
	10	2
	11	0

RX Herculis

	d	h
May	11	21
	12	18
	13	16
	14	13
	15	11
	16	8
	17	5
	18	3
	19	0
	19	21
	20	19
	21	16
	22	13
	23	11
	24	8
	25	5
	26	3
	27	0
	27	21
	28	19
	29	16
	30	13
	31	11

SX Sagittarii

May	2	16
	4	18
	6	20
	8	21
	10	23
	13	1
	15	3
	17	5
	19	7
	21	8
	23	10
	25	12
	27	14
	29	16
	31	18

RR Draconis

May	3	17
	6	12
	9	8
	12	4
	15	0
	17	20
	20	16
	23	12
	26	8
	29	4

U Scuti

	d	h
May	1	21
	2	20
	3	19
	4	18
	5	17
	6	16
	7	15
	8	14
	9	12
	10	11
	11	10
	12	9
	13	8
	14	7
	15	6
	16	5
	17	4
	18	3
	19	2
	20	1
	21	0
	21	22
	22	21
	23	20
	24	19
	25	18
	26	17
	27	16
	28	15
	29	14
	30	13
	31	12

RX Draconis

May	1	1
	2	22
	4	19
	6	17
	8	14
	10	12
	12	9
	14	7
	16	4
	18	2
	19	23
	21	21
	23	18
	25	16
	27	13
	29	10
	31	8

RV Lyræ

	d	h
May	3	22
	7	13
	11	3
	14	17
	18	8
	21	22
	25	13
	29	3

U Sagittæ

May	1	11
	4	20
	8	5
	11	14
	15	0
	18	9
	21	18
	24	3
	28	12
	31	21

SY Cygni

May	6	7
	12	7
	18	8
	24	8
	30	8

WW Cygni

May	4	5
	7	12
	10	20
	14	4
	17	11
	20	19
	24	3
	27	10
	30	18

SW Cygni

May	3	20
	8	10
	12	23
	17	13
	22	3
	26	17
	31	6

VW Cygni

May	6	11
	14	21
	23	7
	31	18

UW Cygni

	d	h
May	2	19
	6	6
	9	17
	13	3
	16	14
	20	1
	23	12
	26	23
	30	10

W Delphini

May	1	8
	6	4
	10	23
	15	18
	20	14
	25	9
	30	5

RR Delphini

May	1	20
	6	10
	11	0
	15	15
	20	5
	24	20
	29	10

VV Cygni

May	1	18
	3	5
	4	17
	6	4
	7	16
	9	3
	10	15
	12	2
	13	14
	15	1
	16	13
	18	0
	19	11
	20	23
	22	10
	23	22
	25	9
	26	21
	28	8
	29	20
	31	7

UZ Cygni

May	29	12

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

Maxima of Variable Stars of Short Period not of the Algol Type.

RW Cassiop.
d h
(—5 19)
May 6 22
21 17

RX Aurigæ
(—4 0)
May 9 9
21 0

Y Aurigæ
(—0 18)
May 2 1
5 22
9 19
13 15
17 12
21 8
25 5
29 2

T Monoc.
(—7 23)
May 26 11

W Geminorum
(—2 22)
May 1 11
9 9
17 7
25 5

ζ Geminorum
(—5 0)
May 1 1
11 5
21 8
31 12

RU Camelop.
(—9 12)
May 3 10
25 16

V Carinæ
(—2 4)
May 4 9
11 1
17 18
24 11
31 3

T Velorum
(—1 10)
May 4 2
8 18
13 9
18 0
22 16
27 7
31 22

W Carinæ
(—1 0)
May 1 19
6 4
10 13
14 22
19 6
23 15
28 0

S Muscæ
d h
(—3 11)
May 9 3
18 19
28 11

T Crucis
(—2 2)
May 2 13
9 7
16 0
22 18
29 11

R Crucis
(—1 10)
May 5 23
11 19
17 15
23 10
29 6

S Crucis
(—1 12)
May 3 23
8 16
13 8
18 1
22 17
27 10

W Virginis
(—8 5)
May 17 13

V Centauri
(—1 11)
May 1 16
7 4
12 16
18 4
23 15
29 3

R Triang. Austr.
(—1 0)
May 3 9
6 18
10 3
13 13
16 22
20 7
23 17
27 2
30 11

S Triang. Austr.
(—2 2)
May 2 20
9 3
15 11
21 19
28 3

S Normæ
(—4 10)
May 10 6
20 0
29 18

RV Scorpii
d h
(—1 10)
May 1 5
7 6
13 8
19 9
25 11
31 12

RV Ophiuchi
Minimum.
May 2 21
6 13
10 6
13 22
17 15
21 7
25 0
28 16

X Sagittarii
(—2 22)
May 1 1
8 2
15 2
22 2
29 2

Y Ophiuchi
(—6 5)
May 14 9
31 12

W Sagittarii
(—3 0)
May 7 1
14 15
22 5
29 19

Y Sagittarii
(—2 2)
May 5 8
11 3
16 21
22 16
28 10

U Sagittarii
(—2 23)
May 2 16
9 10
16 4
22 22
29 16

β Lyræ
(—3 7)
(—3 2)
May 2 23
10 5
16 21
23 3
29 19

κ Pavonis
(—1 7)
May 4 0
13 3
22 5
31 7

U Aquilæ
d h
(—2 4)
May 3 3
10 4
17 4
24 5
31 5

U Vulpeculæ
(—2 3)
May 8 14
16 14
24 13

SU Cygni
(—1 7)
May 1 20
5 16
9 12
13 9
17 5
21 1
24 21
28 18

η Aquilae
(—2 6)
May 1 18
8 23
16 3
23 7
30 11

S Sagittae
(—3 10)
May 8 20
17 5
25 14

X Vulpeculæ
(—2 1)
May 2 10
8 17
15 1
28 9
27 16

V Vulpeculae
Minimum
May 12

X Cygni
(—6 19)
May 10 8
26 17

T Vulpeculae
(—1 10)
May 2 2
6 12
10 23
15 9
19 20
24 6
28 17

WZ Cygni
d h
Minimum
May 1 10
2 4
3 18
4 23
6 3
7 7
8 11
9 15
10 19
11 23
13 3
14 7
15 11
16 15
17 19
18 23
20 3
21 7
22 11
23 15
24 19
25 23
27 4
28 8
29 12
30 16
31 20

TX Cygni
May 26 11

VY Cygni
(—2 14)
May 6 13
14 10
22 6
30 3

VZ Cygni
(—3 6)
(—2 12)
May 5 0
9 17
14 17
19 10
24 10
29 4

δ Cephei
(—1 10)
May 4 9
9 18
15 3
20 12
25 20
31 5

V Lacertae
(—0 17)
May 5 3
10 2
15 2
20 2
25 1
30 1

Maxima of Variable Stars of Short Period not of the Algol Type

Continued.

X Lacertae			X Lacertae			RS Cassiop.			RY Cassiop.			Y Lacertae		
	d	h		d	h		d	h		d	h		d	h
Minimum							(—1	19)		(—7	10)	May	6	22
May	3	14	May	19	22	May	7	5	May	9	21		11	6
	9	1		25	9		13	12		22	0		15	14
	14	12		30	19		19	19	Y Lacertae				19	21
							26	3		(—1	10)		24	5
									May	2	15		28	12

Approximate Magnitudes of Variable Stars on Mar. 1, 1908.

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R.A. 1900.		Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
X Androm.	0	10.8	+46	27	<13.2	R Orionis	4	53.6	+ 7	59	9.4
T Androm.		17.2	+26	26	8.2*d*	R Leporis		55.0	—14	57	11.0
T Cassiop.		17.8	+55	14	11.4*d*	V Orionis	5	0.8	+ 3	58	12.8*d*
R Androm.		18.8	+38	1	13.9*d*	T Leporis		0.6	—22	2	11.0
S Ceti		19.0	— 9	53	7.8 *i*	R Aurigae		9.2	+53	28	10.5*d*
Y Cephei		31.3	+79	48	11.5 *i*	S Aurigae		20.5	+34	4	10.0
U Cassiop.		40.8	+47	43	9.1 *i*	W Aurigae		20.1	+36	49	11.0*d*
V Androm.		44.6	+35	6	10.0 *i*	S Orionis		24.1	— 4	46	12.4*d*
RW Androm.		41.9	+32	8	12.0 *i*	T Orionis		30.9	— 5	32	9.8
RR Androm.		45.9	+33	50	<13	S Camelop.		30.2	+68	45	8.8 *i*
W Cassiop.	0	49.0	+58	1	10.2	RR Tauri		33.3	+26	19	11.6
RX Androm.		58.9	+40	46	12.5 *i*	U Aurigae		35.6	+31	59	12.6*d*
U Androm.	1	9.8	+40	11	12.6 *i*	Z Tauri		46.7	+15	46	<12.6
S Piscium		12.4	+ 8	24	10.6 *i*	V Camelop.		49.4	+74	30	<13
S Cassiop.		12.3	+72	5	13.0 *i*	U Orionis		49.9	+20	10	10.4 *i*
U Piscium		17.7	+12	21	13.6*d*	Z Aurigæ		53.6	+53	18	11.4*d*
R Piscium		25.5	+ 2	22	12.6 *i*	X Aurigae	6	4.4	+50	15	<13.5
RU Androm.		32.8	+38	10	13.5*d*	V Aurigae		16.5	+47	45	9.0
Y Androm.		33.7	+38	50	13.0*d*	V Monoc.		17.7	— 2	9	11.8*d*
X Cassiop.		49.8	+58	46	9.4 *i*	S Lyncis		35.9	+58	0	<13
U Persei		53.0	+54	20	8.2	X Gemin.		40.7	+30	23	12.0*d*
S Arietis		59.3	+12	3	12.0	W Monoc.		47.5	— 7	2	10.4*d*
R Arietis	2	10.4	+24	35	10.0*d*	Y Monoc.		51.3	+11	22	12.8 *i*
W Androm.		11.2	+43	50	<13	X Monoc.		52.4	— 8	56	7.8
Z Cephei		12.8	+81	13	13.0 *i*	R Lyncis		53.0	+56	28	10.8*d*
o Ceti		14.3	— 3	26	7.2*d*	RS Gemin.		55.2	+30	40	11.0
S Persei		15.7	+58	8	8.6	R Gemin.	7	1.3	+22	52	13.0*d*
R Ceti		20.9	— 0	38	9.6 *i*	V Can. Min.		1.5	+ 9	2	<12.5
U Ceti		28.9	—13	35	9.0*d*	R Can. Min.		3.2	+10	11	8.4 *i*
RR Cephei		30.4	+80	42	13.3	RR Monoc.		12.4	+ 1	17	13.0*d*
R Trianguli		31.0	+33	50	7.0 *i*	V Gemin.		17.6	+13	17	9.6*d*
T Arietis		42.8	+17	6	8.0	S Can Min.		27.3	+ 8	32	12.8*d*
W Persei		43.2	+56	34	9.2	T Can. Min.		28.4	+11	58	12.8
U Persei	3	5.5	+14	25	9.0*d*	Z Puppis		28.3	—20	27	<12.8
X Ceti		14.3	— 1	26	8.6 *i*	U Can. Min.		35.9	+ 8	37	9.2 *i*
Y Persei		20.9	+43	50	9.0	S Gemin.		37.0	+23	41	13.2 *i*
UPersei		23.7	+35	20	12.6*d*	T Gemin.		43.3	+23	59	9.6*d*
Nov. Per. 2		24.4	+43	34	13.2	U Puppis		56.1	—12	34	13.2*d*
T Tauri	4	16.2	+19	18	11.6	R Cancri	8	11.0	+12	2	11.0*d*
R Tauri		22.8	+ 9	56	<12.6	V Cancri		16.0	+17	36	10.8*d*
W Tauri		22.2	+15	49	9.2*d*	RT Hydrae		24.7	— 5	59	8.4 *i*
S Tauri		23.7	+ 9	44	10.8 *i*	U Cancri		30.0	+19	14	12.8
T Camelop.		30.4	+65	57	8.0	X Urs. Maj.		33.7	+50	30	10.5 *i*
RX Tauri		32.8	+ 8	9	<13	S Hydrae		48.4	+ 3	27	8.6
X Camelop.		32.6	+74	56	12.0	T Hydrae		50.8	— 8	46	8.2
V Tauri		46.2	+17	22	9.8	T Cancri		51.0	+20	14	9.4

Approximate Magnitudes of Variable Stars on Mar. 1, 1908—Con.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A 1900		Decl. 1900		Magn'
	h	m	°	′			h	m	°	′	
S Pyxidis	9	0.7	−24	41	10.0*d*	X Coronae	15	45.2	+36	35	9.0
W Cancri		4.0	+25	39	12.4*d*	R Serpentis		46.1	+15	26	13.2*d*
X Hydrae		30.7	−14	15	10.6*d*	V Coronae		46.0	+39	52	8.3 *i*
Y Draconis		31.1	+78	18	<12.8	R Librae		47.9	−15	56	<12.6
R Leo. Min.		39.6	+34	58	9.8*d*	RR Librae		50.6	−18	1	9.0*d*
RR Hydrae		40.4	−23	34	12.8	— Coronae		5.2	+29		11.7 *i*
R Leonis		42.2	+11	54	7.0*d*	RZ Scorpii		58.6	−23	50	9.6 *i*
Y Hydrae		46.4	−22	33	6.5	Z Scorpii	16	0.1	−21	28	10.5
V Leonis		54.5	+21	44	13.5	R Herculis		1.7	+18	38	11.0 *i*
R Urs. Maj.	10	37.6	+69	18	12.3*d*	RR Herculis		1.5	+50	46	9.2
V Hydrae		46.8	−20	43	11.0 *i*	U Serpentis		2.5	+10	12	13.0
S Leonis	11	5.7	+ 6	0	10.2	X Scorpii		2.7	−21	16	10.5
R Comae		59.1	+19	20	13.8*d*	W Scorpii		5.9	−19	53	<13
T Virginis	12	9.5	−52	9	13.0	RX Scorpii		5.9	−24	38	11.4
SS Virginis		20.1	+ 1	19	7.8	RU Herculis		6.0	+25	20	12.6
R Corvi		14.4	−18	42	10.5 *i*	R Scorpii		11.7	−22	42	<12.9
T Can. Ven.		25.2	+32	3	11.6 *i*	S Scorpii		11.7	−22	39	11.5
Y Virginis		28.7	− 3	52	11.6 *i*	V Ophiuchi		21.2	−12	12	8.5
T Urs. Maj.		31.8	+60	2	9.7*d*	U Herculis		21.4	+19	7	13.0
R Virginis		34.4	+ 7	32	8.6*d*	Y Scorpii		23.8	−19	13	<12.8
RS Urs. Maj.		34.4	+59	2	8.5 *i*	SS Herculis		28.0	+ 7	3	9.5 *i*
S Urs. Maj.		39.6	+61	38	8.0	S Ophiuchi		28.5	−16	57	11.0*d*
RU Virginis		42.2	+ 4	42	10.0	T Ophiuchi		28.0	−15	55	9.8 *i*
U Virginis		46.0	+ 6	6	<13	W Herculis		31.7	+37	32	11.8*d*
RT Virginis		57.6	+ 5	43	8.4	R Draconis		32.4	+66	58	8.0 *i*
RV Virginis	13	2.8	−12	38	<12.5	RR Ophiuchi		43.2	−19	17	9.6
V Virginis		22.6	− 2	39	8.8	S Herculis		47.4	+15	7	9.2
R Hydrae		24.2	−22	46	8.6*d*	RV Herculis		56.8	+31	22	12.2
S Virginis		27.8	− 6	41	9.6	R Ophiuchi	17	2.0	−15	58	10.2
T Urs. Min.		32.6	+73	56	1.2*d*	U Lyrae	19	16.6	+37	42	12.0*d*
R Can. Ven.		44.6	+40	2	8.8*d*	TY Cygni		29.8	+28	6	<13
RR Virginis		59 6	− 8	43	13.2	R Cygni		34.1	+49	58	13.6
Z Bootis	14	1.7	+13	59	12.6 *i*	RT Cygni		40.8	+48	32	12.0d
Z Virginis		5.0	−12	50	10.9 *i*	χ Cygni		46.7	+32	40	9.2 *i*
U Urs. Min.		15.1	+67	15	11.0*d*	Z Cygni		58.6	+49	46	9.0*d*
S Bootis		19.5	+54	16	9.0 *i*	U Cygni	20	16.5	+47	35	7.0
RS Virginis		22.3	+ 5	8	10.7 *i*	V Cygni		38.1	+47	47	13.0*d*
V Bootis		25.7	+39	18	8.2*d*	X Cephei	21	3.6	+82	40	<13.2
R Camelop.		25.1	+84	17	8.4 *i*	T Cephei		8.2	+68	5	9.0 *i*
R Bootis		32.8	+27	10	10.3*d*	S Cephei		36.5	+78	10	7.6 *i*
V Librae		34.8	−17	14	10.6 *i*	RV Pegasi	22	21.0	+29	58	13.5*d*
U Bootis		49.7	+18	6	12.0*d*	S Lacertae		24.6	+39	48	13.2*d*
RT Librae	15	0.8	−18	21	12.8 *i*	R Lacertae		38.8	+41	51	13.6
T Librae		5.9	−19	38	12.5 *i*	RW Pegasi		59.2	+14	46	8.4*d*
Y Librae		6.4	− 5	38	11.2 *i*	R Pegasi	23	1.6	+10	0	13.0
S Librae		15.6	−20	2	8.8*d*	V Cassiop.		7.4	+59	8	12.2 *i*
S Serpentis		17.0	+14	40	12.9 *i*	W Pegasi		14.8	+25	44	10.2*d*
S Coronae		17.3	+31	44	8.8 *i*	S Pegasi		15.5	+ 8	22	13.2
RS Librae		18.5	−22	33	9.3*d*	Z Androm.		28.8	+48	16	11.3
RU Librae		27.7	−14	59	13.0 *i*	— Androm.		33.8	+35	13	9.0
X Librae		30.4	−20	50	11.6 *i*	Z Cassiop.		39.7	+56	2	<12.8
S Urs. Min.		33.4	+78	58	10.4 *i*	RR Cassiop.		50.7	+53	8	<12.5
U Librae		36.2	−20	52	11.1 *i*	R Cassiop.		53.3	+50	50	11.8*d*
Z Librae		40.7	−20	49	<13	Z Pegasi		55.0	+25	21	8.6*d*
R Coronae		44.4	+28	28	6.2	Y Cassiop.		58.2	+55	7	12.0 *i*

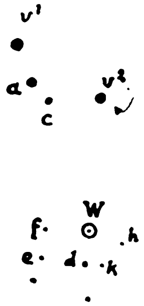
The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whitin, Mt. Holyoke, and Harvard Observatories.

Variable Star Note.

W Cassiopeiæ.—In the February number of POPULAR ASTRONOMY a few typographical errors appeared in the record of this variable, and to hinder any misleading effect, a corrected copy is inserted in this issue.

1905 May 27 Between a and c; brighter than d. Morning very clear.
June 26 Between a and c.
July 6 The same.
Sept 17, 24 Equal to h; less than d.
Oct. 15 Between d and h.
Oct. 23, 26 Equal to h: less than e or f.
Nov. 3 The same.
Nov. 14, 20, 30 Between h and k.
Dec. 3 Dimmer than h or k.



VICINITY OF W CASSIOPEIÆ.

1906 Aug. 12, 19 Equal to c.
Sept. 16, 26 Equal to d; less than c.
Oct. 3, 6, 12 Equal to d; brighter than h.
Nov. 4, 20 Less than e or f; equal to h.
1907 Aug. 8, 25 Brighter than d or c, less than a.
Sept. 1, 4, 12 The same.
Sept. 15 Equal to a.
Sept. 23 Less than a, brighter than c.
Sept. 29 Slightly brighter than c or d. Night clear.
Oct. 2, 7, 14 Equals d; brighter than e.
Oct. 28, 30 Less than d, equals e.
Nov. 2, 7, 21 The same.
Nov. 24 Less than e.

ROSE O'HALLORAN.

San Francisco,
February 20, 1908

GENERAL NOTES.

Occultation of Zeta Tauri. On February 11th., I observed with my 5-inch telescope, power 136 diameters, the occultation of ζ Tauri, and saw what I have never before observed, viz. a momentary fading of light before extinction. The star was bright and well-defined, but so much daylight remained that I could not see the dark limb of the Moon, so I did not know at what moment to expect occultation, but looked steadily at the star. While so doing, I perceived for an instant that the star was fading, and then it was gone. The time of fading was less than a second but it was long enough to make me conscious that the star *was being* occulted. The difference between this and all other occultations which I have ever seen was like the difference between the turning off a gas light and an electric light. In the one case you know the light *is going out*, in the other, it is *instantly gone*. The dimming may have been due to something in our own atmosphere. If not, I am inclined to believe that the occultation occurred at a point on the Moon's limb where something seemed to obscure the light of the star. Whatever may have been the cause, I am certain that there was the momentary fading of the star's light.

TILTON C. H. BOUTON.

Henniker, N. H.
February 13, 1908.

The Paris Observatory. An illustrated article, the leader in the March number of the *Bulletin* of the Astronomical Society of France gives a brief history of that old, and very famous institution. The cuts showing the building in the process of completion, the medal commemorative of the foundation of the Observatory in 1667, the antique instruments then in use, as compared with the modern condition and equipment of the same Observatory, makes very interesting reading especially when presented by such a gifted writer as Camille Flammarion. He knows well about the history of this great Observatory, for he has had much to do with the ecent parts of it.

Why there are no Mountains on Mars. The study of the planet Mars furnishes satisfactory evidence that it has no mountains at all comparable to those found upon the Earth, and the question naturally arises why were mountains not formed on Mars, as well as on our own planet? In three memoirs recently communicated to the American Philosophical Society held at Philadelphia, two of which have been published in the Proceedings for 1906 and 1907 respectively, the writer has shown that the mountains have been formed by the expulsion of lava from beneath the sea, owing to the accumulation of steam beneath the Earth's crust, by the secular leakage of the ocean bottoms. The effect naturally is greatest near deep seas, because of the great fluid pressure on the bed of the ocean, and it is around the margins of such oceans that the great mountain chains are formed.

If then we had a desert like Mars, with no large or deep seas, there should be no mountains on it because appreciable leakage would not take place, as upon the Earth. And as mountain formation would not be in progress, the planet would be undisturbed by earthquakes.

It is true that at present the Moon has mountains without any water, but this is due to the fact that the water formerly upon the Moon has escaped into space, owing to the feeble attraction of our satellite, which is unable to retain the molecule of water vapor. The quantity of water once upon the Moon may have been quite large, and the mountain building on our satellite dates from this earlier stage of development. In the case of Mars, however, the planet probably is able to retain most of its water vapor, but the bodies of water are so small that the effect on mountain building is insensible.

T. J. J. SEE.

Astr. Nachr. No. 4232.

Theoretical Parallax of the Great Nebula in Andromeda. If the linear semi-diameter (Δ) and the angular semi-diameter (s) of any nebula, be known, its distance (δ) from the Earth, and its parallax (π), expressed in seconds of arc, are determinable through the following equations: $\delta = \frac{\Delta}{\tan s}$; (1), and, $\pi = \frac{\omega}{\delta}$; (2) in which ω represents the number of seconds in an arc equal in length to the radius of a circle—its value being 206,264.81.

In the February number of POPULAR ASTRONOMY I described my theoretical method of determining the radius of the primitive nebula whence the Sun and the planetary—and other—members of the solar system have been evolved, this nebulous mass being considered as a *sphere* the radius whereof, according to my determination therein set forth, is 12,850 times the mean distance of the Earth from the Sun.

Regarding this nebula as really *oblate*, or oval,—like the great nebula in Andromeda—I have found its longer semi-axis to be three times the aforesaid value of the *spherical* radius, or 38,550 *astronomical units*, and this is taken as the value of Δ, while from the reproduction of the superb *Ritchey* photograph, in the March number P. A. the angular semi-diameter (s) is found to be, very approximately 1°, so that, as determined through equation (1) the value of δ is 2,208,520 times the Earth's mean semi-distance from the Sun—the great nebula in the constellation Andromeda being therefore, 205,172,000,000,000 miles distant from the Earth.

The above stated value of δ, and that of ω as aforesaid, being substituted in equation (2), there results as the theoretical value of the parallax (π) of the Andromeda nebula, 0″.094. Now, the parallax of that nebula, as found by Carl Bohlin of Stockholm, Sweden—according to a statement published in the January number (151) of P. A.—is 0″.17, this being a mean of three values, viz. 0.20, 0″.19 and 0″.08 determined by him, whence it appears that my theoretical value, set forth above, is in close agreement with the smallest of those determined by Mr. Bohlin. It seems to me that instrumental determinations of a parallax as small as this are most liable to give values in *excess* of the *true* one, and that the smallest of Mr. Bohlin's three results is, most probably the nearest to the true value. In fact, if we take one-tenth of a second of arc as the parallax of the great nebula in Andromeda, this figure will probably be as close an approximation to the true value as can be made under present conditions. This nebula, by reason of its well-defined, spiral, conformation as well as its spectroscopic aspect, is, evidently, in an advanced stage of development, and, in every respect, quite similar to the solar nebula which, if it could now be viewed from a sufficiently great distance, would present much of its primitive appearance—the "zodiacal light" being, probably, a *palimprest* of a portion of the primitive nebulous mass whence the solar system as it is now known, has been derived.

SEVERINUS J. CORRIGAN.

St. Paul, Minnesota.
March 14, 1908.

How an Objective May Lose Figure. We were much interested in one paragraph found in a paper on the photometric observations by Joel Stebbins director of the observatory at the University of Illinois. The paragraph is as follows:—

"When the writer took charge of this Observatory in 1903, he found that the 12-inch objective had not given satisfaction for some years. The out of focus images were elliptical, and with good seeing the definition was rather poor. However, the lens was far from useless, and it seemed best to go ahead with the program of double stars, most of which were easy objects for an instrument of this size. During the summer of 1905, the writer was to be absent from the Observatory, and the lens was shipped to Allegheny at the request of Mr. Brashear, who naturally become interested when he learned that an objective of his manufacture was not giving satisfaction. He found that the metal ring which holds the lenses in the cell had been pressed down on one side, and allowed to remain, causing a permanent bending principally of the flint lens. Although he was in no way responsible for this occurrence. Mr. Brashear kindly refigured both lenses without cost to the Observatory, and the objective was returned in October 1905. The defects were corrected, and we now have a first class objective."

Photometric Observations of Double Stars by Joel Stebbins.

A recent publication by Joel Stebbins Director of the Observatory at the University of Illinois is at hand. The publication is an important one, in that it considers not only angle and distance of the components of a double star, but also their magnitudes as well. It is a well-known fact that the weak point in the work of double star observations by the old micrometric methods is in relation to the magnitudes of the components which is always estimated by the observer. If he is experienced such estimates will probably be quite nearly true; but if he is not a skillful observer, the estimated results will be uncertain.

This part of the work by former methods has not been considered very important, for the aim was the study of the motion of the components, rather than their physical condition in regard to brightness. It is certainly important to have this feature added in the study of the double stars in the future when it can be done.

Dr. Stebbins has used, in this work, a 12-inch refractor by Brashear, mounting by Warner and Swasey, which was erected in 1906. He finds the driving clock runs well, giving star images nearly stationary except for a vibration of about 8″, periodic in four minutes, which is due to the eccentricity of the driving worm.

He uses a polarizing photometer by Alvan Clark and Sons, in the form devised by Professor Pickering, and described in Vol II. p. 4 of the *Annals* of Harvard College Observatory, designated photometer H. A. Wollaston, prism forms two images of each star, and these images are varied in intensity by rotating a Nicol prism between the eye and the eyepiece. When the stars are close together the ordinary image of one can be brought adjacent to the extraordinary image of the other, and the difference of magnitude is easily derived from the positions of the Nicol which produce equality in the two images compared."

Other interesting details of the method of work, and the results already obtained are given in this paper which will be of service to any who may wish to know more about it.

This publication contains a list of 107 double stars whose measures are catalogued on this plan. It is the intention of the director to continue this work, for he says there is enough work within the range of his instrument to keep an observer busy for his entire life.

Present Surface Temperatures of Mars, Venus and Mercury. The smaller planets Mars, Venus and Mercury, when viewed in contradistinction to the four great outer planets Jupiter, Saturn, Uranus and Neptune, may be regarded as quite similar to, and comparable with, the Earth, in respect to *mass*, dimensions and—in a certain sense—physical conditions, so that the absolute temperature of the surface of each, *relative* to the known, uniformly distributed and constant, temperature of the superficial matter of our globe at a depth of about 100 feet below its solid surface, which temperature is known to be, approximately, 52° Fahrenheit, or 512° of the *absolute* scale may be, in each case, taken as the *ratio* between the maximum internal temperature of the planet, and that in the case of the Earth, all of which absolute temperatures are set forth in Table IIa, on page 150 of the March number (153) of P. A., that of the Earth being, 6,800°; of Mars, 5,640°, of Venus 7,120° and of Mercury, 7,934°. .

Therefore, the surface temperatures are: for Mars $\frac{5640^\circ}{6800^\circ} \times 512^\circ = 424^\circ$; or — 36° Fahrenheit; for Venus $\frac{7120^\circ}{6800^\circ} \times 512^\circ = 536^\circ$; or + 76° Fahrenheit, and for Mercury $\frac{7934^\circ}{6800^\circ} \times 512^\circ = 597^\circ$; or 137° Fahrenheit. Since any uncertainty in the value of the maximum internal temperature of the Earth attaches, in equal measure, to the case of each of the three other planets the *ratio* aforesaid is, obviously, unaffected, so that the value of the intrinsic temperature at a small depth below the solid surface, may be regarded as sufficiently well determined.

These are the temperatures due to the internal planetary heat alone, the augmentation caused by thermal radiation from the Sun being an independent quantity the maximum value whereof may be taken at about 70° F for the Earth, which would give, as the greatest temperature on the surface exposed to direct solar heat, the maximum intrinsic temperature 52° + the solar augmentation 70°, or 122° F, which is about the greatest temperature (in the shade) recorded in the hottest regions of our globe. The augmentation in the case of each of the other three planets is, obviously, inversely proportional to the square of its *relative* distance from the Sun, so that for Mars the value to be added to the intrinsic temperature (— 36°) aforesaid is + 76° F, making the actual surface temperature 0° Fahrenheit, from which determination it may be inferred that the climate of Mars, at best, is one of Arctic severity or that of an elevated plateau at an altitude of four, or five miles above sea-level, with respect to temperature compared with terrestrial conditions in this regard, and that the types of life thereon (if any there be) must correspond to those existing upon the Earth in similar situations. At the same time, the nature of the surface matter of Mars may be such that it may have a somewhat higher maximum temperature, particularly in the polar regions where it is exposed (during a period of insolation about twice as long as in the case of the Earth) to the direct solar rays, so that the temperature may at times, rise somewhat above the freezing-point as seems to be indicated by the behavior of the polar snow-cap.

The augmentation to be added to the intrinsic-temperature of the planet Venus (76°) is 114°, making a maximum surface temperature of 190° F which is not far below that of boiling water—a fact that accounts well for the dense clouds which seem to envelop that planet and reflect the incident sunlight so well that Venus is at times, the most brilliant object in the heavens except the Sun. This temperature corresponds to that which, according to a determination of my theory, prevailed upon the Earth during the latter part of the Huronian-Cambrian Age of geological history, when the primitive forms of life first appeared upon the Earth, as evidenced by the molluscan fossils, the *trilobites*, the noted Eozoon Canadense etc., in the animal kingdom, and by the casts of the vegetable, "fucoids" all well suited to their environment in the warm, shallow waters of that remote age, between 50 and 60 millions of years ago, according to my determination as set forth in the III Part of my work treating of the "genesis of the solar system". In the case of the planet Mercury the augmentation due to solar heat is 393°, and this, added to the intrinsic temperature, gives 530° F as the maximum surface temperature on Mercury,—which is not much below that of the melting-point of lead—a fact that precludes the possibility of the existence of any known form of life on that planet. All of the above results are quite consistent with the best known facts.

SEVERINUS J. CORRIGAN.

St. Paul, Minnesota.

The Orbits and "Velocity-Curves" of Spectroscopic Binaries.*

In looking over the published papers on spectroscopic binaries, it will be remarked that the "velocity-curves"—as hitherto drawn for these objects—are often unsymmetrical. A closer examination reveals a curious *general similarity* in the form of such curves; the *ascending* branch of the curve, with few exceptions, being of greater length than the *descending* branch. This fact, although of great theoretical interest, seems to have been hitherto overlooked by astronomers. Its significance will be seen when we try to interpret it in accordance with received ideas. The result may be stated as follows:

Let D denote the time-interval during which the star's "radial velocity" is *decreasing*; I the interval during which it is *increasing* (algebraically); ω the longitude of periastron, reckoned from the ascending node. On the hypothesis of elliptic motion we have:

$D < I$ if ω is between 0° and 180°,
$D > I$ if ω is between 180° and 360°.

Now for the list of thirty spectroscopic binaries given in the paper, we find:

$D = I$ for 1 star,
$D > I$ for 4 stars,
$D < I$ for 25 stars.†

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*Abstract of a paper communicated to the Royal Astronomical Society of Canada, revised and amended by the author March 11, 1908.

† Excluding these stars for which e is equal to or less than 0.10, we have:

$D = I$ for 1 star,
$D > I$ for 2 stars,
$D < I$ for 21 stars.

It should be added that the list of 30 binaries—with one notable exception—includes only stars for which the oscillation curve appears to be certainly unsymmetrical.

Thus in a large proportion of cases, the periastron is located (apparently) in the first or second quadrant of the orbit. A yet more remarkable feature is the apparent *grouping* of the periastra about certain values of ω. That such a distribution of the apses really exists is of course very improbable—so improbable that we are certainly justified in seeking for a different explanation of the observed facts. In other words, the elliptic elements e and ω, as computed for the orbits in question, are probably illusory; the "observed radial velocities," upon which they are based, being vitiated by some neglected source of systematic error.

After a careful study of the problem involved, the writer has been led to formulate a definite theory on the subject as outlined below. Without underestimating the difficulties of the problem, or denying the possibility that some other (and perhaps more probable) solution may yet be found, it is believed that the explanation here given rests upon a substantial basis:

(1) The disks of the stars under notice are not uniformly bright. The distribution of surface brightness in *longitude* is, for each star, unequal, and for some stars, distinctly unsymmetrical. Such conditions, combined with rapid axial rotation, would result in an unsymmetrical broadening of the spectral lines. The *effective* result would be a periodic shift of these lines, as measured on the spectrograms.

(2) The orbits of such binaries (especially those of short period) are, in general, nearly circular.

(3) The measured "radial velocity" is the resultant of orbital motion and axial rotation—as indicated above.

(4) Tidal action, as modified by friction and the general circulation of the stellar material, will probably account fully for the conditions postulated in (1). One very interesting and important consequence of this theory should be stated here, viz., that many (perhaps all) spectroscopic binaries are variable in brightness; though the range of their periodic light-changes must, in general, be small. Accurate photometric observations of such objects should, therefore, afford a crucial test of our hypothesis.

It would appear that both the light- and "velocity"- curves of the δ Cephei variables may be explained in conformity with these views. Confirmatory evidence is afforded by other facts of observation—e.g., the asymmetry in the light-curves of certain Algol stars—notably S Cancri, U Coronæ, and δ Librae.

For stars of the δ Cephei type, we must assume that the distribution of surface brightness is distinctly unsymmetrical. In ordinary cases, however, such an assumption is unnecessary.* The usual form of the "velocity-curve" (as indicated by the relation $D < I$) admits of a very simple and direct explanation. It is only necessary to suppose that the star's surface brightness at any point depends upon the *height of the tide* (due to a revolving satellite) at that point: *high* tide corresponding to *minimum* and *low* tide to *maximum* brightness. The orbit is regarded as circular (or nearly so), and the star is assumed to *rotate* in the same general direction as it *revolves*—an assumption that is both natural and theoretically probable. It should be added that the influence of tidal friction—where the periods of axial and orbital motion are unequal—may modify, in an important degree, the resulting form of the oscillation-curve.

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* The degree of asymmetry (where such exists) must depend largely upon the *relative* distance of the tide-raising body.

In a future paper I hope to deal with various details of the theory outlined above and to discuss some practical methods for the separation of effects due, respectively, to axial rotation and orbital revolution of the stars under notice.

J. MILLER BARR.

St. Catharine's, Ontario,
Canada.

Observatory of the Rev. J. H. Metcalf. In the sixty-second annual report E. C. Pickering the Director of the Astronomical Observatory of Harvard College, the following paragraph appears on page 8.

"It is the policy of the Harvard Observatory to aid, when possible, specialists who display marked skill in any department of astronomy. Coöperation has accordingly been established with the Observatory of the Rev. J. H. Metcalf so that the work there has been materially extended. This secures for the Harvard Observatory the immediate use of many excellent photographs and the eventual possession of certain valuable instruments. During the past year, Mr. Metcalf and his assistant have taken 200 photographs with a 12-inch doublet constructed by him. The greater portion of these plates were made by following upon a star, and giving an additional motion to the plate equal to that of an asteroid.

This method proves extremely effective in discovering and following asteroids and has led to the discovery of 33 asteroids, and of comet 1907 b, by Mr. Metcalf. The planet Eros also was found readily on July 4, 1907, on the first photograph taken for this purpose."

Mr. Metcalf is desirous that the orbits of these asteroids be computed so that a record of them may be made. He urges that observatories, colleges or individuals able to do the work and willing to make such a contribution to science will signify to him their desire to undertake the care of one or more of these planets.

The remarkable success of this new plan for photographic observation of faint comets and faint asteroids is claiming the attention of astronomers generally. It will be used more and more as time goes on.

Standard Tests of Photographic Plates by Edward S. King was published by Harvard College Observatory, as volume lix, No. 1, of its *Annals*.

Mr. King's discussion of the subject is full and detailed, the principal results attained in his investigation being summarized without respect to order of importance are given below.

1. The accuracy with which measures can be made with a photographic wedge, when it is under standard conditions. This is shown by the results in Table III, by the small residuals in Table IV, and by the almost exact duplication of the measures given in Table VI. It is shown also by the determination of the slight play of the scale, mentioned on page 5, amounting to only 0.03 magnitudes.

2. The difficulty of obtaining absolute results from photographic measures. This is shown by the diversity of results, when the experiments were made under almost exactly the same conditions.

3. The advantage of a system, in which the effect of the several elements contributing to the result have been studied from the same collection of plates.

4. The derivation of the nature of the error arising from the density of the film. The original plan did not provide for such an error, nevertheless

the material was sufficient to determine it.

5. That a little fogging of the plate is beneficial to the sensitiveness, but beyond a small amount becomes detrimental.
6. The care necessary to protect the sensitive film from all influences that may act like light, or affect the sensitiveness.
7. The necessity of repeating experiments sufficiently to eliminate the effect of such extraneous influences.
8. The slight differences found in the sensitiveness of the plates fresh from the maker and those three months old, or of plates developed immediately, and those developed three months after exposure.
9. The gain in the sensitiveness of the plates in use, amounting to 0.41 magnitudes, or almost 50 per cent, for the period discussed.

This paper is a suggestive one. It considers the features of the photographic plate that practical men want to know. The impression that we get in examining it, is that its results are preliminary in character, but doubtless point in the right direction. It would certainly interest those who deal much in astronomical photography to see this important investigation carried on still further.

Differential Equations by Cohen. This new book of 271 pages by Abraham Cohen, Associate in Mathematics at Johns Hopkins University, on Differential Equations is an elementary treatise and is published by Messrs. D. C. Heath and Co., Boston and Chicago.

The book is the result of the author's work in classes for some years as an instructor and it therefore takes the practical form that a teacher of large experience can give it. It can be pursued with advantage, by a student who has had a year's study in the calculus and such a student will find the course a splendid drill for him if he contemplates advanced studies in engineering, physical science, mathematical physics or the study of the higher pure mathematics including applications to practical astronomy.

We are interested to notice that the author plans to issue another book probably of 'advanced character, that will give the student knowledge of the wider range of Differential Equations showing more fully the splendid field that this branch opens to one prepared to go into it.

For an introductory work the one now in hand will commend itself highly for the purpose to those able to judge of it, or prepared to use it for study.

Differential and Integral Calculus by Osborn. Integral Calculus by Professor George A. Osborn of the Massachusetts Institute of Technology is a text that will interest any teacher of this branch who wants a text well planned and thoroughly up to date. The development of the various themes commonly pursued in first rate engineering schools, will be found in this text in a little different order from that pursued in some prominent engineering schools. In our judgment the author's arrangement is excellent. We have pursued the Sheffield School plan in preparing students in this branch of study either for engineering or for practical astronomy. In these two respects the Granville text has met our expectations well. It needs two full years of close study 16 hours per week to prepare the student thoroughly in both the Integral and the Differential for either of these two scientific lines of work. In that time he can master the principles and have practice enough in solving the given problems to test his knowledge and to exercise his powers of application in a breadth of training that ought to insure exceptional ability in practical research. Anything less will fall short of a standard of scholarly value that ought to be rigorously maintained.

Professor Osborn's book is strongly recommended to teachers and students of mathematics.

The publishers are Messrs. D. C. Heath & Co., of Boston and Chicago.

A Course in Mathematics by Woods and Bailey. Volume 1, of A Course in Mathematics by Frederick S. Woods and Frederick H. Bailey, Professors of Mathematics in the Massachusetts Institute of Technology, recently published by Messrs. Ginn and Company, Boston, New York, Chicago and London, is before us.

These well-known authors of text-books in mathematics have devised a new plan for the study of the branches that have very generally gone under the names of Algebra, Analytic Geometry, Differential and Integral Calculus and Differential Equations. They have aimed to select from these various branches the essentials of each and relate them into one consecutive whole that would make two volumes for an entire course of mathematics for the work of students for two years in the engineering school. The first volume covers algebraic equations, functions of one variable, analytic geometry and the differential calculus.

It consists of 364 pages. To do this work the student is supposed to have finished trigonometry in the secondary school.

The first hundred pages of volume one in this new course deals with algebra beginning with elimination by determinants and ending with quadratics. A full discussion of roots is included and illustrations by the graphical method are freely used. The study of the algebraic function in general requires a knowledge of analytic geometry and the calculus and these principles must be understood before the student can advance even to simple applications. We also notice that it is necessary to use simple integration in some cases to carry out this new plan.

The subjects for study and the order of them, in the main, are logical and excellent, but the fear that arises in our mind is that too much is expected of the student in the way of preparation, on the one hand, and in ability on the other, to do the work expected of him in the time specified. There is not enough exercise in knowledge of principle and its applications to give the student the independence in thinking and doing for himself before leaving one theme to go to another more or less remotely connected with it.

If the student were expected to stop with the algebraic function and a few of the elementary transcendental functions, he might work the new plan successfully. But the authors think it is better to give less of the properties of these functions and more of the transcendental curves, which, it seems to us, is not the best way to study the generalizations of mathematics at this stage of the student's progress.

Also, we fear the plan requires the student to go over too much ground in the time given to it. This is the serious mistake that most recent authors are making. It is absolutely impossible for the good average student to do the work as it ought to be done in the time usually given for it. The effect of this is never satisfactory to student or teacher. It gives the wrong impression to the inexperienced instructor about what he ought to do in a given time, and leads him to crowd the student to the limit of his ability and often beyond it to do what is expected of him, and because he fails or succeeds very indifferently, he is discouraged and leaves the study of mathematics for something easier.

We have so often seen such results as these that we can not forbear speaking of them when so good a book as the one in hand is, in many respects, yet has this danger in its way that we have briefly and too hurriedly pointed out.

For years we have thought along this line and often spoken of it as conviction has grown upon us. Fully ten years ago while talking with Professor Simon Newcomb of Washington, D. C., in regard to this matter of teaching the calculus, he made this same point in clear and definite way. We thought then he was right and we are sure of it now.

Catalogue of Bright Clusters and Nebulae. The foregoing is the title of a paper by Solon I. Bailey which appeared as No. VIII of Volume LX of the *Annals* of Harvard College Observatory.

Mr. Bailey gives the following provisional classification of nebulae and clusters.

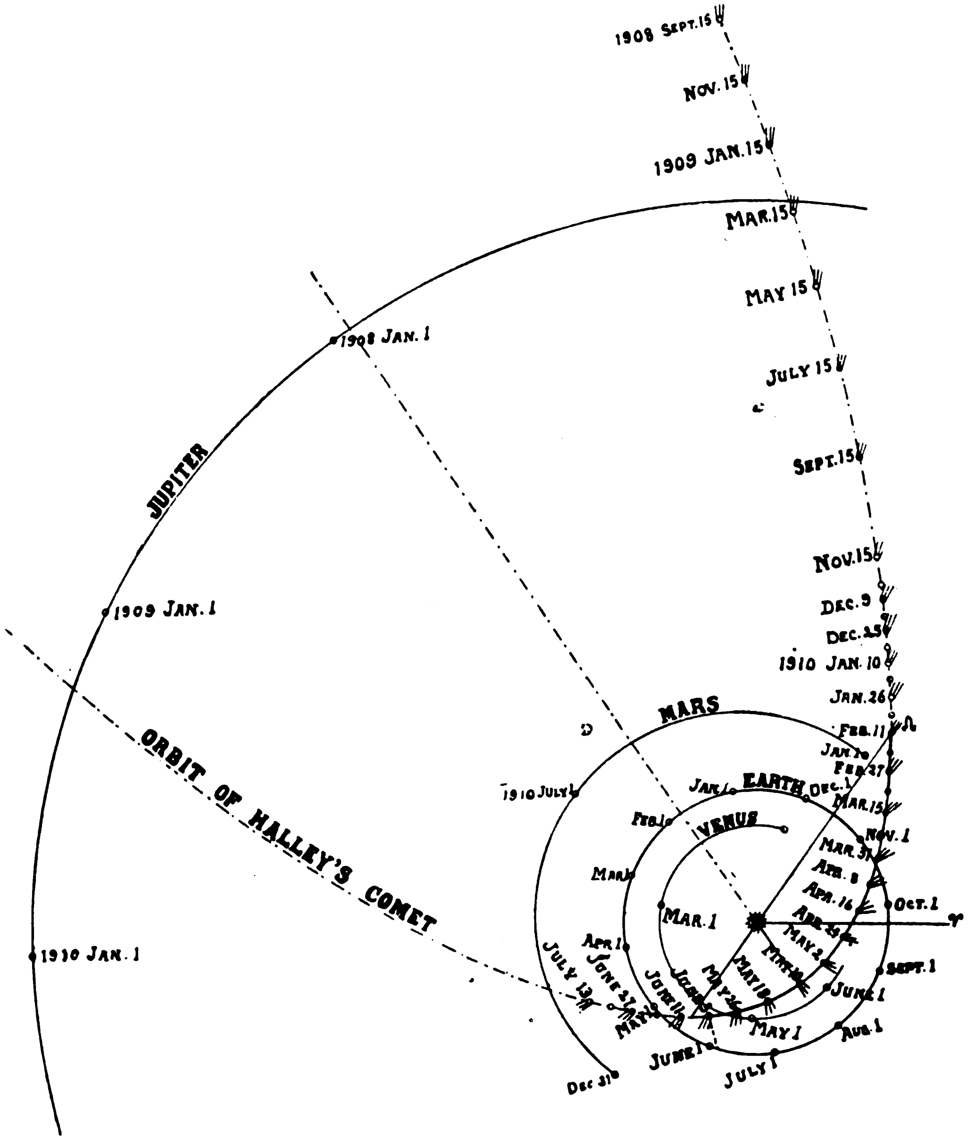
A. Vast, faint, irregular nebulosities, shown on photographs of long exposure. Examples; Nebula in Cygnus, Great Spiral about Orion.
B. Gaseous Nebulae. Objects having Gaseous Spectra.
  B1. Large, diffused, irregular. Examples; Orion Nebula, ηCarinae Nebula.
  B2. Planetary, ring, and other small, well-defined gaseous nebulae. Examples; N.G.C. 3587 (planetary), N.G.C. 6720 (ring), N.G.C. 6618.
  B3. Nebulous stars. Examples; N.G.C. 1514, N.G.C. 2003.
C. White Nebula and Globular Clusters. Objects having continuous Spectra.
  C1. Nebulae, small, unresolved, of somewhat definite form, generally round or elliptical. This group probably includes the great majority of small nebulae, many thousands in number.
  C2. Spiral Nebulae. Examples; N. G. C. 224 (The Great Nebula in Andromeda) N.G C. 5194 (Spiral in Canes Venatici).
  C3. Globular Clusters. Examples: N.G.C. 5139 (ω Centauri), N. G. C. 104 (47 Tucanae), N.G.C. 6205 (Great Cluster in Hercules).
D. Irregular Clusters.
  D1. Fairly condensed, somewhat regular, stars of comparatively uniform magnitudes. Examples; N.G.C. 2437, N.G.C. 6494.
  D2. Fairly condensed, irregular, stars of different magnitudes. Examples; N.G.C. 869 and 884 (Double Cluster in Perseus), N.G.C. 4755 (κ Crucis).
  D3. Coarse, irregular, stars of different magnitudes. Examples; Hyades, Pleiades.

This catalogue of bright stars and clusters is an extremely interesting one, not only in its detailed descriptions, but especially also in the many fine reproductions from photographic plates. Plates 4 and 5 that bring out the nebulous regions about the Milky Way in the vicinity of Sagittarius and Scorpio and that surrounding η Carinæ are surprisingly clear, clean and full of interesting detail when examined under magnifying power. The original negatives must have been very good, the half-tones first rate and the printing almost faultless. We have had some experience in this kind of work and we know what it means and what it costs to be successful in doing such work well. We think Mr. Bailey's work in this paper is admirable.

Errata. In the March number, page 164, first line of second paragraph for "σ Hydra" read δ Hydra, and in next paragraph on same page, tenth line for "2° 15′ declination" read 1° 45′ S. Declination, twelfth line for "2° 45′" read 2° 15′, and in next line for "39° 41′" read 39° and 41°, and in last line of some paragraph for "43° 45′" read 43° 15′. Scale of Plate III should read 1mm = 41″.

The title from the table of contents of Mr. W. H. Pickering's article on Drawing Ellipses was unfortunately omitted.

PLATE XIV.



HALLEY'S COMET AND THE PLANETS IN 1910.

Popular Astronomy.

Vol. XVI, No. 5. MAY, 1908. Whole No. 155

THE NEXT APPARITION OF HALLEY'S COMET.

H. C. WILSON.

FOR POPULAR ASTRONOMY.

The great comet known as Halley's has a period which has varied from 79 to 74½ years in the last seven centuries, owing to the disturbing effect of the planets Jupiter and Saturn upon its orbit. Its path around the Sun is very elongated; at perihelion the comet is nearer than Venus to the Sun, while at aphelion it is farther off than Neptune, being then thirty-five times as far as the Earth from the Sun. The comet has been observed at each of its apparitions certainly as far back as the year 1222 A. D., and it is extremely probable that the identification of the great comets of 1145 and 1066 with Halley's comet is correct. Back of these the identifications are more or less vague, although two, those of the years 451 and 760 A.D. are fairly certain.

The French astronomer Pontécoulant carried the calculation of the perturbations of this comet back to 1531, and recently* Messrs. Cowell and Crommelin of the Royal Observatory at Greenwich have extended the calculations back to 1222, and are now working on the revolutions 1066-1145 and 1145-1222. The result of these computations has been to prove that Hind's conjecture as to the identity of the comet of 1301 with Halley's is correct, but that his similar identification of the comet 1223 is erroneous, the perihelion of Halley's comet occurring in September 1222 instead of July 1223. "There was, however, a much more remarkable comet which appeared at the exact epoch of the calculation, and examination shows that the greater part of the statements made concerning it by contemporary writers are quite consistent with its being Halley's, so that the identity is placed beyond a reasonable doubt."

Concerning the comets of 1066 and 1145 Messrs. Cowell and Crommelin add this remark: "Though the computations for the revolutions 1066-1145, 1145-1222, are still incomplete, enough has been done to make it extremely probable that

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* *Monthly Notices* R.A.S. LXVII. p. 111 and p. 173.

Hind's identification is correct in each case, though his elements of the apparition of 1066 clearly need modification. They differ more widely from the present elements than perturbations will account for. However, the positions are so vaguely recorded that large alterations in them are possible."

We have thus one great comet whose history has been traced back over eight centuries, and in that time it has come to perihelion eleven times and has not failed of being seen and recorded at a single apparition. It has at each return been visible to the naked eye and several times has been a splendid object, creating great interest and even terror among the people who saw it. The tail of the comet has varied very much in appearance at the different apparitions, owing to the different angles at which it was seen and the different background of dark sky or bright twilight against which it was projected. In 1066 it was a "famous object which created universal dread throughout Europe. In England it was looked upon as a presage of the success of the Norman invasion." In 1145 according to the Chinese records, on May 14 it had a tail 10° long. In 1222 it is recorded that in the months of August and September a fine star of the first magnitude, with a large tail, appeared. According to the Chinese the tail was 30 cubits long and the comet remained in sight for two months. In 1301 and 1378 it was visible for six weeks. In 1456 it occupied a space nearly 70° in length, and spread terror throughout Europe, being visible for a month. In 1531 and 1607 it does not appear to have been so conspicuous, the tail being recorded as only 7° long. At the latter of these two apparitions Kepler described the comet as a star of the first magnitude, but so trifling was the tail that it was at first doubted whether it had any. Again in 1682 the comet attracted little attention except among astronomers; the tail was observed as 12° to 16° long. This apparent waning of the comet led astronomers to fear that in 1759, its first predicted return, it might be so faint as not to be visible at all. However the predictions of its course were so accurate that it was found, with the aid of small telescopes, by two observers three months before reaching perihelion. The tail did not become visible until after perihelion and when it should have been brightest was seen against bright twilight and so was not conspicuous, but in the southern hemisphere where the circumstances were more favorable it was visible to the naked eye and its length on one date was estimated at 47°. In

1835 it was visible to the naked eye during the whole of October, with a tail from 20° to 30° long. The question now naturally arises, will the next return, in 1910, be under favorable or unfavorable circumstances? Shall we expect to see a great, magnificent comet as in 1456, or a comparatively insignificant object as in 1607, or will it be an ordinary big comet as it 1835? In order to aid in answering this question I have collected together the elements of the comet's orbit at the different apparitions which have been observed and have drawn the diagram which appears as the Frontispiece of this number of POPULAR ASTRONOMY.

APPROXIMATE ELEMENTS OF HALLEY'S COMET
REDUCED TO THE EQUINOX OF 1910.

Perihelion Passage	Angle from Ascending node to Perihelion	Longitude of Ascending Node	Inclination of Orbit to Ecliptic	Perihelion Distance	Period Years
451 July 3	108°.5	53°.3	16°	0.60	
760 June 11	107.5	52.5	17	0.60	...
1066 Apr. 1	...	...	...	...	...
1145 Apr. 29	...	...	...	...	79.1
1222 Sept. 15	105.6	51.6	16.5	0.67	77.4
1301 Oct. 22	...	...	...	...	79.1
1378 Nov. 8	107.77	54.67	17.9	0.584	77.0
1456 June 8	104.82	50.08	17.62	0.581	77.7
1531 Aug. 25	104.30	50.77	17.00	0.579	75.2
1607 Oct. 27	107.25	52.66	17.14	0.585	76.2
1682 Sept. 14	109.26	54.35	17.76	0.583	74.9
1759 Mar. 12	110.65	55.92	17.62	0.585	76.5
1835 Nov. 16	110.64	56.19	17.76	0.586	76.7
1910 May 10	111.54	57.18	17.78	0.59	74.5

Motion retrograde.

The diagram was prepared by the aid of ephemerides of the comet computed by Mr. F. E. Seagrave of Providence, Rhode Island, and the elements differ slightly from those given in the last line of the table, but not enough to affect the shape of the diagram appreciably. Mr. Seagrave adopts May 10 for the date when the comet will be at perihelion. The computations of Messrs. Cowell and Crommelin point to an earlier date, probably about April 8 for perihelion passage. Comparing this with the dates in the table we see that this coincides very closely with that for the apparition in 1066 when the comet was a famous object.

According to the table, if we accept the records of 451 and 760 as being genuine records of Halley's comet, it has been at perihelion in all the months of the year except January, February, May and December. The great displays appear to have been when the perihelion passage occurred in April, June, July and November. The reasons for this will be plain to one who studies the diagram. The dotted curved line represents that portion of the comet's orbit which lies below the plane of the ecliptic; the smooth curve, including the dates February 12 to June 3, is above that plane. The inclination of the comet's orbit to the ecliptic being about 18°, the reader must think of that part of the diagram as being tilted out of the plane of the paper, revolved about the line of nodes through the angle 18°, so that the point marked May 2 would be about the highest point of the curve. Now imagine the Earth to be moving in the plane of the paper and the comet in the tilted curve, and to pass the perihelion point (marked May 10 in the diagram) about April 1. It takes the comet about 40 days to pass from its perihelion out to the Earth's distance from the Sun, so that it would reach the nearest point to the Earth's path about May 11 and during the first half of May the two bodies would be relatively close together; the nearest approach that could occur would be about May 4, when the comet, if it were directly below the Earth, would be roughly 6,000,000 miles away. A few days' change in the date of perihelion would here produce a very great change in the comet's apparent course through the heavens. If perihelion should be a few days before the first of April, the comet would cross in front of the Earth and so be seen in parts of the sky far from the Sun when nearest the Earth. In 1759 the passage occurred too early and in 1145 too late, if the date be correct, for the most magnificent effect.

For the perihelion passages in June and July it will be noticed that the comet is nearest the Earth just after or close to the time of perihelion when the tail has its greatest development, and also when the comet is near its highest elevation above the ecliptic, so that even when in conjunction with the Sun it is so far north as to be visible both evening and morning. In 1456 it was for a time circumpolar so that it could be seen above the northern horizon all night.

In August, September and October the conditions are even better so far as position in the sky is concerned but the nearest approach to the Earth occurs before the greatest development of the tail has been reached. For a November perihelion, especially in the latter part of the month, the favorable position of the comet in the sky during October largely offsets the lack of development of the tail, and so the apparition in 1835 was a favorable one. Had the comet passed the

Earth two weeks later than it did its distance on October 20 would have been only 15,000,000 miles and its tail might have appeared much larger than it did.

Now as to the 1910 apparition. The comet is now out between the orbits of Jupiter and Saturn. It will be within the distance of Jupiter's orbit after March 1, 1909. It is possible that some one with the aid of a great telescope or a photographic camera may catch sight of the expected visitor during the winter of 1908-09. We may begin to search for it as early as September 1908, provided good ephemerides are at hand. Almost certainly it may be found by September or October 1909. It will then be only a round nebula, whatever tail it has being almost directly behind it as seen from the Earth. If the date of perihelion should be May 10, the comet will be lost behind the Sun in the early part of April, reappearing in the morning sky about the first day of May. It should reach its greatest brilliancy in the last days of May but the morning dawn will prevent its having the most striking effect. It will pass between the Earth and the Sun about June 1 and there is a possibility then of the tail extending so far out over the Earth that it may be very conspicuous in spite of the deep twilight in which the head of the comet must be observed. After June first the comet should be visible in the evening in the western sky, a more or less splendid object according as the effect of the lessening twilight or the increasing distance of the comet be the more important factor in changing its brilliancy.

If the date of perihelion should be April 8, as Messrs. Cowell and Crommelin predict, the circumstances may be quite different. We must then diminish all the dates on the diagram of the comet's path by thirty-two days. The comet will be lost in the twilight in March and reappear from the dawn in April. It will approach much closer to the Earth as it passes between the Earth and the Sun in May, but will be much more nearly in line with the Sun, so that at the time of conjunction we shall probably not be able to see it at all for two or three days. For a few days before this, i. e., about May 1 it should be a splendid morning comet and during the latter half of May it should be a fine object in the evening.

One fact which will strike the eye of the reader at once upon examining the table of elements of Halley's comet, which I have given above, is the great change in the period of the comet which may occur from one revolution to the next. It has in some cases amounted to more than two years, and it does not continue in the same direction in successive revolutions but sometimes increases and sometimes decreases the period. The longest revolution so far recorded is that of 1222-1301 and that of 1066-1145 is very near the same, 79 years and one month. The shortest round is the one now being accomplished, being a little less than 74 years six months. This extreme range of over four years in the period renders necessary the most careful and laborious calculation of the effects of the attraction of all the planets upon the comet, and it seems a marvel that the computers have come so near to predicting the exact date of perihelion at previous apparitions. In 1759 Clairaut and Lalande predicted a date twenty-three days too late, but Laplace has since shown that if the mass of Saturn had been accurately known at the time when the computations were made, the error of the final result would have been within nine days. The planets Uranus and Neptune were then unknown so that their influence was entirely neglected. In 1835 five computers obtained different dates ranging from October 31 to November 26. The actual perihelion occurred November 16 so that all were within sixteen days of the true date. Pontécoulant predicted November 14 and so was only two days in error. If the computers for 1910 can beat this record they will do well.

Halley's comet is sometimes spoken of as one of the Neptune family of comets. As a matter of fact Neptune, as the orbit of the comet is now situated, can have very little influence in disturbing it. The inclination of the comet's path is such that it nowhere approaches closer than 750,000,000 miles to Neptune's path. Both the nodes are near the other end of the orbit, near the paths of Earth, Venus and Mars and these little planets have more influence upon the comet's motion than can Neptune have. It is difficult to see therefore how Neptune can have been instrumental in capturing this comet. It is true there is some indication of a shift of the line of nodes around the orbit, and in long ages past the descending node may have been in the vicinity of Neptune; in any case the time is very remote.

THE SOLAR ECLIPSE OF JUNE 28, 1908 AS VISIBLE IN THE UNITED STATES.

WM. F. RIGGE, S. J.

FOR POPULAR ASTRONOMY.

The solar eclipse of June 28, 1908 will be well visible all over the United States. The Sun will everywhere be high in the sky, and the magnitude of the eclipse will vary from one-tenth in the state of Washington to the annular phase in Florida. The accompanying maps will probably furnish all the information desirable.

Figure 1 shows the central time of the beginning of the eclipse, as well as the position of the point of first contact. The full lines denote the time, the large numbers 8 and 9 representing the hours 8 and 9 o'clock in the morning, and the smaller ones, 10, 20, 30, 40, 50, the intervening minutes. By means of these lines the time of the beginning of the eclipse may be found for any locality to the nearest minute. It need hardly be said that Eastern time will be one hour later and Mountain and Pacific times respectively one and two hours earlier than the central time shown on the map.

The "one-dot-and-one-dash" lines, marked N 200 to N 260, indicate the position angles of the point of first contact on the Sun's limb, counting from the north point towards the east. The "three-dot-and-one-dash" lines, marked V 240 to V 350, show the same point of first contact as measured from the Sun's vertex or uppermost point, also towards the east.

Figure 2 gives the time of the middle of the eclipse, that is, the time of the maximum obscuration, together with its amount. The large numbers 9 and 10 mean, as before, 9 and 10 o'clock, and the smaller ones, 10, 20, 30, 40, 50, the intervening and subsequent minutes. The other numbers, from 1 to 9, denote the magnitude of the eclipse as expressed in tenths of the Sun's diameter obscured. The appearances of the Sun thus variously eclipsed are shown in Figure 3.

The belt on Figure 2 marked Annular Eclipse shows where the Moon will be seen to completely enter the Sun's disk but unable to obscure the whole of it. On the border lines of this path the Moon will just graze the Sun's limb, and the eclipse

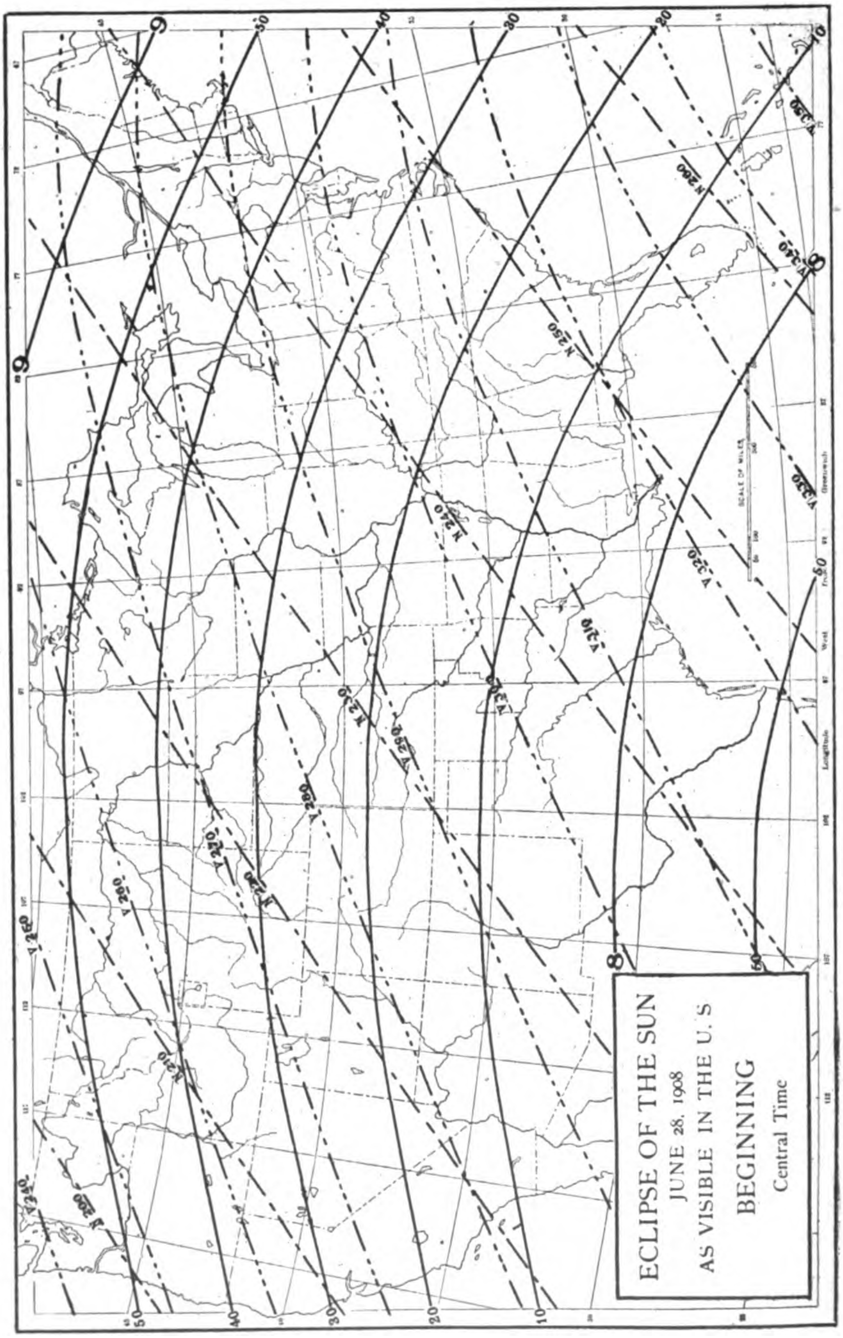

ECLIPSE OF THE SUN
JUNE 28, 1908
AS VISIBLE IN THE U. S
BEGINNING
Central Time
SCALE OF MILES
9
8
50
40
30
20
10
V 260
V 270
A 280
A 290
N 200
N 210
N 220
N 230
N 240
N 250
N 260
V 310
V 320
V 330
V 340
V 350

Figure 1.

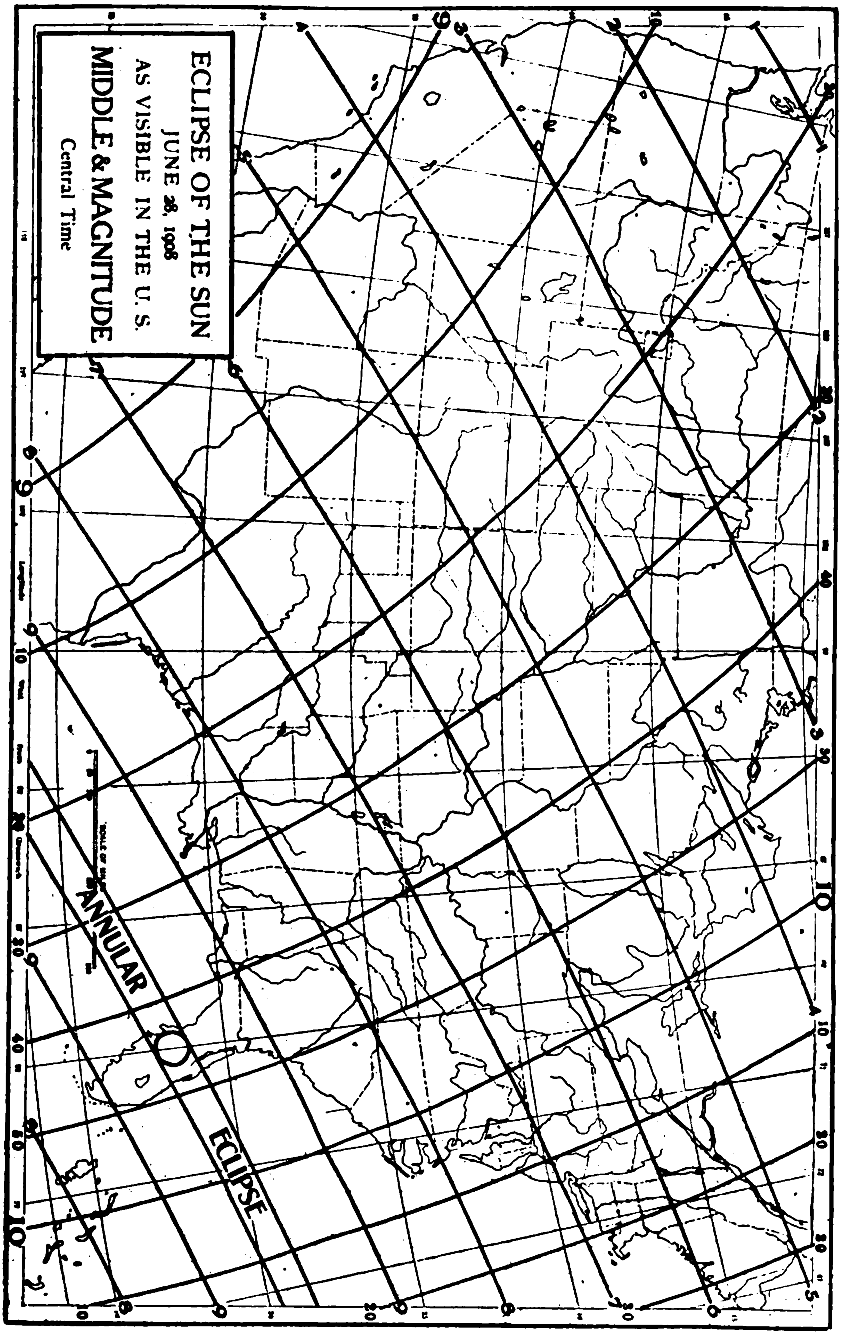

ECLIPSE OF THE SUN
JUNE 28, 1908
AS VISIBLE IN THE U. S.
MIDDLE & MAGNITUDE
Central Time
ANNULAR
ECLIPSE

FIGURE 2.

will appear as shown in the last but one drawing on Figure 3. On the central line of the annulus path, which has not been drawn on Figure 2, but which may easily be supplied by estimation, the Moon's center will be seen to pass exactly over the Sun's center, and the Sun will appear as a narrow ring of light, for which reason this is called an annular, or ring, eclipse. This is illustrated in the last drawing on Figure 3. The small ellipse on Figure 2 shows the extent of country where the annular eclipse will be seen at the same moment, the time being $9^h\ 45^m\ 0^s$.

As such an annular eclipse is quite a rare and most beautiful sight and well worth a journey of many miles to see, a very detailed map of the path of this eclipse across the narrow peninsula of Florida will be found in Figure 4. This map has been prepared at great pains from the latest and large wall map of the United States as issued by the General Land Office of the Department of the Interior, corrected to June 30, 1905. The scale of this map is 25.9 miles to an inch.

After plotting the central and border lines of the annulus path as given in the *American Ephemeris* directly on the original map, a copy of the eclipse region was made by measuring the position and length of all the necessary range and township lines down to the one-six-hundredth part of an inch, and transferring these measurements to Figure 4 under a three-fold enlargement. As the latitude and longitude lines were found to be slightly unevenly spaced on the government map, it was judged better to reproduce the eclipse region exactly as it lay, rather than introduce any personal, although justifiable, alterations.

The cities and towns were plotted with reference to the range and township lines, and these lines were allowed to remain on the map in order to serve for the insertion of smaller unmentioned places, as well as furnish a scale of measurement and orientation, although a considerable irregularity was detected among them on the government map. The broken lines connecting the towns show the Florida railroad system. After all the data to be found upon the government map had been transferred to Figure 4, the boundaries of the counties and the names of many other towns, taken mainly from Rand McNally & Co.'s New Family Atlas, 1891, and a few from the Columbian Atlas, 1898, were added in script.

The numbers 28 and 29 on the border of the map indicate the 28th and 29th parallels of north latitude, and the numbers

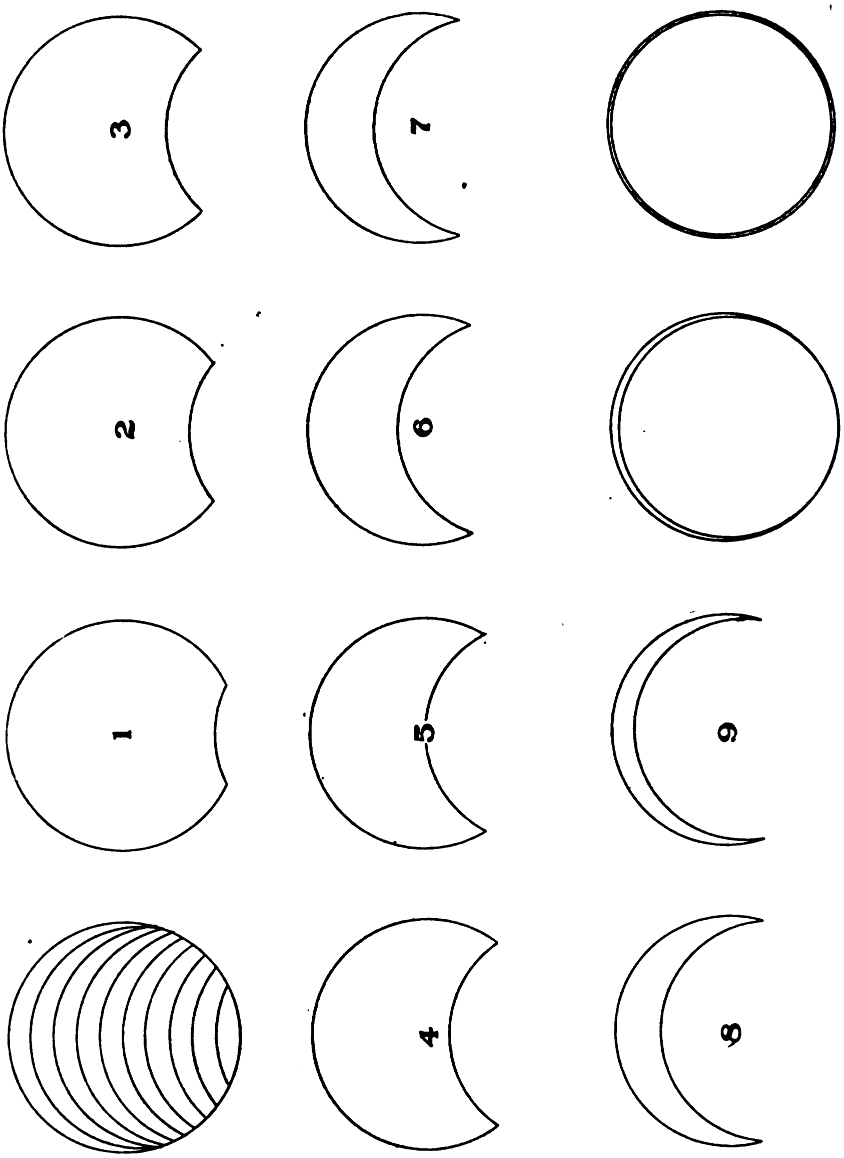
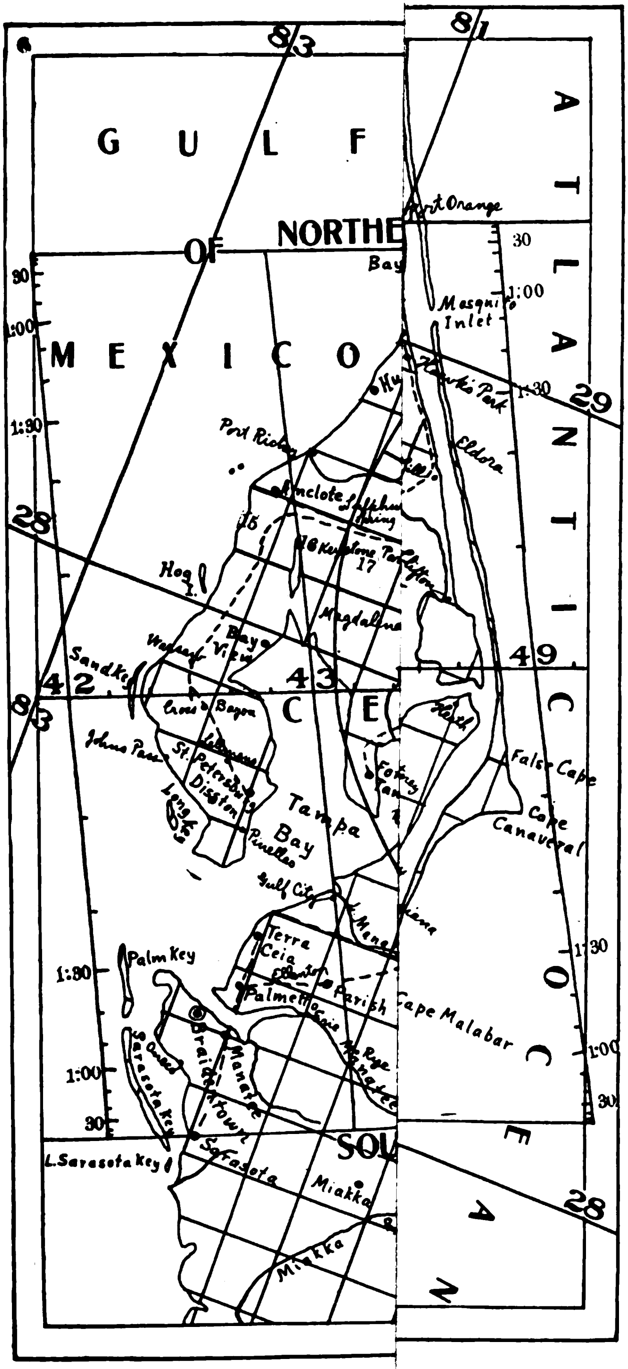


FIGURE 3. APPEARANCES OF THE SUN AS VARIOUS TENTHS OF ITS DIAMETER ARE ECLIPSED.

81, 82, 83, the corresponding meridians of longitude west of Greenwich. The line running through the middle of the map and marked 42 to 49, is the central line of the eclipse, and these numbers mean the corresponding minutes after 9 o'clock in the morning, central time, or after 10 o'clock, eastern time, when the annular eclipse will be central at these points. The other two lines parallel to the central line are the northern and southern limits of the annulus path, outside of which the eclipse will not be annular. The lines passing through the numbers on the central line and extending from one limit line to the other, are the mid-phase lines. By measuring the distance of a place from any of these mid-phase lines in a direction parallel to the central line and on the scale marked thereon, the time of the middle of the eclipse may be found to the nearest second.

The extent of the region covered by the negative shadow at 9 o'clock 45 minutes is shown by the large ellipse centered at number 45, in latitude 28° 11′.2 and longitude 81° 54′.8. The known duration of the eclipse at this place gave the diameter on the central line, and the mid-phase line gave its conjugate, which together with the angle between them furnished the major and minor axes and thus permitted of its construction. As a test of the accuracy of this computation and the preceding graphic measurement, the major axis was found to be exactly equal to the minor axis multiplied by the secant of the Sun's zenith distance, 24° 25′, and to lie within one degree of the Sun's azimuth, S 81° 10′ E. The local hour angle was found to be 26° 24′ or 1^h $45^m.6$ east, giving 10^h $14^m.4$ as the apparent solar time.

The duration of the annular phase may be found for any place by drawing a line through it and the ellipse parallel to the central line, and measuring the length of the chord on the time scale shown on the central line. But owing to the slight distortion referred to above, the varying separation of the limit lines and the consequent variation of the ellipse this method is not very reliable. To correct these errors to some extent a scale has been placed on the mid-phase lines 42, 45 and 49. The numbers 30, 1:00, 1:30, mean 30^s, 1^m 00^s, 1^m 30^s, and together with their intermediate 10 seconds' marks, indicate for places at their respective distances from the central line, the time that the annular phase will begin before and cease after the time of the middle of the eclipse, and hence give the half duration of the annular phase.



Popular Astronomy, No. 155.

In order then to find this time for any particular place, its distance from the central and limit lines ought to be measured in a direction parallel to the mid-phase lines, and the scale corrected in proportion. And finally, as another element of variation is introduced by the variable duration of the eclipse on the central line, being

3^m $49^s.0$	at	9^h	42
49.4			43
49.8			44
50.2			45
50.6			46
51.0			47
51.4			48
51.8			49

the graphic method cannot reasonably be expected to be correct within ten seconds for places very close to the border, such as Bayport and DeLand, while for places near the central line, such as Tampa and Titusville, it may probably give the nearest second or two.

In an annular eclipse the vertex of the Moon's shadow cone does not reach the Earth. When this cone is produced beyond the vertex, it forms what is termed the negative shadow, which of course is no true shadow but a part of the penumbra. The cross section of this negative shadow cone increases as it approaches the Earth and hence is smaller on the surface of the Earth than it is on the fundamental plane which passes through the Earth's center. This fact reduces the width of the Sun's annulus. In the present eclipse the Sun's semidiameter is 15′ 43″.8, and the width of the annulus 47″.0 as seen on the fundamental plane, but only 33″.7 as seen in Florida. The Sun will there appear to be a ring whose width is one-fifty-sixth of its diameter, 0.0178. It may be of interest to state that the place No. 45 on Figure 4 is the distance 0.91060 of a terrestrial radius above the fundamental plane at the time mentioned, and the vertex of the Moon's shadow 3.118 terrestrial radii above the same plane.

Finally Figure 5 gives the time of the end of the eclipse all over the United States.

The following examples may serve to illustrate the use of these eclipse maps.

Place	Time	Beginning		Position Angles		Middle		Magnitude	End	
		h	m	°	°	h	m		h	m
Washington	Eastern	9	36	N 244	V 300	11	04	0.72	12	50
Omaha	Central	8	26	N 228	V 284	9	31	0.50	11	01
Denver	Mountain	7	22	N 224	V 281	8	17	9.45	9	40
San Francisco	Pacific	6	27	N 212	V 268	7	03	0.28	8	06

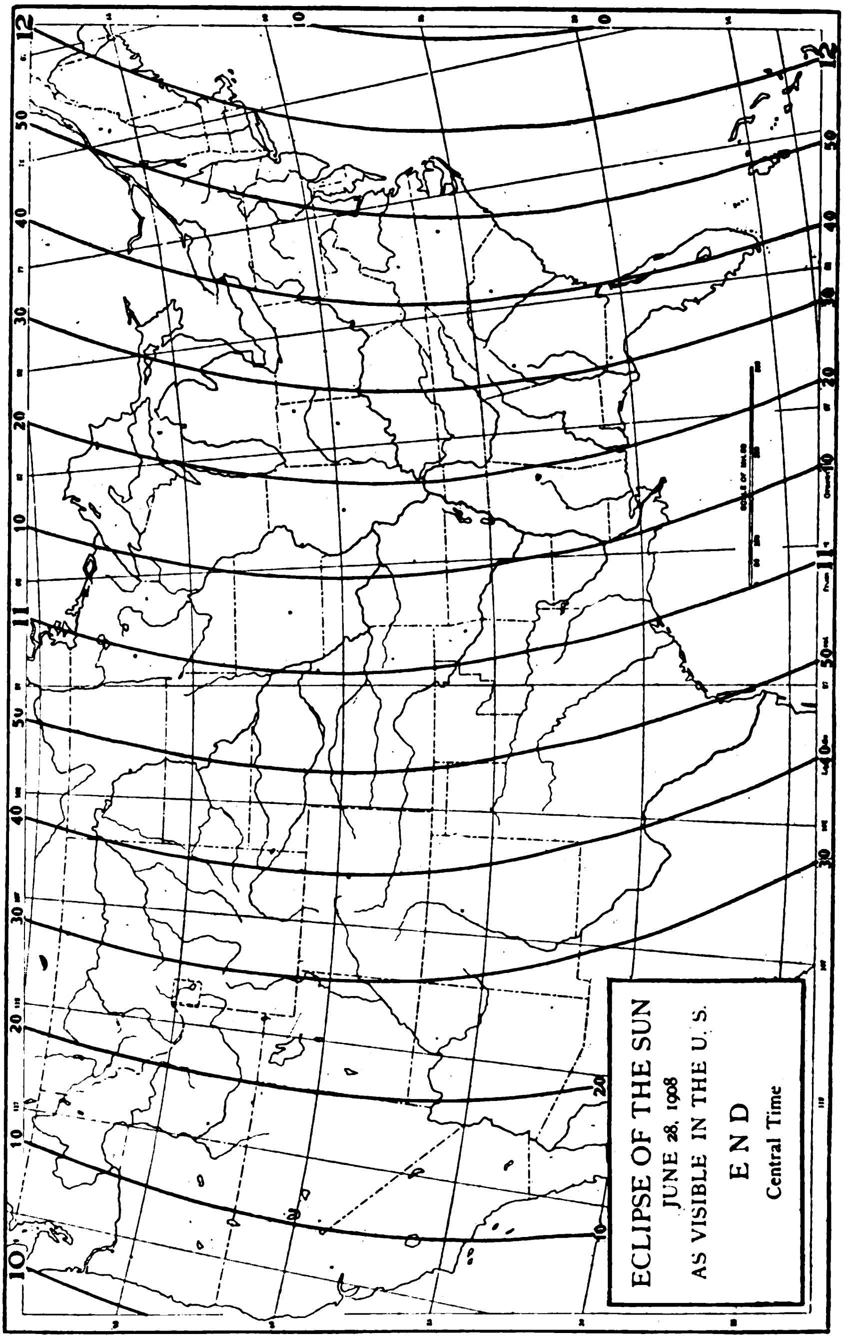

ECLIPSE OF THE SUN
JUNE 28, 1908
AS VISIBLE IN THE U. S.
END
Central Time
12
50
40
30
20
10
11
50
40
30
20
10
10

FIGURE 5

ANNULAR ECLIPSE.

Place	Beginning		Middle		End		Duration	
	m	s	m	s	m	s	m	s
Tampa	41	28	43	23	45	18	3	49
DeLand	47	20	47	43	48	06	0	46

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Omaha, Nebraska.

THE PATH OF THE SHADOW OF A PLUMMET BEAD.*

ELLEN HAYES.

The actual determination of a north-and-south line is one of the most valuable exercises for the beginner in elementary practical astronomy; and of the various methods there is perhaps none more satisfactory than that which consists in the use of shadows cast on a horizontal surface by the end of a vertical pin, or by a bead on a plumb-line. Theoretically, of course, only two shadows of equal length are necessary, but in practice it is a good plan to mark the shadow-points for a number of positions of the shadow of the bead. The curve obtained by connecting these points cannot fail to attract the observer's attention. It is evident from mere geometrical considerations that the curve will be a conic section, in general, a hyperbola. Analysis, however, has here its usual advantage over a geometrical treatment of the case, and the equation to the curve is invested with more than usual interest, since the coefficients are functions of the observer's latitude and the declination of the Sun. The equation may be obtained as follows:

From Chauvenet's *Astronomy*, Vol. 1, Sec. 14, we have the familiar formulas,

$$\cos\phi\cos\delta\cos t = \cos\zeta - \sin\phi\sin\delta \qquad (1)$$

$$\cos\phi\cos\delta\cos t = \sin\zeta\cos A + \cos\phi\sin\delta \qquad (2)$$

in which t is the Sun's hour angle, A its azimuth, ζ its zenith distance, δ its declination, and ϕ the observer's latitude. Dividing eq. (2) by eq. (1),

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* Read before Section A, American Association for the Advancement of Science, December, 1904.

$$\tan\phi = \frac{\sin\zeta\cos A + \cos\phi\sin\delta}{\cos\zeta - \sin\phi\sin\delta}. \qquad (3)$$

If h is the height of the bead above the horizontal plane, and ρ the distance of the shadow-point from the point in which the plumb-line meets the plane,

$$\frac{\rho}{h} = \tan\zeta = \frac{\sin\zeta}{\sqrt{1-\sin^2\zeta}}$$

and

$$\rho^2 - \rho^2\sin^2\zeta = h^2\sin^2\zeta;$$

hence

$$\sin\zeta = \frac{\rho}{\sqrt{h^2+\rho^2}}.$$

Only the plus sign is retained after extracting the square root because ζ is always positive.
Also,

$$\frac{\rho}{h} = \frac{\sqrt{1-\cos^2\zeta}}{\cos\zeta}$$

and hence

$$\cos\zeta = \frac{h}{\sqrt{h^2+\rho^2}}.$$

Only the plus sign is here retained because ζ is less than 90° when the Sun is above the horizon.

Substituting these values of $\sin\zeta$ and $\cos\zeta$ in eq. (3),

$$\tan\phi = \frac{\dfrac{\rho}{\sqrt{h^2+\rho^2}}\cos A + \cos\phi\sin\delta}{\dfrac{h}{\sqrt{h^2+\rho^2}} - \sin\phi\sin\delta}. \qquad (4)$$

This is a polar equation to the path of the shadow with A as the vectorial angle and ρ the radius vector. In place of A, which is measured from the south westward, we may write $\theta = -(180^\circ - A)$. The vectorial angle is then measured from the north counter-clockwise. At the same time the sign of ρ must be changed. Substituting $-\cos\theta$ for $\cos A$ and $-\rho$ for ρ, eq. (4) becomes

$$\tan\phi = \frac{\dfrac{\rho}{\sqrt{h^2+\rho^2}}\cos\theta + \cos\phi\sin\delta}{\dfrac{h}{\sqrt{h^2+\rho^2}} - \sin\phi\sin\delta} \qquad (5)$$

which is precisely what we had to begin with, so far as form is concerned. This polar equation may now be transformed to one in rectangular coördinates with the pole as origin and the north-and-south line for the x-axis, the north being taken as the positive end. Introducing the usual relations,

$$x = \rho \cos \theta, \quad y = \rho \sin \theta, \quad x^2 + y^2 = \rho^2,$$

eq. (5) becomes

$$\tan \phi = \frac{\dfrac{\sqrt{x^2+y^2}}{\sqrt{h^2+x^2+y^2}} \cdot \dfrac{x}{\sqrt{x^2+y^2}} + \cos \phi \sin \delta}{\dfrac{h}{\sqrt{h^2+x^2+y^2}} - \sin \phi \sin \delta}$$

or

$$\frac{h \tan \phi}{\sqrt{h^2+x^2+y^2}} - \tan \phi \sin \phi \sin \delta = \frac{x}{\sqrt{h^2+x^2+y^2}} + \cos \phi \sin \delta$$

i. e.,

$$\begin{aligned} \frac{h \tan \phi - x}{\sqrt{h^2+x^2+y^2}} &= \cos \phi \sin \delta + \frac{\sin^2 \phi}{\cos \phi} \sin \delta \\ &= \sin \delta \sec \phi. \end{aligned}$$

From which we obtain

$$h^2 \tan^2 \phi - 2h \tan \phi \, x + x^2 = (h^2 + x^2 + y^2) \sin^2 \delta \sec^2 \phi \, ,$$

or,

$$\begin{aligned} (1 - \sin^2 \delta \sec^2 \phi) \, x^2 - \sin^2 \delta \sec^2 \phi \, y^2 - 2h \tan \phi \, x \\ + h^2 \tan^2 \phi - h^2 \sin^2 \delta \sec^2 \phi = 0. \end{aligned}$$

The absolute term readily reduces to

$$\frac{h^2}{\cos^2 \phi} \sin (\phi + \delta) \sin (\phi - \delta),$$

so that finally we have

$$\begin{aligned} (1 - \sin^2 \delta \sec^2 \phi) \, x^2 - \sin^2 \delta \sec^2 \phi \, y^2 - 2h \tan \phi \, x \\ + \frac{h^2}{\cos^2 \phi} \sin (\phi + \delta) \sin (\phi - \delta) = 0 \qquad (6) \end{aligned}$$

In discussing this equation it is only necessary to consider the northern hemisphere.

Since the coefficient of y^2 is always minus, three cases arise, according as the coefficient of x^2 is +, 0, —; that is, according as

$$\sin^2 \delta \sec^2 \phi < = > 1.$$

When

$$\sin^2 \delta \sec \phi = 1,$$

the coefficient of x^2 vanishes and the curve is a parabola. This condition may be stated:

$$\sin \delta = \cos \phi; \text{ i. e., } \phi = 90^\circ - \delta.$$

The maximum value of δ being ϵ, the obliquity of the ecliptic, the lowest latitude in which the curve can be a parabola is that of the arctic circle and it is a parabola on that circle only at the time of the summer solstice. The parabola travels northward at the same rate that the Sun's declination decreases. Behind it, that is, for plumb-lines in more southern latitudes, follow hyperbolas; and ahead of it, to the north, the curves are ellipses. For, if $\phi < 90^\circ - \delta$, $\cos\phi > \sin\delta$, and hence $1 > \sin^2\delta\sec^2\phi$, and consequently the coefficients of x^2 and y^2 have unlike signs. On the other hand, if $\phi > 90^\circ - \delta$, $1 < \sin^2\delta\sec^2\phi$, and the coefficients have like signs. Hence, in the "land of the midnight Sun" so long as the plumb-line is in a latitude greater than the complement of the Sun's declination, the path of the shadow of the bead is an ellipse, becoming a circle at the pole. These conclusions may also be reached by observing that lines parallel to the asymptotes of the hyperbola are

$$(1 - \sin^2\delta\sec^2\phi)\,x^2 - \sin^2\delta\sec^2\phi\,y^2 = 0$$

or,

$$y = \pm\frac{\sqrt{1 - \sin^2\delta\sec^2\phi}}{\sin\delta\sec\phi}\,x \tag{7}$$

hence,

$$\frac{b}{a} = \frac{\sqrt{1 - \sin^2\delta\sec^2\phi}}{\sin\delta\sec\phi}$$

and

$$e = \sqrt{\frac{a^2 + b^2}{a^2}} = \frac{1}{\sin\delta\sec\phi} = \frac{\cos\phi}{\sin\delta}, \tag{8}$$

that is, the eccentricity varies directly as the cosine of the latitude and inversely as the sine of the declination;

and $\quad e > = < 1 \quad$ according as $\quad \phi < = > (90^\circ - \delta)$.

If we write the equation in the form

$$x^2 - \frac{\sin^2\delta\sec^2\phi}{1 - \sin^2\delta\sec^2\phi}\,y^2 - \frac{2h\tan\phi}{1 - \sin^2\delta\sec^2\phi}\,x$$
$$+ \frac{h^2}{\cos^2\phi}\;\frac{\sin(\phi + \delta)\sin(\phi - \delta)}{1 - \sin^2\delta\sec^2\phi} = 0,$$

and make $\phi = 90^\circ$, the coefficients of y^2 and x take the form $\frac{\infty}{\infty}$ and the absolute term contains the expression, $0.\infty$. Evaluating these indeterminate forms in the usual manner, the equation becomes

$$x^2 + y^2 - h^2\cot^2\delta = 0 \tag{9}$$

that is, the radius of the circle is $h \cot \delta$, as evidently it ought to be when we remember that at the north pole the Sun's altitude equals its declination.

On the equator $\phi = 0°$, and the equation reduces to

$$(1 - \sin^2 \delta)\, x^2 - \sin^2 \delta\, y^2 - h^2 \sin^2 \delta = 0;$$

or,

$$x^2 - \tan^2 \delta\, y^2 - h^2 \tan^2 \delta = 0 \qquad . \qquad (10)$$

and the center of the hyperbola is now directly underneath the plumb-bob. Also, the asymptotes are

$$y = \pm \cot \delta \; x\,;$$

that is, the asymptotes make with the east-and-west line an angle equal to the declination of the Sun. The sunrise and sunset shadows of course coincide with these asymptotes.

At the equinoxes $\delta = 0$, and the equation becomes for all latitudes,

$$x^2 - 2h \tan \phi \; x + h^2 \tan^2 \phi = 0.$$

Hence, the shadow-path consists of two coincident straight lines

$$x - h \tan \phi = 0 \qquad (11)$$

that is, an east-and-west line distant $h \tan \phi$ from the point where the plumb-line meets the plane, and on the north side of that point. It follows that on March 21 and September 23 *any* two points, say two forenoon points, will enable us to draw an east-and-west line.

This degenerate form of the generic hyperbola must be regarded as the fundamental one since it is also the path of the shadow of the bead if the *mean* Sun could shine on it. This fictitious mean-sun shadow is thus seen to be a straight line not merely at the equinoxes but on all days of the year, with its position depending only on the latitude of the plumb-line and, of course, on the height of the bead above the plane.

If $\phi = \delta$ the absolute term of the equation vanishes. Hence, when the Sun's declination equals the latitude of any place within the torrid zone the curve for that day passes through the origin, and the noon shadow is merely the projection of the bead on the horizontal plane. This agrees with the obvious geometrical requirements of the case.

Thus far no distinction has been made between summer and winter. It may now be noticed that only the *squares* of the declination factor appear in the coefficients of the equation. As a consequence, the days of the year go in pairs. That is, if on any day of the year between the vernal equinox and the following autumnal equinox the Sun's declination is δ', we have for any latitude, ϕ', a hyperbola of definite eccentricity and transverse axis, and for the winter day when the Sun's declination is $-\delta'$ the hyperbola is precisely the same as regards dimensions and position. But we know experimentally that the meridian shadow of a gnomon of given height is longer in winter than in summer. We are thus led to the conclusion that the south branch of the hyperbola is the actual shadow-path when the Sun's declination is δ', and the north branch the path when the declination is $-\delta'$.

Making $y = 0$ in eq. (6) and solving for x we have the meridian values of x, namely:

$$x_1 = \frac{h \tan \phi}{1 - \sin^2 \delta \sec^2 \phi} \pm \frac{h}{1 - \sin^2 \delta \sec^2 \phi} \sqrt{\tan^4 \phi - (\cos^2 \delta \tan^2 \phi - \sin^2 \delta)(1 - \sin^2 \delta \sec^2 \phi)}$$

The expression beneath the radical sign reduces to $\sec^4 \phi \cos^2 \delta \sin^2 \delta$, hence

$$x_1 = \frac{h}{1 - \sin^2 \delta \sec^2 \phi} (\tan \phi \pm \sec^2 \phi \cos \delta \sin \delta \qquad (12)$$

These values of x_1 are the two intercepts on the meridian axis. One-half their sum,

$$\frac{h \tan \phi}{1 - \sin^2 \delta \sec^2 \phi}$$

is the distance of the center of the hyperbola from the origin. Since the x corresponding to an actual shadow must have the greater value when δ is negative, the plus sign in eq. (12) is rejected for both summer and winter, and we have simply

$$x_1 = \frac{h}{1 - \sin^2 \delta \sec^2 \phi} (\tan \phi - \sec^2 \phi \cos \delta \sin \delta) \qquad (13)$$

This conclusion is verified by noticing that for ζ_1, the Sun's meridian zenith distance,

$$\frac{x_1}{h} = \tan \zeta_1 ;$$

and that for summer time

$$\phi = \zeta + \delta$$

while for winter time

$$\phi = \zeta - \delta;$$

that is, for summer time

$$x = h \tan(\phi - \delta)$$

and for winter time

$$x = h \tan(\phi + \delta).$$

We can now compare these differently derived values of x by writing

$$\tan(\phi - \delta) = \frac{\tan\phi - \sec^2\phi \cos\delta \sin\delta}{1 - \sin^2\delta \sec^2\phi}$$

being positive. An identity results from this statement and the assumption of equality is therefore justified. If we suppose δ negative we have a second identity.

If $\tan\phi < \sec^2\phi \cos\delta \sin\delta,$

x_1 is negative and the shadow falls on the south side of the plumb-line. This condition readily reduces to

$$\sin 2\phi < \sin 2\delta; \quad \text{that is,} \quad \phi < \delta.$$

This is only possible south of the tropic of cancer, during the summer time. The same result may be reached by noting the intercepts on the east-and-west axis.

Making $x = 0$ in eq. (6),

$$y = \pm \frac{h}{\sin\delta} \sqrt{\sin(\phi + \delta)\sin\phi - \delta};$$

hence, if $\phi < \delta$, y is imaginary, and the shadow-path must lie wholly on the south side of the east-and-west axis.

If we introduce into eq. (6) the condition, $\delta = 90° - \phi$, we have

$$y^2 + 2h \tan\phi\, x + h^2(1 - \tan^2\phi) = 0.$$

The parabola is seen to be convex northward, since the intercepts on the east-and-west axis are real, $1 - \tan^2\phi$ being now a negative quantity. Also, the distance from the origin to the vertex of the curve is

$$\frac{h(1 - \tan^2\phi)}{2\tan\phi}.$$

This result may be obtained independently by observing that the meridian altitude of the Sun is 2δ if $\delta = 90° - \phi$; and hence

$$\frac{h}{x^1} = \tan 2\delta; \quad \text{or,} \quad x_1 = \frac{h}{\tan 2\delta} = \frac{h(1 - \tan^2\phi)}{2\tan\phi}.$$

If $\delta = -(90^\circ - \phi)$, the Sun appears only on the horizon due south. In this case, eq. (6), on account of its form, fails to reveal the character of the parabola, but if the given condition be introduced into eq. (13),

$$x_1 = \frac{h}{0}\,[\tan\phi - \sec^2\phi\cos(\phi - 90^\circ)\sin(\phi - 90^\circ)]$$

$$= \frac{2h\tan\phi}{0} = \infty.$$

In other words, when the Sun is seen only on the horizon due south, the shadow of the bead, that is, the vertex of the parabola, is infinitely distant.

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SOME OF THE RESULTS OF ASTRONOMICAL PHOTOGRAPHY PERTAINING SPECIALLY TO THE WORK WITH A PORTRAIT LENS.*

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In the present paper I wish to offer a few specimens of astronomical photographs which have been made with portrait lenses. These pictures, which are from my own work, are fair samples of what can be done with this class of lens. They have been selected to show the variety and extent of the work, which covers the Milky Way, the nebulæ, the larger star clusters, meteors, comets, the earthlit and the totally eclipsed Moon, etc. Most of the pictures were made with the 10-inch Brashear lens of the Bruce telescope of the Yerkes Observatory.

THE ADVANTAGES OF PHOTOGRAPHY IN ASTRONOMY.

Before the application of photography to the study of the heavens, one saw the sky but poorly indeed, and in the light of the revelations of the photographic plate today, one is almost tempted to say that he did not see the heavens at all, so vastly has photography enlightened us as to the actual appearance of the sky and its citizens.

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There are two causes that have helped to produce this wonderful power that photography has given us. First, above all, the great sensitiveness of the photographic plate over that of the human eye. Second, the fact that our plates show us a vastly larger space of the heavens than the visual telescope does—in some cases a thousand times greater than is shown by our most powerful telescopes of today. A wide field of view is of the utmost importance in the study of the tails of comets, of the larger nebulæ and of the cloud forms and structure of the Milky Way, for these in general are very large. The field of view of a visual telescope, which is at most but a mere speck of the sky, is entirely too small to take in the whole of such an object. In the case of the Milky Way, the structural details are on such a grand scale that their true forms could not even be guessed at with the ordinary telescope. The importance, therefore, of the large field that the photographic plate gives us is very evident.

But there is one thing which we must take into account. The time element enters strongly into the photographic part. One may look into a telescope and he will see at once, if the conditions are favorable, the faint star or faint nebula he has in the field of view—it is but a moment that the eye takes to fix the image before it. Perhaps some very faint and difficult object may require a little longer, but it is only because a special moment of steadiness is waited for. The photographic telescope with its highly sensitive plate will not catch the object in that same time. It may require an hour or more before it "sees" it. But with the eye there is no cumulative effect; on the contrary, indeed, it soon becomes tired, so that in a sense, the longer you look the less you see, merely from the fatigue of the eye. With the plate there is no fatigue. The longer it looks the more it sees, so, though it may take it an hour to see what the eye readily perceives in a moment, it does not stop at that point but goes on seeing more yet, the longer it looks. In this way it soon registers things that the eye cannot perceive at all with equal optical means, and in many cases it reveals objects—especially among the nebulæ—that the eye may never see in the actual sky. And, what is of immense advantage, it permanently records what it sees, so that the exact appearance of a nebula may be preserved for future reference perhaps hundreds of years hence, while the view obtained by the eye is as evanescent as the fleeting glimpse of the object itself. Even though the observer should make a careful drawing it is too often worthless, and misleading, for reference with other drawings, made later on; for the astronomer is seldom or never an artist.

If one examines drawings of the same celestial object by different observers, he is often struck with the want of agreement in these pictures. There are a few of the more prominent nebulæ such as the celebrated ones of Orion and Andromeda, which have been drawn by many observers. There is a strange want of resemblance among these pictures, and what is worse still there is often but little resemblance to the object itself. There was always the possible excuse that the object had actually changed its appearance in the sky. Photography, however, in the past twenty years has shown that such appreciable changes have not really occurred, though they must occur in the course of time.

The best illustration of this want of harmony in different delineations of the same astronomical subject is shown in the large number of drawings of the solar corona made by numerous observers at the total eclipse of the Sun in 1878 which were collected and published by the United States government. No two of the forty odd drawings closely resembled each other and few of them looked at all like the indifferent photographs obtained at the time. Indeed these drawings and other similar ones led an eminent astronomer four years later to declare that the corona was not a real phenomenon belonging to the Sun, but that it was partly a diffraction effect and partly in the eye of the observer, so that each observer, as it were, saw a different phenomenon—an idea that no one would think of holding today when photography has long since clearly demonstrated the solar origin of the corona.

The real cause of these various discrepancies lay mainly in the want of artistic skill in the observer, who saw the things all right but was unable to draw them correctly, especially was this so in the case of an eclipse of the Sun, where the excitement of the moment was enough to unnerve most observers.

Perhaps the greatest sufferer from this want of pictorial skill was the occasional comet. These bodies are really subject to remarkable and rapid changes and hence a misrepresentation was all the more unfortunate. In the case of the nebulæ one could simply throw out the poor representations as being due to lack of skill. In the case of the comet no one can tell whether the want of agreement in the various drawings was not due to actual changes in the comet itself. Happily today, the lack of artistic skill in the individual plays almost no part in astronomical work. The photographic plate, not only with an accuracy far beyond that of the most skillful artist but with an eye almost infinitely more sensitive, sees the faintest details of a comet or a nebula and records them with a faithfulness unheard of before.

Today the sensitive plate is not only taking the place of the astronomical draughtsman, but it is also running the most skillful measurer a close race. The facility and ease with which great numbers of star places can be measured on the photographic plate, commend it to the most exacting astronomer.

Photography has materially altered our ideas of the nebular theory. From the views of the nebulæ with telescopes not sufficiently powerful to properly deal with them, and hence with views that were more or less erroneous, a theory was elaborated that appealed to the popular mind with a wonderful fascination. There is much that must be changed in this theory to meet the rigid requirements of modern science and to satisfy the demands of what has been revealed in the forms of the nebulæ by the photographic plate.

It is in dealing with the nebulæ that astronomical photography has attained one of its most remarkable triumphs. These bodies in reality shine with a light that has comparatively little effect on the human eye but to which the photographic plate is singularly sensitive. To our eyes the nebulæ are seen "through a glass darkly," as it were, while to the eye of the sensitive plate they are more or less brilliant objects.

Our old ideas of the dimensions of these vast bodies have also been greatly changed. In the days of purely visual astronomy, the great nebula of Orion, covering as it does some half a degree of the sky, was looked upon as inconceivably great in actual extent in space—yet photography has not only increased its extent very greatly, but it has revealed other nebulæ, unknown to us before, that are hundreds of times vaster than this great nebula of Orion. The Pleiades are in the midst of a mighty system of nebulosity that covers at least one hundred square degrees of the sky, and whose actual extent in space almost defies calculation.

Four or five degrees north of the star Antares, in the Scorpion, is a faint star just fairly visible to the naked eye.

This is known as Rho Ophiuchi. If one examines the space about this star with a telescope he sees nothing remarkable except that there are fewer small stars in this region—yet photography shows us that the sky here is covered by an enormous and magnificent nebula which apparently lies in a hole in the sky. From this great vacant region—vacant in the sense of there being few or no stars in it—narrow dark lanes run eastward for many degrees. But the singular thing is that the nebula seems in some way to be responsible for the absence of stars at this point. Whether this is due to the obscuration of the light of the small stars, that ought to be here, by the nebula, which would in that case prove it to be nearer to us than the stars, or whether the presence of the nebula has in some way destroyed or dispersed the stars cannot be told.

Perhaps the most extraordinary revelations of photography in astronomy have been in the case of comets. These wonderful objects with their vast trains sweeping through space are singularly subject to disturbances by other celestial bodies. The photographic plate has shown us that the comets utterly transform themselves in a few hours' time, for, though of vast dimensions, they are in reality but flimsy affairs with little or no solidity. In these changes, so faithfully recorded by photography, they sometimes, through the distortions of their trains, reveal the presence of some kind of resisting medium or of some unknown bodies through whose attraction, or by collision with which their tails are twisted, broken or deformed in the most extraordinary manner. This was the case with one of the comets of 1893 where photographs on successive nights show the tail disrupted and broken, undoubtedly by such an encounter. What this really means we have yet to learn. Possibly the comet passed through a dense swarm of meteoric bodies in its flight around the Sun. Photographs of another comet showed the tail entirely separated from the head and drifting away in space. From these last pictures it was shown that the particles forming the tail were leaving the comet with a velocity of twenty-nine miles a second.

IMPORTANCE OF THE PORTRAIT LENS.

The strangest thing in connection with these statements is that the greater portion of these photographic revelations have been made with instruments that are extremely crude in comparison with the elaborate and expensive telescopes with which our great observatories are equipped today. Indeed in many cases the lenses were not made for the purpose to which they have been put. It was only incidentally that their services came to be of benefit to astronomy. I have often thought of the strange difference in the present use of these lenses and the one for which they were originally made. Though it would be hardly fair to attribute their origin to the purpose of human vanity, it was certainly vanity that had much to do with it, for these large lenses were made purely for the taking of portraits. In the days of the wet plate process the slowness of the sensitive agent used in the plates made it necessary to employ very large lenses so as to collect a greater quantity of light, and thus to shorten the time of the sittings. Their use has therefore not fallen to a lower level in this change but has risen to a much higher one —from the picturing of human vanity in the human face to the picturing of the sublime features of the face of the heavens. Their great light grasping power is no longer needed for the enlightenment of human vanity—not that that evil has in any way become extinct—but from the fact that with the extremely rapid dry plates of today the work can be done with very much smaller and less expensive lenses.

DESCRIPTION OF PLATES.

Nebulæ and Nebulosities.

For an example of nebular photography with a portrait lens perhaps one of the best specimens is that of Plate I* (exposure 4 hours), which shows the "North America Nebula." Though this plate does not represent all that is visible on the original negative, it yet shows how beautiful the nebula is, and how appropriate was Dr. Max Wolf's naming of it. The nebula is not a faint object with a telescope—indeed it was discovered over a hundred years ago by Sir William Herschel. It is not, however, suited for visual observations. With a small telescope one sees only a diffusion of feeble light which has no definite form or limits. It is, nevertheless, excellently and specially adapted for photographic representation because of the peculiarity of its light, which is very rich in photographic qualities. A long exposure, however, is required to show the fainter outlying masses of nebulosity which are clearly shown in the present picture. This photograph was made with the 10-inch Bruce portrait lens of the Yerkes Ob-

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* This plate has been omitted because it is too large for insertion in Popular Astronomy.

servatory in the splendid atmosphere of Mount Wilson, California, where the writer had taken it in 1905, through the courtesy of Professor Hale, for the photographing of the Milky Way.

This picture exemplifies in a striking manner a peculiarity which is often found in connection with these large nebulosities and to which I have frequently called attention. That is the apparently free mixture of stars and nebulosity without any evidence of condensation of the nebulosity about the stars. I do not think this is necessarily a case of accidental projection of the stars and nebulosity, for there are numerous similar cases in the sky. In the present case one can trace out a similarity of configuration of the outlines of the nebula and the massing of the stars, which would strengthen the idea that they are at the same distance from us. This fine object is in the Milky Way a short distance east of Alpha Cygni, which star is shown at the western edge of the plate.

A good example of the fainter and more difficult nebulosities is shown in Plate XVII, the nebulous region of Gamma Cygni (exposure 6 hours 30 minutes). These nebulosities are not visible with the telescope because of their exceeding faintness. Their full extent is not shown in the photograph, for they extend considerably beyond the limits of the plate. It will be seen that Gamma Cygni, the star in the middle of the picture, is in a region of diffused nebulous matter which extends over a large area and is gathered in masses of greater brightness at different points, but is in general formless and diffused.

The lower picture of Plate XVII is a still finer example of the photographic nebulosities—*i.e.*, nebulosities that are too faint to be seen with the telescope and for the knowledge of which we are dependent on the photographic plate. This is the magnificent region of the great nebula of Rho Ophiuchi (exposure 4 hours 30 minutes). Unfortunately the reproduction is a failure, for much of the nebulosity and the great vacancies connected with it, that are so wonderfully shown in the original, are all but lost in this half-tone.

I think there is no other region in the entire sky so remarkable as this of which Rho Ophiuchi appears to be the center. The great nebula itself, which seems to cover almost this entire region with its extensions, and its association with the extraordinary star vacancy here are very puzzling, and lead one to believe that the apparent paucity of small stars at this point is due in some way to the presence of the nebula.

PLATE XV.

N

Double Cluster of Perseus
1904 September 15

N

Two Meteor Trails, and Star Cloud in Scutum
1904 April 20

Photographed with the Bruce telescope, Yerkes Observatory

PLATE XVI.

N

Meteor Trail
1899 June 7

N

Brooks' Comet and Meteor
1893 November 13

Photographed at the Yerkes and Lick Observatories

The great dark lane or rift running to the east, extends as far as the region of Theta Ophiuchi and seems to be a part of the system of vacancies that occur to the east and south of Theta.

The great nebula is full of remarkable details. There are a number of principal condensations, that of Rho Ophiuchi being perhaps the most striking. The nebula extends to, and involves, the bright naked-eye star Sigma Scorpii in a strong condensation full of details. In several wave-like masses it involves and reaches beyond Antares, one of the brightest stars in the sky. It seems to faintly cover a great part of the sky here, extending so far north, perhaps, as to connect with the remarkable nebula about Nu Scorpii. There are traces of it extending as far south as Tau Scorpii.

Perhaps as remarkable as any thing in connection with this nebula is the fact that it is so faint that the eye, armed with the most powerful telescope, cannot see it. Its light seems to be almost entirely photographic, and though too faint to be seen in the telescope it is doubtless very bright to the photographic plate.

At the lower part of this plate, a half inch to the left of the small cluster (M 4), is apparently an ordinary star. This is the bright red star Antares which is the brightest in this region of the sky, but which, from its red color, appears quite small and insignificant on the photograph. A half inch above the cluster is the star Sigma Scorpii which is much less than Antares. Sigma Scorpii is the center of a bright condensation of the nebulosity which in the original is seen to connect with the larger nebulosity (in the middle of the plate) about the star Rho Ophiuchi. The dark lanes running from the nebula east, though strong and conspicuous in the original, are nearly lost in the reproduction.

The first picture in Plate XV is a photograph of the region of the double cluster of Perseus (exposure 5 hours 55 minutes), which gives a good idea of the gradual massing of the stars from a region of uniform distribution into two clusters whose stars are brighter than the average of that part of the sky.

Meteors.

The unpredicted appearance of the occasional meteor, the suddenness with which it appears and the rapidity of its flight across the sky, make it impossible to locate its path with exactness by eye observations alone; though observers skilled in this class of work can secure a close approximation to the path. If two such observers are separated by several miles, a fair idea may be obtained of the distance of the meteor and of its actual path through our atmosphere. In general, however, there is always much uncertainty attached to [illegible] results. What one really sees is a more or less bright point of light darting suddenly across the sky—the duration of whose flight seldom exceeds one second of time and the image of which vanishes from the brain almost as soon as it is formed. It may well be imagined how difficult is the exact location of the path of this fleeting point among the stars. If the meteor could have left a line of light on the sky along the full extent of its course for a few minutes, then one could locate its position fairly with respect to the stars, and yet this would still have considerable uncertainty attached to it from the fact that at best only an estimate (and no measures) could be made with the naked eye of the position.

In photographing the sky with wide angle lenses it is not an uncommon thing for a meteor to take its flight across the region which is being photographed. In this case when it is bright enough, the meteor actually does leave a permanent path among the stars; for the moving point of light affects the sensitive plate, continuously, marking out thus a "trail" among the star images, which is permanent and whose position can be measured with very great accuracy.

If a second camera, some distance from the first one, is also photographing the same part of the sky the meteor trail will be recorded by both cameras and its displacement on the two plates as photographed from these two points on the Earth, can be determined accurately and the distance and path of the meteor will become known. Such an instance occurred at the Yerkes Observatory where the same meteor was photographed with two cameras (by Mr. Frank Sullivan and the writer) separated by 400 feet only. The parallax or displacement of the trail among the stars was clearly shown. Measures of these two plates show that the meteor was about 90 miles above the Earth's surface.

In Plates XV and XVI are given specimens of meteor photographs selected from a great number of such plates. The lower photograph of Plate XV (region of M 11, exposure 2 hours 40 minutes), shows the trails of two meteors which were nearly in a straight line, so that, at first thought, one would suppose it was the trail of one meteor which had been

PLATE XVII.

N

Nebulous Region of Gamma Cygni
1905 August 28

N

Nebulous Region of Rho Ophiuchi
1905 April 5

Photographed with the Bruce telescope, Yerkes Observatory

PLATE XVIII.

N

Giacobini's Comet
1905 December 29

N

Giacobini's Comet
1906 January 5

Photographed with the Bruce telescope, Yerkes Observatory

interrupted near the middle of its flight. Both meteors were moving toward the south, it is assumed (for they were not seen by the observer), and were undoubtedly Lyrids—having a radiant in the constellation of Lyra.

Plate XVI (α 17 hours 20 minutes, δ south 15°; exposure 1 hour 34 minutes) shows in the first case the full flight of a meteor which evidently exploded near the end of its path, as indicated by that portion of the train which is of greater brightness. The lower photograph shows a great meteor trail and Brook's comet, IV, 1893 (exposure 2 hours 5 minutes). The bright trail was caused by a very large meteor which was seen by the observer. It was moving toward the south-east and exploded just off the edge of the plate. By one who is regularly photographing the sky with these rapid lenses, meteors are thus frequently caught in their flight.

Comets.

Plate XVIII shows two views of Giacobini's comet (c 1905). The first of these (December 29, exposure 1 hour 38 minutes) is the most interesting because of the peculiar form of the tail of the comet. The edges of the tail are convex and sharply defined, and they taper to a narrow neck where they join the head, which is quite large. The tail was doubtless a hollow cone. There is a narrow hazy strip running from the lower or south edge of the tail near the middle of the plate. In the original this can be traced across the edge of the tail onto the tail itself. On the next night December 30, all this definiteness of form had disappeared and the tail was very wide and diffused.

The lower plate (exposure 1 hour) is very interesting, but the main features of the tail are lost in the reproduction. Both photographs have suffered greatly in making the half-tones.

The Lunar Surface under Various Kinds of Light.

Plate XIX shows two photographs of the Moon. The size of the lunar image on photographs with a portrait lens (a half inch in diameter with the 10-inch telescope) is too small to be of any importance in the study of its crater and mountain-scarred surface. Such photographs, ordinarily, are, therefore, not worth the making. But there are conditions under which the Moon may be photographed to advantage with these lenses—not for a study of the craters and mountains however. The first of these pictures (enlarged) shows the new Moon with the slender sunlit crescent embracing the dark or night part, where no direct sunlight reaches the surface, or in other words it is the "old Moon in the new Moon's arms," which sometimes forms such a beautiful picture in the western sky at the vanishing of twilight when the Moon is but a few days old. With the exception of the bright crescent, what we see is the lunar night, but it is a full "Moon" night, for the illumination is entirely by sunlight reflected from the surface of the Earth onto the night side of the Moon. At that time if one were placed on this night part he would have seen the Earth shining in the night sky like a great round Moon (nearly full) some thirteen times bigger than the Moon ever appears to us. The distinctness with which the lunar surface is shown in the photograph (with only 20 seconds' exposure) gives an idea of how brilliant the full Earth must be when shining in the lunar night. This picture was made for comparison with the full Moon and with the totally eclipsed Moon, for the surface is then shown under three different kinds of illumination, *i. e.*, direct sunlight (full Moon), reflected sunlight (Earth lit Moon), and refracted sunlight (totally eclipsed Moon) to see if any difference could be detected in the appearance of the surface as affected by these various illuminations. Portrait lenses are specially suited for this purpose.

The second picture of this plate is a photograph of the totally eclipsed Moon (exposure 9 minutes) in which the only illumination is due to the sunlight refracted through the Earth's atmosphere and bent into the shadow of the Earth onto the Moon. One of the reasons for making this picture was a hope that if any small body should be attending the Moon in its journey around the Earth (a small satellite for instance) it might be outside the shadow at the time, and being thus illuminated by the Sun, would show on the photograph. The Moon itself is ordinarily so bright that it would drown out the light of any faint body that might attend it.

Both the photographs of Plate XIX are essentially ruined in the reproduction.

LIST OF LANTERN SLIDES.

This paper, when read, was illustrated by a number of lantern slides of the various photographs. A list of these is given below for completeness. I have arranged the slides in the order of subjects.

I. *The Earth-lit and the Totally Eclipsed Moon.*

Slide 1.—The new Moon showing the lunar night, illuminated by the "full Earth."

Slide 2.—This is the totally eclipsed Moon illuminated only by refracted sunlight coming through the dense atmosphere near the Earth's surface.

II. *The Milky Way, Star Clusters and Nebulæ.*

Slide 4.—The great star clouds of Sagittarius, east of the Scorpion.

Slide 5.—The double cluster of Perseus.

Slide 6.—The nebulous region of Gamma Cygni.

Slide 7.—The "North America Nebula" in Cygnus.

Slide 8.—The nebulous region of Rho Ophiuchi.

Slide 9.—The nebulosities of the Pleiades. This shows well the remarkable thread-like strips of nebulosity, especially the one from Electra and the one near and parallel to it. The extent of the nebulosities is greater than usually shown in photographs of the cluster. The original negative shows the exterior nebulosities surrounding the cluster. Exposure 3 hours 40 minutes.

III. *Meteors.*

Slide 10.—This shows two large meteors which followed nearly the same path across the plate.

Slide 11.—This shows the full flight of a large meteor on 1899, June 7.

Slide 12.—These two pictures are of the same meteor, but with two cameras 400 feet apart. The small scale picture was made by Mr. Frank Sullivan with 3.4-inch portrait lens attached to the 40-inch telescope during Professor Frost's spectroscopic observations. The other was made with the 6-inch lens of the Bruce photographic doublet. An inspection of the trail with respect to stars near which the meteor passed shows a decided parallax. The distance of the meteor above the Earth's surface, from these two pictures, was about 90 miles.

IV. *Comets.*

Slide 13.—Swift's comet on 1892, April 7, showing a large mass and separate system of tails which were going out from the comet.

Slide 14.—Giacobini's comet, 1905, December 29. The picture shows the remarkable appearance of the tail, which on this date was quite unlike the tail of any other comet.

Slide 15.—Borrelly's comet on 1903, July 24. The second photograph on this slide was made by Mr. R. J. Wallace. The interval between the two pictures is 3 hours. The tail which was separated from the comet, had receded noticeably in three hours. Measures of the plates showed that the particles forming the tail were moving away from the comet at the rate of 29 miles a second. (See *Astrophysical Journal*, October, 1903.)

V. *Vacant Regions and Holes in the Heavens.*

Slide 16.—This is a remarkable region of .vacancies in a great nebulous background in the constellation of Taurus (See *Astrophysical Journal* for 1907, April.)

Slide 18.—Vacant lanes running from the nebulous region of Rho Ophiuchi towards the east.

Slide 19.—Great vacant regions about the star Theta Ophiuchi, (See *Popular Astronomy*, No. 140.)

Yerkes Observatory, 1907.

FAITH AND THE FOURTH DIMENSION.*

HAROLD JACOBY,

Rutherfurd Professor of Astronomy.

Why should the astronomer come into this chapel of St. Paul to fill a few minutes out of your busy day with his spoken thought? Paul himself asks the question: "Doeth he it by the works of the law or by the hearing of faith?" What is the astronomer's answer to that question? Does he depend on the law alone?

There is a difficulty through which many young men pass, through which especially the ablest young men must often pass: it is the difficulty of holding fast to the faith. Can this great body of spiritual truth be real? The young man turns in his doubt to the realm of science, where stern logic holds sway, where dwell the truths that seem to admit of complete logical proof. But the whole range of science contains nothing more firmly founded on irrefragible reasoning than the simple

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* Address delivered in St. Paul's Chapel, Columbia University, New York, at one of the daily services, March 9th, 1908.

propositions of elementary geometry. Perceptible dimly in the remotest haze of intellectual antiquity; codified first by the Greek; conned by the Arab in the days of Harun-al-Rashid; pondered in the cloistered cell of the monk of Spain; important product of the far-famed early press of Venice; advancing unchallenged through more than twenty centuries of the darkness, and of the twilight, and of the dawn:—Euclid, geometer of geometers, ὁ στοιχειωτής, maker of the very elements, where stands he now?

In the year 1830, Nikolai Lobachevsky, son of a Russian peasant, put forth his epoch-marking proof that the well-known propositions of elementary geometry are not necessarily true, that Euclid's demonstrations are not in accord with the extreme requirements of rigid logic. For instance, you all remember the well-known theorem of elementary geometry concerning the sum of three angles of a triangle. Lobachevsky built up and published a complete system of geometry in which this proposition does not occur, and in which this proposition is not true.

If we accept the principles of inductive science there is but one way to test the truth or falsity of this theorem of the angles. It is necessary to experiment, to make actual measurements upon an actual triangle. But real measurements can never be accurate absolutely. They all depend ultimately upon fallible human senses and more or less defective instruments made by fallible human hands. Slight errors of observation always occur; these render results uncertain; it is possible to prove by observation that the angle theorem is very nearly true, but not that it is *true*. It may even be that the divergence from truth might show itself in an increasing degree if it were possible to execute our measurements upon very large triangles. Even astronomy is limited to measurements made from the Earth: possibly, if we could go forth into the profound depths of space; if we could bridge the distance by which we are sundered from the stars; if we might even pass beyond the confines of the visible sky and push our mighty triangle to the very fringe of the invisible universe:—possibly then, and then only, could we make evident the truth.

Now this idea of Lobachevsky involves a revision of our notions concerning space: his idea can hold only in a space different from that we have inherited from Euclid. Lobachevsky's is space of four dimensions. For my present purpose it is not necessary to explain in detail or to understand fully the mysterious fourth dimension. Regard it, if you will, as a mere figment of mathematical imagination: the fact remains that science today knows not, and cannot ascertain without impossible experimentation, whether Euclidean geometry is a truth.

But we all believe our geometry; none credit as real the half-ridiculous phenomena of an imaginary fourth dimension. Astronomers study the skies; physicists theorize in their laboratories; all believe in ordinary common-sense geometry. Therefore is it possible for science, like religion, to believe something not logically proven.

Science today has attained only to the portal of knowledge: when her forces shall have stormed the citadel, when she shall stand upon the deepest foundation stone of truth attainable by man, she will find, surely, that stone bedded upon some kind of faith, some belief outside the domain of rigid logic.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

Part III. (Continued.)

The Nature of the Solar Radiations and their Relation to Terrestrial Magnetism and Other Meteorological Phenomena.

FOR POPULAR ASTRONOMY.

Experimental determinations of what is called the "solar constant," which is the quantity of heat radiated, in unit time, from unit surface of the Sun, and received, in the same time, upon unit surface at the Earth, have been made, in the quite recent past, by several skillful and eminent physicists—Pouillet, in France; Langley in the United States, and others—one of the latest results in this line of investigation being that announced by the distinguished German astrophysicist, Scheiner, in his book treating of solar radiation and the temperature of the Sun, published at Leipzig in 1899, A. D.

According to Dr. Scheiner, the quantity of heat, measured in thermal units, (the unit here taken being the pound-degree Fahrenheit; i.e., one pound of water raised through one degree of the Fahrenheit scale) received, per second, upon one square foot placed at a right-angle to the solar rays, just outside the Earth's atmospheric envelope, is between one-fifth and one-quarter of a unit, the corresponding values of the radiation from one square foot at the Sun's surface being equal to the product of the aforesaid quantities by 46,200 which is the square of the mean distance of the Sun from the Earth, measured in terms of the radius of the solar globe, which radius is taken as 1, the resulting limiting values of the "rate of radiation" at the Sun's surface being, therefore, 9,240 *TU* and 10,780 *TU* respectively.

The former of these two values is in closer agreement with other determinations than is the latter, it being not far from a "mean" of all the most reliable measurements, and it will, therefore, be taken, in this connection, as representing, with all needful accuracy, the actual mean thermal radiation, per second, from one square foot of the Sun's surface, the difference between this and the several other determinations being largely due, simply, to variance between the estimates of the percentage of terrestrial atmospheric absorption of the solar thermal radiations.

The quantity of heat generated by the perfect combustion of one pound of *carbon* is, approximately, 14,500 thermal units, so that the heat-energy radiated, per second, from one square foot of the solar surface matter is equivalent to that developed by the complete combustion of nearly three-fifths of a pound, avoirdupois, of the best coal, in the same time, and as there are nearly 66 quintillions of square feet in the whole surface of the Sun, it follows that, *if each and every square-foot of said surface radiates the same quantity of heat*, the total thermal emission from the Sun is equal to that which would result from the perfect combustion of 20 quadrillions of tons of coal, per second, and the question as to the source of supply, and the final disposition, of so enormous a quantity of thermal-energy has long been—as it now is—a most interesting one, much mooted among physicists and others who have studied solar phenomena.

The great German physicist, Helmholtz, about 50 years ago, was probably the first one to definitely assign, as the source of supply of this enormous quantity of thermal radiation, the slow contraction of the gaseous mass which constitutes the Sun, and working upon the assumption that the solar matter is of *uniform density* throughout its volume, and undergoing condensation *from infinite distance* under the action of its inherent force of gravity, he demonstrated that a contraction amounting to only one ten-thousandth part of the diameter of the Sun would suffice to generate as much heat as would, at the present rate of radiation, be emitted by that body in 2,100 years, the rate of contraction of the solar diameter being, in this case, about 4.1 miles in one hundred years; but more recent determinations, based upon Helmholtz's principle, and employing later and more accurate values of the "rate of radiation," give nearly 9¼ miles, per century, or 16 inches per day, as the rate of contraction requisite for the maintenance of the present output of solar heat.

According to the principles of my theory, in this connection —as set forth in the February number of POPULAR ASTRONOMY —the contraction of the Sun's volume, under the action of gravity, whereby the solar heat has been generated and is maintained, is considered as a case of gaseous compression governed by certain laws of "thermodynamics," and as beginning when the radius of the volume of the condensing nebulous mass was so extended that the gaseous matter was in equilibrium, as to density, pressure and temperature, with the luminiferous ether, which condition involves compression from only a *finite and comparatively small distance*, and not as a contraction from *infinite distance* as under the concept of Helmholtz above stated, yet, notwithstanding this, and other, material differences between the concepts of the two theories in this connection, the present rate of contraction of the Sun's diameter, according to my determination is 9.28 miles, per century, a value substantially identical with that derived, as above stated, from the most recent investigation founded upon the aforesaid "principle" of Helmholtz—a remarkable coincidence which is not at all *fortuitous*, it being due to a certain relation between the density and pressure of the ether, the centripetal force of gravity, and the antagonistic centrifugal force of radiation one consequence whereof is what has been termed the "pressure of light"—all of which relations are rigorously explicable by my theory of radiation and of the constitution of the transmitting medium, the ether.

The aforesaid deductions from the experimentally determined value of the *solar constant*, are all based upon the postulate that the thermal emissivity of the solar surface matter is the same over the whole area of the Sun, which is the idea generally held: but there is no positive proof whatever, that each, and every, square foot of the Sun's surface is emitting thermal radiations uniformly at the rate indicated by the pyrheliometrically determined value of the *solar constant*, while there are certain facts of observation that lead directly to an opposite conclusion.

I shall now endeavor to demonstrate that, under the concepts of my theory as to the constitution of the transmitting medium which is known as the "luminiferous ether," and of the *modus operandi* in the propagation of radiant energy thereby, *the "rate of radiation" of the Sun's heat is variable with respect to heliographic latitude and longitude*, and that the area of maximum thermal emission is continually shifting relatively to these coördinates, and I shall adduce testimony, based upon well-observed phenomena of solar physics, in behalf of my claim that the planetary bodies of the solar system, which are continually changing their positions relative to any given heliographic latitude and longitude, are the prime—if not the sole—factors operating in the causation of certain peculiar and variable phenomena frequently observed upon the visible portion of the Sun's surface. To physicists, the assertion that any material surface cannot radiate heat and experience a consequent fall of temperature unless there be another material surface, or matter, at a lower temperature, somewhere in the lines of propagation, or the "rays," to serve as a receiver, or "absorber" of the energy radiated (which is equivalent to a statement that the matter of the transmitting medium, itself, cannot act as such an "absorber") may seem a *bold* one and not susceptible of verification, or one even negatived by terrestrial experience in respect to "radiation" because we have no experience of a body, heated above the temperature of its surroundings, retaining, absolutely unimpaired, its temperature unless an adequate supply of heat be furnished it from some source of thermal energy.

But it should be noted that, in all cases of radiation upon the Earth, each radiating surface is surrounded by material surfaces that serve as absorbers of the emitted radiance, and that not even the resources of the best equipped laboratory, in the hands of the most skilful experimenter, can remove the radiating body from this hampering environment, and it is only when from the vantage ground of the astronomical and astrophysical observatory, the actions and reactions continually in operation upon the surface of the Sun, that greatest of laboratories, viewed from the standpoint of either the chemist or the physicist are observed, and subjected to analysis, that the true state of the case, in this connection, is revealed. The Sun, completely enveloped by the matter of the all-pervading luminiferous ether which is well-nigh infinitely extended, is continually sending, in straight lines, through this medium, its thermal, and other, radiations outward into space even to the distance of the most remote star, these radiations being propagated with the velocity of light and with an intensity decreasing as the square of the distance from the solar surface, but the only portion of this enormous output of thermal energy from the Sun, of which we have actual cognizance, is the *modicum* of heat received upon one-half the Earth's surface, as measured by the portion falling upon the very small area of a pyrheliometric instrument.

The fixed stars, numerous and large as they are, lie at such enormous distances from the Sun that their absorptive effect upon solar radiation may be regarded as practically *nil*, and moreover, their surface temperatures are quite as high as—if not greater than—that of the Sun, so that according to the "principle of exchanges," each returns an equivalent thermal radiation to the latter body, the thermal emissivity thereof being consequently unaffected, in any sensible degree, by the stars, so that we may reasonably conclude that it is only the matter of the solar system—planetary and other—which is at an adequately lower surface temperature and sufficiently proximate to the solar globe, that can act as absorbers of the Sun's radiations, and it will now be demonstrated that the only significant factors, in this regard, are the Earth and the other seven known planets.

According to my hypothesis in this connection, solar thermal radiation can be emitted uniformly at the known rate indicated by the *solar constant*, only when the sum of what may be termed the "effective areas" of the planets, reduced to the solar surface, is equivalent to said surface, such a combination of areas presented normally to the rays of the Sun, and therefore parallel to the surface of that body being comparable to the concave surface of a spherical shell contiguous to, and completely enveloping, the solar globe, and acting as an absorber of the thermal energy emitted from the surface of the Sun; but if—as is the case—the sum of the *effective areas* is *less* than the whole surface of the Sun, the actual thermal radiation will be likewise *less* than that which would be emitted from the whole surface, its measure being the ratio between the total *effective area* and the total solar surface.

The whole area of the Earth relative to that of the Sun is, obviously, proportional to the square of the ratio between the mean diameters of these two bodies and as this diameter of the Earth is 7912.4 miles and that of the Sun 864,340 miles the ratio is $\frac{7912.4}{864,340} = 0,009154$ the square of which, or the number 0.0000838, is the area of the whole surface of the Earth relative to that of the Sun. But the solar heat that falls upon any planetary body is emitted from only one-half the Sun's surface and is received, in unit time, by only one hemisphere of the planet, and for these two reasons, alone, the *effective area* is only one-fourth of that just stated; moreover, the radiations leaving the Sun do not all come to the Earth, in parallel lines, from a surface normal to the rays, but are inclined at divers angles, those emitted near the Sun's limb, obviously, passing through a greater thickness of solar atmosphere, or absorbing vapors, than those emitted from the central portions of the solar disk, by reason of which fact the *effective area* is further reduced by one-third, so that one-sixth of the relative geometric area aforesaid,—which is 0.0000840—represents the real *effective area* of solar radiation, in so far as the Earth alone is considered, and this will be designated by E its value being 0.0000140 of the whole area of the Sun. The value of E for any other planet is determinable through the equation; $E = 0.0000140\left(\frac{\rho}{a}\right)^2$; in which ρ represents the mean diameter of the planet, relative to that of the Earth, and a the relative mean-distance from the Sun, in terms of the Earth's mean distance which is taken as 1, and through this equation I have derived the values of E for the eight known planets of the solar system, which are set forth in the following table:

TABLE A

Planet	Mean Diameter (Miles)	ρ	α	E	Percentage of ΣE
Mercury	3,000	0.3791	0.39	0.0000132	11.
Venus	7,500	0.9483	0.72	0.0000242	20
Earth	7,912	1.0000	1.00	0.0000140	11.½
Mars	5,000	0.6407	1.52	0.0000025	2
Jupiter	81,500	10.3031	5.20	0.0000549	45
Saturn	71,000	8.9732	9.54	0.0000124	9¾
Uranus	29,900	3.7789	19.18	0.0000005	0.½
Neptune	37,200	4.7025	30.07	0.0000003	0.¼
			Σ	0.0001220	100

The *effective area* of the Sun, with respect to thermal radiation, is equal to the whole geometric area which contains 6543×10^{16} square feet multiplied by the factor ΣE, which is 0.0001220, as set forth in Table A, the product being 7983×10^{12} square feet, and since the rate of radiation at the Sun's surface, experimentally determined as above stated, is 9,240 thermal units per square foot, per second, the whole mean *effective* radiation from the Sun is 7376×10^{16} thermal units, per second, or only the $\frac{1}{8200}$th part of that which would be emitted were the emissivity of all parts of the solar surface the same, which is the commonly held view.

The aforesaid quantity of thermal energy radiated by the Sun, per second, is that which would be developed by the complete combustion of $2\frac{2}{5}$ trillions of tons of the best coal in the same time, instead of 20 quadrillions of tons which is the quantity in the case of *equal* radiation from the whole surface of the Sun, and, therefore, all quantities similarly dependent upon the value of the solar area, that have been heretofore deduced under the commonly accepted hypothesis in this connection, should be reduced to the 8,200th part of the values generally given by writers on this subject, if my hypothesis be true—and I have reason to claim that it is, but even these greatly reduced quantities are so enormous that they almost surpass ordinary comprehension.

In the preceding part of this paper, in the March number of POPULAR ASTRONOMY, (pp. 157-159), I pointed out the fact that under the conditions of my theory in this connection the volume of the Sun is yet undergoing a heat-generating compression caused by the force of gravity, and that the compressive process will continue until the density of the solar mass will have risen from its present value, 1.4 to 2.66 which is, approximately, the density of the surface matter of the Earth, after which time gaseous compression and the consequent generation of heat will end, the Sun then entering upon an extremely prolonged course of persistent decadence, as to temperature, which will cause that body to cease its function as the dispenser of radiant-energy, and which will ultimately reduce it to much the same conditions, as to temperature density, etc., as those now prevalent in the case of the Earth. I also demonstrated therein that, under these conditions, the contraction of the Sun's volume will continue until its diameter is reduced to 0.8074 of its present length which is 864,340 miles and, therefore, this contraction will be through a distance of 166,480 miles, the maximum internal absolute temperature of the solar matter increasing during the process, from its present value of roundly, 13,400 degrees Fahrenheit to 15,800 degrees, and its corresponding surface, or *effective* radiating, temperature from 6,700 degrees to 7,900 degrees, the increase of 2,400 degrees in the internal temperature representing only one-third of the whole augmentation that would result if the compression were adiabatic, or under the condition that no heat were radiated, or otherwise abstracted from the condensing mass during the progress of the compressive action. The heat thus lost during the process is two-thirds of all that generated by the compression, the temperature-loss (Te) being, therefore, 4,800 degrees, and the whole quantity of heat (Tu) lost by the solar mass during the process of compression from the present density 1.4 up to 2.66, is determinable through the equation; $Tu = W.\ s.\ Tu$; in which W represents the weight of the Sun, which is 4351×10^{27} pounds, avoirdupois, the specific-heat (s) of the solar mass being 0.20 and the temperature-loss (Te), as aforesaid, 4,800 degrees, the value of Tu being therefore 4177×10^{30} thermal-units. It is obvious that the number of years required for the completion of this process of compression, and the attainment of the maximum temperature of the Sun, were the rate to remain constant at its present value during the process, must be equal to $\frac{Tu}{Q}$, the denominator Q representing the quantity of heat radiated, per annum, at the present rate of thermal emission, its value being determinable through the equation; $Q = t.'' E.A.R$; in which t'' represents the number of seconds in a year of 365¼ days; A the *whole* area of the Sun, which is 6543×10^{16} square-feet; E the coefficient 0.0001220 for the reduction to the "effective area" as set forth in Table A, and R the present "rate of radiation," per square foot, per second, as deduced from the experimentally determined value of the *solar constant*, its value being as stated on a preceding page, 9,240. thermal units, the value of Q as determined through the equation last set forth being, therefore, 2328×10^{24} thermal units.

A division of the above stated value of Tu by this value of Q, gives as the result 1,794,500 which represents the number of years that must elapse before the Sun reaches the epoch of greatest compression and temperature, and since the contraction of the solar diameter, in that time, is through a distance of 166,480 miles the present rate of contraction is 9¼ miles per century or sixteen inches per day which is just equal to this rate as derived from the "principle of Helmholtz," aforesaid.

The latter value has been derived under the *assumption* that the contraction of the solar volume has been from *infinite distance*, an assumption that may be regarded as not well founded, because, if the volume of the Sun be expanded to *infinity*, the density of the solar mass would fall correspondingly below the density of the luminiferous ether that fills all known space, which density fixes the limit of all gaseous expansion, according to a fundamental concept of my theory, the limiting density or that of the ether, being, according to my determination, $\frac{1}{1926 \times 10^{13}}$ (as stated in the February number of POPULAR ASTRONOMY) when referred to the normal density of the atmospheric gases, which I have taken as the standard in this case because, according to a fundamental concept of my theory, the nebulous matter whence the solar mass has been derived, and also the matter of the luminiferous ether is *gaseous*. Furthermore, Helmholtz *assumed* that radiation takes place uniformly from all portions of the Sun's surface, while my concept is that it is emitted from only the 8,200th part of the whole surface or, rather, in a quantity that is equivalent to the maximum radiation from that portion of the geometric area of the Sun. The rate of contraction if the former assumption were the correct one would be 8,200 times the value 9¼ miles, per century, which I have derived, and which is identical with that resulting from the application of "Helmholtz principle" under his assumptions, but at so great a rate the whole contraction, through 83,240 miles of the *radius* of the solar globe, would be completed in only 210 years, which is manifestly an utterly inadequate period in view of known facts derived from observation of the phenomena of solar physics. The agreement, aforesaid, between the two values of the rate of contraction—that of Helmholtz and the one that I have obtained, analytically, from the principles of my theory—resulting as it does from the peculiar physical relations stated in a preceding paragraph, constitutes strong proof of the truth of my hypothesis as to the "effective area," (*E*) of solar radiation as a function of the relative planetary areas reduced to the Sun's surface, and also of my fundamental concept of the density of the luminiferous ether, relative to the normal density of atmospheric air, as marking the limit of expansion in the case of all gaseous matter, and as the initial density at which the gaseous nebulæ are developed from the matter of said ether the absolute temperature whereof is the fundamental temperature whence, by gaseous compression in the case of the primitive solar nebula, the present temperature of the Sun has been evolved.

During this process the *effective*, radiating temperature of the Sun's surface will be increased, as aforesaid, by 1,200 degrees and this augmentation will, obviously, have the effect of increasing the rate of radiation and, therefore, the rate of contraction of the solar volume so that the time required for the completion of the whole process and the attainment of the maximum temperature, will be *less* than 1,794,500 years, which would be the length of the period were solar radiation to progress uniformly at the present rate. By means of an algebraic expression for the "law of radiation" that I have analytically derived from the principle of my theory and which holds good for very high as well as very low temperature, of a radiating surface, I have found that the increase of surface temperature aforesaid will reduce the period required for the completion of the process of compression to—*roundly*—1,080,000 years, during which time the intensities of all the solar radiations, thermal, luminous and electrical will be increased to 164 times their present values, the terrestial magnetic force being augmented by the same ratio, as will also be all atmospheric disturbances, electrical and mechanical, that are due to solar action upon the tenuous matter of the upper atmosphere and productive of what are called "storms."

In fact, under the conditions of my hypothesis in this connection, the increase of the *effective* surface-temperature of the Sun which is now 6,700 Fahrenheit, *absolute*,(about the temperature of the voltaic arc), or at the point where dissociation of the component atoms of the spherical molecules of the atmospheric gases, and the disruption of these molecules—productive of electrical action—begins, may not appear in the form of *heat*, the increase of energy due to the rise of the temperature aforesaid, being expended in *electrical and mechanical work*, upon the atmosphere, in which case there may be no sensible increase in the value of the *solar constant*, such a condition being the cause of the *constancy*. The aforesaid conclusion to which my theory inevitably leads is, of course, directly opposed to the view now held by many physicists who, basing their opinion upon the fact that the solar radiation is so enormous, regard the sun as a *waning* star whereas, under my hypothesis, all its energies are *waxing* and will continue to do so for not less than one million years from the present time. After the epoch of maximum compression and temperature, the solar energies will *begin to wane*, but, as determined through my formula for the "rate of radiation," a further period of 720 millions of years must elapse before they fall back to their present intensities, after which an additional but lesser time will be required to bring them to a point so low that the Earth will be rendered uninhabitable; so that we may reasonably conclude that there will be no *permanent loss* of solar energy, capable of seriously affecting the welfare of mankind, for, roundly, two million years to come. When we consider the fact that the history of the human race—taking it in the widest sense — is all included within a period of, probably, 10,000 years, and that the solar radiations upon which the welfare, and even the very existence of that race depend, will not be disastrously impaired (at least by reason of *fall* of solar temperature) for 200 times the length of that period, we may reasonably regard our globe as only entering upon an epoch wherein the physical conditions will be well adapted to the existence of the human race—at least in so far as these conditions are dependent upon the solar energies radiated to the Earth.

Finally, in this connection, it is demonstrable, through my algebraic expression for the "law of radiation," that after the epoch of maximum compression and temperature and the return of the present conditions of solar radiation, a vastly longer period, amounting to 6¼ quadrillions of years, must elapse before the Sun finally cools to the present temperature of the Earth and becomes a "dark star" of which, according to a very modern astrophysical concept there are some wandering through the depth of space like "derelicts," on the ocean, occasionally colliding with other stellar bodies, in which case a portion of the kinetic energy due to their motion, thus arrested, is converted into heat sufficient to render them again self-luminous—or even to restore them to their primitive gaseous condition—any such body appearing then as a Nova, or new star.

If we consider the absorptive effect due to any one planet—

the Earth for instance—upon thermal radiation from the visible hemisphere of the Sun, under the condition of my theory that it is only to the planetary matter that such radiation can be emitted in sensible quantity, it is obvious that the area of maximum radiation, or of *greatest cooling*, will be that corresponding to the projection of the planet's *effective* area upon the solar disk. When the Earth is in the plane of the solar equator, i. e.,—at the nodes of this plane with the ecliptic,—this projected area will be central upon the disk, and from this focal area the rate of thermal radiation will decrease, on all sides, down to the limb of the Sun, instead of being uniformly constant over the whole visible hemisphere of that luminary. Under this condition it is obvious that, for each planet, there are two limiting *heliographic latitudes*,—one north and the other south of the solar equator,—between which this projection of the effective area, or the region of greatest radiation and consequent cooling, must be situate, and these limiting latitudes (l') are determinable in the following manner. Taking 7° 06′ as the inclination of the solar equator, to the ecliptic, and 74° 18′ as the heliocentric longitude of the ascending-node of the former plane, upon the latter, and also the like inclinations and longitudes of nodes, of the seven other planets, relative to the ecliptic, and reducing all to the solar equator as the *fundamental plane*, by means of the well-known formulæ of Spherical Astronomy for such reduction, I have obtained the values of the inclination (i') and of the heliocentric longitude (Ω') of the ascending-node, set forth in Table B, the limiting heliographic latitudes (l') between which the projections of the effective planetary areas and, therefore, of the regions of *greatest cooling* are to be found, being determined through the following equation, $l' = a \cos i' \tan i'$; in which a represents the mean distance of each planet, from the Sun, relative to the Earth's mean-distance therefrom, the values of a being taken from Table A, and those of l' being set forth in the following table:

TABLE B

Planet	Ω'	i'	l'	Earth at 90° from Nodes				
	°	°	°					
Mercury	97.6	13.0	5.0	March	28	and	September	30
Venus	96.9	8.6	6.1	"	27	"	October	1
Earth	74.3	7.1	7.1	"	5	"	September	7
Mars	83.8	8.5	12.8	"	14	"	"	18
Jupiter	244.3	7.4	33.8	February	23	"	August	28
Saturn	237.9	8.4	54.3	"	17	"	"	21
Uranus	79.9	7.3	67.7	March	10	"	September	13
Neptune	241.4	6.1	72.3	February	20	"	August	25

The theoretical results which I have thus derived and tabulated, as above, are, to say the least, *very suggestive* concerning some of the most remarkable, interesting and important phenomena of solar physics and I think that the concordance between my theoretical results and those of observation which is disclosed, cannot be attributed to any chance combination of figures—there are too many factors in the problem to admit of such a contingency. Under this theory, heat is of course, regarded as radiating, in some degree, from all parts of the Sun's surface, the internal matter, which is at an absolute temperature of 13,400 degrees Fahrenheit, according to my determination, rising upward to the surface as glowing (but relatively weakly-luminous,) gases which there part with a portion of their heat and fall to a temperature of 6,700 degrees which is the effective, radiating surface temperature and that at which highly heated carbon-vapor would be, by loss of heat, transformed into finely-divided, *incandescent solid* particles such as those of which the Sun's *photosphere* is most probably composed and which furnish the continuous part of the solar spectrum. The density of this cooler surface matter must be *double* that at which it was when in its more highly heated state, because the absolute temperature of the matter has been decreased, after reaching the surface, to *one-half* that which it possessed when in the interior of the solar globe, and becoming thus heavier, it must sink gradually, and in some cases fall rapidly back to the interior whence it arose in its hotter and lighter state, the whole process being one of *convection* due to difference of temperature and density between the internal and the surface matter, as it must be because, as is well-known, the "thermal conductivity" of gases is very low, and it is to these ascending convection-currents of highly heated but *weakly-luminous* gases, and to the descending streams of heavier and cooler but *highly incandescent* matter, that the "prominences," "jets", "spots," filaments and faculæ and the generally mottled appearance of the solar disk are due.

St. Paul, Minn.

To be continued.

PLATE XIX.

N

Earth-lit New Moon
1907 February 14

N

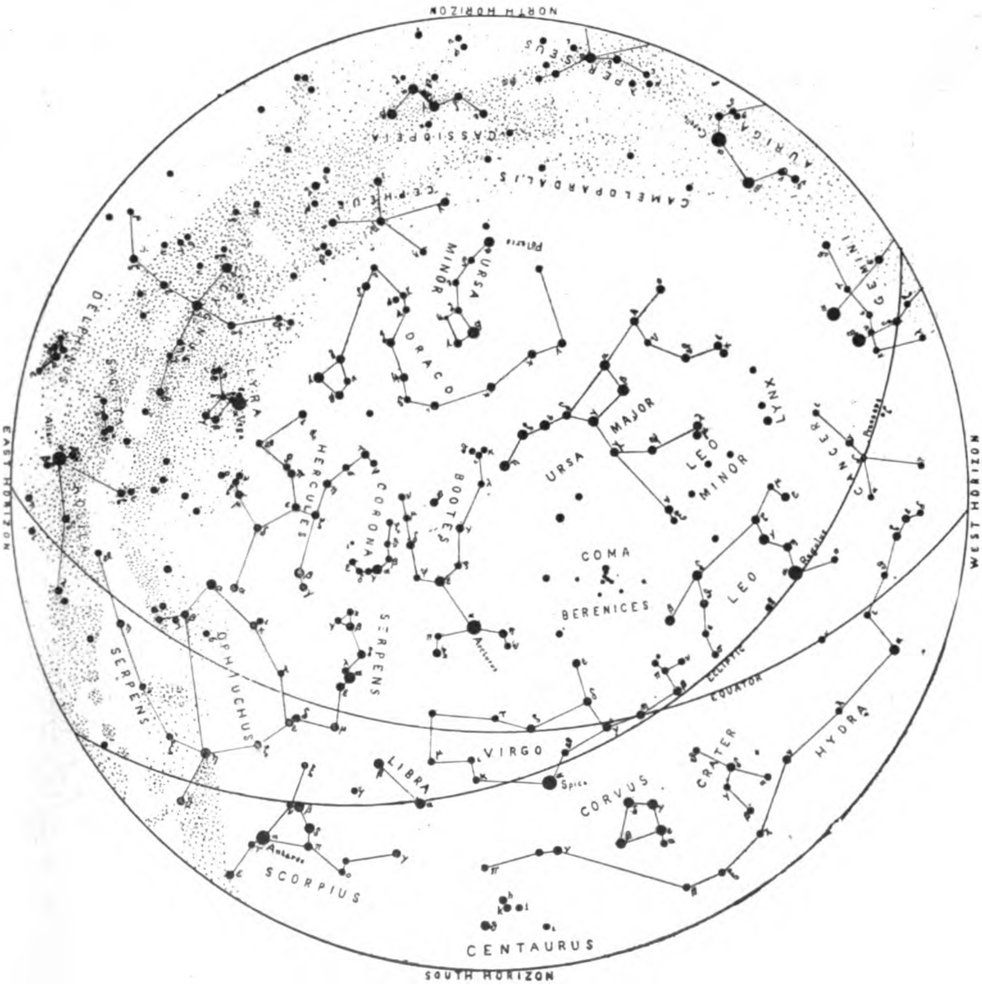
Total Eclipse of the Moon
1906 February 8

Photographed with the Bruce telescope, Yerkes Observatory

PLANET NOTES FOR JUNE 1908.

H. C. WILSON.

Mercury will be at greatest elongation, east from the Sun 24° on the evening of June 7, and will be visible as evening star for a few days about that time. Its brilliancy, however, will be low at that time, so that it will not be very conspicuous to the naked eye. Mercury will be in conjunction with Mars on June 7 at 10 a. m., and with Neptune on June 10 at 10 p. m., Central Standard Time. At the former date Mercury will be only 19′, or about two-thirds of the Moon's apparent diameter, north of Mars



THE CONSTELLATIONS AT 9:00 P. M., JUNE 1, 1908.

and on the latter Mercury will be 1° 37′ north of Neptune. Mercury will again be in conjunction with Neptune on June 30 at 10 p. m., being then 3° 17′ south of Neptune.

Venus begins the month as a very brilliant star in the west in the evening, but is now moving rapidly in between the Earth and Sun and so turning more and more of her dark side toward us. Her brilliancy will thus diminish in the ratio of 184 to 15 during the month, aside from the effect of the twilight glare. She will be at inferior conjunction on July 5. The phase of Venus is now crescent, diminishing from 0.25 on June 1 to 0.01 on June 30.

Mars will be in conjunction with Venus June 22 at 2 p. m., but Mars will then be on the farther side of his orbit from the Earth while Venus will be on the nearer side of hers so that the contrast between the two will be extreme.

Mars will be in conjunction with Neptune on June 12 at 4 a. m., Mars being then 1° 53′ north of Neptune.

Jupiter is past its best position for this year but is still brilliant in the western sky in the early evening.

Saturn is to be observed in the morning, toward the southeast, coming to quadrature, 90° west from the Sun July 1.

Uranus is nearing opposition, and may be studied after midnight on any clear night. It is in the constellation Sagittarius.

Neptune is too close to the Sun for observation in June.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T. h	m	Angle f'm N. °	EMERSION. Washington M.T. h	m	Angle f'm N °	Duration. h	m
June 9	80 Virginis	5.6	10	59	113	12	12	304	1	13
11	o^2 Libræ	6.2	13	46	116	14	52	277	1	06
13	Bradley 2162	6.3	7	48	54	8	25	346	0	37
14	Bradley 2276	5.2	9	11	72	10	11	314	1	00
15	B A.C. 6576	6.1	9	00	119	9	59	254	0	59
15	χ Sagittarii	5.5	14	04	55	15	14	291	1	10
16	Piazzi xx, 146	6.2	13	51	61	15	07	274	1	16

Phenomena of Jupiter's Satellites.

Central Standard Time, beginning at noon.

	h	m			
June 2	7	32	I	Tr.	In.
	8	03	IV	Oc.	Dis.
	8	38	I	Sh.	In.
	9	25	III	Oc.	Dis.
	9	53	I	Tr.	Eg.
3	8	12	I	Ec.	Re.
4	7	56	II	Sh.	Eg.
6	7	34	III	Sh.	Eg.
9	8	18	IV	Oc.	Dis.
11	7	21	I	Sh.	Eg.
	7	38	II	Sh.	In
	8	33	II	Tr.	Eg.
June 13	7	39	III	Tr.	Eg.
	7	51	III	Sh.	In.
17	8	49	I	Oc.	Dis.
18	8	21	II	Tr.	Eg.
	8	24	II	Tr.	In.
	9	16	I	Sh.	Eg.
20	7	31	II	Ec.	Re.
	8	16	III	Tr.	In.
25	8	1	I	Tr.	In.
26	8	26	I	Ec.	Re.
	9	12	IV	Oc.	Re.

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

COMET NOTES.

Ephemeris of Encke's Comet.

[For Berlin noon; from *Astronomische Nachrichten* 4241]

1908	α app.			δ app.		log *r*	log Δ	Aber. Time	
	h	m	s	°	′			m	s
May 26	3	2	7	— 5	39.7	9.8483	9.6129	3	25
27	2	57	24	7	2.1	8593	6021		19
28		52	33	8	25.3	8702	5920		15
29		47	35	9	49.1	8806	5829		11
30		42	29	11	13.8	8908	5739		7
31		37	16	12	39.3	9007	5659		4
June 1		31	54	14	4.3	9108	5484	3	0
2		26	24	15	30.3	9196	5515	2	58
3		20	44	16	56.9	9287	5451		55
4		14	56	18	23.7	9376	5394		53
5		8	57	19	50.6	9462	5343		51
6	2	2	47	21	18.1	9546	5295		49
7	1	56	24	22	45.7	9627	5248		48
8		49	49	24	13.2	9707	5210		46
9		42	58	25	40.5	9786	5177		45
10		35	54	27	8.5	9862	5151		44
11		28	33	28	34.0	9.9936	5130		43
12		20	58	29	59.7	0.0008	5111		42
13		13	5	31	24.6	0078	5097		41
14	1	4	57	32	47.9	0148	5088		40
15	0	56	32	34	9.0	0216	5083		40
16		47	50	35	27.9	0282	5083		40
17		38	52	36	45.2	0348	5091		41
18		29	34	37	59.3	0414	5105		41
19		19	58	39	10.9	0473	5123		42
20	0	10	4	40	19.8	0532	5147		43
21	23	59	54	41	25.0	0593	5176		44
22		49	31	42	24.0	0651	5210		45
23		38	54	43	18.5	0708	5250		47
24		28	6	44	9.3	0765	5295		49
25		17	10	44	55.7	0820	5345		51
26	23	6	7	45	36.2	0875	5401		53
27	22	55	0	46	13.2	0927	5460		55
28		43	52	46	44.7	0978	5524	2	58
29		32	46	47	11.4	1030	5594	3	1
30		21	45	47	32.8	1080	5668		4
July 1		10	53	47	50 0	1129	5742		7
2	22	0	15	48	2.5	1178	5826		11
3	21	49	48	48	10.8	1226	5910		14
4		39	36	48	14.5	1273	5997		18
5		29	42	48	14.5	1319	6087		22
6		20	12	48	11.4	1364	6178		27
7		11	4	48	5.3	1488	6272		31
8	21	2	17	47	56.1	1452	6368		36
9	20	53	53	47	44.1	1495	6466		41
10		45	52	47	30.1	1537	6564		46
11		38	12	47	14.4	1580	6664		51
12		30	55	46	57.6	1621	6765	3	56
13		24	1	46	39.5	1661	6867	4	2
14		17	31	46	20.2	1701	6070		8
15		11	21	45	59.8	1740	7075		14
16		5	32	45	38.8	1779	7181		20
17	20	0	1	45	16.9	1818	7285		26
18	19	54	50	44	56.8	1855	7388		32
19		49	56	44	37.1	1892	7492		39
20		45	20	44	16.5	1929	7596		46
21		41	0	43	57 1	1965	7702		53
22	19	36	55	−43	38.1	0.2000	9.7808	4	59

M. KAMENSKY.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
June	3	4
	5	16
	8	4
	10	15
	13	3
	15	15
	18	3
	20	15
	23	2
	25	14
	28	2
	30	14

Z Persei

June	1	5
	4	6
	7	7
	10	9
	13	10
	16	12
	19	13
	22	14
	25	16
	28	17

RY Persei

June	7	1
	13	22
	20	19
	27	15

RZ Cassiop.

June	2	7
	3	12
	4	16
	5	21
	7	2
	8	6
	9	11
	10	16
	11	21
	13	1
	14	6
	15	10
	16	15
	17	20
	19	0
	20	5
	21	10
	22	15
	23	19
	25	0
	26	5
	27	9
	28	14
	29	19
	30	23

Algol

	d	h
June	2	6
	5	3
	8	0
	10	21
	13	18
	16	14
	19	11
	22	8
	25	5
	28	2

RT Persei

June	1	9
	2	6
	3	2
	3	22
	4	19
	5	15
	6	12
	7	8
	8	4
	9	1
	9	21
	10	18
	11	14
	12	10
	13	7
	14	3
	14	23
	15	20
	16	16
	17	13
	18	9
	19	5
	20	2
	20	22
	21	19
	22	15
	23	11
	24	8
	25	4
	26	0
	26	21
	27	17
	28	14
	29	10
	30	6

RS Cephei

June	3	20
	16	6
	28	16

Y Camelop.

June	1	16
	5	0
	8	7

Y Camelop.

	d	h
June	11	14
	14	21
	18	5
	21	12
	24	19
	28	3

RR Puppis

June	2	7
	8	18
	15	4
	21	14
	28	1

V Puppis

June	1	12
	2	23
	4	10
	5	21
	7	8
	8	19
	10	6
	11	17
	13	4
	14	15
	16	2
	17	12
	18	23
	20	10
	21	21
	23	8
	24	19
	26	6
	27	17
	29	4
	30	15

S Cancri

June	8	8
	17	19
	27	7

S Velorum

June	1	18
	7	16
	13	15
	19	13
	25	12

RR Velorum

June	1	5
	3	2
	4	22
	6	19
	8	15
	10	12
	12	8
	14	5
	16	1

RR Velorum

	d	h
June	17	22
	19	18
	21	15
	23	11
	25	8
	27	4
	29	1
	30	21

SS Carinae

June	1	20
	5	4
	8	11
	11	18
	15	1
	18	8
	21	16
	24	23
	28	6

Z Draconis

June	1	2
	2	10
	3	19
	5	3
	6	12
	7	20
	9	5
	10	14
	11	22
	13	7
	14	15
	16	0
	17	9
	18	17
	20	2
	21	10
	22	19
	24	3
	25	12
	26	21
	28	5
	29	13
	30	22

RZ Centauri

June	2	16
	3	15
	4	13
	5	12
	6	10
	7	9
	8	7
	9	6
	10	4
	11	3
	12	1

RZ Centauri

	d	h
June	13	0
	13	23
	14	21
	15	20
	16	18
	17	17
	18	15
	19	14
	20	12
	21	11
	22	9
	23	8
	24	6
	25	5
	26	3
	27	2
	28	0
	28	23
	29	21
	30	20

SS Centauri

June	2	20
	5	7
	7	19
	10	6
	12	18
	15	5
	17	17
	20	4
	22	16
	25	3
	27	14
	30	2

δ Libræ

June	2	6
	4	14
	6	22
	9	5
	11	13
	13	21
	16	5
	18	13
	20	21
	23	5
	25	12
	27	20
	30	4

U Coronæ

June	1	8
	4	19
	8	5
	11	16
	18	14
	22	1

Minima of Variable Stars of the Algol Type.—Continued.

U Coronæ

	d	h
June	25	12
	28	23

R Aræ

	d	h
June	3	8
	7	18
	12	4
	16	14
	21	1
	25	11
	29	21

U Ophiuchi

	d	h
June	1	17
	2	13
	3	9
	4	5
	5	1
	5	21
	6	17
	7	14
	8	10
	9	6
	10	2
	10	22
	11	18
	12	14
	13	10
	14	7
	15	23
	16	19
	17	15
	18	11
	19	7
	20	3
	21	0
	21	20
	22	16
	23	12
	24	8
	25	4
	26	0
	26	21
	27	17
	28	13
	29	9
	30	5

Z Herculis

	d	h
June	4	6
	8	6
	12	6
	20	6
	24	5
	28	5

RS Sagittarii

	d	h
June	2	20
	5	6
	7	16
	10	2

RS Sagittarii

	d	h
June	12	2
	14	22
	17	8
	19	18
	22	4
	24	14
	27	0
	29	10

V Serpentis

	d	h
June	1	4
	4	15
	8	2
	11	13
	15	0
	18	11
	21	22
	25	9
	28	19

RX Herculis

	d	h
June	1	8
	2	5
	3	3
	4	0
	4	21
	5	19
	6	16
	7	13
	8	11
	9	8
	10	5
	11	3
	12	0
	12	22
	13	19
	14	16
	15	14
	16	11
	17	8
	18	6
	19	3
	20	0
	20	22
	21	19
	22	16
	23	14
	24	11
	25	8
	26	6
	27	3
	28	0
	28	22
	29	19
	30	16

SX Sagittarii

	d	h
June	2	20
	4	21
	6	23

SX Sagittarii

	d	h
June	9	1
	11	3
	13	5
	15	7
	17	8
	19	10
	21	12
	23	14
	25	16
	27	18
	29	20

RR Draconis

	d	h
June	1	0
	3	20
	6	16
	9	12
	12	8
	15	4
	18	0
	20	20
	23	16
	26	11
	29	7

RZ Ophiuchi

	d	h
June	21	12

U Scuti

	d	h
June	1	11
	2	9
	3	8
	4	7
	5	6
	6	5
	7	4
	8	3
	9	2
	10	1
	11	0
	11	23
	12	22
	13	20
	14	19
	15	18
	16	17
	17	16
	18	15
	19	14
	20	13
	21	12
	22	11
	23	10
	24	9
	25	8
	26	6
	27	5
	28	4
	29	3
	30	2

RX Draconis

	d	h
June	2	5
	4	3
	6	0
	7	22
	9	19
	11	17
	13	14
	15	12
	17	9
	19	6
	21	4
	23	1
	24	23
	26	20
	28	18
	30	15

RV Lyræ

	d	h
June	1	17
	5	8
	8	22
	12	12
	16	3
	19	17
	23	8
	26	22
	30	12

U Sagittarii

	d	h
June	4	6
	7	15
	11	1
	14	10
	17	19
	21	4
	24	13
	27	22

SY Cygni

	d	h
June	5	8
	11	8
	17	8
	29	9

WW Cygni

	d	h
June	3	1
	6	9
	9	17
	13	0
	16	8
	19	16
	22	23
	26	7
	29	14

SW Cygni

	d	h
June	4	20
	9	10
	14	0
	18	13

SW Cygni

	d	h
June	23	3
	27	17

VW Cygni

	d	h
June	9	4
	17	14
	26	1

UW Cygni

	d	h
June	2	20
	6	7
	9	18
	13	5
	16	16
	20	2
	23	13
	27	0
	30	11

W Delphini

	d	h
June	4	0
	8	19
	13	15
	18	10
	23	5
	28	1

RR Delphini

	d	h
June	3	0
	7	15
	12	5
	16	20
	21	10
	26	0
	30	15

VV Cygni

	d	h
June	1	18
	3	6
	4	17
	6	5
	7	16
	9	4
	10	15
	12	3
	13	14
	15	2
	16	13
	18	0
	19	12
	20	23
	22	11
	23	22
	25	10
	26	21
	28	9
	29	20

UZ Cygni

	d	h
June	29	19

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
June	5	12
	20	7

RU Camelop.

	(−9	12)
June	16	23

V Carinæ

	(−2	4)
June	6	20
	13	13
	20	5
	26	22

T Velorum

	(−1	10)
June	5	14
	10	5
	14	20
	19	12
	24	3
	28	18

W Carinæ

	(−1	0)
June	1	9
	5	18
	10	3
	14	12
	18	21
	23	6
	27	15

S Muscæ

	(−3	11)
June	7	3
	16	18
	26	10

T Crucis

	(−2	2)
June	5	5
	11	22
	18	16
	25	10

R Crucis

	(−1	10)
June	4	2
	9	22
	15	18
	21	13
	27	9

S Crucis

	(−1	12)
June	1	3
	5	19
	10	12

S Crucis

	d	h
June	15	4
	19	21
	24	13
	29	6

W Virginis

	d	h
	(−8	5)
June	3	20
	21	2

V Centauri

	(−1	11)
June	3	15
	9	3
	14	15
	20	3
	25	15

R Triang. Austr.

	(−1	0)
June	2	21
	6	6
	9	15
	13	1
	16	10
	19	19
	23	5
	29	14
	29	23

S Triang. Austr.

	(−2	2)
June	3	10
	9	18
	16	2
	22	10
	28	17

S Normæ

	(−4	10)
June	8	12
	18	6
	28	0

RV Scorpii

	(−1	10)
June	6	14
	12	15
	18	17
	24	18
	30	19

RV Ophiuchi Minimum.

June	1	9
	5	1
	8	18
	12	10

RV Ophiuchi

	d	h
June	16	3
	19	19
	23	16
	27	8

X Sagittarii

	(−2	22)
June	5	3
	12	3
	19	3
	26	4

Y Ophiuchi

	(−6	5)
June	17	15

W Sagittarii

	(−3	0)
June	6	10
	14	0
	21	14
	29	5

Y Sagittarii

	(−2	2)
June	3	5
	8	23
	14	18
	20	13
	26	7

U Sagittarii

	(−2	23)
June	5	10
	12	4
	18	22
	25	15

β Lyræ

	(−3	2)
	(−3	7)
June	5	1
	11	17
	17	23
	24	15
	30	20

κ Pavonis

	(−1	7)
June	9	9
	18	11
	27	14

U Aquilæ

	(−2	4)
June	7	6
	14	6
	21	7
	28	8

U Vulpeculæ

	d	h
	(−2	3)
June	1	13
	9	12
	17	12
	25	11

SU Cygni

	(−1	7)
June	1	14
	5	10
	9	7
	13	3
	16	23
	20	20
	24	16
	28	12

η Aquilae

	(−2	6)
June	6	15
	13	20
	21	0
	28	4

S Sagittae

	(−3	10)
June	2	23
	11	8
	19	18
	28	3

X Vulpeculæ

	(−2	1)
June	3	0
	9	8
	15	15
	21	23
	28	7

V Vulpeculae Minimum

June	18	23

X Cygni

	(−6	19)
June	12	2
	28	12

T Vulpeculae

	(−1	10)
June	2	3
	6	13
	11	0
	15	10
	19	21
	24	7
	28	18

TX Cygni

June	10	5
	24	22

VY Cygni

	d	h
	(−2	14)
June	7	0
	14	20
	22	17
	30	13

VZ Cygni

	(−2	12)
	(−3	6)
June	3	4
	7	21
	12	21
	17	15
	22	15
	27	8

δ Cephei

	(−1	10)
June	5	5
	10	14
	15	23
	21	8
	26	16

V Lacertae

June	4	0
	9	0
	14	0
	18	23
	23	23
	28	23

X Lacertae

June	5	6
	10	16
	16	3
	21	13
	27	0

RI Cassiop.

	(−1	19)
June	1	10
	7	17
	14	0
	20	7
	26	14

RY Cassiop.

	(−7	10)
June	2	4
	14	7
	26	11

Y Lacertae

	(−1	10)
June	1	20
	6	3
	10	11
	14	18
	18	26
	23	10
	27	17

Approximate Magnitudes of Variable Stars on Apr. 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.		R. A. 1900.	Decl. 1900.		Magn.	Name.		R.A. 1900.	Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
X Androm.	0	10.8	+46	27	<13	X Gemin.	5	40.7	+30	23	11.0
T Androm.		17.2	+26	26	9.0*d*	W Monoc.		47.5	− 7	2	10.7
T Cassiop.		17.8	+55	14	2.0*d*	Y Monoc.		51.3	+11	22	11.4 *i*
R Androm.		18.8	+38	1	13.0 *i*	X Monoc.		52.4	− 8	56	7.6
Y Cephei		31.3	+79	48	12.5	R Lyncis		53.0	+55	28	12.0*d*
U Cassiop.		40.8	+47	43	8.3 *i*	RS Gemin.		55.2	+30	40	11.2
RW Androm.		41.9	+32	8	10.0 *i*	V Can. Min.	7	1.5	+ 9	2	<14
V Androm.		44.6	+35	6	9.6 *i*	R Gemin.		1.3	+22	52	<13.5
RR Androm.		45.9	+33	50	<12.6	R Can. Min.		3.2	+10	11	8.4
RV Cassiop.		47.1	+46	53	<12.6	RR Monoc.		12.4	+ 1	17	<13.5
W Cassiop.		49.0	+58	1	10.0 *i*	V Gemin.		17.6	+13	17	11.0*d*
RX Androm.		58.9	+40	46	13.0	S Can Min.		27.3	+ 8	32	12.0
U Androm.	1	9.8	+40	11	11.0 *i*	T Can. Min.		28.4	+11	58	14.0 *i*
S Cassiop.		12.3	+72	5	12.4 *i*	Z Puppis		28.3	—20	57	13.3
RU Androm.		32.8	+38	10	<12.6	U Can. Min.		35.9	+ 8	37	10.3*d*
Y Androm.		33.7	+38	50	<12.6	S Gemin.		37.0	+23	41	12.5 *i*
X Cassiop.		49.8	+58	46	9.6*d*	T Gemin.		43.3	+23	59	10.5*d*
U Persei		53.0	+54	20	8.2	U Puppis		56.1	—12	34	13.6*d*
R Arietis	2	10.4	+24	35	12.0*d*	R Cancri	8	11.0	+12	2	11.8*d*
W Androm.		11.2	+43	50	<13	V Cancri		16.0	+17	36	11.6*d*
Z Cephei		12.8	+81	13	<13	RT Hydrae		24.7	− 5	59	9.4*d*
o Ceti		14.3	− 3	26	8.3*d*	U Cancri		30.0	+19	14	<13
S Persei		15.7	+58	8	8.6	X Urs. Maj.		33.7	+50	30	9.6 *i*
R Ceti		20.9	− 0	38	8.6	S Hydrae		48.4	+ 3	27	7.7 *i*
RR Cephei		30.4	+80	42	<13	T Hydrae		50.8	− 8	46	8.7*d*
R Trianguli		31.0	+33	50	5.6 *i*	T Cancri		51.0	+20	14	9.6*d*
T Arietis		42.8	+17	6	8.7	S Pyxidis	9	0.7	−24	41	11.6*d*
W Persei		43.2	+56	34	9.6*d*	W Cancri		4.0	+25	39	12.6*d*
U Arietis	3	5.5	+14	25	10.0*d*	X Hydrae		30.7	—14	15	12.0*d*
X Ceti		14.3	− 1	26	10.0*d*	Y Draconis		31.1	+78	18	<13
Y Persei		20.9	+43	50	9.4*d*	R Leo. Min.		39.6	+34	58	11.0*d*
R Persei		23.7	+35	20	10.3 *i*	RR Hydrae		40.4	—23	34	<13.4
T Tauri	4	16.2	+19	18	12.0*d*	R Leonis		42.2	+11	54	8.6*d*
R Tauri		22.8	+ 9	56	<13	Y Hydrae		46.4	—22	33	6.5
W Tauri		22.2	+15	49	9.6*d*	V Leonis		54.5	+21	44	<13.5
S Tauri		23.7	+ 9	44	10.4	R Urs. Maj.	10	37.6	+69	18	13.0*d*
T Camelop.		30.4	+65	57	8.6	W Leonis		48.4	+14	15	<13
RX Tauri		32.8	+ 8	9	<13	V Hydrae		46.8	—20	43	10.0
X Camelop.		32.6	+74	56	13.5*d*	S Leonis	11	5.7	+ 6	0	10.8*d*
V Tauri		46.2	+17	22	11.0*d*	R Comae		59.1	+19	20	14.0
R Orionis		53.6	+ 7	59	10.8*d*	T Virginis	12	9.5	− 5	29	13.6
R Leporis		55.0	—14	57	9.6 *i*	R Corvi		14.4	−18	42	10.5 *i*
V Orionis	5	0.8	+ 3	58	12.6 *i*	T Can. Ven.		25.2	+32	3	11.2 *i*
T Leporis		0.6	—22	2	10.6 *i*	Y Virginis		28.7	− 3	52	10.4 *i*
R Aurigae		9.2	+53	28	11.4*d*	T Urs. Maj.		31.8	+60	2	11.5*d*
S Aurigae		20.5	+34	4	9.0 *i*	R Virginis		33.4	+ 7	32	10.4*d*
W Aurigae		20.1	+36	49	11.6*d*	RS Urs. Maj.		34.4	+59	2	9.6*d*
S Orionis		24.1	− 4	46	13.0*d*	S Urs. Maj.		39.6	+61	38	9.6*d*
T Orionis		30.9	− 5	32	9.5	RU Virginis		42.2	+ 4	42	9.0 *i*
S Camelop.		30.2	+68	45	8.8 *i*	U Virginis		46.0	+ 6	6	10.4 *i*
RR Tauri		33.3	+26	19	11.5	RT Virginis		57.6	+ 5	43	8.6
U Aurigae		35.6	+31	59	11.0 *i*	RV Virginis	13	2.8	—12	38	<13.5
Z Tauri		46.7	+15	46	<13	V Virginis		22.6	− 2	39	10.4*d*
V Camelop.		49.4	+74	30	<13	R Hydrae		24.2	—22	46	8.4 *i*
Z Aurigæ		53.6	+53	18	10.4 *i*	S Virginis		27.8	− 6	41	11.0*d*
X Aurigae		4.4	+50	15	9.6 *i*	T Urs. Min.		32.6	+73	56	12.6*d*
V Monoc.		17.7	− 2	9	11.4 *i*	R Can. Ven.		44.6	+40	2	10.8*d*
V Aurigae		16.5	+47	45	9.6*d*	RR Virginis		49.6	− 8	43	<13.5
R Monoc.		33.7	+ 8	49	11.0	Z Bootis	14	1.3	+13	59	9.8 *i*
S Lyncis		35.9	+58	0	13.6	Z Virginis		5.0	—12	50	10.8

Approximate Magnitudes of Variable Stars on Apr. 1, 1908—Con.

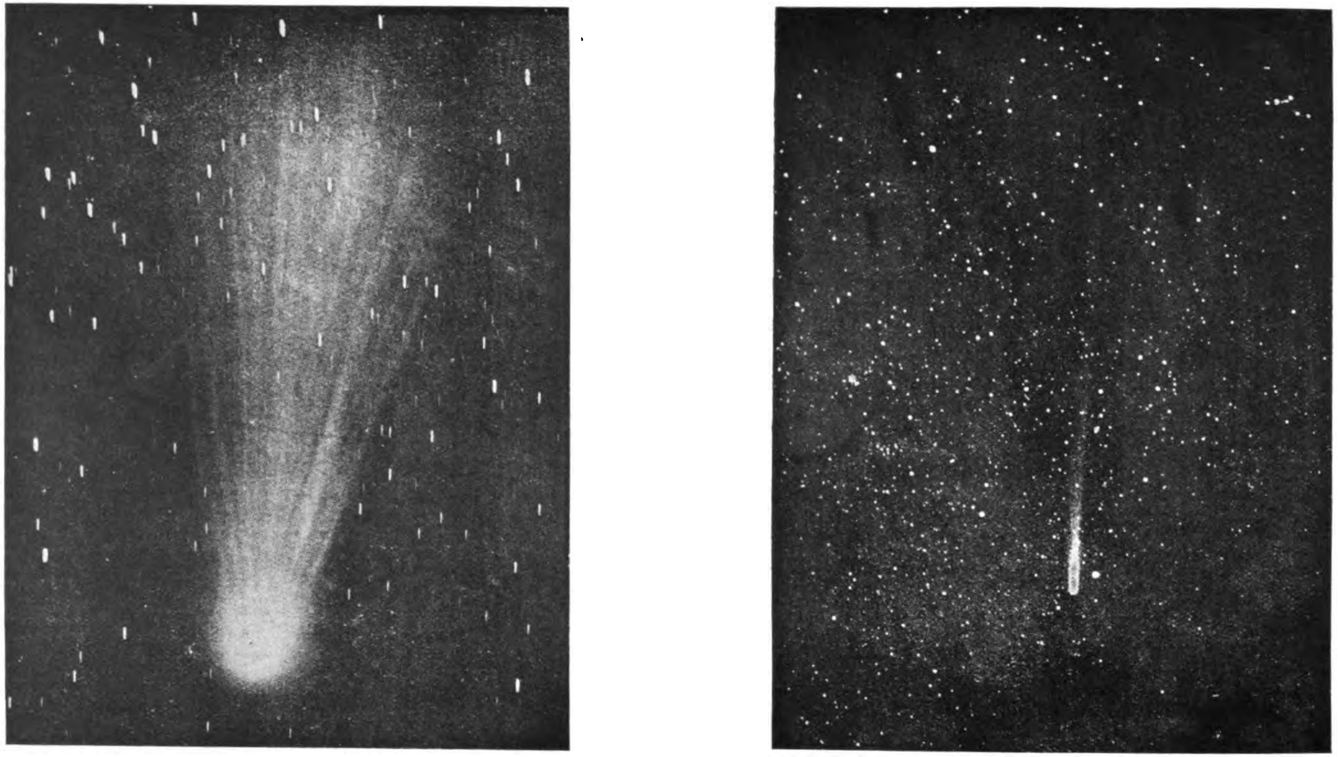
Name.	R. A. 1900. h	R. A. 1900. m	Decl. 1900. °	Decl. 1900. ′	Magn.	Name.	R. A 1900 h	R. A 1900 m	Decl. 1900 °	Decl. 1900	Magn.
U Urs. Min.	14	15.1	+67	15	11.5*d*	RV Herculis	16	56.8	+31	22	11.0 *i*
S Bootis		19.5	+54	16	8.6 *i*	R Ophiuchi	17	2.0	—15	58	11.0*d*
RS Virginis		22.3	+ 5	8	12.6*d*	RT Herculis		6.8	+27	11	11.6 *i*
V Bootis		25.7	+39	18	9.3*d*	Z Ophiuchi		14.5	+13	7	12.6*d*
R Camelop.		25.1	+84	17	8.4*d*	RS Herculis		17.5	+23	1	10.5 *i*
R Bootis		32.8	+27	10	12.2*d*	RU Ophiuchi		28.1	+ 9	30	12.0*d*
V Librae		34.8	—17	14	11.0*d*	RS Ophiuchi		44.8	— 6	40	11.0
U Bootis		49.7	+18	6	12.5*d*	RT Ophiuchi		51.8	+11	11	<13.2
RT Librae	15	0.8	—18	21	13.0*d*	T Draconis		54.8	+58	14	10.6
T Librae		5.9	—19	38	10.8 *i*	RY Herculis		55.4	+19	29	9.4*d*
Y Librae		6.4	— 5	38	12.6	V Draconis		56.3	+54	53	10.2 *i*
S Librae		15.6	—20	2	10.2*d*	T Herculis	18	5.3	+31	0	11.8 *i*
S Serpentis		17.0	+14	40	12.0 *i*	W Draconis		5.4	+65	56	10.0
S Coronae		17.3	+31	44	9.2*d*	X Draconis		6.8	+66	8	10.2
RS Librae		18.5	−22	33	11.5*d*	W Lyrae		11.5	+36	38	9.6
RU Librae		27.7	—14	59	11.2 *i*	T Serpentis		23.9	+ 6	14	<12.5
X Librae		30.4	—20	50	10.5 *i*	X Ophiuchi		33.6	+ 8	44	8.0
S Urs. Min.		33.4	+78	58	9.0 *i*	RY Lyrae		41.2	+34	34	<12.5
U Librae		36.2	—20	52	9.3 *i*	RW Lyrae		42.1	+43	32	<12.5
Z Librae		40.7	—20	49	13.0	Z Lyrae		56.0	+34	49	<12.5
R Coronae		44.4	+28	28	5.8	RX Lyrae		50.4	+32	42	<12.5
X Coronae		45.2	+36	35	12.5*d*	RW Cygni		25.2	+39	39	8.6*d*
R Serpentis		46.1	+15	26	10.6 *i*	RT Lyrae		57.8	+37	22	12.0
V Coronae		46.0	+39	52	7.8	R Aquilae	19	1.6	+ 8	5	10.6*d*
R Librae		47.9	−15	56	<13	V Lyrae		5.2	+29	30	11.8
RR Librae		50.6	−18	1	10.6*d*	RS Lyrae		9.3	+33	15	11.0
— Coronae		52.2	+29	32	13.5	RY Ophiuchi		11.6	+ 3	40	<12.6
RZ Scorpii		58.6	−23	50	9.3 *i*	RU Lyrae		9.1	+41	8	12.0
Z Scorpii	16	0.1	—21	28	10.3 *i*	U Draconis		9.9	+67	7	11.0 *i*
R Herculis		1.7	+18	38	9.0 *i*	U Lyrae		16.6	+37	42	10.3 *i*
RR Herculis		1.5	+50	46	9.6*d*	TY Cygni		29.8	+28	6	11.4 *i*
U Serpentis		2.5	+10	12	9.6 *i*	R Cygni		34.1	+49	58	<13
X Scorpii		2.7	−21	16	12.4*d*	RV Aquilae		35.9	+ 9	42	9.4 *i*
W Scorpii		5.9	—19	53	<13	RT Aquilae		33.3	+11	30	13.8
RX Scorpii		5.9	—24	38	12.6*d*	RT Cygni		40.8	+48	32	12.8*d*
RU Herculis		6.0	+25	20	12.8	TU Cygni		43.3	+48	49	10.6 *i*
R Scorpii		11.7	—22	42	<13	χ Cygni		46.7	+32	40	6.0 *i*
S Scorpii		11.7	−22	39	<13	Z Cygni		58.6	+49	46	10.6*d*
W Coronae		11.8	+38	3	12.2	U Cygni	20	16.5	+47	35	7.8 *i*
V Ophiuchi		21.2	−12	12	7.7 *i*	X Cephei	21	3.6	+82	40	13.4 *i*
U Herculis		21.4	+19	7	12 0 *i*	T Cephei		8.2	+68	5	7.0 *i*
Y Scorpii		23.8	—19	13	11.5 *i*	S Cephei		36.5	+78	10	7.8 *i*
SS Herculis		28.0	+ 7	3	9.5	S Lacertae	22	24.6	+39	48	13.0*d*
S Ophiuchi		28.5	—16	57	13.0*d*	R Lacertae		38.8	+41	51	11.0 *i*
T Ophiuchi		28.0	—15	55	9.0 *i*	V Cassiop.	23	7.4	+59	8	8.6 *i*
W Herculis		31.7	+37	32	13.5*d*	RR Cassiop.		50.7	+53	8	12.2*d*
R Draconis		32.4	+66	58	7.5 *i*	R Cassiop.		53.3	+50	50	12.2*d*
RR Ophiuchi		43.2	—19	17	10.5*d*	Y Cassiop.		58.2	+55	7	10.6 *i*
S Herculis		47.4	+15	7	9.6*d*						

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Vassar, Mt. Holyoke, Whitin and Harvard Observatories.

New Variable 6.1908 Geminorum.—In *A. N.* 4237 Professor Ceraski announces as a new variable the star BD. + 15° 1573. Its magnitude as given in the BD is 9.0. Upon 17 photographs taken at Moscow in 1899-1907 it appears of constant magnitude, about 9.0, but upon 4 plates it is

PLATE XX



28-in. Reflector 1907 Aug. 14d 15h 8.2m

1¼-in. Lens 1907 Aug. 14d 15h 0.2m

COMET *d* 1907 (DANIEL), MAX WOLF
HEIDELBERG

fainter. On the photographs taken March 18 and 24, 1903 and March 11, 1904, it appears only a few tenths of a magnitude fainter, but upon that of April 5, 1907 it is 1½ magnitudes below the normal. It is probably of the Algol Type. Its position is

1855.0	$\alpha = 7^h\ 19^m\ 07^s.32$	$\delta = +15^\circ\ 56'\ 50''.1$
1900.0	$7\ \ 21\ \ 41.68$	$+15\ \ 51\ \ 39\ .9$

Approximate Elements of Three Variables. In *A. N.* 4238 Mr. S. Enebo of Dombaas, Norway, gives the following approximate elements depending upon his own observations;

79.1907	Aurigæ	Min.	= 1907 Oct. 4 8^h	Gr.m.t.	$+ 1^h\ 12^m\ 48^s$ E
			= 2417853.375	"	$+ 1^d.533$ E
80.1907	Aurigæ	Max.	= 1907 Sept. 14	"	$+ 10^d\ 21^h$ E
			= 2417833	"	$+ 10^d.9$ E
142.1907	Cassiopeiæ	Min.	= 1907 Nov. 30 9^h	"	
			= 2417910.4	"	$+ 36^d4$ E

The range of brightness of 79.1907 is $8^m.0 - 8^m.7$, that of 80.1907, $9^m.0$—$9^m.7$ and that of 142.1907, 8.8 — 9.6. The last apparently belongs to the Algol type and the change of light at minimum occupies at least three days.

GENERAL NOTES.

Photographs of Daniel's Comet *d* 1907.—In *Monthly Notices* of R. A. S. for January 1908 are reproductions of two beautiful photographs of this comet taken at Heidelberg by Professor Max Wolf on August 14, 1907. One taken with a 1¼-inch lens shows a tail twelve degrees long. The other, taken with a 28-inch reflector, shows the head and tail for about one degree from the nucleus. In this portion of the tail one can count from fifteen to twenty bright streaks separated by dark ones emanating from the head of the comet.

Professor Wolf says that photographs of the comet were taken at Heidelberg on ten nights from July 21 to August 27, and that he also made drawings of the comet as seen with the 28-inch reflector on six of the same nights. The following remark made by Professor Wolf is interesting:

"The most striking result appears to me the difference between the visual and the photographic appearances. All the drawings show a minimum of luminous radiation in or around the axis of the tail in the region turned away from the Sun. All the photographs show the brightest tails near the axis, exactly in the parts where visually there was a minimum of brightness. This very curious difference, which was remarked several years before in other comets photographed here seems to be placed beyond doubt by the photographs taken with the reflector.

"Besides this, it is very interesting, and perhaps in opposition with accepted theories, that the short arms of the tails furthest outside the axis are nearly all curved".

"Mirage" from Blast Furnaces. I have read in the Literary Digest a comment on an article by Mr. William E. Sperra published in your number for March relating to a "mirage" from blast-furnaces at Newburg, Ohio.

Having spent some years in the vicinity of steel mills and observed similar lights in the sky on numerous occasions I would like to suggest a possible explanation of the phenomenon.

The mouth of a Bessemer converter does not open directly upward but is inclined at possibly 30° and from this opening a beam of light is projected which becomes of exceeding intensity at the height of the blast. On a night when a slight haze or mist is present in the atmosphere this beam is visible like the beam from a search light from the mouth of the converter to a great altitude, while on a perfectly clear night it is wholly invisible. On nights which appear to be thus perfectly clear and starlit there are frequently very slight clouds in the upper atmosphere which become visible upon receiving any illumination from beneath. If we were able to observe the cloud from directly in line with the converter we should see a single round spot of light reflected there but due to the inclination of this ray and the obliquity of our line of vision this spot appears elongated and most intense near its center. This brightness varies greatly during the period of blast and, of course disappears entirely during the interval when the particular converter is out of blast. The fact that only the portion of the cloud in line with the beam receives any light causes this spot to appear with no background other than the starlit heavens.

Ithaca, N. J. LESLIE D. HAYES.

Sale of Instruments from Manora Observatory. The following notice is received: "The Manora Observatory will be sold within a few months. That gives an opportunity to our readers of acquiring the 7-inch equatorial with accessories at a relatively moderate price. The extraordinary performances of that instrument are known. It showed the satellites of Mars, Uranus and Neptune, Hyperion, permitted the measurement of the companion of Sirius, when it was shown only by the Lick equatorial (distance 3″.74) and of β 79 (distance 0.″56), dissolved the Great Andromeda Nebula into stars, enabled Mr. Brenner to discover 200 new objects on Mars, and was declared by all astronomers who examined it, to be an incomparable instrument."

Relation Between the Color and the Period of Variable Stars. It has been known for some years that there is an intimate relation between the colors and the periods of variable stars. The appearance of Professor Pickering's second catalogue of variable stars (*Harvard Annals* 55), with color data for about 300 stars, led Mr. S. Beljawsky, of the observatory at Göttingen, to undertake a new study of the subject. His results are given in *A. N.* 4238.

The color estimates of all the observers concerned were made on one of the two scales adopted by Chandler and Osthoff. For an approximate reduction of the one scale to the other Mr. Beljawsky adopted the numerical relation indicated in Table I.

TABLE I

Color	Scale	
	Osthoff	Chandler
White	0	0
	1^{c}	0.5^{c}
	2	1.0
	3	1.5
Pure Yellow	4	2.0
	5	2.6
	6	3.3
Orange	7	4.2
	8	5.4
	9	7.2
Pure Red	10	10.0

After reducing the estimates made according to Chandler's scale to make them correspond with Osthoff's scale, the averages of the color numbers were taken in groups according to the class of the star and the length of its period. These averages are collected in Table II, and those of classes IV and II are plotted in Figure 1. The numbers of Table II are represented by the round dots. Their progress is followed roughly by the dotted line which is almost straight.

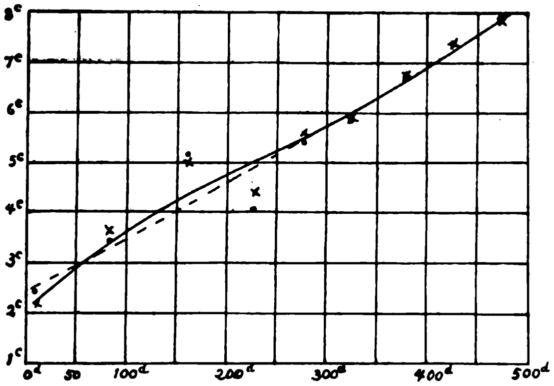


FIGURE 1

TABLE II

Class	Period	Mean Period	Mean Color	No. of Stars
V	Algol Type	—	$0^{c}.83$	13
IV	Short Period	10	2.44	20
II	<100d	80	3.4	4
"	100d— 200d	163	5.11	24
"	200 — 250	226	4.07	34
"	250 — 300	274	5.45	35
"	300 — 350	325	5.83	49
"	350 — 400	374	6.70	36
"	400 — 450	418	7.38	24
"	450 — 500	474	7.9	7
III	Irregular	—	7.29	44

In Table III the stars are grouped according to declination north and south of the equator. The results show no marked tendency of the colors of these stars to vary systematically with the declination. If the zone from 0° to 30° north declination were considered alone there would be an apparent systematic change but when the entire range north and south is taken into account the systematic character of the change disappears.

TABLE III

Decl.	Color	Mean Period	No. of Stars
°	c	d	
— 56	6.37	300	16
— 38	6.53	284	14
— 24	4.90	286	16
— 16	5.74	301	18
— 5	6.05	300	13
+ 6	4.83	309	23
+ 12	5.26	323	15
+ 17	5.63	284	17
+ 24	6.56	280	12
+ 35	5.63	282	16
+ 44	6.05	331	12
+ 54	6.15	336	13
+ 68	5.67	309	9

The average color number for a northern star is $5^{c}.70$
" " " " " " southern " " 5 .89

It is evident from Table III that the average period of the known variables of class II is in the vicinity of 300 days. After the color numbers of those stars in Table II had been reduced to the period 300 days by means of the curve in Figure 1 they were again grouped according to their brightness. The results of this grouping are given in Table IV and plotted in Figure 2. They show considerable inter-dependence between color and magnitude.

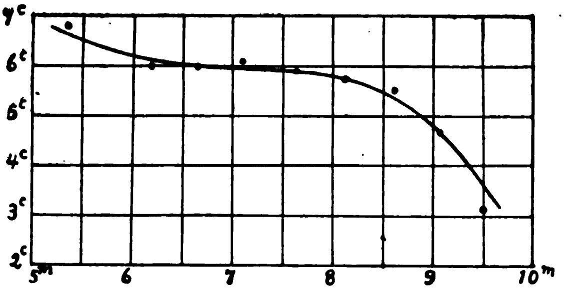


FIGURE 2

TABLE IV

Limits of Mag.	Mean Magnitude	Color	No. of Stars
m	m	c	
>6	5.3	6.8	11
6.0 — 6.4	6.22	6.0	10
6.5 — 6.9	6.66	6.0	17
7.0 — 7.4	7.10	6.10	27
7.5 — 7.9	7.66	5.90	32
8.0 — 8.4	8.12	5.75	46
8.5 — 8.9	8.62	5.56	33
9.0 — 9.4	9.07	4.65	26
9.5 — 9.9	9.5	3.1	4

In view of the dependence of the color upon the brightness of the star, those brighter than the 5th magnitude and fainter than 9.5, were omitted from the further discussion. A new reduction of the color numbers in Table II was made and the means given in Table V are represented by the crosses in Figure 1.

TABLE V

Mean Period	Mean Color	No. of Stars
d	c	
13	2.2	13
80	3.6	4
163	5.04	22
226	4.44	32
274	5.62	34
325	5.79	47
374	6.64	35
418	7.30	21
474	7.8	7
Irregular	7.85	26

Finally Mr. Beljawsky compared the periods of the variables with the amplitude of their variation in magnitude, finding that the amplitude increases with the period up to a period of about 200 days. Beyond 250 days the data concerning the amplitude of variation are too incomplete to be used in the discussion. The results of this comparison are shown in Table VI and Figure 3.

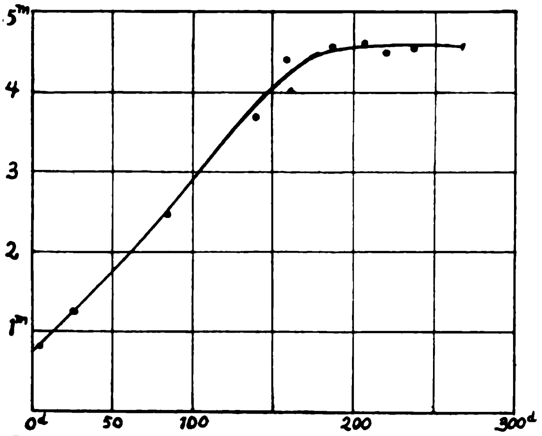


FIGURE 3

TABLE VI

Limits of Period d d	Mean Period d	Amplitude m	No. of Stars
0 — 10	4.6	0.83	48
10 — 40	23.0	1.23	15
50 — 100	84	2.5	6
100 — 150	140	3.75	15
150 — 175	163	4.40	12
175 — 200	187	4.60	13
200 — 214	206	4.67	19
214 — 225	220	4.53	17
225 — 250	237	4.58	30

The Great Nebula in Andromeda. In the April number of *Knowledge* is found a very interesting article by J. Ellard Gore. We can only refer to some points in it. He says if we assume the parallax of the nebula to be about one one-hundredth of a second of arc it would still be within the bounds of our sidereal system, about 326 light years in distance from us, whereas the remote portions of the Milky Way must be at a distance of about 3000 light years. This assumed parallax is probably too large, for it would make its mass eight thousand million times as great as the mass of the Sun.

Mr. Gore calls attention to the fine photograph of this nebula by Dr. Roberts and notices in it several faint stars. It is impossible to tell whether the nebula is in the same order of distance as these small stars, for some of them seen between its branches may be farther away and others may be projected on the nebula.

The study of the spectrum of this nebula is interesting though difficult. It shows that its mass is not wholly gaseous. According to Scheiner, its spectrum is continuous, similar to the solar spectrum, and the greater part of the stars composing the nucleus, he thinks belongs to the second spectral class. According to his view this would mean that the nebula is in an advanced stage of development. No trace of bright nebular lines are present so that the interstellar space in the great nebula, "just as in our stellar system, is not appreciably occupied by gaseous matter."

Mr. Gore examines the suggestion that the Andromeda nebula may be an external universe outside of our sidereal system and comparable in size with it. If the diameter of the Milky Way is 6000 light years, and that of the Andromeda nebula is of the same size, Mr. Gore finds that its distance from us would be 150,000 light years. But this distance is 8000 times as great, as that indicated by Bohlin's parallax hence the relative size to that found above would be 8000 cubed which would mean a mass equal to four trillion times the Sun's mass. This seems so incredibly large that it must be rejected, and that the view of an external universe for the place of the Andromeda nebula is highly improbable.

"Mr. Gore concludes this interesting article as follows:—

It is evident, however, that the mass of the Andromeda must be enormous, and if it belongs to our sidereal system, and if the other great nebulae have similar masses, it seems quite possible that the mass of the *visible* universe may much exceed that of the visible *stars*, and may be equal to 1,000 million times the Sun's mass—as supposed by Lord Kelvin—or even much more.

In August, 1885, a star of about the seventh magnitude blazed out close to the nucleus of the Andromeda nebula. The new star was independently discovered by several observers towards the end of August. It was not visible to Temple at the Florence Observatory on August 15 and 16, but is said to have been seen on August 17 by M. Ludovic Gully. It was, however, certainly seen by Mr. T. W. Ward at Belfast, Ireland, on August 19 at 11 p.m., when he estimated it 9½ magnitude, and it was independently detected by M. Lajoye on August 30, by Dr. Hartwig at Dorpat on August 31, and by Mr. G. T. Davis at Theale, near Reading, on September 1. On September 3 the star was observed as 7½ magnitude at Dun Echt Observatory by Lord Crawford and Dr. Copeland, and its spectrum was found to be "fairly continuous." On September 4, Mr. Maunder, at the Greenwich Observatory, found the spectrum "of precisely the same character as that of the nebula, *i. e.*, it was perfectly continuous, no lines, either bright or dark, being visible, and the red end was wanting." Dr. Huggins, however, on September 9, thought he could see some bright lines in its spectrum. The star gradually faded away, and on February 7, 1886, was estimated as only 16th magnitude with the 26-inch refractor of the Washington Observatory. From a series of measures made by Professor Asaph Hall he found "no certain indications of parallax." Professor Seeliger has investigated the decrease in the light of this star on the hypothesis that it was a cooling body which had been suddenly raised to an intense heat by the shock of a collision, and finds an agreement between theory and observation. Professor Auwers points out the similarity between this outburst and the new star of 1860, which appeared in the cluster 80 Messier, and thinks it very probable that both phenomena were due to physical changes in the nebulæ in which they occurred.

The appearance of this temporary star in the Andromeda nebula seems to be further evidence against the hypothesis of the nebula being an "external universe." For, as I have shown above, our Sun placed at a distance of 150, 000 light years would shine only as a star of the 23rd magnitude, or over 15 magnitudes fainter than the temporary star. This would imply that the star shone with a brightness of over a million times that of the Sun, and would, of course, indicate a body of enormous size. But the rapid fading away of its light would, on the contrary imply a body of comparatively small size. We must, therefore, conclude that the nebula, whatever it may be, is not an external universe, but probably forms a member of our sidereal system."

The Sun's Radiation Less than Supposed. In an article in the Los Angeles *Times* by J. E. Watkins of date April 5, 1908, are found some surprising statements in regard to the radiation of the Sun, which are credited to Mr. Abbott, said to be in charge of the U. S. Astrophysical Observatory on Mount Wilson California.

In this article Mr. Abbott claims that exaggerated estimates of the Sun's radiation which reaches the Earth have prevailed during the last thirty years.

From his measurements he claims that it is not more than half as much as formerly supposed, and only about half as much as Professor Langley determined in the course of his study of this difficult physical problem.

Head of Southern Observatory. The superintendence of the work at the proposed Southern Observatory of the Carnegie Institution has been offered to Astronomer R. H. Tucker, of the Lick Observatory, at present in acting charge of the latter, during the absence of the director.

The plan of observing is the design of Lewis Boss, director of the Dudley Observatory at Albany, who has been engaged for many years in the observation and reduction of a large and accurate fundamental catalogue of stars. The work of the Southern Observatory will include the stars that are too far south to be measured at the observatories of the northern hemisphere. It is expected that three years will be required for the plan, and the Southern station will be located either in New Zealand, South America, or South Africa. The party will probably consist of seven observers, several of whom have already been engaged.

The selection of one of the Lick Observatory staff for the prosecution of this work is one of the instances of the recognition of the standing of this institution in professional work that have not been uncommon of late. The requirements of this particular plan are mainly those of experience, technical skill, and persistence in the execution of a scheme of work. The work of a large observatory is very much specialized, just as professional work has developed in other lines.

It was as an observer, specially trained, that Mr. Tucker was invited, fifteen years ago, to join the Lick Observatory force, and to take charge of the Meridian Circle and its work. Three quarto volumes have been since published, entirely devoted to the results of the observations made with this instrument during this period at the Lick Observatory. The work is of the character that has been fundamental in the development of our knowledge of the universe of stars and in tracing the motions of the planets of our complex solar systen. The larger observatories in all parts of the world have always a force of astronomers working along this line. The smaller observatories rarely do any of this class of work.

This present expedition suggests, in a way, the early trip of Lieutenant Gilliss to Chile, to observe the southern stars; and the much more extensive and successful scheme of Dr. B. A. Gould, both of which eventually resulted in the foundation of national observatories at Santiago, Chile, and at Cordoba, Argentine Republic, respectively. There were earlier expeditions to the Cape of Good Hope, the first of LaCaille, and, later, one of Herschel which led to the establishment of Royal Observatory at Cape Town, now one of the finest in the world. The present scheme is expeditionary only, and the equipment will be brought back to this country when the specific work is completed.

The large Pistor and Martins Meridian Circle, of the Dudley Observatory, will be used for the Southern plan, and it introduces some feeling of sentiment from the fact that the first professional observations of the astronomer, who is to take charge of this work, were made with that instrument.

Should San Luis, in the Argentine Republic, be finally selected as the observing station, there would be additional fitness in the working out of the scheme, since it was from the National Observatory at Cordoba, two hundred miles distant, that the observer came here, fresh from nine years' service under the southern skies.

The Mills Expedition, of the Lick Observatory, is now located at Santiago, under the charge of Dr. H. D. Curtiss ; and while the Cordillera of the Andes would lie between the two stations, making a barrier of no ordinary magnitude, the two stations might easily get into touch with each other, by exchanging compliments. The work of the two stations does not conflict in any way; the established one is for the physical investigation of Southern Stars, by means of the spectroscope; the new one will confine its work to the measurement of the position of the stars.—*San Jose Mercury*, January 24th.

Occultations by the Moon in Præsepe a record of some recent observations which I made. I used a four-inch alt-azimuth refractor, which I had made in Toronto last year. The objective I bought in 1906, and finding it to give satisfactory results, had the instrument constructed. Some time if you wish I will give a description of its construction; also of a nine and one-half-inch reflecting telescope the glass speculum of which I ground myself by hand, and figured it also; and which I am now building, although it is not yet completed.

On April 4, in the evening I observed the conjunction of the Moon, Venus and Mars. When seeing became good in the evening, conjunction had been passed a little; but the three bodies were quite close, and presented an interesting view in the western sky. The irradiation about Venus prevented anything being seen on the planet's surface, as is almost always the case, when that planet is in the field. The Moon however was wonderfully clear and distinct. The dark part of the Moon was perfectly visible, and details on the surface of the dark part were very noticeable. Mare and mountains were quite easily seen, and the boundaries of seas and plains were quite marked. Even the rays radiating from Plato could be easily identified. The Moon was then 5 days old. Later in the evening the sky grew cloudy, obscuring all celestial objects.

On April 9, I observed within the space of one hour, five occultations of stars by the Moon. The Moon was then in Cancer, and by 11 p. m. had approached close to the cluster known as Præsepe. The first two stars occulted were probably 8th magnitude stars, for they were very small, much smaller than the last two, which are given as magnitudes 6.5 each in the Nautical Almanac. Then a still smaller star was occulted, after the first two, the third one being perhaps a ninth or even a tenth magnitude star. It was so faint that it became an effort to follow it continuously, but I kept it in view until occultation occurred. Then the two 6.5 magnitude stars followed, the one about 8 minutes in advance of the other. At first I had difficulty in fixing my sight on the outline of the dark portion of the Moon, which, of course fades into indistinctness after about the fifth day in age of the Moon, but, by keeping the bright part of the Moon just outside of the field, I was able to judge very closely the time when the occultation was likely to occur. In each case the extinction of the star's light was seemingly instantaneous, there being no "hanging" of the star on the Moon's edges as observers have frequently noticed; nor was there a dimming of the light before extinction, as also has been said to frequently occur.

Had I remained observing longer, I think other occultations would have been witnessed, for the path of the Moon lay close to a part of the cluster where the stars were numerous, and which would probably have been eclipsed by the Moon in its way across the sky.

I never read of so many occultations having been seen within so short a period before, and therefore have made this account of them. The first occultation occurred at 11:10 p. m., and the fifth took place at 11:38 p. m. I did not keep a minute record of the times of each of the occultations. My observations were conducted with the 4-inch glass, and the magnifying power was about 100.

Toronto, Canada.

ALBERT R. J. F. HASSARD.

A Relation of Mass to Energy.[*] In a paper of which this is an abstract it is shown that the momentum of any purely electric system having any internal motions and constraints, but possessing on the whole a kind of average symmetry, is given by the expression

$$M = \frac{2 W_t v}{V^2 \left[1 + \left(\frac{v}{V}\right)^2\right]} .$$

Here M is the momentum of the system, (v) its velocity as a whole, V the velocity of light and W_t the part of the total electromagnetic energy which is represented by the components of the electric and magnetic forces which lie perpendicular to the direction of motion of the system. This is a highly general result and is obtained by a method involving the generalized constraints of the system.

When the second order of the ratio v/V may be neglected, W_t is equal to two thirds the total electromagnetic energy (W) of the system (because of the average symmetry before mentioned) and hence we have

$$\text{Mass} = \frac{4\ \mathrm{I}}{3V^2} W.$$

This gives the electromagnetic mass of the system in terms of its total content.

If the electrical theory of matter be accepted this result applies to the mass of any piece of matter and we have the mass proportional to the total contained energy.

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[*] Abstract of a paper presented at the Chicago meeting of the Physical Society, December 30, 1907, to January 2, 1908.

It is shown that if this hypothesis is accepted the irregularities which exist in the table of atomic weights are in harmony with the evolutionary theory of the elements.

Also on this basis gravitation must be considered as acting between quantities of confined energy and not between masses in any other sense.

Comparison Stars for U Geminorum. Harvard College Observatory Circular number 136 contains a list of twenty-two comparison stars with a table of results that will be useful for those wishing such information up to date of March 30, 1908.

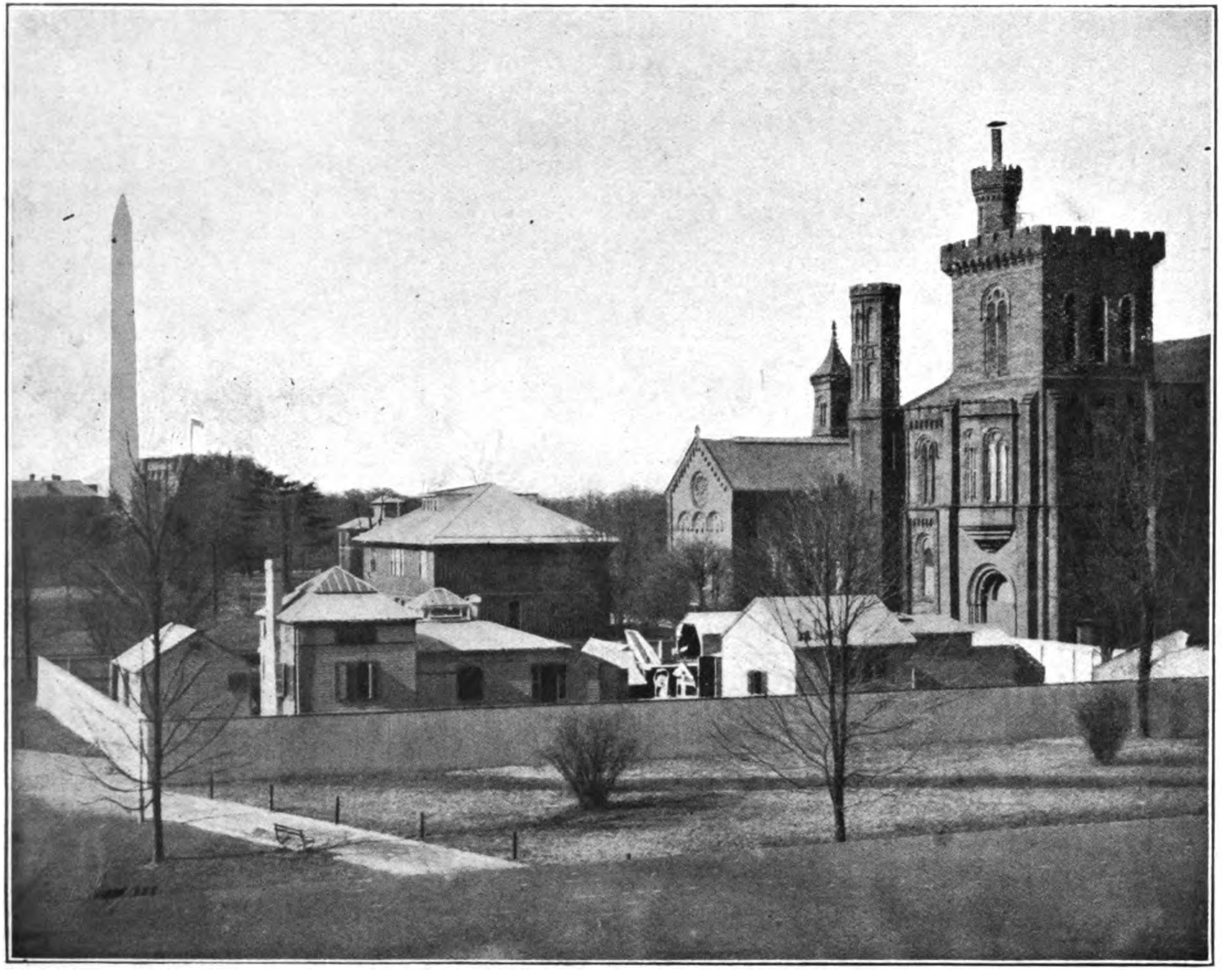
Doctor of Science. We are pleased to notice that during the past year Bates College, Lewiston, Maine, has conferred upon O. C. Wendell, now at Harvard Observatory, the richly deserved honor of the degree of Doctor of Science.

The Hough Double Stars by Eric Doolittle. A useful publication by the University of Pennsylvania, in the Astronomical Series Vol III, part III, is just received. It is by Professor Eric Doolittle of Flower Observatory, and is a catalogue and remeasurement of 648 double stars discovered by Professor G. W. Hough, now director of the Dearborn Observatory at Evanston, Ill., since the year 1881. Professor Doolittle speaks of the neglect of the Hough double stars as follows:

"When making up a new observing list for the Flower Observatory in 1899, it was decided to include all Hough pairs in which prior measures had indicated motion as well as those which did not seem to have been adequately measured elsewhere. It soon became evident that the entire list had been remarkably neglected. Of the 490 pairs which have now been published for 13 years, there are but 17 which have been systematically observed, and of these no less than 11 are certainly entirely fixed. Altogether, 383 of these pairs have never been measured except by the discoverer himself, and of these, 199 have only been measured the year of discovery, and 43 only on a single night, or not measured at all.

This neglect is perhaps due to the fact that these close pairs, and those of very unequal magnitude in which motion was shown, are about as difficult as the stars discovered by Mr. Burnham. The number of pairs of this kind, especially since the discoveries of Hussey and Aitken, is becoming so great that it is perhaps not surprising that a large proportion of them are to some extent neglected. It is true that when Hough's first catalogue was published, his own and Mr. Burnham's discoveries comprised a very large proportion of the stars of this type, but since such pairs can in general only be reached with moderately large telescopes, and even with these only when atmospheric conditions are unusually favorable, the proportion of the pairs to the number of observers and to the number of available nights was large. Beside this, the long list of measures at the end of Catalogues III and IV may have led to the impression that Hough himself was adequately observing his own stars; without specially looking the matter up it could not be ascertained that many of them were wholly neglected. Mr. Burnham's new general catalogue, when it is published, unquestionably will greatly increase the efficiency of double star work in this respect for many years to come."

PLATE XXI.



The Astrophysical Observatory of the Smithsonian Institution, Washington.

Popular Astronomy.

Vol. XVI, No. 6. JUNE-JULY, 1908. Whole No. 156

THE STORY OF HALLEY'S COMET.

JOHN CANDEE DEAN.

FOR POPULAR ASTRONOMY.

After an absence of seventy-five years, and after visiting a region that is perhaps fifty million miles more distant than the outermost planet of the solar system, Halley's comet is again approaching us, and even now, is nearer to us than the planet Saturn.

The return of this celebrated comet—the first known to move in a closed orbit—causes it to be an object of extraordinary attention. Its brilliancy, its sensational size, the records of its returns, extending back nearly two thousand years—the consternation spread throughout the world by the belief that it would destroy the Earth, make it the most famous comet in history.

In 1682, during the reign of Charles II, a comet appeared of extraordinary size which was observed by Newton, Halley and other astronomers of the time. Halley followed its course among the stars and comparing his observations with the records of previous comets, came to the conclusion that the comets of 1456, 1531 and 1607 were but different appearances of the same object. He staked his reputation on a prediction that the comet would return in about seventy-five years. True to this prediction, it did appear in 1758, when Halley had been sleeping in his grave for sixteen years. The reason that the name of Palitsch, a Saxon peasant has been preserved to posterity is, that his eye was the first to catch sight of the returning comet.

Comets have always been considered precursors of war and other horrible woes. This belief, even now, is not confined to the unlearned. Once it was universal. In the year 43 B. C. a comet appeared that was so bright it could be seen in the daytime. This was the year following the assassination of Julius Caesar, and the Romans believed it to be his metamorphosed soul armed with fire and vengeance. No wonder that the great comet added to the confusion following the death of Caesar. Rome was without a ruler. Civil war added to the prevailing consternation. Octavius was playing with the senate, waiting for his opportunity to assume control. Caesar's assassins had either been killed or driven from Rome. Brutus and Cassius fell at Philippi and the delicate neck of Cicero had been severed by a single stroke of a Roman soldier's sword.

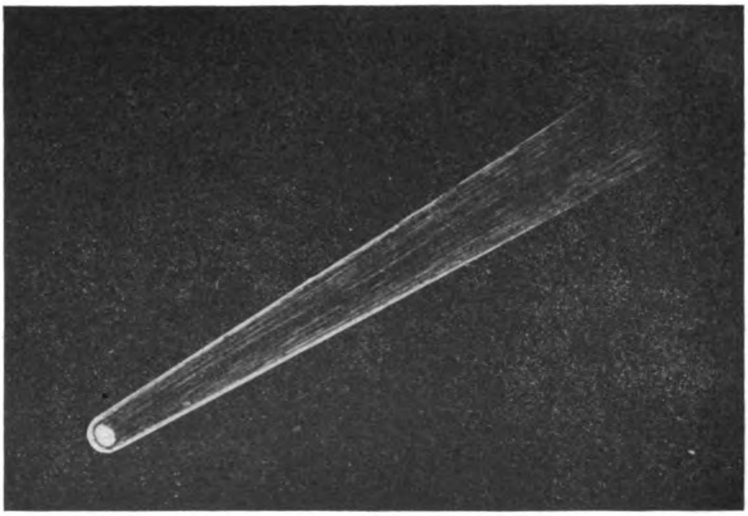


FIGURE 1
HALLEY'S COMET OF 1682.

When the great die, it is natural to think that all nature is convulsed.

"A little ere the mightiest Julius fell,
The graves stood tenantless, and the sheeted dead
Did squeak and jibber in the Roman streets:
As stars with trains of fire and dews of blood,
Disasters in the Sun; and the moist star;
Upon whose influence Neptune's empire stands,
Was sick almost to doomsday with eclipse."

Calphurnia had warned Caesar of his impending fate by saying—

"When beggars die there are no comets seen;
The heavens themselves blaze forth the death of princes."

In 1680, only two years before the appearance of Halley's comet, there blazed forth a comet that was remarkable for being the one which Newton first proved to be moving under the Sun's attraction. It was also notable for having been investigated by Halley, who found that this brilliant celestial body had appeared at intervals of about five hundred and seventy-five years, of which this was the fourth recorded return. Its first appearance, which closely followed the death of Caesar, has just been referred to; its second visit was in the year 531; its third in 1106; its fourth in Halley's time; and its fifth may be looked for by our expectant posterity about the year 2255.

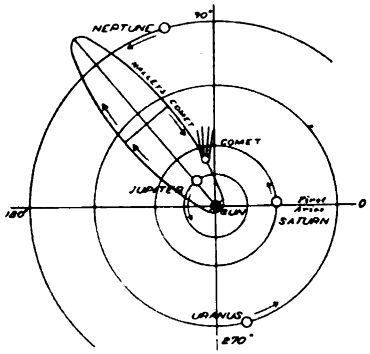


FIGURE 2
ORBIT OF HALLEY'S COMET.
Showing position of the major planets for July 1st, 1908 and probable position of Halley's Comet on that date.

When Halley traced the orbit of his comet of 1682, he discovered it coincided with that of the comet observed by Kepler in 1607. So close were the orbits together, that if drawn in the heavens, the human eye could almost see them joined in a single line. He found that it was also true of the comet seen in 1531. This was conclusive proof that these bodies were identical. It is said that from the testimony of early writers, Halley traced the returns of his comet back for seventeen centuries.

One of the early appearances of Halley's comet was in 1066, and because this was the year of the Norman Conquest of England, unusual attention was drawn to it. To William, the Conqueror, it was an auspicious sign in the heavens, but to Harold and his army it proved a portentous omen.

In the library of the city of Bayeux, France, is preserved a remarkable piece of tapestry of great archaeological interest by reason of the details shown of arms and costumes. It is embroidered with episodes of the Norman Conquest from Harold's visit to the Norman court, to his death at the Battle of Hastings, and is said to have been made by Matilda, queen of William the Conqueror. On it is figured Halley's comet of 1066.

On the return of this comet in 1456, a wider terror was spread than ever known before. It was described by those who saw it as an object of unheard of dimensions, with a tail that stretched more than a third of the way across the heavens. The belief was general among all classes that the comet would destroy the Earth and that the Judgment Day was at hand. Three years before, the victorious Turks had captured Constantinople. This year Mohammed II, surnamed "The Conqueror," crossed the Hellespont with his army and threatened to overrun all Europe. The terror was such that the people seemed regardless of the present and anxious only for the future. They gave up all hope and prepared for their doom. Treasure uncounted was poured into the apostolic chamber, by the frightened people. Alfonso Borgia was pope, under the title of Calixtus III. He ordered the Ave Maria repeated three times a day instead of two, and to the prayer was added—"Lord save us from the Devil, the Turks, and the Comet." He ordered the church bells rung at noon, which was the beginning of a practice still common in Christian countries.

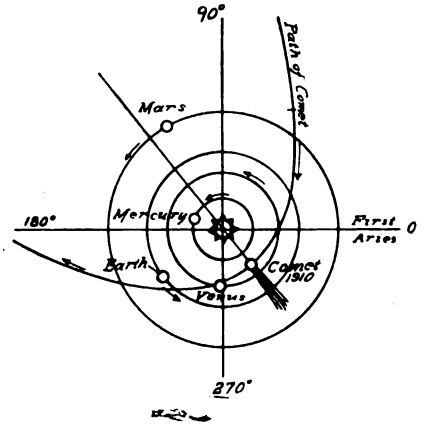


FIGURE 3.
ORBIT OF HALLEY'S COMET.
Showing the position of the Terrestrial planets on May 1st, 1910 and probable perihelion position of Halley's Comet on that date.

FIGURE 4.
DONATI'S COMET OF 1858.

At length the fiery comet began to wane; a victory had been achieved over the demon in the firmament, the Turks were checked by Hunyady at Belgrad, but tranquility was not fully restored until the final disappearance of the comet.

Halley's comet of 1682 was larger and brighter than that of 1456. Its tail was more than ninety-six million miles in length, but science had robbed it of its terrors, and history pointed to the failure of its predecessor. Newton had just discovered the law of universal gravitation, which explained the motion of planets and comets around the Sun and placed the solar system on a mechanical basis.

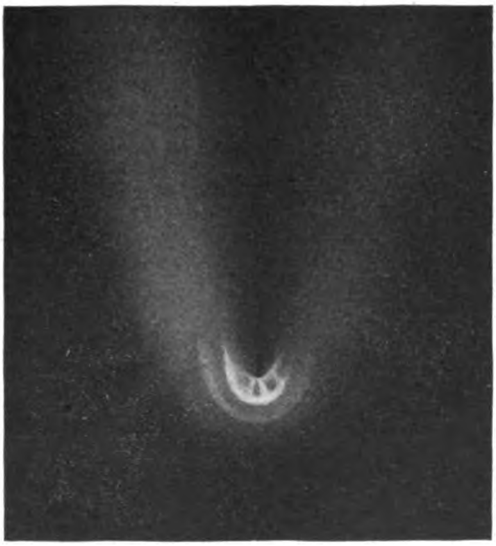


FIGURE 5.
HEAD OF DONATI'S COMET.

The tendency of a superstition to persist, even after closely allied phenomena have been explained on a purely natural basis, is illustrated in the belief that planetary motion was due to guiding spirits. Although Copernicus discovered that the planets revolved around the Sun, instead of the Earth, he still believed that their motion was controlled by these spirits. Galileo confirmed the truth of the heliocentric theory, but his faith in the supernatural motion of the planets was undisturbed.

Not until the genius of Newton had discovered the law of universal gravitation, and provided a mathematical foundation for Kepler's laws, were these conducting spirits entirely dismissed. It required the discoveries of three great men and two centuries of time to disprove the foolish fancy of little men.

Edmund Halley was a great astronomer who had an illustrious career. He was secretary of the Royal Society, professor of geometry at Oxford, and Astronomer Royal.

William III placed him in command of a ship for scientific exploration, more especially for the purpose of studying the variation of the magnetic needle, and also ordered him to visit the American colonies to make such observations as were necessary for the more accurate determination of their longitude and latitude. Halley's constant gaiety, cosmopolitanism, and good fellowship, won for him great popularity with his colleagues, while his reputation as a scientist was earned by the most arduous and protracted labor.

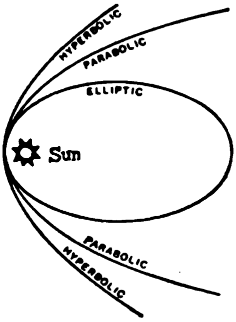


FIGURE 6.
ORBITAL CURVES OF COMETS.
Periodic comets move in elliptical orbits. Comets of higher speed move in parabolic orbits. Comets of the highest speed move in hyperbolic orbits. The last two curves carry them off into the wilderness of space, never to return.

His career was closely interwoven with that of Newton's. It is related that Halley, Hook and Sir Cristopher Wren were at London debating about the forces controlling planetary motion. Finally Halley announced that he would go down to Cambridge and present the question to the great Newton. Going direct to the philosopher's rooms at the University, he at once asked—"What orbit will a planet move in, if attracted by the Sun inversely as the square of the distance?" "In an an ellipse" said Newton. "How do you know that?" said the astonished Halley. "I have calculated it" said Newton. He then told of many more wonderful discoveries, and, to Halley's joy, informed him that they were all written out in a manuscript which he would give him to read; but to Halley's dis-may the volume could not be found. It had been mislaid, and he returned to London without it.

Afterward Newton reproduced his manuscript and forwarded it to Halley. He found that it was an orderly and scientific unfolding of the achievements of the greatest scientist that the world had produced. It satisfactorily solved all the great problems of astronomy. It showed that comets like the planets, revolve in regular orbits. It gave to the world the great discoveries for which mankind had long been waiting, and furnished a foundation for modern thought and modern science.

Perhaps Halley's greatest achievement was in rescuing this work from oblivion, obtaining the consent of the author to publish, paying the expense himself of publication and personally seeing the work through the press. It is known as Newton's "Principia" and is said to be incomparably and indisputably the greatest scientific work ever published.

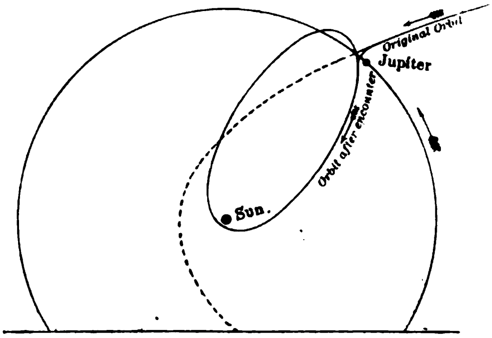


FIGURE 7.
SHOWING HOW JUPITER ENTRAPS COMETS.
The original orbit of comet is indicated by the dotted line. When the comet happens to pass near Jupiter, it is drawn out of its course and takes the new elliptical orbit shown, the outer end of which is near Jupiter's orbit.

The discovery that Halley's comet was periodic established the fact that many comets are members of the solar system and governed by the same laws of motion as the Earth and other planets. Their orbits, however, are flat ellipses and their planes of revolution bear no relation to the ecliptic.

If a periodic comet were the only member of the solar system, its path would be an exact ellipse and its period of revolution unchangeable, but, owing to gravitational attraction of the great outer planets, comets are sometimes drawn out of their courses, which affects their time of revolution around the Sun; hence, it becomes necessary to compute each return separately. The last return of Halley's comet was in 1835. Four great astronomers had figured its orbit, and assigned November as the time for its nearest approach to the Sun. This proved to be correct. It passed its perihelion on November 16th and was visible from August 5th, 1835 to May 5th, 1836. The late Compte de Pontecoulant published the result of his computations in 1864 and gave May 1910 as the time for the comet's next perihelion passage. It is quite probable that photographs of Halley's comet will be obtained before the end of this year. Figure 10 shows the apparent positions of the comet in the heavens for every three months, from July 1st, 1908 to October 1st, 1909, after which time it will probably be visible to the naked eye.

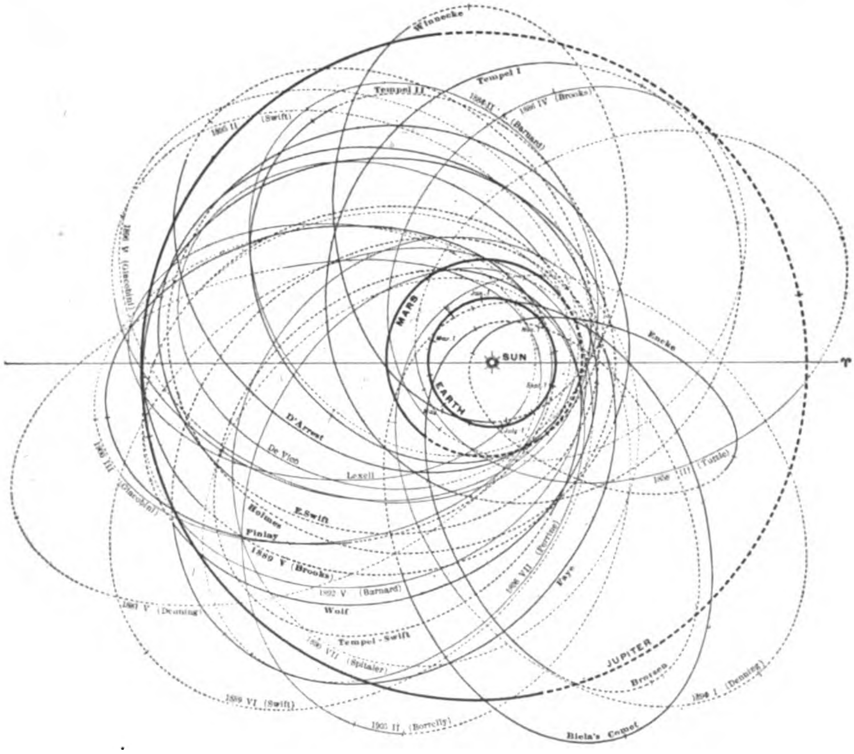


FIGURE 8.
JUPITER'S FAMILY OF COMETS.

From what has been said, it will be observed that the period of Halley's comet is about seventy-five and a half years. Figure

2 shows that its orbit extends beyond Neptune's; in fact, at aphelion it is five hundred million miles farther from the Sun than Neptune is, while at perihelion it is thirty-eight million miles nearer to the Sun than the Earth is. The Earth's orbit is too small to appear in this figure, and Figure 3, drawn on a much larger scale, is introduced to show the comet's orbit when near the great luminary.

For the past thirty-five years, Halley's comet has been traveling toward us, and it is now nearer to us than Saturn. The plane of the comet's orbit is at an angle of seventeen degrees to the plane of the Earth's orbit, and its motion is retrograde, or in a direction opposite that of the planets. All the planets move eastward, while Halley's comet moves westward. It must not be assumed that its orbit is so large that it extends into the region of the fixed stars. The distance to the nearest of the fixed stars is so vast that a comet moving under the Sun's attraction from that region would require twenty-million years for a complete revolution.

Not more than one comet in five is periodic. When the flight of a comet is more than twenty-six miles a second, at a distance of ninety-three million miles from the Sun, its orbit will be either a parabola or a hyperbola, and after passing around the Sun, these curves will carry it off into limitless space never to return. If, however, the speed is less than stated above, the orbit will be elliptical, and as the ellipse is a closed curve, the comet will re-appear at regular intervals.

Certain periodic comets have had their orbits changed from parabolas to ellipses by the disturbing attraction of the outer planets. This problem was worked out by Laplace, who found that when an irregular comet passed closely in front of a large planet, its velocity would be retarded to such an extent that it would fall into an elliptical orbit and become periodic. If the planet were Jupiter it would be said that the comet had been "captured" by Jupiter, and belonged to "Jupiter's family." Its aphelion point would then remain near Jupiter's orbit. Neptune has a family of six comets including Halley's; Uranus a family of three; Saturn two, and Jupiter about thirty. Figure 8 shows the orbits of Jupiter's family of comets. It is large because its mass is greater than that of all the other planets combined, and its influence over comets is proportioned to its mass. The individuals of Jupiter's family are small and their periods of revolution run from three to nine years.

Large comets are magnificent objects, as bright as Venus, with nebulous heads sometimes as large as the Moon, and luminous trains extending one-third of the way across the sky. The most celebrated comet of the nineteenth century was Donati's, which attained its greatest brilliancy in October 1858. Its orbit is elliptical, and its period of revolution around the Sun is nearly two thousand years. This comet is shown in Figure 4, and its remarkable head, from the drawing made by Bond (who was director of Harvard Observatory at the time of its appearance) is shown in Figure 5.

Comets consist of three parts—

1st—The nucleus, or bright starlike kernel, which is the real comet, and from which the other parts are evolved.

2nd—The coma or hazy envelope surrounding the nucleus.

3rd—The tail or luminous train stretching away into space. Sometimes the tail is entirely wanting or hardly discernible.

It is a strange fact that the tail follows the comet as it approaches the Sun and goes before it when it recedes from the Sun. The tail develops as the comet draws near the great luminary, and diminishes in size and splendor as it moves away from it. On the contrary, the nucleus and coma always contract when near the Sun and expand again as the comet recedes.

The mass or weight of comets is small compared with other heavenly bodies, but their volume is much larger than any member of the solar system. The mass assumed by Young for the very largest comet, like Halley's, is equal to a ball of iron 150 miles in diameter. The tail is so unsubstantial as to be below the density of the best vacuum scientifically obtained. It is millions of times less dense than our atmosphere.

Comets have neither tails nor light until they approach the Sun. The tails are evolved by the stimulus of the Sun's heat. They become luminous by solar light and heat. When a distant comet is discovered through the telescope, it is merely a round nebula, but as it approaches the Sun the nucleus appears and a luminous jet or tail developes.

The very recent discoveries in radio-activity and of light pressure, give a complete explanation of the nature of tails of comets. Professor Arrhenius, of the University of Stockholm, is the father of nearly all the theoretical interpretations of observed phenomena of mechanical pressure of sunlight.

The tails of comets at first show the presence of hydrocarbons, and as they approach still nearer to the Sun, metallic vapors appear. The matter composing the tail is driven out of the nucleus by solar heat and is repelled by light pressure into space, where it passes away never to be recovered by the comet. The tail increases in size as the comet passes nearer to the Sun. Iron, magnesium, and other metallic vapors appear, and as the heat increases, the hydrocarbons break up into smoke or soot. The pressure of sunlight is probably due to the bombardment of corpuscles constantly flung from the Sun. This pressure is delicate for a given area, and for the whole Earth's surface amounts to only 70,000 tons; but very finely divided matter, like the soot of the comet's tail, is acted on energetically and driven out with enormous velocity. The Sun's powerful light illuminates the particles of free carbon and causes the tail to glow with a silvery light.

Closely associated with the subject of comets is that of meteors, or shooting stars, which occasionally penetrate the atmosphere and fall to the Earth. They are supposed to be fragments of comets, as will be shown presently. It is estimated that about five hundred meteoric stones annually strike the Earth's surface. Most of these are small, not weighing more than a pound or two, while some weigh hundreds of pounds. The largest known meteorite is that which was brought from the west coast of Greenland in 1897 by Lieutenant Peary, U.S.N. It weighs ninety-tons and is composed of 92 per cent iron, and eight per cent nickel. The only pure iron found on the Earth's surface is of meteoric origin. Meteors are black, cold and invisible until they enter our atmosphere. The friction due to shooting through the air at an incredible velocity of perhaps forty miles a second, fuses them to a white heat, causing them to glow with the brilliancy of the electric arc. Before they enter the atmosphere, they are called meteoroids; while luminous they are called meteors; after they strike the Earth they are called meteorites.

The mean velocity with which meteors enter the upper atmosphere is about twenty-six miles a second, or one-hundred times the muzzle speed of a rifle bullet. It is calculated that five hundred million meteors collide with the air every day and although their average size may not be larger than a buckshot, the enormous penetrating power of even the smallest meteoric grains would be sufficient to destroy all life were it not for the thick, soft, elastic, kindly envelope of air that surrounds us.

Nearly all meteors burn out and volatilize by air friction within a second of time, while still fifty miles from the Earth's surface. Until the discovery of the mechanical theory of heat, the phenomenon of burning meteors was a stumbling block to investigators. Lord Kelvin showed that a thermometer placed in front of a rapidly moving body rose one degree when passing through the air at 125 feet per second and the temperature increased as the square of the velocity. A few grains of meteoric iron striking the atmosphere with the velocity of celestial matter evolves as much light and heat as the explosion of several pounds of gunpowder.

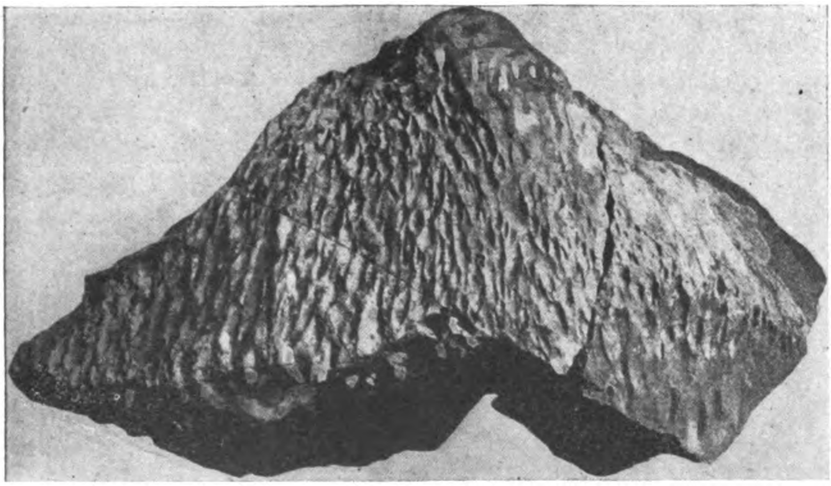


FIGURE 9.
A METEORITE. WEIGHT 700 lbs. PHOTO BY FARRINGTON.

The very few large, firm meteors that pass through the atmosphere without being destroyed by potential heat, have their motion reduced to the moderate velocity of 400 to 500 feet per second. At Upsala, Sweden, fragments of a meteor struck the ice of a lake in winter and rebounded without breaking the ice.

It is believed that vast swarms of meteoroids revolve around the Sun. Under certain favorable conditions these meteoric rivers become visible to the naked eye. A few minutes after sunset, especially in the spring, an afterglow of white light, resembling the Milky Way, may be seen extending from the western horizon along the Zodiac towards the zenith. It is conical in shape with the middle of its base where the Sun sets. It is called the zodiacal light and has been observed for ages. It is also visible in the early morning. In the Orient, where there are religious ceremonies at the break of day, the light is called the "fox's tail" or "false dawn." It is supposed to be the reflected light from myriads of meteoroids revolving around the Sun, extending their course far beyond the orbit of Neptune, the outermost planer of the solar system.

When comets pass quite close to the Sun they are subjected to disintegrating influences, and have been known to divide even while under the observation of astronomers. Whenever a comet begins to break up, the disintegration continues until it becomes a mere group of cometary fragments moving in a great elliptical orbit around the Sun. Roche, Maxwell and others have discovered a law which explains the breaking up of comets. It is called the "Law of Disruptive Approach" and is substantially as follows:—

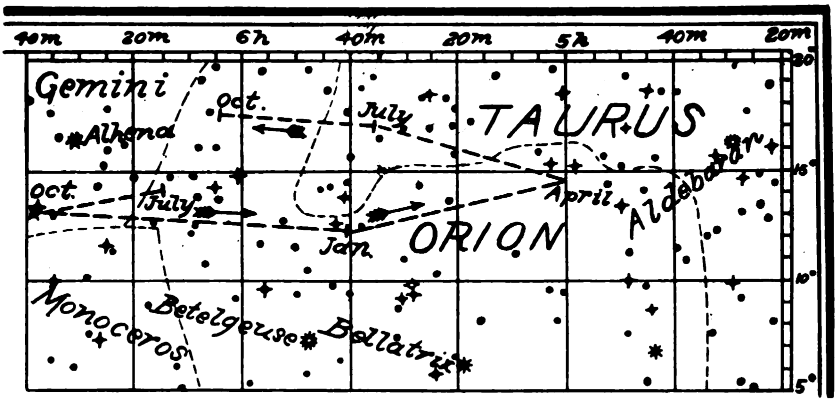


FIGURE 10.

COURSE OF HALLEY'S COMET.

The dotted lines connect the predicted positions of Halley's Comet for every three months from July 1st, 1908 to October 1st, 1909.

Whenever a celestial body passes within a certain distance of a larger, denser body, it will be torn into fragments by differential attraction. The critical distance varies with the relative sizes of the two bodies, and is called "The Roche Limit." This law not only explains the cause of the disruption of comets, but also accounts for the phenomenon of the rings of Saturn. By the disruptive approach of one or more of Saturn's Moons, within the Roche limit, they have been pulverized into meteors, which form the beautiful rings that revolve around the planet.

Mention has been made of gases being driven out from the nuclei of comets by the heat of the Sun, thereby contributing material for the phenomenon of the tail. It has been found that meteorites are saturated with occluded gases, hydrogen, helium and carbon oxides. At one time Dr. Odling lighted up the theater of the Royal Institution with gas brought down from interstellar space by meteorites.

Because comets, unlike planets, observe no one direction in their orbits, but approach and recede from their great center of attraction in every possible direction, the danger of their collision with the Earth has raised a question of serious interest.

There is not the slightest doubt that if the head of a large erratic comet should strike the Earth, it would instantly reduce it to chaos, mingling its elements in ruin, which would result in universal death to nearly all forms of life. Should the nucleus of such a comet even sweep through the regions of our atmosphere, the resulting intensity of light would probably blind every eye that beheld it, and the gases evolved would vitiate the air so as to render it unsuitable for breathing.

The question of the danger of collision with comets was of such importance that the French government at one time called the attention of its ablest astronomers to the solution of the problem, and after mature examination they reported as follows:

"We have found that out of 281,000,000 of chances, there is only one unfavorable. Admitting then, for a moment, that the comets which may strike the Earth with their nuclei would annihilate the whole human race, the danger of death to each individual, resulting from the appearance of the unknown comet, would be exactly equal to the risk run, if in an urn there was only one single white ball among a total of 281,000,000 balls, and that his condemnation to death would be the inevitable consequence of the white ball being produced at the first drawing.

From an examination of Figure 3 some may infer that there is danger of Halley's comet clashing with some one of the planets. It must be remembered that this comet moves at an angle to the plane of planetary motion and loops through that plane at points where there is no possibility of collision.

Indianapolis, Indiana,
March 26, 1908.

THE CONSTANTS FOR THE EQUATOR.

ROBERDEAU BUCHANAN.

FOR POPULAR ASTRONOMY.

These constants as they are called are employed for the purpose of computing the rectangular coördinates of a planet in order to find the Right Ascension and Declination directly from the elements; but if applied to the major planets, they are very liable to lead the computer into one or more mistakes which would vitiate his results, and which it is the object of this article to point out. And moreover the astronomies which give these formulæ do not allude to this fact in any way.

The source of error is first, that this method does not take account of the perturbations of the heliocentric latitude, and the second is, what quantity is to be considered as the perturbations? This is also very likely to lead to another error.

It will perhaps make this matter more clear to give all the formulæ. The usual formulæ which are rigorously correct in all cases are as follows:

First Group: Rigorous formulæ

$$\lambda = \iota + \text{Equation of the Equinoxes} \qquad (1)$$

$$\left.\begin{aligned} x &= r\cos\beta\cos\lambda \\ y &= r\cos\beta\sin\lambda\cos\epsilon - r\sin\beta\sin\epsilon \\ z &= r\cos\beta\sin\lambda\sin\epsilon + r\sin\beta\cos\epsilon \end{aligned}\right\} \qquad (2)$$

The formulæ for the Constants for the Equator are as follows, their deviation may be found in Watson's Theoretical Astronomy, pp. 88-93, under Admiral Davis' Appendix of Gauss' Theoria Motus.

Second Group:

$$\Omega = \theta + \text{Equa. Equinoxes} \qquad (3)$$

$$i = i_1 + \Delta\ i \qquad (4)$$

$$\tan E = \frac{\tan i}{\cos\Omega} \qquad (5)$$

$$\left.\begin{aligned} \cot A &= -\tan\Omega\cos i & \sin a &= \frac{\cos\Omega}{\sin A} \\ \cot B &= \frac{\cos i\cos(E+\epsilon)}{\tan\Omega\cos E\cos\epsilon} & \sin b &= \frac{\sin\Omega\cos\epsilon}{\sin B} \\ \cot C &= \frac{\cos i\sin(E+\epsilon)}{\tan\Omega\cos E\sin\epsilon} & \sin c &= \frac{\sin\Omega\sin\epsilon}{\sin C} \end{aligned}\right\} \qquad (6)$$

And the coördinates are

$$\left.\begin{aligned} x &= r \sin a \sin (A + u) \\ y &= r \sin b \sin (B + u) \\ z &= r \sin c \sin (C + u) \end{aligned}\right\} \qquad (7)$$

As the equation of the equinoxes is added to the longitude ι in equation (1) to reduce the latter as given in the *Nautical Almanac* from the mean equinox of January 1 to the equinox of the given date, so it must be added to the node θ Equation (3) in the second group.

The latitude β_0 given in the tables of the planets as shown in a previous article in POPULAR ASTRONOMY XV, p. 140 is computed as follows:

$$\sin \beta_0 = \sin i \sin u \qquad (8)$$

which is generally tabulated. Then in using the Tables:

$$\beta = (\beta_0 - C^1) + pp + (\text{Pert} + C^1) + \text{sec var} \qquad (9)$$

We will now compare these equations last given which belong to the first group with the equations of the second group. The constant C^1 (ibid. p. 141,) is merely for the convenience of using the tables; it is the sum of all the constants added to each table ot perturbations, in order to make all the quantities positive; and to keep up the equality it is deducted from the principal term of the longitude radius vector or latitude as the case may be. It is sometimes omitted. The proportional part *pp* is merely the interpolation from the tabular values to the exact value of the argument. The secular variation is taken account of in the second group by the change Δi in the inclination of the orbit i which is given in the Tables as the change in 100 years to be multiplied by the fraction of a century after 1900. The remaining term, the perturbations, it is seen are not taken account of in the second group. It will be noticed that in equation (2) that they do not affect the coördinates x; since a small change in β would have very little effect upon its cosine but this affects y and z through the term $\sin \beta$. We can easily ascertain what effect the perturbations have upon the other coördinates by differentiating the two latter of equations (2) with β as the variable in the second member.

$$\left.\begin{aligned} dy &= - r \sin \beta \sin \lambda \cos \epsilon d\beta - r \cos \beta \sin \epsilon d\beta \\ dz &= - r \sin \beta \sin \lambda \sin \epsilon d\beta + r \cos \beta \cos \epsilon d\beta \end{aligned}\right\} \qquad (10)$$

The results being generally very small the first terms in the second member containing sin β are generally insignificant and may be neglected; cos β may be placed equal to unity, and we have left:

$$\begin{aligned} dy &= -r \sin \epsilon d\beta \\ dz &= r \cos \epsilon d\beta \end{aligned} \qquad (11)$$

in which $d\beta$ is to be taken as the perturbations of the latitude and dy, dz, are its effects upon the coördinates. But for practical use, these formula must be still further transformed. Since $d\beta$ is given in arc, while y and z are given in parts of radius the second members must be multiplied by sin 1″ and as ϵ changes very slowly we may for a number of years to come, take it as 23° 27′ with its sine and cosine constant and multiplying the second number by 10^7 to give the results in units of the seventh decimal of logarithms we have, combining the constants and giving the result by its logarithm

$$\begin{aligned} dy &= -[1.285]\, r d\beta \\ dz &= [1.648]\, r d\beta \end{aligned} \qquad (12)$$

And here the second source of error may arise, $d\beta$ must be taken as purely the perturbations, freed from secular variation of the latitude which is generally combined with them in using the tables, and if a constant has been added to the tables of the latitude, it must be deducted; dy and dz are then the effects of the perturbations upon the coördinates y and z to which they are to be algebraically added.

In case the perturbations of the planet may be large, equation (10) should be examined to ascertain whether the omitted terms become appreciable.

These equations look formidable, but they are quite easy, since the quantities vary slowly and may be computed for an interval of five or ten days, using seven place logarithms.

The constants for the equator were first used for finding the geocentric places of newly discovered asteroids. In this case there are no perturbations to be considered; and the equations of the equinoxes may be omitted at first, to be taken account of at the end of the work. The constants then vary quite regularly and may be computed for an interval of at least one year if necessary, and interpolated for the intermediate dates. The elements of the asteroid are supposed to have been computed, and the work then proceeds as follows.

The mean anomaly M is found from the mean motion and the epoch date; the eccentric anomaly E from Kepler's equa tion $M = E_1 - e \sin E$; and the true anomaly v and distance r, from the equations

$$\sqrt{r} \sin \tfrac{1}{2} v = \sqrt{a(1+e)} \sin \tfrac{1}{2} E$$
$$\sqrt{r} \cos \tfrac{1}{2} v = \sqrt{a(1-e)} \cos \tfrac{1}{2} E$$

Then u is given by the following

$$u = v + \pi - \Omega.$$

With the constants for the equator the coördinates x, y, z, may now be computed and the geocentric place derived by the usual formulæ. Finally the results may be reduced to the equinox of the date by applying the equation of the equinoxes in right ascension and declination which may be taken from the *Nautical Almanac.* Professor Watson in his Theoretical Astronomy gives an example of this work, with also a method of solving Kepler's equation.

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THE ART OF NUMERICAL CALCULATION.

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FOR POPULAR ASTRONOMY.

The circumstances affecting the numerical solution of problems are so different from those accompanying analytical investigations that the qualifications of the computer are quite distinct from those of the mathematician. Yet they include something more than the ability to combine numbers with rapidity and precision, for the practice of the art of computation requires, in a high degree, judgment, while the dexterous manipulation of figures depends mainly upon a specialized development of the memory. The possession of one of these faculties by no means implies the existence of the other. Indeed the extraordinary memory for figures exhibited by such prodigies as Dase, Mondeux, and Inaudi is frequently accompanied by a deficiency in those qualities necessary for the practice of the art in its broader sense.

It is the purpose of this paper to indicate the origin and nature of the requirements of the computer, and to formulate certain details important for the numerical solution of problems occurring in scientific investigations.

I

In order to understand the nature of the qualifications of the computer, we must consider, first, the origin and character of the data entering into computations; second, the distinctive features of the aids used by the calculator for the facilitation of his work; and, finally, the limitations of mathematical expressions when used as a basis for quantitative investigations.

The data used by the computer are usually the result of observation and experiment, and as such, are affected by errors of observation. Errors of observation, carefully to be distinguished from mere blunders, such as the incorrect reading of a circle by a whole degree or an exact number of minutes, arise from a variety of causes. The limitations of the observer's senses, defects of construction and adjustment in the instrument, and variations in the temperature of the surrounding air cause the final result to differ from the value sought by the observer. Certain disturbing factors can be neutralized by a special arrangement of the observing program; others can be minimized by care and the use of instruments of high precision; but even when instrument maker and observer have done their best there remains in the final result an uncertainty beyond control, whose magnitude varies with the nature and circumstances of the observations. It may amount to a considerable fraction of a foot, as in the measurement of a long line with the surveyor's chain, or it may be only a few billionths of a millimeter, as in the precise determination of the wave length of a line of the solar spectrum. It may be a minute of arc, as in the measurement of the altitude of a star with the engineer's transit, or only one or two tenths of a second, as in the precise determination of latitude with the modern zenith telescope.

The aids employed by the computer for the facilitation of his work are numerous. That most commonly used is the ordinary logarithmic-trigonometric table, and the remarks which follow apply particularly to this contrivance, although they are true, in a measure, of the various other aids used to lessen the labor of numerical calculation.

The quantities whose numerical values are contained in a table of logarithms can not be expressed exactly in the form of a decimal fraction. The difference between the true value and the numerical expression for the same can be reduced to any assigned limit by sufficiently increasing the number of decimals, but, however great this number, the representation will not be exact. The tabular values of the logarithms are therefore approximations. The approximations of a 7-place table are of a higher order than those of a 5-place table, but they are, nevertheless, approximations. Further, the computer usually requires, not the printed values of the function, but those corresponding to intermediate values of the argument. Thus, he may desire the logarithm of the sine of 26° 18′ 36.″4 to six places of decimals, a quantity not given in any logarithmic table. The ordinary 6-place table contains the logarithms of the trigonometric functions for every 10″, and the required logarithm must be found by interpolation from the tabular values for 26° 18′ 30″ and 26° 18′ 40″. This introduces an additional uncertainty for the interpolation process is usually inexact. The total error in the interpolated quantity has a maximum value of one unit of the last place of decimals, although its average is less. Generalized, this result may be expressed as follows:

$$\mathrm{E}\,[f(x)] = 10^{-r}\,. \qquad (1)$$

The symbol E followed by $f(x)$ in brackets is a general notation signifying the maximum error in $f(x)$. For the case considered, $f(x)$ represents a quantity interpolated from a table of r places with the argument x. For inverse interpolation, namely, that which derives the value of x corresponding to a given $f(x)$, the maximum error of the interpolated quantity is

$$\mathrm{E}\,[x] = 10^{-r}/2\,f'(x) \qquad (2)$$

where $f'(x)$ is the first derivative of the tabular function $f(x)$.

From (1) it will be observed that the maximum error affecting the result of a direct interpolation is independent of the nature of the function and the part of the table used, and varies only with the number of decimals employed. For inverse interpolation the error varies not only with the number of decimals, but also with the nature of the function and the magnitude of the quantity x. As an illustration, consider the following special cases: $f(x) = \log x$, $f(x) = \log \sin x$, $f(x) = \log \cos x$, $f(x) = \log \tan x$. The application of (2) gives,

when x is interpolated from $\log x$, $\mathrm{E}[x] = 10^{-r}\,\frac{x}{2\mathrm{M}}$,
" " $\log \sin x$, $\mathrm{E}[x] = 10^{-r}\,\frac{\rho''}{2\mathrm{M}} \tan x$,
" " $\log \cos x$, $\mathrm{E}[x] = 10^{-r}\,\frac{\rho''}{2\mathrm{M}} \cot x$,
" " $\log \tan x$, $\mathrm{E}[x] = 10^{-r}\,\frac{\rho''}{4\mathrm{M}} \sin 2x$,

in which $\mathrm{M} = 0.434\ldots$, the modulus of the common system of logarithms, and $\rho'' = 206265''$, the number of seconds in the radian. Thus, the maximum error in a number interpolated from its logarithm is proportional to the number itself; and the maximum errors in an angle, x, derived from $\log \sin x$, $\log \cos x$, and $\log \tan x$ are respectively proportional to $\tan x$, $\cot x$, and $\sin 2x$. For the case of the sine and cosine they may be very large owing to the presence of the tangent and cotangent as factors. The last three relations express analytically the well-known fact that the value of an angle can be determined with greater precision from the logarithm of its tangent than from that of its sine or cosine.

Finally, the numerical solution of a problem is accomplished by substituting into a mathematical expression the values of the data corresponding to the problem in question. This involves the combination of a series of numbers which are approximations, for, as we have seen, both the data of observation and the quantities derived from the tables of logarithms are uncertain. The final result must therefore be an approximation. Its error arises partly from the errors in the data and partly from the limitations of the tables. That part arising from the former source we may call the Resultant Error of Observation, while that originating in the limitations of the tables is known as the Accumulated Error of Calculation. The magnitude of these errors depends largely upon the nature of the formula which expresses the analytical solution of the problem. This may be such that the errors of observation enter into the final result greatly reduced in magnitude. For example, in the determination of the value of one division of a scale by a comparison with a second scale of known length, we have for the required quantity an expression of the form

$$d = \frac{r_n - r_0}{n}$$

in which r_n and r_0 are readings from the second scale corresponding to the 0th and the nth divisions of the first. Whatever the magnitude of the errors of observation, they enter into the final result by only $1/n$th of their amount. On the other hand, quite the reverse may be true. Thus, in the calculation of the ratio a/b, where $a>b$, and b itself is affected by an uncertainty, an error of observation if you will, the resultant error of observation will exceed the error affecting b approximately in the ratio of a to b^2. With the errors of calculation the case is different. Here there is almost always a certain multiplication of error, so that the accumulated error of calculation is usually in excess of the uncertainties attached to the individual numbers which enter into the computation; and, generally speaking, the longer the calculation, the greater will be the accumulation or multiplication.

Again, the solution of a given problem is frequently capable of expression in a variety of ways. Analytically considered, these may be identical, but viewed from the standpoint of practical applications, they may present the greatest diversity. For example, the two expressions

$$y = 2 \sin^2 1/2\, x \tag{3}$$

$$y = 1 - \cos x \tag{4}$$

are theoretically equivalent, but when used for the calculation of values of y corresponding to given values of x, they are by no means identical, especially for values of x near 0°. As an illustration, consider the final errors resulting from an r-place calculation of (3) and (4) for the determination of y corresponding to $x = 2° \pm 2'$, where we may think of x as the result of an observation whose uncertainty is expressed by the appended quantity $\pm 2'$. An appropriate investigation shows that their maximum values are

$$\mathrm{E}\,[y] = 0.00002 + 0.003 \times 10^{-r}, \tag{3a}$$

$$\mathrm{E}\,[y] = 0.00002 + 3 \times 10^{-r}. \tag{4a}$$

The first terms in the right members are the resultant errors of observation. The last are the accumulated errors of calculation. So far as the precision to be obtained with a specified number of decimals is concerned, the advantage is obviously in favor of equation (3).

With these facts before us we are in a position to appreciate better the qualifications required of the computer. His aim must be so to arrange the calculation that the errors in the data and the errors of calculation will produce the minimum possible effect upon the final result, and, at the same time, to derive this result with the least possible expenditure of time and labor. It is evident that his task is one of some complexity. The conditions to be satisfied are, to a certain extent, contradictory. For example, the accumulated error of calculation can be reduced to any desired limit by sufficiently increasing the number of decimal places employed; but any such increase carries with it a notable increase in the labor of calculation. On the other hand, a reduction of labor can often be brought about by a modification of the formula to be calculated, but this in turn may involve a sacrifice of precision.

The adjustment of these variable factors to each other and to the requirements just expressed demands a nice balancing of detail, which becomes only the more difficult when it is considered that the problems presenting themselves for solution, and the conditions under which they arise, are the most diverse imaginable. It is obvious that the computer has to deal with questions whose answers are not to be discovered through the exercise of whatever skill he may possess in the manipulation of figures, however important this accomplishment may be for the technical performance of his labors. They can be found only in a detailed knowledge of what has been but outlined in the preceding paragraphs. In addition, the computer must ever be upon the alert with a discriminating judgment, if his work is to be consistent in its details, and economical of the time and energy required for its execution.

II

Leaving now the consideration of the subject in its general aspects, we proceed to a discussion of matters of more immediate practical significance.

(a) *General Arrangement and Procedure.*

Computations are most conveniently made upon cross section paper whose squares measure one-fifth or one-sixth of an inch on the side. Before any figures are entered, the symbols for the quantities to be combined should be written in a vertical column at the left of the sheet, care being taken to bring together, as nearly as may be, those symbols or arguments whose numerical values are to be combined. Even though the same quantity enter into the calculation at several points, write its argument but once. A very little practice will make it possible to add or subtract numbers which are separated by several intervening quantities. The numbers are to be written in a vertical column immediately to the right of the column of arguments. If the same calculation is to be performed for a number of similar sets of data, the work should appear in parallel vertical columns, that for each set occupying a column by itself. In such a case do not complete the first column before beginning the others, but work across the page, inserting all the numbers corresponding to any given argument before proceeding to the others. If, however, several trigonometric functions of the same angle are required, all should be interpolated with a single opening of the table, even though their symbols occupy widely separated positions in the column of arguments. Further, in computing for similar sets of data, do not enter arguments for quantities which are constant for all the sets, but write the values of such constants on the lower edge of a card or slip of paper. This can be held above the numbers with which the constants are to be united and moved along from column to column as the additions or subtractions are performed. The beginner will proceed with the greatest security by writing the arguments fully and completely, although the experienced computer is able to abbreviate the work by omitting some of the arguments and performing the corresponding operations mentally. Thus, it is possible to form the sum of two logarithms, enter the table, and interpolate the corresponding number without writing down the result of the addition. The argument for the sum can therefore be omitted, but such abbreviations are to be introduced gradually, and only after some skill has been acquired.

Whenever it becomes necessary to abbreviate a number, say to r places, by dropping the higher decimals, increase the digit of the rth place by one unit when the neglected quantity exceeds one-half a unit of this place. If the decimals neglected are less than half a unit of the rth place, they are to be dropped without change in that place. When the neglected part is exactly a half unit of the rth place, it is a good rule to increase the digit of the rth place by one unit, in case that digit is odd; otherwise, drop the higher places without change in the rth place. Errors arising from the abbreviation will thus tend to neutralize each other in the long run.

(b) *Aids to the Computer.*

Machines for addition, multiplication etc. Their operation is so simple that they require no special treatment in this place. Their construction is such that there is no accumulated error of calculation, unless the quantities involved are abbreviated by dropping higher decimal places.

The sliderule. In effect, this instrument is a graphical table of logarithms. In its usual form, the accumulated error of calculation generally amounts to a few units of the fourth place of decimals. It is, therefore, in nowise a substitute for tables of logarithms of 5, 6, and 7, or even 4 places. It is extremely convenient for certain classes of computation, but many experienced computers maintain that properly constructed tables of logarithms give more satisfactory results. In any case, its continued use results in a strain upon the eyes far greater than that accompanying the use of well printed tables.

Multiplication tables. The best are the *Rechentafeln* of Crelle, published by Reimer of Berlin. These tables give directly the exact products of numbers of three figures or less; and can be used for the determination of products of numbers of any magnitude. They can also be used for division, most conveniently, when the divisor is of three figures or less. Their only objection is their bulk. They should be in the hands of every computer.

Logarithmic-trigonometric tables. Those most generally useful are of five places of decimals, although 3, 4, 6, and 7-place tables are also frequently required, and should be within reach of all who have to deal with astronomical or geodetic calculations. In purchasing tables, care should be exercised, for many are badly arranged and unfit for the purpose for which they are intended. With the exception of 3-place tables, those not giving the differences of the adjacent logarithms, at least for the tables of trigonometric functions, should be avoided. The same is true of those not containing auxiliary tables of proportional parts. The tabulation of the logarithms of the trigonometric functions to six places of decimals for every minute of arc, only, is likewise a bad arrangement. It is also important that the tables for the sine and cosine should not be separated from those of the tangent and cotangent. And, finally, it is desirable to select tables containing addition-subtraction logarithms. There are numerous other points of minor importance, but a more detailed discussion can be replaced by the following list of satisfactory tables. The list does not pretend to be complete.

Four-place tables:
- Slichter, Macmillan ;
- Bremiker, Weidmannsche Buchhandlung, Berlin.

Five-place tables:
- Becker, Tauchnitz, Leipzig;
- Gauss, Strien, Halle;
- Albrecht, Stankiewicz, Berlin;
- Newcomb, H. Holt & Co., New York ;
- Hussey, Allyn & Bacon, Boston ;
- Bremiker, Weidmannsche Buchhandlung, Berlin.

Six-place tables:
- Bremiker, edited by Albrecht, Nicolaische Verlags-Buchhandlung, Berlin.

Seven-place tables:
- Vega, edited by Bremiker, Weidmannsche Buchhandlung. This is the best 7-place table.
- Bruhns, Tauchnitz, Leipzig.

In Bremiker's 4 and 5-place tables, the arguments for the trigonometric functions are expressed in decimals of a degree, the intervals being 0°.1 and 0°.01, respectively, for the body of the tables.

It is assumed that the student is familiar with the fundamental principles underlying the construction and use of the ordinary logarithmic-trigonometric tables. The details of their usage can therefore be dismissed with the following precepts:

(1) Do not use negative characteristics. When such occur, increase them by ten, and operate as though a minus ten were written after the logarithm. When two such logarithms are added, the sum will have an appended minus twenty, which should be reduced to minus ten, dropping at the same time ten units from the characteristic.

(2) In case the number corresponding to a given logarithm is negative indicate that fact by writing a subscript n after the logarithm. In combining a number of logarithms, affix a subscript n to the result when the number of n-logarithms is odd. If this is even, the resulting logarithm needs no subscript.

(3) Derive the logarithm of the secant and cosecant from those of the cosine and sine, respectively, by subtracting the latter from zero. This is most easily accomplished by subtracting each digit of the logarithm from 9, proceeding from left to right, until the last is reached, which is to be subtracted from 10.

(4) Interpolate all the functions required for any given angle

with a single opening of the table.

(5) In the formation of powers of numbers, care must be exercised when the power is fractional, and the number less than unity. After the logarithm of the number has been multiplied by the power, p, the appended characteristic, which is normally -10, will be $-10p$. This must be reduced to -10 by adding $10(1-p)$ to the characteristic proper and subtracting the same quantity from the characteristic appended to the result of the multiplication.

Addition-subtraction logarithms. The purpose of these tables is to determine the logarithm of $a+b$ when the logarithms of a and b are given. The following illustrates the principle underlying their construction and use:

Let

$$A = \log N,$$

$$B = \log (N+1),$$

where N represents any number. The addition-subtraction logarithmic table contains the values of B tabulated with the argument A.

Now suppose

$$N = \frac{b}{a}$$

whence

$$A = \log b - \log a,$$

and

$$B = \log \left(\frac{b}{a} + 1\right) = \log (a+b) - \log a,$$

or

$$\log (a+b) = \log a + B.$$

This is the fundamental equation for addition. The procedure is as follows:

Form $$A = \log b - \log a.$$

Interpolate B with A as argument.

Then,

$$\log (a+b) = \log a + B.$$

Again, let

$$N = \frac{a}{b} - 1,$$

whence

$$A = \log (a-b) - \log b,$$

and

$$B = \log \frac{a}{b} = \log a - \log b.$$

These are the fundamental equations for subtraction. The procedure is as follows:

Form

$$B = \log a - \log b.$$

Interpolate A with B as argument.

Then,

$$\log (a - b) = \log b + A.$$

The arrangement of the tables assumed $a > b$ for the solution of both the addition and the subtraction problem. The application of these tables involves the performance of one subtraction, one addition, and one interpolation. The use of the ordinary logarithmic table for the derivation of the same result involves three interpolations and one addition or subtraction. Further, as an illustration, in the 5-place tables of Gauss, the ordinary table covers 18 pages while the addition-subtraction table covers but 12, of which only 4½ are necessary for the addition problem. Finally, it can be shown that the uncertainty of a result derived from the addition-subtraction table is less than that accompanying the use of the ordinary table. From every standpoint, therefore, whether that of the number of operations to be performed, the number of pages to be thumbed, or the accuracy of the final result, the advantage is in favor of the addition-subtraction table.

Tables of squares, cubes, etc. Special tables. Barlow's Tables, containing the squares, cubes, square roots, cube roots, and reciprocals of all integers up to 10,000, is one of the most convenient. The roots are given to seven places of decimals, and the reciprocals partly to nine and partly to ten places. Some of the 5-place logarithmic tables, such as those of Gauss and Albrecht, also contains tables of squares. Any table of squares or cubes can be used inversely for the derivation of square and cube roots.

In addition to the various aids mentioned there are innumerable special tables designed for the solution of special problems. Almost any problem which has to be solved repeatedly for different sets of data can be simplified through the use of specially constructed tables. In this connection there is abundant opportunity for the exercise of ingenuity and skill on the part of the computer.

(c) *Resultant Error of Observation. Accumulated Error of Calculation. Number of Decimal Places.*

The estimation of the effect on the final result due to uncertainties in the data, in other words, the evaluation of the resultant error of observation, is most conveniently made by means of the relation obtained by differentiating the formulæ to be solved with respect to the final result and the quantities whose values are given. The substitution of the uncertainties in the data for the corresponding differentials in this expression leads to a knowledge of the numerical value of the differential of the final result, which may be taken as the resultant error of observation.

The determination of the maximum possible value of the accumulated error of calculation for any given set of formulæ is a more or less complicated process. Since, however, the accumulated error seldom, if ever, reaches its maximum, a knowledge of its average magnitude is of more practical importance. This varies with the character of the equations to be solved, and its exact evaluation presents some difficulty. But for formulæ containing no critical features, such as abnormally large multipliers or small divisors, or differences defined by two relatively large and nearly equal quantities, or angles to be interpolated from sines or cosines, the following, based upon the theory of probabilities, gives an approximate expression of the average uncertainty in the logarithm of a result:

$$U_L = 0.4 \times 10^{-r} \sqrt{n} \qquad (5)$$

where r is the number of decimal places employed, and n the number of quantities involved in the calculation. If the final result is a number, N, its approximate average uncertainty will be given by

$$U_N = 10^{-r} N \sqrt{n}, \qquad (6)$$

or, if an angle, by

$$U_A = 0.4 \times 10^{-r}\, 206265'' \sqrt{n}. \qquad (7)$$

The following table shows the results given by (5), (6), and (7) for tables of 3 to 7 places, n being equal to unity. To obtain the accumulated error of calculation for any given case, it is only necessary to multiply the proper tabular value by the square root of the number of quantities entering into the calculation.

No. of Decimals = r	$n = 1$		
	U_{L}	U_{N}	U_{A}
3	0.4×10^{-3}	$10^{-3} N$	1.′4
4	0.4×10^{-4}	$10^{-4} N$	8″
5	0.4×10^{-5}	$10^{-5} N$	0.8
6	0.4×10^{-6}	$10^{-6} N$	0.08
7	0.4×10^{-7}	$10^{-7} N$	0.008

Experience shows that these results are in close agreement with the average values actually occurring in practice.

The determination of the number of decimal places to be used in any given calculation is a matter of great importance. If the number chosen is too small, the precision of the data will be sacrificed. If too large, much unnecessary labor will be expended—just how much, is suggested by the fact that the relative amounts of time required to execute a calculation with 4, 5, 6, and 7 places of decimals are approximately expressed by the numbers 1, 2, 3, and 5, respectively, i. e., five times as much labor is required to complete a given calculation with 7-place logarithms as would be required if only 4-place tables were used. In practice, the number actually to be employed is usually determined by the accuracy of the given data. If this is to be used to its full advantage, a sufficient number of decimals must be employed to make the accumulated error of calculation small as compared with the resultant error of observation. Having determined the amount of the latter, the above table affords such indications as are necessary for the choice. Thus, if the resultant error of observation for a certain calculation consisting of sixteen logarithms is of the order of 10″, we find that 5-place tables should be used. The multiplication of the values of U_{A} corresponding to 4, 5, and 6-place tables by the square root of 16 gives for the accumulated errors of calculation 32″, and 3″.2, and 0″.3, respectively. The first of these being in excess of 10″, shows that the use of 4-place tables would sacrifice the precision of the data. The last is unnecessarily small as compared with the resultant error of observation, showing that the use of 6-place tables would involve a needless amount of labor. The second value, on the other hand, indicates that 5-place tables will entail the minimum of labor consistent with the precision desired.

Again, required the number of decimals necessary for a calculation involving 25 logarithms, in which the resultant error of observation is 0.0001, the result itself being a number whose approximate value is 100. The expression for the accumulated error of calculation is

$$U_N = 10^{-r} \times 100 \times 5 = 5 \times 10^{2-r}.$$

To make this small as compared with the resultant error of observation, r must be taken equal to 7.

For formulæ free from the critical features mentioned in the second paragraph of this section, the resultant error of observation will usually be of the order of the uncertainties in the data. The choice of the number of decimals is then very simple. If the data consists of numbers, it is only necessary to choose a number of decimals greater by one than the number of significant figures in the given quantities. If, on the other hand, the data consists of angles, a glance at the tabular values of U_A affords the necessary information.

The above suggestions by no means cover all the cases which may arise in practice, but they give an indication as to the general method of procedure.

(d) *The Adaptation of Formulæ.*

The following general suggestions indicate the more important points to be borne in mind.

(1) Whenever possible, transform equations containing sums or differences of terms into expressions containing only products or quotients. Thus, the equations

$$\begin{aligned} \sin \delta &= \cos z \sin \phi - \sin z \cos \phi \cos A, \\ \cos \delta \cos t &= \cos z \cos \phi + \sin z \sin \phi \cos A, \qquad (8) \\ \cos \delta \sin t &= \sin z \sin A, \end{aligned}$$

defining δ and t in terms of z, ϕ, and A can be reduced to the form

$$\begin{aligned} \sin \delta &= m \sin (\phi - M), \\ \cos \delta \cos t &= m \cos (\phi - M), \qquad (9) \\ \cos \delta \sin t &= \sin z \sin A, \end{aligned}$$

by introducing the auxiliaries m and M defined by

$$\begin{aligned} m \sin M &= \sin z \cos A, \\ m \cos M &= \cos z. \end{aligned} \qquad (10)$$

The solution of (10) and (9) thus replaces the solution of (8). Although the number of equations involved in (9) and (10) is five as against three in (8), the calculation is usually simpler in arrangement and control.

(2) Whenever possible, calculated angles should be determined from the tangent. This does not mean that the formulæ are necessarily to be arranged so as to express explicitly the tangent of a required angle. As an illustration, M in (10) will be determined from its tangent, derived by subtracting $\log m \cos M$ from $\log m \sin M$, although the equations do not express the tangent of M explicitly. The same is true of the determination of t from the last two of (9). It is possible to replace equations (9) and (10) by a single group of three equations giving directly the tangents of M, t, and δ; but this is not to be recommended, for there is no saving in labor, and the use of (9) and (10) as they stand introduces symmetry into the arrangement of the work, and simplifies the determination of the quadrants and the control of the calculation.

(3) Avoid formulæ expressing a quantity as the difference of two relatively large and nearly equal numbers. The comparison of equations (3) and (4) made in a previous section illustrates the disadvantage connected with expressions of this type.

(4) When it is necessary to determine a quantity differing but little from a second quantity whose value is known, arrange the formulæ in such a way as to express the *difference* of the two. The calculated difference applied to the known quantity then gives the desired result. Developments in series are frequently useful in this connection. Thus, the geocentric latitude, ϕ', is given by the relation

$$\tan \phi' = (1 - e^2) \tan \phi, \qquad (11)$$

in which ϕ' is the astronomical latitude, and e, the eccentricity of a meridional section of the Earth. The numerical value of the latter is approximately 0.08, whence it follows that ϕ' differs but little from ϕ. In accordance with the above mentioned principle, (11) is replaced for the purpose of numerical calculation by the following equivalent expression

$$\phi' - \phi = - 690''.65 \sin 2\phi + 1''.16 \sin 4\phi \ldots \qquad (12)$$

in which the neglected terms are insensible. The first term in the right member of (12) calculated with 5-place and the second, with 3-place logarithms, gives the same precision as 7-place tables used in connection with (11).

(5) Calculations can frequently be much simplified by the use of approximate formulæ. It is obviously permissible to

neglect those terms in an equation whose numerical values are small as compared with the resultant error of observation. One of the most common methods of introducing such simplifications consists in the substitution of the first terms of the developments in series of the sine, cosine, and the tangent of small angles for the trigonometric functions themselves. Since,

$$\begin{aligned} \sin x &= x - \frac{x^3}{6} + \ldots \\ \cos x &= 1 - \frac{x^2}{2} + \ldots \qquad (13) \\ \tan x &= x + \frac{x^3}{3} + \ldots \end{aligned}$$

it follows that the errors resulting from the substitution mentioned will be of the order of $x^3/6$, $x^2/2$, and $x^3/3$, respectively. The evaluation of the errors in any given case is readily accomplished by means of the approximate relations

$$\begin{aligned} x^2 &= (x \text{ in degrees})^2 \times 1' , \\ x^3 &= (x \text{ in degrees})^3 \times 1'' . \end{aligned} \qquad (14)$$

Thus, for $x = 15'$, the substitution of x for $\sin x$ introduces the error

$$\frac{1}{6}\left(\frac{1}{4}\right)^3 \times 1'' = \frac{1''}{384} .$$

For the same value of x, the substitution of 1 for $\cos x$ produces the error

$$\frac{1}{2}\left(\frac{1}{4}\right)^2 \times 1' = \frac{1'}{32} = 2'' , \qquad \text{approximately} .$$

It will be noted that the use of the suggestion in (4) will frequently make possible substitutions of this character, for an arrangement of the formulae expressing the difference between the required quantity and a nearly equal known quantity oftentimes introduces the trigonometric functions of small angles.

As an illustration, the equation

$$\sin h = \cos \pi \sin \phi + \sin \pi \cos \phi \cos t \qquad (15)$$

expresses the relation between the north polar distance of a star, π, its hour angle, t, its altitude h, and the latitude of the place, ϕ. The latitude can be calculated when the remaining quantities are known. One of the most convenient methods results from an application of (15) to the star Polaris. Since the latitude equals the altitude of the celestial pole above the horizon, and since this latter differs at most by 1° 12′ from the altitude of Polaris, it is desirable to express (15) as a function of $H = \phi - h$. The resulting equation in H is

$$\sin H = -\sin \pi \cos t + \tan \phi \,(\cos H - \cos \pi). \qquad (16)$$

Since $H \leqq \pi = 1^\circ\, 12'$, (16) can be replaced by the approximate relation

$$H = -\pi \cos t + \frac{\pi^2}{2} \tan \phi \sin^2 t, \qquad (17)$$

in which terms of the order of π^3 or higher have been neglected. The maximum error of (17) is 1″ or 2″. The appearance of ϕ in the last term of (17) seems to require a knowledge of the quantity for whose determination the equation has been designed, viz., the latitude. But, since the coefficient of this term is very small, a rough approximation for ϕ, which can be obtained in a variety of ways, is all that is required.

(e) *Control and Checking of Computations.*

The acquirement of accuracy in the performance of numerical calculations is largely a matter of intelligent practice. The mistakes of the beginner are due in part to an inability to concentrate his attention upon the large number of details involved in even a relatively short calculation. With experience, the more frequently occurring operations are reduced to a more or less mechanical process. This reduces the strain upon the attention, and thereby lessens the liability to error. But this liability is never entirely removed, and the most skillful computer occasionally makes mistakes. It is therefore essential that all calculations should be controlled. The importance of this cannot be too strongly emphasized, especially for the beginner. The methods of checking are numerous. Generally each type of problem requires its own special method of treatment. One of the most satisfactory methods of control is afforded by the derivation of a result from two independent sets of formulæ. There are many cases, however, in which the application of such a test is impossible. Another is the so-called method of differences, which can be applied when the same set of formulæ is to be calculated for several uniformly varying sets of data. In such cases the final results, and indeed, the numerical values of any given quantity in the calculation, present a systematic variation as one passes successively from one set of data to another. The test is applied by forming the successive differences of the numerical values of the final results or of such quantities as it is deemed necessary to control. A numerical error in one or more of the separate calculations reveals itself through an irregularity in the variation of the differences. The control is a searching one and is capable of bringing to light even the neglected decimals forming a part of the accumulated error of calculation. The arithmetic mean of a series of numbers can be checked by forming the differences between the mean and the individual numbers, regard being paid to the algebraic sign. If the calculated mean is correct, the sum of the positive differences will equal that of the negative differences.

Other methods of checking will readily suggest themselves to the computer after a moderate amount of experience, but whatever the method, he must constantly be on his guard not to place too much confidence in a mere agreement of numerical results, for no process of checking is absolute. An agreement in numerical results signifies at most a certain *probability* that a calculation has been correctly performed. This probability may be large or small according to the nature of the test, but it never becomes equal to certainty. For example, the method of differences affords an invaluable control in so far as isolated errors are concerned, but it is quite incapable of discovering systematic errors affecting similarly all of the separate calculations. It is therefore desirable that several different tests should be applied. For those rare cases in which all ordinary processes of checking become impossible, the calculation should be repeated by a second computer, working quite independently of the first; and failing this, by the original computer himself. But this last method should be adopted only as a final resort, and then only after a considerable interval of time has elapsed, for it is a well-known fact that an error once committed is very likely to recur in the repeated calculation.

The preceding remarks relate particularly to the detection of errors already committed. Something should also be said as to the methods of *preventing* errors. The most important things are care, attention, and deliberation. The systematic arrangement of the work explained under (a) contributes much. The method of combining numbers is of importance. When two numbers are to be added or subtracted, the combination should be made from *left* to *right*. With a little practice this method affords an increase in both accuracy and rapidity as compared with the usual process. With the beginner each result should be verified as the calculation progresses, always by an independent method, if possible. Thus, additions, in the case of two numbers, can be performed both from left to right and from right to left; for more than two numbers, by adding from the top downward and from the bottom up; subtractions can be controlled by adding the difference to the subtrahend; interpolations of trigonometric functions, by a comparison of the difference of the logarithms of the sine and cosine with the logarithm of the tangent. Finally, the computer should be on the watch for such impossible results as values of a sine or cosine greater than unity, and the occurrence of negative values for essentially positive numbers.

Under no circumstances should these details be neglected unless the computer has acquired a very considerable skill, for it is a matter of experience that the location and correction of errors in a completed calculation consumes far more time than is required for the execution of the work with that deliberation which assures some degree of accuracy in the final result. In addition, the consciousness of having exercised all possible care gives a feeling of security which, in the attempt to secure freedom from errors, is a psychological factor of no small importance.

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AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

Part III. (Continued.)

THE NATURE OF THE SOLAR RADIATIONS AND THEIR RELATION TO TERRESTRIAL MAGNETISM AND OTHER METEOROLOGICAL PHENOMENA.

FOR POPULAR ASTRONOMY.

An inspection of the two last columns of Table A clearly shows the predominating influence of the great planet Jupiter in respect to solar radiation and the consequent phenomena, particularly as to the cooling effect upon the Sun's surface matter, which is the cause of these phenomena. The very considerable influence of each of the three smaller planets, Mercury, Venus and the Earth is, also, distinctly indicated, while the quite insignificant values of E in the case of the large outer planets Uranus and Neptune, the considerable, but not great value in that of Saturn and the very small effect due to Mars, corroborate my claim that only the eight known planets of the solar system need be regarded as sensible factors in the process of solar radiation as viewed in the light of my theory thereof.

As the planets are all revolving around the Sun, their projected areas, and the corresponding regions of *greatest cooling*, upon the solar surface, obviously move, *pari-passu*, in heliographic longitude, and it is evident that there is a considerable number of combinations possible among all these planetary effects, so that at times there may be at least an approximation to *conjoined* action between Mercury, Venus and the Earth —either separately or together—and Jupiter; on the other hand the influences of these three smaller planets may be exerted *against* that of the great planet, the combined influence of the three planets aforesaid being almost equal to that of Jupiter particularly when Mercury is in "perihelion," when its influence is 58½ per cent *greater* than that indicated for mean-distance in Table A, the influence of Jupiter being *less* than the mean indicated, by about ten per cent when that planet is in "aphelion," and greater by about the same amount when it is in "perihelion". If Jupiter were the only planet thus reacting upon the Sun, the aforesaid effects caused thereby would, in all probability, have a period equal to that of this planet's sidereal revolution which is 11.86 years, but by reason of the competitive action of the planets of shorter period, and particularly of these three above referred to, this must be reduced *somewhat* toward Wolf's period of sunspot variation, which is 11.11 years, or three-quarters of a year less than the period of Jupiter.

The action of the more slowly moving planets, Saturn, Uranus and Neptune, tends to lengthen the period above that of Jupiter, but, as indicated in Table A, their influence in this respect is small. The researches of some of the earlier and eminent investigators in this part of the field of solar physics—De la Rue, Stewart and Loewy—indicated laws of variation connecting spot-frequency with the movements of the planets Jupiter, Earth, Venus and Mercury, and the great specialist in this line, Wolf, accepted the theory of *planetary influence*. He projected the results of his observations of spot-frequency in a continuous curve and found therein a series of small undulations succeeding each other at an average interval of 0.637 of a year, and as the periodic time of Venus is 0.616 of a year, the coincidence is sufficiently close to warrant a belief in the physical connection aforesaid. A longer period of variation was suspected by Wolf, and a probable connection between this and the conjunction of Saturn with Jupiter was suggested by the late Professor Proctor in 1865 and subsequently advocated by Professor Loomis, the distinguished astronomer and meteorologist,—then of Yale University. Observations of sun-spots made by later investigators tend to confirm these views but, in so far as I have been able to learn, no one has, heretofore, traced this *planetary influence* upon the *frequency* and heliographic distribution of sun-spots, to the correlation between solar thermal radiation and the absorption thereof by the planets in the manner conceived by my theory.

My theoretical investigation as to the distribution of the areas of *greatest cooling* upon the Sun's surface with respect to *heliographic latitude* has led to even more striking and suggestive results, as is indicated by the values of (*l'*) set forth in Table B wherein it appears that the highest limiting latitudes within which such areas are to be found are ± 72°.3, in the case of those due to the planet Neptune, while the lowest are ± 5°.0 in the case of Mercury and these are almost exactly the limiting latitudes—north and south of the solar equator—between which sun-spots—which are here regarded as caused by downfalls of cooler, heavier matter (made so by radiation from the projected planetary areas) through the *photosphere* and into the interior of the solar globe whence this matter has previously arisen in a hotter and, therefore, lighter state are found. Since, as indicated by the respective values of *E* in Table A, the *cooling area* due to the influence of each of the planets Neptune and Uranus is extremely small, sun-spots caused by these planets at the high latitude, ± 72° and ± 68° respectively, must be small and, by reason of the slow motion of these two outer planets, quite infrequent, those due to Saturn (latitude 48°) being somewhat more notable and frequent—but the Martian effects (latitude ± 13°) are quite inconsiderable. At latitude ± 34° the predominant action of Jupiter in this process of sun-spot formation begins, followed at latitudes ± 7° by the considerable effects due to the Earth; at latitude ± 6° by those attributable to the planet Venus, and at ± 5° by the disturbance due to Mercury. Of course all these planets, by reason of their revolution around the Sun, exert a spot-producing influence at all latitudes within the limiting ones aforesaid, from the farthest northern to the uttermost southern limits across the Sun's equator, but any spot at a higher latitude than that given for any planet, in Table B, must be attributed to some one of the planets of greater mean-distance, as is evident from the equation whence these limiting latitudes (l') have been derived. Indeed, from the values of E in Table A and these values of (l') from Table B, together with the magnitude of the disturbed solar area, we may be able to identify any spot with the planet causing it.

There are two facts which account, simply and satisfactorily for the comparative infrequency of sun-spots on, or very near, the solar equator, the first being that the motion of the planets and, therefore, of the areas of maximum cooling effect which they cause upon the Sun's surface and which are factors in the formation of the spots by the descent of the cooled and heavier matter through the hotter and brighter substances constituting the "photosphere," is much greater with respect to heliographic latitude, when the planets are near the nodes of their orbits, with the plane of the solar equator, than when they are in the vicinity of 90° from said nodes, just as the apparent motion of the Sun, in "declination" is much greater at, and near, the "equinoxes," than at, or near, the "solstitial" points, 90° distant, the time of passage across the equatorial belt being, therefore, comparatively short and the opportunity for spot-formation correspondingly less than in the higher solar latitudes where sun-spots are generally observed. The second fact is that, while maximum areas of cooling do exist in the regions near the solar equator and even on that line when the planets causing them are crossing it and the cooled denser matter tends to sink downward under the *centripetal* action of solar gravity, there is in operation also, a *centrifugal* force and a component *tangential* motion, due to the Sun's axial rotation, which is greatest at the solar equator, this factor operating to prevent or, at least, to retard, the fall of this matter and to cause it to move forward in the direction of the rotation from east to west, upon the Sun's disk, this action, obviously tending to greatly lessen the probability of the formation of sun-spots in the solar equatorial regions although they do occasionally appear there; the greater thickness of the solar atmosphere near the equator also operates to retard the fall. By reason of temperature differences, there must be horizontal convection-currents, along the Sun's surface, from both the polar and the equatorial regions, toward the zones of sun-spots, or the areas of greatest cooling, on each side of the solar equator, which movement, together with that caused by the Sun's rotation, must result in a tendency to vortex—motion in the spotted areas—"clockwise" in the southern, and "contra-clockwise" in the northern hemisphere of the Sun, in a manner analogous to that in the case of cyclonic movements in the terrestrial atmosphere. Furthermore, the hotter matter ejected from the interior and cooled by radiation, in the upper portions of the solar atmosphere (appearing therein as the faculæ) and becoming, therefore, denser, may well have a surface drift of as much as 10°--or even more—both in heliographic latitude and longitude, before descending to, and penetrating, the photosphere, thereby causing the appearance of a "sun-spot". Thus, in the case of Mercury, Venus and the Earth, the limiting latitudes of the "projections" of the planetary areas are ± 5°; ± 6° and ± 7°, respectively, so that while these may mark the extreme regions of the areas of greatest cooling due to these planets, the solar matter, so cooled, may *drift* northward and southward, to latitudes 15°, or 20°, before falling to a depth sufficiently great to cause the appearance of a "sun-spot"; and, for the same reason, the matter cooled in latitude ± 34°, by radiation to the planet Jupiter may *drift* down to ± 25° or even lower, before penetrating the photosphere, and the same reasoning applies in the case of the planet Saturn. Furthermore, since by the rotation of the solar globe at a greater *angular* rate than that of the revolution ot the planets, in their orbits in the same direction, the projection of the planetary areas must appear to lag behind in heliographic longitude and, therefore, the corresponding areas of maximum cooling, due to each planet, must extend in elongated belts parallel to the solar equator, and the resultant sun-spots must often, on this account, appear in groups, or "chains," extended in an easterly and westerly direction on the Sun's disk. The drifting of the "faculae" and the "spots", as well as the grouping of the former about and above the latter, and the formation of groups of "spots" extending across the disk, in lines roughly parallel to the solar equator, are facts well attested by observation all constituting testimony, of no inconsiderable weight, in favor of my theory in this connection.

These areas of greatest cooling effect upon the Sun's surface are, of course, not limited, strictly, to the *projections* of the areas of the planets causing them, but may extend over several degrees of heliographic latitude and longitude, but it is quite reasonable to assume that the mean diameter of a sun-spot, or disturbed area, will bear some comparatively close proportion to the diameter of the planet causing the disturbance in the manner aforesaid, and we may properly take the ratios anywhere between one-fourth and four times the planetary diameter, as the limiting values of the mean diameters of the said "spots," or areas. Thus in the case of disturbances caused by the planet Mercury, this diameter would be from 750 miles to 12,000 miles, corresponding to an angular diameter on the solar disk of 2″ — 24″; in the case of the planet Venus, and also in that of the Earth, the value may lie between 2,000 miles and 32,000 miles (5″ — 72″), and in that of Jupiter and also Saturn between 20,000 miles and 320,000 miles (45″ — 720″) all of which theoretical values agree well with those observed, there being of course occasional combinations of disturbed areas due to approximate conjunctions of the planets—particularly Mercury, Venus and the Earth each of which is of comparatively short "period."

When the Earth is at 90° from the nodes of the planets, with reference to the solar equator, the plane of its orbit approaches most nearly to those of the other planets when they are in such position that their action upon the Sun is most intense, so that whatever *reaction* upon the Earth and its atmospheric envelope is caused by the outbursts of the more highly heated matter from below the surface of the solar globe should, likewise, be of maximum intensity at, or about, the times when the Earth is in the aforesaid position with respect to each of the other planets—the dates of this event, in each case, being set forth in the last column of Table B. These outbursts of superheated gases are caused by the violent descent of the superficial matter of the Sun, made cooler and denser by radiation to each planet, this matter immediately upon cooling, and before descending, appearing as the "faculae" which are observed to hover, in greatest number, in the vicinity of and even over the "spots," while the displaced and ascending ejected gases from the interior appear in the form of the red "prominences," "protuberances," "flames" "eruptions" and "jets," the two last phenomena being especially results of the more sudden and heavy downfalls of the cooler masses which displace portions of the hotter internal matter and cause them to be violently ejected upward, along the lines of least resistance, this matter appearing in the form of the "jets," "eruptions," etc., somewhere in the vicinity of the "spots", the slower, and more uniform processes of convection giving rise to the quiet "prominences," "domes" and kindred phenomena observed above the Sun's photosphere. Now, it is obvious that if the effects caused, at the Earth, by these solar disturbances, be due *directly* to the sun-spots, such effects should be most marked when the "spots" are upon or near the central meridian of the solar globe, and when the vertical axis of the spot is directed most nearly toward the Earth, but if the terrestrial meteorological phenomena—aurorae, magnetic storms and perturbations, areas of low barometric pressure and consequent storm centers—be due (as I claim that they are) to an abnormal radiation consequent upon the ejection of hotter matter from the interior of the Sun, then these phenomena must be manifested *subsequently* to the appearance of the sun-spot, because it is very evident that the "jets," "eruptions," etc., must *follow*, in point of time, the downfall of the cooled masses, through the photosphere, (whereby the "spots" are caused) the outbursts of superheated matter, and their consequent effects occurring after the lapse of a sensible, and even a considerable, time after the transit of a sun-spot over the "central meridian."

Moreover, since the intensity of the divers meteorological disturbances depends upon, both the intensity and extent of the eruptive action upon the Sun, and the direction of the vertical axes of the "jets" etc., with respect to the Earth, it follows that, in the case of many notable "spots" in which the *downfall* of the cooled masses is gradual and not violent, or the vertical axis of the ejected mass is directed away from the Earth, there may be no sensible meteorological disturbances whatever when a large sun-spot transits the "central meridian" of the solar globe, and since these "jets" and "eruptions" may be active—particularly in the equatorial regions—without the appearance of a sun-spot, magnetic and other meteorological phenomena may be manifested, as they often are, in the *absence* of the "spots"—all of which confirms my claim that it is the ascending ejected hotter matter from the interior of the Sun (appearing as the "jets and eruptions") and not the cooled descending matter (productive of the "spots,") that, by its excessive radiation, is the chief factor in the causation of the meteorological phenomena displayed at the Earth's surface and in the atmospheric envelope of our globe.

I shall now introduce some testimony based upon observational data, in support of my views on the several points above discussed in this part of my paper. In a communication published in No. 111 of ASTRONOMY AND ASTRO-PHYSICS (Jan. 1893) under the title "Sun-spots and Magnetic Perturbations in 1892," Professor A. Ricco of the Observatory of Catania, Sicily, gave the results of his observations of certain sun-spots very prominent at about the time of the "maximum" just preceding the last one, recently passed, and he correlated them therein, with certain data derived from the curves of the photo-magnetographs for 1892, which had been sent to him by the United States Naval Observatory; from the data in his communication I have made the following tabulation:

Table C.

No.	Date 1892	Principal Sun-spot	Diameter (Miles)	Heliographic Latitude	Magnetic Perturbations	Deviation	Retardation	Disturbing Planets
				°		'	Hours	
1	Jan. 4	Very Large	32,000	+ 20	Very Large	42	38	Saturn; Mercury; Earth
2	" 28	Large	24,000	— 16	Large	28	21	Jupiter; Venus
3	Feb. 12	Extraordinary	88,000	— 30	Extraordinary	90	45	" "
4	Mar. 7	Near East Limb	50,000	— 29	Large	48	48	Jupiter: Mercury
5	" 10	Extraordinary	48,000	— 29	Very Large	53	45	" "
6	April 23	Large	20,000	+ 11	Large	41	51	Venus; Mercury Earth
7	" 24	Large	24,000	+ 16	Large	46	45	Venus; Mercury Earth
8	May 16	Extraordinary	40,000	— 16	Extraordinary	42	49	Jupiter

The transits of the "spots" across the central meridian of the Sun occurred between 2:00 p. m. and 8:00 p. m. in all cases except those of Nos. 3 and 4, in which they took place between 2:00 a. m. and 4:00 a. m.

An inspection of Table C discloses, at once, the very significant facts that the dimensions of the principal sun-spots, and the extent of the magnetic-perturbations as measured by the maximum "deviation" of the magnetic needle from its undisturbed position in "declination", as set forth (in minutes of arc) in the seventh column, *correspond exactly*, and that the time which elapsed between the transit of each sun-spot across the "central meridian" of the solar globe, and the occurrence of the respective maximum perturbation of the magnetic-declinations, as set forth in the eighth column, was between 21 hours and 51 hours, the "retardation" being therefore, on an average, 36 hours, which fact tends strongly to corroborate my claim that the magnetic perturbations are caused by excessive—but short-lived—radiation from matter ejected from the interior of the Sun (maximum internal absolute temperature 13,400° F) heated above the mean, normal radiating temperature of the Sun's surface matter, which is roundly 6,700° Fahrenheit, according to my several determinations referred to in preceding parts. This latter is practically the absolute temperature between the poles of an arc-lamp operating in atmospheric air at normal pressure, the atmospheric molecules between said "poles" being *disrupted* by the passage of the electric current, and the component atoms of these molecules being continually subjected to a process of "dissociation" and "recombination" while the lamp is in operation. It is just above the absolute temperature (6679° Fahrenheit) at, and above, which, according to a fundamental concept of my "electronic theory of matter"—the component atoms of each molecule of a gas at normal atmospheric pressure and temperature, grouped two and two, in myriads of "diatomic-couples" in each molecule, are "dissociated," the molecules composed thereof *disrupted* and their atoms released from the closed paths around each molecular center around which (according to my "astronomical theory of the molecule") they have been revolving, under Kepler's 3rd law, in normally *circular* orbits when undisturbed by impacts from the vibrating atoms of a source of heat, or radiating surface; in *elliptical* orbits the eccentricity whereof increases with the vibrational velocity of said atoms (which velocity is proportional to the absolute temperature of the radiating surface) when affected by *radiation*, and in *hyperbolic* orbits when the orbital velocity of the revolving atoms of the gaseous matter has been increased (by the velocity imparted by the impinging atoms of the heated surface) beyond the *parabolic* limit which according to my determination, to be set forth subsequently, corresponds to the absolute temperature 6679° Fahrenheit in the case of radiation in atmospheric air at normal pressure and temperature. When this limiting temperature, and corresponding orbital velocity, is exceeded the component atoms of each gaseous molecule affected by the radiation, fly off in practically straight lines, this action constituting an electrical discharge, according to a fundamental concept of my theory.

The names of the planets active in the formation of the respective sun-spots are set forth in the last column of Table C. I having derived these data from the heliocentric positions of planets as given in the *American Ephemeris* for 1892 and from the values Ω', i' and l' in Table B in May number of POPULAR ASTRONOMY. It should be noted here that, by reason of a clerical error in copying from my computing sheets, the longitude (Ω') of the ascending node, the inclination (i') and the limiting heliographic latitudes (l'), with respect to the solar equator, should be, in the case of Jupiter, 84°.8, 7°.0 and 32°.4 and in that of Saturn 92°.2, 6°.6 and 47°.6, instead of the values of these quantities set forth in Table B, and also that in connection with the prominent sun-spots here discussed the action of other planets Mars, Uranus and Neptune may be ignored because, as indicated by the values of E in Table A, this action is comparatively very small in each case, so that the discussion will be confined to the planets named in Table C, above. I have found that on January 4, 1892, Saturn, Mercury and the Earth were the only planets "projected" against the northern hemisphere of the Sun, and in a resultant position such as would cause a sun-spot in heliographic latitude + 20°, having regard to the *drifting* of the cooled matter in the upper regions of the solar atmosphere, southward from the "projected" latitude of the planet Saturn, and northward from that of each of the two other planets, the names of all these bodies being set forth in the order of the intensity of their action. The diameter of this sun-spot as set forth in Table C, was 32,000 miles which is nearly one-half that of the principal planet—Saturn—active in the causation of the "spot," both Saturn and Mercury being then "projected" against the visible hemisphere of the Sun. In the case of the sun-spot crossing the "central meridian," on January 28, 1892 in heliographic latitude — 16°, the only planets in position to effect this result were Jupiter and Venus, the diameter of the principal "spot" being only a little less than one-third the diameter of Jupiter which was projected against the invisible hemisphere of the Sun, to the south of the solar equator, while the projection of Venus was on the visible hemisphere and, likewise, to the south. The principal sun-spot crossing the "central meridian," on February 12, was due, in greatest part, to the action of Jupiter which was then projected against the invisible hemisphere of the Sun almost exactly in heliographic latitude — 30°, this "spot," therefore, having originated on the other side of the solar disk, appearing, thereafter on the eastern "limb," while Venus, projected against the visible portion of the disk, acted in a subsidiary manner. The diameter of the principal "spot" in this case was 88,000 miles, or about equal to the combined diameters of the two planets, which fact taken in connection with their positions relative to the Sun, makes it quite evident that Jupiter and Venus—particularly the former—were the only factors in the causation of this sun-spot. On March 7, as the record shows, a similar, large "spot" was observed near the eastern limb of the Sun, and on March 10 it crossed the "central meridian," in heliographic latitude —29°, or within one degree of the position of the "spot" observed on February 12, the principal factor in these two latter cases being also the planet Jupiter, with Mercury acting in a subsidiary manner, the diameters of these "spots" being about one-half the combined diameters of the planets causing them. The position of the chief factor Jupiter, on March 7th and 10th, was on the side of the Sun opposite to that visible from the Earth, so that, as in the case on February 12th, the "spot" must have been formed on the invisible hemisphere of the solar globe and brought into view, around the eastern limb, by the axial rotation of the Sun. The "spot" observed on March 7th and also that on March 10th, were regarded by the observer as a return of the "spot" of February 12, and it may have been, but, under my theory of the causation of these phenomena, it may with equal probability have been one *newly formed* on the opposite side of the Sun, during the interval between February 12th and March 7-10, and this raises a question as to the time of duration of a "spot," and casts some doubt as to the alleged persistence of this phenomenon through one or more complete rotation periods of the Sun. It is quite evident that, under my view, a sun-spot newly formed by a planet of "long period"—such as Jupiter or Saturn —would be situate in nearly the same heliographic latitudes as, and present a somewhat similar appearance to, one formed by either planet on the opposite side of the Sun during one, or more, immediately preceding rotation periods of that body. The diameter of the "spots" of March 7-10 was 42,000 miles, or about one-half the combined diameters of the planets causing them.

The sun-spots that crossed the "central meridian" on April 23 and 24, in latitudes + 11° and + 16°, were caused by Venus, Mercury and the Earth, the diameters, which were respectively 20,000 miles and 24,000 miles, being about equal to the combined diameters of these three planets, and nearly three times that of Venus, or the Earth, considered separately, and, on each date, Venus and Mercury were projected against the visible hemisphere of the Sun.

The sun-spot that crosssd the "central meridian" on May 16th, in latitude — 16^c was due practically to Jupiter alone, its diameter having been about one-half that of said planet which was, on that date, projected against the southern hemisphere of the Sun, sufficiently near the heliographic latitude at which the "spot" appeared. On a preceding page I stated that, according to my theory, there must be some near proportion between the diameter of a sun-spot and that of the planet, or planets, causing it, and placed the ratio at roughly from ¼ to 4, but, from the records above discussed, it appears that the limiting ratios were much less than these, being more nearly ½ to 2, which fact is strongly corroborative of my theory in this connection. As stated, the relation between the magnitude of each sun-spot included in Table C, and the range of the corresponding magnetic perturbation at the Earth, is most remarkable, while the "retardation" of these "perturbations" is in strict accordance with my theory as to the occurrence of "eruptions" and "jets" of very highly heated matter from just below the solar photosphere, as a *consequence* of the downfall of the cooled heavier matter from the upper regions of the solar atmosphere, productive of the "spots". Perturbations, or fluctuations of the three elements of "terrestrial magnetism" are very evidently caused by actions taking place upon the Sun, the "diurnal," "monthly," "semi-annual" and "secular" irregularities of magnetic declination-range and magnetic storms, being analogous to irregularities of atmospheric "temperature," "pressure" and correlated "humidity," which depend upon solar action, and are recognized as well established factors in the causation of the combination of ordinary meteorological phenomena which we call "weather"—there being also what may be termed "magnetic-weather". Therefore a study, from the view-point of my theory of the nature and *modus operandi* of the electro-magnetic, and other radiations from the Sun, by and through the luminiferous ether, and of the molecular constitution and extent of the terrestrial atmosphere through which these radiations are transmitted to the Earth's surface after undergoing certain important modifications dependent upon the molecular properties of the atmospheric gases, may throw some light upon the nature of the relations between these solar radiations and "terrestrial magnetism", as well as other meteorological phenomena, which relation—not long ago wholly unknown, or doubted—has during the past decade, or two, become more, and more, apparent to physicists, although the nature thereof has not heretofore been definitely ascertained.

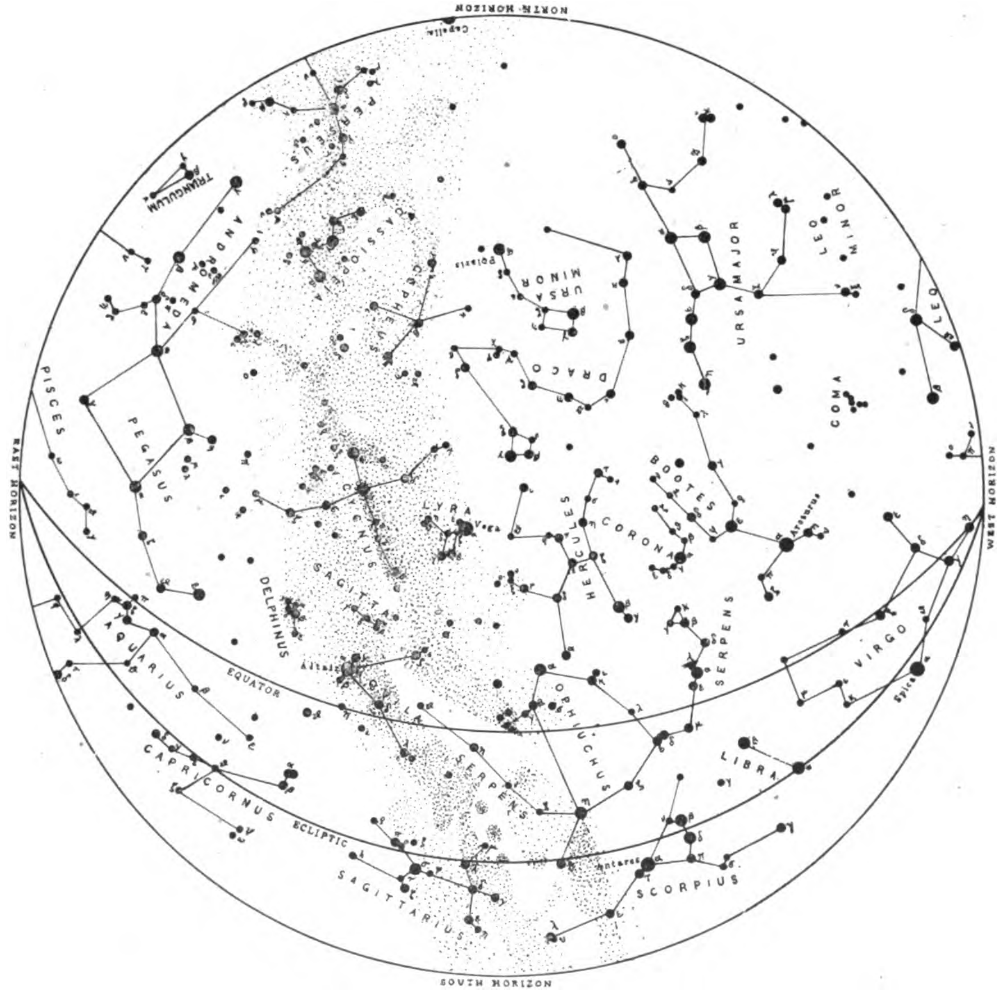
Saint Paul, Minnesota.

To be continued.

PLANET NOTES FOR JULY AND AUGUST 1908.

H. C. WILSON.

Mercury will be at inferior conjunction July 4, and will be visible as morning star during the last two days of the month. The planet will be at greatest elongation, 19° 51′ west from the Sun on July 25. It will not be visible during August, being at superior conjunction August 20. Mercury will be in conjunction with Neptune, 0° 44′ south of the latter, on the morning of July 28. On August 18 at 12^h C. S. T., Mercury will be 1° 2′ north of Jupiter and on August 20 at 2^h C. S. T., it will be 40′ north of Mars.



THE CONSTELLATIONS AT 9:00 P. M., AUGUST 1, 1908.

Venus will be at inferior conjunction on July 5, and so will not be visible during the first half of the month. After that she will be seen as morning star, reaching her greatest brilliancy August 11 and then waning slowly for several months. Venus and Mercury will be in conjunction a little way west of the Sun on the morning of July 15.

Mars will be at conjunction with the Sun on August 21 and will be too close to the Sun to be observed during the summer. Mars will be in conjunction with Jupiter on August 13 and with Mercury August 20.

Jupiter will be in conjunction with the Sun August 17 and so may not be observed during the summer.

Saturn is at quadrature 90° west from the Sun July 1 and will be visible in the latter half of the night. The plane of the rings now makes an angle of nearly eight degrees with the line of sight from the Earth, so that the rings can be fairly well seen. Saturn is to be found easily without the aid of a telescope, toward the southeast in the morning, in the constellation Pegasus.

Uranus will be at opposition July 6 and so will be in best position for study during the summer months. This planet requires the use of a good telescope, and may be found in the constellation Sagittarius.

Neptune will be in conjunction with the Sun July 6 and so cannot be seen during the summer.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T.		IMMERSION. Angle f'm N.	EMERSION. Washington M.T.		EMERSION. Angle f'm N	Duration.	
			h	m	°	h	m	°	h	m
July 4	ν Virginis	4.2	9	27	67	10	08	346	0	41
12	26 Sagittarii	6.1	6	42	32	7	06	348	0	24
14	27 Capricorni	6.1	15	15	88	16	19	228	1	04
17	30 Piscium	4.7	14	24	338	14	34	322	0	10
17	33 Piscium	4.7	15	57	42	17	12	251	1	15
18	20 Ceti	4.9	12	35	117	13	13	187	0	38
Aug. 16	*n* Virginis	6.5	10	01	99	11	01	304	1	00
5	o^1 Libræ	6.2	7	00	114	8	24	297	1	24
8	Bradley 2276	5.2	5	52	52	04	38	334	0	46
9	B A.C. 6576	6.1	5	39	106	6	43	266	1	06
9	χ^3 Sagittarii	5.5	10	51	49	11	56	296	1	05
10	Piazzi xx, 146	6.2	9	57	59	11	10	278	1	13

COMET NOTES.

Ephemeris of Comet 1907 *d*.

(For Berlin Midnight, from *A. N.* 4245.)

1908	α 1908.0			δ 1908.0		log *r*	log Δ	Mag.
	h	m	s	°	′			
June 1	13	52	06	—0	14.3	0.6193	0.5303	11.7
3		51	16	0	14.2			
5		50	30	0	14.6	0.6239	0.5416	
7		49	48	0	15.4			
9		49	10	0	16.7	0.6285	0.5530	11.9
11		48	36	0	18.3			
13		48	06	0	20.2	0.6330	0.5644	
15		47	40	0	22.5			
17		47	17	0	25.2	0.6374	0.5756	12.1
19		46	59	0	28.2			
21	13	46	44	—0	31.5	0.6417	0.5869	

Ephemeris of Comet 1907 *d*.—Continued.

1908		α 1908.0 h	m	s	δ 1908.0 °	′	log *r*	log Δ	Mag.
June	23	13	46	33	—0	35.2			
	25		46	26	0	39.1	0.6460	0.5981	12.2
	27		46	22	0	43.3			
	29		46	21	0	47.8	0.6502	0.6091	
July	1		46	23	0	52.5			
	3		46	29	0	57.5	0.6544	0.6200	12.4
	5		46	38	1	02.7			
	7		46	50	1	08.1	0.6585	0.6307	
	9		47	05	1	13.7			
	11	13	47	24	—1	19.6	0.6626	0.6412	12.5

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours. Alternate minima are given this month.]

U Cephei

	d	h
July	3	2
	8	1
	13	1
	18	1
	23	0
Aug.	2	0
	6	23
	11	23
	16	23
	21	22
	26	22
	31	22

Z Persei

July	1	18
	7	21
	14	0
	20	3
	26	5
Aug.	1	8
	7	11
	13	13
	19	16
	25	19
	31	21

RY Persei

July	4	12
	18	6
	31	23
Aug.	14	17
	28	10

RZ Cassiop.

	d	h
July	2	4
	4	13
	6	23
	9	8
	11	18
	14	3
	16	12
	18	23
	21	7
	23	16
	26	1
	28	11
	30	21
Aug.	2	6
	4	15
	7	1
	9	11
	11	19
	14	5
	16	14
	18	23
	21	9
	23	18
	26	4
	28	13
	31	22

RX Cephei

July	2	4
Aug.	3	12

Algol

July	3	19
	9	13
	15	7
	21	0
	26	18
Aug.	1	11
	7	5
	13	0
	18	16
	24	10
	30	4

RT Persei

	d	h
July	1	3
	2	20
	4	12
	6	5
	7	22
	9	15
	11	7
	13	0
	14	17
	16	10
	18	3
	19	19
	21	12
	23	5
	24	22
	26	14
	28	7
	30	0
	31	17
Aug.	2	9
	4	2
	5	19
	7	12
	9	5
	10	21
	12	14
	14	7
	16	0
	17	16
	19	9
	21	2
	22	19
	24	12
	26	4
	27	21
	29	14
	31	7

λ Tauri

	d	h
July	4	0
	11	22
	19	19
	27	17
Aug.	4	15
	12	13
	20	10
	28	8

RW Tauri

July	3	0
	8	13
	14	2
	19	15
	25	4
	30	16
Aug.	5	5
	10	18
	16	7
	21	20
	27	9

RV Persei

July	1	7
	5	6
	9	5
	13	4
	17	2
	21	1
	25	0
	28	23
Aug.	1	21
	5	20
	9	19
	13	17
	17	16
	21	15
	25	14
	29	12

RW Persei

	d	h
July	7	16
Aug.	3	1
	29	11

RS Cephei

July	11	2
Aug.	4	22
	29	18

RW Geminorum

July	2	0
	7	18
	13	11
	19	5
	24	22
	30	16
Aug.	5	9
	11	3
	16	21
	22	14
	28	8

Y Camelop.

July	1	10
	8	1
	14	15
	21	6
	27	21
Aug.	3	12
	10	2
	16	17
	23	7
	29	22

SS Carinae

July	1	13
	8	4
	14	8
	21	9
	27	23

Minima of Variable Stars of the Algol Type.—Continued.

SS Carinæ

	d	h
Aug.	3	13
	10	4
	16	18
	23	9
	29	23

Z Draconis

	d	h
July	2	7
	5	0
	7	17
	10	10
	13	4
	15	21
	18	14
	21	7
	24	0
	26	17
	29	10
Aug.	1	4
	3	21
	6	14
	9	7
	12	0
	14	17
	17	10
	20	4
	22	21
	25	14
	28	7
	31	0

RZ Centauri

	d	h
July	1	18
	3	15
	5	12
	7	9
	9	6
	11	3
	13	0
	14	21
	16	18
	18	15
	20	12
	22	9
	24	6
	26	4
	28	1
	29	22
	31	19
Aug.	2	16
	4	13
	6	10
	8	7
	10	4
	12	1
	13	22
	15	19
	17	16
	19	13
	21	10
	23	7
	25	4

RZ Centauri

	d	h
Aug.	27	1
	28	22
	30	19

SS Centauri

	d	h
July	2	13
	7	12
	12	11
	17	10
	22	9
	27	8
Aug.	1	7
	6	6
	11	5
	16	4
	21	3
	26	2
	31	1

δ Libræ

	d	h
July	2	12
	7	4
	11	19
	15	11
	21	3
	25	19
	30	10
Aug.	4	2
	8	18
	13	9
	18	1
	22	17
	27	8

U Coronæ

	d	h
July	2	9
	9	7
	16	5
	23	3
	30	0
Aug.	5	22
	12	20
	19	17
	26	15

R Aræ

	d	h
July	4	7
	13	4
	22	0
	30	20
Aug.	8	17
	17	13
	26	10

U Ophiuchi

	d	h
July	1	21
	3	14
	5	6
	6	22
	8	14
	10	7
	11	23
	13	15
	15	7

U Ophiuchi

	d	h
July	17	0
	18	16
	20	8
	22	0
	23	17
	25	9
	27	1
	28	17
	30	10
Aug.	1	2
	2	18
	4	10
	6	3
	7	19
	9	11
	11	3
	12	20
	14	12
	16	4
	17	21
	19	13
	21	5
	22	21
	24	14
	26	6
	27	22
	29	14
	31	7

Z Herculis

	d	h
July	2	5
	6	5
	10	5
	14	5
	18	4
	22	4
	26	4
	30	4
Aug.	3	4
	7	4
	11	3
	15	3
	19	3
	23	3
	27	3
	31	3

RS Sagittarii

	d	h
July	1	20
	6	16
	11	12
	16	8
	21	4
	26	0
	30	20
Aug.	4	16
	9	12
	14	8
	19	4
	24	0
	28	20

V Serpentis

	d	h
July	2	6
	9	4
	16	2
	23	0
	29	21
Aug.	5	19
	12	17
	19	15
	26	12

RX Herculis

	d	h
July	1	14
	3	8
	5	3
	6	22
	8	16
	10	11
	12	6
	14	1
	15	19
	17	14
	19	9
	21	3
	22	22
	24	17
	26	11
	28	6
	30	1
	31	19
Aug.	2	14
	4	9
	6	3
	7	22
	9	17
	11	11
	13	6
	15	1
	16	20
	18	14
	20	9
	22	4
	23	22
	25	17
	27	12
	29	6
	31	1

SX Sagittarii

	d	h
July	1	21
	6	1
	10	5
	14	8
	18	12
	22	16
	26	20
	30	23
Aug.	4	3
	8	7
	12	10
	16	14
	20	18

SX Sagittarii

	d	h
Aug.	24	21
	29	1

RR Draconis

	d	h
July	2	3
	7	19
	13	11
	19	3
	24	19
	30	11
Aug.	5	3
	10	19
	16	10
	22	2
	27	18

U Scuti

	d	h
July	1	1
	2	23
	4	21
	6	19
	8	16
	10	14
	12	12
	14	10
	16	8
	18	6
	20	3
	22	1
	23	23
	25	1
	27	19
	29	17
	31	14
Aug.	2	12
	4	10
	6	8
	8	6
	10	4
	12	1
	13	23
	15	21
	17	19
	19	17
	21	15
	23	13
	25	10
	27	8
	29	6
	31	4

RX Draconis

	d	h
July	2	13
	6	8
	10	2
	13	21
	17	16
	21	11
	25	6
	29	1
Aug.	1	20
	5	15
	9	10

Minima of Variable Stars of the Algol Type.—Continued.

RX Draconis

	d	h
Aug.	13	5
	17	0
	20	18
	24	13
	28	8

RV Lyræ

	d	h
July	4	3
	11	8
	18	12
	25	17
Aug.	1	22
	9	3
	16	7
	23	12
	30	17

U Sagittarii

	d	h
July	1	7
	8	2
	14	20
	21	14
	28	8
Aug.	4	3
	10	21
	17	15
	24	10
	31	4

SY Cygni

	d	h
July	5	9
	17	9
	29	9
Aug.	10	10
	22	10

WW Cygni

	d	h
July	2	22
	9	13
	16	5
	22	20
	29	11
Aug.	5	2
	11	18
	18	9
	25	0
Aug.	31	15

SW Cygni

	d	h
July	2	7
	11	10
	20	14
	29	17
Aug.	7	21
	17	0
	26	4

VW Cygni

	d	h
July	4	11
	21	8
Aug.	7	4
	24	1

UW Cygni

	d	h
July	3	22
	10	19
	17	17
	24	15
	31	12
Aug.	7	10
	14	8
Aug.	21	5
	28	3

W Delphini

	d	h
July	2	20
	12	11
	22	1
	31	16
Aug.	10	7
	19	22
	29	12

RR Delphini

	d	h
July	5	5
	14	10
	23	14
Aug.	1	19
	11	0
	20	5
	29	10

VV Cygni

	d	h
July	1	7
	4	6

VY Cygni

	d	h
July	7	5
	10	4
	13	3
	16	2
	19	1
	22	0
	24	23
	27	22
	30	20
Aug.	2	19
	5	18
	8	17
	11	16
	14	15
	17	14
	20	13
	23	12
	26	11
	29	9

UZ Cygni

	d	h
July	31	2
Aug.	31	9

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(—5	19)
July	5	2
	19	22
Aug.	3	17
	18	12

RX Aurigæ

	d	h
	(—4	0)
July	6	12
	18	4
	29	19
Aug.	10	10
	22	1

Y Aurigæ

	d	h
	(—0	18)
July	2	19
	6	16
	10	12
	14	9
	18	6
	22	2
	25	23
	29	19
Aug.	2	16
	5	13
	10	9
Aug.	14	6
	18	3
	21	23
	25	20
	29	16

RU Camelop.

	d	h
	(—9	12)
July	9	5
	31	12
Aug.	22	18

S Muscæ

	d	h
	(—3	11)
July	6	2
	15	18
	25	9
Aug.	4	1
	13	17
	23	9

T Crucis

	d	h
	(—2	2)
July	2	3
	8	21
	15	14
	22	8
	29	1
Aug.	4	19
	11	13
	18	6
	25	0
	31	17

R Crucis

	d	h
	(—1	10)
July	3	5
	9	1
	14	21
	20	16
	26	12
Aug.	1	8
	7	4
	13	0
	18	19
	24	15
	30	11

S Crucis

	d	h
	(—1	12)
July	3	22
	8	15
	13	8
	18	0
	22	17
	27	9
Aug.	1	2
	5	18
	15	3
	19	20
	24	13
	29	9

W Virginis

	d	h
	(—8	5)
July	8	9
	25	15
Aug.	11	22
	29	4

V Centauri

	d	h
	(—1	11)
July	6	14
	12	2
	17	14
	23	2
	28	14
Aug.	3	2
	8	13
	14	1
	19	13
	25	1
	30	13

R Triang. Austr.

	d	h
	(—1	0)
July	3	9
	6	18
	10	3
	13	13
	16	22
	20	7
	23	17
	27	2
	30	11
Aug.	2	21
	6	6
	9	15
	13	1
	16	10
	19	19
	23	5
	26	14
	29	23

S Triang. Austr.

	d	h
	(—2	2)
July	5	1
	11	9
	17	17
	24	0
	30	8

Maxima of Variable Stars of Short Period not of the Algol Type
Continued.

Aug. 5 16
d h
12 0
18 8
24 15
30 23

S Normæ
(—4 10)
July 7 18
17 12
27 6
Aug. 6 0
15 18
26 12

RV Scorpii
(—1 10)
July 6 21
12 23
19 0
25 2
31 3
Aug. 6 5
12 6
18 8
25 9
30 11

RV Ophiuchi
Minimum.
July 4 13
8 6
11 22
15 15
19 7
23 0
26 16
30 9
Aug. 3 1
6 18
10 10
14 3
17 19
21 12
25 4
28 21

Y Ophiuchi
(—6 5)
July 4 18
21 21
Aug. 8 0
25 3

W Sagittarii
(—3 0)
July 6 19
14 9
21 23
29 14
Aug. 6 4
13 18
21 8
28 23

Y Sagittarii
(—2 2)
July 2 2

Y Sagittarii
d h
7 20
13 15
19 9
25 4
30 23
Aug. 5 17
11 12
17 6
23 1
28 19

U Sagittarii
(—2 23)
July 2 9
9 3
15 21
29 9
Aug. 5 3
11 20
18 14
25 8

β Lyræ
(—3 7)
(—3 2)
July 7 12
13 18
20 10
26 16
Aug. 2 8
8 14
15 6
21 12

κ Pavonis
(—1 7)
July 6 16
15 18
24 20
Aug. 2 22
12 1
21 3
30 5

U Aquilæ
(—2 4)
July 5 8
12 9
19 9
26 10
Aug. 2 10
9 11
16 12
23 12
30 13

U Vulpeculæ
(—2 3)
July 3 11
11 11
19 10
27 10
Aug. 4 9
12 9
20 8
28 8

SU Cygni
d h
(—1 7)
July 2 8
6 5
10 1
13 21
17 18
21 14
25 10
29 6
Aug. 2 3
5 23
9 19
13 16
17 12
21 8
25 5
29 1

η Aquilae
(—2 6)
July 5 8
12 13
19 17
26 21
Aug. 3 1
10 6
17 10
24 14
31 18

S Sagittae
(—3 10)
July 6 12
14 21
23 6
31 16
Aug. 9 1
17 10
25 19

X Vulpeculæ
(—2 1)
July 4 14
10 22
17 6
23 13
29 21
Aug. 5 4
11 12
17 20
24 3
30 11

V Vulpeculae
Minimum
July 26 18

X Cygni
(—6 19)
July 14 21
31 6
16 15

T Vulpeculae
(—1 10)
July 3 4
7 15
12 1

T Vulpeculae
d h
July 16 12
20 22
25 8
29 19
Aug. 3 5
7 16
12 2
16 13
20 23
25 10
29 20

TX Cygni
July 9 16
24 9
Aug. 8 2
22 20

VY Cygni
(—2 14)
July 8 10
16 7
24 3
Aug. 1 0
8 21
16 17
24 14

VZ Cygni
(—2 12)
(—3 6)
July 7 2
12 2
16 19
21 19
21 19
26 13
31 13
Aug. 5 6
10 6
14 23
19 23
24 17
29 17

δ Cephei
(—1 10)
July 2 10
7 19
13 3
18 12
23 21
29 6
Aug. 3 15
8 23
14 8
19 17

δ Cephei
d h
25 2
30 11

V Lacertae
(—0 17)
July 3 22
8 22
13 21

V Lacertae
d h
July 18 21
23 21
28 20
Aug. 2 20
7 19
12 19
17 19
22 18
27 18

X Lacertae
Minimum
July 2 11
7 21
13 8
18 18
24 5
29 15
Aug. 4 2
9 12
14 23
20 10
25 20
31 7

RS Cassiop.
(—1 19)
July 2 21
9 4
15 12
21 19
28 2
Aug. 3 9
9 16
15 23
22 6
28 13

RY Cassiop.
(—7 10)
July 8 14
20 17
Aug. 1 21
14 0
26 4

Y Lacertae
(—1 10)
July 2 1
6 8
10 16
14 23
19 7
23 14
27 22
Aug. 1 6
5 13
9 21
14 4
18 12
22 19
27 3
31 11

Approximate Magnitudes of Variable Stars on May. 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	11.0*d*	S Gemin.	7	37.0	+23	41	10.0 *i*
T Cassiop.		17.8	+55	14	12.0 *i*	T Gemin.		43.3	+23	59	12.0*d*
R Androm.		18.8	+38	1	11.0 *i*	U Puppis		56.1	−12	34	14.0
Y Cephei		31.3	+79	48	12.5	R Cancri	8	11.0	+12	2	11.0 *i*
U Cassiop.		40.8	+47	43	8.6*d*	V Cancri		16.0	+17	36	13.0*d*
V Androm.		44.6	+35	6	10.0*d*	RT Hydrae		24.7	− 5	59	8.5
W Cassiop.		49.0	+58	1	9.5	U Cancri		30.0	+19	14	10.0
U Androm.	1	9.8	+40	11	10.0 *i*	X Urs. Maj.		33.7	+50	30	9.8*d*
S Cassiop.		12.3	+72	5	9.5 *i*	S Hydrae		48.4	+ 3	27	8.8*d*
X Cassiop.		49.8	+58	46	9.5	T Hydrae		50.8	− 8	46	9.8*d*
U Persei		53.0	+54	20	8.5*d*	T Cancri		51.0	+20	14	8.5 *i*
W Androm.	2	11.2	+43	50	<13	S Pyxidis	9	0.7	−24	41	12.5*d*
Z Cephei		12.8	+81	13	<13	W Cancri		4.0	+25	39	13.5*d*
S Persei		15.7	+58	8	8.9	X Hydrae		30.7	−14	15	11.5 *i*
RR Cephei		30.4	+80	42	12.0 *i*	Y Draconis		31.1	+78	18	10.5 *i*
R Trianguli		31.0	+33	50	6 5*d*	R Leo. Min.		39.6	+34	58	11.7*d*
W Persei		43.2	+56	34	10.5*d*	RR Hydrae		40.4	−23	34	11.0 *i*
U Arietis	3	5.5	+14	25	11.2*d*	R Leonis		42.2	+11	54	9.3*d*
Y Persei		20.9	+43	50	9.7*d*	Y Hydrae		46.4	−22	33	7.5*d*
R Persei		23.7	+35	20	8.6 *i*	V Leonis		54.5	+21	44	10.0 *i*
T Tauri	4	16.2	+19	18	12.6	R Urs. Maj.	10	37.6	+69	18	12.8 *i*
R Tauri		22.8	+ 9	56	12.0 *i*	W Leonis		48.4	+14	15	10.8 *i*
W Tauri		22.2	+15	49	10.5*d*	S Leonis	11	5.7	+ 6	0	12.2*d*
S Tauri		23.7	+ 9	44	11.0*d*	R Comae		59.1	+19	20	14.0
T Camelop.		30.4	+65	57	8.6*d*	T Virginis	12	9.5	− 5	29	13.7
X Camelop.		32.6	+74	56	11.0 *i*	R Corvi		14.4	−18	42	10.0 *i*
V Tauri		46.2	+17	22	11.7*d*	SS Virginis		20.1	+ 1	19	7.5
R Orionis		53.6	+ 7	59	11.8*d*	T Can. Ven.		25.2	+32	3	10.1 *i*
V Orionis	5	0.8	+ 3	58	<13	Y Virginis		28.7	− 3	52	10.0 *i*
R Aurigae		9.2	+53	28	12.3*d*	T Urs. Maj.		31.8	+60	2	12.4*d*
S Aurigae		20.5	+34	4	9.3*d*	R Virginis		33.4	+ 7	32	11 0
W Aurigae		20.1	+36	49	12.6*d*	RS Urs. Maj.		34.4	+59	2	11.0*d*
T Orionis		30.9	− 5	32	9.6	S Urs. Maj.		39.6	+61	38	9.8*d*
S Camelop.		30.2	+68	45	9.5*d*	RU Virginis		42.2	+ 4	42	9.0
RR Tauri		33.3	+26	19	10.6 *i*	U Virginis		46.0	+ 6	6	9.0 *i*
U Orionis		49.9	+20	10	6.8 *i*	RT Virginis		57.6	+ 5	43	8.5
V Camelop.		49.4	+74	30	<13	RV Virginis	13	2.8	−12	38	<13.5
Z Aurigæ		53.6	+53	18	9.8 *i*	V Virginis		22.6	− 2	39	13.5
X Aurigae	6	4.4	+50	15	8.3 *i*	R Hydrae		24.2	−22	46	8.0 *i*
V Aurigae		16.5	+47	45	9.2	S Virginis		27.8	− 6	41	11.0
V Monoc.		17.7	− 2	9	11.5	T Urs. Min.		32.6	+73	56	13.5*d*
R Monoc.		33.7	+ 8	49	11.6	R Can. Ven.		44.6	+40	2	11.2*d*
S Lyncis		35.9	+58	0	12.0 *i*	RR Virginis		49 6	− 8	43	14.0
X Gemin.		40.7	+30	23	12.6*d*	Z Bootis	14	1.3	+13	59	8.8 *i*
W Monoc.		47.5	− 7	2	10.6	Z Virginis		5.0	−12	50	11.0
Y Monoc.		51.3	+11	22	9.4 *i*	U Urs. Min.		15.1	+67	15	11.5
X Monoc.		52.4	− 8	56	8.3*d*	S Bootis		19.5	+54	16	8.0 *i*
R Lyncis		53.0	+55	28	13.2*d*	RS Virginis		22.3	+ 5	8	14.0*d*
RS Geminorum		55.2	+30	40	10.5 *i*	V Bootis		25.7	+39	18	9.8
V Can. Min.	7	1.5	+ 9	2	<13.5	R Camelop.		25.1	+84	17	9.2*d*
R Gemin.		1.3	+22	52	13.5	R Bootis		32.8	+27	10	11.8 *i*
R Can. Min.		3.2	+10	11	7.5 *i*	V Librae		34.8	−17	14	12.4*d*
RR Monoc.		12.4	+ 1	17	<13.5	U Bootis		49.7	+18	6	11.5
V Gemin.		17.6	+13	17	12.6*d*	RT Librae	15	0.8	−18	21	10.4 *i*
S Can. Min.		27.3	+ 8	32	10.8 *i*	T Librae		5.9	−19	38	12.4*d*
T Can. Min.		28.4	+11	58	12.5 *i*	Y Librae		6.4	− 5	38	12.2
Z Puppis		28.3	−20	57	13.8*d*	S Librae		15.6	−20	2	11.0*d*
U Can. Min.		35.9	+ 8	37	10.0	S Serpentis		17.0	+14	40	10.5 *i*

Approximate Magnitudes of Variable Stars on May 1, 1908—Con.

Name.		R. A. 1900.	Decl. 1900.		Magn.	Name.		R. A 1900	Decl. 1900		Magn.
	h	m	°	′			h	m	°		
S Coronae	15	17.3	+31	44	9.0	X Draconis	18	6.8	+66	8	10.0 *i*
RS Librae		18.5	−22	33	12.0*d*	RY Ophiuchi		11.6	+ 3	40	11.5 *i*
RU Librae		27.7	−14	59	10.0 *i*	W Lyrae		11.5	+36	38	12.0*d*
X Librae		30.4	−20	50	12.5*d*	SV Herculis		22.3	+24	58	14.0
S Urs. Min.		33.4	+78	58	8.8	T Serpentis		23.9	+ 6	14	12.0
U Librae		36.2	−20	52	10.4*d*	RZ Herculis		32.7	+25	58	13.5
Z Librae		40.7	−20	49	13.4	X Ophiuchi		33.6	+ 8	44	7.0
R Coronae		44.4	+28	28	5.9	RY Lyrae		41.2	+34	34	<14.3
X Coronae		45.2	+36	35	14.0	RW Lyrae		42.1	+43	32	14.0
R Serpentis		46.1	+15	26	9.5 *i*	Z Lyrae		56.0	+34	49	13.3
V Coronae		46.0	+39	52	7.5 *i*	RX Lyrae		50.4	+32	42	<14.0
R Librae		47.9	−15	56	<14	ST Sagittarii		55.9	−12	54	12.8 *i*
RR Librae		50.6	−18	1	12.4*d*	RT Lyrae		57.8	+37	22	13.6*d*
Z Coronae		52.2	+29	32	13.5	R Aquilae	19	1.6	+ 8	5	11.8*d*
RZ Scorpii		58.6	−23	50	11.6	V Lyrae		5.2	+29	30	14.0*d*
Z Scorpii	16	0.1	−21	28	9.8 *i*	RX Sagittarii		8.7	−18	59	9.0
R Herculis		1.7	+18	38	7.8 *i*	RW Sagittarii		8.1	−19	2	9.6
RR Herculis		1.5	+50	46	9.5	S Lyrae		9.1	+25	50	14.0
U Serpentis		2.5	+10	12	8.6 *i*	RS Lyrae		9.3	+33	15	14.2
X Scorpii		2.7	−21	16	12.5	RU Lyrae		9.1	+41	8	<14
W Scorpii		5.9	−19	53	<14	U Draconis		9.9	+67	7	10.0
RX Scorpii		5.9	−24	38	13.6*d*	W Aquilae		10.0	− 7	13	8.4 *i*
RU Herculis		6.0	+25	20	13.0*d*	T Sagittarii		10.5	−17	9	9.0
R Scorpii		11.7	−22	42	13.5	RY Sagittarii		10.0	−33	42	7.0
S Scorpii		11.7	−22	39	14.3*d*	R Sagittarii		10.8	−19	29	9.7
W Coronae		11.8	+38	3	12.6	S Sagittarii		13.6	−19	12	<14
V Ophiuchi		21.2	−12	12	8.5*d*	Z Sagittarii		13.8	−21	7	13.6
U Herculis		21.4	+19	7	11.0 *i*	TZ Cygni		29.8	+28	6	11.0
Y Scorpii		23.8	−19	13	11.8	U Lyrae		16.6	+37	42	12.0
SS Herculis		28.0	+ 7	3	11.9*d*	T Sagittae		17.2	+17	28	9.0
S Ophiuchi		28.5	−16	57	13.4*d*	TY Cygni		29.8	+28	6	13.5
T Ophiuchi		28.0	−15	55	10.4*d*	R Cygni		34.1	+49	58	11.0 *i*
W Herculis		31.7	+37	32	13.6	RV Aquilae		35.9	+ 9	42	13.5
R Draconis		32.4	+66	58	7.4	RT Aquilae		33.3	+11	30	8.6
RR Ophiuchi		43.2	−19	17	11.8*d*	RT Cygni		40.8	+48	32	12.0
S Herculis		47.4	+15	7	11.8*d*	TU Cygni		43.3	+48	49	9.8
RV Herculis		56.8	+31	22	11.0	X Aquilae		46.4	+ 4	13	<13.5
R Ophiuchi	17	2.0	−15	58	12.4*d*	χ Cygni		46.7	+32	40	5.0 *i*
RT Herculis		6.8	+27	11	12.0	RR Aquilae		52.4	− 2	11	9.3 *i*
Z Ophiuchi		14.5	+13	7	13.4	RS Aquilae		53.7	− 8	9	12.8
RS Herculis		17.5	+23	1	11.6*d*	Z Cygni		58.6	+49	46	12.4*d*
RU Ophiuchi		28.1	+ 9	30	13.2*d*	X Cephei	21	3.6	+82	40	12.0 *i*
RS Ophiuchi		44.8	− 6	40	11.3	T Cephei		8.2	+68	5	7.0 *i*
RT Ophiuchi		51.8	+11	11	<13	S Cephei		36.5	+78	10	7.0
T Draconis		54.8	+58	14	9.3 *i*	S Lacertae	22	24.6	+39	48	11.0 *i*
RY Herculis		55.4	+19	29	10.3*d*	R Lacertae		38.8	+41	51	9.0 *i*
V Draconis		56.3	+54	53	10.6*d*	V Cassiop.	23	7.4	+59	8	7.5
T Herculis	18	5.3	+31	0	9.2 *i*	Z Cassiop.		39.7	+56	2	11.0 *i*
W Draconis		5.4	+65	56	9.8 *i*	R Cassiop.		53.3	+50	50	12.5*d*
						Y Cassiop.		58.2	+55	7	9.5 *i*

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Vassar, Mt. Holyoke, and Harvard Observatories.

The Variable Star 31.1907 was found to be bright, magnitude 10.5 on April 29 at 13h G. M. T. In the course of the next two hours, the increase any, was only slight. Observations were then stopped by clouds. At the last maximum it remained above the magnitude 12.5 for about five days.

EDWARD C. PICKERING.

Astronomical Bulletin, No. 327.
Harvard College Observatory,
Cambridge, Mass.

New Variable 7.1908 Monocerotis.—In *A. N.* 4245 Professor W Ceraski announces a new variable in Monoceros. Its position is

1855.0	$\alpha = 7^h\ 22^m\ 07^s$	$\delta = -4°\ 0'$
1900.0	7 24 21	$-4\ \ 5$

On the photographs its brightness is estimated as follows:

1899 Feb. 6	<12½	mag.	(invisible)
1900 Mar. 19	<12½	"	"
1901 " 15	<12	"	"
1903 " 16	10½	"	
1905 " 2	9½	"	
1907 Feb. 16	10½	"	
1908 Mar. 4	11½	"	

The Light Curve of RV Tauri.—In *A. N.* 4243 Mr. S. Enebo gives an interesting curve, drawn from about 100 of his own observations of this variable, in the interval from August 27, 1906 to March 1908. The curve as shown in Figure 1 appears to be that of a variable of the β Lyræ type, with a period of 78.57 days, superposed upon another of much longer period. The magnitude of the star at its maximum diminished from $8^m.9$ on September 18, 1906 to $9^m.4$ on April 2, 1907. During the winter of 1907-08 it increased to about $8^m.6$. The two minima of β Lyræ type are nearly symmetrical, one

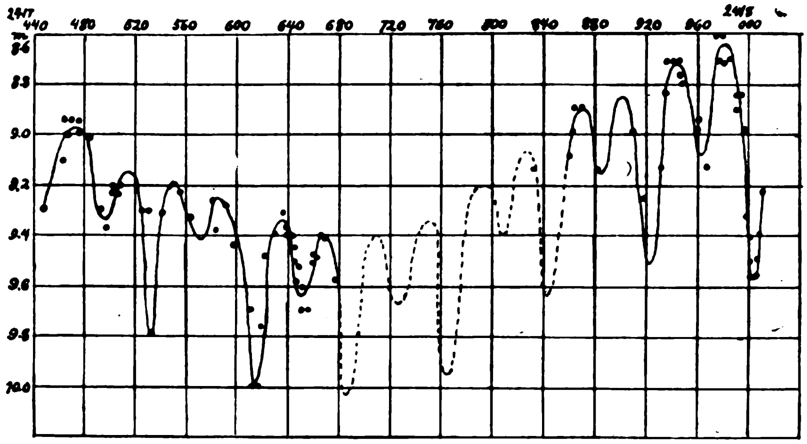


FIGURE 1

having more than double the range of the other. Mr. Enebo gives for the elements of the β Lyræ-variation

Chief minimum	= 2417609.6	Gr. M. T.	+ 78ᵈ.57 E
Secondary "	= 2417648.9	"	+ 78 .57 E
Maximum	= 2417629.2	"	+ 39 .285 E.

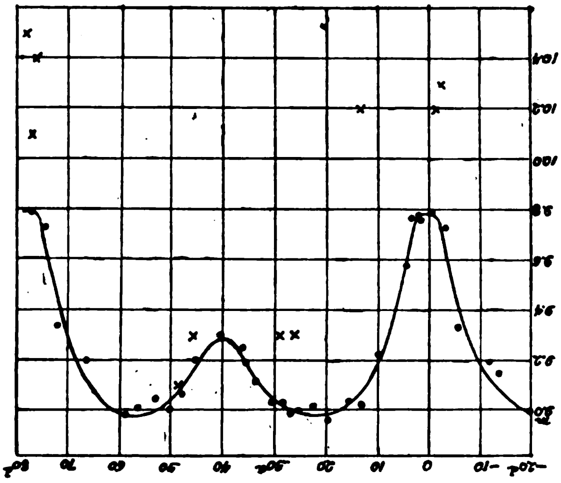


FIGURE 2.

Figure 2 shows the curve when all the observations have been reduced so as to make the normal brightness at maximum 9.0.

GENERAL NOTES.

Jupiter's Eighth Satellite. Continued observations of the moving object observed near Jupiter by Mr. Mellotte, of the Greenwich Observatory staff, has confirmed the first supposition that it was a new satellite. The body has also been photographically recorded at the Lick Observatory and by Dr. Wolf at Heidelberg. It is slightly brighter than J. VII. Details are given of the measured positions relative to Jupiter from 1908 January 27, to March 23, and on analysis it is found that these positions may be satisfied on the assumption that the new satellite has a retrograde orbital motion; the co-ordinates of the pole of its orbit plane are R.A. = 334° 48′; N. decl. = 56° 44′; distance from Jupiter = 0.24 of an astronomical unit; daily motion about Jupiter 0°.266. It passed the minor axis of the apparent ellipse on February 18.

KNOWLEDGE AND SCIENTIFIC NEWS.
May, 1908.

Spectrum and Brightness of Nova Persei. Professor J. Hartmann describes the conclusions he has been able to formulate from his recent observations of the body now representing Nova Persei. For this work he designed a new spectroscope having a collimator objective of 40 mm. aperture and 60 c. m. focal length, made of ultraviolet glass, two right and left handed quartz half-prisms of 30°, and a camera objective of quartz, 40 mm. aperture and 32 c. m. focal length. With this apparatus attached to the 80 c. m.

refractor he obtained an excellent photograph of the Nova spectrum on October 15 and 18, 1907, with a total exposure of 8¼ hours, the magnitude of a star being 11.4. The spectrum obtained was found to be very similar to that of the Wolf Rayet star B. D. 35° 4001. The line λ 4688 is the strongest in both spectra, while the fairly strong Wolf Rayet line λ 4618 is comparatively faint in the Nova. The nebula lines, which were very strong during the first part of the period of decline, are now very faint or absent.

ASTRONOMISCHE NACHRICHTEN.
February 8, 1908.

The Calendar. In examining the question as to the frequency with which any given day of any month will fall on Sunday, or other day of the week, a very curious general law was discovered—a law not hitherto noticed, so far as I know.

To illustrate:—the fourth of March fell on Sunday in 1821, then again in 1827, 1832, 1838, and 1849; the intervals being in succession 6, 5, 6, and 11 years. From 1849 to 1877 the like intervals are found. And these intervals would follow in the same order for all time, except for the fact that centesimal years which are not divisible by 400 are not leap years, as 1700, 1800, 1900, 2100, 2200, &c. Thus three times in 400 years the regular intervals are interrupted for a period of twelve or fifteen years, but the old order is soon restored.

THE RULE IS UNIVERSAL—*Every day of the year falls on every day of the week four times in 28 years.* The intervals for the successive years would always be 6, 5, 6, and 11. but for the fact above stated that the 29th of February is dropped three times in 400 years. Astronomers will see that these 28 years stand for the *Solar Cycle.*

It may be well to pursue this subject a little further. Following 1877, the 4th of March fell on Sunday in 1883, 1888, 1894, 1900 and 1906, the intervals being 6, 5, 6, 6, and six years. If 1900 had been a leap year, the regular intervals would have appeared.

After the adoption of the constitution of the United States, (the election for President being in leap years,) the date for the inauguration would be the 4th of March next following a leap year. The first inauguration day which fell on Sunday was in 1821, at Monroe's second term.

In 1849 it occurred again, at Taylor's inauguration, and again in 1877, when Hayes became President. It will not occur again until 1917, nine years in the future. After that year it will occur six times at intervals of 28 years, the last of the six being in the year 2085. Following that year, it will not again take place for forty years, the same interval as that between 1877 and 1917. Whenever this 28-year period includes a centesimal year which is not a leap year, as 1900, 2100, &c., the period is increased to forty years, neither more nor less.

In 1685 March 4th fell on a Sunday, and counting forward for a few years into the next century, the successive intervals are 6, 5, 7, 5, 6, 11. Four centuries later, the like intervals will occur, but not before. This series of years includes the year 1700. The 4th of March 1781 was Sunday, and counting forward a few years into the following century, we find the series of intervals to be 6, 5, 6, 6, 6, 11. Here we pass by the year 1800. Four centuries later the same intervals will occur again. In like manner if we pass over the year 1900, we find the same series which we had in passing over

1800. But in passing over 1600, 2000, &c, which are leap years, only the regular four numbers are found, viz. 6, 5, 6, 11. All possible changes and variations take place in 400 years. The first of January 1600, 2000, &c., will fall on the same day of the week, and so on forever. So any day of any month in the year 1601 will fall on the same day of the week, as the like day of 2001. And the same law holds good for each successive year of the four hundred,—a degree of regularity which is somewhat remarkable and which would hardly have been considered probable before the investigation was made.

R. W. McFarland.

Emeritus Professor of Civil Engineering, Ohio State University.

Physical Phenomena of the Transit of Mercury. I wish to acknowledge the kind attention of astronomers, observing the last transit of Mercury, to the phenomenon of the complete illumination of the planet's disk when half of it was projected on the chromosphere. The observations as a whole, while not as decisive as could be wished, seem to point to the reality of the phenomenon as originally observed by me May 6, 1878. The illumination mentioned seems to be a very delicate phenomenon, and perhaps visible only at a critical moment. I should therefore deem it worth the while of observers to make the attempt to see this phenomenon at future transits of the planet Mercury.

Our observations at the Philadelphia Observatory failed to disclose the phenomenon mentioned. No suitable time-pieces being available, the entire attention was given to the physical phenomena. Dr. Paul R. Heyl and myself observed through the 8″ telescope, and, alternating in our view of the planet, could not see any suggestion of the full illumination of the planet when half way off the limb of the Sun. The seeing was not good, the Sun's limb showing considerable atmospheric disturbance. I have since realized that I made a mistake in endeavoring to have two observers use the same telescope for verification of the phenomenon mentioned. It is quite certain that only one observer can use the telescope to advantage in such a trial, although I had felt rather sure that, if the seeing were good enough, two observers could verify the phenomenon through the same instrument.

While the planet was approaching the solar edge I noticed a grayish illumination of the following semi-disk of Mercury, and, without describing the phenomenon, asked Dr. Heyl to see if he noticed any difference of illumination in the planet. He reported no difference, and at subsequent trials could not see what I saw then, and subsequently. My faith in the reality of the semi-illumination of the planet while approaching the solar edge was somewhat staggered by this negative decision of my friend, and hence I made up my mind that I would make no report of the phenomenon, although I saw this grayish illumination change position as the planet approached the limb of the Sun.

On reading the detailed description of the observations of Professor G. A. Hill, as reported by Dr. W. S. Eichelberger in No. 601 of the *Astronomical Journal*, I decided to state that I had verified, in its essential elements, Professor Hill's physical observations of the dull illumination of the following half of the planet early in the approach to the limb, and the change of this illumination to the preceding side. It was all so evident and yet so puzzling to me, and so completely unverified by the colleague who so kindly agreed to try to verify anything seen, that but for the excellent report of Dr. Eichelberger the appearance would never have been mentioned.

It seems worth while to say to observers of the transit of Mercury that it is utterly useless to endeavor to see a *ring* about the planet. It seems quite certain that none such exists, and that it is only possible to see the gray illumination of the disk just before its approach to the solar limb, and at its midway position on the limb.

In conclusion I would draw attention to the negative results of so excellent a physicist and observer as Dr. Heyl, as against the positive observation of the very curious phenomenon by Professor G. A. Hill and myself. Should there not be some plan of applying delicate standard tests to the eyes of astronomical observers so as to decide scientifically and definitively who ought to see and who ought not to see the different classes of celestial phenomena? MONROE B. SNYDER.

Philadelphia Observatory.
May 14, 1908.

Volume II of the Astrophysical Observatory of the Smithsonian Institution. We are in receipt of the second volume of the Annals of the Astrophysical Observatory of the Smithsonian Institution at Washington, D. C., under the direction of C. G. Abbot, with F. E. Towle Jr. as Aid.

This quarto volume of 245 pages, 44 tables and 29 fine illustrations is a masterful piece of work in its line. Our frontispiece is a reproduction of a photograph of the Observatory building.

This Astrophysical Observatory was founded through the efforts of the Institution's late secretary, Professor S. P. Langley, who was its director until his death. The work described in this volume is a continuation of researches on the relations of the Sun to climate and life on the Earth in which the brilliant Langley was a pioneer investigator. The writer well remembers the long and earnest work of this great man in the hope of laying a certain and secure foundation for successful study of the radiation of the Sun that there might be reliable means of forecasting climatic conditions for some time in advance. That his methods of work were scholarly, certain and exact, the best talent of today does not seriously question.

This new volume shows plainly that the hope of Langley may yet be largely realized in the years to come, for it contains apparently careful and comparable measurements of the solar radiation extending over a considerable period of past time, and these seem to indicate that the Sun's radiation alters in its intensity from time to time and that these alterations are sufficient to effect the temperature of the Earth very appreciably. Such approaches to these delicate physical questions are very encouraging for practical and hopeful weather predictions when the fundamental facts are better known.

The Red Spot on Jupiter. An interesting report on the condition and motion of the Red Spot on the planet Jupiter appears in the last number of the *Journal* of the British Astronomical Association. The great south tropical disturbance in connection with the Red Spot has claimed the attention of the Jupiter section of the society for some time past. The points of observation have been to note the mode of transference of the dark matter from the following to the preceding side of the Red Spot hollow; to notice the interval of time elapsing between the arrival of the preceding end of the disturbance and the following end of the Red Spot, and the appearance of the dark matter on the tropical zone above the preceding 'shoulder', to notice also the effect of the conjunction on the motion of the Red Spot.

The results of recent observations seem to show that portions of the disturbed area are accelerated as they approach the Red Spot hollow; that at previous conjunctions the dark matter seemed to be passing around the south side of the Red Spot; that the length of the disturbance has varied considerably since the beginning of the apparition, and that the rotation period of the Red Spot is undoubtedly less than during the earlier part of the apparition.

The variety of interesting details in the report of this work on the surface markings of Jupiter in the vicinity of the Red Spot is very useful matter in the full record that this section of the society is making. We earnestly hope that like painstaking observation and continued study of this planet may be done as well on this side of the ocean. In this work, as in all other, organized effort pays most largely.

Recently Discovered Manuscript of Archimedes. In the May number of the *Bulletin* of the *American Mathematical Society*, page 382, occurs an account of a recent discovery of a new manuscript of Archimedes, by Charles S. Slichter. The information that he gives of the discovery is derived from two important accounts published by Professor J. L. Heiberg. "One account is printed in Volume 42 of *Hermes* which contains the Greek text of the last treatise of Archimedes which is recovered nearly complete in the newly found manuscript. A German translation of the Greek text, and an interesting commentary by Zeuthen, is printed by Heiberg in the Bibliotheca Mathematica Vol 7. page 321."

This article is valuable for the compact statement of the many points of interest that the newly found manuscript reveals. Mathematicians will be eager to get full knowledge of it from these very helpful sources.

As an illustration of the method of treatment of this new matter we give the final paragraph:—

Archimedes makes it clear that he is using this method (described before) to discover the theorems, and that it is not founded on demonstration. But in speaking of spheres as "filled up" by circles, and of surfaces as "made up" of lines he is not misusing the method of infinitesimals, nor treading on dangerous ground. In fact the elements which "fill up" the magnitudes are always so taken by Archimedes, that the process can be immediately satisfied by an exhaustive proof. From this point of view his scheme may be regarded as analogous to the modern method of infinitesimals when founded on the doctrine of limits. There is a normal and systematic procedure, although tedious and laborious, for converting the mechanical proofs into exhaustive proofs. Therefore Archimedes may be regarded as having taken the decisive step in founding a method which in essential respects is that of the Integral Calculus. If he had been like many modern mathematicians, he would have omitted the exhaustive proofs altogether, but would have added to each of his mathematical demonstrations a set phrase like this: "It is easy to see that an exhaustive proof may be constructed in the usual manner. This is left to the reader."

Correlation of Stellar Characters. In volume 66 p. 445 of the *Monthly Notices* appeared a paper of much interest which presented in full, as far as carried, considerations on the correlations of stellar characters by Winifred Gibson and Karl Pearson of London.

In volume 58, No. 5, p. 415 this interesting correlation of the stellar data is continued, covering a space of 33 pages with six illustrative diagrams. We have room only for the conclusions drawn from this extended and painstaking work.

Conclusions.—While we are fully aware how badly the mere statistician may stumble in dealing with astronomical data, we still think that the general relationships shown by the statistical correlation constants may be of value to astronomers. They serve to indicate the directions in which closer relationships may be found, and where, possibly, more effective classifications may be made. The values given in the accompanying general scheme are certainly not final, but we do not think that they give at all misleading values, or values really far from the truth. There remains much to be done, and the scheme indicates some of the values which yet remain to be found. While parallax touches one element only of position, direction, as indicated by the usual stellar coördinates is a second; this "position" in the narrower sense has not been discussed in the present paper. We have purposely included it in the table, to indicate that we have not overlooked those position correlation problems to which the astronomer is now turning, and to which approach is possible from more than one direction. We hope later to deal with the question of correlation of stellar characters and position. Taken as a whole, we are, we think, compelled to conclude that the associations between parallax, proper motion, and magnitude are considerably less than we should anticipate if we hypothecated any approach to a uniform distribution of stars with a system of random velocities throughout space. The existence of correlations between color and spectral class, not only with magnitude, but with parallax and proper motion, suggests, if it does not demonstrate, that chemical constitution and luminosity are dependent in some manner not only on spatial distribution, but on velocity in space.

Correlation of Stellar Characters.

	Color.	Spectral Class.	Magnitude.	Parallax.	Proper Motion.	Position
Color	1.00	.71	.30	?	?	?
Spectral class	.71	1.00	.69(.43, .54*)	.36	.36	?
Magnitude	.30	.69(.43, .54*)	1.00	.30	.35	?
Parallax	?	.36	.30	1.00	.30	?
Proper motion	?	.36	.35	.39	1.00	?
Position	?	?	?	?	?	1.00

* According to Pickering's and Lockyer's classifications respectively.

Astronomy at Marsovan, Turkey. A recent letter from Dr. A. G. Sivaslian, of Marsovan, Turkey says that he has quite completed the manuscript of a text-book on Astronomy which he has been preparing for some months past, references to which have already been made in this publication.

In preparing the star charts he says: "I tried to prepare star charts for every third month of the year, similar to those published in the Popular Astronomy. Now I have changed my mind and am preparing a single chart which will contain stars down to 30° south declination. In its preparation I have copied the northern constellation from Poole Brothers' charts published in Popular Astronomy, and condensed the southern constellations to the same scale in declination as the northern constellations. It will be a circular chart of about eight inches in diameter and will be folded in the middle.

The transit of Mercury was the most interesting astronomical event since I came here. According to calculation it was to begin at 12:44 p. m. In the morning after chapel exercises I gave a short talk to the students about the transits of Mercury and Venus, and told them about the transit of that day, but there was not much prospect of our seeing it. It was cloudy all the morning. At noon I went to dinner; at 12:30 there were some breaks in the clouds so I ran to the college. Our three-inch telescope was already in its place inside of a south window. At 12:40 there was a break very near to the Sun, so I pointed the telescope to the Sun and waited. At 12:45 I saw the Sun the first time and the planet was already on the Sun just past the second contact. I could see the Sun only about two minutes. I took the telescope down to the campus with the hope that there might be other breaks, but very soon thicker clouds gathered and it began to rain. So I had to take the telescope into the building again. After 3:00 p. m. the sky cleared a little, and I was able to show the planet to all the students class by class. Toward four o'clock I took the telescope to the girls' school and there Miss Willard showed it to her astronomy class."

Brilliant Meteors seen from Dumont, Iowa. Saturday evening April 18th, 1908 at 10:30 I saw a meteor fall from high in the northeastern heavens towards the northwest continuing to fall until quite near the horizon where it became extinct.

There was a full Moon and as the meteor fell it looked nearly as large as the full Moon. As it fell it left a long glowing trail and numerous sparks behind it; it lit everything up with a beautiful white light making it nearly as light as day. I think that the meteor was falling about twenty-five or thirty seconds I did not hear any unusual sound.

On August 14, 1907 at eleven o'clock I witnessed a meteor fall from high in the southeastern heavens toward the northwest. It was a very dark night there being no Moon and as that meteor fell it looked larger than a full Moon. I did not hear any unusual sound. It fell slower than any other meteor I have seen. I think it must have been falling more than a minute. It fell from very high in the southeast to very near the horizon in northwest. A beautiful white light was shed around making it very nearly as bright as sunlight. It left a long glowing trail after it, but no sparks.

ETHEL F. LOOMIS.

Dumont, Iowa.

Mr. Lowell's Illustration of Saturn's Rings. The accompanying plate in this number is to replace that of the March one in order to bring out the features of the Saturnian ring-system observed at Flagstaff in 1907, especially of its shadow on the ball and of that shadow's black core. Owing to the small size of the first cut and of the general difficulties of reproduction it failed to show these peculiarities, the detection of which constituted an essential part of the paper—and so we run this time an unusually large cut at Mr. Lowell's request even at the expense of the looks of the page.

New Earthquake Theory. The new theory of earthquakes and volcanoes is objectionable. I will give a few reasons for my opinion.

At a depth of two miles the temperature is 212° more or less according to ocality. A geyser is simply a deep hole or well reaching down to the hot rocks with a stream of water entering its sides. While the water in the bottom is heating the well is filling, the pressure becoming greater on the heated water in the bottom, circulation being cut off so the heat can not escape, the much heated water in the bottom is converted into steam forcing the water above out in a splendid display, these actions taking place at regular intervals so long as the heat is applied at the bottom and the water comes in.

In volcanoes the crust of the Earth has a vent or opening down to the liquid interior which remains some distance below sea level the world over except raised by water entering this opening far beneath the surface of the molten mass through another fissure or vent connected with the surface water of the ocean or more likely a lake or other intake of a high altitude far above the surface of the molten mass which would give sufficient pressure to force the water into the volcanic tube raising the molten mass above the water gradually until an eruption would take place which would throw out a part or all of the contents. The molten matter rising again from beneath the same operation would be repeated in duration of time according to the water pressure and supply.

We have a fine illustration of volcanoes in some California wells, say one 300 feet deep, the water rises 200 feet in it or within 100 feet of the surface, a small pipe is put down to the bottom of the well through which air is forced causing the water and air to flow out at the top by turns, the weight of the water preventing the air coming through it in small bubbles but holds it in larger volumes which fill the caisin of the well for a number of feet, thus showing how the molten mass in a volcano might float on a large volume of steam. This would account for the different heights at which lava stands in different volcanoes.

The adherents of the new theory seem to have overlooked the fact of the land and mountains being full of water within a few feet of the surface at least as attested by the many springs and seeps forming into rivers carrying the water overland to the sea, thus giving a water pressure of from a few feet to several miles according to elevation under the land greater than it has under the sea. Such a theory would have us believe a light weight would raise a heavier one. Again the idea of a light liquid like water or steam penetrating into a heavier molten liquid such as the intérior of the Earth must be would be like a cork sinking in water. If water never had existed on the Earth there would be mountains and earthquakes just the same, but no violent ejections of volcanoes and perhaps none at all.

The lay of the land and mountains certainly does not or never has depended on the lay of the seas as is claimed in paragraph one and two, but the oceans depend on the lay of the land for their locality.

As the Earth's crust becomes thicker its surface becomes more uneven by the shrinkage of the interior, some coasts going down and some lifting up as nearly all parts have been submerged and elevated many times by turns.

If the mountains were formed by expansion there would be great gaping fissures on their divides constantly widening and not as we find, the strata shoved together, broken up and twisted and mixed in more or less confusion. As to gravity being less on the elevated portions of the Earth as stated in paragraph 12 ; it does not necessarily depend on a light or porous substance beneath for as we leave the main body of the Earth gravity decreases.

G. M. CROWL.

Covina, California.

Young and Jackson's Elementary Algebra. There are things in this new book that will commend themselves to experienced teachers in Algebra. They pertain to the present general movement for better teaching in Algebra. This fact appears in the following ways:

1. The book gives little of mathematical theory, but much of the utility of the subject.
2. It aims at logical and practical values in mental drill.
3. It makes the properties of the equation a central thought in the plan of the book.
4. The graph is freely used more as a means of illustration than as an analytic method.

The usual courses in Algebra including quadratics are given in this book, and the evidences of a teacher's skill are everywhere present in the detail of it.

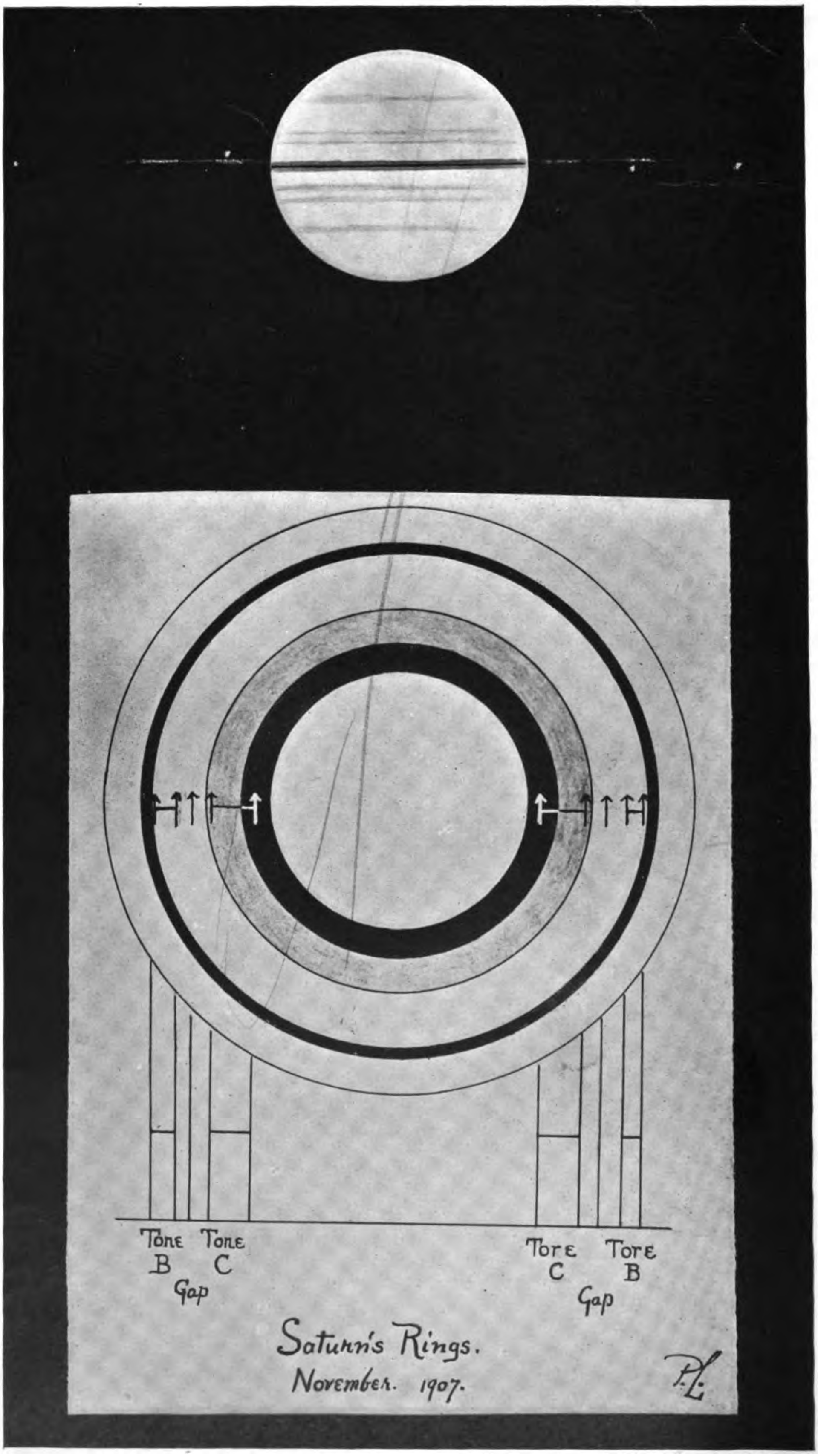
Revue Canadienne, a monthly publication of 44 years standing, has this year passed under the control of professors of Laval University, Montreal. It appears to be a useful exponent of University life in general.

Longitude of Observatory at Mare Island Navy Yard. The longitude of the Observatory at Mare Island Navy Yard has been recently determined by electrical time signals from Lick Observatory at Mount Hamilton, California, R. H. Tucker and R. F. Sanford being in charge at the last named Observatory. The Lick Observatory longitude was determined in 1888 and was found to be $8^h\ 6^m\ 34^s.81$ west of Greenwich. The difference between Mt. Hamilton and Mare Island is $2^m\ 30^s.74$.

The longitude of the Observatory at Mare Island is $8^h\ 9^m\ 5^s.55$ west of Greenwich. We notice an interesting feature in this determination. It was that at one station mean-time signals were used in the exchange while at the other sidereal-time signals were used. The large relative rate of the latter signal is spoken of as an advantage in the determination.

Haustein's Skeleton Models and Goniostat are helpful as class-room devices for practical demonstrations in drawing arithmetic, perspective shadows, stereometry, axiometry, crystallography and astronomy.

Astronomy by Postcard. Dr. E. D. Roe, Jr., of Syracuse, N. Y., has sent us a number of postcards having photographs of instruments, sun-spots and his Observatory. The illustrations were fairly good for photographs taken in this way.



Saturn's Rings.
November. 1907.

Popular Astronomy.

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TWO SCOTTISH ASTRONOMERS OF TODAY.

HECTOR MACPHERSON, JR.

FOR POPULAR ASTRONOMY.

In POPULAR ASTRONOMY for April 1906 a sketch was given of distinguished Scottish astronomers from the earliest times. Among these were included two living astronomers, Sir David Gill and Mr. William Peck. Supplementary to these may be mentioned Dr. Thomas Anderson and Dr. A. W. Roberts.

Dr. Anderson and Dr. Roberts may be conveniently classed together, as they have many points in common. Both occupy a foremost place among the observers of variable stars. Indeed they must be included among the four or five greatest observers and investigators of variable stars at the present day. Neither of them holds an official position in astronomy; both are hard working amateurs who have enriched the science by their investigations and observations. The work of the one has been supplementary to that of the other; for while Dr. Anderson has his home at Haddington in Scotland, and studies the northern stars, Dr. Roberts has for many years been an exile Scot in South Africa and has therefore made his name as an observer of the southern skies.

Dr. Anderson is a native of Edinburgh, the capital of Scotland, where he was born on February 6, 1853. From his earliest years he was devoted to astronomy and his first experience in observing was when he beheld Donati's Comet in 1858. When twelve or thirteen years of age he studied the works of the late Rev. James Gill, a Scottish amateur astronomer, by which he learned to identify the constellations and even to insert the stars which Mr. Gill had omitted. After he succeeded in identifying the constellations, he mastered Ferguson's *Astronomy* and every book and article on astronomy on which he could lay his hands. In 1869 he entered the University of Edinburgh, where he took his degree in 1874. His intention was to become a clergyman but after he had completed his studies he was obliged to abandon his proposed pastoral work owing to a partial failure of eyesight. However, he continued his studies in astronomy and in classics, and in 1880 the University of Edinburgh conferred on him the degree of Doctor of Science for his classical studies. Dr. Anderson too, continued his astronomical studies, scanning the heavens nightly, little expecting the important astronomical discovery he was destined to make.

On the morning of February 1, 1892, Professor Copeland at the Royal Observatory received the following anonymous post-card—"Nova in Auriga. In Milky Way, about two degrees south of Chi Aurigæ preceding 26 Aurigæ. Fifth magnitude slightly brighter than Chi". In the evening Copeland and his assistants turned the telescope of the Scottish National Observatory on the indicated region, and there in the place mentioned in the post-card was the new star. The discovery aroused deep interest in the scientific world. It afterwards transpired from an examination of Professor Pickering's photographs taken at Harvard, Massachusetts, that the star had been shining in the heavens since early in December 1891. It had attained its maximum on December 20, and was of the fifth magnitude when Dr. Anderson detected it. At the time Dr. Anderson discovered the Nova, all the means at his disposal were Klein's star-atlas, and a 1-inch pocket telescope, magnifying ten times; and yet with these modest instruments he discovered a star which escaped the attention of all the astronomers of the world. In the words of Mr. Maunder, of Greenwich,—"But for his zeal in studying the heavens it would without doubt have escaped notice altogether and the spectroscopic revelations which it yielded would have been wholly lost."

This was Dr. Anderson's first discovery, but it was not the last. The idea occurred to him that new stars might not be such rare objects as were generally supposed, and he resolved to commence a systematic search for them. He procured a good binocular, and a 2¼-inch telescope, afterwards superseded by a 3-inch refractor. He extended his search to all the stars contained in the Bonn Charts, and in these he was obliged to fill up the blanks, by means of charts containing 70,000 stars which he himself constructed. In his own words—"Thus armed I began to hunt for new stars. I worked with might and main, never going to rest as long as the sky remained clear". The hunt for new stars however, was not so successful as he expected and accordingly he extended the search to variable stars. In this branch of research he has been most successful. He was rewarded in 1893 by two discoveries ot variables, T Andromedae, with a period of 281 days, and V Cassiopeiae, with a period of 231-5 days which was discovered by means of a binocular when near a maximum. Dr. Anderson has proved himself one of the most successful students of variable star astronomy. He has discovered totally forty-nine variable stars, from 1893 down to 1906. Dr. A. W. Roberts remarks—"No town can claim to its credit so great a number of variable stars as the old gray capital of Scotland." And if Dr. Anderson continues his discoveries, at the present rate, the capital of Scotland will be run a close race in variable star astronomy by the country town of East Lothian, for Dr. Anderson left Edinburgh, and settled at Northrig, Haddington, in the spring of 1904.

On the morning of February 22, 1901, at 2:40 a. m., Dr. Anderson when "casting a casual glance round the sky" discovered the great new star in Perseus. At the time of this discovery, the star was of 2.7 magnitude, and still increasing in brilliance. On the night of February 23 it was brighter than Capella, and the brightest star in the northern hemisphere. The star was discovered by several observers besides Dr. Anderson; notably by M. Borisiak, at Kiev, in Russia, and by Mr. Gove, in Dublin. Dr. Anderson's discovery, however, attracted universal attention, as it was the second temporary star which he had detected. He received the Gunning Prize of the Royal Society of Edinburgh, and the medal of the Société Astronomique de France in 1901, and in the following year the Council of the Royal Astronomical Society of London conferred on Dr. Anderson the Jackson-Gwilt Medal. The President of the Society in the following words summed up the importance of Dr. Anderson's services to astronomy—"Nova Aurigae was discovered by you on February 1st, 1893, when of the fourth magnitude, and but for your discovery it might have escaped observation. Nova Persei was discovered on February 22nd of last year (1901), when of 2.7 magnitude and low down in the sky. This early discovery of yours made it possible for Pickering to obtain its spectrum before its maximum was reached. It is no small matter to have discovered one of these Novæ, but it is a very *tour de force*, such as *à priori* would have seemed impossible, to have discovered both, and I am delighted that we have the opportunity to congratulate you on your success and to do honor to your astronomical zeal and intimate knowledge of the sky."

This exactly states what Dr. Anderson has done for astronomy, only something might have been said of his work as a discoverer of variable stars which has made Scotland famous for investigation of this kind.

In this sphere his only Scottish rival is Dr. Roberts. Alexander William Roberts was born on December 4, 1858 at Farr, in Sutherlandshire. On his mother's side he is of an old crofter family, descended from Adam Gordon, third son of an Earl of Huntley who died in 1528. In 1864 the family left the Highlands and moved to Leith, the port adjoining Edinburgh, and there the future astronomer received his education. In 1896 he entered Moray House Training College, Edinburgh, where he remained for two years; and at the end of that time he applied to Professor Piazzi Smyth for an assistantship in the Royal Observatory, Edinburgh. The Astronomer Royal however, advised him not to enter a public observatory, and in 1878 Dr. Roberts went to Wick, in Couthness, as a teacher. After studying at Edinburgh University, he was in 1883 appointed to the mission staff of the College of the Scottish Church at Lovedale, in Cape Colony, which position he still retains. No sooner had he settled in South Africa than he determined to study astronomy in the southern hemisphere. During the early years of his residence there, he went over the mathematical side of the science, and it was not until 1891 that he commenced the series of observations by which his name has now become famous. In that year he commenced the systematic study of southern variable stars, his sole instrumental equipment being an old theodolite and an opera-glass. By 1894 he had surveyed the southern skies south of thirty degrees south declination, and he was rewarded by the discovery of no less than twenty variable stars, of which four are of the Algol type. Dr. Roberts, however, relinquished his search for new variables. He concluded that it was more profitable to study minutely known variables than to continue the search; and the result of his subsequent investigation has fully justified his opinion on this point.

Since 1900, in which year he acquired a new equatorial refractor, Dr. Roberts has devoted his attention chiefly to the remarkable class of objects known as Algol variables. or eclipsing stars. These stars are not inherently variable. In reality they are close binaries, the stars and their satellites being in revolution round their respective centers of gravity; and the one star obscures the other merely because the plane of the orbit happens to lie in our line of sight. In the words of Sir David Gill—"Two stars revolve round about each other nearly in a plane directed towards the Sun, and consequently one star in the course of its revolution obliterates the other. When the stars are not in the same line with the Sun we see as a single star their combined light, when in a line we see the light of only one plus such part of the light of the second as is not obscured by the first".

By a careful study of the light curves of these variable stars, Dr. Roberts has actually succeeded in determining in some cases the density of the stars, their figure and the elements of the systems. As the outcome of a number of investigations he finds on the average, that the mean density of the Algol variables is only one-ninth that of the Sun. But perhaps the most remarkable of Dr. Robert's researches have been those which have disclosed the absolute elements of the binary system. His investigations of the southern variable designated as RR Centauri have been absolutely unique. He discovered the variability of this star in 1896 and since its discovery he has collected an extensive series of determinations of its magnitude. As the result of these investigations he finds that the variations of RR Centauri result from the revolution of ellipsoids in actual contact; that is to say it cannot be said for certain whether the variations are due to two stars revolving or one star rotating. As the late Miss Clerke expresses it in her "Modern Cosmogonies"—the stars "are of just one-third the solar density and the forms satisfying photometric requirements by the varying areas of luminous surface presented to sight in different sections of their path show a surprising agreement with the bi-prolate figure given by Professor Darwin's analysis as the shape of a body on the verge of disruption through accelerated rotatory movement". In the case of V Puppis, another southern variable, Dr. Roberts remarks that the two stars revolve round each other in actual contact. A moment's consideration will show the marvellous accuracy of Dr. Roberts' researches. By a study of the light changes of these variables, Dr. Roberts has been enabled to point to at least two stars in the heavens on the verge of disruption, thus confirming in a striking manner Sir George Darwin's theory of tidal friction as a factor in stellar evolution.

Mention must be made also of his method of determining the absolute dimensions of an Algol variable star. In January 1906 he published a paper on this subject, in which as the result of observations on two variables U Pegasi and RR Centauri, he finds that the distance of the component stars which go to form the system of U Pegasi is 63,200,000 miles, and the distance in the system of RR Centauri, 3,880,000 miles—and this without knowing the distance of the stars. It will easily be seen that but for the accuracy and care with which Dr. Roberts has discussed his observations, he would have been unable to obtain these data. As Dr. Roberts remarks:—"The theory that underlies this important determination is the simple one that light takes an appreciable interval of time to traverse the orbit of a binary star. A moment's reflection will make it evident that this circumstance must make itself manifest as an acceleration in the apparent occurrence of both the primary and secondary maximum phases. The time of passing the primary and secondary maxima will however, remain unchanged; that is, the approach and recession of the component stars relative to the Earth as they revolve round one another will be translated, owing to the measurable velocity of light, into a corresponding hastening and retarding of the successive phenomena of eclipse." So great precision is necessary that the problem of determining the absolute dimensions of a variable star system, is as Dr. Roberts points out, beset with difficulties; and it is to his lasting credit that he has accomplished so much in this direction by mere visual observations.

Dr. Roberts' other researches include his determination of the oblateness of close binary stars; and his discovery of personal error in the observation of variables. Besides this he has determined the magnitudes of all stars brighter than the 9.2 magnitude which are situated south of thirty degrees south declination. Altogether he has made about 250,000 estimates of stellar brilliance, and has kept a close watch on 120 variables, and this in spite of the fact that he studies astronomy in his leisure only. No better tribute to the work of Dr. Roberts exists than the words of Sir David Gill—"I know few instances of more successful devotion of small means and limited opportunity to the attainment of great scientific ends than the work of Dr. Roberts." It seems to be a characteristic of our Scottish astronomers that, in spite of many obstacles, they have triumphed over all difficulties and have made good their claim to a high place in the world of science. Both Dr. Anderson and Dr. Roberts have maintained the best traditions of Scottish astronomy by their enthusiastic devotion to the science and by their unwearied study of the starry skies.

Johnsburn, Balerno,
Midlothian, Scotland.

THE TRIAD OF STARS.

E. WALTER MAUNDER, F.R.A.S.
Superintendent of the Solar Department in the Royal Observatory, Greenwich, England.

Three astronomical symbols are found on a great number of the sculptures discovered in Assyria and Babylonia. They are represented in connection with the worship of the gods; they are carved over the heads of the figures of the kings; and they occupy the crown of the little sculptured pillars which record the transfer of landed property. A visit to the Babylonian Room, and the Assyrian Galleries of the British Museum, will bring quite a number of examples under the notice of the student; and some of these are reproduced in the illustrations to the Official Guide to the Babylonian and Assyrian Antiquities. Thus plate xxii, gives a reproduction of a tablet 'sculptured with a scene representing worship of the Sun-god in the Temple of Sippar, and inscribed with a record of the restoration of the temple by Nabu-pal-idinna, king of Babylonia, about B.C. 870. In the upper part of the tablet the Sun-god is seen, seated within a shrine upon a throne, the sides of which are sculptured with figures of mythical beings in relief'.

Above the head of the Sun-god, and under the roof of the shrine, are the three astronomical symbols referred to—the Triad of Stars,— and an inscription gives the commentary, as rendered by Colonel Conder:

> 'The Moon-god, the Sun-god, the Ištar, dwellers in the abyss, announce to the years what they are to expect.'

The same three symbols appear in the guide on plate xi., which is a representation of a 'fine limestone landmark or boundary-stone, inscribed with a valuable text recording the restoration and confirmation of certain rights and privileges to Ritti-Marduk, the Warden of Bit-Karziyabku, a district which was apparently situated on the confines of Elam, by Nebuchadnezzar I., king of Babylon, about B.C. 1120.'

The first of these three symbols is often found by itself. Thus the Official Guide, plate xxiii, No. 1., gives a reproduction of a 'Cylinder seal inscribed with the name of Khashkhamer, viceroy of the city of Ishkun-Sin, and an address to the Ur-Gur, king of Ur, about B. C. 2500. The scene represents Ur-Gur being led into the presence of Sin, the Moon-god.'

Above the Moon-god, who is seated on a throne, is a crescent Moon on its back, like a cup or boat. The significance of this symbol being adopted in connection with the Moon-god is very clear. The Moon-god was specially associated with the beginning of the month, with the reappearance of the Moon in the sky, after the three or four days of its disappearance during conjunction with the Sun. But it was not the young Moon of any month that was thus distinguished. There is one month in the year when the crescent takes this boat-like position most fully, floating on an even keel above the western horizon; this is the crescent nearest to the spring equinox. The symbol, therefore, sets forth a special hour of a special day of a special month. It is the hour after sunset, of the first evening when the young Moon is visible, in spring-time. For those nations who reckoned their months from the observed reappearance of the Moon, and who therefore began their day at sunset it marked out at one and the same time the beginning of the day, and of the month, and of the year. It was the natural, indeed the inevitable, sign of the first month of the year—the year beginning with spring-time. Had the Babylonians begun their year with the young Moon of autumn, their symbol for the Moon-god would have been the crescent with its horns, the one vertically above the other, as on the Turkish flag at the present day. But the symbol of the Babylonian Moon-god is never found in any other position than with the line of its horns horizontal.

Just as the first member of the Triad of Stars set forth the presiding deity of the first month of the year, so the other two members—the two stars—set forth the presiding deities of the second month of the year; for the second month was held to be under the patronage of a pair of deities, 'the Heavenly Twins.' And, as the symbol for the first month expressed an easily observed astronomical fact, so did the symbols for the second month. For about 2000 B.C. the young Moon of the second month of the year set together with the bright twin stars, Castor and Pollux, as we name them today.

At the time when the second month of the year was marked by the setting together of the young Moon and the twin stars, the first month was marked by the setting of the young Moon, and Capella, and an inscription, translated by Professor Sayce and Mr. Bosanquet in the *Monthly Notices of the Royal Astronomical Society*, vol. xxxix. p. 455, shows not only that the beginning of the year was fixed in this manner, but that a certain curious relation had also been recognized and turned to use. Their translation runs as follows:

'When on the first day of the month Nisan the star of stars (or *Dilgan*) and the Moon are parallel, that year is normal. When on the third day of the month Nisan the star of stars and the Moon are parallel, that year is full.'

In this observation the young Moon was used as a pointer to connect the position of the Sun with the index star. In the ordinary way this setting together of the Moon and the index star, which in this case was Capella, could only take place on one of the first three evenings of the first month; for if in any month the two set together on the fourth evening they would also set together on the first evening of the next month, which would thus be pointed out as the actual 'Nisan.' The setting together of the Moon and star on the third evening meant that the Moon had by that time moved more than twenty degrees further from the position of the Sun, so that the Sun would be more than twenty degrees—equivalent to the distance which it moves in twenty days—further short of the position of the star. The beginning of the year, therefore, would be put very early. As twelve lunations are eleven days short of the solar year, these eleven days *plus* the twenty or more days by which a year thus opening would begin early, would make up an entire month, and the year would have to be reckoned as 'full,' that is, as containing a thirteenth month.

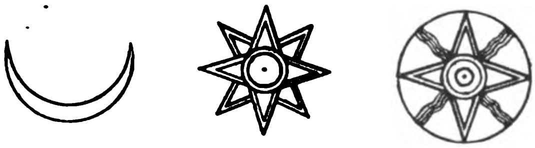
But the constant recurrence of the Triad of Stars, as practically a single symbol, is not fully explained by referring it to a combination of the symbols for the first two months. About 4000 B.C., the setting together of the young Moon with the twin stars, Castor and Pollux, took place, on the average, about the time of the spring equinox. For many centuries, therefore, the Moon on its back, side by side with a pair of bright stars, was seen low down on the western horizon, on one of the first three evenings of the first month of the year. The Triad of Stars is therefore nothing but a picture of a single astronomical configuration observed by men year after year, through many centuries, some six thousand years ago. It was therefore the natural, the inevitable, symbol of the beginning of the year, and therefore of the year itself, and of time generally.

The sunset gave the beginning of the day; the young Moon, seen in the sunset glow, gave the beginning of the month; the young Moon seen on its back in the sunset glow, together with the twin stars, gave the beginning of the year. No simpler means for recognizing the commencement of the year, and for synchronizing the month with the year and with the day, could have been devised. It required no instruments; no knowledge of the principles of astronomy; no recognition of particular stars other than the two used as the index; and in the words of the inscription over the shrine of the Sun-god at Sippar, the Triad of Stars, dwellers in the abyss of heaven would

> 'Announce to the years what they are to expect';

the observation of the beginning of the year, itself indicating whether the year was to be one of twelve months or of thirteen.

No simpler method could then have been devised. But it had one drawback, a drawback which the early observers could not have understood or foreseen. Owing to the 'precession' of the Earth's axis, a sidereal year—that is, a year as marked by the return of the Sun to the neighborhood of the same star—is slightly longer than a solar or tropical year, marked by the return of the Sun to the same part of the

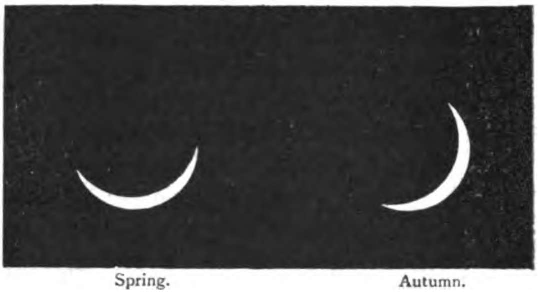


THE TRIAD OF STARS.
From a Boundary-Stone, of date about 1200 B. C., now in the Louvre.

celestial equator. As the terrestrial seasons depend on the position of the Sun relative to the equator, a sidereal year tends to have its commencement later and later in the seasons, at the rate of about one day in a little less than seventy-two years. In two thousand years, the beginning of the year, as given by the observation of the Triad of Stars, would have fallen a full month late. When this was recognized the error could easily be corrected, since the bright star Capella was then so placed as to be ready to serve as index star in the place of the twin stars. As the constellation figures which have come down to us through the Babylonians and Aratus and Ptolemy were designed some time in the third millenium before the Christian era, it is not improbable that the change of index stars was made at the same time. Capella probably continued to be the index star until about 700 B.C.; it seems clear that it was still in use in the year 1063 B.C. For the eclipse of the Sun which was total at Babylon on July 31 of that year was recorded as having taken place on Sivan 26. Had the Babylonians at that date reckoned their year from the new Moon next after the spring equinox, Sivan 26 could not have fallen so late as July 31; whereas, if the Capella method was still in use, the month Sivan would have practically coincided with July as the eclipse shows to have been the case.

At some date, not very far removed from 700 B.C. an important astronomical revolution was effected. We have no historical record of the revolution, but its results are apparent. The Zodiac which had hitherto been divided into eleven or twelve constellations of very unequal extent, was now divided into twelve signs, all exactly equal. The Bull, which had hitherto been the first constellation, now became the second sign, and the Ram, which had been the last constellation, became the first sign. It is probable that at the same time Capella was abandoned as the index star, since it now gave an obviously late beginning for the year; and there being no suitable star to take its place, the method of using an index star was superseded by the direct observation of the equinox.

It is easy to see how the original meaning of the Triad passed out of recollection, whilst the symbol itself was still retained. When Capella became the index star, the Triad became divided, and the crescent on its back being naturally assigned to the first month, drew with it the allotment of that month to Sin, the Moon-god, whose symbol the crescent was. The twin stars, now symbol of the second month, just as naturally involved the allotment of that month, to the Heavenly Twins—the king and queen of heaven—Šamaš and Ištar—the ruler of the day and the ruler of the night. At a much later date, when the planets were recognized, and Venus the morning star was identified with Venus the evening star, it was natural to assign this beautiful attendant on the Sun to Ištar as the consort of Šamaš. Consequently in the later presentations of the Triad we find the twin stars differentiated in form; one is a disk bearing a four-rayed star with four streams of light, elsewhere the symbol of Šamaš, the Sun-god; the other an ordinary eight-rayed star. But on the earliest example that we have of the Triad—the triumphal stele of Naram-Sin, now in the Louvre—we find both stars are of the latter type; both simple eight-rayed stars; neither of them the solar disk.



POSITION OF THE CRESCENT MOON AT THE TWO EQUINOXES FOR LATITUDE 25°N.

A SIMPLE APPLICATION OF VECTORS.

ARTHUR B. TURNER.

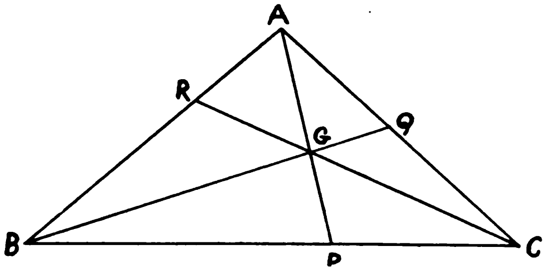
FOR POPULAR ASTRONOMY.

Since the vectors drawn from a common origin to A, B, C and G terminate in a plane

$$(1) \qquad aA + bB + cC + gG = 0$$

$$(2) \quad \text{and} \qquad a + b + c + g = 0$$

where a, b, c and g are scalar coefficients.



Rearranging (1) and (2) and dividing, we have

$$(3)\quad \begin{cases} P = \dfrac{bB + cC}{b + c} = \dfrac{aA + gG}{a + g} \\ Q = \dfrac{aA + cC}{a + c} = \dfrac{bB + gG}{b + g} \\ R = \dfrac{aA + bB}{a + b} = \dfrac{cC + gG}{c + g} \end{cases}$$

where P, Q and R are vectors drawn from the same origin.

1st Case.

Assume $a = b = c$, then $g = -3a = -3b = -3c$ and equations (3) become

$$P = \frac{B + C}{2} = \frac{A - 3G}{1 - 3}$$
$$Q = \frac{A + C}{2} = \frac{B - 3G}{1 - 3}$$
$$R = \frac{A + B}{2} = \frac{C - 3G}{1 - 3}$$

whence, lines $\overline{AP}$, $\overline{BQ}$ and $\overline{CR}$ become the medians which intersect at the point G. We also see that G divides the medians in the ratio of 2:1

2nd Case.

assume

$$\begin{cases} a = m a' \\ b = mb', \\ c = mc' \end{cases} \text{then } g = -m\,(a' + b' + c') = -2\,m\,s$$

where a', b', and c' are the sides of the given triangle $A\,B\,C$ and m is a constant.

By substitution

$$\begin{cases} P = \dfrac{b'B + c'C}{b' + c'} = \dfrac{a'A - 2sG}{a' - 2s} \\ \quad\text{etc.} \qquad \text{etc.} \\ \quad\text{etc.} \qquad \text{etc.} \end{cases}$$

whence lines $\overline{AP}$, $\overline{BQ}$ and $\overline{CR}$ become the bisectors of the angles A, B and C and they intersect at the point G; and

G divides	AP in the ratio		$(b' + c') : a'$
" "	BQ " "	"	$(a' + c') : b'$
" "	CR " "	"	$(a' + b') : c'$

3rd Case.

assume

$$a = m \tan A$$
$$\text{then } g = -m(\tan A + \tan B + \tan C)$$
$$b = m \tan B,$$
$$= -m \tan A \tan B \tan C$$
$$c = m \tan C$$

and we have

$$P = \frac{\tan B.B + \tan C.C}{\tan B + \tan C} = \frac{\tan A.A - \tan A \tan B \tan C\, G}{\tan A - \tan A \tan B \tan C}$$

etc. etc.

etc. etc.

In this case $\overline{AP}$, $\overline{BQ}$ and $\overline{CR}$ become the altitudes of the triangles and G becomes their point of intersection and it divides

$\overline{AP}$	in the ratio	$(\tan B + \tan C) : \tan A$
$\overline{BQ}$	"	$(\tan C + \tan A) : \tan B$
$\overline{CR}$	"	$(\tan A + \tan B) : \tan C$

4th Case.

assume

$$a = m \sin 2A$$
$$b = m \sin 2B, \text{ then } g = -m(\sin 2A + \sin 2B + \sin 2C)$$
$$c = m \sin 2C$$

and

$$P = \frac{\sin 2B.B + \sin 2\,C.C}{\sin 2B + \sin 2C} = \frac{\sin 2A.A - (\sin 2A + \sin 2B + \sin 2C)G}{\sin 2A - (\sin 2A + \sin 2B + \sin 2C)}$$

whence G becomes the intersection of theper pendiculars erected at the middle points of the sides of the triangle, and it divides

AP	in the ratio	$(\sin 2B + \sin 2C) : \sin 2A$
	etc.	etc.
	etc.	etc.

5th Case.

$$\text{Suppose } c = -b = -a$$
$$\text{then } g = -(a + b + c) = +c$$

and

$$P = \frac{bB - bC}{b - b} = \frac{B - C}{0} = \infty$$

and the line $\overline{AP}$ is parallel to side BC of the triangle.

$$Q = \frac{aA - aC}{a - a} = \frac{A - C}{0} = \infty$$

and the line $\overline{BQ}$ is parallel to side AC of the triangle

$$R = \frac{aA + aB}{a + a} = \frac{A + B}{2} = \frac{cC + cG}{c + c} = \frac{C + G}{2}$$

and the line CR bisects the sides AB of the triangle. G is the point where line $\overline{CR}$ meets the lines parallel to the other two sides. This point divides $\overline{CR}$ externally in the ratio of 2:1.

Montclair, N. J
April 16, 1908.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

Part III. (Continued.)

THE NATURE OF THE SOLAR RADIATIONS AND THEIR RELATION TO TERRESTRIAL MAGNETISM AND OTHER METEOROLOGICAL PHENOMENA.

In the consideration of this part of the subject reference will be made to certain numerical values of the magnitudes and motions of the ultimate particles of matter, these values having been derived through a rigorous analysis from the fundamental concepts of my theory, linear dimensions being expressed in inches, and "mass" in pounds avoirdupois, as these are units more familiar, probably, to the greater number of readers, than CGS units, although the latter are preferable from a strictly scientific standpoint and will necessarily be used when I come to a discussion of electro-magnetic action; in any case these units are easily intercovertible.

Under my theory, the molecules of all simple gaseous matter, when in the normal state, consist of perfectly spherical, elastic, solid particles theoretically *divisible* but actually *undivided,* continuous in all portions of their volumes, incompressible, impenetrable, rigid and possessing absolutely no other properties except *mass*; *motion*, and *inertia*. These ultimate particles of all matter, the "atoms," being absolutely homogeneous and of equal *dimensions* and *mass*, the differentiation of the one uniform primal type of matter, (the Ursthoff) into the host of known chemical "elements" and "compounds," being effected by changes in the forms of atomic orbits, of the orbital velocities of the atoms therein, and of the particular groupings of these atoms and their orbits in each molecule, and, under my theory, the specific nature of these changes, and the absolute measurements thereof, are determinable.

The critical reader will, probably, note that my above stated concept of the nature and properties of each and every atom of matter is practically identical with that of the *ideally perfect*, elastic homogeneous incompressible fluid conceived by Lagrange, mathematically elaborated by Helmholtz, with respect to rotational movements therein, and upon which Sir William Thomson (the late Lord Kelvin) based his famous "theory of vortex atoms." The essential point of difference between that theory and mine is that the latter regards these atoms as being, not in *permanent* contact with each other,--thus forming a *continuous* fluid medium,—but as *discrete* particles endowed with the "vector-property" of revolution around the center of the molecule of which they are the sole components, the molecules themselves being in permanent contact *inter se*—a medium composed of myriads of these molecules, although *discontinuous*, acting exactly as would the ideally perfect, continuous, elastic fluid in so far as the transmission of "radiance" of all kinds is concerned. Furthermore, under my theory, one of the most difficult questions of "molecular physics", viz, that as to the connection between "gross ponderable matter" and the so-called "imponderable ether" is solved in the most simple manner, because a fundamental concept of that theory is that the ultimate particles of *all matter* (using the word "ultimate" in its strictest sense) are the ultimate particles of the "ether" itself. The initial differentiation of this "Ursthoff", or simple, fundamental cosmic matter, into the more complex forms such as those with which we are most familiar upon the Earth, occurred in so far as the solar system is concerned *et ab uno disce omnes* when the primitive solar nebula, the evolution whereof I have described, from the view point of my theory, on preceding pages, began to compress toward the density and dimensions of the Sun at the present time, the transformation of the normally circular orbits of the atoms of the nebulous mass being effected by this compression, and consequent heating, of the molecules, and the subsequent abstraction, or loss, of heat (or, what is equivalent thereto, the reduction of orbital velocity of the atoms) below certain "critical points" this action resulting in the formation of the many chemical combinations of matter—"gaseous," "liquid" and "solid"—known to physical science. Applying the principles and algebraic formulæ of Analytical Mechanics concerning the "impact of bodies", to the case of an indefinitely great number of almost infinitesimal, spherical, perfectly elastic, homogeneous particles such as the "atoms" conceived by my theory, moving in *rectilinear* paths and in *all directions*, each having its "center of inertia" coincident with its "center of figure", I have demonstrated that the attainment of a condition of ultimate equilibrium in a volume of such matter, requires that these atoms be deflected from their originally *rectilinear* paths, extended in all directions, into *circular* paths or orbits, any one atom having any given direction being thereby "associated" with another atom the rectilinear motion whereof was in a *diametrically opposite* direction to that of its "associate", the motion of the second atom in its resultant circular path being, likewise, in an opposite direction, (the idea of "polarity," in a certain sense is thus introduced since, if one atom be regarded as moving in a direction that may be called "plus" the other, complementary, atom must move in a "minus" direction, these two ultimate particles of matter forming what I have termed an "atomic-couple," and this arrangement being the foundation of the "diatomic" structure of simple gases as conceived by chemistry. Although physical science, in all probability, can never comprehend, and need take no cognizance of, either the absolute origin, or the ultimate destiny, of these fundamental particles of matter endowed only with *mass*, *motion* and *inertia* and the few simple properties of the "ideally perfect fluid" aforesaid, it can trace the upbuilding therefrom of the whole complicated structure of the known material universe. Furthermore, in order that physical equilibrium should be established, and conserved, among an indefinitely great number of such "atomic-couples," it is necessary that a definite number thereof should arrange themselves with reference to a fixed point, in such wise that the complementary atoms revolve around this point in circular orbits, this arrangement of these atoms around the fixed point as a "focus", or center, being comparable to a spherical shell (having the thickness of an atom) inclosing the common center and constituting a *physical* molecule which is simply a *mechanical* arrangement of matter, the atoms and molecules as ordinarily defined by Chemistry, consisting of *specific groupings* and *modes of motion* of the myriads of absolutely similar, *chemically inert*, ultimate particles of matter that, in my theory, are termed "atoms". It should here be distinctly noted that, while there is a difference between the two, there is no *conflict* between my concept of the atoms and their motions and of their congregation, under the conditions of equilibrium and the "laws of motion", into the spherical molecule aforesaid, and the concept of Chemistry as to atoms and molecules and Dalton's law of chemical combination—these "chemical" concepts being, in fact, dynamical deductions from the "physical" concept upon which my theory is founded, and we may consider these myriads of ultimate particles, grouped two and two, or *diatomically*, in the *physical* molecule, as merged in two larger masses corresponding to the two atoms of a *chemical* molecule in the case of gases.

Furthermore, in the quite recently enunciated "electronic theory," the "electrons" are regarded as corpuscles smaller than the atoms and as revolving in orbits around the latter (as do the planets around the Sun), while in the theory advanced by me nearly a decade previously, the absolutely ultimate particles of matter that I have called "atoms" are themselves, the "electrons" in no wise connected with, or revolving around a larger *mass* or atom, their motions being around a common center which is that of the molecule of which they are the components; this distinction between the two theories—in some respects similar—should be noted because it leads to some important results, as will be demonstrated. The number of atomic-couples in a molecule is definite, and determinable by the condition that each atom must have a "mean free path" around the circumference of the spherical molecular shell, the atoms whereof make impact with and displace each other, only when passing through the "nodes" of their circular orbits around the molecular center, each atom being thus displaced twice in each orbital revolution the extent of displacement or, as it may be termed, "amplitude of vibration" being in each case, the semi-diameter of the atom. These vibrations determine the "molecular heat" and the fundamental absolute temperature of a mass of gaseous matter composed of such molecules, and from said temperature the semi-diameter, or radius, of each spherical atom can be determined in ***absolute measure***, my value of the diameter of an atom $\left(\frac{1}{1273 \times 10^{19}}\text{; inch}\right)$ having been derived by this method, from the absolute temperature of the luminiferous ether, which I have determined as stated in the preceding part of this paper. It is very evident, from a simple geometrical consideration, that the number (n) of atoms in a molecule, under the condition that each atom must have a "mean free-path" around the circumference of the molecular shell, is determinable through the equation $n = 2.\frac{d}{\Delta}$ (1) in which the numerator (d) represents the diameter of a molecule, and the denominator that of an atom. As stated in a preceding part of this paper I have found, by a method to be set forth in detail, that the diameter of a molecule of the atmospheric gases at normal pressure and temperature (Barometer 30 inches, Temperature 32° Fahrenheit, or 492° of the "absolute scale") is $\frac{1}{7359 \times 10^{4}}$; inch which is very nearly the same as the value determined for *hydrogen*, by Loschmidt, and of the same order of magnitude as the determinations made by the late Lord Kelvin and others, by methods entirely different from mine. With this value of d and that of the diameter of an atom as stated in a preceding paragraph, substituted in equation (1) the number of atoms in the normal atmospheric molecule which I have adopted as the "standard," is found to be 3460×10^{11}. The number of molecules in contact with unit surface of one square inch, being inversely proportional to the square of the molecular diameter (d), is under the normal conditions aforesaid, 5416×10^{12}, or 7798×10^{14} per square foot, these spherical molecules, in each case, forming a layer, or "interface", the thickness whereof is equal to the molecular diameter aforesaid, a fact that should be well noted because the actions and reactions in operation in this layer or "interface", constitute the whole scheme of "radiation," thermal, luminous and electro-magnetic, this "interface" being also the seat of "chemical action" and "contact force". The number of spherical molecules in a volume is proportional to $\frac{1}{d^3}$ so that, under the normal conditions, there are 3985×10^{20} molecules in one cubic inch and 6887×10^{23} in one cubic foot. Now the weight of one cubic foot of dry atmospheric air, under the normal conditions, as determined by Regnault, is 0.080727 of a pound avoirdupois, so that, dividing this weight by the aforesaid number of molecules in a cubic foot, we obtain as the weight of each molecule $\frac{1}{8531 \times 10^{24}}$ of a pound avoirdupois and dividing this value by the number of atoms in a normal molecule, stated in a preceding paragraph, there results $\frac{1}{2952 \times 10^{39}}$, pounds avoirdupois, as the weight of an "atom." Furthermore, since "mass" is equal to "weight" divided by the terrestrial "force of gravity" (g) the value whereof is, very approximately, 32.2 feet per second, the "mass" of an atom is $\frac{1}{9505 \times 10^{40}}$ of a pound avoirdupois, while that of a molecule composed of these atoms is $\frac{1}{2745 \times 10^{26}}$ pounds. This "mass" of an atom may properly be regarded as the smallest unit of "mass", and g times this value as the least unit of "weight," in all Nature, the diameter of an atom which is $\frac{1}{1273 \times 10^{19}}$ inch being the shortest *linear* unit therein.

A body having a "mass," or "weight", as small as the aforesaid values, may, in certain sense, be regarded as "imponderable" because these quantities are far beyond the possibility of experimental determination, but they are nevertheless *finite* and very accurately determinable, by mathematical analysis, from measured quantities of the same order.

Considered singly, an atom is practically an *incomprehensible* quantity, but the number of them in even a very small volume —such as a cubic inch—is so enormous, as the values thereof stated in a preceding paragraph demonstrate, that they are brought well within the range of our comprehension, and can be regarded and treated as other measurable quantities.

The volume of an atom is geometrically deducible from the diameter of that particle, and therefrom the number of atoms in one cubic foot can be ascertained, these *incompressible*, solid particles being regarded as packed, in this volume, in absolute contact *inter se*—not as grouped in "molecules" in which they are really widely separated,—and since the weight of each atom is known, that of the quantity in each cubic foot can be easily found, a division of this weight by that of a cubic foot of water under the normal conditions (62½ pounds avoirdupois) giving as the density of an atom, relative to the normal density of water, the value 4×10^{26} to within less than one per cent.

The greatest density of any known solid is that of the metal platinum (hammered and wire-drawn) this density being 21¼, the density of an atom being therefore two-septilion times this value, so that the atomic density, although *finite*, may be regarded as *practically* infinitely great, and since these atoms, of uniform dimensions and density, are not only the ultimate particles of gases and so-called "gross matter", in general, but also of the ether itself, the enormous atomic density aforesaid is most significant.

A·mass of these almost infinitely small and imponderable particles each *impenetrable*, *incompressible*, and *continuous* throughout its volume (being divisible but undivided,) perfectly spherical, elastic, homogeneous and of enormous density and rigidity, as well as perfectly smooth (a mass of these atoms being absolutely devoid of *viscosity*) would constitute the "ideally perfect fluid" conceived by Lagrange, in which all stresses between any two contiguous portions of the fluid are normal to the surface separating these portions, but motion in this "fluid" would be of the type termed "irrotational". It was Helmholtz who first pointed out the conditions of rotational motion in such a fluid and the remarkable properties of a vortex-ring which was subsequently adopted by the late Lord Kelvin as the true form of an atom, as enunciated in his famous "theory of vortex-atoms." Now my concept of the vector-property of orbital rotation of the atoms around the centers of their respective molecules, accounts perfectly, for all the motions and stresses known to take place in the "luminiferous ether" and which give rise to all the phenomena of "radiation", heat, light, electrical, magnetic and chemical action, as will be demonstrated. The origin of the orbital motions of these atoms (to which motions all the vast energies of the material universe are traceable) and the forms of the atomic orbits, are distinctly definable through my theory under which, as stated, the ultimate particles of the primal matter of the universe are considered as moving, originally, in *rectilinear* paths and in *all* directions and then, under the conditions of equilibrium and the laws governing the "impact of bodies",—as expressed by certain equations of Analytical Mechanics,—being grouped, in definite and enormously great numbers, in the form of the hollow spherical molecules of vastly larger dimensions than those of the atoms composing them. These atoms by reason of the fact that each must have a "mean free path" around the spherical surface of the molecule, constitute only a very small portion of said surface although their number per molecule is enormous (346×10^{12} in the case of the molecules of the atmospheric gases under the normal conditions) but while these atoms are really widely separated their "angular velocity" or number of revolutions per second, around the molecular center, is so great (854×10^{18}, per second) that, in so far as ordinary extraneous forces operating against a molecule are concerned, these atoms may be regarded as being *at all points of the molecular surface at the same time*, and as constituting the practically, solid shell of the hollow molecule which therefore possesses very great rigidity, elasticity and impenetrability, but these properties in the case of the "molecule" are not so great as those in that of the "atom," in which they are *perfect*.

A molecule may therefore according to my concept be regarded as a center of force due to the orbital motion of its component atoms and as a form of vortex-atom in an "ideally perfect fluid" such as that which I have described on a preceding page.

Therefore my theory may be regarded as simply a *modification* of those of Lagrange, Helmholtz and Lord Kelvin in this respect, but it is an *important modification* because it has led to practical analytical results agreeing well with the facts of observation and which results have never been attained—and are apparently unattainable—through the first named theories. The same statement may be made concerning the relation between the ordinary "kinetic theory of gases" and mine, the latter giving not only *all* the practical results obtained through the former but also a considerable number of very important ones that are evidently beyond the reach of the "kinetic theory" aforesaid, which regards the motions and properties of "molecules" instead of the motions and properties of the "atoms" composing these molecules and which are the prime factors under my theory. All the atoms of each molecule are *constrained* to move in their orbits by the practically *incessant* impacts of the revolving atoms of the immediately surrounding and contiguous molecules, whereby a force is developed that is exerted toward the center of each molecule and thus constitutes a "centripetal force" which operates in a manner perfectly analogous to that of "gravity", it being, however, not really a force of *attraction*, as the latter is commonly regarded, but one of *constrained motion* caused by, practically *incessant*, atomic impacts from without each molecule and directed toward a center within the *absolutely void* interior of the molecular shell; in other words, it is a "push" and not a "pull" as the "force of gravity" is conceived to be, and it exactly balances the "centrifugal force" due to the orbital motion of the revolving atoms. This "centripetal force" being due to the actual impacts of the atoms of contiguous molecules, it is very obvious that my concept thereof is absolutely free from any assumption of *action at a distance* without the agency of intervening matter. This is a very important fact because the canons of science do not permit us to assume the existence of a force of attraction operating between the component atoms of a molecule, through an *absolute void* even though the distance separating these atoms be almost *infinitesimal*,—any more than they permit us to make a similar assumption in the case of the widely separated molar masses of the universe composed of these atoms, viz. the Sun, planets and other members of the solar system, and the far distant stars, but we are at perfect liberty to treat this force as if it were one of *attraction* exerted through an absolute void.

While this "centripetal force", as aforesaid is not absolutely continuous in time but is the result of a succession of impulsive forces, or impacts, and is therefore *propagated in time*, the number of revolutions and consequent impacts is so enormous—being 854×10^{18} in the case of the normal molecules of the atmospheric gases—that the interval between the impulses, or impacts, cannot be more than the $\frac{1}{854 \times 10^{18}}$ of a second ($461\frac{3}{8}$ times this in the case of the ether in outer space) so that the force aforesaid may be regarded as practically, continuous in time, as that of "gravity" is supposed to be; it is, therefore, practically an *incessant* force, and we know from Analytical Mechanics that the "acceleration" of a body moving in an orbit under the action of an "incessant force" which may be represented by F, is proportional to $\sqrt{F}$.

Now, designating the semi-diameter of each molecule (which radius is the mean-distance in the atomic orbit) by a it is obvious, from a simple geometric consideration, that if the molecules be compressed, or expanded, and the values of the quantity represented by a be consequently reduced, or increased, without any loss or gain of atomic linear velocity (which is equivalent to the statement "if there be no loss or gain of "heat" in the mass, the process being *adiabatic*") the "angular velocity," or number of revolutions per second, will be proportional to $\frac{1}{a}$, simply, without regard to the action of the accelerating force (F), and when this is taken into account the "angular velocity (μ) is expressed by the equation $\mu = \sqrt{F}$; (A), but since the accelerating force (F) is proportional to the number of impulses, or impacts, per second, and these to $\frac{1}{a}$, it follows that $\sqrt{F} = \frac{1}{a^{\frac{1}{2}}}$ and substituting this expression in equation (A_1) there results the following $\mu = \frac{1}{a^{\frac{3}{2}}}$, ($B_1$) and since the time of revolution (τ) is inversely proportional to the "angular velocity" (μ), it is expressed by $\tau = a^{\frac{3}{2}}$, (C_1); whence $\tau^2 = a^3$; (D_1).

Equation (D_1) expresses the fact that in the case of the atoms revolving around the center of each molecule, according to my theory, "the squares of the times of revolution are directly proportional to the cubes of the mean-distances," my law expressed as aforesaid being *identical* with Kepler's 3rd law of planetary motion" whence it follows, as a corollary, that the law of the force that *constrains* these atoms in their orbits, is that of the "inverse square" of the distance of the atoms from the centers of their respective molecules, this law being, therefore, *identical* with Newton's "law of gravitation." I have thus found that both laws rest upon the basic-fact of the primordial *rectilinear* motion of the atomic masses, the origin of both these masses and motion being inscrutable from a scientific view-point; that the "centripetal force" in this case is one of *compression*, and not of *tension*, it being a "push,' and not a "pull", as stated above; that it is not exerted at a distance through a *void*, but between the material atoms temporarily in absolute contact at extremely frequent intervals, and that it is, therefore, *propagated in time* although the time of propagation is almost inconceivably short, as I have pointed out on a preceding page.

These conditions existing in the case of the ultimate particles of all matter, lead, almost irresistibly, to the conclusions of the hypothesis advanced by LeSage in the early part of the 19th century—and held subsequently by others—

which asserts that what is called "the attraction of gravitation" is in reality a force due to an *unbalanced* pressure from the ethereal matter in space, and tending to *push* one body inward toward another, the former body being, as it were in a *dynamic shadow* cast by the latter, this condition being, of course, mutual. Certain facts brought to light by my theory, and bearing directly upon this question, will be discussed on a subsequent page. In the discussion immediately preceding, the orbits of the atoms when undisturbed are regarded as perfectly *circular* and their molecules as perfectly *spherical*, the center of *apparent attraction* being in this case at the molecular center which is the actual condition in the case of a *perfect* gas, and pre-eminently in that of the luminiferous ether but when such matter is forcibly compressed and heated by the consequent increase of the atomic motion and this motion with its resultant heat is subsequently reduced by any means of abstraction, the atoms fall into *elliptical* orbits the eccentricity whereof increases with the degree of cooling, and when a certain "critical temperature"—proper to each gas—has been reached the atoms set themselves in definite groupings dependent upon the form of each orbit and the velocity of the atoms therein, a mass of such molecules first enter the *liquid* state, while a still further decrease of heat to a lower critical temperature will raise the eccentricity closely to "infinity" in which case the atomic orbits become sensibly *straight lines*, and the orbital revolutions simply *longitudinal* vibrations and from the matter then entering the *solid* state, the atoms in most cases being so arranged in their orbits as to give rise to the phenomena of crystallization.

Thus, according to my theory, all the different kinds of matter of which we are cognizant, have been derived from one uniform type of atom each "in the beginning" moving in a *rectilinear* path which subsequently became *circular*, this process resulting in the development of the *molecular* condition first evidenced in the ether and subsequently in the matter of the gaseous nebulae.

The *linear* velocity (V_0) in the atomic orbit is found by multiplying the *angular velocity* as expressed by equation (B_1), by the mean distance (a), the resultant expression being $V_0^2 = \frac{1}{\sqrt{a}}$, ($E_1$); and since a represents the semi-diameter of a spherical molecule of perfectly gaseous matter, it follows that this "linear velocity" is inversely proportional to the square-root of the diameter (d) of each molecule, which diameter is inversely proportional to the cube root of the volume-density (D) of a gas composed of these spherical molecules, so that, when proportional quantities only are considered, $V_0^2 = D^{\frac{1}{3}}$, (G_1) which is an expression for the relative ability of gaseous media, of different densities, to transmit radiant energy; equation (F_1) is the expression in the case of luminous "radiance" the quantity expressed by $D^{\frac{1}{6}}$ being a factor in connection with the so-called "pressure of light".

The dimensions and masses of the atoms and molecules have been set forth above, but the "mass" is only one factor in the analytical formulae for the "energy" of the universe composed of these atoms and molecules, the other—and predominant—factor being the *motion* of the "mass" as expressed by the velocity of the atoms in their orbits around the molecular centers, the absolute values of which velocity will now be considered.

Under my theory, the fundamental orbital velocity in all Nature, is that of the atoms of the molecules of the "luminiferous ether," in their normally circular orbits around their respective molecular centers, this velocity being 6182×10^6 feet per second, 2π times the "velocity of light" which is, simply, the "projection" of this linear orbital velocity upon the diameter of each molecule of the ether aforesaid—it being, obviously, a *radial* quantity—and it has been well determined experimentally by several eminent physicists—the latest and most accurate results being those of Newcomb and of Michelson. The "velocity of light"—which is here taken at 186,340 miles, (9839×10^5 feet or 2999×10^7 centimeters per second,)—is one of the few elements of observation that form the basis upon which all the analytical and numerical determinations of my theory firmly rest.

By the compressive action of terrestrial gravity the dimensions of a normal molecule of the atmospheric gases at the Earth's surface, is reduced to the $\frac{1}{241,720}$ part of the diameter of a molecule of the ether in outer space where said molecule is at the limit of maximum gaseous expansion, and since the linear velocity of a body moving in an orbit, according to "Kepler's 3rd law", is inversely proportional to the square root of the mean distance which in this case, is the semi-diameter of the molecule, it follows that the linear velocity of the atoms of the normal atmospheric molecule, which I have adopted as the standard, is 3039×10^9 feet, per second, or 491⅜ times the linear velocity of the atoms of the molecules of the ether. In my theory, as in the modern, commonly accepted thermodynamic one, (of which mine is only a *modification*), heat is regarded merely as a "mode of motion" of a mass, one of my fundamental concepts in this connection being that the absolute temperature of any gas is directly proportional to the linear velocity of the atoms in their orbits, and, in the case where the volume,—and therefore the diameter,—of each molecule is kept *constant*, it is directly proportional to the number (N) of revolutions of these atoms in unit-time; so that, if we regard the aforesaid linear velocity of the atoms of the ether, in their molecular orbits, as corresponding to the unit of absolute-temperature (T_1) or to 1° above absolute zero, the absolute temperature of the atmospheric gases, under the normal conditions, at the Earth's surface, is 491⅜ degrees; or 32° above zero according to the ordinary Fahrenheit scale, and this is, precisely, the normal temperature upon which all my numerical computations of temperature, extending through the whole range of my theory, have been based.

Furthermore, since the normal molecules of the atmospheric gases and of the ether are regarded as perfectly *spherical* the molecular diameters are inversely proportional to the cube root of the relative density of gaseous matter composed of such molecules, and since the relative density of the ether is, according to my determination to which reference has been made in a preceding part, $\frac{1}{1412 \times 10^{13}}$ of that of air at barometric pressure of 30 inches of mercury,, and at temperature 32° Fahrenheit, the diameter of a molecule of the ether is 241,720 times that of the normal atmospheric molecule (the value whereof is roundly $\frac{1}{73{,}585{,}000}$ of an inch) and therefore 0.003285, or a little less than $\frac{1}{304}$ of an inch, this linear dimension, although so small, being the diameter of the *most greatly expanded* molecules of the *least dense* matter in all nature—the omnipresent all—prevading fluid medium called the "luminiferous ether" whence, under my hypothesis, all known forms of matter have been derived in the manner, and through the processes that I have described. According to my theory, as stated in a preceding paragraph, the absolute temperature (T) of gaseous matter is proportional to the number (N) of revolutions, and consequent impacts, of the atoms of the molecules *inter-se* in unit, time, these atoms moving with the fundamental orbital velocity (V_0), as expressed by the equation $NV_0 = TV_0$. But, under my theory, the pressure (P) of all gaseous matter is caused by the practically *incessant* impulses and impacts of the revolving atoms of the molecules of the gas *inter se*, and against the internal surface of the walls of a containing vessel or, in the case of "atmospheric pressure," against the restraining surface of the Earth, on the one hand, and on the other (through a rapidly decreasing series of atmospheric densities and pressures, upward through a height of 250 miles, as determined through my theory) by the equilibrating pressure of the gaseous matter of the luminiferous ether in outer space, the pressure, density and temperature whereof are the fundamental limiting quantities, in these respects, upon which all others are based, according to my theory.

Saint Paul, Minnesota.

To be continued.

WIND PRESSURE ON AN OBSERVATORY DOME.

E. D. ROE, JR.

For Popular Astronomy.

In Vol. 14, (1906), p. 348 of Popular Astronomy the writer gave formulas for the wind pressures on a smooth hemispherical dome as follows:

$$X = 2\,Fr^2 \int_0^{\frac{\pi}{2}} \int_0^{\frac{\pi}{2}} \cos^2\theta \sin\theta \, d\theta \, d\phi = \tfrac{1}{3}\,F\pi r^2,$$

$$Y = 2\,Fr^2 \int_0^{\frac{\pi}{2}} \int_0^{\frac{\pi}{2}} \sin^2\theta \cos\theta \cos\phi \, d\theta \, d\phi = \frac{2}{3\pi}\,F\pi r^2,$$

$$Z = Fr^2 \int_0^{\frac{\pi}{2}} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sin^2\theta \cos\theta \sin\phi \, d\theta \, d\phi = 0,$$

to which may be added,

$$Z = Z_1 + Z_2 ,$$

$$Z_1 = Fr^2 \int_0^{\frac{\pi}{2}} \int_0^{\frac{\pi}{2}} \sin^2\theta \cos\theta \sin\phi \, d\theta \, d\phi = \frac{1}{3\pi} F\pi r^2 ,$$

$$R = \left(1 + \frac{4}{\pi^2}\right)^{\frac{1}{2}} \frac{1}{3} F\pi r^2 = \left(1 + \frac{4}{\pi^2}\right)^{\frac{1}{2}} X ,$$

where F is the normal pressure of the wind per unit of surface, r is the radius of the dome, X is the horizontal pressure in the direction of the wind, Y is the vertical pressure, Z is the lateral pressure perpendicular to the plane of the horizontal and vertical pressures, Z_1 is the lateral pressure on a single side, and R is the total or resultant pressure. We note that Z_1 is equal to one-half of the vertical pressure, and that the total pressure R acts through the center of the dome at an angle of 32° 29′ to the horizon.

It may be of interest to get some idea of the actual pressures sustained. For an indicated wind velocity of 78.67 miles per hour, which corresponds to a corrected or actual velocity of 61.27 miles per hour, the normal pressure per square foot at sea level is 15 lbs. This is obtained from a table of corrected velocities for given indicated velocities, and a table for pressures corresponding to indicated velocities by means of the formula,

$$P = .0040 \frac{B}{30} SV^2 , \qquad \text{where}$$

P = pressure, in pounds avoirdupois,
S = surface, in square feet,
V = corrected velocity of wind, in miles per hour,
B = height of barometer in inches.*

Assuming $B = 30$, and a 61.27 mile wind, corresponding to an indicated velocity of 78.67 miles per hour, we should have with the pressure of 15 lbs. to the square foot† for a 14 ft. dome, the size of the writer's dome,

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* Anemometry, Professor C. F. Marvin, Department of Agriculture, Washington, D. C., 1907, p. 17.

† "Great dependence cannot be placed in the values for indicated velocities beyond 50 or 60 miles per hour, as thus far direct experiments have not been made at the higher velocities though it is probable the corrected values are throughout much more accurate than values computed from older formulas and uncorrected velocities." Anemometry, p. 18.

$X =$ 770 lbs. approximately,
$Y =$ 490 " "
$Z_1 =$ 245 " "
$R =$ 912.66 " " *

pressures which the dome should easily bear.

From the formulas for the pressure on a hemispherical dome, we see that the pressures on two hemispherical domes under the same conditions are to each other as the squares of their radii.

Assuming the same (61.27 miles per hour) wind as before, we should have for a 90 ft. dome

$$\frac{X}{770} = \left(\frac{45}{7}\right)^2, \text{ or}$$

$X =$ 31,821 lbs. = 15.91 tons,
$Y =$ 20,250 lbs. = 10.125 tons,
$Z_1 =$ 10,125 lbs. = 5.062 tons,
$R =$ 37,717 lbs. = 18.858 tons.

In the paper cited from Vol. 14, the writer remarked that an easily moving dome would turn with the wind. This actually occurs in the case of the writer's dome. In fact the dome moves so easily that it can be turned by the pull or push of one's little finger without difficulty.

Syracuse University,
April 4, 1908.

THE STONYHURST DISKS FOR MEASURING THE POSITION OF SUN-SPOTS.

A. L. CORTIE, S. J.
Director of the Section.

The Disks.—The originals of the disks, which were made for use at the Stonyhurst Observatory, were drawn to a scale of 10½ inches to the solar diameter. Their accuracy has been verified by the method set forth in a paper in the "*Monthly Notices*" of the Royal Astronomical Society, Vol. 57, pp. 141-147, January 1897. From a comparison instituted between 77 positions of sun-spots obtained by the use of the disks, and the extremely accurate measurements of the same spots made

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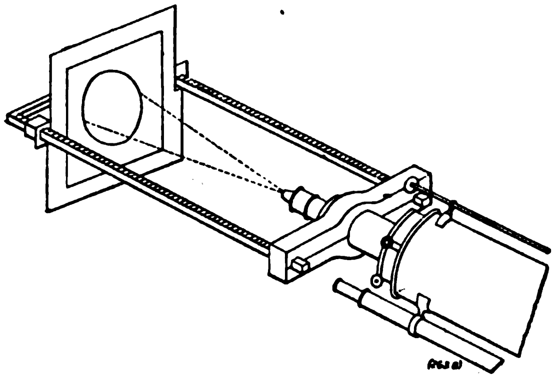
* In computing these values $\frac{22}{7}$ was taken for the value of π.

on the Greenwich photographs with the measuring machine, it was found that the greatest difference in longitude was 0°.6 in three cases, while 63 positions differed only between 0°.3 and 0°. Of 73 comparisons in latitude five differed 0°.7, while 55 positions were within the limit 0°.3. These disks, eight in number, are true orthographic projections of the parallels of latitude and meridians of longitude, corresponding to the eight values 0° to ± 7° of the heliographic latitude of the center of the Sun's apparent disk. The limitations of absolute accuracy in obtaining sun-spot positions by the means of orthographic projections are set forth in the paper already cited.

The disks have been carefully copied from the originals on a reduced scale of 6 inches to the Sun's diameter by Messrs. Casella and Co., 11, Rochester Row, Victoria Street, London, S.W. They are reproduced on cardboard or on glazed linen, so that they can be used either on a sketching-board at the end of the telescope for direct projection of the Sun's image, or in the case of the set on glazed linen, for placing over a disk-drawing of sun-spots and faculæ. The use of the disks for measuring positions is explained in the following paragraphs. In addition to the set of disks there is required the table for P, D, L: P the position angle of the N. end of the Sun's axis from the N. point of the Sun; D the heliographic latitude of the center of the Sun's disk, or the apparent pole tilt of the Sun's axis; and L the heliographic longitude of the center of the Sun's disk. This table is published each year in the "*Companion to the Observatory*" (Messrs. Taylor and Francis, Red Lion Court, Fleet Street, London, E.C., price 1s.), the positions being given for intervals of five days, the values for intervening days being easily obtained by interpolation. In addition a simple table of natural cosines is needed ("Mathematical Tables for Ready Reference," by Francis Castle M.I.M.E., Macmillan & Co., price 2d).

Method of Drawing and Orientation.—The use of the disks presupposes that the Sun is observed by projection. An efficient method of procedure is as follows. A drawing-board is supported in a light frame which can be attached by means of a collar-piece to the draw-tube of the telescope containing the eye-piece, which it should fit tightly, but not so tightly but that it can be rotated round the draw-tube. A lining of felt is very suitable for this purpose. A convenient form of projection apparatus is shown in the accompanying diagram. The cross-bar containing the collar is made in two pieces; into the lower one are fitted the rods that carry the frame supporting the drawing-board, the upper portion being fastened over the lower half by strong hooks and eyes. The apparatus is easily attachable to and detachable from the telescope draw-tube. On a sheet of drawing paper a circle is described of the diameter, 6 inches, required to contain the projected solar image, and a horizontal diameter is drawn across the circle. Selecting a spot on the Sun's image, preferably a small one, if such be visible, the whole frame containing the drawing-board is turned about the draw-tube until the spot runs along the horizontal diameter. This fixes the direction of the Earth's equator and the N. and S. points. Looking at the projected image, the W. or preceding limb of the Sun is on the left hand, and the N. point, as Mr. Whitelow* has pointed out, in any position at all of the image, is 90° counter-clockwise from the E. point. This simple rule is efficient in fixing the cardinal points when an altazimuth telescope is used. The Sun's image is now made to fill the circle by means of the slow-motion gear, and the outlines of the spots and faculæ are quickly traced with a pencil, a red pencil being preferably used for the faculæ. Note the year, month, day, and G. M. T. when the outlines of the spots were drawn. Details can now be filled into the outlines at leisure. The positions so obtained are correctly oriented with regard to the Sun's apparent N. point. The disks may now be employed with the drawings to obtain the true heliographic coördinates of the spots and faculæ. If the cardboard disks are used they can themselves be placed on the sketching-board to receive the Sun's image. Select the



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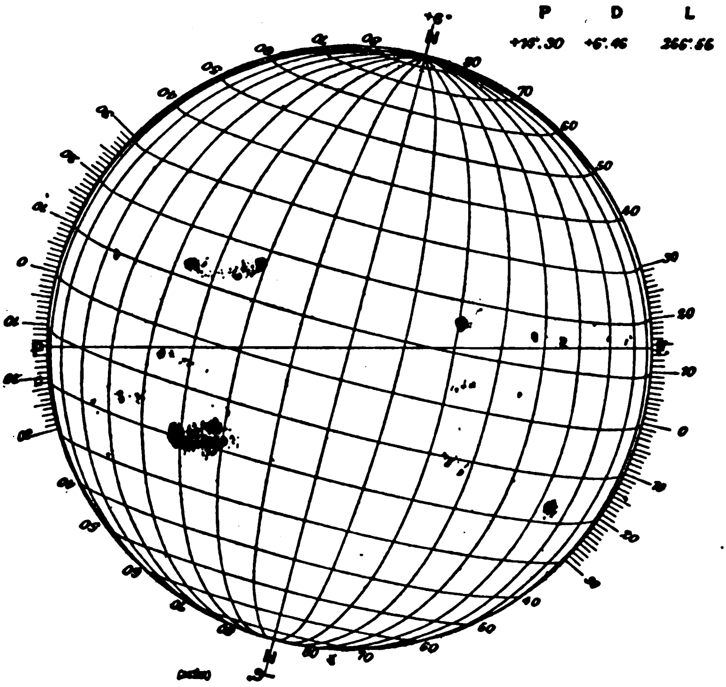
* Twelfth Report of the Southport Society of Natural Science, 1906-1907 pp. 29-31.

disk with the value for D which gives the whole degree obtained from the tables in the "*Companion to the Observatory*," draw a horizontal diameter upon it, and to obtain the Sun's apparent N. point proceed according to the preceding instructions. Now look out the value P from the tables and turn the whole frame accordingly. This operation is facilitated by the fact that the disks have upon them graduated arcs for every degree to 30° N. and S. on each limb. For example, let P = + 14°.30 on the day of observation. Turn the frame and board in a clockwise direction until the horizontal diameter is + 14°.30 below the zero division on the W. limb, and correspondingly above it on the E. limb. For negative values of P the frame must be turned counter-clockwise. If the linen disks are used, they are laid over the completed drawing and turned to the proper value of P required as exemplified in the annexed figure.

1893, August 9. 9h.37m.   *Ephemeris at time of Drawing:-*



Readings of the Positions.—Read off from the disk the apparent angular positions above or below the Sun's equator, and left (preceding) or right (following) of the central meridian which contains one at least of the Sun's poles. In estimating degrees near the limb allowance must be made for foreshortening on the projected image of the solar hemisphere. The values of L, the longitude, always increase from E. to W., hence angular distances measured eastward or to the right of the central meridian are $-^{ve}$, those to west or left are $+^{ve}$. In the accompanying figure, for instance, selecting the spot in the *s.f.* quadrant the disk readings are — 16°.8 south of equator and 53°.5 east of central meridian.

Latitude.—The estimated angular distance N. or S. of the equator needs correction in the following manner. The true D for the day of observation is expressed in degrees and minutes of arc or decimals of a degree, *e.g.*, on the date of the illustrating figure D = + 6°.46. But the disks are constructed only for degree values of D. It is evident that for a spot on the central meridian a correction of 0°.46, or nearly half a degree, the difference between true D and disk D would have to be applied to its disk reading to give its true latitude, while at the limbs the correction would vanish. For intermediate positions the difference between true D and disk D must be multiplied by the natural cosine of the angular distance of the spot E. or W. of the central meridian. In the case illustrated the angular distance is 53'.5. The natural cosine is .59. The correction is .46 × .59 or approximately 0°.3, and hence the true latitude is —16°.5 South. A little consideration will show that when disk D is numerically less than true D, then for D $+^{ve}$ the correction to spot positions as read is $+^{ve}$, for D $-^{ve}$ the correction is $-^{ve}$, spots N. of the equator being $+^{ve}$, and south of the equator being $-^{ve}$. The opposite holds when disk D is numerically greater than true D. For instance in the present example the disk D + 7° might equally well have been employed.

The rule is—

$$\text{True D} > \text{disk D} \left\{ \begin{array}{l} \text{D} +^{ve} \text{ correction } +^{ve} \\ \text{D} -^{ve} \text{ correction } -^{ve} \end{array} \right.$$

$$\text{True D} < \text{disk D} \left\{ \begin{array}{l} \text{D} +^{ve} \text{ correction } -^{ve} \\ \text{D} -^{ve} \text{ correction } +^{ve} \end{array} \right.$$

regard being had to the signs of the spot-positions N. $+^{ve}$ S. $-^{ve}$.

Longitude—First find the longitude of the central meridian for the day and time of observation. In the Table L is given for Greenwich mean noon at intervals of five days. Interpolate for interim dates. L must next be corrected for the time of observation; if the observation be taken before mean noon the correction is $+^{ve}$, if after mean noon $-^{ve}$. Although the difference in longitude of the central meridian for an interval of 24 hours varies with the time of year, it is sufficiently accurate to take 13°.22 as the mean difference in longitude 24 hours. The following short table will facilitate the computation:—

h	°	m	°	m	°
1 =	0.55.	10 =	.092.	1 =	.009.
2 =	1.10.	15 =	.137.	2 =	.018.
3 =	1.65.	20 =	.183.	3 =	.028.
4 =	2.20.	25 =	.229.	4 =	.037.
5 =	2.75.	30 =	.275.	5 =	.046.
6 =	3.30.	35 =	.321.		
7 =	3.85.	40 =	.367.		
8 =	4.40.	45 =	.412.		
9 =	4.95.	50 =	.458.		
10 =	5.50.	55 =	.504.		

All that remains after correcting L is to add or subtract the angular value of the spot's position as read on the disk W. or E. of the central meridian.

EXAMPLE 1.

Date of Drawing.—1893, August 9, 9^h 37^m G.M.T.
Spot.—s.f. Type IV_b.
Thus "*Companion to the Observatory*":—

D = + 6°.46. P. = + 14°.30.
L for Greenwich mean noon = 265°.25.
+ Correction for time of drawing 2^h = 1°.10.
20^m = 0°.183
4^m = 0°.028
L, 9^h 37^m G.M.T, = 266°.56.

Disk Values.—Disk + 6°.
Latitude S. — 19°.8 Longitude E. — 53°.5.

Latitude:—

Reading = — 16°.8 S.
Factor for 53°.5 = .59.
True D — disk D = + .46.
Correction = + .46 × .59 = .27.
Latitude = — 16.8 + .3 = — 16°.5 S.

Longitude:—

L for 9^h 37^m G.M.T. = 266°.56.
Reading = 53°.50.
Longitude = 213°.1.

(The Greenwich results for the same spot were latitude — 16°.1 S., longitude 213°.1.)

EXAMPLE 2.

The nucleus of the leading spot of the great group. Type III_a. *Disk Values.* Latitude — 20°.0 S. Longitude W. + 31°.5 W.

Latitude:—

Reading — 20°.0 S
Factor for 31°.5 = .85.
True D — disk D = + .46.
Correction = + .46 × .85 = .39
Latitude = — 20.0 + .4 = — 19°.6 S.

Longitude:—

L for $9^h 37^m$ G.M.T. = 266°.56.
Reading = + 31°.50.
Longitude = 298°.1.

The process of measurement is made clear from the annexed diagram.

DETERMINACION DE LA HORA Y DE LA LATITUD GEOGRAPHICA DE UN LUGAR PAR LA OBSERVACION DE LOS MOMENTOS EN QUE EOS ALTURAS DE ALGUNAS ESTRELLAS SON IQUALES[*].

G. O. JAMES.

FOR POPULAR ASTRONOMY.

In this catalogue Prof. Obrecht has selected and arranged 130 pairs of stars suitable for time observations in the southern hemisphere by the method of equal altitudes, and it may be worth while to outline in some detail the method followed in the hope that the work of preparing a similar catalogue for the northern hemisphere may be undertaken.

The pairs are arranged in the order of the local sidereal time T at which the two stars are at the same altitude h and tabulated for each degree of latitude from —0° to —60°, so that the pair most convenient to the time of the desired observation may be easily selected. The difference in declination between the stars of a pair is less than 1° so that they lie at approximately the same azimuth east and west, and the catalogue gives in addition to the altitude h the azimuth a of a point on the celestial sphere whose altitude is h and whose declination δ is half the sum of the declinations of the stars of the pair, together with the first derivatives

$$\frac{dh}{dt} \quad \text{and} \quad \frac{da}{dt}$$

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[*] Por A. Obrecht, Santiago de Chile, 1907.

of these quantities with respect to the time.

If the two stars are observed at the instants T—Δt and T+Δt their approximate coördinates are

$$h_e = h_o = h - \frac{dh}{dt}\Delta t$$

$$A_e = 360^\circ - \left\{a + \frac{da}{dt}\Delta t\right\} + v$$

$$A_o = a + \frac{da}{dt}\Delta t + v$$

where v is a correction term independent of the time, whose value is tabulated.

The chronometer correction C_p is computed from the formulae

$$k \equiv \frac{u}{2\,\frac{dh}{dt}}$$

$$t\ \text{corr} = t\ \text{obs} + k\,(l - l')$$

$$\delta \equiv \frac{\delta_e + \delta_o}{2} \qquad \alpha \equiv \frac{\alpha_e + \alpha_o}{2}$$

$$\epsilon \equiv \frac{\delta_e - \delta_o}{2} \qquad \rho \equiv \frac{\alpha_e - \alpha_o}{2}$$

$$H \equiv \rho + \frac{t_o - t_e}{2}$$

$$T \equiv \epsilon \tan\delta \cot H - \epsilon \tan\phi \operatorname{cosec} H$$

$$\Delta T \equiv \frac{T^3}{6} + \frac{T\epsilon^2}{3} + \frac{T^2\epsilon}{2} \tan\delta \cot H$$

$$C_p = \alpha + T + \Delta T - \frac{t_o + t_e}{2}$$

in which l and l′ are the readings of the ends of the level bubble, u the value of one division of the level in seconds of of arc, t_e and t_o the chromometer times of observing the western and eastern star.

The correction ΔT is generally negligible, but where it is appreciable it is tabulated in the catalogue. Obrecht estimates the precision of the observation as about the same as for the instrument in the meridian.

Compared with a time determination from *Polaris and a Southern Star** the method is far inferior both in observation and computation when made with an engineer's transit or theodolite, and so far as time alone is concerned the labor of preparing a special catalogue would not be justified. Its value however is due to the fact that the observation of a latitude star can be combined with the time observation and value of

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* G. O. James, No. 148, page 475, 1907.

the latitude obtained which is independent of the circle readings and refraction, thus furnishing a method for latitude determinations second to that of the zenith telescope only. The selection of the latitude star—a star having approximately the same altitude as that of the time pair but a different declination—may be made from a map as suggested by Obrecht, and the correction to the approximate latitude is then given by the formulae below, the primes referring to the latitude star.

$$H_e \equiv t_e + C_p - \alpha_e$$
$$H_o \equiv t_o + C_p - \alpha_o$$
$$H^1 \equiv t^1 + C_p - \alpha'$$
$$P_e \equiv \sin \delta_e \sin \phi + \cos \delta_e \cos \phi \cos H_e$$
$$P_o \equiv \sin \delta_o \sin \phi + \cos \delta_o \cos \phi \cos H_o$$
$$P^1 \equiv \sin \delta^1 \sin \phi + \cos \delta^1 \cos \phi \cos H^1$$

$$P \equiv \frac{P_e + P_o}{2}$$

$$\Delta\phi = \frac{P^1 - P}{\sin 1''} \frac{\cos \phi}{\sin \delta - \sin \delta^1}$$

The precision of the latitude determination is the same as that of the time.

A better method of selecting the latitude star might be the following. An *Ephemeris* star is chosen whose right ascension α^1 and declination δ^1 are nearly equal to T and $90^\circ - \phi + \delta$, thus crossing the meridian at approximately the time T and at nearly the altitude h. If this star is observed on the meridian at the time $\theta' = \alpha^1$ and altitude h^1 then the instants at which the stars of the time pair lie at this same altitude are given by

$$\Delta t = \frac{h^1 - h}{\frac{dh}{dt}} .$$

H^1 may then be put equal to zero and

$$\Delta\phi = \frac{\cos(\phi - \delta^1) - P}{\sin 1''} \frac{\cos \phi}{\sin \delta - \sin \delta'} .$$

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IS THE UNIVERSE INFINITE?

OWEN ELY.

FOR POPULAR ASTRONOMY.

The question of the extent of the universe is one which can only be given a theoretical solution with the means at hand today. Omitting consideration of theological discussion, no argument has so far been advanced which satisfactorily resolves it. The black rifts in the Milky Way cannot be considered as glimpses into starless space, for the light of more distant suns may be obscured by great masses of dark gas, which we know to exist throughout space. The theory of Professor Newcomb, probably the best attempt to solve the problem, considers that were the stars infinite in number their light would make the whole sky brighter than the Sun; for the number of stars increases as their light becomes fainter, in direct proportion—thus the Earth should receive an equal amount of light from every sphere of stars any number of unit-distances from the Earth. But dark suns are thought to be greater in number than those visible, and there are likewise vast swarms of meteors and masses of floating gases, all of which catch a portion of the light which flows from beyond them and prevent it from reaching us. There is also to be considered the elasticity of the ether, i. e., whether the ether is absolutely perfect as a light-carrying medium. Thus, since we can make no estimate of the amount of light absorbed by bodies in space, and so far have not computed the light-carrying power of the ether, Professor Newcomb's method is fallible.

But a better means, perhaps, would be to consider the effect of gravitation in an infinite universe; for, so far as we know, the power of attraction is transmitted perfectly by the ether and is not hindered by any form of matter in space. However distant the stars, they exercise a power of attraction over the Earth as surely as does our own Sun. Not only do they attract the Earth as a whole, but they decrease the power of gravity which holds it together. The weight of particles in the Earth is lessened to an infinitesimal extent by this attraction, just as the Moon lessens their weight and causes the phenomena of tides; except that the stars, lying on all sides of the Earth, affect it equally on all sides.

To explain this decrease in gravity, take the action of the Moon for illustration: its attraction causes a dimunition in the force of gravity of $\frac{1}{8424000}$, on the nearest part of the surface, this figure being the difference between $\frac{1}{59^2}$ and $\frac{1}{60^2}$ (the Earth's center being 60 radii distant and its surface only 59), multiplied by $\frac{1}{80}$, the fraction of the Earth's mass contained in the Moon. Taking this point as the end of a diameter passing through the Earth's center, we find that nearly the same decrease is evident at the other end of the diameter. The reason for this fact is that the center being nearer the Moon than the farthest side, the Moon tends to pull the nearest half away from the farthest. The difference between $\frac{1}{60^2}$ and $\frac{1}{61^2}$ shows the amount of the disturbance. About midway between these points, where the Moon is near the horizon, its attraction is both horizontal and vertical, and gravity is increased about half the amount which it was decreased at the other points. So, taking the Earth as a whole, every body in space causes a decrease in gravity equal to $\frac{1}{(x-1)^2} - \frac{1}{x^2}$ or $\frac{2x-1}{(x^2-x)^2}$ of itself (x = number of radii distant), multiplied by the relative mass of the body.

It cannot be said that the "pull" of the stars on opposite sides of the sky would be mutually counteracting, thus nullifying the tendency of each to decrease the strength of the Earth's gravity, for, as was shown in the case of the Moon, every body causes a nearly similar decrease at both the nearest and farthest points of the Earth's surface.

Now if it is supposed, as in Professor Newcomb's method, that the stars are infinite in number, and—since the same considerations of number and effect of distance apply to gravitation as well as to light—that each section or sphere of stars in space exercises an equal attraction for the Earth, each lessening the effect of gravity, there would be exerted on every particle of the Earth's mass an irresistible pull outward from the center of the Earth—weight would cease to exist and the attraction of the Sun and planets would be *nil* in comparison to the strength of that force. As we consider the universe boundless, we may imagine any star or point in space as the center of it, instead of the Earth, and hence the same conditions would prevail everywhere. Since gravity would no longer be effective in the Earth or any other body, it is probable that all compounds and masses in the universe would be torn apart and the indivisible particles strewn through space at equal distances from each other.

Are these conclusions from such a theory justified? What other effects would be possible?

To concede that our universe is limited in extent is not to deny that other vast universes may exist, whose distance from it may be as great compared to the distance from the Earth of the farthest star which our telescopes disclose, as that distance is to the diameter of the Earth. To consider the space outside the suns which shine about us as an empty void, destitute of matter or energy, is unthinkable and contradictory to reason. We cannot conceive of absolute nothingness—space would no longer exist when there remained nothing to measure it by.

Probability is against the existence of an infinite universe. The atom is composed of a number of tinier particles—which again may be sub-divisible—but they are not infinite in number. A molecule is composed of a definite number of atoms, and the number of molecules in any body—a rock, an Earth, or a star—is not infinite, though immeasurable. Going higher, we see a planetary system or a group of Suns which revolve about each other. Is it possible that, a step further, we reach a stage where there is an infinite conglomeration of like "particles"? We cannot use earthly comparisons or considerations of size in reflecting that the universe of which our Earth is the most infinitesimal particle may be simply an atom in the immensity of space. The legions of Suns which roam about us may be the floating motes in the sunshine in a greater world.

Perhaps in the future we may obtain better methods and new data upon which to base our inquiry as to the universe and its extent, and perhaps we may learn how to conceive of space—for we cannot imagine infinity in any form. For the present we must be satisfied by logic which seems to point to a finite universe—but beyond that universe we are lost.

Saint Paul, Minnesota.

SOME OPPORTUNITIES FOR ASTRONOMICAL WORK WITH INEXPENSIVE APPARATUS.* III.

GEORGE E. HALE.

(Conclusion.)

I now wish to speak rather more particularly of another phenomenon mentioned here the other night, which is peculiarly adapted for investigation with a small solar image. I refer to the differences between the spectrum of the center of the Sun and the spectrum ot the Sun's disk near the limb, as shown in the next photograph. Here is a spectrum of the center of the Sun, and here is the spectrum of the Sun at a point a short distance inside of the limb. You will see at once the remarkable changes that take place. The broad H_1 and K_1 lines (or bands) are greatly reduced in width; and the same thing occurs, I think, in the case of all lines that are accompanied by wings. In this region of the ultra-violet many of these lines have wings, which are lost or greatly reduced near the edge of the Sun. This causes a remarkable change in the appearance of the spectrum. Several other curious things occur. Not only do these wings change in intensity very much, but the central part of the line, which seems to be sharply distinguished trom the wings, undergoes a decided change of intensity also, so that we find from a preliminary examination of the plates that the lines that are strengthened in sun-spots are generally strengthened near the edge of the Sun, while the lines that are weakened in sun-spots are generally weakened near the edge of the Sun. This is true, I think, in the great majority of cases. Again, we find another curious thing: almost all of the lines derived from points near the Sun's limb are shifted towards the red in the spectrum with reference to lines from the center of the disk. But there are some striking exceptions, and one of them is most significant: the lines in this fluting of cyanogen are not appreciably displaced. As we know from laboratory experiments that flutings are not displaced by pressure, whereas lines are thus displaced, we seem to have an interesting confirmation of the conclusion previously reached by Halm from his visual obser-

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[*] *Monthly Notices*, November, 1907. From a lecture delivered at the Royal Astronomical Society, London, which Mr. Hale illustrated by means of lantern slides.

vations of two lines in the red—that the displacement of these lines is to be ascribed to pressure.*

This investigation is a many-sided one, with applications to both solar and stellar phenomena. There is room here for many investigators, who can obtain results quite equal, and very likely superior, in value to any we can get at Mount Wilson. A large image of the Sun is not required, because the effect is very appreciable at some distance from the limb. It is also a matter of no importance whether the definition of the solar image be good or bad. The one essential point is that the spectrograph be fairly powerful, and this is a very simple thing to realize at moderate expense. I hope to see this subject taken up by several observers, who will determine the shifts and the relative intensities of the Fraunhofer lines, seek for evidence of periodic changes, and work out an explanation of these remarkable phenomena which will harmonize with some explanation of the relative intensities of the same lines in sun-spots and in the spectra of stars.

I may now touch upon another field of solar research, and consider the possibility of doing useful new work with the spectroheliograph, which is by no means as expensive and formidable an instrument as one might suppose. The slide shows the first spectroheliograph used on Mount Wilson, before we built the more permanent one now employed; and since the fact that we did substitute a permanent instrument for the temporary one might lead to the inference that the former did not give good results, I may add that the photographs made with the wooden instrument are even better than the later ones. They show only narrow zones of the solar surface, but for sharpness they have never been surpassed.†

There is a rectangular wooden platform here mounted on a pier. At each corner of the platform was screwed a small cast-iron block, in which a V-shaped groove had been planed. In each groove was a steel ball. A moving platform, also built of wood, carried the optical parts of the spectroheliograph and rested on these balls, so that it could be moved

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* This conclusion is further confirmed by the fact that lines of a given element, which exhibit unequal displacements at a certain pressure in the laboratory, in general show corresponding displacements near the Sun's limb. It remains to be seen, however, whether some other hypothesis may not be equally capable of accounting for the observed phenomena.

† In the 5-foot spectroheliograph now employed, the dispersion is great enough for photography with the hydrogen as well as the calcium lines. For this reason the exposures are longer, and the definition somewhat less perfect though quite satisfactory for practical purposes.

across the image of the Sun (formed by a cœlostat telescope). The motion was produced by a small electric motor, belted with a piece of fish-line to this large wooden pulley, which drove a screw passing through a lead nut fastened to the movable platform. The screw was cut on a foot lathe and the nut cast on it. This simple mechanism provided the means of producing a slow uniform motion of this upper platform across the image of the Sun. The arrangement of the optical parts was precisely the same as in the Rumford spectroheliograph.

The next slide shows some photographs taken with the permanent instrument. Such photographs as these made with the calcium and hydrogen lines, open up for investigation a large field, which anyone can enter with just such an equipment as I have described—a very simple instrument, with small prisms and lenses, and built almost entirely of wood.

I will show you in the next photograph some pictures obtained with the wooden instrument. You will notice that in this case the motion was not absolutely uniform; you can detect the slight irregularity of motion, but it did not affect the usefulness of the negatives. This is a direct photograph of the Sun; this is made with the H_1 line of calcium, and this is the same region as photographed with the H_2 line of calcium. If somebody would go to work with such an instrument and let us know exactly what such photographs as these mean, they would at least confer a very great favor upon me, because hitherto I have been unable to determine the relative parts played by the continuous spectrum of the faculæ and the light of the line H_1 line of calcium in producing the photographs. That question is still open, and many investigations will be required to settle it beyond doubt.

In this H_2 photograph we probably have a picture of the calcium vapor at a higher level than the level represented by the H_1 plates. You see, for example, this bridge of calcium vapor across the spot, which is not shown by H_1. Many investigations of great interest could be carried on with such a spectroheliograph as I have described. I wish I had time to go into them; there is only one I may mention, and that is the comparison of the calcium and the hydrogen images.

I might mention various other methods of employing spectroheliographs, and I may remark in passing that with a Littrow spectrograph, or any long focus spectrograph, and a fixed solar image, one can undertake other work of various kinds, such as a determination of the solar rotation, along some such plan as Dunér or Halm followed, but using different lines in the spectrum, and benefiting from the advantages of photographic methods. In all such work, coöperation with other investigators is greatly to be desired, because it might otherwise frequently happen that two men would be doing the same thing, whereas it would be just as easy for them to supplement each other's work instead of duplicating it.

One other phase of the subject which I should like to have time to discuss, but cannot, is that of stellar spectroscopy.

I might go on to speak of the possibilities of work on variable stars, but they are familiar to most of you. The observation of many wide double stars, my friend Burnham tells me, has been neglected since the time of Herschel, because the large instruments, and even the small ones, have been devoted to closer objects, so that in revising his great catalogue Burnham had to measure with the 40-inch a great many wide doubles which had not been looked at perhaps since Herschel discovered them more than a century before. Important double-star work is always open to men with small instruments, if a micrometer is available.

Then I might go on to the case where a man has no telescope at all, and still wants to make contributions to astrophysics. I do not now speak of such splendid work as Anderson did when he discovered Nova Persei with the naked eye; but if one were convinced that the overcast sky of London would never open again, he could still work in his laboratory and make important contributions by identifying lines and bands in spot spectra, as Professor Fowler has been doing of late, or by researches in a score of other fields.

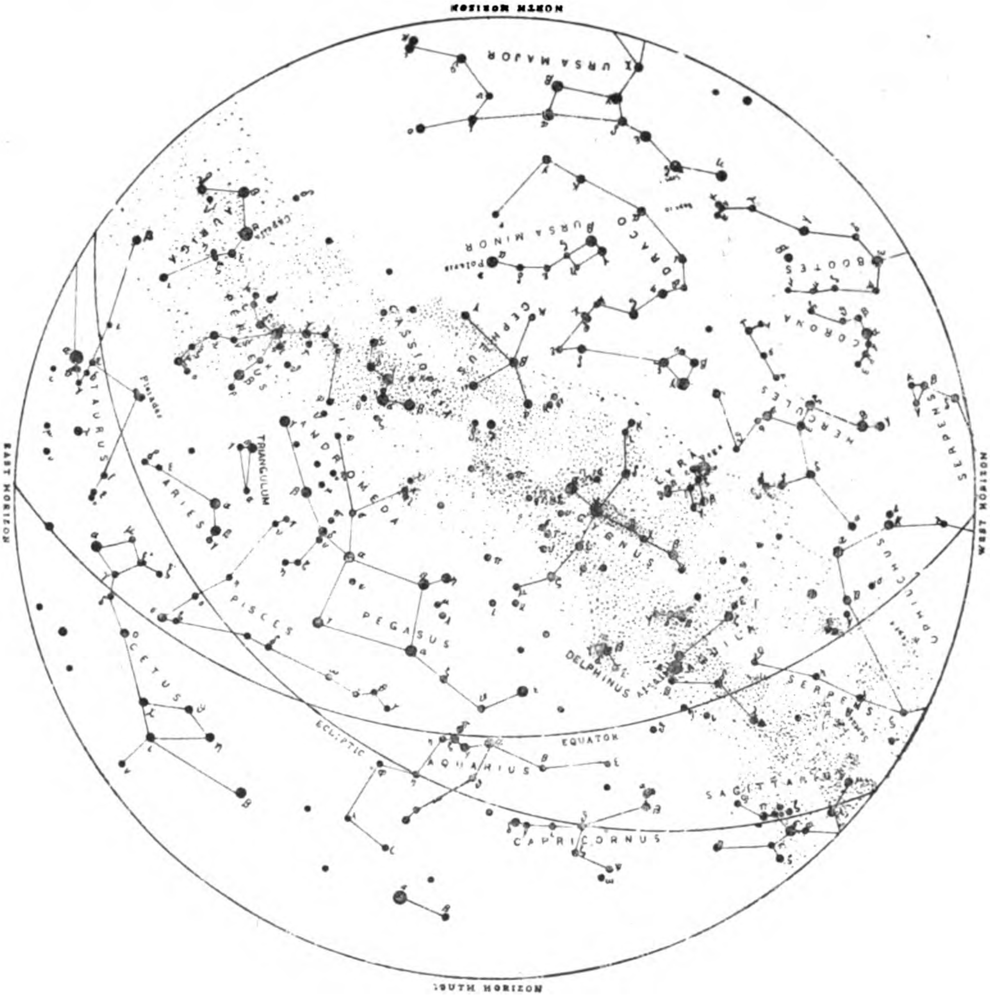
I will close with a few practical suggestions. One reference to the matter of atmosphere. I have often been strongly impressed (since my work in Chicago) with the belief that a smoky atmosphere has some advantages in astronomical work, for it seems that the seeing is frequently improved in solar observations when the sky is smoky. It is perfectly possible to get good good results anywhere, provided sufficient care is taken. One must consider, for example, the best time of day for solar work. It usually happens that the best definition of the Sun occurs in the early morning and the late afternoon. Mr. Newall tells me that this is as true at Cambridge as it is at Mount Wilson. This is worth looking into if one takes up work on the Sun. Further, one must have a definite plan of work. This is of prime importance. Devote your entire attention to a single investigation, involving, if possible, two or three parallel series of observations, so devised as to throw light on one another. Frequently the value of a given series of observations may be enormously enhanced if other observations are available to aid in their interpretation. For example, in studying the spectra of sun-spots, the character of the spots, their motions, and changes of form, and the distribution of the flocculi in their neighborhood, may be vital factors in interpreting the spectroscopic phenomena. Then, again, there is the great possibility that new methods and new instruments can be applied. Up to the present time I think the interferometers of Michelson or of Pérot and Fabry have never been systematically employed for work on the Sun: that admirable method which Fabry is using at the present in the determination of absolute wave-lengths would perhaps be very useful indeed if applied to the measurement of the displacement of solar lines at the center and at the limb. I also believe that the echelon spectroscope has never been used for the observation of the narrow bright lines in the chromoshpere. Furthermore, we are always confronted by the possibility of perfecting our optical apparatus. I have been trying for years to get good prisms of large size, but cannot get homogeneous glass, and therefore it now seems necessary to attack the problem of fluid prisms.

I hope I have shown that it is possible not merely to do work of an inferior quality, but to do work of the first quality, with small or inexpensive instruments; work that cannot be duplicated or will not be duplicated with large instruments; in other words, that there is a splendid field for any man who wishes to accomplish results, wherever he may be situated, and however simple his means of research may be. I feel so strongly on this subject that I hope the suggestions I have made will not be entirely without effect. We need the ideas of men from all parts of the world; we need the contributions they can make; and we need them even more than we need larger instrumental means than we now possess.

PLANET NOTES FOR SEPTEMBER AND OCTOBER, 1908.

H. C. WILSON.

Mercury will be at greatest elongation, east from the Sun 25° 34′, on Oct. 4. It will not be very conspicuous at this time, having only about half of its maximum brilliancy. On Oct. 28 the planet will be at inferior conjunction.



THE CONSTELLATIONS AT 9:00 P. M., OCTOBER 1, 1908.

Venus will be brilliant as morning star during these two months, decreasing slowly from 163 to 91 on the scale of brightness used in the Nautical Almanac. Venus will be at greatest elongation, 46° 2′ west from the Sun on Sept. 14. Venus and Jupiter will be in conjunction on the morning of Oct. 13. At 10 a.m., Central Standard time on that date the two planets will be only

36′ or a little more than the Moon's diameter apart, Venus being south of Jupiter.

Mars will be in aphelion Sept. 20 and will be too near the Sun for satisfactory observation during these months.

Jupiter is morning star with Venus and will be too near the Sun for study during September. In October he will be far enough out from the Sun's rays to be observed for a short time in the morning.

Saturn will be at opposition Sept. 29 and in fair position for observation during the two months. The inclination of the plane of the rings to the line of sight from the earth is 7° 10′ on Sept. 1 and decreases to 5° 14′ on Nov. 1.

Uranus will be at quadrature, 90° east from the Sun, Oct. 6, and so may be studied with the aid of a telescope in the early evening. Uranus will be stationary in right ascension on Sept. 22 and after that will move slowly eastward.

Neptune will be at quadrature, 90° west from the Sun, Oct. 10. Neptune will be stationary in right ascension, $7^h\ 13^m\ 48^s$ on Oct. 20 and after that for the rest of this year its motion will be very slowly westward. The declination of Neptune on Oct. 20 will be north 21° 35′. The planet is in the constellation Gemini a little way southwest from the star δ.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T.		Angle fm N.	EMERSION. Washington M.T.		Angle fm N	Duration.	
			h	m	°	h	m	°	h	m
Sept. 6	B.A.C. 6814	6.3	6	35	137	7	24	216	0	49
7	27 Capricorni	6.1	12	50	97	13	45	218	0	55
9	BD. —11°,6032	6.3	15	04	92	15	57	210	0	53
10	30 Piscium	4.7	9	18	30	10	15	273	0	57
10	33 Piscium	4.7	11	02	62	12	17	232	1	15
12	Piazzi I, 249	6.5	17	38	57	18	45	251	1	07
13	85 Ceti	6.3	8	09	70	9	01	243	0	52
14	Mayer 121	6.4	9	02	83	9	52	233	0	50
14	Mayer 136	5.9	18	07	44	19	17	279	1	10
16	Piazzi v, 184	6.5	17	58	55	19	20	287	1	22
18	58 Geminorum	6.0	14	11	125	15	01	224	0	50
Oct. 9	Lalande 2632	6.5	9	47	14	10	38	280	0	51
9	ν Piscium	4.6	18	14	46	19	03	270	0	49
10	25 Arietis	6.5	13	44	16	14	42	281	0	58
13	*n* Tauri	5.1	16	38	75	18	03	265	1	25
14	3 Geminorum	5.6	13	14	124	14	07	209	0	53
14	9 Geminorum	6.2	18	10	30	18	52	331	0	42
16	μ^1 Cancri	6.2	18	30	84	19	55	304	1	25
19	*i* Leonis	5.8	17	15	52	17	57	352	0	42
27	B.A.C. 5436	6.2	4	47	74	5	52	310	1	05

Saturn's Satellites.

1 Mimas. Period $0^d\ 22^h.6$.

	h		h		h		h
Sept. 3	14 9 W	Sept. 16	8.0 E	Sept. 30	11.2 E	Oct. 16	11.7 E
4	13.5 W	17	6.6 E	Oct. 1	9.8 E	17	10.3 E
5	12.1 W	19	15.3 W	2	8.5 E	18	8.9 E
6	10.7 W	20	13.9 W	5	15.7 W	19	7.5 E
7	9.3 W	21	12.5 W	6	14.4 W	23	13.4 W
8	7.9 W	22	11.1 W	7	13.0 W	24	12.0 W
11	15.0 E	23	9.7 W	8	11.6 W	25	10.6 W
12	14.6 E	24	8.4 W	9	10.2 W	26	9.2 W
13	12.2 E	25	7.0 W	10	8.8 W	27	7.9 W
14	10.8 E	27	15.4 E	11	7.4 W	28	6.5 W
15	9.4 E	28	14.0 E	14	14.5 E	31	13.6 E
		29	12.6 E	15	13.1 E		

II Enceladus. Period $1^d\ 8.9^h$

Sept. 1	0.7 E	Sept. 16	2.3 E	Oct. 1	4.0 E	Oct. 16	5.6 E
2	9.5 E	17	11.2 E	2	12.8 E	17	14.5 E
3	18.4 E	18	20.1 E	3	21.7 E	18	23.4 E
5	3.3 E	20	4.9 E	5	6.6 E	20	8.2 E
6	12.2 E	21	13.8 E	6	15.5 E	21	17.1 E
7	21.1 E	22	22.7 E	8	0.3 E	23	2.0 E
9	5.9 E	24	7.6 E	9	9.2 E	24	10.9 E
10	14.8 E	25	16.4 E	10	18.1 E	25	19.8 E
11	23.7 E	27	1.3 E	12	3.0 E	27	4.6 E
13	8.6 E	28	10.2 E	13	11.9 E	28	13.5 E
14	17.4 E	29	19.1 E	14	20.7 E	29	22.4 E
						31	7.3 E

III Tethys. Period $1^d\ 21^h.3$.

Sept. 1	4.4 E	Sept. 16	6.8 E	Oct. 1	9.1 E	Oct. 16	11.4 E
3	1.7 E	18	4.1 E	3	6.4 E	18	8.7 E
4	23.0 E	20	1.3 E	5	3.7 E	20	6.0 E
6	20.3 E	21	22.6 E	7	1.0 E	22	3.3 E
8	17.6 E	23	19.9 E	8	22.3 E	24	0.6 E
10	14.9 E	25	17.2 E	10	19.5 E	25	21.9 E
12	12.2 E	27	14.5 E	12	16.8 E	27	19.2 E
14	9.5 E	29	11.8 E	14	14.1 E	29	16.5 E
						31	13.8 E

IV Dione. Period $2^d\ 17^h.7$.

Sept. 3	10.4 E	Sept. 17	2.6 E	Oct. 3	12.5 E	Oct. 19	22.5 E
6	4.0 E	19	20.3 E	6	6.2 E	22	16.1 E
8	21.7 E	22	13.9 E	8	23.8 E	25	9.8 E
11	15.3 E	25	7.6 E	11	17.5 E	28	3.5 E
14	9.0 E	28	1.2 E	14	11.1 E	30	21.1 E
		30	18.9 E	17	4.8 E		

V Rhea. Period $4^d\ 12^h.5$.

Sept. 1	12.5 E	Sept. 15	1.5 E	Oct. 3	2.8 E	Oct. 16	15.8 E
6	0.8 E	19	13.8 E	7	15.1 E	21	4.1 E
10	13.2 E	24	2.1 E	12	3.5 E	25	16.5 E
		28	14.5 E			30	4.8 E

VI Titan. Period $15^d\ 23^h.3$.

Sept. 4	8.6 I	Sept. 16	3.1 E	Oct. 2	0.6 E	Oct. 17	22.1 E
8	4.8 W	20	6.2 I	6	3.7 I	22	1.3 I
12	0.5 S	24	2.4 W	10	0.0 W	25	21·6 W
		27	22.0 S	13	19.6 S	29	17.2 S

VII Hyperion. Period $21^d\ 7^h.6$.

Sept.	6.0 I	Sept.	14.9 S	Oct.	1.6 W	Oct.	18.4 I
	10.4 W		21.1 E		6.1 S		22.8 W
			27.2 I		12.3 E		27.3 S

VIII Iapetus. Period $79^d\ 22^h.1$.

Aug.	25.9 S	Sept.	14.2 E	Oct.	4.2 I	Oct.	24.0 W

VARIABLE STARS.

New Variable 9.1908 Lyncis.—This was found on May 5 by Mme. L. Ceraski of Moscow. Its position is

1855.0 $\alpha = 6^h27^m50^s$ $\delta = +59° 59'$
1900.0 6 31 51 +59 57

The following estimates of its photographic brightness are given in A.N. 4248.

		Mag.				Mag.	
1906	Jan. 28	11.5		1907	Feb. 10	10.2	
	Feb. 17	11.8			Mar. 5	11.3	
	Mar. 29	<12	(invisible)		6	11.3	
	April 16	<12	"		April 7	<12	(invisible)
	" 20	<12	"	1908	Mar. 30	9.0	

Apparently the period is 13 or 14 months or half of that interval.

New Variable 10. 1908, Lacertæ.—In A.N. 4251 Prof. W. Ceraski announces another variable discovered by Mme. Ceraski upon the Moscow photographs May 12. Its position is approximately

1855.0 $\alpha = 22^h06^m49^s$ $\delta = +43° 03'$
1900 0 22 08 41 +43 16

Judging from about 30 photographs obtained between 1898 and 1907, the brightness varies from 9.5 to 11.5 magnitude. The period is long, some months, or the variable is irregular.

New Variable 11. 1908, Orionis.—This was discovered on May 17 by Mme. Ceraski on the photographs taken at Moscow. Its position as given in A.N. 4252 is

1855.0 $\alpha = 6^h13^m57^s.01$ $\delta = +14° 44' 30''.7$
1900.0 6 16 31.05′ +13 43 30.8

The star is BD+14° 1259 ($8^m.5$) and is found in the Leipzig A.G. catalogue. From 29 photographs taken between 1896 and 1908 it appears that the magnitude varies between 8.3 and 9.0 and that the period is probably short.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours. Alternate minima are given this month.]

U Cephei

	d	h
Sept.	3	10
	8	9
	13	9
	18	9
	23	8
	28	8
Oct.	3	7
	8	7
	13	7
	18	6
	23	6
	28	6

Z Persei

Sept.	3	23
	10	2
	16	4
	23	7
	28	10
Oct.	4	12
	10	15
	16	18
	22	21
	28	23

RU Persei

Sept.	4	7
	18	0
Oct.	1	18
	15	11
	29	5

RZ Cassiop.

Sept.	1	3
	3	12
	5	22
	8	7
	10	17
	13	2
	15	11
	17	21
	20	6
	22	15
	25	1
	27	10
	29	20
Oct.	2	5
	4	14
	7	0
	9	9
	11	18
	14	3
	16	13
	18	22
	21	8
Oct.	23	17
	26	3
	28	12
	31	21

RX Cephei

Sept.	4	19
Oct.	7	3

Algol

Sept.	2	0
	4	21
	10	15
	16	8
	22	2
	27	20
Oct.	3	13
	9	7
	15	1
	20	18
	26	12

RT Persei

	d	h
Sept.	1	3
	2	20
	4	13
	6	5
	7	22
	9	15
Sept.	11	8
	13	0
	14	17
	16	10
	18	3
	19	19
	21	12
	23	5
	24	22
	26	15
	28	7
	30	0
Oct.	1	17
	3	10
	5	2
	6	19
	8	12
	10	5
	11	22
	13	14
	15	7
	17	0
	18	17
	20	9
	22	2
	23	19
	25	12
Oct.	27	4
	28	21
	30	14

λ Tauri

Sept.	1	8
	9	5
	17	2
	25	0
Oct.	2	22
	10	20
	18	17
	26	15

RW Tauri

Sept.	1	22
	7	11
	13	0
	18	13
	24	1
	29	14
Oct.	5	3
	10	16
	16	5
	21	18
	27	7

Minima of Variable Stars of the Algol Type.—Continued.

RV Persei	d	h
Sept.	2	11
	6	10
	10	9
	14	7
	18	6
	22	5
	26	3
	30	2
Oct.	4	1
	8	0
	11	22
	15	21
	19	20
	23	19
	27	17
	31	16

RW Persei		
Sept.	11	16
Oct.	8	1

RS Cephei		
Sept.	11	4
Oct.	6	0
	30	21

RW Geminorum		
Sept.	5	1
	8	19
	14	12
	20	6
	25	23
Oct.	1	17
	7	10
	13	4
	18	21
	24	15
	30	9

RW Monoc.		
Sept.	2	21
	6	17
	10	12
	14	8
	18	3
	21	23
	25	18
	29	14
Oct.	3	9
	7	5
	11	0
	14	20
	18	15
	22	11
	26	6
	30	2

RU Monoc.		
Sept.	1	7
	3	2
	4	21
	6	16
	8	11
	10	6
	12	1

RU Monoc.	d	h
Sept.	13	20
	15	15
	17	10
	19	5
	21	0
	22	19
	24	14
	26	9
	28	4
	29	23
Oct.	1	18
	3	13
	5	8
	7	3
	8	22
	10	17
	12	12
	14	7
	16	2
	17	21
	19	16
	21	11
	23	6
	25	1
	26	20
	28	15
	30	10

R Canis Maj.		
Sept.	1	14
	3	21
	6	3
	8	10
	10	16
	12	23
	15	5
	17	12
	19	18
	22	1
	24	7
	26	14
	28	20
Oct.	1	3
	3	10
	5	16
	7	23
	10	5
	12	12
	14	18
	17	1
	19	7
	21	14
	23	20
	26	3
	28	9
	30	16

Y Camelop.		
Sept.	2	5
	8	20
	15	11
	22	1

Y Camelop.	d	h
Sept.	28	16
Oct.	5	7
	11	21
	18	12
	25	3
	31	17

RR Puppis		
Sept.	6	18
	19	15
Oct.	2	11
	15	8
	28	5

V Puppis		
Sept.	1	4
	4	1
	6	23
	9	21
	12	19
	15	17
	18	14
	21	12
	24	10
	27	8
	30	6
Oct.	3	4
	6	1
	8	23
	11	21
	14	19
	17	17
	20	14
	23	12
	26	10
	29	8

S Cancri		
Sept.	1	16
	20	16
Oct.	9	15
	28	14

S Velorum		
Sept.	4	16
	16	13
	28	10
Oct.	10	7
	22	4

RR Velorum		
Sept.	1	22
	5	15
	9	8
	13	1
	16	18
	20	11
	24	4
	27	21
Oct.	1	14
	5	7
	9	0
	12	17
	16	10
	20	3

RR Velorum	d	h
Oct.	23	20
	27	13
	31	6

SS Carinæ		
Sept.	2	6
	8	21
	15	11
	22	2
	28	16
Oct.	5	7
	11	21
	18	11
	25	2
	31	16

δ Libræ		
Sept.	1	0
	5	16
	10	8
	14	23
	19	15
	24	7
	28	22
Oct.	3	14
	8	6
	12	22
	17	13
	22	5
	26	21
	31	12

U Coronæ		
Sept.	2	13
	9	11
	16	8
	23	6
	30	4
Oct.	7	1
	13	23
	20	21
	27	18

R Aræ		
Sept.	4	6
	13	3
	21	23
	30	19
Oct.	9	16
	18	12
	27	9

U Ophiuchi		
Sept.	1	3
	2	19
	4	11
	6	3
	7	20
	9	12
	11	4
	12	21
	14	13
	16	5
	17	21
	19	14

U Ophiuchi	d	h
Sept.	21	6
	22	22
	24	14
	26	7
	27	23
	29	15
Oct.	1	7
	3	0
	4	16
	6	8
	8	0
	9	17
	11	9
	13	1
	14	17
	16	10
	18	2
	19	18
	21	10
	23	3
	24	19
	26	11
	28	4
	29	20
	31	12

Z Herculis		
Sept.	4	2
	8	2
	12	2
	16	2
	20	2
	24	1
Oct.	2	1
	6	1
	10	1
	14	1
	18	0
	22	0
	26	0
	30	0

RS Sagittarii		
Sept.	2	15
	7	11
	13	7
	18	3
	22	23
	27	19
Oct.	2	15
	7	11
	12	7
	17	3
	21	23
	26	19
	31	15

V Serpentis		
Sept.	2	10
	9	8
	16	6
	23	3
	30	1

Minima of Variable Stars of the Algol Type.—Continued.

V Serpentis

	d	h
Oct.	6	23
	13	21
	20	19
	27	16

RX Herculis

	d	h
Sept.	1	20
	3	14
	5	9
	7	4
	8	22
	10	17
	12	12
	14	7
	16	1
	17	20
	19	15
	21	9
	23	4
	24	23
	26	17
	28	12
	30	7
Oct.	2	1
	3	20
	5	15
	7	9
	9	4
	10	23
	12	17
	14	12
	16	7
	18	2
	19	20
	21	15
	23	10
	25	4
	26	23
	28	18
	30	12

SX Sagittarii

	d	h
Sept.	2	5
	6	9
	10	12
	14	16
	18	20
	22	23
	27	3
Oct.	1	7
	5	10
	9	14
	13	18
	17	21
	22	1
	26	5
	30	9

RR Draconis

	d	h
Sept.	2	10
	8	2
	13	18
	19	10
	25	2
	30	18
Oct.	6	10
	12	1
	17	17
	23	9
	29	1

U Scuti

	d	h
Sept.	1	3
	3	1
	4	22
	6	20
	8	18
	10	16
	12	14
	14	12
	16	10
	18	7
	20	5
	22	3

U Scuti

	d	h
Sept.	24	1
	25	23
	27	21
	29	18
Oct.	1	16
	3	14
	5	12
	7	10
	9	8
	11	5
	13	3
	15	1
	16	23
	18	21
	20	19
	22	16
	24	14
	26	12
	28	10
	30	8

RV Lyræ

	d	h
Sept.	3	7
	10	12
	17	17
	24	21
Oct.	2	2
	9	7
	16	12
	23	16
	30	21

U Sagittae

	d	h
Sept.	3	13
	10	7
	17	2
	23	20
	30	14
Oct.	7	8
	14	3
	20	21
	27	15

SY Cygni

	d	h
Sept.	3	10
	15	11
	27	11
Oct.	9	11
	21	12
	27	12

WW Cygni

	d	h
Sept.	3	23
	10	14
	17	5
	23	21
	30	12
Oct.	7	3
	13	18
	20	10
	27	1

SW Cygni

	d	h
Sept.	4	7
	13	11
	22	14
Oct.	1	18
	10	21
	20	1
	29	4

VW Cygni

	d	h
Sept.	1	11
	18	8
Oct.	5	5
	22	1

UW Cygni

	d	h
Sept.	4	0
	10	22
	17	20
	24	17
Oct.	1	15
	8	13
	15	10
	22	8
	29	6

W Delphini

	d	h
Sept.	3	8
	12	22
	22	13
Oct.	2	4
	11	18
	21	9
	31	0

RR Delphini

	d	h
Sept.	3	0
	12	5
	21	9
	30	14
Oct.	9	19
	19	0
	28	5

VV Cygni

	d	h
Sept.	1	8
	4	7
	7	6
	10	5
	13	4
	16	3
	19	2
	22	1
	25	0
	27	22
	30	21
Oct.	3	20
	6	19
	9	18
	12	17
	15	16
	18	15
	21	14
	24	12
	27	11
	30	10

UZ Cygni

	d	h
Oct.	1	17

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
Sept.	2	7
	17	2
Oct.	1	22
	16	17
	31	12

RX Aurigæ

	d	h
	(−4	0)
Sept.	2	16
	14	7
	25	22

RX Aurigæ

	d	h
Oct.	7	13
	19	4
	30	19

Y Aurigæ

	d	h
	(−0	18)
Sept.	2	13
	6	10
	10	6
	14	3
	18	0
	21	20
	25	17

Y Aurigæ

	d	h
Sept.	29	13
Oct.	3	10
	7	7
	11	3
	15	0
	18	20
	22	17
	26	13
	30	10

T Monoc.

	d	h
	(−7	23)
Sept.	11	12

T Monoc.

	d	h
Oct.	8	12

W Geminorum

	d	h
	(−2	22)
Sept.	5	2
	13	0
	20	22
	28	20
Oct.	6	18
	14	16
	22	14
	30	12

ζ Geminorum

	d	h
	(−5	0)
Sept.	10	1
	20	5
	30	8
Oct.	10	12
	20	16
	30	19

RW Camelop.

	d	h
	(−9	12)
Sept.	14	0
Oct.	6	7
	28	13

Maxima of Variable Stars of Short Period not of the Algol Type

Continued.

V Carinæ

	d	h
	(— 2	4)
Sept.	1	22
	8	14
	15	6
	21	23
	28	16
Oct.	5	8
	12	1
	18	18
	25	10

T Velorum

	(— 1	10)
Sept.	1	17
	6	8
	11	0
	15	15
	20	6
	24	22
	29	13
Oct.	4	4
	8	20
	13	11
	18	3
	22	18
	27	9

W Carinæ

	(— 1	0)
Sept.	1	4
	5	13
	9	22
	14	7
	18	16
	23	1
	27	10
Oct.	1	8
	6	3
	10	12
	14	21
	19	6
	23	15
	28	0

S Muscæ

	(— 3	11)
Sept.	2	0
	11	16
	21	8
Oct.	1	0
	10	16
	20	7
	29	23

T Crucis

	(— 2	2)
Sept.	7	11
	14	4
	20	22
	27	16
Oct.	4	9
	11	3
	17	20
	24	14
	31	7

R Crucis

	d	h
	(—1	10)
Sept.	5	7
	11	3
	16	22
	22	18
	28	14
Oct.	4	10
	10	6
	16	1
	21	21
	27	17

S Crucis

	(— 1	12)
Sept.	2	22
	7	14
	12	7
	16	23
	21	16
	26	19
Oct.	1	1
	5	18
	10	10
	15	3
	19	19
	24	12
	29	4

V Centauri

	(—1	11)
Sept.	5	1
	10	13
	16	0
	21	12
	27	0
Oct.	2	12
	8	0
	13	12
	19	0
	24	11
	29	23

R Triang. Austr.

	(— 1	0)
Sept.	2	9
	5	18
	9	4
	12	13
	15	22
	19	8
	22	17
	26	2
	29	11
Oct.	2	21
	6	6
	9	16
	13	1
	16	10
	19	20
	23	5
	26	14
	30	0

S Triang. Austr.

	d	h
	(—2	2)
Sept.	6	7
	12	15
	18	22
	25	6
Oct.	1	14
	7	22
	14	5
	20	13
	26	21

S Normæ

	(—4	10)
Sept.	4	6
	14	0
	23	18
Oct.	3	12
	13	6
	23	1

RV Scorpii

	(—1	10)
Sept.	5	12
	11	14
	17	15
	23	17
	29	18
Oct.	5	20
	11	21
	17	23
	24	0
	30	2

RV Ophiuchi
Minimum.

Sept.	1	13
	5	6
	8	22
	12	15
	16	7
	20	0
	23	16
	27	9
Oct.	1	1
	4	18
	8	10
	12	3
	15	9
	19	12
	23	4
	26	21
	30	13

X Sagittarii

	(—2	22)
Sept.	4	6
	11	7
	18	7
	25	7
Oct.	2	8
	9	8
	16	8
	23	8
	30	9

Y Ophiuchi

	d	h
	(— 6	5)
Sept.	11	6
	28	9
Oct.	15	12

W Sagittarii

	(—3	0)
Sept.	5	13
	13	3
	20	18
	28	8
Oct.	5	22
	13	12
	21	3
	28	17

Y Sagittarii

	(— 2	2)
Sept.	3	14
	9	8
	15	3
	20	22
	26	16
Oct.	2	11
	8	5
	14	0
	19	18
	25	13
	31	8

U Sagittarii

	(— 2	23)
Sept.	1	2
	7	20
	14	14
	21	8
	28	2
Oct.	4	19
	11	13
	18	7
	25	1
	31	19

β Lyræ

	(— 3	7)
	(— 3	2)
Sept.	3	9
	10	1
	16	7
	22	23
	29	5
Oct.	5	21
	12	3
	18	19
	25	1
	31	17

κ Pavonis

	(—1	7)
Sept.	8	7
	17	9
	26	12
Oct.	5	14
	14	16
	23	18

U Aquilæ

	d	h
	(— 2	4)
Sept.	6	13
	13	14
	20	15
	27	15
Oct.	4	16
	11	16
	18	17
	25	17

U Vulpeculæ

	(— 2	3)
Sept.	5	7
	13	7
	21	6
	29	6
Oct.	7	5
	15	5
	23	4
	31	4

SU Cygni

	(— 1	7)
Sept.	1	21
	5	17
	9	14
	13	10
	17	6
	21	3
	24	23
	28	19
Oct.	2	15
	6	12
	10	8
	14	4
	18	1
	21	21
	25	17
	29	14

η Aquilae

	(— 2	6)
Sept.	7	23
	15	3
	22	7
	29	11
Oct.	6	15
	13	20
	20	24
	28	4

S Sagittae

	(—3	10)
Sept.	3	4
	11	14
	19	23
	28	8
Oct.	6	17
	15	3
	23	12

X Vulpeculæ

	(—2	1)
Sept.	5	19
	12	2
	18	10

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

X Vulpeculæ

	d	h
Sept.	24	18
Oct.	1	1
	7	9
	13	17
	20	0
	26	8

V Vulpeculae
Minimum

Sept.	2	13
Oct.	10	8

X Cygni

	(—6	19)
Sept.	2	1
	18	10
Oct.	4	19
	21	4

T Vulpeculae

	(—1	10)
Sept.	3	7
	7	17
	12	4
	16	14
	21	0
	25	11
	29	21
Oct.	4	8
	8	18
	13	5
	17	15
	22	2

T Vulpeculae

	d	h
Oct.	26	12
	30	23

WZ Cygni
Minimum

Sept.	1	4
	2	8
	3	12
	4	16
	5	20
	7	0
	8	4
	9	8
	10	12
	11	17
	12	21
	14	1
	15	5
	16	9
	17	13
	24	23
	27	3
	27	7
	28	11
	29	15
	30	19
	31	23

TX Cygni

Sept.	6	13
	21	7
Oct.	6	0
	20	18

VY Cygni

	d	h
	(—2	14)
Sept.	1	10
	9	7
	17	4
	25	0
Oct.	2	21
	10	18
	18	14
	26	11

VZ Cygni

	(—2	12)
	(—8	6)
Sept.	3	10
	8	10
	13	4
	18	4
	22	21
	27	21
Oct.	2	15
	7	15
	12	8
	17	8
	22	2
	27	2

δ Cephei

Sept.	4	19
	10	4
	15	13
	20	22
	26	7
Oct.	1	15
	7	0
	12	9

δ Cephei

	d	h
Oct.	17	18
	23	3
	28	11

V Lacertae

	(—0	17)
Sept.	1	17
	6	17
	11	17
	16	16
	21	16
	26	15
Oct.	1	15
	6	15
	11	14
	16	14
	21	13
	26	13
	31	13

X Lacertae
Minimum

Sept.	5	17
	11	4
	16	14
	22	1
	27	12
Oct.	2	22
	8	9
	13	19
	19	6
	26	16
	30	3

RS Cassiop.

	d	h
	(—1	19)
Sept.	3	21
	10	4
	16	11
	22	18
	29	1
Oct.	5	8
	11	15
	17	23
	24	6
	30	13

RV Cassiop.

	(—7	10)
Sept.	7	7
	19	11
Oct.	1	14
	13	18
	25	21

Y Lacertae

	(—1	10)
Sept.	4	18
	8	2
	13	9
	17	17
	22	0
	26	8
Oct.	1	15
	5	23
	10	7
	14	14
	18	22
	23	5
	27	13
	31	20

Approximate Magnitudes of Variable Stars on August 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R.A. 1900.		Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
T Androm.	0	17.2	+26	26	<11.8	T Urs. Maj.	12	31.8	+60	2	10.3 *i*
T Cassiop.		17.8	+55	14	8.5	R Virginis		33.4	+ 7	32	9.1*d*
R Androm.		18.8	+38	1	7.6 *i*	RS Urs. Maj.		34.4	+59	2	13.3 *i*
U Cassiop.		40.8	+47	43	12.6*d*	S Urs. Maj.		39.6	+61	38	8.3 *i*
W Cassiop.		49.0	+58	1	8.8 *i*	RU Virginis		42.2	+ 4	42	9.0*d*
S Cassiop.	1	12.3	+72	5	9.3*d*	U Virginis		46.0	+ 6	6	11.5*d*
Z Cephei	2	12.8	+81	13	9.5 *i*	RT Virginis		57.6	+ 5	43	9.0
T Camelop.	4	30.4	+65	57	11.5*d*	V Virginis	13	22.6	− 2	39	13.5 *i*
R Aurigae	5	9.2	+53	28	13.8*d*	T Urs.Min.		32.6	+73	56	12.8 *i*
S Camelop.		30.2	+68	45	9.0	R Can. Ven.		44.6	+40	2	12.0
R Lyncis		53.0	+55	28	13.8	Z Bootis	14	1.7	+13	59	12.1*d*
Y Draconis		31.1	+78	18	9.8*d*	U Urs. Min.		15.1	+67	15	10.4 *i*
R Urs. Maj.	10	37.6	+69	18	8.5 *i*	Z Virginis		5.0	—12	50	13.8*d*
R Comae	11	59.1	+19	20	8.5	S Bootis		19.5	+54	16	11.8*d*
T Virginis	12	9.5	− 5	29	11.3 *i*	RS Virginis		22.3	+ 5	8	13.0
SS Virginis		20.1	+ 1	19	7.5	V Bootis		25.7	+39	18	9.0 *i*
T Can. Ven.		25.2	+32	3	10.2*d*	R Camelop.		25.1	+84	17	12.0*d*
Y Virginis		28.7	− 3	52	12.3*d*	R Bootis		32.8	+27	10	7.0 *i*

Approximate Magnitudes of Variable Stars on Aug. 1, 1908—Con.

Name.	h	R. A. 1900. m	Decl. 1900. °	′	Magn.	Name.	h	R. A 1900 m	Decl. 1900 °		Magn.
V Librae	14	34.8	−17	14	13.0	RZ Herculis	18	32.7	+25	58	9.2 *i*
U Bootis		49.7	+18	6	11.5*d*	X Ophiuchi		33.6	+ 8	44	7.1
RT Librae	15	0.8	−18	21	10.2*d*	RY Lyrae		41.2	+34	34	<14.0
T Librae		5.0	−19	38	<14.0	RW Lyrae		42.1	+43	32	<14.0
Y Librae		6.4	− 5	38	9.0 *i*	RX Lyrae		50.4	+32	42	13.5 *i*
S Librae		15.6	−20	2	7.8 *i*	ST Sagittarii		55.9	−12	54	<14.0
S Serpentis		17.0	+14	40	8.8 *i*	Z Lyrae		56.0	+34	49	9.2 *i*
S Coronae		17.3	+31	44	11.6*d*	RT Lyrae		57.8	+37	22	12.8 *i*
RS Librae		18.5	−22	33	8.0	R Aquilae	19	1.6	+ 8	5	10.5 *i*
RU Librae		27.7	−14	59	9.6*d*	V Lyrae		5.2	+29	30	<13.8
X Librae		30.4	−20	50	14.0	RW Sagittarii		8.1	−19	2	8.7 *i*
S Urs. Min.		33.4	+78	58	8.8*d*	RX Sagittarii		8.7	−18	59	11.3*d*
U Librae		36.2	−20	52	13.7*d*	S Lyrae		9.1	+25	50	13.5
Z Librae		40.7	−20	49	13.0	RS Lyrae		9.3	+33	15	13.5 *i*
R Coronae		44.4	+28	28	6.1	RU Lyrae		9.1	+41	8	13.0 *i*
X Coronae		45.2	+36	35	9.8 *i*	U Draconis		9.9	+67	7	12.1*d*
R Serpentis		46.1	+15	26	8.0*d*	W Aquilae		10.0	− 7	13	9.8*d*
V Coronae		46.0	+39	52	11.2*d*	R Sagittarii		10.8	−19	29	7.3*d*
R Librae		47.9	−15	56	13.2*d*	T Sagittarii		10.5	−17	9	7.0
RR Librae		50.6	−18	1	13.5	RY Sagittarii		10.0	−33	42	7.5
Z Coronae		52.2	+29	32	10.8 *i*	S Sagittarii		13.6	−19	12	9.0 *i*
RZ Scorpii		58.6	−23	50	10.2 *i*	Z Sagittarii		13.8	−21	7	8.8
Z Scorpii	16	0.1	−21	28	9.5	TZ Cygni		13.4	−50	0	9.4*d*
R Herculis		1.7	+18	38	11.5*d*	U Lyrae		16.6	+37	42	12.2
RR Herculis		1.5	+50	46	8.0 *i*	T Sagittae		17.2	+17	28	9.9*d*
U Serpentis		2.5	+10	12	10.8*d*	TY Cygni		29.8	+28	6	10.5 *i*
X Scorpii		2.7	−21	16	10.2 *i*	RT Aquilae		33.3	+11	30	11.1*d*
W Scorpii		5.9	−19	53	10.3 *i*	R Cygni		34.1	+49	58	8.9*d*
RX Scorpii		5.9	−24	38	10.0 *i*	RV Aquilae		35.9	+ 9	42	10.7*d*
RU Herculis		6.0	+25	20	8.8 *i*	RT Cygni		40.8	+48	32	8.5*d*
R Scorpii		11.7	−22	42	13.5*d*	TU Cygni		43.3	+48	49	12.8
S Scorpii		11.7	−22	39	11.0 *i*	X Aquilae		46.5	+ 4	13	<13.5
W Coronae		11.8	+38	3	8.1	χ Cygni		46.7	+32	40	7.0*d*
W Ophiuchi		16.0	− 7	28	9.5 *i*	RR Aquilae		52.4	− 2	11	11.0*d*
V Ophiuchi		21.2	−12	12	11.0*d*	RS Aquilae		53.7	− 8	9	13.5
U Herculis		21.4	+19	7	8.0 *i*	Z Cygni		58.6	+49	46	11.7 *i*
Y Scorpii		23.8	−19	13	9.5 *i*	SY Aquilae	20	2.3	+12	39	9.0
SS Herculis		28.0	+ 7	3	11.8*d*	R Capricorni		5.7	−14	34	13.5
T Ophiuchi		28.0	−15	55	12.1*d*	S Aquilae		7.0	+15	19	10.8*d*
S Ophiuchi		28.5	−16	57	<13.5	RU Aquilae		8.0	+12	42	<12.0
W Herculis		31.7	+37	32	10.0 *i*	W Capricorni		8.6	−22	17	13.7*d*
R Draconis		32.4	+66	58	12.2*d*	Z Aquilae		9.8	− 6	27	9.8 *i*
RR Ophiuchi		43.2	−19	17	12.5	R Delphini		10.1	+ 8	47	7.5
S Herculis		47.4	+15	7	11.0 *i*	RT Capricorni		11.3	−21	38	7.8*d*
RV Herculis		56.8	+31	22	<14.0	WX Cygni		14.8	+37	8	11.6 *i*
R Ophiuchi	17	2.0	−15	58	12.0 *i*	U Cygni		16.5	+47	35	7.6*d*
RT Herculis		6.8	+27	11	14.0*d*	RW Cygni		25.2	+39	39	8.0
Z Ophiuchi		14.5	+ 1	37	9.9 *i*	RU Capricorni		26.7	−22	2	<13.3
RS Herculis		17.5	+23	1	8.3 *i*	ST Cygni		29.9	+54	38	8.8
RU Ophiuchi		28.1	+ 9	30	11.2 *i*	S Delphini		38.5	+16	44	8.7 *i*
RS Ophiuchi		44.8	− 6	40	11.4	T Delphini		40.7	+16	2	10.9*d*
RT Ophiuchi		51.8	+11	11	12.0	V Aquarii		41.8	+ 2	4	8.5
RY Herculis		55.4	+19	29	12.2 *i*	W Aquarii		41.2	− 4	27	10.6 *i*
V Draconis		56.3	+54	53	13.8	V Delphini		43.2	+18	58	9.0 *i*
T Herculis	18	5.3	+31	0	10.0*d*	T Aquarii		44.7	− 5	31	7.0 *i*
W Draconis		5.4	+65	56	12.0*d*	RZ Cygni		48.5	+46	59	9.0 *i*
X Draconis		6.8	+66	8	<12.0	R Vulpeculae		59.9	+23	26	11.2*d*
RY Ophiuchi		11.6	+ 3	40	9.0*d*	X Cephei	21	3.6	+82	40	10.5 *i*
W Lyrae		11.5	+36	38	7.8 *i*	Z Capricorni		5.0	−16	35	10.1
SV Herculis		22.3	+24	58	10.0 *i*	T Cephei		8.2	+68	5	6.7*d*
T Serpentis		23.9	+ 6	14	<13.8	RR Aquarii		9.8	− 3	19	9.1

Approximate Magnitudes of Variable Stars on Aug. 1, 1908—Con.

Name.	R. A. 1900.		Decl. 1900		Magn.	Name.	R. A. 1900.		Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
X Pegasi	21	16.3	+14	2	10.0	S Lacertae	22	24.6	+39	48	9.9*d*
S Cephei		36.5	+78	10	8.0*d*	R Lacertae		38.8	+41	51	9.5 *i*
RU Cygni		37.3	+53	52	7.6	RW Pegasi		59.2	+14	46	9.2
RR Pegasi		40.0	+24	33	10.0 *i*	R Pegasi	23	1.6	+10	0	11.8 *i*
V Pegasi		56.0	+ 5	38	10.8 *i*	V Cassiop.		7.4	+59	8	11.5*d*
RT Pegasi		59.8	+34	38	12.2*d*	R Cassiop.		53.3	+50	50	10.1 *i*
Y Pegasi	22	6.8	+13	52	9.9 *i*						

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whiteside, Taft and Harvard Observatories.

GENERAL NOTES.

It is requested that items of news regarding work in practical astronomy and kindred sciences be communicated to this journal frequently that all its readers may be benefited thereby.

Atmosphere Currents at Very High Altitudes is the title of a paper contributed by Professor C. C. Trowbridge from the Phenix Physical Laboratory of the University of New York. Although prepared nearly a year ago it reaches late reprints of the *Monthly Weather Review* of last year.

The Orbits and Velocity Curves of Spectroscopic Binaries. In March-April number of The Journal of the Royal Astronomical Society of Canada, Mr. J. M. Barr has given some interesting facts from a mathematical study of this theme derived from a list of thirty spectroscopic binaries. He touches on some important points that have already brought forth some criticism. He argues in a fair scientific spirit.

Proper Motion of Small Stars. In *Monthly Notices* for May, 1908, S. W. Burnham of Yerkes Observatory, Williams Bay, Wis., writes of "One of a very few examples I have been able to find, and perhaps the only one worth mentioning, is an isolated small star having a decided proper motion. This star 17 Lyræ (Σ 2461), is a faint star of the 12th magnitude." In his brief paper Mr. Burnham gives a diagram and a series of measures in his study of this star.

Comets 1825 I and 1886 III. The former of these comets has been under study by Hans Boegshold and the latter by Caroline E. Furness and Emma P. Waterman, in relation to which a definitive orbit has been found and published in the *Astronomische Nachrichten.* The work on the comet of 1886 III appears to be thorough and painstaking.

Variation of Latitude at Cincinnati. Professor J. G. Porter, Director of the Observatory at Cincinnati, has recently issued Publication No. 16 on the Variation of Latitude at Cincinnati for a period of seven years (1899-1907). In the conclusion of this paper he says: "The mean latitudes for the different years show considerable fluctuation as is seen from the following table:

Year	Mean Latitude ° ′ ″	Year	Mean Latitude ° ′ ″
1900	39 08 19.25	1903	39 08 19.38
1901	19.21	1904	19.36
1902	19.31	1905	19.21

This does not signify, of course, that the mean value of the latitude actually changes, but merely that the annual digressions are not symmetrical with reference to the mean position.

Taking the average value of the different latitudes of stars, we get a slightly more accordant series, but it is evident that entirely to eliminate the effect of the variation a still longer form of observation is necessary."

From the comparison of 12 groups of stars made up from an observing list of 192 stars the general mean of this series is

39° 08′ 19.″29 ∓ 0.″011

making the proper reduction to the center of the dome of the Observatory the latitude of the Cincinnati Observatory is found to be

39° 08′ 19 ″76 ± 0.″011.

General Index for the Astrophysical Journal. It will be of great interest to our readers to know that a general index of the *Astrophysical Journal*, by authors and by subjects, including volumes I to XXV, and dates from January, 1895, to June, 1907, has been completed by Storrs B. Barrett, Librarian of the Yerkes Observatory. This index has already been published. It makes a neat, handy volume of 133 pages, in size the same as the *Astrophysical Journal.* The compiler has been thoughtful in the arrangement and the choice of different kinds of type for subjects, names and other references. We do not see how the plan could have been better for the space used.

We also notice that the editors acknowledge the generous aid of Professor E. C. Pickering to the amount of one hundred dollars from the International Science Fund to aid in the publication of this index.

Professor Pickering has very kindly offered the same aid to POPULAR ASTRONOMY if we can see our way clear to publish a general index of 10 volumes of the *Sidereal Messenger*, 3 vols., of *Astronomy and Astro-Physics* and 16 volumes of POPULAR ASTRONOMY. We have not yet received encouragement enough to meet the considerable expense that will be incurred in this matter for us. We still have hope that we may some way be able to make a general index of our 29 volumes which is now very much needed for a ready reference of about 25 years of astronomical publication.

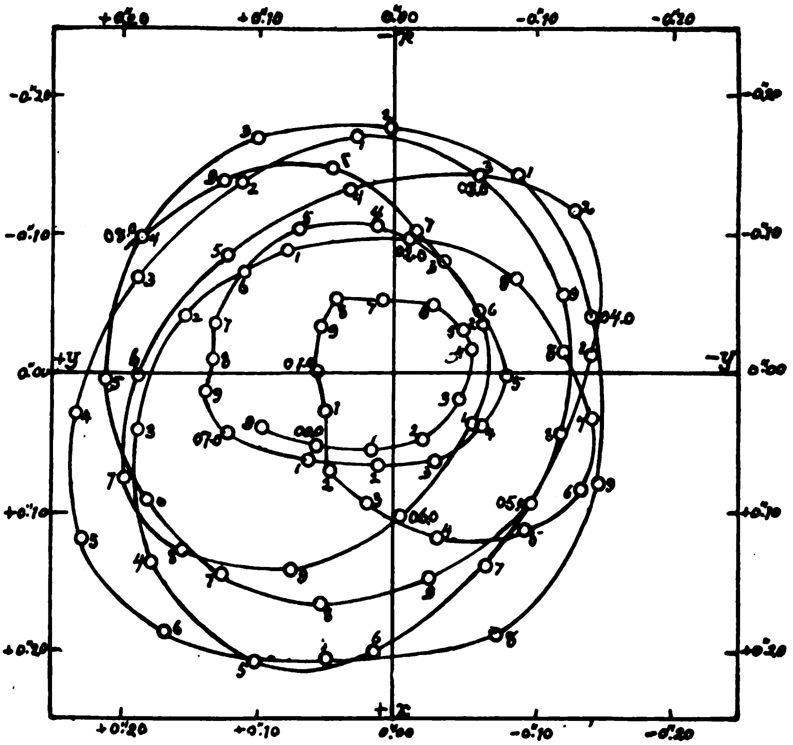
Partial Eclipse of the Sun. The partial eclipse of the Sun which occurred June 28, 1908, is not reported fully, but among the notes received are two photographs from which the half-tones of the frontispiece are made.

The pictures were taken by Mr. David E. Hadden at Alta, Iowa; the first was taken with a visual telescope, using enlarging lens and orthochromatic plates through a deep yellow ray screen, and the second about the time of greatest obscuration with fairly good definition.

The Variation of Latitude.—In A.N. 4253 Prof. Th. Albrecht of Potsdam, Germany, gives provisional results of the latitude observations at the six stations of the International Latitude Commission for the year 1907.0 to 1908.0. The following table gives the deviations of the observed latitudes from the adopted mean latitudes of the stations for each tenth of the year.

$\phi - \phi_0$

	Mizusawa	Tschardjui	Carloforte	Gaithersburg	Cincinnati	Ukiah
1907.0	−0″.08	−0″.09	+0″.09	+0″.12	+0″.15	+0″.13
.1	−0.11	−0.07	+0.07	+0.06	0.00	+0.04
.2	−0.12	−0.04	+0.04	0.00	−0.10	−0.03
.3	−0.11	−0.02	+0.02	−0.07	−0.14	−0.09
.4	−0.07	+0.01	−0.02	−0.12	−0.15	−0.12
.5	−0.01	+0.04	--0.05	−0.13	−0.12	−0.12
.6	+0.05	+0.03	−0.07	−0.09	−0.07	−0.06
.7	+0.11	−0.02	−0.08	−0.02	−0.01	+0.05
.8	+0.13	−0.08	−0.10	+0.05	+0.06	+0.16
.9	+0.06	−0.14	−0.17	+0.12	+0.13	+0.23
1908.0	−0.04	−0.19	−0.11	+0.18	+0.16	+0.24



Upon the accompanying chart the position of the north pole of the earth, relative to its mean position, as determined by Prof. Albrecht from the combination of the results from the six stations, is plotted for the eight years 1899.9 to 1908.0. The smoothness of the curve shows the remarkable accuracy of the observations as well as the systematic but complicated character of this minute movement of the pole.

The Density of the Algol Variables.—In A.N. 4250 Mr. F. Ristenpart obtains estimates of the densities of several of the Algol type variable stars, assuming them to be binary stars with relatively dark companions. He uses the formula

$$\delta = \frac{a^3 . U^2}{A^3 . u^2 (1+\kappa^3)}$$

in which δ represents the average density of the two bodies, a and A the semimajor axes of the orbits of the companion star and of the earth respectively, expressed in units "of the brighter star in relation to the Sun," u and U the periods of revolution of the companion star and of the earth in days, κ the semidiameter of the companion, that of the brighter star being taken as 1. The density of the Sun is also taken as 1. The results and some of the data used are given for ten variables in the accompanying table. A remarkable feature of these results appears in the small density of these stars as compared with the Sun. They seem to indicate also that the longer the period the less the density of the system.

In the case of the stars Z Persei and Z Draconis the elements were computed on the two hypotheses, that the occulting star is smaller and that it is larger than the bright star. The density comes out remarkably close to the same on both hypotheses.

Name	Period	Brightness Normal m	Minimum m	Duration of Light change	Minimum
VW Cygni	8.4306	10.32	12.26	20.0	6.7
SY Cygni	6.0059	11.06	12.98	19.0	2.2
W Delphini	4.8061	9.64	11.90	17.2	1.2
SW Cygni	4.5729	9.42	11.50	11.8	2.2
UW Cygni	3.4508	10.54	12.70	10.5	1.3
U Sagittae	3.3806	6.65	8.96	13.1	1.4
WW Cygni	3.3177	10.00	12.91	11.8	1.0
Z Persei	3.0564	10.00	12.38	11.1	1.3
RW Tauri	2.7689	7.87	11.54	7.9	1.3
Z Draconis	1.3574	10.40	12.52	4.7	0.2

Name	κ = Radius of fainter Star	a = semiaxis of orbit	δ = Density (Sun = 1)
VW Cygni	2.01	9.86	1.020 = 1/50
SY Cygni	0.91	4.77	0.023 = 1/44
W Delphini	0.94	4.29	0.025 = 1/40
SW Cygni	1.46	7.42	0.064 = 1/16
UW Cygni	1.28	5.89	0.075 = 1/13
U Sagittae	0.94	4.01	0.041 = 1/24
WW Cygni	1.19	4.87	0.052 = 1/19
Z Persei	0.94 1.27	4.27 4.95	0.061 0.057 = 1/17
RW Tauri	1.39	6.57	0.136 = 1/7
Z Draconis	1.09 0.93	4.77 4.40	0.346 0.345 = 1/3

Seen at Toronto. August 3rd., 1908, at 8 p. m. the sky presented an appearance which I never observed before. Rising from the western horizon and traversing about ⅓ of the sky were a number of brightly colored bands, which I shall attempt to describe. The southerly one was very wide, and covered the entire southwest part of the sky. It was a deep blue color, and was followed by a band of red, very wide also, which joined it to the north. These were followed by five narrow bands of red and blue alternating, after which came a wide red band, then a narrow blue and a narrow red band, then one of blue, very wide, and lastly a red band, also wide, and extending to the northern horizon. These bands were narrow towards the western horizon, which seemed to be their radiating point, and they widened as they rose towards the zenith. A small portion of the sky just where the Sun had gone down was quite red, the blue bands having faded into the red at the horizon. My observation of them lasted for perhaps ten minutes, and they seemed to undergo no noticeable change during that time. A great many other persons saw them as well, for the display occurred while returning from a holiday excursion. When at half-past eight I had an opportunity again of seeing the sky, the display had vanished

On August 8, 1908, I was observing the planet Saturn with a four inch refractor. Titan was visible with all powers from 50 to 200, and another satellite,—possibly Rhea,—was visible with power of 200. It lay midway between Titan and the planet. The crape ring was distinctly visible, the outer rings also were very interesting. They are tilted quite noticeably. The planet promises to be a very interesting object this summer,—and its position for observation will be excellent.

I am making a 9½ inch reflector, which is now nearly completed. On the 8th of August, 1908, while testing the instrument I turned the still unsilvered glass upon the Moon, and could observe with powers of 100 and 200, details distinctly visible on its surface. I used power of 400 also, but the illumination was much reduced. Still even with it, detail was distinct. When one remembers that only about 2 per cent of the light falling on an unsilvered glass surface is reflected, the result seems encouraging. The focal length of the mirror is 80 inches, and I have done all the work connected with its construction and almost all the making of the mounting and tube myself during spare moments taken from a professional life.

ALBERT R. J. F. HASSARD, B. C. L.,
9 North St., Toronto, Ontario, Canada.
August 10, 1908.

Partial Solar Eclipse, June 28, 1908.—Observations at Ladd Observatory, Providence, R. I., observers Winslow Upton and John Edwards.

Sky generally overcast with light clouds of varying density. Definition unusually good, the roughness of the edge of the Moon showing plainly on the Sun.

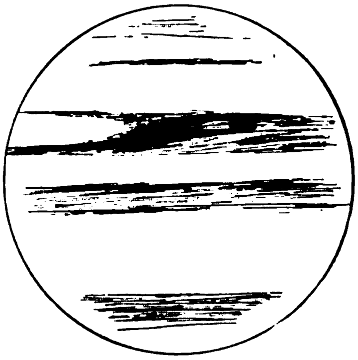
The first contact was doubtfully observed by W. U. with helioscope attached to 12-inch equatorial, the aperture reduced to 3 inches, power 100. The contact was suspected at 9h. 50m. 16sec. corrected Eastern time; for 19 sec. clouds completely obscured the image; at 9h. 50m. 35sec. when seen again, the notching was well marked. Estimated time is not earlier than 9h. 50m. 16s., not later than 9h. 50m. 25s.

The last contact was well observed by W. U. at 12-inch equatorial as above but with power 180, and by J. E. at 4-inch finder, power 40. Both observers obtained 12h. 59m. 6s. corrected eastern time.

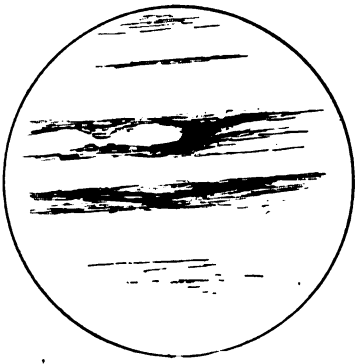
The calculated times of contact were 9h. 50m. 32s. and 12h. 59m. 22s. from data of American Ephemeris. Correction to calculated times is therefore —16s.

The obscuring of the largest sun-spot upon the Sun was observed between 10h. 55m. 8s. and 10h. 57m. 16s. The limb of the Moon seemed to be bent outward at southern penumbra and hollowed inward at northern penumbra. The latter was more marked after the whole umbra was concealed, but the former was then less evident. These apparent distortions are likely to be due to the irregularities of the Moon's limb, especially as the most prominent distortion persisted after the whole spot was concealed.

WINSLOW UPTON.



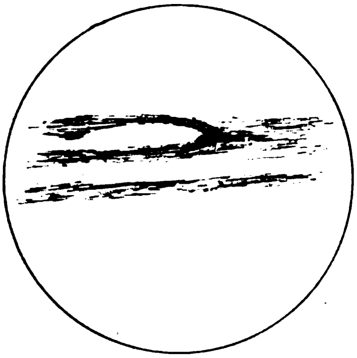
Jan. 25, 9:30.



Feb. 20, 9:30.

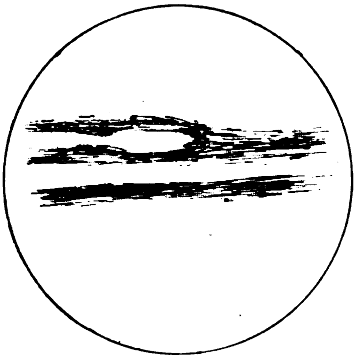
Jupiter Observations. The long oval opening in the great southern belt of Jupiter is a marked feature on several of the drawings made by the writer during the recent opposition.

Feb. 29, 8:30.



Mch. 3, 9:15.

It is much more conspicuous and extended than at the opposition of December 1906, and shows a constriction in the oval which in some cases



Apr. 1, 8:30.

Apr. 6, 9:30.

gives the outline almost the form of the curve called the lemniscate. This form was best shown on the drawings of February 20, March 3, and April 1.

An eclipse or occultation of satellite I by satellite II was witnessed early in the evening February 18; of II by III March 5; and a partial eclipse of II by III May 1.
S. F. WHITING.

Whitin Observatory, Wellesley College,
Wellesley, Mass.

Meteorite.—I have the following record of the falling of a meteorite on Saturday evening, October 5, 1907, at 10 o'clock, P. M.

It seems to have been first observed by people in Maryland and southern Lancaster County. The first particular notice taken of it was at Lancaster, Pennsylvania. When first seen it appeared to be a red spot which gradually became larger until it was about the size of a man's head. The light which it emitted when near was of a greenish-blue color. Shortly after the meteorite was seen a noise like an explosion was heard. Whether the meteorite was responsible for said noise, or whether it originated from some other source, cannot be ascertained. Persons residing in the southeastern section of the city said that their houses were shaken, and the same thing was reported by the firemen of No. 5 engine house. In the northeastern section of the city it appeared to be only a few feet above the two-story houses, and was leaving a trail like that of a sky rocket. Its course seemed to be from south to north.

Neffsville, a small village about 4 miles north of Lancaster, has a report that a man was driving along the turnpike with a 2-horse team, and suddenly he was startled by a roaring, hissing noise, like that of a sky rocket, only on a much larger scale. The horses, as well as the man, were scared by the noise and light caused by the meteorite. He stated that he distinctly heard a dull thud upon the turnpike a few feet ahead of the team as though a piece of some heavy object had fallen to the earth.

Lititz and Warwick, about 8 miles north of Lancaster, also report that the inhabitants were startled by the terrifying noise and dazzling light caused by this meteorite. At Warwick, people rushed out of their houses, thinking that the end of the world was at hand, and some even stated that their houses were shaken. By the time it reached the above place it appeared to be composed of three parts which rushed through the sky quite close together. When last seen it appeared to have fallen on the Elizabeth hills.

It was also reported that it fell to the earth in Center or Clearfield counties, Pennsylvania, but it is doubtful whether this is correct. It may have been seen in northern Pennsylvania and Ohio, and southern New York as stated in your issue of November 1907, and that its falling to the earth in the above counties may be merely a delusion.

I remember very distinctly the noise caused by the meteorite's flight or explosion. It was like the roar of a terrific explosion. I have spoken with a number of persons who saw and heard the meteorite, and all seem to give different descriptions of the heavenly body, but all who saw it say that the sight was awe-inspiring, and one long to be remembered. The night was perfectly clear and moonless, and this, no doubt, accounts for its dazzling light and splendor.

I have made it a rule to make observations and keep records of the interesting phenomena that take place in the heavens, but I have no record of the meteorite which is supposed to have passed through this section on Wednesday night, October 2, 1907, and I think that probably the dates may be confused.

A Venus Observation.—On May 24, 1908, I observed Venus with my four-inch refractor, using powers 100 and 200. I began observations as soon as I could pick up Venus in the western sky. About one-third of the disk of the planet seemed to be illuminated. By consulting an ephemeris, I observed that the actual portion of the disk which was illuminated then was .318. At all times the irradiation was such as to render detail in observation quite impossible. There, however. did seem to be distinctly perceptible variation in the brightness of the planet, a gradual shading from the portion nearest the Sun towards the terminator being noticeable. At three points about equally separated from each other, lying along the terminator, for about one-half of its central extent, the shading seemed to be more concentrated. The terminator had a rough or irregular edge, which was very different from the smoothness of the circular edge next to the Sun. It is true that the dazzling was very great, and great uncertainty at all times prevailed regarding the edges, but there was no mistaking the characteristics I have mentioned. For, on leaving the instrument for a few moments, and returning, without having immediately in memory the variations in shading, they at once forced themselves on the observation. The central portion of the terminator was of a grayish color. At the extremities of the terminator a change in its direction towards the planet's poles was visible. On the evening of June 5, the appearance of the planet in the telescope made an interesting object of comparison with the Moon, then about four days old, and to which it bore considerable resemblance, the two objects being not far apart in the sky.

I find the companion of Polaris a much easier object with the telescope during moonlit nights than when the sky is dark.

ALBERT R. J. F. HASSARD, B. C. L.

Toronto, Canada.

Ephemeris of Halleys' Comet.

In the *Monthly Notices* of R. A. S. for March 1908, Messrs. Cowell and Crommelin have given provisional elements of a new orbit of Halley's comet for its return to perihelion in 1910. In the calculation of these elements, nearly all the perturbations have been included except those of the plane of the orbit and which affect the node and inclination. In the case of these last two elements, the corresponding elements of Pontecoulant's final orbit have been provisionally adopted pending the calculation of the perturbations of these elements. Any subsequent change, however will be so small that an ephemeris for finding purposes has been calcuated by them with the co-operation of Dr. Smart, beginning Oct. 1, 1908 and extending to July 13, 1910. As it is possible, however, that the comet might be found before the first of October of the present year, I have computed an ephemeris from the same elements for intervals of ten days, extending through August and September. As will be seen in the table below, the comet will be over two hours from the Sun on the first of August. This angular distance steadily increases so that by the last of the month the comet will be about four hours from the Sun and by the last of September, about six hours.

Date.	Halley's Comet				Sun	
	R. A.	Dec.	Millions of miles from		R. A.	Dec.
			Sun	Earth		
1908 Aug. 2	6^h 34^m 21^s	+ 13′ 27′.9	654	731	8^h 49^m	+ 17° 49′
12	6 37 53	+ 13 20.5	647	715	9 27	+ 15 2
22	6 41 0	+ 13 11.4	639	696	10 4	+ 11 50
Sept. 1	6 43 37	+ 13 0.9	632	676	10 41	+ 8 20
11	6 45 33	+ 12 49.2	625	654	11 17	+ 4 37
21	6 46 41	+ 12 36.7	617	632	11 53	+ 0 46
Oct. 1	6 46 54	+ 12 23.9	610	608	12 29	− 3 8

O. C. Wendell.

Harvard College Observatory,
Cambridge, Mass.

An Astronomical Expedition to Argentina.

The Department of Meridian Astrometry of the Carnegie Institution, in charge of Professor Lewis Boss of the Dudley Observatory at Albany, N. Y., where the work of the department is carried on, is dispatching an expedition to the Argentine Republic to establish a branch observatory there. This observatory will be established at San Luis about 500 miles west from Buenos Aires. This town of about 10,000 inhabitants is located near the eastern edge of the Andean plateau at an elevation of about 2,500 feet. It is reported to have a fine climate with remarkably clear skies.

The new observing station consists of the necessary observing structures, and temporary barracks for office rooms and quarters for the staff. The principal instrument will be the Olcott Meridian Circle of the Dudley Observatory. This instrument will be set up in its new location for the purpose of making reciprocal observatious upon stars already observed at Albany, together with observations upon all stars from south declination to the south pole that are brighter than the seventh magnitude, or which are included in Lacaille's extensive survey of the southern stars made at the Cape of Good Hope in 1750. It is thought that this new scheme of making reciprocal observations on the same stars, with the same instrument, alternately used in the two hemispheres will present peculiar advantages in point of accuracy in the systematic sense. To reach this accuracy has long been the problem of fundamental work in astronomy. It is estimated that the work of observation in Argentina will last three or four years.

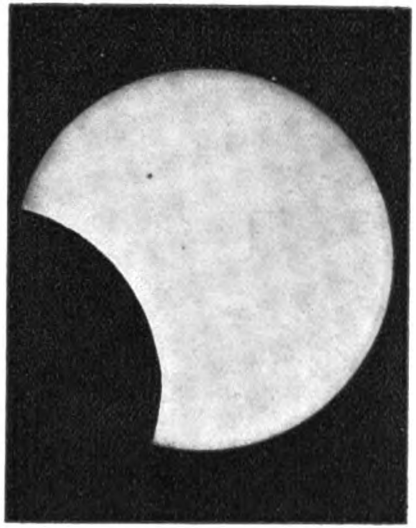
The object of these observations is to gather material for facilitating the construction of a general catalogue of about 25,000 stars, in which will be contained accurately computed positions and motions of all the stars included in it.

The department has already completed for publication a general catalogue of 6,188 stars, including all the most accurately observed stars and all from the North to the South pole of the heavens that are visible to the naked eye. This work has already resulted in interesting conclusions in reference to star-streams, the solar motion in space, and other stellar problems.

The preliminary expedition to establish the new observing station sailed from Brooklyn for Buenos Aires, August 20, on the steamship Velasquez. Accompanying Professor Boss, is Professor Richard H. Tucker, of the Lick Observatory, well known for his work in observation with the Meridian Circle of the Lick Observatory. He will superintend the construction of piers and buildings for the new observatory, and he will be placed in charge of the observations after the station shall be ready for operation. Mr. Varnum, for many years an assistant at the Dudley Observatory, is also a member of the party. Later on the remainder of the staff, which in all will consist of eight persons will be sent to the new observatory when it shall be ready for work.

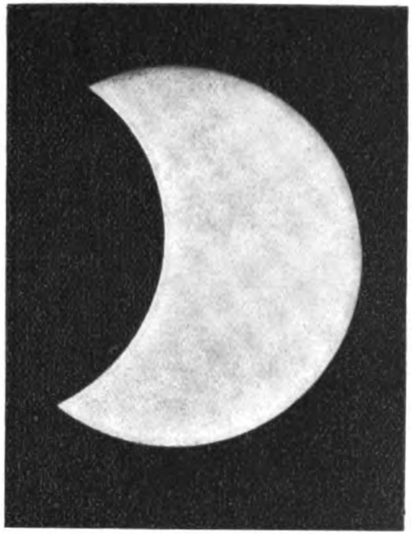
This undertaking has met with cordial recognition from Mr. Epifanio Protela, Argentine minister to the United States, and from other representatives of the Argentine Government, which in the most liberal and enlightened spirit has extended every assistance and courtesy. (*Science*, Aug. 21, 1908)

PLATE XXII



PARTIAL ECLIPSE OF THE SUN

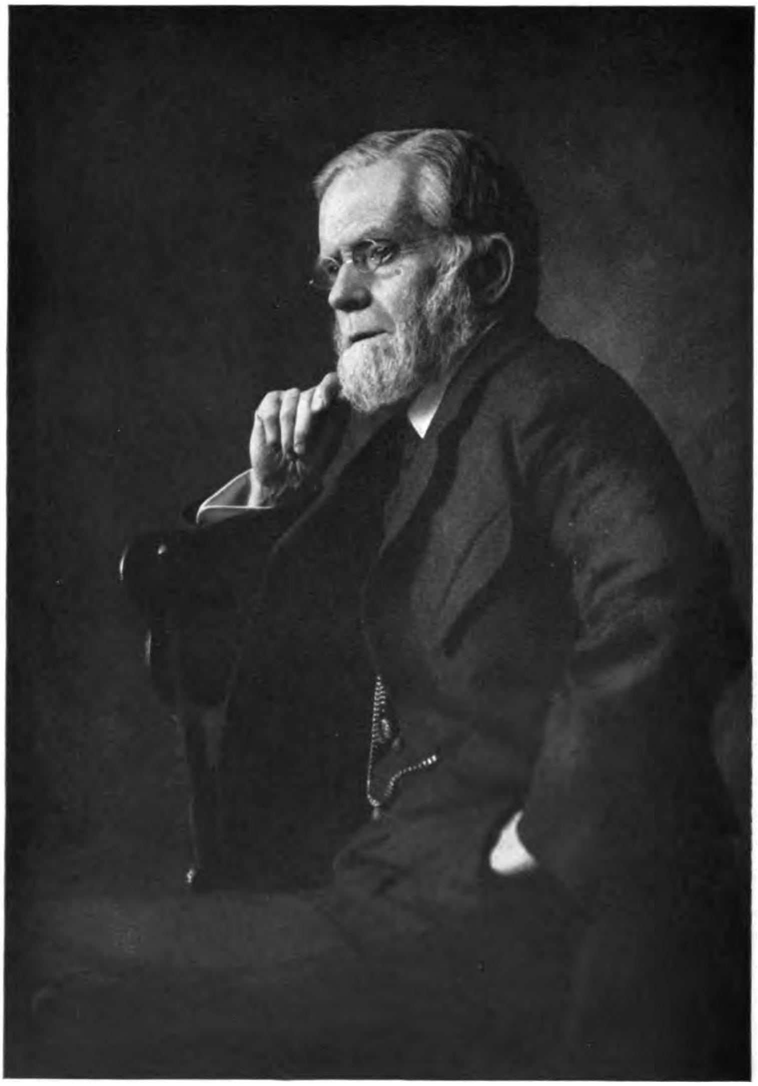
Photographed by David E. Hadden, $8^h\ 56^m\ 48^s$, June 28, 1908, at Alta, Iowa.



PARTIAL ECLIPSE OF THE SUN

Photographed by David E. Hadden, $9^h\ 35^m\ 48^s$, June 28, 1908, at Alta, Iowa.

PLATE XXIII.



THOMAS DAVIS SIMONTON,
1831-1907.

Popular Astronomy.

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ON AN INFINITE UNIVERSE.*

G. W. HOUGH.

In 1720 Halley published a paper in the *The Philosophical Transactions* in which he stated, that since the light diminished at a more rapid rate than the interval between the stars, space would not be equally illuminated if the stars were infinite in number. And secondly, that at a certain distance the stars became invisible.

On the contrary, Chesaux, a Swiss astronomer and speculative writer, asserted "that the light of an infinite number of shining bodies would cause the heavens to appear everywhere equally illuminated with the Sun." And on this ground he affirmed that the universe must be finite unless light is lost in space.

The assertion of Chesaux was apparently regarded as an axiom, and has continued to the present day as the generally accepted doctrine in Astronomy.

I am not informed on what grounds Chesaux based his statement but a century later Olbers gave his support to the idea in a mathematical paper, published in 1826.

The visible universe is composed of a mass of heterogeneous matter, having different degrees of luminosity. The amount of dark matter in space is not definitely known, but it is perhaps the general opinion that it may be equal to that which emits light.

The light emitted from the bodies in space may be said to vary in intensity between zero and that given by the surface of our Sun or even greater. In order, therefore, that the heavens should appear to be of uniform brightness, the light everywhere must be equal in intensity to that at the surface of the most brilliant star.

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* Read before the Astronomical and Astrophysical Society at Put-in-Bay, Ohio, August, 1908.

The statement by Chesaux "equally illuminated with the Sun", I understand, means that the heavens everywhere would appear as bright as the surface of the Sun—viz: a light sheet of the intensity of the Sun's surface, as seen from the Earth.

That the light given by an infinite universe should be exactly equal to the light of our Sun at just 93 millions of miles from that body seems to me so improbable that there is good ground to think that some fallacy is involved in the argument which led to such a conclusion.

The illumination of the heavens by the Sun, or a light sheet, as viewed from the Earth, is not constant during the year, and varies very materially in the solar system.

To an eye placed on Mercury there would be six times as much light and on Neptune only $\frac{1}{900}$ of the light as at the Earth. And we may imagine a planet at about $\frac{1}{11}$ of the distance to the nearest fixed star, where the illumination of the heavens by our Sun would be the same as that furnished by the stars. And we may further imagine an eye placed in space half way to the nearest fixed star where the light would always be the same, and our Sun would appear as a bright star. In other words, the illumination of the heavens by our Sun, or any other sun, would depend on the distance of the eye from the illuminating body and the nature of the illuminating surface.

To an eye placed on a planet revolving around a red star, the heavens would be illuminated with red light.

In the early part of the last century, in order to overcome the objections to the theory of an infinite universe, Struve formulated a theory of the extinction of light passing through space, based on the observations of Sir William Herschel. Sir John Herschel has shown that his father's observations had been misinterpreted. Struve's theory is sometimes quoted but has not been generally accepted by astronomers.

Now if there were an infinite number of suns, there would be an infinite amount of light, but this infinite amount of light would be spread through an infinite volume of space.

From this proposition one cannot determine the intensity of the illumination of space, or whether it is equal everywhere. The illumination would obviously be a function of the brightness of the shining bodies and the interval which separated them.

Since we cannot reason directly about infinity, we may perhaps get some information by starting with a finite universe and moving towards infinity.

Suppose we start our universe with a small number, viz: four stars, and for the sake of simplicity, regard them equal in brightness. Between these four stars there will be a point of minimum illumination at the point where sums of the squares of the distances is a maximum.

As other stars are added this point of minimum illumination will be continually shifted. When we reach infinity, however, there will be no center of minimum illumination and this is all we can infer directly regarding infinity.

Returning now to our four stars. I assume that the illumination at the minimum point is immeasurably less than at the surface of any particular star and this is true whatever the number of stars, even if they be infinite.

If the light at the surface of a star is taken as unity, the light received from any other star at that point, would be $\frac{1}{d^2}$. The light received at our initial point from an infinite number of stars, whose distance is continually increasing, would therefore be the sum of an infinite decreasing series, $\frac{1}{a^2} + \frac{1}{b^2} +$ etc., and the sum of this infinite series can never be equal to unity, provided the ratio between successive terms is greater than the limiting value. If this be true, each star would retain its autonomy and remain a star, and hence space would not be equally illuminated.

From what we know regarding the distance of the stars, the limiting value in the above infinite series is immeasurably less than the real value.

The total light of the visible heavens is stated to be about $\frac{1}{27,000,000}$ of the light of the Sun at 93 millions of miles from that luminary. Assuming that the law of the inverse square of the distance is true to within ½ a million miles of the Sun's surface, and for the remaining distance varies directly as the distance, the ratio of the light at one mile from the surface of the Sun to the rest of the universe is as 1 to 10^{-17}. Referred to the same point, the first term in our infinite series is approximately 10^{-20} and the last term zero.

If we assume that 200 millions of stars are within our reach by means of the photographic plate, it follows that the sum of the first 200 million terms in our infinite series is equal only to

10^{-17} which is strong preservative evidence that the total sum of the above series would never equal unity.

If we take into account the opaque matter in space, every alternate term in the above series would be zero, and besides, we would have an equal number of negative terms, the opaque matter intercepting the light passing from one region of space to another.

That the stars would remain individual stars, however great their number, may be inferred in a simpler manner.

An infinite universe may be made up of an infinite number of finite parts. Now if the stars retain their autonomy and remain separate stars in each of these parts, the same must be true when the parts are joined together to form a unit, since no quantity can be greater than the sum of its parts. Or the proposition may be stated in this way:

In a limited universe, no one would call in question the assertion that each star would retain its autonomy and remain a star, however great the number of the stars and however great the distance. Now if this condition prevailed until we reached the finite limit, say for illustration, to within one mile of infinity, it would be unreasonable to conclude that on the completion of the last mile all the stars would be swallowed up and obliterated in a flood of light

Second. Is Halley's idea regarding the invisibility of stars at a certain distance in any degree confirmed by modern science? The human eye utilizes as light but in a small fraction of the light vibrations in the solar spectrum.

The photographic plate, however, can record, in both ends of the spectrum, vibrations which are no longer light to the human eye. It is said that we can see about 100 millions of stars with our present optical appliances, and photograph about 100 millions more which we cannot see.

And I presume everyone will agree to the proposition that there are stars so remote that the vibrations in the ether make no impression on the photographic plate.

The question naturally arises as to whether these remote stars add to the illumination of the space in which the observations are made.

Some years ago, I determined the actual time required for a standard candle to make a legible impression on various brands of photographic plates. I find the light of a stellar image impressed on a plate after four hours' exposure to be equal to $\frac{1}{3{,}000{,}000}$ of a standard candle at one foot distance.

And taking into account the difference of actinism between white and yellow light, we may conclude that it would require more than 30 millions of stars, requiring four hours' exposure, to be equal to one candle at one foot distance.

And since it is by no means certain that these feeble light waves are light to the human eye, I think we have strong grounds for assumption that the remote stars add but an infinitesimal amount to the illumination of the heavens.

The arguments in support of a finite universe, advanced by Olbers and more recently by Seeliger, 1895, in a paper on gravity, are based on certain assumptions and hence are necessarily of a speculative character.

In the article on Astronomy in the Encyclopedia Brittanica, the writer, after expressing his opinion that the universe is limited, offers the following argument to prove that it is finite. He assumes that there are three times as many stars of each succeeding magnitude than of the previous one—viz: three times as many 7ths as 6ths, etc., down to the 10th or 11th magnitude. Since the light between consecutive magnitudes is diminished 2.5 times and the number of stars increased by three, there would be an increase of light for each succeeding magnitude, which, if continued to infinity, would afford "a flood of light equal to the Sun."

If the universe was constructed on this plan, it follows from this increasing infinite series that the farther away the stars are removed from us the more light we would receive, which is contrary to reason and leads to an absurdity.

An infinite amount of light coming from an infinite distance would be zero. And hence the last term in the above increasing infinite series should be zero instead of the greatest possible.

However, the subject needs no discussion, since the researches of Kapteyn, on the distribution of stars in space, shows that the above assumption of a mean ratio of three was erroneous, as he finds a decrease in star density at the 9th magnitude. Hence the argument for a flood of light equal to the Sun becomes zero.

Kapteyn, I presume accepts the doctrine of a finite universe as would appear from the following consideration. He says the star density becomes less beyond the 9th magnitude, but as yet, little is known regarding the stellar distribution beyond the 12th magnitude. However, he makes the suggestion that the star density may become zero at a distance of 30,000 light years, which of course would be the limit of the universe.

Now with all due respect to the high authorities above quoted, I would remark that if these are the best arguments which can be advanced in proof of a finite universe, the theory rests on a very weak foundation.

Since space is infinite in extent, it would be unreasonable to suppose that only a small portion was utilized to hold matter and all the rest left blank.

In conclusion, to my mind, the idea of a limited universe is of the same nature as entertained by early man, who on a flat earth, thought the sea-horizon was the limit of creation.

Evanston, Ill.

THOMAS DAVIS SIMONTON.

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

Among all the natural sciences there is, probably, none that demands—and receives—from its students as much earnest and unselfish devotion as does astronomy in its divers branches, be the devotee a professional, practical astronomer holding an official and pecuniarily remunerated position as an instrumental worker in a well-equipped observatory; a theoretical astronomer laboring in the co-ordinate field of mathematical research in the profession, on the one hand, or on the other hand, an amateur—using that word in its strict sense—a true lover of the science, imbued with the joy of learning and of the persistent search for Truth for its own sake, laboring not only without pecuniary recompense but often at considerable personal expenditure of time and money, and whose only reward is the indescribable intellectual satisfaction—which surpasses the understanding of the major portion of mankind—that he derives from his studies, and the keen pleasure that he feels in imparting to others, either by tongue or pen, what he himself has learned, and beholding awakened in them a kindred enthusiam and love for the noble science.

To the latter order—although, had the fates so directed his course, his natural aptitude would have led him to distinction in the former—belonged the subject of this biographical sketch,

—Thomas Davis Simonton—who, at the city of St. Paul, Minnesota, on the 14th of last December, when nearly seven years above the scriptural limit of age, passed behind the veil that stretcheth beyond the stars, and is impenetrable by mortal vision, he having been a pioneer of that city not only in point of residence but also in its intellectual, civic and religious life —his work in these several fields having been characteristically unobtrusive, but none the less potent for good.

In both direct line and collateral connections Dr. Simonton—by which title he was generally known in this community—was of the best blood of the land, tracing his ancestry to that sturdy, strong-minded race, the Scotch-Irish, many of whom were early settlers in the state of Pennsylvania, his paternal grandfather —William Simonton—having come thither, as a boy, from the county Antrim, Ireland, in the the year 1765, at the solicitation of an uncle of the same surname, who had preceded him to this country. His was also a scholarly family that has furnished many members distinguished in the church, the law, medicine and the teaching profession and the halls of legislation, his father William Simonton, M. D., having been for many years the leading practicing physician in Dauphin County, Pennsylvania, and the region surrounding Harrisburg; County Auditor, 1823—1826 and—as a Whig—a representative in the 26th and 27th congresses, from 1838 to 1842. His maternal grandfather, an uncle on his father's side, two of his own brothers, and other relatives were ministers of the Presbyterian church—his youngest brother, now dead, having been a missionary of that denomination in Brazil. Another brother, John W. Simonton—who died in 1903 —was an eminent jurist and for years a presiding judge of the 12th Judicial District of Pennsylvania, at Harrisburg, while a fourth brother—James W.—was a professor of mathematics and and also modern languages and literature in Washington and Jefferson College, and is now a *professor emeritus* of that old and well-known institution of learning in western Pennsylvania. With such ancestry and immediate environment, the refined taste, intellectual bent, religious temperament and strong character that distinguished Thomas D.,—the fourth born of the five brothers—were both logical and natural sequences. He was born, January 25, 1831, on his father's farm in West Hanover township, Dauphin County, Pennsylvania, a dozen miles or so northeast of Harrisburg, and his boyhood was spent, as he himself has recorded, in the usual manner of country boys of those days: "Some work, more play in summer, and attendance upon the district school in winter"—he also having been given for several years, a taste of real farm life, upon the family estate owned by his father, and operated under the direction of the latter. In the year 1847 the family removed to Harrisburg where, at the age of sixteen, the subject of this sketch entered upon an academical course, his studies apparently having been along classical lines, his reading including Horace in Latin, and Homer in Greek, and subsequently he spent a winter teaching school in central Pennsylvania. He afterwards received preliminary instruction in the profession that he was to follow in after life, under Dr. James Fleming a dental surgeon of Harrisburg, and for several years thereafter he pursued a thorough course of training in the Baltimore College of Dental Surgery from which he graduated in the year 1852 with the degree of D. D. S., practicing his profession in Harrisburg during the next five years. His particular interest in astronomical science—in so far as the writer has been able to learn by conversation with him—seems to have been awakened when he was quite young, and the great meteoric shower (Leonids) which startled the world on November 13 and 14, 1833, when he was only about three years old, was probably instrumental in this awakening, as he has often narrated to the writer his mother's vivid description of that wonderful phenomenon, famous in the annals of astronomy, and of which she had been a deeply interested and discriminating eye-witness. He often discussed with me, and others, certain scientific questions brought out by the details of this narration, in regard to peculiarities of the phenomenon, which had impressed him, and from which were drawn some apparently well-founded conclusions which, I think, he has set forth in some publication. One of the observed facts, which seemed to him very significant, was that in that copious shower of fiery, incandescent particles of matter some of the meteors were distinctly seen by the narrator to pass directly between the eye and buildings at a little distance away, belonging to the farm, and they caused no noise or sensible disturbance, and were not afterward upon evidence upon the ground toward which they had apparently fallen, the logical conclusion being that these meteors must have been particles of matter so extremely minute that they were probably dissipated as cosmic-dust just before reaching the surface of the earth, or upon reaching it, a conclusion perfectly in concordance with the best scientific opinion as to the small mass and dimensions of the components of all the known meteoric-showers—particularly of the Leonids

—and their particularly complete disintegration, or pulverization, as matter melted by the heat resulting from the friction of these particles, moving with a relative rate of nearly 41 miles per second—with the denser portions of the atmosphere near the surface of the earth.

He was thoroughly conversant with the works of the great German naturalist Alexander von Humboldt, and particularly with his observations and discussions of the aforesaid remarkable celestial phenomenon which seems to have been the *primum mobile* in the development of Dr. Simonton's deep interest in "meteoric astronomy" and all things pertaining to it, which he manifested during the greater portion of his long life, and which led him, when occasion demanded, to write in the daily press and other publications, authoritatively, interestingly and instructively concerning this subject, for the information of the reading public.

But the first evidence of his well-defined interest in, and extensive knowledge of, general astronomy and correlated subjects, was manifested in the year 1857 when he published (Philadelphia, Lindsay & Blakiston, 1857) an admirable translation into English from the German, of a work that had for several years, attracted much attention in religio-scientific circles both in this country and in Europe, the title of this book being "The Bible and Astronomy," it embodying an exposition of biblical cosmology and its relation to natural science, its author being an eminent scholar and theologian, John Henry Kurtz, D. D., Professor of Church History in the University of Dorpat, Russia, and an author of other works. Dr. Simonton's "labor of love" in this connection was his translation into English of the "third improved edition" of this book, and well he performed the task displaying therein not only a scholarly intimacy with the German language, but also a positive genius for smoothing out the complicated idioms of that tongue, and converting them into concise and elegant, clear and forceful English phraseology without sacrificing any of the substance or spirit of the original —his task also involving a thorough knowledge of all the fundamental facts and concepts of modern astronomical science. Both the original work and the translation thereof were, at the time of publication, widely and favorably commented upon in the secular and religious press, and even after the lapse of more than half of a century, during which period most remarkable discoveries in physical science have been made, this book is still timely and well worth reading—although I presume that it is now out of print. Much could be written about this work but the insurmountable limitations of space in this magazine preclude the possibility of further comment thereon in these pages—a remark that is applicable to the other topics discussed in this sketch. In the year 1857, immediately after the publication of the work aforesaid, Dr. Simonton, a young man of twenty-six, removed to St. Paul, Minnesota—then, practically, a frontier town of what was known then as the "far-west"—where he resumed the practice of his profession in which he immediately took, and long held, high place, up to a couple of years prior to his decease, he having then retired upon an ample competence acquired through the practice of his profession. Shortly after his arrival, or about the year 1860, he was largely instrumental in organizing and promoting the Mercantile Library Association of St. Paul, the preliminary meeting for the organization whereof took place in his office. This was the first considerable circulating library in this region, and about twenty years afterward, when it had acquired a nucleus of about 8,000 volumes, it was purchased by the municipality and was merged into what is now the St. Paul Public Library which possesses nearly 100,000 volumes and in which, although not officially connected therewith, Dr. Simonton took deep interest as he was a constant and discriminating reader especially of scientific publications. About the same time he did like public service in promoting the St. Paul Muscial Society, he having been an accomplished violinist.

He was gifted with more than ordinary artistic skill and taste in the use of the brush and pencil, particularly in landscape, his productions in this line, while not numerous, and known chiefly to his family and friends,—he did not pose as an artist—possessing real merit, being true to nature and marked with a delicacy of treatment and artistic correctness in both drawing and coloring; but these amateur pursuits were only subsidiary to his chief delight—the mysteries and problems of astronomy, and the discussion thereof. A thorough knowledge of astronomical science in all its phases is vouchsafed to very few, as this study requires for its mastery not only time and patience but also high mathematical training and a peculiar mental aptitude; moreever it is popularly regarded as a study transcending ordinary comprehension and as leading to no practical, tangible results—a most erroneous and misleading impression which is very far from the truth, as is demonstrable; but at all times and in nearly every community no matter how crude, there is a certain class, small perhaps in number, but intelligent enough to be interested in the phenomena of the heavens, and which is pleased to have its attention called thereto and to receive instruction thereon in a popular manner.

To this class especially, in the early days of St. Paul, Dr. Simonton ministered long and well, both by direct personal address and through his communications to the press and other publications, discussing current phenomena and those to occur, eclipses, occultations, comets, meteoric showers, etc., and explaining them lucidly in popular language. He was thoroughly versed in Descriptive Astronomy and the geography of the heavens and familiar with the host of noteworthy celestial objects, telescopic and other, taking great interest in the observations of double stars, variables, he having been endowed by nature with an extraordinary keenness of vision and power of discernment that would have served him well had he been a professional astronomer. Thoroughly devoted to, and attentive in, his professional duties, and a shrewd man of business, he was by no means a dreamer although he was an enthusiast in astronomical matters, and while his practice was extensive, he always found time to discuss such matters with his friends and acquaintances and all interested wherever they might be, either at their own homes, in his office, or at his residence, where he had, suitably mounted, a three and one-half inch refractor—for a time the only instrument of its kind in the city—and no matter how diffident, by reason of their unfamiliarity with the subject, or even how apathetic some of them may have been, he always succeeded in awakening their interest and implanting in their minds some positive knowledge, and a desire for further information on the subject, and even in the case of some of his hearers in imparting to them a measure of own interest and enthusiasm, he thus informally and almost insensibly to themselves, teaching many. In this respect Dr. Simonton possessed the essential qualities of a successful instructor and educator, although he made no pretense of being either, and I wish to advert particularly to this phase of his character and career, in grateful remembrance of the moral encouragement and practical assistance that, when I was becoming interested in astronomical science, he gave me, and which was freely extended throughout more than the third of a century, almost up to the time of his death, in a manner so unobtrusive that I have often been in doubt as to whether he fully realized its importance to the beneficiary; and there are others also who have been similarly aided by him. About the year 1873 he assisted in founding the St. Paul Academy of Natural Sciences, a modest, but effective, institution that for the time and place was quite well-equipped for its work, it possessing a considerable collection, particularly in the mineralogical and paleontological lines, and which provided free lectures upon divers scientific subjects—prominent among which were astronomy and spectroscopy—one of the first of these having been delivered by Col. Ludlow of the Corps of Engineers, U. S. A., then Chief Engineer of the Dept. of Dakota, in 1874, upon the Transit of Venus about to take place on December 8th of that year. All these lectures were well attended for several years until the Academy succumbed under the stress of adverse financial conditions, much to the regret of Dr. Simonton who had taken great interest in it and whom I first met quite casually in its rooms, where he was perusing a volume of the American Ephemeris in which we were both interested, our mutual interest thus leading to an acquaintance and friendship that continued up to the time of his death, more than thirty-three years afterward, during which period his deep interest in astronomical matters and correlated subjects never abated to my certain knowledge—a fact that attests the firm hold which that science has upon its votaries, and one most fully exemplified in the case of Dr. Simonton.

Not content to let the astronomical section of the Academy be disrupted and its members dissociated by its failure, he gathered a few of us together in an informal coterie and invited us to meet occasionally at his office, which we did, papers on astronomical topics being read and discussed at these meetings, some of the papers having been of sufficient interest to attract attention, and to cause the publication of favorable comment thereon, abroad. These meetings were continued for about a year during which time Dr. Simonton was mentally casting about for ways and means of effecting and providing for a more permanent and larger organization, and seeking also suitable quarters therefor, and being a man of resource and tact he finally succeeded in this quest, through a concatenation of peculiarly favorable circumstances. In some manner he discovered that the constitution of the Minnesota Historical Society, a chartered and semi-official state institution having its rooms, library and collections in the capitol at St. Paul, was broad enough to permit the segregation of portions of its membership into "sections" for specific purposes of an intellectual nature so that if some members desired to form an "astronomical section" they could do so, and that our little society could thus become affiliated with the Historical Society and partake of its privileges—not the least of which was the use of its council chamber in the state capitol, for our meetings. It so happened that at the head of that society was that venerable citizen of St. Paul, Hon. Alexander Ramsey, Ex-Governor of Minnesota, (both as a territory and as a state) Ex-United States Senator therefrom, and subsequently Secretary of War in the cabinet of President Hayes, and who had been a friend and neighbor of Dr. Simonton's father in Harrisburg, Pa., succeeding to the seat of that gentleman in Congress in 1843. Under these favorable circumstances Dr. Simonton succeeded in enlisting the interest and influence of Governor Ramsey in his project, and affiliation of our little organization with the Historical Society was effected about the year 1878, with that distinguished gentleman as the first President of the "Astronomical Section," a position that he held for nearly a year, or up to the time of his appointment as Secretary of War, in 1879, when he was succeeded in the presidency aforesaid by Professor William W. Payne of the chair of Mathematics and Astronomy in Carleton College at Northfield, Minnesota, who is now Director of Goodsell Observatory at that College. The original membership included also Dr. Simonton, Professor Thompson, then of the chair of Astronomy and Mathematics at the University of Minnesota; Major Allen and the late Col. Maguire, both of the Corps of Engineers of the United States Army—the latter at that time Chief Engineer of the Department of Dakota—and about half a dozen others including the writer. Frequent meetings were held and papers upon astronomical and correlated topics read and discussed, and individual opinions on mooted scientific questions exchanged in informal talks between the members—the whole proceedings being interesting, instructive and thoroughly enjoyed by all, particularly by Dr. Simonton himself, who was then in his element.

An amusing incident occurred at one of our evening meetings in the room in the old state capitol, upon which occasion it happened that one of the Justices of the Supreme Court of Minnesota found it necessary to hold a special session to hear arguments on a legal question, and as the courtroom in another part of the building was not at that time available, he made a request through the secretary of the Historical Society for the use of the room in which the Astronomical Section was holding its meeting and was deeply immersed in *in medias res.* By a considerable majority the request was respectfully declined, an action that did not involve "contempt of court" but which indicated how seriously our little society regarded itself, and its consciousness of its dignity, rights and importance, and it may easily be guessed upon which side of the question Dr. Simonton cast his vote.

The course of the Astronomical Section ran smoothly and satisfactorily for several years until one evening in March 1881 while the legislature was in session, the capitol building was destroyed by fire, this catastrophe involving the loss of the room in which our society held so many interesting and profitable meetings; of its books, and a fragment of an iron meteorite that had fallen a short time before in northwestern Iowa and had been secured by the society through the efforts of Dr. Simonton and Professor Thompson.

A couple of months afterward the writer removed to Washington, D. C., and was thereafter uninformed of the career of the homeless society, but I think that its membership—never large—was depleted by the removal of some members to other fields, and that the remaining ones became discouraged by these adverse conditions, but Dr. Simonton's interest in the science did not abate as I knew through an occasional correspondence with him, mainly concerning current astronomical events, and from conversations with him during a visit which he made to Washington in 1883. In the year 1887, accompanied by his wife, he began an extended tour of Europe, his trip continuing about a year and a half during which he visited observatories and other intellectual centers on the continent and in the British Isles. At Nice, he held an extended interview with the distinguished astronomer Perrotin at his observatory there, and also met Flammarion in Paris. In England he attended the meetings of the British Association at Manchester, and at Edinburgh, Scotland, he came into contact with leading scientists and other distinguished persons of that country, and his subsequent narration to the writer—and others—of the details of the interviews with all the eminent men that he had the good fortune to meet during his tour was exceedingly interesting, as his conversational gifts were above the average. He dwelt with particular pleasure upon the circumstances of his visit in London to the venerable founder of the Young Men's Christian Association who received him in the room in which that great institution began its existence.

While, among the natural sciences, astronomy was his chief delight he placed spiritual considerations above all others, and was a deeply religious man, eminently just and righteous—but not self-righteous in the objectionable sense of that word—and his sincerity, honesty and simplicity were transparent and innate qualities. He was devoid and intolerant of cant, hypocrisy, deceit, sham and pretension of any kind, his characteristics in this respect, while both innate and resultants of his religious training, having also, I think, been fostered in a measure, by his study of the mathematical science of astronomy, the exactness whereof has a logical tendency to cultivate the these moral attributes.

Both through racial and family heritage, and also through personal predilection, his religious convictions were those of the Presbyterian form of the Christian faith, but while he was firm, and even uncompromising, in these, he was not intolerant of the honest convictions of others and never obtruded his own upon any one; the breadth of his mental scope and his intellectual acquirements precluding bigotry and prejudice, for he was a man of excellent mental poise, calm, judicious, analytical, and not prone to hasty reasoning or conclusions not absolutely warranted by facts, he, in this respect, following closely the injunction to prove all things and hold fast that which is true.

His demeanor was grave and dignified, but he was cordial and kindly in manner, and even genial—possessing a sense of humor that enabled him to appreciate a clean joke, witticism or anecdote, which he thoroughly enjoyed.

He joined the Central Presbyterian Church upon his settlement in St. Paul; was elected Superintendent of the Sabbath School in 1857, holding that position for several years, and was made an elder of the church in 1858 retaining that office up to the time of his death, nearly half a century later, and he was always devoted to, and foremost in, the works of his church during that long period of service. Although a man of affairs, he led "the simple life" in an ideal home, his immediate family consisting, of late years, of his wife and a son, James Carlisle Simonton, who is connected with the Traffic Department of the Northern Pacific Railway in St. Paul, in an important capacity, and who has inherited his father's noble traits of character, he being the youngest of five children four of whom—two sons and two daughters—passed away in childhood, their mother following them in 1875—whence it will be seen that the subject of this sketch was a man not unacquainted with grief, in which he was, however, sustained by a characteristic Christian fortitude.

In 1879 he married an estimable lady of St. Paul—Mrs. Emma M. Campbell—who now survives, as do two of his brothers, Reverend William, and Professor James S. Simonton.

In person Dr. Simonton was of a little more than medium height, slender rather than robust, and of a somewhat nervous temperament. such as is frequently found in one of his fine mentality, and that, during the latter part of his life, superinduced a tendency to insomnia which was aggravated by any intense mental concentration, and interfered seriously with deep or prolonged application to study.

This he assigned as an adverse condition when I, knowing his devotion to astronomical science, and his natural aptitude therefore, several times suggested that he devote at least a portion of his time to systematic work and research therein. But his mode of living was always so simple and abstemious, that even when he was considerably past three score and ten his age was not specially in evidence; and he was active in both body and mind—even sprightly— up to a very short time prior to his death. Nor had his desire for the existence of a suitable astronomical society in St. Paul waned, and only a short time before he received the final summons, he, several times, earnestly discussed with me the possibility of reviving the old society, but as most of the members had either passed away, or dispersed, and a new generation had arisen which was devoted more to commericalism than to purely scientific pursuits, the times did not seem auspicious for the undertaking, which fact, together with some premonitions of failing health, forced him, very reluctantly indeed, to relinquish his cherished idea in this connection.

The labor necessary to overcome the inertia of a community, rather apathetic on this subject, seemed too great for him under the circumstances, but doubtless there was a considerable number of persons in this city who would have become members of such a society, as has been indicated by the recent formation of an "Astronomical Section" in the newly organized and comprehensive Institute of Arts and Sciences, in which, had his life and health been spared, Dr. Simonton would, without doubt, have taken a deep interest, and become an enthusiastic and valuable member.

About a year ago he paid me a friendly visit and on that occasion looked over some special work upon which I was then engaged, giving me advice concerning it and making suggestions thereon that I have found to be sound and valuable, and his health and spirits seemed to be so fairly good, that I hoped that he, being then at leisure and possessing considerable mechanical ingenuity and dexterity in manipulation, would assist me in some particular, contemplated experiments in the electrical field. But this hope was not to be realized, for at that time the sun of life, for him, was low, and the shadows fast lengthening, and although neither of us had any premonition of the sad fact, our greetings on the occasion of that visit proved to be the final. *Ave atque Vale*!

Very shortly thereafter, for him, the twilight faded, the night fell and he sank to rest to wait the dawn of the Everlasting Day, and with his departure there went out from the walks of life a true, Christian, gentleman of the admirable old-school type, and a scholarly one; a good, useful, and substantial citizen, and a man without guile who was held in high esteem by all who had the honor and privilege of his friendship or, even more or less intimate, acquaintance.

It has appeared to me meet and just that a brief sketch of his life and work should find place in the pages of this magazine which, from to time, for the edification and encouragement of its readers, a majority of whom I presume are persons quite deeply interested in astronomy—true amateurs—thereof—has been pleased to record the intellectual attainments, scientific achievements and labors—modest though these may have been —and also the personal qualities and moral worth of earnest, enthusiastic workers in the field of astronomical science, who have passed beyond—and such an one, in very deed, was Thomas Davis Simonton.

St. Paul, Minnesota, August 1908.

DOOLITTLE'S MEASURES OF HOUGH DOUBLE STARS.*

G. W. HOUGH.

In 1901 Professor Eric Doolittle of the Flower Observatory began the re-measurement of the double stars discovered by myself with the 18-½ inch refractor of the Dearborn Observatory. This work has been published by the University of Pennsylvania and contains 176 pages, quarto.

I am personally under great obligations to Professor Doolittle for undertaking so extensive a piece of work and I am pleased to say that it has been done in a more thorough manner than if undertaken by myself.

When the number of observations of each pair is taken into account, as well as the number of exceedingly close and difficult pairs which been examined and measured, I think it may rank as one of the most important monographs on double stars that has hitherto been published.

The telescope used had an object glass of 18-inch aperture by Brashear. The measurement of so many exceedingly difficult pairs indicates that its optical qualities are all that can be desired and it will rank with the best telescopes of that aperture now in use.

The author devotes nine pages to explanatory notes regarding the various catalogues, method of observing, and other necessary information.

In general, each pair has been measured on five different nights which adds greatly to the value of the work, especially in the case of exceedingly close or otherwise difficult pairs.

The catalogue contains 648 pairs, classified as follows.

Distance	No. pairs
0 K 0″.5	84
0.″5 — 1″	74
1″ — 2″	101
2″ — 5″	172
Over 5″	218

It appears from the above table that more than 25 per cent are less than 1″ in distance and more than 13 per cent less than 0″.5.

During the last thirty years, a comparatively large number of pairs under 0″.5 in distance has been discovered by Burnham, See, Hussey, Aitken and myself.

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* Read before Astronomical and Astrophysical Society, Put-in-Bay, Ohio, August, 1908.

Many of these excessively close pairs, especially some of those found at the Lick Observatory, will undoubtedly prove to be very short period binaries.

The author concluded from his measures that thirty pairs in the above catalogue are clearly binary system, after excluding all pairs which cannot now be seen double or are presumed to be single.

He also finds forty-nine pairs which have considerable proper motion. He has classified fifteen pairs as single, nearly all of which have also been examined at the Lick Observatory. I presume a large proportion of the pairs in this class are in reality single. I notice, however, one of these pairs has been observed at Greenwich, since the publication of his measures.

If a star is presumably single there is no use in wasting valuable time, but if, on the contrary, there is a reasonable probability that it was double at the time of discovery, it is likely to turn out a short period binary and should be examined occasionally.

It sometimes happens that a pair is easily seen at the time of discovery, either because there was good seeing at the time or that the components were at the maximum distance. Hence, the discovery position, if simply an estimate, should have great weight in deciding on its probable duplicity.

The rapid binary, 13 Ceti, is a good example. At the date of discovery in 1886, it was near its maximum distance and was readily seen, while four years later it was single with the 36-inch Lick telescope. In the discovery of a pair of equal magnitude, if the distance of the components at the time of discovery is not much greater than the theoretical separating power of the telescope, there is a chance of mistaking a spurious elongation as real. But when the distance is a measurable quantity and the star is examined with different eye pieces on different nights, there is a very slight chance for error.

In the case of very unequal pairs, the visibility of the small star will depend on its distance from the primary. Just what this minimum distance is for a given pair and telescope, is not definitely known. From what we know regarding unequal pairs, which have been catalogued, I think it is probable that many of the bright stars are accompanied by small companions that are entirely beyond the reach of our present optical powers.

The companion to Sirius is a good example of our inability to see a small star when at a certain distance from the primary.

The stars which I have found double during occultation by the Moon were, at the time of discovery, I think too difficult to be seen with any telescope in use, but it is possible that in time the components may be at such a distance apart as to be visible.

The most interesting stars of this class are

τ	Tauri	1899	.80 n.p.	0″.15 to 0″.4	4.4—9
ξ	Ophiuchi	1907	.70 foll	1″ to1″.5	4.4—11

In the second case, the small companion was visible at the dark limb of the Moon for about four seconds after the disappearance of the primary.

If occultations of the naked eye stars were more generally observed with a large aperture, I think we should find a considerable number similar to the above class of doubles.

Doolittle also computed an orbit of H_0 212 = 13 Ceti and found elements agreeing very closely with the orbit previously determined by Aitken. The periods for the two computations are 7.42 and 7.35 years respectively.

According to this period, 13 Ceti is the second most rapid binary now known.

We are under great obligations to Professor Aitken for securing a definitive orbit in so short a time, for without his consecutive series of measures, it might have required many years for this purpose, as has been the case with other rapid binaries.

I may add also in this connection that the Greenwich Observatory has undertaken the observation of about 500 pairs, found in the above catalogue and has already published measures for a considerable number.

The material which has been secured during the first 30 years and brought together by Prof. Burnham in his general catalogue will enable the next generation of astronomers to have a wider field of research on double stars than has been possible in the past.

Evanston, Ill.

THE POPE AND THE COMET.

WILLIAM F. RIGGE.

FOR POPULAR ASTRONOMY.

It seems that no article can be written on Halley's comet without bringing in the oft-told story of the bull which Pope Callixtus III so ineffectually launched against it, or of the Angelus bells which were rung to frighten it away, or of the prayers which were to deliver the Christian world from the devil, the Turk and the comet. The truth-loving reader will, therefore, be probably most intensely surprised when he hears that, as an actual fact of sober history, there is no truth whatever in the story, not even in its least details. And the proof is easy and solid.

First. While Newcomb calls the bull a myth, but along with the Columbian and Chambers Encyclopedias believes that prayers were ordered to be said against the comet, no allusion whatever to the pope, the bells and the prayers is made by Sir John Herschell, Grant, Young, Comstock, Todd, Langley, the American Cyclopedia, the Encyclopedia Americana, the Encyclopedia Britannica of 1902, etc. While this may be a negative argument, it is not, however, an inconclusive one, for why should these eminent authorities, all of them non-catholic, not mention the story if it is true, when so many other writers speak of it?

Second. The Bullarium Romanum is a large series of volumes containing in the original Latin all the official documents ever issued by the popes, from St. Peter down to our own day. Owing to the definiteness of the reference and the short reign of Callixtus III, it was an easy task for me to read all the documents of this pope, and I can attest from my own personal knowledge that not only is there no bull against or concerning a comet, there is not even a paragraph, nor a phrase, nor a word, which might be construed to refer to a comet.

Third. The story is so universally told and is to be found in so many writers, such as Arago, Draper, Babinet, Guillemin, White of Cornell, etc., that most persons are really excusable*

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* Note. I lately had the privilege of visiting one of the first astronomers of the country in his own observatory. Seeing some photographs of comets, I remarked pleasantly that is was about time the pope got his bull ready if he

when they are misled into the conviction of its truth, and then simply copy it and pass it on to the next generation. If the reader of these lines is really interested in the matter, I would refer him to an able article entitled "Of a Bull and a Comet" written by John Gerard, S. J., and published in "The Month", London, in February 1907. Here the whole story is traced to its fountain head, and it is shown by the best authorities, nearly all of them non-catholic, that not only no bull was ever launched against the comet, but prayers were not even ordered to be said against it, although the prevailing opinion of the scientific men of the time was that the comet foreboded calamity to the earth. Any one that wishes it may obtain a free reprint of the article in question by applying to the Superintendent of Parish Schools, Broad and Vine Streets, Philadelphia.

Fourth. The article just referred to traces the origin of the whole story about the bull against the comet to this one paragraph of Platina, in his Vitae Pontificum, published in Venice in 1479. As this writer was not only in Rome at the time, but was also archivist of the Vatican when he wrote his history, his authority ought to be of the utmost value. These are his exact words:

"A hairy and fiery comet having then made its appearance for several days, as the mathematicians declared that there would follow a grievous pestilence, dearth, and some great calamity, Callixtus—to avert the wrath of God—ordered supplications, that if evils were impending for the human race, He would turn all upon the Turks, the enemies of the Christian name. He likewise ordered, to move God by continual entreaty, that notice should be given by the bells to all the faithful, at midday, to aid by their prayers those engaged in battle with the Turk."

Let us read the words again and study them carefully. 1. The pope did not issue a bull against the comet, he ordered supplications. 2. He ordered these conditionally, "that if evils were impending," prudently neither admitting nor reject-

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wished to prevent the return of Halley's comet. "Do you know", he said, "I was foolish enough to give credence to this story lately in a public lecture? I was at once deservedly, yet politely, taken to task for it, and I shall certainly never be guilty of such ignorance again." When I told him I intended to write up this story in Popular Astronomy, he urged me: "Do so, by all means, because it is repeated so often and in so many magazines, that people really believe it to be true."

ing the authority of the mathematicians who declared that pestilence, dearth and some great calamity would follow the appearance of the comet. 3. He assumes no authority over the comet nor bids it be gone, he orders supplications, declaring himself to be a suppliant, that if evils were impending, God would turn them upon the enemies of the Christian name. 4. Bells are to be rung to remind the faithful to pray, not to frighten away the comet.

This one quotation from one author, which has been the germ of the whole comet story, weakened as it is by our simple analysis, becomes of no value whatever when we apply the rules of ordinary historical cricitism. We have only the word of Platina that the pope ordered supplications to be made and bells to be rung, he neither refers to any papal document, nor does he quote the pope's exact words. Now, as the Bullarium Romanum contains all the official documents of all the popes, and as not one of the declarations of Callixtus III alludes in any manner whatever, directly or indirectly, to a comet, we have every reason to dismiss the testimony of Platina altogether. For this same reason we must also reject the testimony of each and every writer that mentions the comet story or any of its details, because not a single one of them has ever given the slightest reference to any official document ever promulgated by Callixtus III whether in the Bullarium Romanum or out of it, nor supported his assertion by anything stronger than a quotation from a previous writer who was equally deficient in his historical proofs.

There is, therefore, no foundation whatever for the story that Callixtus III issued a bull against or concerning a comet, that he ordered bells to be rung to frighten it away, and that he ordered prayers to be said to deliver the world from its influence.

Creighton University, Observatory,
Omaha, Nebraska.

SOME RECENT STUDIES OF THE SOLAR SURFACE.

ROSE O'HALLORAN.

FOR POPULAR ASTRONOMY.

The relative distribution of spots on the Sun's surface within a definite period, their general aspects, and their number are details of solar study easily obtained and well worthy of record. There is a hidden cause for each one of them. It has long been known that the southern hemisphere of the Sun is, on the whole, more spotted than the northern. According to Comstock's text-book of Astronomy, disturbance north of the solar equator was less than half that in the southern zones from 1879 to 1890, and an emumeration of the separate areas of discoloration that I observed from November 1891 to November 1901 showed that the disparity continued during the succeeding cycle, though on a decreased scale, the difference being in about the proportion of 3 to 4. In 1902-3 it may be fairly represented by the numbers 7 and 8; but in 1904 a gradual transference took place, the greatest activity becoming slightly predominant in the northern hemisphere. This continued until July 1906, when a pretty even distribution set in lasting until March, 1907, and then the southern hemisphere again became the scene of greater activity. The following record dating from November 1906 to December 1907, a period of fourteen months, includes this last hemispheric transference.

RECORD OF SUN-SPOTS.

Year	Month	No. of spots	Solar Hemisphere		Unknown	No. of Days of Observation
			North	South		
1906	Nov.	12	4	6	2	26
	Dec.	17	8	6	3	22
1907	Jan.	14	4	8	2	17
	Feb.	18	7	3	8	18
	March	11	5	4	2	20
	April	11	2	6	3	25
	May	9	2	3	4	26
	June	4	1	2	1	26
	July	10	4	6		19
	Aug.	12	3	8	1	23
	Sept.	14	5	5	4	25
	Oct.	9	3	4	2	25
	Nov.	12	5	5	2	24
	Dec.	13	4	7	2	20
		166	57	73	36	317

I have applied the word "spot" to any discoloration whether single or in sections closely adjacent, provided the whole be isolated about twenty degrees, as it is then probably due to one immediate cause.

Such numerical estimates have a supplementary value as the accuracy of a real measurement is diminished by the fact that sun-spots exhibit much irregularity of outline and are also more or less affected by foreshortening.

With regard to the shape of spots, tendencies towards the simple geometrical forms are occasionally noticeable; and in a visual telescope examination of umbræ that appeared during these fourteen months, the outlines of seventy were noted when crossing the disk centrally. Of this number one had an approach to squareness, five to roundness, ten to ovality, eleven to triangularity, while the remaining forty-four admitted of no classification. The triangular form, sometimes called pear-shaped, has long been recognized as a frequent deviation from the usual grotesque irregularity. Of the 166 observed 26 may be classed as of mean size and 13 as large. Conspicuity is as important as extent of area, for a spot only 50,000 miles in diameter with an immense umbra may challenge the unaided vision while a scattered or penumbral group of 70,000 miles passes unnoticed.

The visibility of two eruptions, one in the end of January and the other in the beginning of February, 1907, depended more on their round, black umbræ than on their scant penumbral fragments. Much alike in aspect, only in very clear intervals were either discernible without magnifying power as they transited centrally, one north and the other south, eight days afterwards, in southerly zones. When the latter was on the west side of the disk, another group far in the rear enlarged and surpassed it in size and conspicuity. Thirty-seven umbræ, two of which were more than medium size created the discoloring effect of this reinforcement which formed another distinct blur on the southern tracts from the eleventh to the fourteenth of the month. Telescopically, it was in view for thirteen days, a vast length of 130,000 miles prolonging its transit to the eighteenth, when seemingly on the west limb of the Sun.

These solar storms seem to have outlasted one rotation, and in reduced size and changed form to have transited again in due time. The special feature of an equally large group that appeared south of the equator in the June following, was an indication of cyclonic motion. Tendency to a circling formation in its umbræ and fragments was evident with many changes from the sixteenth to the twenty-second of that month when foreshortening obscured its outlines. One of its remarkable phases is well shown in the accompanying illustration.

Sun-Spot, June 16, 1907
8:40 A. M.

Very interesting in another respect was the triangular group of November. When centered on the fifteenth of the month, a brilliant prominence was seen to flare from the Sun's surface to the marvellous height of 325,000 miles. The observer, Dr. Amban of Radcliffe Observatory, England, ascertained that it had moved with the velocity of 10,000 miles in one minute, and having remained in view for half an hour, it gradually broke in

Sun-Spot, November 14, 1907. 8:40 A. M.

fragments and disappeared. Such violent activity is known to occur in the neighborhood of large eruptions, and the changed aspect of the spot, as shown by a comparison of the drawings of the fourteenth and seventeenth may be connected with the uprush of the remarkable Sun flame.

Sun-Spot, November, 17, 1907. 8:40 A. M.

The later sketch is on an enlarged scale, but the changes are quite recognizable, especially the scattered effect when, owing to foreshortening, a more compact appearance was to be expected. This much disturbed area was north of the solar equator. With the exception of an oscillation southward in April, spottedness predominated in the northern zones both in size and number during the present year (1908) up to the end of May. Only spots of medium dimensions appeared during these months, the largest member of the group being that which measured 32,000 miles in diameter on the thirty-first of May.

On four days of this year, namely February the eighteenth, March the third, and the twenty-sixth, and May the twenty-fifth, the disk was unspotted in a four inch lens; and though the maximum is not yet passed, the minimum due in 1912 will probably indicate its approach before long.

San Francisco, California,
June 1908.

PRELIMINARY NOTE ON THE OBSERVATION OF SEVERAL HARVARD VARIABLE STARS DISCOVERED IN 1907.

WM. E. SPERRA.

FOR POPULAR ASTRONOMY.

Through the kindness of Prof. E. C. Pickering of Harvard College Observatory, who furnished charts for the identification of fifteen of the variable stars announced in the H. C. O. Circulars, Nos. 127, 132, and 133, as follows: 42, 43, 45, 46, 63, 64, 147, 148, 154, 158, 160, 161, 162, 174, and 175.1907. 63 and 64.1907 had already been assigned the definite notation of ST and TT Aquilae. Of all the remaining thirteen stars, variation has been detected in 42, 43, 45, 147, 148, 158, 174 and 175: no trace of variation has been noted in 46, 160 and 162. But as this paper is intended to deal with the second and third of the above list only, further details as to the variation of the others will be deferred for a future paper.

43 and 45. 1907 are both in the constellation Draconis and in adjacent fields. Observations of both were commenced on the night of 1908 May 24. For the first three weeks one observation was obtained a night. The first and second night's observation of 43 showed it to be undoubtedly a short period, variable, as on May 24 it was near minimum, whereas on May 25 it was near maximum, but the series being broken by cloudy weather, the true nature of its variation was not suspected until the night of June 17, when a rise was obtained which showed its period to be not a matter of days as was supposed from the first observations, but of hours only. A change in the plan of observation was necessary, and an all night series yielded a minimum for June 20.501 L. M. T., a maximum was observed on June 21.427, 23.431, and 25.398, a minimum on June 26.415, and an all night series on June 27 a decline from maximum. Thus it appeared that similar phases occurred on alternate nights, but at an earlier hour. From a discussion of these observations a period of a little less than 16 hours was deduced—0.6595 days.

An ephemeris was prepared with 1908 May 24.0819 as epoch, and most of the maxima were fairly well represented, the minima not so well. A single observation on the morning of July 4.628 at maximum light served as a check for the ephemeris date of July 4.6204. But it was found that a slightly longer period (0.660) days was required for the minima. Now the basis of the second period was the observed minima of June 20 to June 30, while the maxima went back to May 27.385 to June 26.380, a significant fact as will appear later. These results were communicated by letter to Harvard College Observatory, on July 5.

While the star was kept constantly under observation no comparison was made with my computed ephemeris until August 24, when it was found at minimum, while the ephemeris called for a maximum. This was intolerable and a new discussion was made which included 175 observations extending to Sept. 9. In the first discussion no account was taken of the effect of the equation of light, but in this latter the necessary corrections were made. It was soon found no constant period would represent all the observations within a two or three hours residual, and the evidence was for an unmistakable increase in the length of the period. May 26 to June 21, an interval of 38 periods, its mean length was 0.65909 days; June 21 to July 28 an interval of 56 periods gave as the mean length 0.660409 days; July 28 to Sept. 5 an interval of 59 periods resulted in a mean length of 0.66089 days. Now it is readily seen why it is necessary to use a longer period to represent the minima of June 20 to June 30, as referred to above.

Now as the period is a little less than 16 hours, the maxima fall earlier on each succeeding alternate day, thus resulting in a precession of the maxima, which in about a month's time cause the succeeding maximum to be observable at the same hour of the day. Now if the period of variation is constant, the period of precession will also be constant, and *vice versa*. The first precession period May 27.385 to June 27.380 is an interval of 31 days; the next June 27 to Aug. 1, an interval of 35 days; Aug. 1 to Sept, 7, an interval of 37 days. Showing an increase in length of the precession period, a necessary sequence to the increase in length of period.

The rise requires about six hours, and for the first four is very slow, the decline is very slow requiring about ten hours with a halt six hours after maximum. I have not worked the magnitude range out yet, but is about that given in the H. C. O. Circular No. 127. In a forthcoming paper, I hope to give a detailed result of the observations, and have already exceeded in the intent of this paper.

45. 1907 DRACONIS

This was a much more difficult star to deal with, as in May and June for two succeeding nights it would be bright and the next two faint. And with the weather breaking in, it was June 20 before its short period was suspected, and it was nearly a month later before it was evident that the phases were repeating every fourth day. From a discussion of 122 observations 1908 May 24 to Aug. 20 a mean of 3.9866 days was found for this cycle. But it was still uncertain how many periods were represented by the four days, as my observations covered only about six hours out of each twenty-four. But it was evident that the number must be odd, as the time, four days, was even. I had succeeded in observing only one maximum out of each four days. By successive trials it was found to be divided in seven periods; one period being 0.56952 days, or a little over $13^h\ 40^m$. A mean light curve was constructed, and all observations were fairly well represented.

The rise requires about four hours, at first slow after minimum for an hour and a half, then very rapid until maximum, no halt is made and the decline sets in immediately, and for over an hour after is as rapid as the rise, a halt is made at two to three hours after maximum, the decline then increases for nearly two hours or more, and then for the next five hours is very flat--the lowest point being reached ten hours after maximum. The range is about a magnitude, or 19 light steps on my scale. My elements for this star are, 1908 May 24.0963—0.56952E.

On the night of Aug. 29.490 maximum No. 3 in the series of seven was observed for the first time, giving a residual $O - C = +.0053$ or less than 8^m minus the equation of time—about three minutes. It will yet remain to be seen how closely future maxima will follow the elements which depend on 160 periods. As in the case of the star 43.1907 this is only preliminary.

Cleveland, Ohio,
September 15, 1908.

THE ORBIT OF THE EIGHTH SATELLITE OF JUPITER.

R. T. CRAWFORD.
W. F. MEYER.

The following observations have been used in the determination of the orbit of the eighth satellite of Jupiter:

Gr. M. T. 1908	α (1908.0)	δ (1908.0)	
Jan. 27.5288	131° 27′ 50″	+18° 05′ 05″	Greenwich
March 8.8486	127 09 48	+19 31 36	Lick
April 29.7023	128 26 03	+19 35 49	Lick

The method employed is Leuschner's "Analytical Method of Determining the Orbits of New Satellites," which was used here with success in determining the orbit of the seventh satellite. This method has not been published, but an outline of it was given before the 1906 meeting of the Astronomical and Astrophysical Society of America. An abstract of it and of the results of its application to the case of the seventh satellite were printed in *Science*, n. s. 23: 441-460, and referred to in *Nature*, 74: 64, and in *Publications of the Astronomical Society of the Pacific*, 18, 135. It will soon appear in full as a part of Vol. VII of the *Publications of the Lick Observatory*.

The computation has been based upon the supposition that Jupiter is the primary and the Sun is the principal disturbing body. The determination then gives the osculating orbit for the middle date (March 8), in which the attraction of the Sun as a disturbing body during the period covered by the observations (January 27-April 29) is fully taken into account.

The computation leads to two solutions. For the first the logarithm of the distance from Jupiter at the time of the middle date is $\log r = 9.23826$; for the second $\log r = 9.11627$. The second solution gives an hyperbolic orbit with $\log e = 1.13199$. The elements from the first solution are:

Epoch and Osculation 1908 March 8.8233 Gr. M. T.

$$\begin{array}{rl} M_0 = & 287^\circ.226 \\ \left.\begin{array}{r} \omega = \\ \Omega = \\ i = \end{array}\right. & \left.\begin{array}{r} 61.670 \\ 235.924 \\ 144.854 \end{array}\right\} \text{Equator 1908.0} \\ \phi = & 28.824 \\ \mu = & 0.47702 \\ P = & 2.0662 \text{ yrs.} \end{array}$$

In this method there would result ordinarily two sets of elliptic elements, one with motion direct, the other retrograde. In such an event, as in the case of the seventh satellite, it is necessary to carry on both solutions to see which gives the better representation of observations other than those used in the computation, before decision can be made as to which is the real orbit. In this case, however, one solution, *viz.*, the hyperbola, means nothing under the supposition that the object is a satellite; so the computation was continued for the ellipse only.

The special perturbations due to the action of the Sun were computed by Encke's method as adapted to this problem by Leuschner. Applying these to the rectangular coördinates determined from the osculating elements and computing the places for the dates of five observations the following representation results:

O—C	Jan. 27	Feb. 22	Mar. 8	April 1	April 29
$\Delta\alpha$	—43″	—10″	0″	+38″	+2′ 27″
$\Delta\delta$	+ 7	+ 4	0	—14	—0 51

The ordinary methods of correcting elements to remove residuals failed in this case. Resort was had to the method of arbitrary variation of elements. The fourth approximation leads to the following representation for the same five dates:

O—C	I	II	III	IV	V
$\Delta\alpha \cos \delta$	+4″	+12″	+1″	—9″	+5″
$\Delta\delta$	0	— 3	—1	+3	+1

The first, third and fifth of these are the residuals for the observations upon which the orbit is based. They are well within the errors of observation and outstanding perturbations, so the representation is considered satisfactory and the computation was stopped at this point. The two intermediate places are so well represented that there can be no doubt of the correctness of the supposition that the object is moving about Jupiter as primary.

The maximum effect of the attraction of the Sun is 10″ in right ascension and 5″ in declination. These are for April 29.

The last approximation for the removal of the residuals gives the following:

ELEMENTS.

Epoch and Osculation 1908 March 8.8233 Gr. M. T.

$$M_0 = 294^\circ.286$$
$$\left.\begin{aligned}\omega &= 51.143\\ \Omega &= 236.204\\ i &= 145.795\end{aligned}\right\}\text{Equator 1908.0}$$
$$\phi = 26.073$$
$$\mu = 0.38680$$
$$\log a = 9.26412$$
$$P = 2.5482\ (\text{yrs.})$$

CONSTANTS FOR THE EQUATOR 1908.0.

$$x = r\,[9.94653]\ \sin\ (270^\circ.128 + v)$$
$$y = r\,[9.97766]\ \sin\ (\ 350.110 + v)$$
$$z = r\,[9.74986]\ \sin\ (\ \ 51.143 + v)$$

An ephemeris is based upon these elements and the special perturbations due to the attraction of the Sun will soon be forthcoming.

A part of the check computation was performed by Mr. A. J. Champreux.

Lick Observatory Bulletin No. 137.
August 21, 1908.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

Part III. (Continued.)

THE NATURE OF THE SOLAR RADIATIONS AND THEIR RELATION TO TERRESTRIAL MAGNETISM AND OTHER METEOROLOGICAL PHENOMENA.

The hypothesis that the impacts of the ultimate particles of the atmospheric gases are the cause of the pressure of the atmosphere was enunciated first by Daniel Bernouilli in his work *Hydrodynamica*, published in 1738, (his view being shown to be correct by the English physicist Joule in 1848, this theory being subsequently elucidated by Clausius Maxwell and others) and mine, while apparently trivial has, as stated, led to important practical results unachieved by said kinetic theory.

Pressure (P) being thus proportional to the number (N) of revolutions, or vibrations, of the atoms, in unit-time, which number under my theory, as aforesaid, is proportional to the absolute temperature (T), to the fundamental linear orbital velocity (V_0) and to the mass (M) in unit-volume the following are algebraic expressions therefor; $P = MNV_0 = MTV_0$; (a). For any variable volume (V') we have $D = \frac{M}{V'}$, and the aforesaid equations, when the fundamental orbital velocity (V_0) is taken as unity—as in the case of any definite gas, such as atmospheric air, are reducible to the following; $P = DN$ and $P = DT$; (β), the second of which expresses the well established fact of the thermodynamics of gases, "that the pressure of any gas is proportional to its density multiplied by its absolute temperature, and that when the latter is constant, the pressure is proportional simply to the density (which is Boyle's law), the first expression in the case of variable temperature being that for the law of Charles or of Gay Lassae, and through these expressions the relation between my theory and the ordinary kinetic theory of gases becomes apparent.

The structure of a single spherical molecule constituted of revolving atoms moving according to the postulates of my theory in this respect, involves all the principles of Hydromechanics, the molecule being a "center of force" or a reservoir of kinetic energy, exerted equally in all directions, a condition that fully explains the well-known fact that fluid pressures are exerted equally in all directions when the fluids are confined in a vessel. In the interior of a gaseous mass composed of such molecules so confined, the pressure exerted by any one molecule is under normal conditions exactly counterbalanced by the pressure of similar surroundings and contiguous molecules, the internal mass being therefore in equilibrum to pressure, but in the single layer, or as it may be called interface, in immediate contact with the interior surface of the walls of the vessel, there is an unbalanced pressure caused by the impacts of the atoms of one-half of the layer of molecules in contact with unit-surface, in unit-time, the other half being directed against, and balanced by, the impacts of the atoms of the contiguous internal molecules, an equal pressure caused by one-half of the impulsive forces of a single layer of molecules being exerted likewise, but in an opposite direction against unit-surface of the opposite wall of the vessel.

We may regard this force of pressure in one direction as "positive," and that in the opposite direction as "negative," the arithmetical sum being equal to the total pressure of all the molecules in a layer, and the algebraic resultant being o, which expresses the condition of equilibrium among all the molecules within this superficial layer, the internal molecules acting simply as media for the transmission of pressures and the propagation of radiant energy.

The concept of polarity is therefore again introduced and it will be demonstrated presently that all the phenomena of electricity and magnetism are traceable to the mass and motions of the atoms in this single layer of molecules only, it being the seat of electro-motive force and also of that similar and correlated form of potential or pressure which we call the temperature of a radiating surface, and which is the mainspring keeping in motion those undulatory vibrations which give rise to the phenomena of radiant heat and light; the kinematics of this "interface" will now be discussed.

From Analytical Mechanics we know that the kinetic energy (E_a) of a single atom (as of any material body) of mass (m) moving with a linear velocity (V_0) per second is expressed by the equation $E_a = \frac{1}{2}mV_0^2$; (γ) and that the like energy(E_m) of a molecule composed of any number (n) of these atoms is determinable through the equation $E_m = \frac{1}{2}n\,m\,V_0^2$; ($\delta$) the kinetic energy ($E_s$) of a single layer containing any number (s) of these molecules, being equal to sEm.

The molecules being spherical it is evident that the number (s) in contact with unit-surface is equal to $\frac{1}{d^2}$, the denominator being the square of the diameter (d) of the molecule, and if this diameter be expressed in English inches the unit-surface is one square inch while if it be in centimeters this area is the square centimeter so that $E_s = \frac{n\,m\,V_0^2}{2\,d^2}$; ($\epsilon$)

In this equation V_0 represents the fundamental linear orbital velocity of the atoms of the molecules of the atmospheric gases under the normal conditions of absolute temperature (T_0) and pressure (P_a) these being $T_0 = 491.66$ degrees Fahrenheit and $P_a = 14.730$ pounds per square inch, and it is equal to $T_0 V_1$, when V_1 represents the fundamental linear, orbital velocity corresponding to absolute temperature $T_1 = 1°$, the temperatures designated by T in general being proportional to the number (N) of revolutions, or to the angular velocity of the atoms in their orbits. The fundamental linear orbital velocity (V_1) is that of the atoms of the molecule of the ether and is equal to $2\pi V_1$ or to 2π times the "velocity of light" (V_1) and furthermore since the mass (M) of a molecule is equal to the product of the mass (m) of an atom and the number (n) of atoms in the molecule $M = nm$, and substituting M and also the aforesaid equivalent expressions for V_1 in equation (ϵ) we have the following group of equivalent algebraic expressions for the kinetic energy (E_s) of the single layer of molecules, or "interface," aforesaid, due to the mass and velocity of the atoms thereof.

$$E_0 = \frac{nm}{2d^2} \cdot V_0^2 = \frac{M}{2d^2} \cdot T_0^2 V_1^2 = \frac{2\pi M}{d^2} \cdot T_0^2 V_1^2 \ (\mu)$$

all of which are in foot-pounds if English units are used and in dynecentimeters per second, or ergs, if units of the C G S system are employed. Morever, the normal absolute temperature (T_0) of the atmospheric gases is equal to $D^{\frac{1}{6}}$ when D represents the volume density of the luminiferous ether relative to the similar normal atmospheric density which is taken as 1, and therefore, $T_0^2 = D^{\frac{1}{3}}$, this representing the square of the linear orbital velocity (V_0) of the atoms of the atmospheric gases, relative to the corresponding velocity (V_1) of the atoms of the ether, the relative velocity itself being expressed by $D^{\frac{1}{6}}$. Substituting this equivalent of T_0 in the two right-hand expressions of equation (η) there results the following:

$$E_s = \frac{M}{d2^2} \cdot V_1^2 D^{\frac{1}{3}} = \frac{2\pi^2 M}{d_2} \cdot V_1^2 D^{\frac{1}{3}} \ (\zeta)$$

A division of the first of the expressions on the right hand side of the equation (η) by the velocity (V_1), and the third by its equivalent, $2\pi V_1$, gives the following expressions for the normal pressure (P_a) of the atmosphere.

$$Pa = \frac{nm}{2d^2} \frac{V_0^2}{V_1} = \frac{M}{2d^2} T_0^2 V_1 = \frac{\pi M T^2}{d^2} T^2{}_0 V_1 = \frac{M}{2d^2} V_1 D^{\frac{1}{3}} = \frac{\pi M}{d^2} V_1 D^{\frac{1}{3}} ; \ (\theta)$$

and since "weight" (W) is equal to "mass" (M) multiplied by the terrestrial force of gravity (g), we may substitute $\frac{W}{g}$ for M in all the above equations, the resulting expressions for P_a being the following:

$$Pa = \frac{W}{2gd^2} T_0 V_0 = \frac{W}{2gd^2} \quad T_0^2 V_1 = \frac{\pi W}{gd^2} T_0^2 V_1 = \frac{W}{2gd^2} V_1 D^{\frac{1}{3}} =$$
$$\frac{\pi W}{gd^2} = V^2 D^{\frac{1}{3}} ; \ (\lambda)$$

All of the equations above set forth for the kinetic energy of an atom and of a molecule composed of an enormous—but definite—number of these atoms, and of a single layer of unit-area of these molecules, as well as the algebraic expressions for gaseous pressure, are fully satisfied to within considerably less than one-tenth of one per cent, or to one part in less than a thousand by the absolute numerical values of the many literal factors that appear in the right hand members of these algebraic expressions. These numerical values I have determined through a rigorous analysis based upon the principles of my theory and which are tabulated on a following page, the value of the normal atmospheric pressure (P_a), which involves all these values and which I have determined theoretically through equation(θ) and (γ) being 14.730 pounds, avoirdupois, per square inch, which value is identical—to the third place of decimals—with that resulting from numerous observations, or measurements, of this pressure, made by several well-known physicists of the highest repute, at different times in the recent past. A similiar, and fully satisfactory, agreement exists in the case of the electro-magnetic, electrostatic and electro-chemical units and also in that of the strength of the terrestrial magnetic poles all of which I have derived in absolute measurements of the C G S system, through rigorous analytical expressions based upon the principles of my theory, the normal atmospheric pressure(P_a) in grams per square centimeter being the basic quantity upon which all these electrical and magnetic units rest.

The algebraic expressions for the law of radiation, in the case of both heat and light, which I have derived in like manner give equally satisfactory results, my theoretically determined values agreeing well with those of observation and experiment, as will be demonstrated, and with all these data at hand, the specific nature of the solar radiations and their properties, qualitative and quantitative, can be definitely determined.

According to my theory all electrical action is primarily the result of the disruption of the whole, or a part, of a molecule of gaseous matter, the dissociation of each pair of conjugate atoms thereof which form the atomic couples, and the subsequent recombination of these atoms into a normal molecule, "dissociation" being regarded as positive, and "recombination" as negative, action which, in the ultimate analysis, is reducible, simply, to the motions of the masses of the atoms of said molecule, and results in the causation of the thermal, luminous, and mechanical effects that observation has shown to be concomitant, and correlated phenomena of electrical action which is thus primarily a purely mechanical process.

A molecule of a gas, consisting, as it does under my theory, of myriads of solid, and superlatively dense, atoms revolving with enormous velocity around the center of the molecule, is in effect, a solid shell enclosing the only absolute void, or vacuum, in the material universe, as is evidenced by the fact that, no matter how far the exhaustion of a gas, such as atmospheric air—from a bulb or tube, be carried (even could it be to the practically unattainable, low density and pressure of the ether in space) there is always a remnant of gaseous matter within the vessel, the molecules of this residual matter expanding as the pressure due to the molecules of the portion of the gas exhausted, or removed, from the vessel, is decreased—there remaining therefore a finite density and corresponding pressure although these may be very low, as the $\frac{1}{1,000,000}$ of an atmosphere attained in the bulb of an incandescent electric lamp, or the $\frac{1}{5,000,000}$ or less attained in the vacuum tubes, such as those of Crookes.

The following tables, in the first part of which the numerical quantities are expressed in English units and in the second in the units of the C G S system (the unit of time in both being the second) contain the values in absolute measurement of all the literal quantities which are factors in the algebraic equations derived from the principles of my theory and set forth on preceding pages.

In each table they are given, first for atmospheric air at the standard normal density, pressure and temperature, the density being taken as 1, the pressure (P_a) at 14.730 pounds avoirdupois per square inch, and the absolute temperature (T_0) at 401.66 degrees, or 32 degrees Fahrenheit, while in the second table the normal pressure is 1035.2 grams per square centimeter; and secondly for the luminiferous ether, the values in this case being set forth in the lower part of each table, the density (D) of the ether, relative to that of air at 32° Fahrenheit, being $\frac{1}{1412 \times 10^{13}}$, while for air at nearly 100° below the Fahrenheit zero, or at 360° absolute, which is the intrinsic temperature of air, free from all the heating effects of the Sun, this relative density of the ether is $\frac{1}{1926 \times 10^{13}}$ which is the value set forth in the part of the paper published in the February number of POPULAR ASTRONOMY. In the first column of numbers, common to both tables, are set forth the numerical values of the diameter (d) of a normal molecule, in inches and centimeters, respectively, and in the second column are the values of the diameter (Δ) of an atom in the same units; in the third column is the number (n) of atoms normally in a molecule, these being equal to $\frac{2d}{\Delta}$, and in the fourth column is the number (s) of molecules in contact with unit-surface which is one square inch, and one square centimeter, respectively, and since the molecules are spherical, $s = \frac{1}{d^2}$; the fifth column contains the values of the mass (*m*) of an atom, in pounds avoirdupois, and grams; the sixth column containing weight (*w*) of an atom, in the same units, this being equal to gm when g represents the terrestrial force or gravity, or—32.173 feet per second; in the seventh and eighth columns are the mass(*M*) and the weight(*W*) of a molecule normally composed of a number (*n*) of these atoms, these being simply the quantities in the fifth and sixth columns multiplied by n; in the ninth column of the first table is the density (δ) of an atom (and of all atoms, under my theory) this density being relative to that of water at temperature of maximum density, or 39° Fahrenheit, and in the corresponding column of the second table is the number (l) of normal molecular layers in 4041 cubic centimeters, of mixed hydrogen and oxygen resulting from the electrolysis of one grams of water in one cubic centimeter; it represents the number of layers in a parallelopiped having a base of one square centimeter and a length of 4041 centimeters, and is a factor in the expression in the electrochemical equivalent of water; in the tenth, eleventh and twelfth columns, respectively, are the values of the velocity of light (V_l); the fundamental orbital velocity $V_1 = 2\pi V_l$ for absolute temperature of 1° F, and the orbital velocity V_0 for absolute temperature $T_0 = 419.66$ or 32° Fahrenheit, it being equal to $T_0 V_1$, and these three quantities are expressed in feet and centimeters, per second; in the thirteenth column is the number of molecules in a cubic inch and a cubic centimeter.

With the numerical values in these two tables all the equations set forth on preceding pages and also those to follow can be easily solved, and for convenience in computation the logarithm of each quantity is placed beneath it, the logarithm of each fractional value having the letter *n* appended to the mantissa.

The derivation of the electromagnetic, electrostatic, and electrochemical units in absolute measures of the C G S system, and also the strength of a magnetic pole, will now be set forth, these having been primarily derived from the kinetic energy (E_s) from a single layer of molecules in contact with one square centimeter of a solid surface, and having a thickness equal to the

ENGLISH UNITS.

Atmospheric Air	d Inch	Δ Inch	$N = 2.\frac{d}{\Delta}$.	$s = \frac{1}{d^2}$ Square Inch	m Pound	$w = gm$ Pound
Pressure per square inch 14.730 pounds Temperature $T_0 = 491^\circ.66 = 32^\circ$ Fahrenheit	$\frac{1}{73,585,000}$ 7.866790 n	$\frac{1}{1273 \times 10^{19}}$ 22.104828 n	3460×10^{11} 14.539076	5415×10^{12} 15.733580	$\frac{1}{9500 \times 10^{40}}$ 43.977754 n	$\frac{1}{2953 \times 10^{39}}$ 42.470263 n
The Ether Density (D) Air = 1 $\frac{1}{1412 \times 10^{13}}$ 16.149984 n	$\frac{1}{304.4}$ 2.483445 n	Same.	8364×10^{16} 19.922413	92,660 4.966890	Same	Same

$M = nm$ Pound	$W = gm$ Pound	Density of Atoms (δ) (Water = 1)	V_1 Feet per sec.	$V_1 = 2\pi V_1$ Feet per sec.	$V_0 = T_0 V_1$ Feet per sec.	Molecules in Cubic Inch
$\frac{1}{2746 \times 10^{26}}$ 29.438678 n	$\frac{1}{8534 \times 10^{24}}$ 27.931157 n	3964×10^{23} 26.567497	9839×10^{5} 8.992951	6182×10^{6} 9.791129	3039×10^{9} 12.482779	3984×10^{20} 23.600370
$\frac{1}{1136 \times 10^{21}}$ 24.055341 n	$\frac{1}{3530 \times 10^{19}}$ 22.547820 n	Same	Same	Same	6182×10^{6} 9.791129	28,205,600 7.450335

C G S UNITS.

Atmospheric Air	d Centimeter	Δ Centimeter	$n = 2\frac{d}{\Delta}$	$s = \frac{1}{d^2}$ per sq. cm.	m Gram	$w = gm$ Gram
Pressure per square centimeter 1035.7 dynes Temperature $T_0 = 491°.66 = 32°$ Fahrenheit	$\frac{1}{28,971,000}$ 7.461964 n	$\frac{1}{5012 \times 10^{18}}$ 21.700002 n	3460×10^{11} 14.539076	8393×10^{11} 14.923928	$\frac{1}{2095 \times 10^{38}}$ 41.321084 n	$\frac{1}{6516 \times 10^{36}}$ 39.813593 n
The Ether	$\frac{1}{120}$	Same	8364×10^{16}	14,363	Same	Same
Density (D) Air = 1 $\frac{1}{1412 \times 10^{13}}$ 16.149984 n	2.078619 n		19.922413	4.157238		

M Gram	$w = gm$ Gram	$l = \frac{4041}{d}$	V_1 cm. per sec.	$V_1 = 2\pi V_1$ cm. per sec.	$V_0 - TV_1$ cm. per sec.	Molecules in Cu. Centimeter
$\frac{1}{6054 \times 10^{23}}$ 26.782008 n	$\frac{1}{1882 \times 10^{22}}$ 25.274514 n	1170×10^8 11.068345	2999×10^7 10.476958	1884×10^8 11.275139	9264×10^{10} 13.966786	2432×10^{19} 22.385892
$\frac{1}{2504 \times 10^{18}}$ 21.398671 n	$\frac{1}{7784 \times 10^{16}}$ 19.891177 n		Same	Same	1884×10^8 11.275139	1,721,300 6.235857

molecular diameter (d) expressed here in centimeters and directly from the normal atmospheric pressure (P_a) expressed in grams per square centimeter, the theoretical value whereof, which is 1035.2 [3.015038] having been derived through my several equations for P_a set forth on a preceding page, this value agreeing exactly with that determined experimentally.

The equivalent algebraic expression for P_a involving the mass (m) and the weight (w) of an atom, the mass (M) and weight (W) of a molecule composed of these atoms, and also the relative density (D) of the luminiferous ether, can be easily substituted in the following equations, thus showing the functions of the atoms of the molecules (in unit layer of the interface) in the development and propagation of electric and magnetic action.

The velocity of light (V_l) is 2999 x 10^7 centimeters per second correct to the fourth place, its logarithm being 10.476958, the number (s) of molecules in contact with one square centimeter, and which is designated by s, is equal to the inverse square of the molecular diameter (d), its value being 8393 x 10^{11} [14.923928] and the value of (l) is 1170 x 10^8 [11.068345.]

The following are the algebraic expressions for the aforesaid absolute units:

$$R_m = \frac{P_a}{d^2} V_l^2; (\kappa) \qquad E_m = \frac{P_a}{10d^2} V_l^2; (\iota) \quad e = \frac{E_m}{V_l} = \frac{P_a}{d^2} V_l; \ (\mu)$$

$$\frac{E_m}{e} = V_l; (\gamma) \quad e = \frac{E_m}{l} = \frac{P_a}{ld^2} V_l^2; (\phi) \ I = \frac{2\pi}{g} E_m = \frac{2\pi P_a}{980.2d^2} V_l^2; (\chi)$$

$$S = \frac{I}{R_s^2}; \quad (\psi)$$

Using the numerical data aforesaid, a solution of equation (κ) gives 1109 × 10^6 as the number of absolute (C G S) units in R_m which, under my theory, represents the electromagnetic resistance called the "ohm", the value whereof as determined by the classical experiment of the British Association in 1862 is 1000 × 10^6. Equation (γ) gives for E_m which represents the electromagnetic unit of electromotive force (*EMF*) 1109 × 10^6 which is my theoretical number of units in the volt—the experimental value veing 1000 × 10^5—and therefore the unit of current (C) which is given through the equation $C = \frac{E_m}{R_m}$ and is called the "ampere", is equal to one-tenth of an absolute unit of the C G S system, and this is also the experimental value. Equation (μ) gives for the electrostatic unit of electromotive force, 0.000370 in absolute units, the ratio between E_m and e, as shown in equation (ν) being equal to the velocity of light, which proves both theoretically and practically, the truth of the well-known hypothesis advanced by the late Professor J. Clerk Maxwell that "light" is an electromagnetic phenomenon and that electromagnetic action is propagated by waves through the luminiferous ether, in the same manner and with the same velocity as are luminous radiations. The value E given by equation (ϕ) is 0.0009476 which represents the weight, in grams, of water decomposed by electrolysis into the component gases hydrogen and oxygen in a "voltameter" by unit current per second, this being the well-known electrochemical unit from which the weight of the ions of all the chemical substances is determinable through multiplication through the atomic weight, of the chemical element or compound. My theoretical value of this unit agrees exactly with that experimentally determined by Kohlrausch—a most important fact as it serves as a check upon the determination of the other units.

The quantity represented by I, in the equation (χ) is the maximum total intensity of magnetic force, or the strength of pole, a solution of that equation giving 710,730 absolute units (dynes per square centimeter) as the value of this quantity when all the atoms of each and every molecule in contact with unit surface are affected, this being the highest possible magnetic permeability or the greatest number of lines of force in the unit surface of a magnetized body, the value of a line of force being one dyne per square centimeter—the maximum permeability in the case of soft iron being 17,500 lines as experimentally determined.

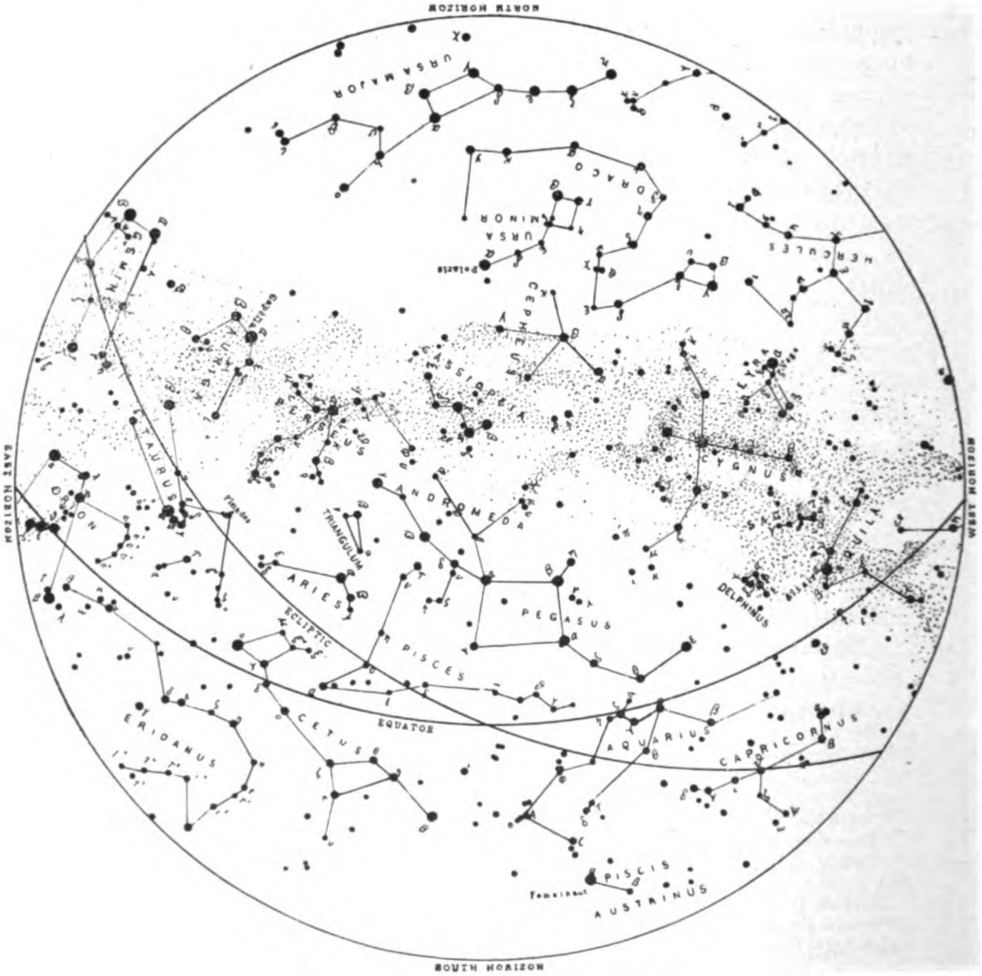
Saint Paul, Minnesota. To be continued.

General Index for Three Magazines. In last year, we issued a circular promising to print a general index of the ten volumes of the *Sidereal Messenger*, three volumes of *Astronomy* and *Astro-Physics* and fifteen volumes of POPULAR ASTRONOMY, at a price of $1.50 in paper covers or $2 50 per volume, in good library binding if 300 subscriptions could be secured to aid in the expense of publication. We received orders for less than 100 copies of the index, and so concluded that we could not afford to prepare it, although Professor E. C. Pickering, Director of Harvard College Observatory, had offered aid to the amount of $100.

When it was announced that the index would not be printed for the lack of funds Professor Pickering kindly solicited further aid for this work and promptly forwarded it to us. We now have sufficient guaranty for the publication, and the work of its preparation is going on. It will require several months to do this work thoroughly and accurately in view of other exacting duties; so subscribers are asked to be patient until the publication can be completed. We may further add that this new general index will cover sixteen volumes of POPULAR ASTRONOMY with the thirteen volumes of the other two publications named above, making in all twenty-nine volumes, instead of twenty-eight as promised heretofore. The price of the index will not be increased. The form of the index will be the same as that recently published for the *Astrophysical Journal.*

PLANET NOTES FOR NOVEMBER, 1908.

Mercury is morning star, in perihelion Nov. 4, stationary in right ascension Nov. 6, and reaching greatest elongation west from the Sun 19° 19′, on Nov. 13. At this elongation the planet will be quite bright, easily picked up with the naked eye.



THE CONSTELLATIONS AT 9:00 P. M., NOVEMBER 1, 1908.

Venus will be in perihelion on the morning of Nov. 12. Her brightness continues to decrease from 91 on Nov. 1 to 73 on Dec. 1, owing to her increasing distance from the Earth. Her phase increases during the month from 0.7 to 0.8 of illuminated diameter. On Nov. 30 at 6 p. m. C. S. T. Venus and Mars will be in conjunction, the former being then 1° 17′ north of the latter.

Mars is in the same region of the sky with Venus as indicated in the preceding note, but is not in favorable position for study. The planet's apparent disk is now only 4″ in diameter.

Jupiter is also visible in the morning and may be found high in the sky toward the southeast at six o'clock.

Saturn is near the meridian at 9 o'clock in the evening in the constellation Pisces. There are no bright stars in this vicinity so that there is no difficulty in identifying the planet without telescopic aid. The rings of Saturn are easily seen as a single ring with the aid of a small telescope. Their plane is inclined only 5° to the line of sight during November so that the divisions of the ring cannot be distinguished.

Uranus may be found in the early evening in Sagittarius but is not in good position for study.

Neptune may be found with the aid of a large telescope in the constellation Gemini in the latter half of the night.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T.		Angle f'm N.	EMERSION. Washington M.T.		Angle f'm N	Duration.	
			h	m	°	h	m	°	h	m
Nov. 1	ϕ Capricorni	5.3	5	12	54	6	30	269	1	18
4	33 Piscium	4.7	6	21	19	7	15	280	0	54
4	Piazzi 0^h, I	6.0	9	13	81	10	20	209	1	07
6	Piazzi I^h, 249	6.5	14	13	87	15	14	222	1	01
7	85 Ceti	6.3	4	41	116	5	14	196	0	33
8	Mayer 136	5 9	13	21	106	14	25	210	1	04
8	Piazzi III^h 215	5.8	17	56	33	18	38	305	0	42
9	B.A.C. 1417	6.4	6	19	25	6	55	297	0	36
10	Piazzi V^h 184	6.5	10	32	104	11	33	221	1	01
11	B.A.C. 2238	5.8	19	05	153	19	46	224	0	41
12	82 Geminorum	6.3	19	47	88	20	53	302	1	06
26	B.A.C. 6465	6.4	5	03	52	6	06	292	1	03
26	B.A.C. 6479	6.4	6	00	82	7	06	260	1	06

COMET NOTES.

New Comet *c* 1908 (Morehouse)—A telegram from Prof. E. C. Pickering, received Sept. 3 announced the discovery of a comet upon a photograph, taken by Morehouse at the Yerkes Observatory on Sept. 1. The comet was described as having a long tail and as moving rapidly southeast or northwest. Its position as estimated from the photograph was

Sept. 1.361 Gr. M. T. $\alpha = 3^h\,20^m$ $\delta = +66°15$.

The following more accurate positions have come to hand up the present writing;

Greenwich M.T.		R. A.			Dec.			Observer.	Place.
		h	m	s	°	′	″		
Sept.	2.7396	3	21	55.	+66	52	24	Fox	Williams Bay
	3.4023	3	19	43.0	+67	14	42	Thiele	Copenhagen
	3.6479	3	18	50.1	+67	23.2		Metcalf	Taunton
	3.7032	3	18	41.	+67	24	57	Fox	Williams Bay
	3.8421	3	18	13.9	+67	29	35	Aitken	Mt. Hamilton
	4.6521	3	15	15.	+67	57	28	Fox	Williams Bay
	4.8470	3	14	32.3	+68	03	59	Aitken	Mt. Hamilton
	5.8705	3	10	21.2	+68	39	30	Aitken	Mt. Hamilton
	14.5534	2	08	59.3	+73	45.6		Metcalf	Taunton

From the first, fifth and seventh of these observations Messrs. Einarsson and Meyer of the Berkeley Astronomicial Department have computed the following preliminary elements and ephemeris:

ELEMENTS

$$\begin{array}{l} T = 1909 \text{ Jan. } 5.702 \text{ Gr. M.T.} \\ \left.\begin{array}{l} \omega = 152^\circ\ 04.'0 \\ \Omega = 90\ 20.5 \\ i = 135\ 56.2 \end{array}\right\} 1908.0 \\ q = 1.1680 \end{array}$$

CONSTANTS FOR THE EQUATOR 1908.0

$$\begin{aligned} x &= r\,[9.85648] \sin (151^\circ\ 35.'5 + v) \\ y &= r\,[9.98098] \sin (258\ \ 37.9 + v) \\ z &= r\,[9.87703] \sin (183\ \ 57.2 + v) \end{aligned}$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1908		True α			True δ		log Δ	Brightness
Sept.	11.5	2^h	38^m	02^s	+71°	57.'0	0.2320	1.30
	12.5	2	30	12	72	31 .4		
	13.5	2	21	31	73	05 .1	0.2202	1.44
	14.5	2	11	54	73	37 .8		
	15.5	2	01	18	74	09 .2	0.2085	1.56
	16.5	1	49	37	74	38 .9		
	17.5	1	36	48	75	06 .4	0.1968	1.67
	18.5	1	22	46	75	31 .1		
	19.5	1	07	31	75	52 .5	0.1854	1.80
	20.5	0	51	06	76	10 .0		
	21.5	0	33	36	76	23 .0	0 1742	1.94
	22.5	0	15	10	76	30 .7		
	23.5	23	56	02	76	32 .7	0.1623	2.08
	24.5	23	36	28	76	28 .6		
	25.5	23	16	48	76	18 .0	0.1528	2.21
	26.5	22	57	21	76	00 .8		
	27.5	22	38	27	75	36 .9	0.1429	2.36
	28.5	22	20	21	75	06 .3		
	29.5	22	03	14	74	29 .4	0.1335	2.57
	30.5	21	47	14	73	46 .6		
Oct.	1.5	21	32	25	72	58 .4	0.1249	2.73
	2.5	21	18	48	72	05 .0		
	3.5	21	06	23	+71	06 .9	0.1170	2.90

Brightness Sept. 3 = 1.00.

It will be seen from this Ephemeris the comet's course has been through the constellation Cepheus and that it is pointing toward Cygnus. Probably during October it will pass through the western part of Cygnus.

At present the comet is not visible to the naked eye and is not very conspicuous in a small telescope. One can see very little of the tail which the photographs are reported to show. At Goodsell Observatory we have had little opportunity to watch the comet and have as yet taken no measures or photographs. In the Harvard College Observatory Astronomical Bulletin No. 337 it is stated that a photograph taken by Rev. Joel H. Metcalf, of Taunton, Mass., on Sept. 14 with an exposure of an hour, shows that the comet is increasing in brightness and that it has a double tail which is irregular on the northern side.

Professor Pickering suggests that good photographs of Morehouse's comet, taken at intervals throughout the night, and in different longitudes, so that its changes may be followed continuously, will have much value. Doublets should be used with exposures of not less than an hour.

Elements and Ephemeris of Comet *c* 1908.—In the supplement to A. N. 4272, which came to hand Sept. 24, Mr. Hermann Kobold, of Kiel, gives elements of Comet *c*, depending upon an observation at Rome Sept. 3 and two at Copenhagen Sept. 4 and 5. These appear to be more accurate than those given in Lick Observatory Bulletin, since the ephemeris represents Mr. Metcalf's observation of Sept. 14 very much more closely. These indicate a still greater probable increase in the brightness of the comet, making it 3.6 times as bright on Sept. 30 as on Sept. 3.

Chart Showing the Apparent Path of Comet *c* 1908 from Sept. 1 to Oct. 3

Elements

$$T = 1908 \text{ Dec. } 24.3175 \text{ Berlin M. T.}$$
$$\left.\begin{array}{l}\omega = 174^\circ\ 13'.13\\ \Omega = 105\ \ \ 3.31\\ i = 140\ \ \ 36.58\end{array}\right\}1908.0$$
$$\log q = 9.96412$$

Ephemeris for Berlin Midnight.

1908		App. α			App. δ		log *r*	log Δ	Brightness
		h	m	s	°	′			
Sept.	6	3	07	40	+69	00.5	0.2995	0.2187	1.2
	7	3	02	53	69	35.9			
	8	2	57	31	70	11.8			
	9		51	32	70	47.6			
	10		44	52	71	23.5	0.2884	0.1904	1.4
	11		37	29	71	59.6			
	12		29	14	72	35.4			
	13		20	13	73	10.1			
	14	2	09	49	73	43.8	0.2769	0.1615	1.7
	15	1	58	22	74	16.3			
	16		45	40	74	46.9			
	17		31	34	75	15.0			
	18	1	16	04	75	39.9	0.2651	0.1325	2.1
	19	0	59	04	+76	00.9			

EPHEMERIS FOR BERLIN MIDNIGHT, Continued.

1908		App. α h	m	s	App. δ °	′	log r	log Δ	Brightness
Sept.	20		40	43	+76	17.2			
	21		21	01	76	27.8			
	22	0	00	21	76	31.9	0.2530	0.1039	2.5
	23	23	38	56	76	28.8			
	24	23	17	13	76	18.0			
	25	22	55	39	75	58.9			
	26	22	34	36	75	31.5	0.2405	0.0767	3.0
	27	22	14	30	74	55.7			
	28	21	55	32	74	12.1			
	29	21	37	55	73	20.8			
	30	21	21	51	+72	22.2	0.2277	0.0520	3.6

Search Ephemerides for the comet Tempel$_3$-Swift.—In A. N. 4269 Mr. E. Manbant of Paris gives elements of this periodic comet for the epoch Sept. 23, 1908, and search ephemerides extending from Aug. 29 to Nov. 1.

ELEMENTS OF COMET TEMPEL$_3$-SWIFT.

$$\begin{array}{rl} T = & 1908 \text{ Sept } 30.88236 \text{ Paris m. t.} \\ M = & 358^\circ\ 37'\ 56''.6 \end{array}$$

$$\left.\begin{array}{rl} \pi = & 43\ \ 59\ \ 57.5 \\ \Omega = & 290\ \ 18\ \ 40.3 \\ \iota = & 5\ \ 26\ \ 33.3 \end{array}\right\} 1910.0$$

$$\begin{array}{rl} \psi = & 39\ \ 37\ \ 38.7 \\ \mu = & 624''.6084 \\ \log a = & 0.502933 \end{array}$$

SEARCH EPHEMERIS.

		R. A. h	m	s	Dec. °	′	log r	log Δ
Oct.	4	7	20	57	+30°	10′.9	0.0622	9.8411
	5		25	10	+30	04.1		
	6		29	19	+29	51.0		
	7		33	24	+29	37.5		
	8		37	26	+29	23.7	0.0634	9.8431
	9		41	23	+29	09.5		
	10		45	16	+28	55.1		
	11		49	05	+28	40.4		
	12		52	51	+28	25.4	0.0655	9.8454
	13	7	56	32	+28	10.2		
	14	8	00	09	+27	54.8		
	15		3	42	+27	39.2		
	16		7	11	+27	23.4	0.0683	9.8478
	17		10	36	+28	07.4		
	18		13	57	+26	51.3		
	19		17	15	+26	35 1		
	20		20	28	+26	18.9	0.0719	9.8501
	21		23	37	+26	02.6		
	22		26	42	+25	46.2		
	23		29	44	+25	29.7		
	24		32	41	+25	13.2	0.0762	9.8524
	25		35	35	+24	56.7		
	26		38	25	+24	40.2		
	27		41	11	+24	23.7		
	28		43	53	+24	07.1	0.0812	9.8544
	29		46	32	+23	50.6		
	30		49	07	+23	34.2		
	31		51	38	+23	17.8		
Nov.	1	8	54	05	+23	01.5	0.0867	9.8562

If the comet's perilielion passage should occur eight days earlier or eight days later than calculated, its position on the first and last of the above dates would be as follows:

	T = Sept 22.88		T = Oct. 8.88	
	R.A.	Dec.	R.A.	Dec.
Oct. 4	$7^h\ 45^m\ 37^s$	+27° 30′.1	$6^h\ 47^m\ 11^s$	+33° 47′.8
Nov. 1	9 10 38	+20 13.4	9 32 25	+26 46.3

The search for the comet should therefore be extended along a line about 15° long running northwest and southeast through the positions given in the ephemeris. The comet's motion will be southeastward from the shoulders of the Gemini through the constellation Cancer.

Search Ephemeris for Halley's Comet.—Mr. F. E. Seagrave sends the following positions calculated by him for Halley's comet, for the dates which will fall in the dark of the Moon in October and November. It is greatly to be hoped that some one will be able to pick up the comet this year although its distance from us is greater than that of Jupiter.

1908		α	δ	log r	log Δ
		h m s			
Oct.	19	6 40 43	+11° 50′ 15″	0.8071	0.7832
	23	6 39 39	+11 45 26	0.8050	0.7765
	27	6 38 22	+11 40 49	0.8029	0.7697
Nov.	19	6 26 57	+11 19 42	0.7904	0.7329
	23	6 24 13	+11 17 16	0 7882	0.7271
	27	6 21 18	0 11 15 17	0.7859	0.7213

Comet *c* 1908. A telegram has been received at this Observatory from Professor R. T. Crawford at Berkeley, Cal., stating that the following elements and ephemeris of Morehouse's comet have been computed by Einarsson and Meyer from observations on Sept. 3, 11 and 18.

ELEMENTS

Time of perihelion passage =	(T)	= Dec. 25.81 G. M. T.
Perihelion minus node	(ω)	171° 31′.
Longitude of node	(☊)	103° 05′
Inclination	(i)	140° 10′.
Perihelion distance	(q)	0.946

EPHEMERIS

G. M. T.		R. A.	Dec.	Light
Sep.	23.5	$23^h\ 40^m\ 21^s$	+76° 29′	2.43
	27.5	22 16 49	75 00	
Oct.	1.5	21 09 50	71 28	
	5.5	20 44 02	66 23	3.95

ASTRONOMICAL BULLETIN, No. 338,
Harvard College Observatory,
Sept. 22, 1908, Cambridge, Mass.

VARIABLE STARS.

The Variable Star 31. 1907. (U Geminorum type) was found by Mr. L. Campbell to be bright, magn. 11.3 on Friday, Aug. $28^d\ 19^h\ 49^m$ G. M. T. A cable message from Kiel received September 1, announced that it was also found to be bright by Hartwig. Photographs taken at Cambridge give the following results.

Date		J. D	Expos.	Magn.
1908			m	
August	23	8177.857	10	<13.2
	28	8182.836	17	10.6
	27	8183.723	15	10.7
	27	8183.842	60	10.6
	27	8183.874	15	10.5
	30	8184.789	15	10.8
	31	8185.835	15	10.7
	31	8185.841	60	10.7

The scale of magnitude is that given in the seventh column of Table I of H. C. 138.

ASTRONOMICAL BULLETIN, No. 331.
Harvard College Observatory,
Sept. 2, Cambridge, Mass.

Elements of the Variable Stars 165 and 167.1907 Leonis.—In *A.N.* 4266 Mr. M. Luizet gives elements of these two variables depending upon his own observations during 1908. For 165.1907 he finds from four observed minima the elements

$$\text{Minimum} = 1908 \text{ April } 22\ 10^h\ 10^m \text{ (Paris M. T.) } +1^d\ 16^h\ 28.^m3\ E$$
$$= 2418054.424 \quad \text{"} \quad \text{"} \quad +1.6863\ E\ .$$

The time occupied by the change of light is about $4^h\ 50^m$, the brightness at maximum about 9.3 mag. and that at minimum 11.2 mag.

For 167.1907 the elements determined graphically from observations covering two maxima and two minima are

$$\text{Maximum} = 2418061 + 59^d\ E$$
$$= 1908 \text{ April } 29 + 59^d\ E\ .$$

The variation is continuous, the brightness increasing during 28 days and diminishing for about 31 days. The range of magnitude is from 7.9 to 9.6.

New Variable 15.1908 Bootis.—In the Comptes Rendus Vol. 147, page 23 Mr. J. Baillaud calls attention to a faint variable found upon the plates taken for the Paris photographic charts. Its position for 1900.0 is

$$\alpha = 14^h\ 41^m\ 31.^s80 \quad \delta = +23^\circ\ 43'\ 59.''7$$

the star is of the δ Cephei type and the range of variation is between magnitudes 12.8 and 14.5. The increase of light lasts $1^h\ 41^m$ and is shorter than the decrease, which lasts $6^h\ 13^m$ or $10^h\ 10^m$.

New Variable 16.1908 Vulpeculæ.—In *A.N.* 4270 Professor H. H. Turner announces the discovery of a new variable by Mr. T. H. Astbury, of Wallingford, England. The star is BD +22° 3647 and its position for 1900.0 is

$$\alpha = 19^h\ 13^m.4 \quad \delta = +22^\circ\ 16'.$$

The magnitude is about 7.0. On July 25 it was fainter than usual and on Aug. 3 it was fully a magnitude fainter than on Aug. 2.

New Variable 17.1908 Persei.—In *A.N.* 4271 Mr. S. Enebo calls attention to the star BD +50° 961. Its magnitude is given in the BD as 9.5, but according to several observations around Nov. 2, 1907, it was less than 11.5. From Feb. 28 to April 21, 1908 it was steady at about magnitude 10.5. On Aug. 5, 15 and 16, 1908 it was equal to BD +50° 959, magnitude 9.5. The star is red in color and the period is apparently long.

Mr. M. Ebell gives the position of the star from the A. G. Zone catalogue as

$$1900.0 \quad \alpha = 4^h\ 9^m\ 1.^s46 \quad \delta = +50^\circ\ 22'\ 33.''0$$
$$1855.0 \quad 4\ \ 5\ \ 39.28 \quad +50\ \ 15\ \ 27.\ 0$$

The star was observed by T. E. Espin on Nov. 9, 1895 as of magnitude 8.8. He noted the color as R R and the spectrum as of Type IV.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
Nov.	2	5
	4	17
	7	5
	9	17
	12	5
	14	17
	17	4
	19	16
	22	4
	24	16
	27	4
	29	16

Z Persei

Nov.	1	1
	4	2
	7	3
	10	4
	13	6
	16	7
	19	9
	22	10
	25	11
	28	13

RY Persei

Nov.	5	1
	11	22
	18	19
	25	16

RZ Cassiop.

Nov.	2	7
	3	11
	4	16
	5	21
	7	1
	8	6
	9	11
	10	15
	11	20
	13	1
	14	6
	15	10
	15	10
	16	15
	17	20
	19	0
	20	5
	21	10
	22	14
	23	19
	25	0
	26	4
	27	9
	28	14
	29	19
	30	23

RX Cephei

	d	h
Nov.	8	10

Algol

Nov.	1	6
	4	2
	6	23
	9	20
	12	17
	15	14
	18	10
	21	7
	24	4
	27	1
	29	22

RT Persei

Nov.	1	7
	2	3
	3	0
	3	20
	4	16
	5	13
	6	9
	7	6
	8	2
	8	22
	9	19
	10	15
	11	11
	12	8
	13	4
	14	1
	14	21
	15	17
	16	14
	17	10
	18	7
	19	3
	19	23
	20	20
	21	16
	22	12
	23	9
	24	5
	25	2
	25	22
	26	18
	27	15
	28	11
	29	8
	30	4

λ Tauri

Nov.	3	13
	7	12
	11	11
	15	9
	19	8

λ Tauri

	d	h
Nov.	23	7
	27	6

RW Tauri

Nov.	1	20
	4	14
	7	9
	10	3
	12	22
	15	16
	18	10
	21	5
	23	23
	26	18
	29	12

RV Persei

Nov.	2	15
	4	15
	6	14
	8	14
	10	13
	12	12
	14	12
	16	11
	18	10
	20	10
	22	9
	24	8
	26	8
	28	7
	30	7

RW Persei

Nov.	3	11
	16	16
	29	20

RS Cephei

Nov.	12	7
	24	17

RW Geminorum

Nov.	2	5
	5	2
	7	23
	10	20
	13	16
	16	13
	19	10
	22	7
	25	4
	28	0
	30	21

RW Monoc.

Nov.	2	22
	4	19
	6	17
	8	15
	10	13

RW Monoc.

	d	h
Nov.	12	10
	14	8
	16	6
	18	4
	20	1
	21	23
	23	21
	25	19
	27	16
	29	14

RU Monoc.

Nov.	1	5
	2	3
	3	0
	3	22
	4	19
	5	17
	6	14
	7	12
	8	9
	9	7
	10	4
	11	2
	11	23
	12	21
	13	18
	14	16
	15	13
	16	11
	17	8
	18	6
	19	4
	20	1
	20	23
	21	20
	22	18
	23	15
	24	13
	25	10
	26	8
	27	5
	28	3
	29	0
	29	22
	30	19

R Canis Maj.

Nov.	1	22
	3	2
	4	5
	5	8
	6	11
	7	15
	8	18
	9	21
	11	0

R Canis Maj

	d	h
Nov.	12	4
	13	7
	14	10
	15	14
	16	17
	17	20
	18	23
	20	3
	21	6
	22	9
	23	12
	24	16
	25	19
	26	22
	28	1
	29	5
	30	8

Y Camelop.

Nov.	4	1
	7	8
	10	15
	13	23
	17	6
	20	13
	23	21
	27	4
	30	11

RR Puppis

Nov.	3	15
	10	1
	16	11
	22	22
	29	8

V Puppis

Nov.	1	6
	2	17
	4	4
	5	14
	7	1
	8	12
	9	23
	11	10
	12	21
	14	8
	15	19
	17	6
	18	17
	20	4
	21	14
	23	1
	24	12
	25	23
	27	10
	28	21
	30	8

Minima of Variable Stars of the Algol Type.—Continued.

S Cancri

	d	h
Nov.	7	2
	16	14
	26	1

S Velorum

Nov.	3	1
	8	23
	14	21
	20	20
	26	18

RR Velorum

Nov.	2	3
	3	23
	5	20
	7	16
	9	13
	11	9
	13	6
	15	2
	16	23
	18	19
	20	16
	22	12
	24	9
	26	5
	28	2
	29	22

SS Carinæ

Nov.	3	23
	7	7
	10	14
	13	21
	17	4
	20	12
	23	19
	27	2
	30	9

Z Draconis

Nov.	1	11
	3	20
	4	4
	5	13
	7	21
	8	6
	9	14
	10	23
	12	8
	13	16
	15	1
	16	9
	17	18
	19	2
	20	11
	21	20
	23	4
	24	13
	25	21
	27	6
	28	14
	29	23

R Aræ

	d	h
Nov.	5	5
	9	15
	18	12
	22	22
	27	8

U Ophiuchi

Nov.	1	8
	2	4
	3	0
	3	21
	4	17
	5	13
	6	9
	7	5
	8	1
	8	21
	9	17
	10	14
	11	10
	12	6
	13	2
	13	22
	14	18
	15	14
	16	11
	17	7
	18	3
	18	23
	19	19
	20	15
	21	11
	22	7
	23	4
	24	0
	24	20
	25	16
	26	12
	27	8
	28	4
	29	0
	29	21
	30	17

Z Herculis

Nov.	3	0
	7	0
	10	23
	14	23
	18	23
	22	23
	26	23
	30	23

RS Sagittarii

Nov.	3	1
	5	11
	7	21
	10	7
	12	17
	15	3
	17	13
	19	23

RS Sagittarii

	d	h
Nov.	22	9
	24	19
	27	5
	29	15

V Serpentis

Nov.	3	14
	7	1
	10	12
	13	23
	17	10
	20	21
	24	7
	27	18

RX Herculis

Nov.	1	7
	2	4
	3	2
	3	23
	4	20
	5	18
	6	15
	7	12
	8	10
	9	7
	10	4
	11	2
	11	23
	12	20
	13	18
	14	15
	15	13
	16	10
	17	7
	18	5
	19	2
	19	23
	20	21
	21	18
	22	15
	23	13
	24	10
	25	7
	26	5
	27	2
	27	23
	28	21
	29	18
	30	15

SX Sagittarii

Nov.	1	10
	3	12
	5	14
	7	16
	9	18
	11	20
	13	21
	15	23
	18	1
	20	3

SX Sagittarii

	d	h
Nov.	22	5
	24	7
	28	10
	30	12

RR Draconis

Nov.	3	17
	6	13
	9	9
	12	5
	15	1
	17	21
	20	17
	23	13
	26	9
	29	4

U Scuti

Nov.	1	6
	2	5
	3	4
	4	2
	5	1
	6	0
	6	23
	7	22
	8	21
	9	20
	10	19
	11	18
	12	13
	13	16
	14	15
	15	13
	16	12
	17	11
	18	10
	19	9
	20	8
	21	7
	22	6
	23	5
	24	4
	25	3
	26	2
	27	0
	27	23
	28	22
	29	21
	30	20

RX Draconis

Nov.	2	15
	4	13
	6	10
	8	8
	10	5
	12	3
	14	0
	15	21
	17	19
	19	16
	21	14

RX Draconis

	d	h
Nov.	23	11
	25	9
	27	6
	29	4

RV Lyræ

Nov.	3	12
	7	2
	10	16
	14	7
	17	21
	21	11
	25	2
	28	16

U Sagittae

Nov.	3	9
	6	19
	10	4
	13	13
	16	22
	20	7
	23	16
	27	1
	30	10

SY Cygni

Nov.	2	12
	8	12
	14	12
	20	12
	26	13

WW Cygni

Nov.	2	16
	6	0
	9	7
	12	15
	15	23
	19	6
	22	14
	25	22
	29	5

SW Cygni

Nov.	2	18
	7	8
	11	21
	16	11
	21	1
	25	15
	30	4

VW Cygni

Nov.	7	22
	16	8
	24	19

UW Cygni

Nov.	1	16
	5	3
	8	14
	12	1
	15	12
	18	22
	22	9
	25	20
	29	7

Minima of Variable Stars of the Algol Type.—Continued.

W Delphini			VV Cygni			VV Cygni			VV Cygni			VV Cygni		
	d	h		d	h		d	h		d	h		d	h
Nov.	4	19	Nov.	2	9	Nov.	11	6	Nov.	20	3	Nov.	28	23
	9	15		3	21		12	17		21	14		30	11
	14	10		5	8		14	5		23	1			
	19	5		6	20		15	16		24	13			
	24	1		8	7		17	4		26	0	UZ Cygni		
	28	20		9	18		18	15		27	12	Nov.	2	0

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

Y Aurigæ	d	h
	(—0	18)
Nov.	3	7
	7	4
	11	0
	14	21
	18	17
	22	14
	26	11
	30	7

T Monoc.		
	(—7	23)
Nov.	4	12

W Geminorum		
	(—2	22)
Nov.	7	10
	15	8
	23	6

ζ Geminorum		
	(—5	0)
Nov.	9	23
	20	3
	30	7

RW Cassiop.		
	(—9	12)
Nov.	20	20

V Carinæ		
	(—2	4)
Nov.	1	3
	7	20
	14	12
	21	5
	27	22

T Velorum		
	(—1	10)
Nov.	1	1
	5	16
	10	7
	14	23
	19	14
	24	5
	28	21

W Carinæ	d	h
	(—1	0)
Nov.	1	9
	5	18
	10	3
	14	11
	18	20
	23	5
	27	14
	31	23

S Muscæ		
	(—3	11)
Nov.	8	15
	18	7
	27	22

T Crucis		
	(—2	2)
Nov.	7	1
	13	19
	20	12
	27	6

R Crucis		
	(—1	10)
Nov.	2	13
	8	9
	14	4
	20	0
	25	20

S Crucis		
	(—1	12)
Nov.	2	21
	7	14
	12	6
	16	23
	21	15
	26	8

W Virginis		
	(—8	5)
Nov.	6	6
	23	13

V Centauri		
	(—1	11)
Nov.	4	11
	9	23
	15	11
	20	23
	26	11

R Triang. Austr.	d	h
	(—1	0)
Nov.	2	9
	5	18
	9	4
	12	13
	15	22
	19	8
	22	17
	26	2
	29	12

S Triang. Austr.		
	(—2	2)
Nov.	2	5
	8	12
	14	20
	21	4
	27	12

S Normæ		
	(—4	10)
Nov.	1	19
	11	13
	21	7
	30	1

RV Scorpii		
	(—1	10)
Nov.	5	3
	11	5
	17	6
	23	8
	29	9

RV Ophiuchi Minimum.		
Nov.	3	6
	6	22
	10	15
	14	7
	18	0
	21	16
	25	9
	29	1

X Sagittarii	d	h
	(—2	22)
Nov.	6	9
	13	9
	20	10
	27	10

Y Ophiuchi		
	(—6	5)
Nov.	1	14
	18	17

W Sagittarii		
	(—3	0)
Nov.	5	7
	12	21
	20	12
	28	2

Y Sagittarii		
	(—2	2)
Nov.	6	2
	11	21
	17	15
	23	10
	28	4

U Sagittarii		
	(—2	23)
Nov.	7	13
	14	7
	21	1
	27	18

β Lyræ		
	(—3	2)
	(—3	7)
Nov.	6	22
	13	14
	19	20
	26	12

κ Pavonis		
	(—1	7)
Nov.	1	20
	10	22
	20	1
	29	3

U Aquilæ	d	h
	(—2	4)
Nov.	1	19
	8	19
	15	19
	22	20
	29	20

U Vulpeculæ		
	(—2	3)
Nov.	8	3
	16	3
	24	2

SU Cygni		
	(—1	7)
Nov.	2	10
	6	6
	10	2
	13	23
	17	19
	21	15
	25	12
	29	8

η Aquilae		
	(—2	6)
Nov.	4	8
	11	13
	18	17
	25	21

S Sagittae		
	(—3	10)
Nov.	1	21
	10	6
	18	15
	27	0

X Vulpeculæ		
	(—2	1)
Nov.	1	16
	7	23
	14	7
	20	15
	26	22

V Vulpeculae Minimum		
Nov.	17	3

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

X Cygni

	d	h
	(−6	19)
Nov.	6	14
	22	23

T Vulpeculae

	d	h
	(−1	10)
Nov.	4	9
	8	20
	13	6
	17	16
	22	3
	26	13

WZ Cygni Alternate Minima

	d	h
Nov.	2	3
	3	7
	4	11
	5	15
	6	19
	7	23

WZ Cygni

	d	h
Nov.	9	3
	10	7
	11	11
	12	15
	13	19
	15	0
	16	4
	17	8
	18	12
	19	16
	20	20
	22	0
	23	4
	24	8
	25	12
	26	16
	27	20
	29	0
	30	4

TX Cygni

	d	h
Nov.	4	11
	19	4

VY Cygni

	d	h
	(−2	14)
Nov.	3	7
	19	1
	26	21

VZ Cygni

	d	h
	(−2	12)
	(−3	6)
Nov.	10	12
	15	12
	20	6
	25	6
	29	23

δ Cephei

	d	h
	(−1	10)
Nov.	2	20
	8	5
	13	14
Nov.	18	23
	24	7
	29	16

V Lacertae

	d	h
	(−0	17)
Nov.	5	12
	10	12
	15	11
	20	11
	25	11
	30	10

X Lacertae Minimum

	d	h
Nov.	4	13
	10	0
	15	11
	20	21
	26	8

RS Cassiop.

	d	h
	(−1	19)
Nov.	5	20
	12	3
	18	10
	24	17

RV Cassiop.

	d	h
	(−7	10)
Nov.	7	0
	19	4
	31	7

Y Lacertae

	d	h
	(−1	10)
Nov.	4	4
	8	12
	12	19
	17	3
	21	10
	25	18
	30	1

Approximate Magnitudes of Variable Stars on September 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R.A. 1900.		Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
X Androm.	0	10.8	+46	27	8.8 *i*	R Urs. Maj.	10	37.6	+69	18	7.5 *i*
T Androm.		17.2	+26	26	<13.5	T Can. Ven.	12	25.2	+32	3	11.0*d*
T Cassiop.		17.8	+55	14	8.0 *i*	T Urs. Maj.		31.8	+60	2	8.0 *i*
R Androm.		18.8	+38	1	7.7	RS Urs. Maj.		34.4	+59	2	10.3 *i*
U Cassiop.		40.8	+47	43	<13.5	S Urs. Maj.		39.6	+61	38	7.5 *i*
RW Androm.		41.9	+32	8	10.8*d*	R Can. Ven.	13	44.6	+40	2	10.8 *i*
W Cassiop.		49.0	+58	1	9.4	Z Bootis	14	1.7	+13	59	13.4*d*
RX Androm.		58.9	+40	46	12.0	U Urs. Min.		15.1	+67	15	9.8 *i*
Z Ceti	1	1.6	− 2	1	10.0 *i*	S Bootis		19.5	+54	16	12.4*d*
U Androm.		9.8	+40	11	<13.0	V Bootis		25.7	+39	18	8.0 *i*
S Piscium		12.4	+ 8	24	<13.2	R Camelop.		25.1	+84	17	13.0*d*
S Cassiop.		12.3	+72	5	9.8*d*	R Bootis		32.8	+27	10	7.6*d*
U Piscium		17.7	+12	21	<13.0	U Bootis		49.7	+18	6	11.5*d*
R Piscium		25.5	+ 2	22	11.8	RT Librae	15	0.8	−18	21	13.6*d*
RU Androm.		32.8	+38	10	10.0	T Librae		5.0	−19	38	<13.0
S Arietis		59.3	+12	3	13.0	Y Librae		6.4	− 5	38	11.6 *i*
W Androm.	2	11.2	+43	50	8.2	S Librae		15.6	−20	2	7.8
Z Cephei		12.8	+81	13	9.5 *i*	S Serpentis		17.0	+14	40	9.0
o Ceti		14.3	− 3	26	5.5 *i*	S Coronae		17.3	+31	44	12.8*d*
R Ceti		20.9	− 0	38	10.2	RS Librae		18.5	−22	33	7.5
U Ceti		28.9	−13	35	9.8	RU Librae		27.7	−14	59	11.7*d*
R Trianguli		31.0	+33	50	11.2	X Librae		30.4	−20	50	11.0 *i*
T Arietis		42.8	+17	6	8.9	S Urs. Min.		33.4	+78	58	10.1*d*
Y Persei	3	20.9	+43	50	8.7	U Librae		36.2	−20	52	12.0 *i*
R Persei		23.7	+35	20	12.4*d*	Z Librae		40.7	−20	49	12.0 *i*
T Camelop.	4	30.4	+65	57	12.4	R Coronae		44.4	+28	28	6.1
R Aurigae	5	9.2	+53	28	13.0	X Coronae		45.2	+36	35	7.9 *i*
U Orionis		49.9	+20	10	10.0*d*	V Coronae		46.0	+39	52	12.0*d*
S Lyncis	6	35.9	+58	0	9.0 *i*	R Serpentis		46.1	+15	26	8.8*d*
R Lyncis		53.0	+55	28	13.0 *i*	R Librae		47.9	−15	56	10.0 *i*
X Urs. Maj.	8	33.7	+50	30	13.8*d*	RR Librae		50.6	−18	1	13.0
Y Draconis	9	31.1	+78	18	11.2*d*	Z Coronae		52.2	+29	32	9.0 *i*

Approximate Magnitudes of Variable Stars on Aug. 1, 1908—Con.

Name.	h	R. A. 1900. m	Decl. 1900. °	′	Magn.	Name.	h	R. A 1900 m	Decl. 1900 °		Magn.
RZ Scorpii	15	58.6	−23	50	8.0 *i*	U Lyrae	19	16.6	+37	42	<13.0
Z Scorpii	16	0.1	−21	28	11.4*d*	T Sagittae		17.2	+17	28	9.8*d*
R Herculis		1.7	+18	38	13.0*d*	TY Cygni		29.8	+28	6	9.8 *i*
RR Herculis		1.5	+50	46	8.0	R Cygni		34.1	+49	58	9.4*d*
U Serpentis		2.5	+10	12	12.2*d*	RV Aquilae		35.9	+ 9	42	13 0*d*
X Scorpii		2.7	−21	16	12.5*d*	RT Cygni		40.8	+48	32	10.0*d*
W Scorpii		5.9	−19	53	10.6	X Aquilae		46.5	+ 4	13	12.0 *i*
RX Scorpii		5.9	−24	38	11.7*d*	χ Cygni		46.7	+32	40	9.7*d*
RU Herculis		6.0	+25	20	8.3 *i*	RR Aquilae		52.4	− 2	11	11.0*d*
R Scorpii		11.7	−22	42	<13.5	RS Aquilae		53.7	− 7	9	13.0
S Scorpii		11.7	−22	39	9.5 *i*	Z Cygni		58.6	+49	46	10.6 *i*
W Coronae		11.8	+38	3	9.8*d*	SY Aquilae	20	2.3	+12	39	11.5*d*
W Ophiuchi		16.0	− 7	28	11.7*d*	S Cygni		3.4	+57	42	13.9
V Ophiuchi		21.2	−12	12	9 0 *i*	R Capricorni		5.7	−14	34	<13.5
U Herculis		21.4	+19	7	7.5 *i*	S Aquilae		7.0	+15	19	11.3*d*
Y Scorpii		23.8	−19	13	11.2*d*	RU Aquilae		8.0	+12	42	<13.6
SS Herculis		28.0	+ 7	3	12.0*d*	W Capricorni		8.6	−22	17	<13.6
W Herculis		31.7	+37	32	8.0 *i*	Z Aquilae		9.8	− 6	27	11.6*d*
R Draconis		32.4	+66	58	12.6*d*	RS Cygni		9.8	+38	28	8.0
S Herculis		47.4	+15	7	9.2 *i*	R Delphini		10.1	+ 8	47	9.1*d*
RV Herculis		56.8	+31	22	13.2	RT Capricorni		11.3	−21	38	8.0
R Ophiuchi	17	2.0	−15	58	10.2 *i*	SX Cygni		11.6	+30	46	10.0
RT Herculis		6.8	+27	11	<13.0	U Cygni		16.5	+47	35	8.1*d*
Z Ophiuchi		14.5	+ 1	37	7.8 *i*	RW Cygni		25.2	+39	39	8.8*d*
RS Herculis		17.5	+23	1	7.8 *i*	RU Capricorni		26.7	−22	2	<13.0
RU Ophiuchi		28.5	+ 9	30	9.2 *i*	Z Delphini		28.1	+17	7	<13.5
RS Ophiuchi		44.8	− 6	40	11.2	ST Cygni		29.9	+54	38	9.6*d*
RT Ophiuchi		51.8	+11	11	<13.6	Y Delphini		36.9	+11	31	<13.7
RY Herculis		55.4	+19	29	10.5 *i*	S Delphini		38.5	+16	44	9.0
V Draconis		56.3	+54	53	<13.0	T Delphini		40.7	+16	2	12.0*d*
T Herculis	18	5.3	+31	0	11.0	V Aquarii		41.8	+ 2	4	8.0
W Draconis		5.4	+65	56	<13.5	W Aquarii		41.2	− 4	27	9.4 *i*
X Draconis		6.8	+66	8	<13.5	V Delphini		43.2	+18	58	11.0*d*
RY Ophiuchi		11.6	+ 3	40	1.22*d*	T Aquarii		44.7	− 5	31	8.0
W Lyrae		11.5	+36	38	8.8*d*	RZ Cygni		48.5	+46	59	9.1*d*
SV Herculis		22.3	+24	58	11.0*d*	X Delphini		50.3	+17	16	10.1 *i*
T Serpentis		23.9	+ 6	14	13.0	— Delphini		50.3	+17	13	13.0
RZ Herculis		32.7	+25	28	8.5 *i*	R Vulpeculae		59.9	+23	26	11.4*d*
X Ophiuchi		33.6	+ 8	44	8.3*d*	X Cephei	21	3.6	+82	40	10.0 *i*
RY Lyrae		41.2	+34	34	13.0	R Equulei		8.4	+12	23	8.8 *i*
RW Lyrae		42.1	+43	32	13.1	T Cephei		8.2	+68	5	7.5*d*
Z Lyrae		56.0	+34	49	12.0*d*	RR Aquarii		9.8	− 3	19	8.0 *i*
RX Lyrae		50.4	+32	42	13.0 *i*	X Pegasi		16.3	+14	2	11.4*d*
ST Sagittarii		55.9	−12	54	<14.0	S Cephei		36.5	+78	10	8.3*d*
RT Lyrae		57.8	+37	22	11.0 *i*	RU Cygni		37.3	+53	52	8.0*d*
R Aquilae	19	1.6	+ 8	5	10.0 *i*	RR Pegasi		40.0	+24	33	12.5*d*
V Lyrae		5.2	+29	30	<14.0	V Pegasi		56.0	+ 5	38	10.0 *i*
RX Sagittarii		8.7	−18	59	12.4*d*	RT Pegasi		59.8	+34	38	11.0 *i*
RW Sagittarii		8.1	−19	2	8.9	Y Pegasi	22	6.8	+13	52	12.0*d*
S Lyrae		9.1	+25	50	<13.6	RS Pegasi		7.4	+14	4	12. 8
RS Lyrae		9.3	+33	15	13 4	S Lacertae		24.6	+39	48	11.4*d*
RU Lyrae		9.1	+41	8	11.0 *i*	R Lacertae		38.8	+41	51	8.0 *i*
U Draconis		9.9	+67	7	13.3*d*	RW Pegasi		59.2	+14	46	10.3*d*
W Aquilae		10.0	− 7	13	11.4*d*	R Pegasi	23	1.6	+10	0	9.2 *i*
T Sagittarii		10.5	−17	9	8.3*d*	V Cassiop.		7.4	+59	8	12.6*d*
RY Sagittarii		10.0	−33	42	7.0	Z Cassiop.		28.8	+48	16	10.5*d*
R Sagittarii		10.8	−19	29	10.5*d*	ST Androm.		33.8	+35	13	11.0 *i*
RT Aquilae		33.3	+11	30	11.6*d*	R Cassiop.		53.3	+50	50	8.0 i
S Sagittarii		13.6	−19	12	11.5*d*	Z Pegasi		55.0	+25	21	11.2 *i*
Z Sagittarii		13.8	−21	7	10.0*d*	Y Cassiop.		58.2	+55	7	10.4*d*

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whiteside, Taft and Harvard Observatories.

GENERAL NOTES.

Brilliant Meteorite. N. Curream Jr., of New Bedford, Mass., observed a brilliant meteorite September 4, 1908, at 8^h 29^m, Eastern Standard time. Two person were with him, at the time, on the roof of a house watching an auroral display, when this meteorite made its appearance in the vicinity of θ Ursæ Majoris and disappeared near the star Capella in Auriga which was close to the horizon in a northwest direction. Its motion was slow, and its color whitish yellow and its train was well marked. It was seen to explode into many fragments of a bluish color, but their fall to the ground could not be observed neither could any sound be heard at the time of the explosion because of the noise in the streets near by.

The train was in view for about twelve seconds of time.

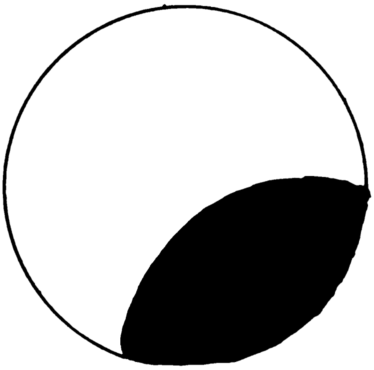
Manora Observatory in Lussinpiccolo (Austria) has been purchased by a private party who plans to continue astronomical work under the direction of Herr Brenner as heretofore. The observatory will be moved 100 meters north of its present place to a permanent position, and the work of the Observatory will be pertaining to the planets.

One Satellite of Jupiter Occults Another. A. Thos. G. Apple director of the Daniel Scholl Observatory, Franklin and Marshall College Lancester, Pa., made an interesting observation on the evening of March 16, 1908. It was reported August 21, 1908.

In watching the eclipse of Jupiter's second satellite, it was seen to reappear about ten seconds of arc from the first satellite. The two satellites were observed to approach each other and when in conjunction occultation took place. The seeing was good, for while ω Leonis could be separated with a 11.5-inch telescope of the Observatory, the two satellites could not be separated.

The Solar Eclipse of June 28, 1908. The most favorable land view of the solar eclipse of June 28 last was from the central plains of Florida, where for nearly four minutes the interesting annular phase was visible over a pathway about eighty-six miles in width. Near 11 A. M. when the Sabbath bells were tolling, and prayer and preaching had chief attention in the scattered cities, a strange gloom glided from over the Gulf, and dissolving the shadows of the steeples gave to the landscape an aspect differing essentially from that of sunrise, sunset or a merely clouded sky. In each of these cases the upper air is brilliantly illuminated, whereas an eclipse dims even the topmost vapors. Only about one-fourteenth of full sunlight was emitted by the slender rim of the solar disk that encircled the dark Moon. That an eclipse may be thus central and not total is a vivid demonstration of the varying distance of the Earth's satellite. Were it in perigee or the nearest point of the lunar orbit its dark shadow would have swept over our globe, and in many places, the eclipse would have been total; but in the recent case, being near apogee, it was about thirty miles more distant, and the shadow terminated several thousand miles above the surface. Thus, though the June Sun had almost its least diameter of 31′ 34″ the apogean Moon was insufficient to cover it.

Nine degrees north and forty degrees west of Florida, our view of the phenomenon was an obscuration of the southwest portion of the early Sun. Owing to a lunar parallactic effect, or the different positions the Moon seems to occupy in the heavens when observed from localities far apart, the two conspicuous spots on the Sun's disk were not encroached upon, as elsewhere, though nearly three-tenths of it were hidden by the invading shadow. As the dark concavity increased and then decreased it was easy to realize the progress of our satellite between its primary and the great luminary.



At a few minutes past eight the final trace of dimness disappeared on the lower limb of the Sun, the entire phase having lasted one hour and thirty-seven minutes.

Rose O'Halloran.

San Francisco, Sept. 7, 1908.

An Aurora which was very unusual was observed here on Friday night, Sept. 4, 1908. The display continued from the time darkness set in until at least after midnight. The entire northern and eastern part of the heavens, from the horizon to the zenith was luminous with the light of the streamers. The display commenced in the northern sky, circling around towards the northwest, and then as the night advanced, gradually moved eastwards until by midnight, they were coming from due east. Some of the streamers coursed southwards almost as far as the planet Saturn, though none that I observed actually reached the planet. The light was flashed in broad beams resembling the flashes from a distant flashlight, and the beams were from ten to one hundred degrees of sky-space in length. At times many of them were flashing simultaneonsly, crossing and recrossing one another. Fully one-third of the sky was luminous at times by this display; and stars as bright as those of the second magnitude were obscured by the light. I do not remember having observed the extinction of any first magnitude stars, partly because not many were in the near neighborhood of the aurora,—Capella had arisen, and although many other stars were invisible during the brighter portion of the illumination, still at no time was Capella hidden from sight. All of the principal stars of Cassiopeia were hidden very often; as were also the North Star, the principal stars of Ursa Major and Ursa Minor, the brighter stars of Perseus, Andromeda, and other constellations towards the north. Algol too was often hidden, and even as far south as Aries the bright stars suffered extinction quite frequently. I never remember having observed a similar display.

On the 14th inst., using a four-inch refracting telescope I observed four large spots on the sun; and in the southwestern quadrant a fairly-well dispersed group of spots was very visible. On the 20th instant I observed no fewer than seven large spots. The central one, (and it was almost exactly in the center of the sun's visible (surface was accompanied by a large number of much smaller spots. The largest spot was in that group, and comparing it as well as my memory will permit, with others observed at other times, and which were measured, I would say it must have been twenty or twenty-five thousand miles in length. We have had very poor skies here lately, the Sun struggling to makes its appearance, and then succeeding but imperfectly, and the stars so faint that a four-inch refractor was barely able to enable an observer to view and hold Saturn's largest satellite, Titan, while stars below the second magnitude were hardly visible to the unaided eye. Last night, however, saw a marked improvement.

Sept. 21, 1908. ALBERT R. J. F. HASSARD,
Toronto, Canada.

Radiant Point for Meteors from Halley's Comet. A near approach of Halley's comet to the Earth on May 12, 1910 is indicated by the recent elements of Messrs. Cowell and Crommelin as given in the Monthly Notices of the R. A. S. for March 1908. Using the ephemeris of Dr. Smart in the same publication, and plotting his Δ's, I find by a graphical interpolation, that the distance of the comet from the Earth on the above date will be about 0.05 or about 4.6 million miles. It therefore seems probable that we may encounter some meteors. Accordingly I have calculated the radiant point for that date. As the eccentricity of the orbit of the comet does not differ greatly from unity and that of the Earth from zero, being respectively 0.96729 and 0.01677, I have made the calculation in three different ways, in order to note the difference in the results. In case 1, the actual eccentricities of both orbits were used in the computation, this being the correct method. In case 2, the eccentricity of the comet's orbit was assumed to be unity and of the Earth's orbit 0.01677, being the correct value of the latter. In case 3, the eccentricity of the comet's orbit was assumed to be unity and that of the Earth, zero.

The three results for the radiant point are given below in the above order.

CASE 1.

R. A. $22^{h}\ 42^{m}.9$ Dec. $+1^{\circ}\ 18'$

CASE 2.

R. A. $22^{h}\ 44^{m}.9$ Dec. $+1^{\circ}\ 29'$

CASE 3.

R. A. $22^{h}\ 45^{m}.9$ Dec. $+1^{\circ}\ 32'$

It will be noticed that the three results do not differ greatly, the first, or correct value, differing from the last by three minutes of time and fourteen minutes of arc; while the result in the second case is intermediate between the other two.

O. C. Wendell.

Harvard College Observatory.

Probable Nature of the Corona. The nature of the radiation of the inner corona has been supposed by some to be principally reflected solar radiation, by others principally due to the incandescence of particles heated by reason of their proximity to the Sun; by others principally luminescence, perhaps similar to the aurora; and by some as a combination of all these kinds of radiation.

A satisfactory theory of the corona must take cognizance of the following facts at least:

1. The color of the corona does not appear to change at varying distances from the limb of the Sun, and the transmissibility of its rays to the asphaltum screen is the same at 1′.5 and 4′.0 from the limb.

2. Its brightness is very small and falls off rapidly with increasing distance from the limb.

3. Its spectrum is mainly continuous near the limb, but shows dark Fraunhofer lines, more and more distinctly, at increasing distances therefrom. A few not very conspicuous bright spectral lines are present near the limb, and perhaps in the outer corona also.

4. Its light is polarized in the outer regions, but polarization grows less marked, and at length disappears near the limb.

5. Its brightness is almost, but not quite, as little transmissible to the asphaltum screen as that of the Sun itself; and far less so than the reflected brightness of ths Moon, but far more so than the reflected brightness of the sky.

6. Any kind of matter so near the Sun must be hot, and must reflect solar rays.

7. There is no evidence of high pressure in the corona.

The considerations (3), (5), and (7), taken together, are hard to satisfy. For if the inner corona were hot enough to give out a spectrum of incandescence satisfying (5), the matter composing it must be gaseous if it is like any matter we know of. Accordingly we should expect a bright line spectrum like that of the chromosphere if the inner corona shines chiefly by incandescence; and furthermore we should expect its rays to increase in transmissibility to the screen, and grow red to the eye, with increasing distance from the Sun.

If we may suppose that the temperature of the corona is everywhere low enough to allow solid or liquid particles to be formed, then all the specifications excepting (3) are easily satisfied by the hypothesis of a corona of reflection. Our knowledge is not sufficient to enable us to prove that the particles even of the inner corona would be too hot to be mainly liquid (that is to say about 3000° to 3500°). If they were all gaseous, the rays reflected would probably be richer than Sun rays in visible light, and this would be contrary to (5). May it not be that while a large proportion of the particles of the inner corona is gaseous, a considerable proportion is liquid or solid? Then may not the light of the inner corona be mainly reflected, like that of the outer corona, but with the bright line spectrum of incandescent gases present in sufficient strength to nearly obliterate the dark Fraunhofer lines of the reflected Sun rays? The continuous spectrum of the incandescent solid and liquid particles present would tend to increase the transmissibility of the coronal brightness to the asphaltum screen; so that the opposite tendency of the diffuse reflection of the gaseous particles would be counteracted. At increasing distances from the limb we may suppose the particles would be cooler and mainly solid or liquid, so that incandescence would wane, and a dark line spectrum would gradually appear. Still the transmissibility and color would be still mainly reflected sunlight, and the particles now so large as not to enrich the proportion of the blue light, but rather slightly to decrease it.

As for the attractive hypothesis of the electrical discharge luminescence, like that of the aurora, one hesitates to recommend recourse to a source so little known. So far as known, too, this hypothesis like the others, has difficulty to reckon with the character of the photographic coronal spectrum.

The cause of the corona-brightness seems very difficult to decide in view of conflicting considerations; but in the judgment of the writer, the hypothesis that it is due to the reflection of ordinary Sun rays, but diluted by radiation of incandescence and perhaps also of luminescence, seems most tenable.

In conclusion it is a pleasure to acknowledge the great aid afforded by the Directors and staff of the Lick Observatory expedition; the conscientious and able work of my assistant Mr. Moore; the intelligent and faithful assistance rendered on the day of the eclipse by Chief Yeoman Chase of the *Annapolis*, and the uniformly cordial and courteous attentions of Governor Moore and the officers of the *Annapolis*, and of many others during the time when the expedition was in transit.

C G. ABBOT.

LICK OBSERVATORY BULLETIN Number 132.

The Canals of Mars. During the summer Percival Lowell has published some interesting matter about the Canals of Mars in prominent magazines that received much attention. Some comments have been favorable and some unfavorable. The extreme views of the writers on either side have not gained the general support of astronomers as far as we know. The intention of the editors of this magazine has been to give the work of practical astronomers a fair presentation in its pages, and leave to the authors the responsibility of the opinions they offer as drawn from what they observe by the aid of the telescope. In this way we have given Mr. Lowell's work full attention because, as largely new matter it has deserved it. If he is not right in his conclusions he is responsible as a scientific man of ability and of remarkable devotion to his work.

In the same spirit we give below an extract from an address by Prof. Harold Jacoby of Columbia University which is a severe criticism on Mr. Lowell's work. We must not be considered as subscribing to these opinions about Martian observation:

"And now let me contrast with this another modern research that seems to illustrate the kind of scientific work sometimes undertaken in ignorance of the true test of value. I refer to the canals of Mars. By no conceivable possibility can this work convey to any one an impression of life everlasting

About it all is an air of unreality; one feels almost as if mankind would forget it before actually becoming aware of its existence. The strongest argument in favor of Martian canals is the intense desire of certain human beings to know other planets inhabited.

If I may be permitted to do so, I should like to turn aside here for a moment, and inquire what we mean by *seeing* a thing. What is the actual process? Light waves coming from the object under examination travel through the luminiferous ether, and finally impinge upon the outer surface of the eye, like surf breaking on an ocean shore. They are concentrated or brought to a focus by the lens in our eye, and produce some kind of an effect which we do not quite understand upon the rods and cones of the retina. This results in an impression being received by the brain, *via* the optic nerve. The brain in its turn does an unexplained something with this impression; what we think we see is equal to that which came through the eye and optic nerve plus what the brain does to it on the arrival at headquarters. It is this little *plus*, I fear that has helped to create the Martian canals and especially the intelligent engineers who built them. The human brain cannot distinguish between that which comes through the optic nerve, and that which the brain adds to it. The sum is what we seem to see.

Once started on the downward path to discovery, the rest is easy. We see what we desire and hope to see; do what we will we cannot prevent this; as Shakespeare says 'Increase of appetite had grown by what it fed on.' "
—THE OBSERVATORY, September, 1908.

The Dispersion of Light in Space. A rather remarkable series of articles has been lately appearing in the *Comptes Rendus* by M. C. Nordmann, of Paris, and M. Tikoff, of Poulkova, relating to experiments made to determine whether light in its passage from a star to the Earth passes through a medium capable of refracting and dispersing it. The experiment consists in determining the light-curves for Algol variable stars for different regions of the spectrum. M. Nordmann examined Algol and λ Tauri, and found that the amplitude and form of the curve are the same for all regions of the spectrum in the case of both stars, but that the phases of the red image are in advance of the blue image, whilst the curves of variation of the green light have an intermediate position in this respect The observations show the following provisional results. The red rays from Algol reach us 16 minutes in advance of the violet rays, and for λ Tauri the advance of the red rays is about three times as great. M. Tikhoff at Poulkova has found similar results from RT Persei and W Ursæ Majoris; but if these experiments prove to be conclusive and the deductions from them well founded, we have to reverse some previous ideas, for it has hitherto been generally held that light of all colors travels through space with identical velocity. In 1882 some experiments by Fizeau's method were made by Messrs. Young and Forbes to prove this, and they arrived at the result that the velocity of the blue rays was about 1.8 per cent greater than that of the red, which is directly opposed to the result of the recent celestial experiments. It has often been pointed out that if such difference of velocity of light of different colors existed, the images of all stars would be lengthened into spectra, there would be a difference of color in a star immediately before and after occultation by the Moon, and similarly other peculiar phenomena would be observed which are not, so that it may be well not to consider this difference of velocity as yet proved.

In a later number of the *Comptes Rendus* (1908 June 15), M. Pierre Lebedew raises objections to this explanation of the observations. He says that the dispersion required by the observations is so great that if we assume it to exist in ordinary gaseous matter it would have an absorption so great that we should not be able to see the stars nor even the Sun. M. Lebedew suggests as another explanation that in the case of a star whose variation of light is caused by an occulting satellite, the observed effects would be caused if the satellite had an atmosphere which absorbed the light of the central star and did not surround the body symmetrically. M. Tikhoff replies to this in a later number.—THE OBSERVATORY, September, 1908.

Halley's Comet. Halley's comet, observed by Halley in 1682, the most sensational of the sky truants known to astronomers, is heading this way again on the visit which it makes every 75 years.

This news comes by way of mundane communication with the Yerkes observatory at Lake Geneva, where elaborate preparations are being made for photographing the visitor. The first plate will be exposed within two weeks and at close intervals thereafter throughout the fall, winter and spring of 1908-9.

The comet will not be visible to the naked eye, however, until well along in 1909, and will swoop into its perihelion, the point of its course closest to the Sun, about May 10, 1910.

Will it strike the earth and smash things up into bits? This has been a popular fear ever since about 12 B. C., but the authorities now assert that the earth is bound to squeeze by with several million miles to spare.

According to the French astronomers there is no danger whatever from Halley's comet and only one chance in 281,000,000 from all the rest of the comets put together.

In its youth Halley's comet, it is said, was a pretty wild young thing and might have made no end of trouble had it not passed too close one day or night, to the planet Neptune, whose mass was so huge in comparison that it exercised an instantaneous attraction for the comet.

They didn't collide, but the comet swerved out of its path, and from being a celestial go-as-you-please turned to chasing its own tail in a perfectly regular ellipse about the Sun, with Neptune exercising a salutary check when its flight tends to the erratic. It is a harnessed, though brilliant thing.

No other comet has had the influence on the human race which this one has had through the dread inspired by its brilliancy and sensational size.

More than one English historian blames Halley's comet for the weakness of the Anglo-Saxon resistance to the invasion of William the Conqueror in 1066. Halley's comet was then flaming nightly in the skies, adding, in the eyes of the superstitious Angles and Saxons, supernatural prestige for the Norman arms.

What is this comet? Is it a metallic mass thrown off from the Sun and whirling through space? Its mass is estimated as equal to that of an iron ball 150 miles in diameter spread out so thin that the total volume of the nucleus, or head of the comet, is much greater than that of the Earth, or, in fact, of any of the planets.

As the comet approaches the Sun the heat drives out metallic vapors of iron and magnesium. As the heat increases the hydrocarbons break up into smoke or soot and trail behind. The bombardment of the Sun's rays on these minute soot particles lights them up to a silvery glow and also drives them out in a sweeping tail.—Detroit News.

The Great Red Spot on Jupiter. In number 4272 of the *Astronomische Nachrichten*, page 389, will be found an article by E. E. Barnard, of Yerkes Observatory, Williams Bay, Wisconsin, on The Great Red Spot of Jupiter. This article gives a brief account of its author's astronomical work on Jupiter during the last thirty years. Its aim is to show what influence the Red Spot has had on other prominent markings on the planet's surface. The accompanying cut, also from the *Astronomische Nachrichten*, shows the position of the Great Red Spot in the midst of the great southern belt, as seen by Mr. Barnard 1908 May 26, by the aid of the 40-inch refractor of Yerkes Observatory. The first satellite is seen just going off the planet's surface at the left, the satellite's black shadow is also seen in the white belt below the spot.

GREAT RED SPOT ON JUPITER
Photographed by E. E. Barnard, May 26, 1908.
13^h 52^m G. M. T.

Through the Depths of Space is a primer of Astronomy written by Hector Macpherson Jr., and published by William Blackwood and Sons of Edinburgh and London.

This young writer on astronomical subjects has already gained an enviable reputation as an author and an earnest student in dealing with themes that must interest the general reader. The field of modern astronomy is so broad and so varied that a well-read student in its best literature can find ample room and ample material for work of this kind. Mr. Macpherson has prepared under the name "Through the Depths of Space" a neat and scholarly monograph which he calls a primer of astronomy. Its eight plates presenting the Pleiades, Moon, Sun, Mars, Jupiter, Saturn, Daniel's Comet of 1907 and the North America Nebula in Cygnus are well chosen objects and what is almost equally important, they are from good half-tones and they are well printed.

The matter of the book is given in eight parts with titles: Our own planet; its place in nature; Moon; Sun; inner planets; outer planets, comets and meteors; stellar universe; in two chapters. It is written in paragraph form with heavy faced titles, so that reference to sub-heads is easy and natural, and the language used is simple, untechnical and direct.

The scientific spirit that characterizes this little book is of a high order. The author is not afraid to give an opinion on modern questions in astronomy, still in doubt, neither does he belittle or scoff at decided convictions of those holding opposing or radical views. Still more important, he can and does recognize, aptly and well, God as the great Author in all of the beautiful handiwork of the heavens. We think this is the secret of the young author's growing success and surprising ability as a writer.

The price of this primer is two English shillings.

Murray's Differential and Integral Calculus. It may be known to some readers, if not all, that Doctor Murray, the author of this new text is now Professor of Applied Mathematics in McGill University. It is also a fact that he has written text-books for schools and colleges on the Infinitesimal Calculus, plane and spherical Trigonometry and on Differential Equations. We have used some of these text-books and know of their value.

The new book before us is mainly made up from matter of his Infinitesimal Calculus, with additional matter relating to indeterminate forms, solid geometry and motion. We notice with special interest the articles that have been written in regard to velocity and acceleration. They will aid students in showing how to express, in mathematical language, the way these phenomena operate in nature, as determined so elegantly and so exactly by the principles of the Calculus.

Of course, this book is intended for beginners in the study of the Calculus; and so in its earlier parts treats of the elements of the branch quite fully and thoroughly. For example, the idea of a continuous function of a variable is set forth amply and in such varied way that a beginner ought to grasp it well from the first. The idea of continuity in the operation of a variable quantity is such a fundamental one in all the important parts of the Calculus, that the author has done well to emphasize it properly in the early pages of this book.

When the author takes up the work of differentiation, the notion of anti-differentiation is placed side by side with it, which is certainly well if not taken too far so as to divide the attention of the student while attempting to get a process that is entirely new to him in the kind of his thinking. A watchful teacher will easily guard this matter.

We notice with a little surprise that when this book takes up the subject of integration formally, it places the method of summation before that of the inverse process. It does not seem to us that this is the best order, because in the elementary work the inverse process is the more simple, being based on the thinking of what has gone before in differentiation and also on the anti-differentiation exercises already provided. There should be a fixed habit of doing in the mind of the student in the pure side of operation before he is asked to make an application of his new method of calculation to practical ends, unless he uses very simple illustrations. We do not think that the order the author has chosen makes a serious drawback for good. It is as he says a matter of choice in which good instructors differ in opinion.

On the whole this new book is a strong one. It is so well prepared that an earnest, ambitious student could study it without the aid of a teacher, and get along in it fairly well. It is also so extensive in the ground it covers and the long list of exercises and problems given, that it would take a good instructor with a class in college or technical school two full years to do it all as well as it should be done. This is our experience with classes in Calculus recently in preparing them for the best engineering schools in this country. That is not too much time to give to this very important part of a student's preparation if his mathematics is to mean something for him when he comes into the practical work of high grade engineering.

This new book contains 491 pages, its figures are many; they are well drawn; its printed page is easy for the eye, and its make-up is first class, such as its publishers, Messrs. Longmans, Greene & Co., always, so far as we know, send out.

Popular Astronomy.

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SOME ASTRONOMICAL FACTS AND FALLACIES.*

J. E. GORE.

The following astronomical facts and fallacies, which I have collected from various sources, are not usually mentioned in books on astronomy, and may prove of interest to the general reader.

It is mentioned in the "Anglo-Saxon Chronicle" that a total eclipse of the Sun took place in the year after King Alfred's great battle with the Danes. Now, calculation shows that this eclipse occurred on October 29, 878 A. D. King Alfred's victory over the Danes must therefore have taken place in A. D. 877, and his death probably occurred in A. D. 899. This solar eclipse is also mentioned in the "Annals of Ulster."

It is stated by many historians that an eclipse of the Sun took place on the morning of the battle of Crecy, August 26, 1346. But calculation shows that there was no eclipse of the Sun visible in England in that year. At the time of the battle the Moon had just entered on her first quarter, and she was partially eclipsed six days afterwards, on the 1st of September. The mistake seems to have arisen from a mistranslation of the old French word *esclistre*, which means lightning. This was mistaken for *esclipse*. The account seems to indicate that there was a very heavy thunderstorm on the morning of the famous battle.

A dark shade was seen on the waning Moon by Messrs. Hirst and J. C. Russell on October 21, 1878, "as dark as the shadow during an eclipse of the Moon."† If this observation is correct it is certainly most difficult to explain. Another curious observation is recorded by Mr. E. Stone Wiggins, who says that a partial eclipse of the Sun by a dark body was observed in the State of Michigan (U.S.A.) on May 16, 1884, at 7 p.m. The

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* KNOWLEDGE AND SCIENTIFIC NEWS, September, 1908.

† *The Observatory*, vol. ii., p. 375.

"Moon at that moment was 12 degrees south of the equator, and the Sun as many degrees north of it." The existence of a dark satellite of the Earth is suggested, but this seems highly improbable.

Investigations on ancient eclipses of the Moon show that the eclipse mentioned by Josephus as having occurred before the death of Herod is probably that which took place on September 15, B.C.5. This occurred about 9.45 p.m., and probably about 6 months before the death of Herod (St. Matthew II., 15).

Kepler states in his *Somnium* that he saw the Moon in thin crescent phase on the morning and evening of the *same* day (that is, before and after conjunction with the Sun). Kepler could see 14 stars in the Pleiades with the naked eye, so his eyesight must have been exceptionally keen.

The "moon maiden" is a term applied to a fancied resemblance of a portion of the Sinus Iridum to a female head. It forms the "promontory" known as Cape Heraclides, and may be looked for when the Moon's "age" is about 11 days. Mr. C. J. Caswell, who observed it on September 29, 1895, describes it as resembling "a beautiful silver statuette of a graceful female figure with flowing hair."

It has been stated that the Moon as seen with the highest powers of the great Yerkes telescope appears "just as it would be seen with the naked eye if it were suspended sixty miles over our heads." But this statement is quite inaccurate. The Moon as seen with the naked eye, or in a telescope, shows us nearly a whole hemisphere of its surface. But were the eye placed only 60 miles from its surface we should see only a small portion of its visible hemisphere. In fact, it is a curious paradox that the nearer the eye is to a sphere the less we see of its surface! The truth of this will be evident from the fact that on a level plane an eye placed at a height of say, 5 feet, sees a very small portion of the Earth's surface indeed, and the higher we ascend the more of the surface we see. I find that at a distance of 60 miles from the Moon's surface we should only see a small fraction of its visible hemisphere (about $\frac{1}{30}$th). The lunar features would also appear under a different aspect. The view would be more of a landscape than that seen in any telescope. This view of the matter is not new. It has been previously pointed out, especially by M. Flammarion and Mr. Whitmell, but its truth is not, I think, generally recognized. Professor Newcomb doubts whether with any telescope the Moon has ever been seen so well as it would be if brought within 500 miles of the Earth.

From careful observations of the Zodiacal Light, Mr. Gavin J. Burns finds that its luminosity is only "some 40 to 50 per cent brighter than the background of the sky. Professor Newcomb has made a precisely similar remark about the luminosity of the Milky Way, viz.: that it is surprisingly small." This agrees with my own observations during many years. It is only on the finest and clearest nights that the Milky Way forms a conspicuous object in the night sky. And this only in the country. The lights of a city almost obliterate it. Mr. Burns finds that the Zodiacal Light appears "to be of a yellowish tint; or if we call it white, then the Milky Way is comparatively of a bluish tint." During my residence in the Punjab, the Zodiacal Light seemed to me constantly visible in the evening sky in the spring months. In the West of Ireland I have seen it nearly as bright as the brighter portions of the Milky Way (February 20, 1890). The "meteoric theory" of the light seems to be the one now generally accepted by astronomers, and in this opinion I fully concur.

From observations of the "Gegenschein," or Zodiacal Counter Glow, Professor E. E. Barnard finds that it is not so faint as is generally supposed. "It is best seen by averted vision, the face being turned 60° or 70° to the right or left, and the eyes alone turned towards it. It is invisible in June and December, while in September it is round, with a diameter of 20°, and very distinct." No satisfactory theory has been advanced to account for this curious phenomenon. Professor Arthur Seale, of Harvard, attributes it to a number of asteroids too small to be seen individually. In "opposition" these would be fully illuminated and nearest the Earth. Its distance from the Earth probably exceeds that of the Moon. Dr. Johnstone Stoney thinks that the Gegenschein may possibly be due to a "tail" of hydrogen and helium molecules repelled from the Earth by solar action. This "tail" would be visible to us by reflected sunlight. There seems to be "a slight lagging of the Gegenschein behind the anti-solar position," and this would agree with Stoney's theory.

The rotation period of the planet Venus seems to be still uncertain. A slow rotation of about 225 days is favored by Perrotin, Schiaparelli, and Terby, while Neisten, Stuyvært, Trouvelot and Leo Brenner support De Vico's old period of about 24 hours.

Projections on the limb of the planet Mars have frequently been observed in America. These are known not to be mountains, as they do not re-appear under similar conditions. They are supposed to be clouds, and one seen in December, 1900, has been explained as a cloud lying at a height of some 13 miles above the surface of the planet and drifting at the rate of about 27 miles an hour. Recent spectroscopic observations at Mr. Lowell's Observatory have proved the existence of water vapor in the atmosphere of Mars. If there are any mountains on Mars they have not yet been discovered. The existence of the so-called "canals" is supposed to be confirmed by Lowell's photographs of the planet; but what these "canals" really represent, that is the question. They have certainly an artificial *look* about them, and they form one of the most curious problems in the heavens. The late Mr. Proctor thought that Mars is "far the reddest star in the heavens; Aldebaran and Antares are pale beside him."* But this does not agree with my experience. Antares is, to my eye, quite as red as Mars, and the color of Aldebaran is quite comparable with that of the "ruddy planet." In the telescope, the color of Mars is, I believe, more yellow than red, but I have not seen the planet very often in a telescope. Sir John Herschel suggested that the reddish color of Mars may possibly be due to red rocks, like those of the old red sandstone, and the red soil often associated with such rocks, as I have myself noticed near Torquay and other places in Devonshire.

From observations of Uranus made in 1896, Mr. Leo Brenner concluded that the planet rotates on its axis in about 8½ hours (probably 8h. 27m.).

The existence of a second satellite of Neptune is suspected by Professor Schaeberle, who thinks he saw it with the 36-inch telescope of the Lick Observatory "on an exceptionally fine night in 1895." † But this supposed discovery has not yet been confirmed.

It has often been stated that the old Indian Emperor Jehangir "had a sword made from a piece of meteoric iron which fell in the Punjab in the year 1620." According to Sir M. E. Grant Duff, President Diaz, of Mexico, had a sword made from an aerolite.§

Many attempts have been made by "paradoxers" to show

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* "KNOWLEDGE," May 2, 1886. † *Journal*, B.A.A., June, 1895.

§ *Journal*, B.A A., July, 1903.

that the Earth is a flat plane and not a sphere. But M. Ricco has found by actual experiment that the reflected image of the setting Sun, seen from a smooth sea, is an elongated ellipse. This proves mathematically beyond all doubt that the surface of the sea is spherical; for the reflection from a plane surface would be *circular*. The theory of a "flat Earth" is, therefore, proved to be quite untenable, and all the arguments (?) of the "Earth flatteners" have now been "blown into space."

With reference to the apparent enlargement of celestial bodies near the horizon, M. Paul Stroobant finds that if G is the size of an object at a certain altitude H, then the formula $G = 100 - 19 \sin H$ represents very well the relation between G and H, if we take 100 as the size on the horizon.† For an object in the zenith this would give $G = 81$.

Mr. Denning thinks that on the return of Halley's comet in 1910, there may possibly be a shower of meteors on or about May 4 of that year, "when the Earth reaches that part of its orbit corresponding with the descending node of the comet," the Earth being then distant about 5½ millions of miles from the comet's orbit.‡

In the Sanskrit epic poem, the "Ramayana," it is stated that at the birth of Rama, the Moon was in Cancer, the Sun in Aries, Mercury in Taurus, Venus in Pisces, Mars in Capricornus, Jupiter in Cancer, and Saturn in Libra. Mr. Walter R. Old has computed that the corresponding date is February 10, 1761 B. C.§

The late Mr. Proctor and Professor Young believed "that the contraction theory of the Sun's heat is the true and only available theory." The theory is, of course, a sound one, but it may now be supplemented by supposing the Sun to contain a certain small amount of radium. This would bring physics and geology into harmony. Proctor thought that the "Sun's real globe is very much smaller than the globe we see. In other words, the process of contraction has gone on further than, judging from the Sun's apparent size, we should suppose it to have done, and, therefore, represents more Sun work" done in past ages. The truth of this idea seems very probable.

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† *The Observatory*, No. 104, 1885.

‡ *Journal*, B.A.A., No. 4, vol. xii. § *Nature*, Nov. 2, 1893.

With reference to the nebular hypothesis, Dr. A. R. Wallace argues that "if there exists a sun in the state of expansion in which our Sun was when it extended to the orbit of Neptune it would, even with a parallax of $\frac{1}{60}$th of a second, show a disk of half-a-second, which could be seen with the Lick telescope." My reply to this is, that with such an expansion there would probably be very little intrinsic luminosity, and if luminous enough to be visible, the spectrum would be that of a gaseous nebula, and no known *star* gives such a spectrum. But some planetary nebula look like small stars, and with a high power would probably show a disk. On these considerations, Dr. Wallace's objection does not seem to be valid.

It is a popular idea that stars may be seen in the daytime from the bottom of a deep pit or high chimney. But this is not the case, and has been often disproved. Stars may, however, be seen in the daytime with even small telescopes. It is said that a telescope one-inch aperture will show stars of the second magnitude, like those in the "belt" of Orion, or the brighter stars of the "Plough"; of two inches, stars of the third magnitude; and of four inches, those of the fourth magnitude. But I cannot confirm this from personal observation. It may be so, but I have not tried the experiment.

The photographic method of charting the stars, although a great improvement on the old system, seems to have its disadvantages. One of these is that the star images are liable to disappear from the plates in the course of time. The reduction of stellar photograph plates should therefore be carried as soon as possible after they are taken. Dr. Roberts found that on a plate originally containing 364 stars, no less than 130 had completely disappeared in 9¼ years.*

It has been assumed by some writers on astronomy that the faint stars visible on photographs of the Pleiades are at practically the same distance from the Earth as the brighter stars of the cluster, and that consequently there must be an enormous difference in actual size between the brighter and fainter stars. But there is really no warrant for any such assumption. Photographs of the vicinity show that the sky all round the Pleiades is equally rich in faint stars. It seems, therefore, more reasonable to suppose that most of the faint stars visible in the Pleiades are really far behind the cluster in space. For if

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* *Journal*, B.A.A., October, 1895.

all the faint stars visible on photographs belonged to the cluster, then if we imagine the cluster removed, a "hole" would be left in the sky, which is, of course, utterly improbable. An examination of the proper motions tends to confirm this view of the matter, and indicates that the Pleiades cluster is a comparatively small one and projected on a background of fainter stars.

It has long been suspected that the famous star 61 Cygni, which is a double star, is a binary system, that is, that the two stars composing it revolve round their common center of gravity, and move through space together. But measures of parallax made by Herman S. Davis and Wilsing seem to show a difference of parallax between the two components of about 0.08 of a second of arc. This difference of parallax implies a distance of about 2¼ "light-years" between the two stars, and "if this is correct, the stars are too remote to form a binary system. The proper motions of 5″.21 and 5″.15 seem to show that they are moving in nearly parallel directions, but are probably slowly separating." Mr. Lewis, however, thinks that a physical connection probably exists.†

From an examination of the heat radiated by some bright stars made by Dr. E. F. Nicholls in America, with a very sensitive radiometer of his own construction, he found that "we do not receive from Arcturus more heat than we should from a candle at a distance of five or six miles."

From a comparsion of Trouvelot's drawing of the small elongated nebula in Andromeda with recent photographs, Mr. Easton infers that this small nebula has probably rotated through an angle of about 15° in 25 years. An examination I have made of photographs taken in different years seems to me to confirm this suspicion, which, if true, is evidently a most interesting phenomenon.

Keeler, Vogel, and Eberhard found that the great Orion nebula is apparently receding from the Earth at the rate of about 11 miles a second. As this is about the Sun's computed velocity through space in the opposite direction, the nebula is probably at rest. Keeler thought "that a nebula of such vast extent and tenuity is more likely to be at rest relatively to the stars of our system than small compact nebular masses or individual stars."

Ptolemy, in his description of the Milky Way, given in the

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† *Journal*, B.A.A., February, 1898.

"Almagest," says nothing whatever of the bright region in Scutum. This is probably due to an omission of the copyists, as it seems impossible to suppose that Ptolemy did not see this remarkable spot.

Easton calls the Milky Way "the most strange and most amazing of optical errors." But I presume he does not suppose the Galaxy to be merely an optical illusion, for the telescope shows that its objective existence is beyond a doubt.

About the middle of September, 1878, Mr. Greely, of Boston (U.S.A), reported to Mr. E. F. Sawyer (the eminent observer of variable stars) that about the middle of August of that year he had seen the famous variable star, Mira Ceti, of about the second magnitude, although the star did not attain its usual maximum until early in October, 1878. Mr. Greely stated that several nights after he first saw Mira it had faded to 4th or 5th magnitude. If there was no mistake in this observation (and Sawyer could find none) it was quite a unique phenomenon, as nothing of the sort has been observed before or since in the history of this famous star. It looks as if Mr. Greely had observed a new or "temporary" star near the place of Mira Ceti, but as the spot is far from the Milky Way, which is the usual seat of such phenomena, this hypothesis seems improbable.

Dante speaks of the four bright stars in the well-known "Southern Cross" as emblematical of the four cardinal virtues, Justice, Temperance, Fortitude, and Prudence; and he seems to refer to the stars Canopus, Achernar, and Fomalhaut, under the symbols of Faith, Hope, and Charity. The so-called "False Cross" is said to be formed by the stars, κ, δ, ϵ and ι, of the constellation Argo Navis. But it seems to me that a better (although larger) cross is formed by the stars α Centauri, and α, β, and γ, of Triangulum Australis.

Mr. Monck has pointed out the names of the brightest stars in the Northern Hemisphere seem to be arranged alphabetically, in order of color, beginning with red, and ending with blue. Thus we have Aldebaran, Arcturus, Betelgeuse, Capella, Procyon, Regulus, Rigel, Sirius, Spica, and Vega. But as the origin of the names is different this must be merely a curious coincidence.* And, to my eye at least, Betelgeuse is redder than Arcturus.

Some interesting observations made recently by Professor W.

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* *The Observatory*, April, 1887.

H. Pickering, in Jamaica, make the value of sunlight 540,000 times moonlight. This makes the Sun's stellar magnitude to be —26.83, and that of full moonlight—12.5. Professor Pickering finds that the light of the full Moon is equal to 100,000 stars of zero magnitude. He finds that the Moon's "albedo" is about 0.0909; or, in other words, that the Moon reflects about one-tenth of the light which falls on it from the Sun. He also finds that the light of the full Moon is about 12 times the light of half Moon; a remarkable and rather a startling result.*

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

Part III. (Continued.)

THE NATURE OF THE SOLAR RADIATIONS AND THEIR RELATION TO TERRESTRIAL MAGNETISM AND OTHER METEOROLOGICAL PHENOMENA.

The cause of terrestrial magnetism being, according to my theory the action of the solar radiations, or vibrational impulses, propagated through the ether from the effective radiating surface of the Sun, which surface has an absolute temperature, according to my theoretical determination, of 6,700 degrees Fahrenheit, which is only 20 degrees above the temperature that effects dissociation of the component atoms of gaseous molecule, such as the normal standard molecule of atmospheric air, and since the effects of solar radiation vary inversely as the square of the distance of the Sun from the Earth, the maximum intensity of terrestrial magnetism, or the strength (*s*) of the magnetic poles is equal to $\frac{I}{R_s^2}$, the denominator representing the square of the mean distance (*R*) expressed in terms of the radius or semi-diameter of the solar globe, its value being 215.02; whence $R_s^2 = 46{,}230$ the (logarithm of which is 4.664956), so that equation (χ) gives 15.3

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* Annals of Harvard College, vol. xli., part i., 1908.

as the strength of pole in absolute units, or dynes per square centimeter, the observed values for the American and the southern poles being 15.2 lines.

This great reduction of the maximum intensity (I) of magnetization signifies that only one atom out of 46,230 in contact with the Earth's surface, in the interface of each square centimeter, is affected by the solar radiation, but from my law of radiation, I have found that if the effective surface temperature of the Sun were increased to 9,230 degrees Fahrenheit all the molecules aforesaid would be affected and disrupted, the electromagnetic condition of the atmosphere at the Earth's surface becoming then the same as exists between the carbon poles of an arc lamp when in operation. The intensity of the terrestrial magnetic forces being thus a function of the absolute temperature of the Sun's effective surface matter it is a measure of that temperature, one of my four concordant determinations thereof having been based on this fact.

Therefore any regular and permanent increase of effective solar surface temperature above 6,700 degrees Fahrenheit, "absolute," must be accompanied by a corresponding increase in the intensity of the total terrestrial magnetic force, and consequently of the horizontal and vertical components thereof, while sudden and temporary outbursts of the more highly heated matter of the Sun, from beneath the photosphere, following the formation of sun-spots, must result in abnormal perturbations of all these forces, and cause magnetic storms and auroral effects, the aurora being, under my theory, due to the dissociation of the atoms of the molecules of the atmospheric gases, and therefore to the development of statical electric effects, especially in the upper regions of the atmosphere envelope (which, as determined through my theory extends to the height of 250 miles above the Earth's surface) where the density is low and the orbital velocity of the atoms consequently less, and the pressure and rigidity of the molecules overcome by the solar radiations, occasional abnormally great impulses carrying the dissociation process even to the surface of our globe, for auroral steamers have been observed to pass downward between terrestrial objects. This action is precisely the same as that produced by discharges of statical electricity (from an induction coil or Leyden jar) in vacuum tubes in which the degree of exhaustion of the air is neither too high nor too low, the effects being similar in appearance, and otherwise, to the auroral steamers, and also the solar corona, which, in part at least, is undoubtedly an electrical phenomenon due to the dissociation of the atoms of the molecules of the ether, or of a tenuous envelope of gas and vapors surrounding the Sun, this giving the characteristic bright line spectrum of an electric discharge, as well as the faint continuous spectrum due to the sunlight reflected from finely divided solid particles suspended in the solar envelope and which may even be incandescent.

A perfect analogy, furnished by laboratory experiment, is well illustrated in a paper (*g.v.*) by Professor Pupin, published in *Astronomy and Astro-Physics* (June, 1892) on electrical discharges in poor vacua, and I think that a vera causa for the aurora, is thus theoretically and experimentally determined, as the results of theory and observation are in perfect agreement.

The algebraic expressions for the electrostatic and electromagnetic aud other correlated units, set forth on a preceding page are founded on the following principles: By reason of the enormous linear velocity of the atoms of the single layer of molecules of the interface aforesaid, the molecules are endowed with a very great rigidity,, and exert a pressure which is equal to the normal atmospheric pressure, (P_a) this layer of molecules sustaining the weight of a column of air having unit surface and extending upward to the limiting altitude (250 miles) the weight of the matter being 14.730 pounds avoirdupois per square inch or 1035.2 grams per square centimeter.

Since under my theory all electrical action productive of a disruptive discharge of static electricity through a dielectric —such as air—is caused by the complete disruption of the molecules in the single layer aforesaid, or the interface between the solid surface and the surrounding gaseous medium, any applied force sufficient to cause disruption of these molecules and the dissociation of their component atoms must be equal to the force of pressure (P_a) and when disrupted discharge takes place, the electrical force is propagated from this layer, through the other molecules of the medium, with a velocity (V_l) which is that of light, and like all its intensities varies--as does that of all the other radiant forces—as the inverse square of the distance which in this case is measured by a unit equal to the diameter(d) of a molecule, or the thickness of a molecular layer of the interface, which is the seat of electromotive force; but the unit of distance in the C.G.S. system which employed in electrical measurements, is the centimeter, which, obviously, contains a number of the molecular-diameter units equal to $\frac{1}{d}$ and therefore the force of pressure (Pa) must be divided by the square of this in order to obtain the intensity at a distance of one centimeter, so that we have d^2Pa and this multiplied by the velocity of propagation (V_1) gives the expression $d^2 Pa V_1$ which is that for mass (M) moving with a velocity (V_1), it being therefore an expression for momentum, while this multiplied by V_1 becomes $d^2 Pa V_1^2$ which is an expression for kinetic energy, one-tenth of it being an expression for the electrical energy in the unit of electro-motive force, or the volt, as set forth in equation (ι) while the former expression for momentum is that for the electrostatic unit of electromotive force, and represents simply a tension expressed by equation (μ) set forth above, the ratio between the two being the velocity of light. The unit of magnetic force (I) is defined as that produced by a current of unit strength, or electromotive force (E_m) flowing through a circular conductor of radius unity, or one centimeter, (the circumference being therefore 2π) and acting upon a pole at the the center of the circle, with a force of one dyne, and since the weight denoted by (P_a) contains g units of mass, or. 980.2 dynes, the quantity designated by E_m must be divided by this, so that the complete expression for (I) becomes $\frac{2\pi}{980.7} E_m$ as set forth in equation (χ); this giving the magnetic "induction" in dynes per square centimeter of pole. This value of (I) divided by the square of the Earth's mean distance (R_s) from the Sun (in radii of the solar globe) gives the expression for the mean strength (S) of the terrestrial magnetic pole as set forth in equation (χ). The electrochemical equivalent (ϵ) expressed by equation (ϕ) is the number of grams of water decomposed per second by unit current of electricity into its component gases hydrogen and oxygen, and since the volume of one gram of water is one cubic centimeter, the volume of the gases resulting from its decomposition by electrolysis is 4041 cubic centimeters constituting a column with a base of one square centimeter and a length of 4041 centimeters, this containing a number of layers of molecules equal to $\frac{1}{d}$, each layer having required a unit of current of electromotive force (E_m) to decompose it, hence the weight of water converted into its ions, hydromake the ohm 1109×10^6 or about 9 per cent greater than the British Association value—or the Earth quadrant—which is 1000×10^6—but this has been in doubt by two per cent. Now the only factors that determine these units are the normal atmospheric pressure (P_a) and the velocity of light (V_l)—both of which have been experimentally determined with great accuracy—and the diameter (d) of the normal standard atmospheric molecule, which is therefore the only factor that may be charged with sensible error, but d is likewise a factor in the equation for the electrochemical equivalent, the determination from which agrees exactly with the experimentally derived and accepted value of Kohlrausch and also in that for the strength of the terrestrial magnetic poles, which equation gives a result agreeing to within about one per cent with that experiment; moreover it is a factor in all the expressions for the normal atmospheric pressure (P_a) which has been theoretically deduced therefrom the result agreeing with that of observation to the fourth place of the decimals.

These three equations therefore furnish a check upon the accuracy of (d) which quantity I have reason to assert is true within a very small fraction of one per cent of its numerical value set forth in the second table and on preceding pages.

Therefore my values for the volt and ohm must be substantially correct, and the true nature of electromagnetic action is determinable through my theory and traceable simply to the mass and motion of the atoms—all of uniform dimensions and density—in their orbits in the hollow spherical molecules of which they constitute the—in one sense—solid and rigid shell. My theory therefore in so far as it is concerned with electricity, is a one-fluid theory, but in the practical application the well-known concepts of polarity and the distinctions of positive and negative are used, as in the two-fluid theory, these terms being easily interpreted and explained.

Under the fundamental concepts of my theory of the physical constitution of gases—including the luminiferous ether—and of the processes of radiation, and the laws governing their operation, it is demonstrable that the transmitting medium for radiance of all kinds, cannot *per se* act as a receiver, or "absorber," of thermal, or other, energy propagated thereby, or, in other words, that a heated surface cannot radiate thermal energy and experience any loss of temperature, unless impact" given by the vibrations of the ultimate particles of the radiating surface to the atoms of the medium at the interface aforesaid, this "velocity of impact" being directly proportional to the absolute temperature of said surface.

Each molecule of the medium—normally a perfect sphere—is thereby *deformed* while the impulse is passing through it, and *reformed* when the additional velocity, imparted by the original impulse from the radiating surface, has been transferred to an atom of a molecule one molecular diameter farther along in the line of propagation or the "ray" as it is called, and each atom of the medium, first acted upon by the impulse from the radiating surface after thus delivering up the additional velocity with which it has been charged, returns to its normally circular orbit and to the point at which it first received the impulse from the atom of the radiating surface, when it will again be acted upon by some atom thereof; again be deflected and transmit onward its acquired velocity, delivering up the whole of it (since each atom is perfectly elastic, spherical and homogeneous, and the "impact" is regarded as *direct* and *central*) the process being repeated indefinitely or so long as the radiation is sustained. The atoms of the medium, revolving in their normally circular orbits around the center of each molecule of which they are the sole components, with a constant normal velocity (of which the "velocity of light" is a function, as will be demonstrated,) act simply as *vectors* for the transmission onward, of the additional velocity, and consequent energy, imparted to them by the impacts of the ultimate particles, or atoms, of the radiating surface. It is obvious that, under such conditions, if there be no complementary material surface situated at some point in the line of the ray, to which the atoms of the medium can deliver up, or impart, the additional velocity received from the radiating surface, this velocity must be returned, *in full*, by the vector atom when it has revolved through the other half of its circular orbit in the molecule, back to the point at which it received the original impulse—which is thus restored to the surface whence it was emitted, the atoms of this surface therefore, in this case, experiencing no loss of vibrational velocity, or, in other words, no loss of heat and, consequently, no fall of temperature. Furthermore, if there be a receiving, or absorbing, surface somewhere along the line of the ray, and at the same absolute temperature as that possessed by the radiating surface, its atoms must be vibrating radially, or longitudinally, with the same velocity as those of the surface of the radiating body, and it will then transmit to the latter, by means of the revolving atoms, or vectors, of the gaseous medium, as much velocity and, therefore energy, or heat, as it receives from said body, the two surfaces being, therefore, in thermal equilibrium; in other words, there can, then, be no radiation and consequent loss of heat from either of the two surfaces the temperatures whereof, under these conditions alone, must remain constant and equal. This fact is expressed by the following, fundamental, algebraic equation that I have derived through a rigorous analysis, from the principles of my theory of the constitution of gases, and their functions in the processes of radiation:

$R = C(a^{\tau} - a^{\tau^1}). D^{\frac{1}{8}}$; (A) in which R represents the "rate of radiation," as it is called, it being the quantity of thermal energy emitted, in unit time, from unit surface of a heated body, immersed in a medium of a density (D) taken relatively to the density of atmospheric air under the normal conditions, but if relative pressure (P) be used instead of density, the factor $P^{\frac{1}{2}}$ must be substituted for $D^{\frac{1}{8}}$, because, in a gaseous medium constituted as my theory postulates, the orbital velocity of the atoms of each molecule is proportional to $D^{\frac{1}{6}}$ and the energy to the square of this, or to $D^{\frac{1}{8}}$ which is the factor in equation (A); but, under my theory the pressure of any gas is caused by, and is proportional to, the number of impacts made by the revolving atoms, in unit time, against the walls of an inclosing vessel—such as the glass bulb of an incandescent electric lamp—while the number of impacts is proportional to the orbital velocity of the atoms, which relative velocity is represented by $D^{\frac{1}{6}}$, D being considered as $\frac{1}{V}$, in which V represents the volume of a molecule of the medium relative to that of a molecule of the atmospheric gases at normal pressure, density and temperature, without regard to the molecular *mass* which is taken as *unity*. From the principles of my theory, as well as from those of the commonly accepted kinetic theory of gases, we have the equations $P = DT = D^{\gamma}$ which express the well-known physical fact that the relative pressure (P) of any gas is directly proportional to the product of the relative density (D) and absolute temperature (T), the exponent γ being, therefore, a temperature factor related to T, its value, as experimentally determined by means of the known value of "velocity of sound" in air under normal conditions, and the elasticity of the atmospheric gases under the same conditions, being 1.408, the quantity represented by γ being the well-known ratio between the specific heat of a gas at "constant pressure" and the specific heat of the same gas at "constant volume." In my theory of the constitution of gases (which is simply a modification of the ordinary kinetic theory) this exponent is a function of the *angular* velocity of the *atoms* of each hollow, spherical molecule of any gas, in their circular orbits, and not of the *rectilinear* motion of the *molecules* themselves—which is the concept of the kinetic theory of gases—and this *angular*, atomic-velocity is inversely proportional to the square root of the cube of the radius (d) of each molecule since, according to my theory, these atoms are revolving continually around the center of each molecule,—of which they are the sole components,—in strict accordance with Kepler's third law of planetary motion, which law asserts that "the squares of the times of revolution are directly proportional to the cubes of the mean distances," and, therefore, it is directly proportional to $D^{\frac{1}{2}}$, and since the *linear* orbital velocity is radius (d) which is directly proportional to $D^{\frac{1}{3}}$, it follows that the linear velocity in the orbit is directly proportional to $D^{\frac{1}{6}}$ equal to this *angular*, velocity multiplied by the molecular and that the capacity of a gaseous medium, for the transmission of radiant *energy*, is directly proportional to the square of the linear orbital velocity aforesaid, or to $D^{\frac{1}{3}}$, as stated in a preceding paragraph and as expressed in the right hand member of equation (A) above set forth. When the temperature remains constant during the process of compression, and, also of rarefaction, of any gas, or, in other words, when the process is "isothermal," the relative pressure (P) and density (D) become synonymous terms, but when, by compression, the atoms of each molecule are brought nearer the center around which they revolve, and therefore closer to each other their motions become accelerated, according to Kepler's third law, and the number of collisions between these ultimate particles, in unit time, is increased and since the molecular heat is due to these collisions, the temperature and pressure of the gas must be raised, the pressure being thereby increased in a greater ratio than is the density in this process of *adiabatic* compression as is expressed by the equation $P = D^{\gamma}$ the exponent in this case being derived by the application of "Kepand if the density D were increased, or also the elasticity (E) decreased by 6½ per cent, the two values of γ would be found in exact agreement, while, if the difference be charged to both E, and D in equal parts, it would require a change of only 3¼ per cent in each quantity in order to equalize the two values of γ aforesaid, but it is not probable that the experimentally determined value of either the elasticity or the density is in error by an amount as great as 3¼ per cent, and it is more likely that the greater part of the discrepancy in question is due to the fact that, in the "kinetic theory," the elasticity (E) is that of each *molecule* of the gaseous matter whereas under the postulate of my theory, it is that of the *atoms* of each molecule. Therefore by regarding the elasticity of each atom as *perfect*, and its coefficient consequently as 1, the two values of γ would be in exact agreement, and equal to 1.5, if the coefficient of elasticity of each *molecule* were less than *unity* by 6½ per cent, and its value therefore 0.935 as it may well be, considering the somewhat complex constitution of atmospheric air which, in the case of even the most carefully conducted experiments, cannot be *absolutely* free from moisture and substances other than purely gaseous matter of perfect elasticity.

I have discussed this question *in extenso*, here, because it has a direct bearing upon some of the most important postulates and concepts of my theory of gases and radiation; viz., those as to the constitution of the molecules of gaseous matter the orbital velocity of the atoms revolving around the center of each molecule and as to the application of "Kepler's third law" to the motions of these atoms as well as to the perfect elasticity and sphericity of these ultimate particles, while it also is intimately connected with the relation between the "kinetic theory of gases" and that which I advanced, first in ASTRONOMY AND ASTRO-PHYSICS in the year 1892 and more fully set forth in my treatise upon the subject, published in 1895, under the title "The Constitution and Functions of Gases."

Moreover, this question is one of prime importance with respect to that part of thermodynamics which treats of the adiabatic compression and expansion of gases, the absolute temperature thereof at the end of each process, and the work expended in compression, or performed by expansion, the equations connecting the initial temperature (T_1) before compression, with the final temperature (T_2) at the end of the process

1.5 being the quantity represented by γ as aforesaid $d^{1.5}$ in this case being synonymous with $a^{\frac{3}{2}}$, which, in physical astronomy is the ordinary notation for the square root of the cube of the "mean-distance" (a) which is identical with (d), set forth above in the case of the circle. Under my theory, the pressure (P) of any gas is caused by, and is proportional to, the number of impacts of its revolving atoms, in unit time, against a restraining surface, and in this connection the atoms of only one layer of molecules, in immediate contact with the restraining surface and having a thickness equal to that of one molecule, need be considered, the centrifugal force of all the revolving atoms of a spherical molecule being exerted equally in all directions whence the well-known principle of hydrostatics, that "fluid pressure is exerted *equally in all directions.*" In the interior of an inclosing vessel, the contact force of the revolving atoms of all the molecules situated within the superficial layer, or interface, aforesaid, is met and balanced, on all sides, by that of the atoms of surrounding continuous molecules, but in the case of the atoms of the superficial layer their contact force is balanced only on the inner hemisphere of each molecule of this layer the atoms in each half immediately in contact with the restraining surface, exerting their otherwise unbalanced force against said surface, thereby causing "pressure" thereon. As will be demonstrated subsequently, this fact as to "contact-force" is one of wide application and great importance especially when we come to consider the nature of electrical action under the concepts of my theory. The number of revolutions, and resultant impacts, of the atoms, productive of "pressure" (P), being proportional to $\frac{1}{d^{1.5}}$ when the motion is governed by a centripetal, accelerating force operating as does that of gravity, there results the equations; $P = DT = D^{1.5}$; which are expressive of the "law of Charles" (or of Gay-Lussac); but, if the revolving body, or atom, be moving in a circle and with a constant linear velocity, but not under the control of an accelerating force similar to that of gravity, it is obvious, from a simple geometrical consideration, that at "angular velocity" and, therefrom, the pressure, will vary only as $\frac{1}{d}$, in which case we have the equation $P = D$ which is expressive of "Boyles law," the exponent γ becoming, in this case simply 1, and the compression and expansion of the gas being unaccompanied by changes of temcube of the molecular radius (d_m) and, therefore, $d_m = \frac{1}{D_m^{\frac{1}{3}}}$, furthermore according to that great fundamental, astronomical concept known as "Kepler's third law of planetary motion" (which law, under a concept of my theory, is applicable equally as well to the ultimate particles of all matter—the atoms—as to the enormous planetary, and stellar, masses which are only aggregations of these atoms) the *angular velocity* is proportional to $\frac{1}{d_m^{1.5}}$, while according to a principle of "analytical mechanics", the *linear* orbital velocity (V_m) is proportional to this quantity multiplied by the radius (d_m); there results the following equation, $V_m = \frac{1}{d_m^{0.5}} = D_m^{\frac{1}{6}}$, whence $V_m^2 = D_m^{\frac{1}{3}}$, the latter equation expressing the kinetic-energy of a molecule, due to the linear orbital velocity of its atoms, under the conditions and law aforesaid. Now since any *perfect* simple gas is composed of myriads of these molecules—which are perfectly homogeneous, throughout an indefinitely great volume, the geometric axiom that "the whole is equal to the sum of all its parts" may be properly applied, in a certain sense, to the case of a volume of gaseous matter composed of these molecules, and it may be stated positively, that the linear orbital velocity of the atoms of these molecules is proportional to $D^{\frac{1}{6}}$ and to $P^{\frac{1}{4}}$, the kinetic energy, therefore, being expressed by $D^{\frac{1}{3}}$ and $P^{\frac{1}{2}}$, which are, as has been stated above factors in the right hand member of equation (A).

In view of these facts, I think that the partial designation of my theory—"an astronomical theory of the molecule"—is not a *misnomer*, and that the title is an appropriate one.

Saint Paul, Minnesota.

To be continued.

(Florida) (—?); Buenos Ayres (—) and Sydney (Australia) (+).

It is interesting to note that these results agree well in the main with the present distribution of the regions which have been examined.

Again, Hann * has drawn attention to the fact that there exists a see-saw between the Azores and Iceland, and he showed that in 80 per cent of cases the largest positive pressure variations at Stykkisholm (Iceland) corresponded to negative pressure variations at Ponta Delgada (Azores), and that the largest negative pressure variations at Stykkisholm were in 87 per cent of cases positive variations at Ponta Delgada.

This result obtained from the observations extending from 1846 to 1900 endorses Hildebrandsson's previous conclusion deduced from observations over the period 1874—1884, and confirms the position of the boundary line shown on Plate I.

In 1903, Professor Bigelow † published a map of the world on which he indicated the distribution of the pressure types according as they followed the Indian (or direct type, as he calls it) or the Cordoba (indirect) pressure variations.

Professor Bigelow also found that there are many regions in which it was very difficult to say exactly which type was followed, and, as he wrote, there may be "differences of opinion as to assignment of some of these curves, but the reader can make any different arrangement that he prefers."

In most of the main features, however, his map suggests a somewhat similar distribution of these pressure types to that given in this memoir. Thus he finds that "the region around the Indian Ocean gives direct synchronism. South America and North America give inverse synchronism, while Europe and Siberia give an indifferent type. Greenland and Iceland seem to have direct type like the Indian Ocean. . .

"The eastern hemisphere tends to direct synchronism, except in Europe and Russia where the indifferent type prevails, and the western hemisphere to the inverse type."

Bearing of this Extensive See-Saw on Seasonal Forecasts.

Before proceeding to refer in detail to the tables and plates of curves which accompany this memoir, attention may be called not only to the strict meteorological relationship of areas of large extent but to the probable utility of this world-wide

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* Kaiserliche Akademie der Wiss. in Wien, Jan. 7, 1904.

† U.S.A. Monthly Weather Review, page 509, Nov. 1903.

Explanation of the Tables of Data and Construction of the Curves.

In this memoir the pressure data and curves for 73 stations, chosen for quality of their records and their geographical positions, are given.

Some stations which were previously used have not been included, because, either from their geographical positions, in relation to neighboring stations now utilized, they were not necessary, or because their records were not sufficiently complete or homogeneous.

An attempt has been made in some of those cases when the published data did not present a homogeneous series, some years being corrected to sea-level and others not so reduced, to allow for this by adding an approximate sea-level correction: the values for those uncorrected years were all altered by the same amount.

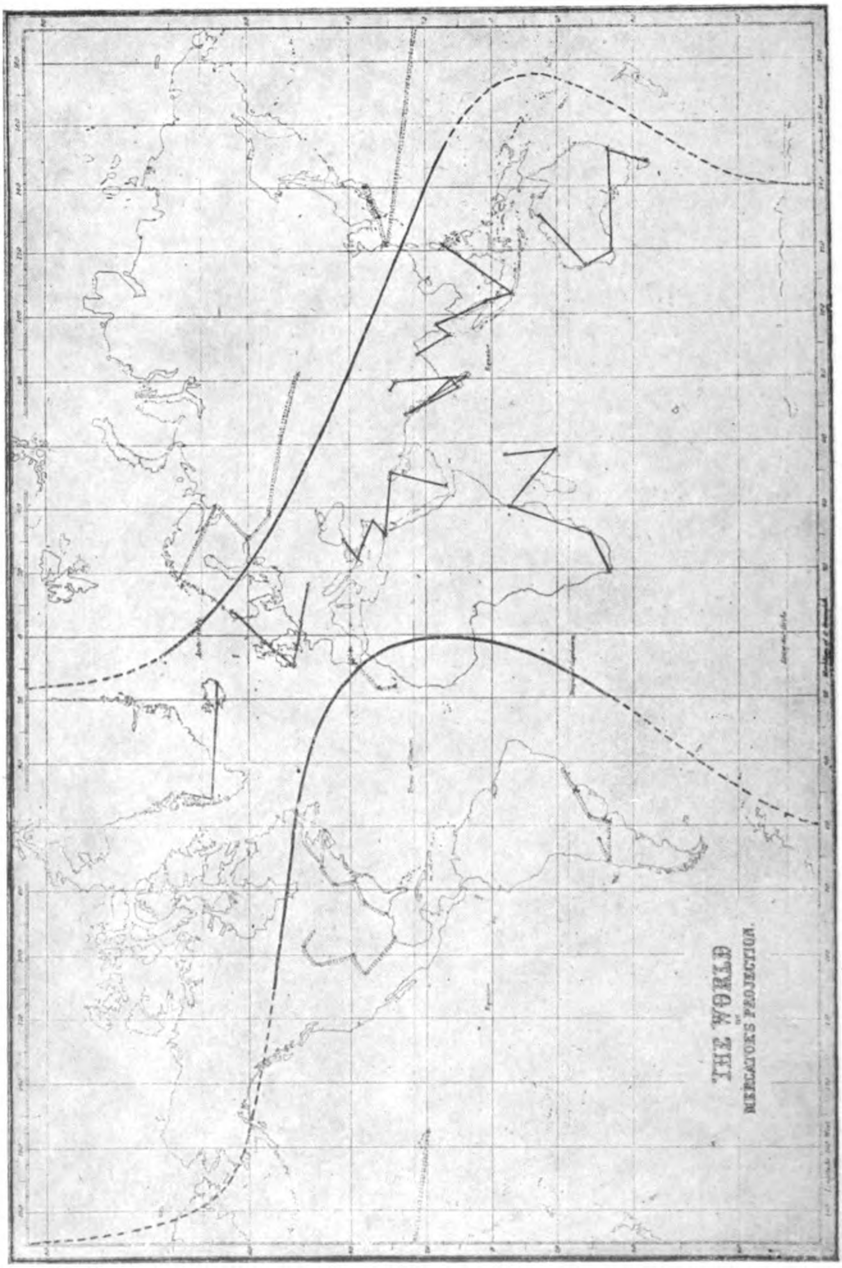
In addition to giving the values of the yearly means, those for the half years, *i. e.*, the means, for the groups of high pressure months and low pressure months respectively, have been inserted, and each of these has, wherever possible, been brought up to date. Exception, however, has been made in the case of Leh, India (altitude 11,503 feet), because the mean annual variation exhibited such a pronounced double swing (*i. e.* two maxima and two minina each year) that it was not thought desirable that this subdivision should be adopted.

At the head of each table after the name of the station, the latitude, longitude, and, when known, the altitude of the station are given and an indication of the reduction of the data. The blank spaces among the monthly values denote absence of available data for those months.

In the last column where a value is given for the mean pressure for a group of months, some months of which are in one year and some in the following, the value is inserted on the line of the earlier year; thus, the mean pressure for Bombay during the period October 1847, to March, 1848, is 29.885 inches, and is given on the line for 1847.

Following the tables is a series of notes giving details as to the manner in which the observations have been treated. These refer chiefly to changes in the altitude of the station and in the times of observations, and to those stations for which several publications had to be referred to in order to make the series of observations complete.

The curves showing the barometric changes from year to


THE WORLD
ON
MERCATOR'S PROJECTION.

work is a matter of congratulation by all interested. After this came the experimental stage in the different lines of hydrogen to gain a knowledge of the efficiency of quick and of slow plates. This must have taken much time and patience to secure the vivid results shown in the illustrations of this paper two of which are hereunto appended.

It is a matter of special interest that we notice the nature of the phenomena described in these papers by Professor Hale. The title of them is solar vortices. This title at once raises the old question about the nature of the sun-spots, and the causes that produce them. There is no one theory of sun-spots that is acceptable to astronomers generally at the present time.

It is not probable that they are craters on the solar surface through which eruptions break out, as was once believed. It is more likely that they are caused, when eruptions take place, by the sink or hollow formed by lessened pressure from beneath the surface, by the uprush of vapors in the vicinity of the spots in the process of formation. The spots probably get the dark color from the descent of cooler and more absorptive matter falling from regions above whatever be the level of the spots themselves in regard to the general level of the solar surface surrounding them. From investigations previously it has been more generally believed that sun-spots have been associated with parts of the solar surface that, at the time, were in very great activity; so much so that these conditions have taken the name of solar storms. But whether the spot causes the storm, or the storm causes the spot is not yet certain. If the spot, as a rule, is generally cyclonic in character, then it would seem that it is chiefly caused by surface action from the drift of vapors of unequal velocity in the same direction or possibly in opposite dircetions. Vertical currents, from principles of mechanics, could only modify the direction of surface currents which were normal to them. Unless the vertical action compared to that of the surface was enormously great, the cyclonic action would continue, being lessened only because of the difference of the two velocities of motion.

Astronomers have not been able in the past to observe enough spots in cyclonic action to warrant the belief that their motion generally was of that kind. The great French astronomer, Faye, believed that sun-spots very generally were formed by cyclonic action. When his views were met by the objection that visual observation of sun-spots generally does not show this, his reply was that the cyclonic action, however, is there, but that it is below the Sun's surface and, of course, could not be observed. This answer was not satisfactory and did not help his contention for obvious reasons. It might be true, but real proofs in support of it were wanting.

Professor Hale has gone into this subject of solar vortices in a way entirely different from that ever followed before. He has had the advantage of getting a large number of photographs of the Sun for the purpose of a more complete study of its surface, as revealed by such helps, because of the new features they contain. As shown by the plates herewith given it will be seen that the hydrogen flocculi literally cover the solar surface. So also it is of the calcium flocculi. Although his work has not yet gone far enough to make results conclusive for a theory founded on ample scientific support, yet there are indications that point in the direction of very interesting revelations if not important discoveries. From his preliminary work notice such facts as these:—

1. In a series of photographs some negatives "show the large flocculus in the act of being drawn into the spots, the small flocculi near the spots remain almost unchanged in position, perhaps because of a difference of level."

2. "Except in the case of the large flocculus, attempts to detect evidences of motion towards the spots have not yet proved successful, even along apparent lines of flow."

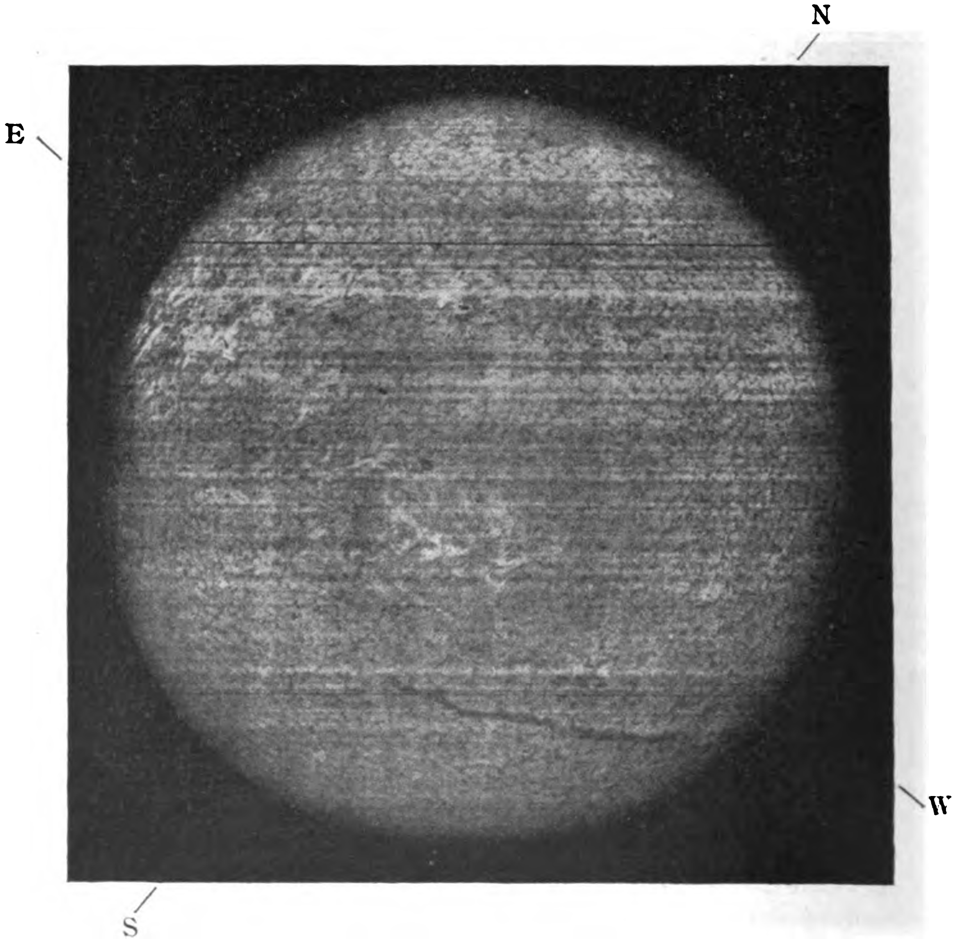
3. One negative taken on June 2, shows a dark comet-like object, which also appears to be a line of flow, that intersects a bright eruptive flocculus. The suggestion is that the eruption does not rise to the level of the vortex.

4. One hydrogen line across bright flocculi shown in these photographs indicates a very complex structure which will require further investigation.

5. "Since the velocity of the hydrogen drawn into the vortex is of the same order as that of the eruptive prominences, distortions of the hydrogen lines at the limb may be due to the motion of this gas in vortices. If the line were to pass through a vortex, distortions toward violet and red observed at the same point might result from motions of approach and recession on opposite sides of the vortex."

6. After June 3, it was noticed that numerous eruptions of hydrogen rose in the neighborhood of spots. It is suggested that these vapors may have been drawn down by the vortex previously.

These two fine plates are taken from the *Astrophysical Journal* for September which came to hand too late for an earlier notice.



The Sun, Showing the Hydrogen ($H\alpha$) Flocculi 1908, April 30, 5^h 06^m p. m.

7. Attention is called to the fact that the distribution of the hydrogen flocculi frequently resembles that of iron filings in a magnetic field. It is also interesting to notice that there is exact correspondence between the analytic relations in the theory of vortices and in the theory of electro-magnetism. These two facts are of great importance and they are very significant data.

8. "We know from the investigations of Rowland that the rapid revolution of electrically charged bodies will produce a magnetic field, in which the lines of force are at right angles to the plane of revolution; corpuscles emitted by the photosphere may perhaps be drawn into the vortices, or a preponderance of positive or negative ions may result from some other cause. When observed along the lines of force, many of the lines in the spot spectrum should be double, if they are produced in a strong magnetic field. Double lines, which look like reversals, have recently been photographed in spot spectra with the 30-foot spectrograph of the tower telescope, (Mount Wilson Solar Observatory) confirming the visual observations of Young and Mitchell. It should be determined whether the components of these double lines are circularly polarized in opposite directions, or, if not, whether less obvious indications of a magnetic field are present."

It is significant that such important data are coming to the surface in such a way that there may be some hope of getting useful results from them after some further study.

COMPARATIVE POWER OF THE 36-INCH REFRACTOR OF THE LICK OBSERVATORY.

W. W. CAMPBELL.

For Popular Astronomy.

In Popular Astronomy for 1905, page 391, Mr. Percival Lowell informed your readers that he and Mr. Lampland were able to see 173 stars in a certain small region of the sky, whereas Mr. Tucker, eleven years earlier, using the 36-inch refractor of the Lick Observatory, charted only 161 stars in the same region. This statement seemed to call for no comment from me. The 17-years' record of the 36-inch refractor (and the atmosphere), in discovering and measuring several thousand difficult double stars and in observing scores of extremely faint objects, spoke for itself indisputably. Recently, however, Mr. Lowell has made it the basis of public claims, in several magazines, that the Lowell 24-inch telescope has "greater space penetrating power", or will show fainter stars than, the 36-inch refractor. This claim has not misled experienced astronomers into believing that it is true, but no doubt thousand of general readers have been misled. To my extreme regret it seems to be my duty to take note of the subject by referring to certain facts involved.

The Lick observations referred to were made in 1894 by an observer whose duties at Mt. Hamilton in the years 1893-1907 related, with only one minor exception, to determining the extremely accurate positions of the *brighter stars with a special telescope of only 6½-inches aperture.* The "one minor exception" was that, at the request of the then Director, he devoted a few hours on a few evenings to charting the stars in certain selected small areas of the sky, using the 36-inch refractor for this purpose. These charts were published with the statement that, owing to certain (described) conditions, probably "some of the fainter stars have escaped" detection and charting. This was his *first* use of a great telescope; it was his *only* use of the 36-inch telescope during the fourteen years referred to: seeing faint objects with great telescopes was not in his line, just as general medical practice is not in the line of a highly specialized surgeon.

Mr. Lowell's observations of one of the these charted regions, with his 24-inch telescope, were made *after he had been using large telescopes for more than ten years in observing difficult objects.* He claimed to be able to see 7½ per cent more stars than the Lick observer. His published account of the observations (POPULAR ASTRONOMY, 1905) leaves the subject open and intangible, by saying that the "moonlight and the rainy season were both drawbacks" to the observations. He does not say whether the Moon was full or only partially full, near the charted region or far from it, when he, a practical astronomer, searched for faint stars near the limit of his telescope's power; nor whether the rains made the air more transparent, or more full of dust and haze, or more or less unsteady.

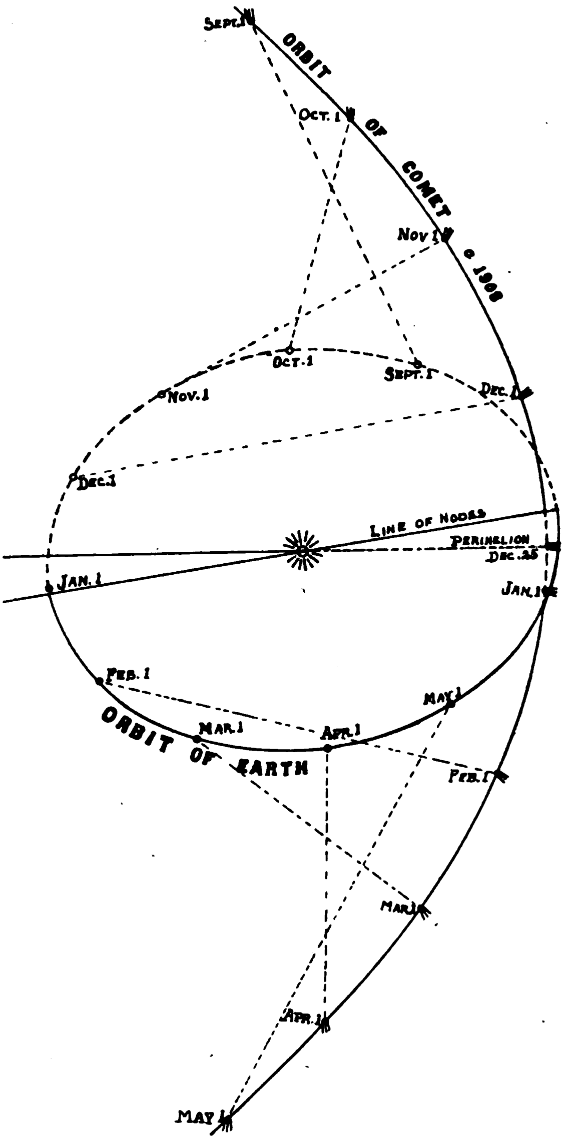
A fortnight ago I requested two of our astronomers of considerable experience with great telescopes, Messrs. Perrine and Aitken, to re-observe the charted region in question, using the 36-inch refractor. In two evenings, August 25, and 26, 1908, 1¾ hours each evening, they examined a little less than one-third of the entire region,—the western third. In the area examined, the early Lick observer charted 51 stars. In the same area, Mr. Lowell, eleven years later, charted 51 stars. In the same area the two recent Lick observers charted 69 stars, —an increase of 35%; and they have no doubt that they could find several additional stars, if they took more time, even with the conditions which then prevailed, as follows: transparency, "some smoke in the air on both nights"; steadiness of air, 3 on a scale of 5; and position in the sky, from 50° to 68° zenith distance during the observations. The region, three degrees south declination, was two hours west of the meridian when the observations began. All astronomers will recognize that these conditions were unfavorable to the Lick observers.

After the two observers had reported on the work of the two evenings, a photograph of the region was secured. It shows that the 69 stars charted visually are there. In addition, two or three stars observed visually, but supposed to be just outside the boundary lines of the region, are shown by the photograph to be just inside the lines; they should really be added to the number 69 quoted above; but as they were not on the visual charts, they continue to be omitted.

The 51 stars charted by Tucker are all included in the 69 charted by Perrine and Aitken, though some are displaced slightly from their true places, due to the early observer's having determined the right ascensions from transits over the bright micrometer wire, and the declinations by estimation and not from measures. Mr. Tucker's and Mr. Lowell's 51 stars are not all the same; some charted by the former were not seen by the latter, and vice versa.

Inasmuch as a survey of one-third the region is just as conclusive for the telescope's power as a survey of the entire region, I ordered the work stopped: there are endless ways in which the telescope and the observers' time can be put to better use.

Mt. Hamilton, California,
Sept. 3, 1908.



ORBIT OF COMET *c*, 1908.

the 6-inch camera show that this appearance was real and that the bright part of the tail was actually detached from the head of the comet and was moving outward at the rate of over 2′ per hour.

On the succeeding night Oct. 1 we exposed four plates, one hour each, in the 6-inch camera and two plates, each for two hours in the eight-inch telescope and in the 2½-inch camera. The conditions of atmosphere, plates and developer were as nearly as possible the same as on the preceding night, but the resulting photographs were entirely different. The tail of the comet was exceedingly faint. With the field-glasses and in the guiding telescope it could not be seen at all. The photographs taken with the 8-inch telescope show the merest trace of a streak emanating from the head. Those taken with the 2½-inch and 6-inch cameras show nearly the same extent of tail as on Sept. 30, but much fainter, and the brightest portion is out near the star β Cephei, about 2° from the comet's head. It thus appears that a remarkable change in the comet took place between Sept. 30 at 12^h 25^m and Oct. 1 at 8^h 19^m Central Standard time. On the subsequent nights during the first part of October clouds and moonlight prevented photographic work.

CONVERGENT OF A MOVING CLUSTER IN TAURUS.*

LEWIS BOSS.

The phenomenon of neighboring stars moving athwart the sky with motions of the same order of magnitude and in sensibly parallel directions has been noticed many years ago. It has been demonstrated that the greater part of the stars in the *Pleiades* are moving in this manner. Numerous instances where two or three stars seem to be moving together in this manner have been pointed out. Where such stars are near enough together to constitute double stars in the ordinary acceptation of the term this is not surprising. But the instances to which I now allude pertain to stars separated by large fractions of a degree, and even in some cases by several degrees. These stars cannot have any perceptible influence upon each

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[*] Extract from the Astronomical Journal, No. 604.

position of the convergent were computed. In view of all the elements of the determination it did not seem worth while to push it to an unwarranted degree of refinement. Before the last approximation it was seen that the deviations in position-angle for No. 1025 and No. 1051 were large, and it was decided to exclude them in the final computation. No. 1051 (BRADLEY 617) is a double star,—Σ 454. It is a binary and is now quite close. A rough estimate of the proper-motion of the mean of the components renders the motion of this star conformable with the stream. The proper-motion of No. 1025 (ABO 105) is less well determined than that of the general run of stars in Table I; it may possibly belong to the stream.

The result of the computation for the convergent places it in the following position for 1875:

R.A. $6^{h}\ 7^{m}.2$; Decl. + 6° 56′.

Another approximation would probably have given a small positive correction to each of these co-ordinates. The probable error of the right-ascension may be roughly estimated as, ± 1°.5, and of declination ± 0°.3; though much smaller errors are indicated from the residuals, C—O.

More than thirty stars in the neighborhood of the Sun have been recognized that have an estimated parallax of ″.10 or more. The prevailing conditions of distance in the *Taurus*-Stream are thus probably not strikingly different from those that prevail in the vicinity of the Sun. The distances from one star to another in that cluster may fairly be termed stellar in the sense in which that term is ordinarily understood. Treating of a Cosmos having such dimensions, and endeavoring to account for a hypothetical uniformity in directions and velocities of the component stars on such a scale, it is evident that we shall have to resort to hypotheses not now included in customary lines of thought. For the most part these stars are certainly too far apart to exert sensible attractions upon each other and, indeed, the effect of such attractions would be to disturb the mutual uniformity in velocities and directions. The galactic latitude of the convergent is —5°. The parallax of the cluster indicates that it is far within the boundary of the Galaxy, so that the cluster must have been for an almost inconceivable time within the limits of the Galaxy, even if its course has been sensibly rectilinear ever since it entered that system. If we suppose that the cluster was condensed from a vast nebula that originally had the present velocity and direction of the cluster, the difficulty is removed another step merely.

well covered, and the longest night series was six hours. After the minima mentioned in the former paper, a decided rise had taken place and then a seeming decline, but the observations ceased too soon to make this certain, and, besides, no rise had been completely observed, and hence it was assumed that the time was occupied in the rise. The ten hour series of Oct. 3, shows a second minimum in this interval after a decided rise from first minimum. Below are the observations in full for the two nights of Oct. 3 and 4, in my definitive light scale and L. M. T., if G. M. T. is desired add 0.227, this also applies to my previous paper.

	Lt		Lt
Oct. 3.289	16.3	Oct. 3.691	7.6
.377	9.9	.705	8.9
.437	6.9	4.279	5.9
.505	7.6	.309	6.4
.539	11.4	.335	6.9
.557	13.8	.376	10.4
.580	9.9	.392	16.3
.599	8.1	.398	19.3
.620	8.9	.410	23.7
.635	8.6	.427	24.0
.650	7.9	.444	22.2

My attention has been called to the fact, and which I had overlooked that Mr. Sigurd Enebo, published a period of $0^d.3978$, in *A.N. 4423* (*P.A. 153.*) I had attempted a somewhat similar period which is one-fifth of three times my period. But the observations of Oct. 3 and 4, completely verify my period of 16 hours. A further fact brought out is that the period has reached its maximum length and is now decreasing.

Unfortunately my elements (*P.A. 158*)for 45. 1907 Draconis was given in L. M. T. instead of G. M. T., which is as follows, 1908 May 24.3733 + $0^d.56952$. An observed maximum Oct. 4 gave a plus residual of about five minutes.

Cleveland, Ohio, October 9, 1908.

EARL OF ROSSE.

W. W. PAYNE.

FOR POPULAR ASTRONOMY.

Laurence Parsons, fourth Earl of Rosse, was born November 17, 1840, and died August 30, 1908. In the account given in the *King's County Chronicle* nothing is said of the early life of this good and great man, except to refer indirectly to what has recently appeared in all the leading papers in the kingdom to name a few: The late Earl of Rosse was a D. C. L. of Oxford, and L. L. D. of Cambridge. He was Chancellor of Trinity, Dublin, of which he was L. L. D. and to which, unsolicited, although a rival aspirant was the late Marquis of Waterford, grand nephew of a former and most venerated Chancellor, His Grace, Lord Primate Beresford. Lord Rosse was also His Majesty's Lieutenant of the King's county, and was elected by his fellow Irish Peers their representative in the House of Lords. He had been also president of the Royal Irish Academy, and was on the Senate of the Royal University, and also president of the Royal society. In Irish church government he was a member of the select vestry, and an official in a number of other minor offices of similar kind.

This remarkably busy man, as all this official relation plainly shows, was also noted for his benevolence in a very unobtrusive way. From what appears in the public prints, it would seem that his annual gifts were very considerable; some of the individual ones going as high as £1000. Another feature of this noble man's thoughtfulness was the interest he felt in the welfare of his employees. He was studiously careful to provide pensions for them in the winter of their lives." In short his whole brilliant career was marked by sound judgment and true benevolence. All these and other rare traits were seen to have had their reflection in eyes that literally beamed with a joy and intelligence that is past the power of verbal description."

At the funeral service, were many things said that showed the appreciation and the great loss that royalty and common people alike were sustaining in the departure of that deeply revered man. The great company in attendance, the many tributes of precious memory, the resolutions of profound regard, the telegrams of sympathy, and the special trains that were run to accomodate the many that wished to share in these last sad rites were a few of the tokens of the genuine affection in which this very worthy man was held.

From a private letter written by J. A. Brashear of Pittsburgh, Pa., by whose favor all this information comes to hand, we learn of his own personal acquaintance formerly with the late Earl of Rosse, and how highly he thought of his friendship, and of his kind invitations to visit Parsonstown while abroad. It is not a small thing to say that the real power of such lives as that lived by the late Earl of Rosse is one of the mightiest things that can come upon this Earth. Such have come, if they are rare, but they come to stay.

eastward movement. At the end of the month Mars will be in Libra while Venus will be in Scorpio.

Jupiter will be at quadrature, 90° west from the Sun, on Dec. 5 and so may be observed during the latter half of the night. Jupiter will reach the stationary part of his apparent path among the stars on the night of Dec. 30, and will then begin his retrograde movement.

Saturn will be stationary on Dec. 7, having finished his retrograde movement, and will for several months from now on move eastward. Saturn will be at quadrature, 90° east from the Sun, on Dec. 25.

Uranus is not in favorable position for observation.

Neptune is nearing opposition and may be studied with the aid of a large telescope during the middle hours of the night. The planet is in the constellation Gemini, a little south and west from the third magnitude star δ. It is moving slowly westward.

Occultations visible at Washington.

			IMMERSION.			EMERSION.				
Date 1908	Star's Name	Magnitude.	Washington M.T. h	m	Angle f'm N. °	Washington M.T. h	m	Angle f'm N °	Duration. h	m
Dec. 3	ν Piscium	4.6	11	35	0	12	11	300	0	36
5	Piazzi iii, 103	6.3	17	31	36	18	09	300	0	38
6	B.A.C. 1417	6.4	18	01	121	18	43	226	0	42
7	*n* Tauri	5.1	10	47	100	12	04	227	1	17
8	1 Geminorum	4.1	5	17	37	5	54	300	0	37
8	3 Geminorum	5.6	7	42	157	7	51	176	0	09
8	8 Geminorum	6.1	11	25	4	11	46	334	0	21
8	9 Geminorum	6.2	11	10	80	12	37	260	1	27
9	48 Geminorum	5.8	11	08	9	11	28	340	0	20
10	μ^1 Cancri	6.2	10	18	134	11	11	226	0	53
19	o^1 Libræ	6.2	16	54	81	17	46	336	0	52
26	κ Capricorni	4.8	5	11	41	6	16	266	1	05
30	Lalande 2632	6.5	9	57	84	10	59	220	1	02

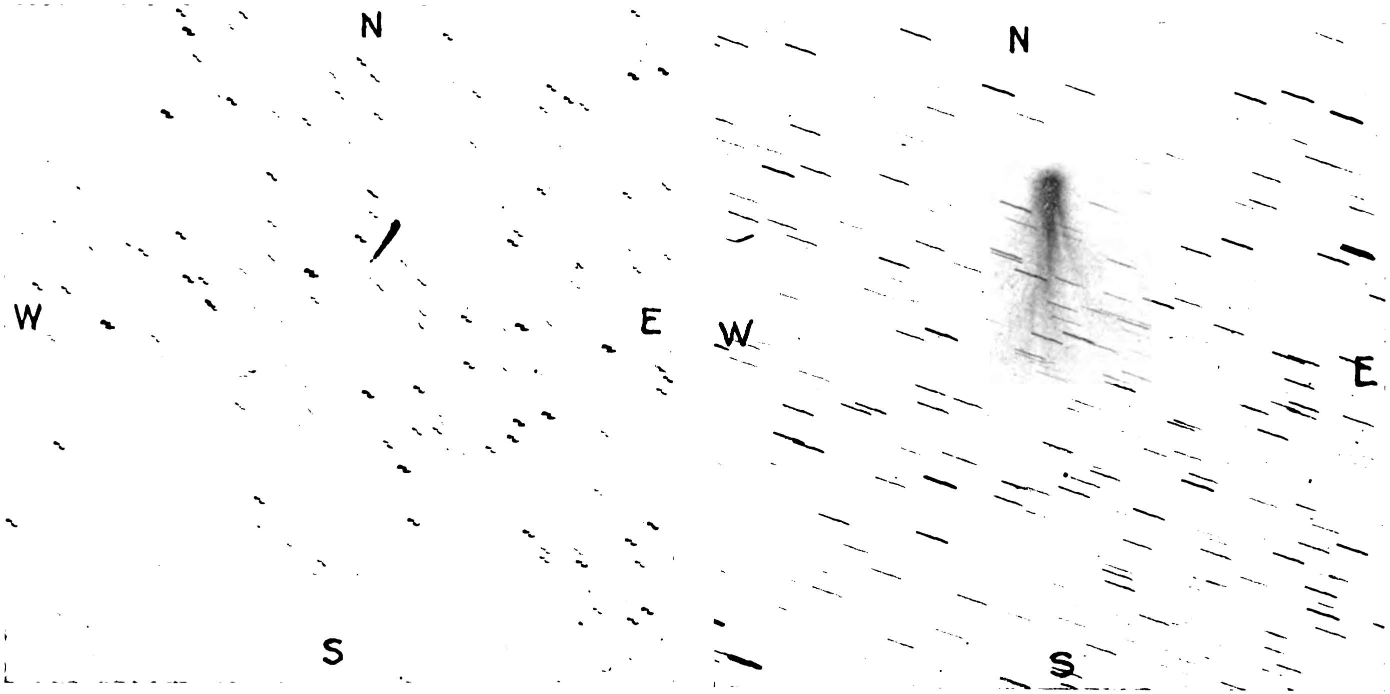
COMET NOTES.

Halley's Comet.—The following circular is worthy of careful attention by all interested:—In the belief that our knowledge of comets may be considerably enlarged through a proper use of the opportunities presented by the approaching return of Halley's Comet and the systematic observation of such other cometary phenomena as may be presented during the next few years, the Astronomical and Astrophysical Society of America has appointed the undersigned as a committee upon comets.

It is the purpose of this committee to canvass the whole field of cometary research, inquiring what parts of that field will best repay systematic cultivation at the present time and securing so far as possible, co-operation in such research. You are respectfully invited to communicate to any member of the committee suggestions with respect either to the subject matter or the methods of such research or such other matter as may seem of advantage in this connection.

Madison, Wis.,
Oct. 1, 1908.

EDWARD E. BARNARD.
CHARLES D. PERRINE,
EDWARD C. PICKERING,
GEORGE C. COMSTOCK,
Chairman.



No. 1. Sept. 14, 1908.
Exposed 7h 47m to 8h 47m E. M. T.

No. 2. Sept. 19, 1908.
Exposed 8h 53m to 11h 10m E. M. T.

PHOTOGRAPHS OF COMET *c* 1908 (MOREHOUSE) BY REV. JOEL H. METCALF.

Ephemeris Comet *c* 1908 (Morehouse). From the following observations by Aitken,

1908 Gr. M.T.		Comet's Apparent α			Comet's Apparent δ		
Sept.	3.84212	3^h	18^m	$13^s.91$	+67°	29′	35″.1
	11.99736	2	33	21.11	+72	17	36.3
	18.6915	1	13	21.0	+75	43	30

the last of which was communicated by telegraph, a second set of elements and an ephemeris have been derived:

ELEMENTS.

$$\begin{aligned} T &= 1908 \text{ December } 25.8090 \text{ Gr. M.T.} \\ \left.\begin{aligned} \omega &= 171^\circ\ 31'\ 09'' \\ \Omega &= 103\ \ 04\ \ 45 \\ i &= 140\ \ 10\ \ 14 \end{aligned}\right\} & \\ q &= 0.945540 \end{aligned}$$

O—C	I	III
$\cos\delta\Delta\alpha$	0″	0″
$\Delta\delta$	+2	0

As these elements differ considerably from the preliminary elements (Bulletin No. 138), computed with one day intervals, the observation by Fox used in the first orbit, and noted at that time as probably approximate, was suspected to have a large residual. Comparison of this observation with this second set of elements shows residuals of 2^s in right ascension, and 0′.1 in declination. These are sufficiently large to account for the difference between the two orbits.

CONSTANTS FOR THE EQUATOR 1908.0

$$\begin{aligned} x &= r\,[9.892938]\sin(154^\circ\ 41'\ 14'' + v) \\ y &= r\,[9.953594]\sin(267\ \ 37\ \ 17 + v) \\ z &= r\,[9.882333]\sin(202\ \ 04\ \ 32 + v) \end{aligned}$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1908		True α			True δ			Log Δ	Br.
Sept.	27.5	22^h	16^m	$49^s.8$	+74°	59′	40″	0.0791	2.95
Oct.	1.5	21	09	49.8	71	28	10		
	5.5	20	24	02.3	66	22	23	0.0370	
	9.5	19	54	00.8	60	13	47		
	13.5		34	07.2	53	27	22	0.0160	4.92
	17.5		20	38.4	46	24	54		
	21.5		11	19.3	39	25	00	0.0213	
Oct.	25.5	19	04	47.6	32	42	22		
Nov.	2.5	18	56	56.1	20	43	30	0.0684	5.38
	10.5		53	03.2	+10	55	15		
Nov.	26.5		50	32.1	− 3	22	55	0.1938	
Dec.	12.5		50	11.0	13	25	45		
Dec.	28.5	18	49	54.8	−21	33	54	0.2839	2.84

Brightness September 3 = 1.00.

A part of the check computation was performed by Miss Sarah Morgan.

S. EINARSSON,
W. F. MEYER.

Lick Observatory Bulletin, 139,
Sept. 22, 1908.

Provisional Designation		Harvard Number	DM		R.A. 1900			Decl. 1900		Mag.	
			°		h	m	s	°	′		
29.1908	Sagittarii	3071	−23	14072	18	06	58	−23	08.5	7.2	8.2
30.1908	Sagittarii	3072	−19	4645		11	07	−19	06.6	8.0	9.2
31.1908	Sagittarii	3073		—		11	40	−13	06.1	10.1	10.7
32.1908	Sagittarii	3074	−25	13054		15	57	−25	17.1	8.9	11.2
33.1908	Sagittarii	3075	−16	4859		18	57	−16	50.7	8.6	10.0
34.1908	Scuti	3076	−12	5045		18	54	−12	45.2	8.6	9.3
35.1908	Scuti	3077	− 9	4736		21	05	− 9	15.2	7.5	8.5
36.1908	Cor.Austr.	3078	−42	13498		33	37	−42	19.8	9.8	10.4
37.1908	Scuti	3079	− 7	4683		38	19	− 7	49.9	7.5	8.4
38.1908	Sagittarii	3080	−19	5148		38	43	−19	29.8	8.8	9.7
39.1908	Sagittarii	3081	−34	13135		43	03	−34	47.5	8.9	10.5
40.1908	Sagittarii	3082	−20	5283		44	47	−20	23.5	7.6	8.6
41.1908	Sagittarii	3083	−23	14922	18	53	38	−23	50.2	8.8	9.9
42.1908	Sagittarii	3084		R	19	01	16	−29	01.2	9.0	<13

Notes.—18.1908 Max. = 2411360 + 237 E. 19.1908 Nova found on plate taken May 4, 1906, mag. 11.0; rose to 8.8 in July; sank to 11.0 May 7, 1907. 20.1908 Algol type. 21.1908 short period. 22.1908 Algol type? 23.1908 probably Algol type. 24.1908 short period. 25.1908 short period. 26.1908 Algol type. 27.1908 Algol type? 28.1908 Algol type? 29.1908 probably short period. 30.1908 short period? 31.1908 long period. 32.1908 Algol type. 33.1908 probably short period. 34.1908 probably short period. 35.1908 Algol type? 37.1908 probably short period. 38.1908 Algol type? 39.1908 Algol type? 40.1908 probably short period. 41.1908 probably short period. 42.1908 period probably several months.

Variable Star (29.1907) RZ Aurigæ.—In A.N. 4272 Mr. E Hartwig discusses a number of observations of this Algol type variable obtained in March and April of this year, and concludes that the period cannot be greater than $3^d\ 0^h\ 14^s$, and that it is possibly $1^d\ 12^h\ 05^s.6$. A minimum occurred March 27, 1908 at $8^h\ 35^m.1$, Gr. m. t. The place of this star for 1900.0 is

$$\alpha = 5^h\ 42^m\ 52^s.69 \qquad \delta = +31°\ 40'\ 07''.6.$$

According to the photographs the amplitude of variation is from 9.5 to 14.5 magnitude, but Mr. Hartwig's visual estimates make the range only from $11^m.5$ to $13^m.6$.

Variable Star (31.1907) SS Aurigæ.—In A.N. 4272 Mr. Hartwig calls attention to the fact that the period of variable SS Aurigæ is irregular ranging possibly from 54 to 66 days. During most of this period the star is invisible or at least below 13.5 magnitude. It rises within one day to about 9.7 magnitude, remains at this brightness for not more than 8 days, then quickly sinks to invisibility. It seems to be of the U Geminorum type. Its position for 1900.0 is

$$\alpha = 6^h\ 05^m\ 48^s.09 \qquad \delta = 47°\ 45'\ 53''.8.$$

A large number of observations from the Harvard photographs are given in the Harvard Circular No. 138.

Variable Star (78.1907) Aurigæ.—According to S. Enebo this star is of the Algol type and its elements are

$$\text{Min.} = 2418046.37 \text{ Gr. m.t.} + 4^d.04 \text{ E.}$$

The observed amplitude of variation is from 7.8 to 8.7 magnitude.

Minima of Variable Stars of the Algol Type.—Continued.

RU Monoc.

	d	h
Dec.	23	5
	24	2
	25	0
	25	21
	26	19
	27	16
	28	14
	29	11
	30	9
	31	6

R Canis Maj.

Dec.	1	11
	2	14
	3	18
	4	21
	6	0
	7	4
	8	7
	9	10
	10	13
	11	17
	12	20
	13	23
	15	2
	16	6
	17	9
	18	12
	19	15
	20	19
	21	22
	23	1
	24	4
	25	8
	26	11
	27	14
	28	18
	29	21
	31	0

Y Camelop.

Dec.	3	19
	7	2
	10	9
	13	17
	17	0
	20	7
	23	15
	26	22
	30	5

RR Puppis

Dec.	5	18
	12	5
	18	15
	25	1
	31	11

V Puppis

Dec.	1	19
	3	6
	4	17
	6	4

V Puppis

	d	h
Dec	7	14
	9	1
	10	12
	11	23
	13	10
	14	21
	16	8
	17	19
	19	6
	20	17
	22	3
	23	14
	25	1
	26	12
	27	23
	29	10
	31	21

X Carinæ

Dec.	1	16
	2	18
	3	20
	4	22
	6	0
	7	2
	8	4
	9	6
	10	8
	11	10
	12	12
	13	14
	14	16
	15	18
	16	20
	17	22
	19	0
	20	2
	21	4
	22	6
	23	8
	24	10
	25	12
	26	14
	27	16
	28	18
	29	20
	30	22

S Cancri

Dec.	5	13
	15	0
	24	12

S Velorum

Dec.	2	17
	8	15
	14	13
	20	12
	26	10

RR Velorum

Dec.	1	19
	3	15
	5	12

RR Velorum

	d	h
Dec.	7	8
	9	5
	11	1
	12	22
	14	18
	16	15
	18	4
	20	8
	22	4
	24	1
	25	22
	27	18
	29	15
	31	11

SS Carinæ

Dec.	3	16
	7	0
	10	7
	13	14
	16	21
	20	5
	23	12
	26	19
	30	2

Z Draconis

Dec.	1	8
	2	16
	4	1
	5	9
	6	18
	8	3
	9	11
	10	20
	12	4
	13	13
	14	21
	16	6
	17	15
	18	23
	20	8
	21	16
	23	1
	24	9
	25	18
	27	3
	28	12
	29	20
	31	4

RZ Centauri

Dec.	1	16
	2	14
	3	13
	4	11
	5	10
	6	8
	7	7
	8	5
	9	4
	10	2

RZ Centauri

	d	h
Dec.	11	1
	11	23
	12	22
	13	20
	14	19
	15	17
	16	16
	17	14
	18	13
	19	11
	20	10
	21	8
	22	7
	23	5
	24	4
	25	2
	26	1
	26	23
	27	22
	28	20
	29	0
	29	19
	30	17
	31	16

SS Centauri

Dec.	3	6
	5	17
	8	5
	10	16
	13	4
	15	15
	18	3
	20	14
	23	2
	25	13
	28	1
	30	12

δ Libræ

Dec.	3	2
	5	10
	7	18
	10	2
	12	10
	14	18
	17	2
	19	19
	21	17
	24	1
	26	9
	28	17
	31	1

U Coronæ

Dec.	1	7
	4	18
	8	5
	11	15
	15	2
	18	13
	22	0
	25	11
	28	22

RR Draconis

	d	h
Dec.	2	0
	4	20
	7	16
	10	12
	13	8
	16	4
	19	0
	21	20
	24	16
	27	12
	30	8

RX Draconis

Dec.	1	1
	2	23
	4	20
	6	17
	8	15
	10	12
	12	10
	14	7
	16	5
	18	2
	20	0
	21	21
	23	19
	25	16
	27	13
	29	11
	31	8

WW Cygni

Dec.	2	13
	5	20
	9	4
	12	12
	15	19
	19	3
	22	11
	25	18
	29	2

SW Cygni

Dec.	4	18
	9	8
	13	22
	18	11
	21	1
	23	1
	27	15

VW Cygni

Dec.	3	5
	11	15
	20	2
	28	12

UW Cygni

Dec.	2	18
	6	5
	9	15
	13	2
	16	13
	20	0
	23	11

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

WZ Cygni Alternate Minima			WZ Cygni			WZ Cygni			WZ Cygni			WZ Cygni		
				d	h		d	h		d	h		d	h
			Dec.	7	5	Dec.	15	9	Dec.	23	13	Dec.	31	18
	d	h		8	9		16	13		24	17			
Dec.	1	8		9	13		17	17		25	21			
	2	12		10	17		18	21		27	1			
	3	16		11	21		20	1		28	6	TX Cygni		
	4	20		13	1		21	5		29	10	Dec.	3	22
	6	0		14	5		22	9		30	14		18	15

Approximate Magnitudes of Variable Stars on October 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.		R. A. 1900.	Decl. 1900.		Magn.	Name.		R.A. 1900.	Decl. 1900		Magn.
	h	m	°	′			h	m	°	′	
X Androm.	0	10.8	+46	27	10.8*d*	X Camelop.	4	32.6	+74	56	11.5
T Androm.		17.2	+26	26	11.2 *i*	V Tauri		46.2	+17	22	<12.6
T Cassiop.		17.8	+55	14	8.2	R Orionis		53.6	+ 7	59	<12.7
R Androm.		18.8	+38	1	8.0*d*	R Leporis		55.0	—14	57	8.0
S Ceti		19.0	— 9	53	11.0 *i*	V Orionis	5	0.8	+ 3	58	10.8
Y Cephei		31.3	+79	48	9.0	T Leporis		0.6	—22	2	8.8
U Cassiop.		40.8	+47	43	13.0 *i*	R Aurigae		9.2	+53	28	9.5 *i*
RW Androm.		41.9	+32	8	11.7*d*	S Aurigae		20.5	+34	4	9.0
V Androm.		44.6	+35	6	11.2 *i*	W Aurigae		20.1	+36	49	10.1
RR Androm.		45.9	+33	50	10.6*d*	S Orionis		24.1	— 4	46	10.4 *i*
RV Cassiop.		47.1	+46	53	12.5	T Orionis		30.9	— 5	32	11.2
W Cassiop.		49.0	+58	1	9.0	S Camelop.		30.2	+68	45	9.4
RX Androm.		58.9	+40	46	12.6*d*	RR Tauri		33.3	+26	19	10.0
Z Ceti	1	1.6	— 2	1	11.8*d*	U Aurigae		35.6	+31	59	9.5*d*
U Androm.		9.8	+40	11	<12.4	— Aurigae		42.9	+31	39	10.5
S Piscium		12.4	+ 8	24	<12.0	U Orionis		49.9	+20	10	9.6*d*
S Cassiop.		12.3	+72	5	10.0*d*	V Camelop.		49.4	+74	30	<12.0
U Piscium		17.7	+12	21	<12.0	Z Aurigæ		53.6	+53	18	10.8
R Piscium		25.5	+ 2	22	<12.4	X Aurigae	6	4.4	+50	15	8.5
RU Androm.		32.8	+38	10	11.8*d*	— Aurigae		6.5	+47	47	<13.5
Y Androm.		33.7	+38	50	12.0	V Aurigae		16.5	+47	45	<12.0
X Cassiop.		49.8	+58	46	11.6	V Monoc.		17.7	— 2	9	7.4
U Persei		53.0	+54	20	9.5	W Monoc.		47.5	— 2	7	9.8
S Arietis		59.3	+12	3	<12.4	S Lyncis		35.9	+58	0	11.1*d*
R Arietis	2	10.4	+24	35	<12.0	X Gemin.		40.7	+30	23	10.1
W Androm.		11.2	+43	50	9.5*d*	Y Monoc.		51.3	+11	22	<12.5
Z Cephei		12.8	+81	13	12.2*d*	X Monoc.		52.4	— 8	56	8.0
o Ceti		14.3	— 3	26	3.5 *i*	R Lyncis		53.0	+55	28	11.2 *i*
S Persei		15.7	+58	8	9.0	RS Geminorum		55.2	+30	40	11.2
R Ceti		20.9	— 0	38	90. *i*	V Can. Min.	7	1.5	+ 9	2	8.8
RR Persei		21.7	+50	49	<12.3	R Gemin.		1.3	+22	52	7.8*d*
U Ceti		28.9	—13	35	17.3 *i*	R Can. Min.		3.2	+10	11	10.2
RR Cephei		30.4	+80	42	10.0 *i*	RR Monoc.		12.4	+ 1	17	10.6
R Trianguli		31.0	+33	50	10.3 *i*	V Gemin.		17.6	+13	17	9.2
T Arietis		42.8	+17	6	8.5	S Can. Min.		27.3	+ 8	32	8.0
W Persei		43.2	+56	34	8.8	T Can. Min.		28.4	+11	58	9.7
U Arietis	3	5.5	+14	25	12.6	U Can. Min.		35.9	+ 8	37	<12.6
X Ceti		14.3	— 1	26	9.5	S Gemin.		37.0	+23	41	<12.8
Y Persei		20.9	+43	50	9.6	T Gemin.		43.3	+23	59	9.1
R Persei		23.7	+35	20	11.4 *i*	R Cancri	8	11.0	+12	2	9.0
T Tauri	4	16.2	+19	18	10.3	V Cancri		16.0	+17	36	9.6
R Tauri		22.8	+ 9	56	12.1*d*	RT Hydrae		24.7	— 5	59	9.0
W Tauri		22.2	+15	49	9.3	U Cancri		30.0	+19	14	<12.6
S Tauri		23.7	+ 9	44	<12.5	X Urs. Maj.		33.7	+50	30	<12.2
T Camelop.		30.4	+65	57	<12.0	S Hydrae		48.4	+ 3	27	10.0
RX Tauri		32.8	+ 8	9	12.5	T Hydrac		50.8	— 8	46	8.8 *i*

Approximate Magnitudes of Variable Stars on Nov. 1, 1908—Con.

Name.	R. A. 1900. h	m	Decl. 1900 °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
Z Capricorni	21	5 0	−16	35	11.2*d*	S Lacertae	22	24.6	+39	48	12.2*d*
R Equulei		8.4	+12	23	10.4*d*	R Lacertae		38.8	+41	51	12.2*d*
T Cephei		8.2	+68	5	8.6*d*	S Aquarii		51.8	−20	53	<12.4
RR Aquarii		9.8	− 3	19	10.4*d*	RW Pegasi		59.2	+14	46	12.0*d*
X Pegasi		16.3	+14	2	12 8*d*	R Pegasi	23	1.6	+10	0	7.7 *i*
T Capricorni		16.5	−16	35	12.0	V Cassiop.		7.4	+59	8	12.2
Y Capricorni		28.9	−14	25	12.0	W Pegasi		14.8	+25	44	9.5 *i*
S Cephei		36.5	+78	10	9.0*d*	S Pegasi		15.5	+ 8	22	12.2
RR Pegasi		40.0	+24	33	<13.4	ST Androm.		33.8	+35	13	9.2 *i*
V Pegasi		56.0	+ 5	38	9.0 *i*	R Aquarii		38.6	−15	50	10.1
U Aquarii		57.9	−17	6	11.6	Z Cassiop.		39.7	+56	2	11.0
RT Pegasi		59.8	+34	38	10.5 *i*	RR Cassiop.		50.7	+53	8	12.7
T Pegasi	22	4.0	+12	3	<13.2	Z Aquarii		47.1	−16	25	8.1
Y Pegasi		6.8	+13	52	11.0	V Ceti		52.8	− 9	31	13.0
RS Pegasi		7.4	+14	4	<13.5	R Cassiop.		53.3	+50	50	9.0 i
X Aquarii		13.2	−21	24	12.0	Z Pegasi		55.0	+25	21	10.5 *i*
RT Aquarii		17.7	−22	34	9.4	W Ceti		57.0	−15	14	7.5
RV Pegasi		21.0	+29	58	9.0 *i*	Y Cassiop.		58.2	+55	7	<13.0

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign<, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whitin and Harvard Observatories.

GENERAL NOTES.

Dr. Luiz Cruls' Death. The sad news of the death of Dr. Luiz Cruls, Director of the Observatory at Rio de Janeiro is announced. Dr. H. Morize succeeds the late Professor Cruls in the directorship of the Observatory.

Dr. Kurt Wegener will relieve Dr. Angenheister of the direction of the Simoan Observatory of the Götlingen Academy of Sciences.

Pocket Compass Sun-Dial of 1451. An illustrated interesting article on the Pocket Compass Sun-Dial of 1451 is the leader in the September number of *Terrestrial Magnetism and Atmospheric Electricity.*

Ephemeris of Minor Planet Diana (78) is just received. It covers the months of November and December of 1908. The computation is by Professor Dubjago from elements in Jahrbüch for 1910.

Sun-Spots and the Weather. We notice by the California papers that Rev. Jerome S. Ricard, director of the Santa Clara College Observatory, in California has become apparently a successful reader of sun-spots so that he can predict the weather for two weeks in advance on the Pacific slope. Since predictions by Mr Ricard's plan are, at least, nine days longer time ahead than the Government Signal Service can do, it is desirable to know how he does it. Without hazarding opinion in regard to its accuracy, we give his own words as follows:—

"A seven-year period of solar observation has been convincing, beyond the

He ordered the Ave Maria repeated three times a day instead of two and to the *prayer* was added—'Lord save us from the Devil, the Turk and the Comet.' He ordered the church bells, rung at noon, which was the beginning of a practice still common in Christian countries.'

"I do not understand that the noon bells were rung to *frighten* the comet, but to remind the faithful to repeat the *prayer*. I venture to say that no serious writer has ever claimed that Calixtus III issued a bull against Halley's Comet."

A Brilliant Meteor.—On September 4, 1908 at 8^h 28^m Eastern Mean time a very large meteor was seen all over New England. Evidently its course was nearly from West to East. As seen from Taunton it was in the northeast. Very slow in its flight, it was perhaps seen for 15 seconds in all. It passed just under α Persei and just over β. It was seen here starting from about right ascension $4^h + 60°$ declination and passed to 2^h $42^m + 34°$. I have corresponded with every one I have heard of as seeing this meteor but have not yet discovered any one who noted its path among the stars.

Note on Telescopic Meteors.—In Popular Astronomy No. 141 I drew attention to the great number of meteors seen while comet sweeping during the last two summers. I have kept a more systematic count of those seen and find that my former estimate of two per hour holds very well. One one night, August 2, 1907, 16 were counted in two hours of observing. In no case has an hour gone by without seeing at least one.

As bearing on the apparent arc of these telescopic meteors I have several times seen them start and disappear within the field of the comet seeker, that is they were less than $1\frac{1}{2}°$ in their visible flight. Another interesting observation was of the large apparent diameter of a few of them. They were not lines of light but bands of light in one case having a breadth of at least 1′ of arc.

JOEL H. METCALF.

Taunton, Mass., Oct. 7, 1908.

Relief in Lantern Slides. Autochrome lantern slides, which are much in evidence just now at the exhibition of the R.P.S. at the New Gallery, very frequently show an almost startling effect of relief on the screen, and a similar appearance is also very often observable with color slides made by the Sanger-Shepherd and other processes. Monochrome slides give the effect only sometimes, and it will generally be most often observed in the slides of some particular worker. At one lecture it may be so striking as to give rise to comments among the audience, while at another lecture given by some one else not a single slide may show it. We have frequently been asked to explain this effect, which the average man wrongly describes as "stereoscopic," and the fact that it is so common with color slides and so uncommon with monochrome images suggests a very sufficient reason. It is simply because the color slides are truer in their representation of distance than the monochrome slides, or, in other words, because they give truer perspective. Truth of outline is not sufficient in itself to give true perspective. Colors and color values also play a most important part, and if they happen to be false the effect of solidity or distance vanishes even though the linear perspective is true. In a color slide there is no translation of color into monochrome, and therefore if the colors themselves are truly made as exacting as mathematics and, above all, the elementary sciences of physics and chemistry have been reduced to a basis which enables these sciences to be presented in a way which, in my opinion, must soon entirely revolutionize technical education. I believe that our engineers and many of our engineering professors fail to realize the change that has taken place in the technical possibilities of elementary physics, in the last ten or fifteen years, and therefore we find these men expecting our teachers of mathematics to lift themselves and a large superstructure by pulling on their boot straps, these faithful teachers being held responsible for the most serious faults which underlie technical education. Let the heads of our technical schools look rather to their teachers of physics, demanding of them the best that modern science teaching can give, and allowing them the necessary time to accomplish what is desired. * * * On p. 450 Mr. Franklin further says:—"As a teacher, I am concerned with average men; and every year I am more and more amazed to see the feebleness with which men hold things in the mind, and more and more impressed with the tremendous power with which men hold things in the hand, a power which, as Plato says, encompasses with eternal security an ancient polity and divisions of rank founded on possession, but which also, alas! as Ruskin says, too often takes the name of Christ in vain, and leagues itself with his chief enemy covetousness which is idolatry."

This entire paper is clear, strong, decisive and very suggestive in many kindred lines.

Comstock's Field Astronomy for Engineers. We are in receipt of a copy of Comstock's Field Astronomy for Engineers which is a revision of a text-book published by the same author with same title in 1902. This revised book has given the author an opportunity to introduce into it such changes· without modifying its scope or plan, as he thinks will increase its usefulness. The most marked changes occur in the following articles:

"The relation of Sidereal to Mean Solar Time," is better stated in the new edition, because the mathematical part is improved. "Refraction" is the title of another article that is changed in regard to one formula which the author claims is accurate to half a second of arc down to altitudes greater than 20°. In his knowledge of refraction in recent years, the author has been regarded as good authority. The section dealing with the "Orientation by Polaris" is much changed for the better because of simplicity and precision in treatment. The same may be said in regard to the sections treating of "Azimuth observations at Elongation" and "Time and Azimuth from Two Stars."

As in the previous edition, there are many illustrations of instruments used in field work, in the revised text which make it a useful reference book for the practical engineer. The author has also furnished tables at the end of the volume, which, for the first time, as far as we know, make it possible for the engineer or surveyor to determine time, latitude and azimuth with a fair degree of precision without access to an almanac for the star coördinates. If he so desire, he may use observations of the Sun for the same purpose and reduce them by means of any common almanac that happens to be at hand. While this is of small consequence at an Observatory, it is quite otherwise in the case of men in the field who are not provided with the professional outfit of the astronomer.

Our readers will also be interested in the table of differential coëfficients, and the new method of treating azimuth observations of a circumpolar star made near elongation.

On the whole, Professor Comstock has done excellent service for engineering science in bringing out so good a text-book as this which he has recently revised, made more complete and somewhat enlarged.

The publishers are Messrs. John Wiley and Sons, of New York and London, 1908. Price is $2.50.

NORTH

COMET 1908 *c* (Morehouse)

1908 October 3, 17h 7m G. M. T. Exposure 2h 28m; 10-inch Lens, Bruce Telescope, Yerkes Observatory

The result so far is the best collection of photographs of a comet yet obtained, and the accumulation of material that must be of the highest importance in the solution of the mysteries of comets—even if it does prove revolutionary in some of its results. It is too early to digest this material, especially as the comet is still under observation and doubtless will give us yet more valuable information.

Daniel's comet was visible only for a short time in the mornings and permitted but a comparatively short observation before daylight. The duration of its visibility above the horizon when bright, was too short to allow much change to be shown by successive exposures. It was necessary therefore to compare photographs made at different observatories on the same night to show the changes, which, to begin with, were neither striking nor great.

The present comet was placed at a high declination (+76° part of the time) and visible through the entire night. A splendid opportunity was thus offered to detect changes in it at the same observatory by frequent photographs during the night. Added to this fact was the still more important one that the comet, much of the time, was changing rapidly and sometimes violently.

During part of September the atmosphere was filled with dense haze and smoke, so that for some days the Sun itself could scarcely shine through with a feeble yellow light. At night only the brighter stars could be seen. Under these conditions it was very difficult to get anything in the way of a photograph of the comet, and then only with long exposures. The guiding was also specially difficult because of the faintness of the comet.

There have been several periods of remarkable outbursts in the comet. Between these displays it has not been lacking in interest, for there is essentially not a single picture that is not more or less important. The principal disturbances, which are covered by my plates, occurred on September 30 and October 15. There was doubtless one also on or about October 6, the main part of which was lost here in moonlight.

The first picture of September 30 scarcely suggested what sort of an aspect the comet would present before the night was over. It showed it different from its previous appearance, but not enough so to cause special remark. The succeeding photographs on that night, however, became more startling, the last one being extremely remarkable and beautiful. The tail had become cyclonic in form and was attached to the head (which was counted for by the lower altitude.

On October 30 the comet was again faint to the eye, much less bright than on the 29th, though it could be seen as a faint hazy spot with a faint streak from it. The comet, therefore, suddenly brightened up sometime between October 28 and 29 and faded out again by the 30th. On October 29 the head seemed to become smaller in the guiding telescope and the part of the tail visible in the field became narrower.

I have several times examined the comet with the 40-inch, but these views, from the contracted field and the great power of the instrument, have been unsatisfactory. On September 20 I could see that the tail near the head was almost disconnected and that it was receding from the comet. This brighter portion of the tail was several minutes long. At $8^h\ 13^m$ (C.S.T.) the center of mass was 7′.0 south of the head. "It is quite noticeable, and is about 1¼′ wide by about 3′.5 long." At $11^h\ 33^m$ the mass had moved away from the comet and was 11′ distant. It had changed much in form. The apparent rate of recession was 1′.2 per hour in this interval. A photograph which I made on the same night showed that this object was the disconnected end of a considerable tail and that a fainter stream connected it with the head. On October 11 a minute nucleus of 14^m or 15^m, like a faint star, was visible following the central brightness of the head by about 5″. As the comet was moving rapidly southwards and I was measuring it for position, there was no question as to this being the nucleus. On account of its unsymmetrical position, I at first supposed it was a faint star.

The early observers of comets noticed the fact that the tails of these bodies were always directed away from the Sun. It was naturally concluded that this peculiarity was due to a repulsive force existing in the Sun, which drove the smaller particles of the comet off into space. This conclusion was readily reached but the force itself was unrecognized. Modern astronomy, through the researches of Arrhenius and the experiments of Nichols and Hull, has shown that the repulsive force is really the pressure of the Sun's light upon the smaller particles of the comet. If the particle is so small that its surface is relatively large compared with its mass, then the sunlight pressing against it will overcome the pull of gravity and drive the particles away into space. The smaller the particles the greater will be their velocity. From this it will be seen that when the conditions are right the smaller particles will be sifted out from the

COMET 1908 *c* (Morehouse)

1908 October 4, 19h 5m G. M. T. Exposure 1h 45m; 10 Inch Lens, Bruce Telescope, Yerkes Observatory

COMET 1908 *c* (Morehouse)

1908 October 4, 19h 5m G. M. T. Exposure 1h 45m; 10-inch Lens, Bruce Telescope, Yerkes Observatory cope of the Yerkes Observatory. They show how rapidly the comet changed its character. In that of October 3 the tail is made up of a number of separate rays. These rays in the last photograph of that night were diffusing together, doubtless to form the tail shown in the second picture—October 4th. In this last one (Oct. 4) the head was very small—smaller than is shown in the reproduction; the tail was curved and irregular on its northern side.

There is no resemblance between these two photographs of the same object on these two successive nights. Yet the transformations were so great and rapid that on September 30 there was almost no resemblance between the comet in the first picture and in the last one of that night—an interval of less than four hours. The tail has sometimes been perfectly straight and at others violently curved. Indeed this comet could readily produce all of Bredikkine's three types of tail in as many days or less. These pictures have shown how unsafe it is to say that a comet was of a certain class or type from any one picture of it. It is not at all likely that the nature of the particles has changed in producing the various tails shown by this comet.

Yerkes Observatory,
October, 1908.

ON AN INFINITE UNIVERSE.

W. H. S. MONCK.

FOR POPULAR ASTRONOMY.

That the limited quantity of light which we receive from the stars does not prove the universe to be limited even on the hypothesis that no light is lost in transmission may, I think, be conceded. But though we may make suppositions which would reconcile the actual facts with an infinite universe, the question arises whether these suppositions are not of such an improbable character as to render a finite universe almost certain. Thus if the stars became more thinly scattered the farther we proceeded in every direction from the Sun taken as a center, the number of stars might be infinite and yet the total amount of light very limited. But if there is no reason to regard the Sun as situated in the center of the universe and if we regard it as a comparatively insignificant star which has but little influence on the motions of the other bodies which surround it, the hypothesis that the Sun is situated in the densest portion of the universe

Sun. But if there are (as I presume there are) dark bodies in space, a considerable portion of the sky may be covered by black disks instead of bright ones and the general illumination of the sky may fall considerably short of that of the Sun's disk owing to these black spaces. Both the bright and the black disks would probably be too small to be seen as separate objects, and the presence of the black disks would be only indicated by a general reduction in the luminosity of the sky as compared with that of the Sun.

I have compared the numbers of stars of each magnitude in some of the Photometric Catalogues in which Pogson's scale has been adopted; and the general result has been that while the theoretic *ratio* of 4 to 1 is never attained, the ratio of 2½ to 1 is always exceeded, so that the total light of the stars of the stars of the $n + 1$th magnitude is always greater than the total light of those of the nth magnitude. But these catalogues only take us as far the 8th magnitude (perhaps not so far) and from the comparatively small amount of the total star-light, I think this state of things must be inverted before we go much further and that very possibly the total light of the stars of the tenth magnitude exceeds the total light of the stars of the eleventh magnitude. Assuming this to be the case, however, the question remains whether this falling off in the total light of the fainter stars is due to a thinning out of the stars when we reach the average distance of a tenth-magnitude star or to the loss of a considerable portion of the light of the more distant stars in transmission. The latter seems to me to be more probable.

Assuming that there is no loss of light in transmission the intrinsic brightness of a star-disk will be the same at all distances. For the light varies inversely as the square of the distance and so does the angular magnitude of the disk, so that the dimensions of the visible object are reduced in exactly the same proportion as its total light, In the case of the stars what we see is not the real disks but a spurious disk caused by the imperfection of our eyes or our instruments; but I think there can be no doubt that this defect does not reduce the quantity of light which we perceive while it evidently cannot increase it. The total amount of light which we receive from the sky is therefore the same that we would receive if all the star-disks were seen in their real dimensions with their real intrinsic brilliancy: and from this we may draw conclusions as to what proportion of the visible sky is covered by luminous star-disks.

er exposure fails to indicate. What fails to excite consciousness may still be active, and may with a little more activity of the same kind be rendered perceptible. Sight is peculiarly circumstanced in this respect. We receive the star-light in the daytime but do not see the stars. We fail to see a good many of them on a moonlight night, and on a very dark night if the sky is clear, we can see stars that are not usually visible. We might not impossibly see a star of the tenth magnitude with the naked eye if all other light could be excluded. Contrast of light is an important element as regards the visibility or invisibility of any object. A small star may be lost in the glare of a large one though it would be seen easily enough if the large star were removed. Light which is insufficient to produce conscious perception may nevertheless by affecting the organ of vision render it more susceptible to similar influences than it would otherwise; and the organ when under the influence of a strong light will not be perceptibly affected by minor lights which under more favorable circumstances would be easily perceived. Assuming the ether to be completely transparent, can we believe that the entire sky might be covered with luminous star-disks and yet appear black to us because each disk taken separately was too small to be seen? The Sun's luminous surface consists of an assignable number of square inches. One square inch of it would, I presume, be invisible to a spectator on the Earth if all the rest were shut out by an eclipse; but will it be contended that the Sun's surface cannot be seen because it is composed of luminous parts too small for separate vision?

The argument in favor of a finite universe does not turn on the total light of the sky being finite but on its being very small—too small to be consistent with an infinite universe unless we make some rather extravagant supposition with regard to star-distribution. Supposing that $\frac{1}{500,000}$ part of the sky were covered with star-disks having an average brilliancy equal to that of the Sun and that these star-disks were distributed impartially over the sky, the entire sky ought to be as bright as the full Moon. Is this degree of brightness attained even in the densest star-cluster? If the number of stars be infinite, it seems strange that on drawing a line at random through space the chances are at least 500,000 to 1 that it will never encounter a star although produced to infinity.

But is there any mode of testing the current hypothesis that no light is lost in transmission through the ether? I think there is.

RIGIDITY OF THE EARTH.*

T. J. J. SEE.

Rigidity of the Earth Calculated from the Theory of Gravity, on the Hypothesis that the Distribution of Rigidity in the Globe is Everywhere Proportional to the Pressure.—It has not been supposed by previous investigators that a method could be devised for deducing the rigidity of a body like the Earth from the theory of gravity; but in 1905 it occurred to the present writer that such a method could be found if we could adopt a suitable hypothesis for the variation of the rigidity with the pressure. Previous investigations of the internal state of the heavenly bodies had justified the law of Laplace as giving an excellent approximation to the law of density for the Earth and the rest of the encrusted planets; and the monatomic law had been found most satisfactory for the Sun and fixed stars (cf. *A. N.* 4053). These laws enable one to obtain the pressure at every point of the radius of the heavenly bodies. For in several ways Laplace's law of density is fairly well established for the Earth, and on equally good grounds the density of the Sun is believed to conform essentially to the monatomic law.

From a study of the laws of density, pressure and temperature within the heavenly bodies it appeared to me (as it had independently appeared to Arrhenius five years before) that matter under these extreme conditions must be essentially gaseous; and as it is above the critical temperature, it is made to behave in confinement as an elastic solid. Now in all gaseous masses the density is proportional to the pressure so long as the gas remains perfect; and the gas does not cease to be perfect when the temperature is above the critical value, though it it may acquire in confinement the property of an elastic solid if the pressure be great enough to bring the molecules within a distance at which the molecular forces become effective in spite of the high temperature. Thus while the property of rigidity in cold solids depends wholly on molecular forces which prevent deformation, this property for gaseous matter in confinement under such pressure that it acquires the property of an elastic solid, is due wholly to the pressure. The molecular forces giving effective rigidity must increase in proportion to the pressure, or in a higher ratio.

If according to hypothesis the matter is made solid by pres-

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* Extract from Dr. See's Physics of the Earth.

$$P = \int_0^x p.4\pi r^2 x^2.rdx \tag{3}$$

$$= \frac{3(\sigma_0 g)^2.r4\pi r^3}{2(\sigma_1 g)q^4}\left(\int_0^x \frac{\sin^2(qx)}{x^2}x^2 dx - \sin^2 q \int_0^x x^2 dx\right),$$

which by integration becomes

$$P = \frac{3(\sigma_0 g)^2 r 4\pi r^3}{2(\sigma_1 g)\, q^4}\left(\frac{qx - \sin(qx)\cos(qx)}{2q} - \sin^2 q\,\frac{x^3}{3}\right), \tag{4}$$

As our integration is to include the whole sphere of the Earth, we put $x = 1$, and then we have

$$P = \frac{3(\sigma_0 g)^2.r4\pi r^3}{2(\sigma_1 g)q^4}\left(\frac{q - \sin q \cos q}{2q} - \frac{\sin^2 q}{3}\right). \tag{5}$$

The total volume of the Earth is $(\frac{4}{3})\pi r^3$, and hence the average pressure per unit of area on all concentric spherical surfaces is

$$R = \frac{P}{\frac{4}{3}\pi r^3} = \frac{3}{4\pi r^3}\int_0^x p.4\pi r^2 x^2.rdx \tag{6}$$

$$= \frac{9(\sigma_0 g)^2.r}{2(\sigma_1 g)q^4}\left(\frac{q - \sin q \cos q}{2q} - \frac{\sin^2 q}{3}\right).$$

If r is expressed in meters, the mean pressure or mean rigidity R comes out in kilograms per square meter. To reduce the result to atmospheres we divide by 10,333. The result for the Earth is $R = 748{,}843$ atmospheres, about the rigidity of wrought iron.

This method takes no account of the Earth's solid crust, and is therefore too small; morever viscosity increases within the Earth, owing to the rise of temperature downward. We give hereafter an approximation to the increase of rigidity by determining the mean rigidity of the Earth's *matter*, as distinguished from that of the *various layers* composing the globe, just found by the above analysis.

To find the mean rigidity of the Earth's *matter* we must consider not only the pressure but also the density or mass per unit volume of the imprisoned matter in each layer. The result represents a mean rigidity in which every elementary spherical shell composing the globe is allowed a weight proportional to its mass, which is multiplied by the pressure to which it is subjected.

The theory of the determination of the mean rigidity of the Earth's matter is as follows:

$$P' = \int^x p\,.\,4\pi r^2 x^2\,.\,rdx\,.\,\sigma = 4\pi r^3 \sigma_0 \int_0^x p\,.\,x^2 dx\,\frac{\sin(qx)}{qx}. \tag{7}$$

Substituting for p its value from (2), we get any concentric layer may be taken to be inversely as the pressure to which the imprisoned matter is subjected. *It is remarkable that the curve of pressure as we descend in the Earth becomes therefore also the curve of effective rigidity for the matter of which the Earth is composed.* Thus the rigidity of the matter at the Earth's center probably is at least three times that of nickel steel used in armor plate; as we approach the surface the effective rigidity constantly exceeds that of nickel steel until we come within less than 0.4 of the radius from the surface, where the pressure is less than 1,000,000 atmospheres.

"To imagine a mechanical substitute for the Earth's constitution, without the introduction of pressure, suppose an alloy of adamant to give the material at the center of such a globe, of the same size but devoid of gravitation, a hardness three times that of armor plate. The outer layers as we approach the surface must then be supposed softer and softer, until it is like armor plate at a little over 0.6 from the center, and finally a very stiff fluid near the surface. In addition to this arrangement of its effective internal rigidity the actual Earth is enclosed in a spheroidal shell of solid rock analogous to granite. One can easily see that tidal forces applied to all the particles of such an artificial armored sphere would produce but very slight deformation, because of the enormous effective rigidity of the nucleus.

"The principal uncertainty in this result arises from the admissible variations in the assumed Laplacean distribution of density within the Earth. Both Radau and Darwin (cf. *Monthly Notices*, Roy. Astro. Soc., December, 1899) have pointed out that considerable variations in the internal distribution of density are possible without invalidating the well-known argument drawn from the phenomenon of the precession of the equinoxes; yet on physical grounds it seems clear that pressure is the principal cause of the increase of density towards the Earth's center. And since this does not vary greatly for moderate changes in the law of density, the principal of continuity shows that the actual law of density within the Earth cannot depart very widely from that of Laplace. The above value of theoretical rigidity of the Earth may therefore be taken as essentially accurate, and I think no doubt can remain that the rigidity of our Earth as a whole considerably exceeds that of steel. The original conclusions of Kelvin and Darwin are therefore confirmed by the present dynamical considerations based upon the theory of universal gravitation."

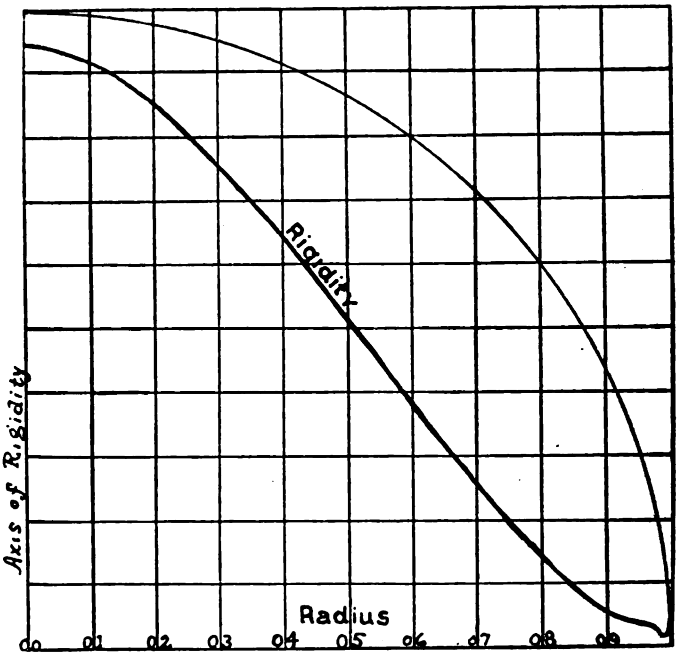
In this connection we should remember that the experimental show that a molten layer underlies the crust, and occasionally is forced to the surface.

3. This underlying molten rock moves in world-shaking earthquakes, and frequently is expelled from beneath the sea under the land to form mountain ranges along the coast.

4. We may prove this expulsion of lava by the observed seismic sea waves which indicate a sinking of the sea bottom, and by the simultaneous uplift of mountains and coasts.

From these considerations it follows that the Earth is most nearly liquid just beneath the crust, and has the greatest rigidity at the center. As the plastic or quasi-viscous layer beneath the crust is thin, and possessed of considerable rigidity, *it too remains quiescent except when set in motion by the dreadful paroxysms of an earthquake.*

In tidal and other observations the Earth therefore behaves as a solid, and the rigidity of the Earth inferred by Kelvin and Darwin is confirmed. Yet a layer of plastic matter or quasi-viscous fluid exists just beneath the crust, and when disturbed by earthquakes gives rise to the development of ridges in the crust called mountains, chiefly by the expulsion of lava from under the sea.



CURVE OF RIGIDITY OF THE EARTH, SHOWING THE PLASTIC LAYER JUST BENEATH THE CRUST.

The supposition, that only three bodies sensitive to color are found in the eye, corresponds fairly well to the observations; the supposition of four or six bodies would perhaps be better. But it would be best to examine the anatomy of the eye and see if it were not possible to discover the resonant bodies. If these bodies do not vary too much from the corresponding wave-lengths, we may hope that they will not be so small as to escape our examination, for under the microscope it is very easy to measure a wave-length. Through H. Miller's well-known experiment the shadows of the bloodvessels in the retina can be observed. Now since these vessels extend just to the layer of rods and cones but not into it, and since there is no nerve substance behind this layer, it follows that in this layer we must seek the end-elements, *i. e.* the light-receiving and color-refracting mechanism. If their dimensions are approximately or exactly like those of their corresponding wave-lengths, then we should be able to find them; and since the range of visible light amounts to something less than an octave, the smallest body should be, accordingly, about half as large as the largest.

Now we find that the cones consist of two parts—an inner segment, that stands on the "membrana limitans externa." and an outer segment that again is set upon the first. In the upper part of the inner segment is a clear strongly refracting substance which is separated from the other part by an ellipsoidal surface—the so-called ellipsoidal body. The outer segment of the cone consists of a row of disks which gradually grow smaller from the base to the point. A thin axial filament seems to run through the whole length [Ritter's filament]; yet this is not sure. The rods are constructed exactly analogous to the cones; they possess all their parts, but their forms are different. As the name indicates the outer segments of the rods are cylinders and not cones. The cones and rods form, crowded together side by side in a very fine mosaic, the cone and rod-layer of the retina.

Where the keenness of vision of the retina is the greatest, there are found only cones; just as in general the keenness of vision varies in proportion to the number of cones. Thus in the parts near the circumference—the "ora serrata"—, where there are almost no cones, there is also almost no sight, although the region is crowded full of little rods. We know already that every cone is capable of transmitting perception of light and color; hence we can assume, that only the cones are capable of it.

Zenker (1867), one of the first explorers of the retina with the perfected microscope, who well knew the wave-lengths of the edge of the image should lie on both cones at the same time but it would be most improbable. If the diameter should reach just double the distance between two cones, then the image could touch one single cone only at one single point; and that could happen only for the shortest time. For cases lying between the two it is clear that the object is perceived sometimes as a point, sometimes as a surface. If one looks at two little wires at such a critical distance, one will always be in doubt whether one is seeing one or two wires; one moment we are quite sure of seeing two objects, the next moment we believe we can see but one, because the image lies first on one cone and then on two. The nearer we come to the upper limit the longer become the periods of certainty and the shorter the periods of doubt: then, thanks to the persistency of the perceptions, we will finally be observing two objects quite distinctly without the image having always to cover two cones. Now the least distance of two distinguishable retinal-images is 3,65—4,64 μ (Helmholtz) and falls somewhat below the doubled distance of two cones, which amounts to 4—6,25 μ. Here we have a direct proof that the cones are the actual end-elements.

Now if the outer segments are really the light-perceiving bodies, then the space between them must be dark. So that a very small point-formed image of the retina, as e. g. that of a star, will be seen only when it falls upon a cone, and it will be dark when it falls between two cones. If so tiny an image move back and forth over the mosaic, then it should be perceived as first light and then dark, or, as we are accustomed to say, it would twinkle. If we are observing a star of low elevation whose rays must suffer an irregular refraction in low layers of air, then its image wavers back and forth a little over the cone-mosaic and it does, in fact, twinkle. This gives a further demonstration of our statement as well as an explanation of the twinkling of stars.

Now the question arises, whether all rays of all colors must unite in exactly the same depth of the background of the eye, *i. e.* in the same plane, or whether—for the clearest focus—the image must lie in different planes according to the different colors. It is worthy of note that Helmholtz has always referred to the first supposition. He always writes about the plane of the retina, as though there really were such a plane, where all impressions are perceived most distinctly. And yet the layer of cones is 60—100 μ thick. As we shall at once see, the image of a colored object must lie in a very definite position or plane in order to be seen most distinctly. If there be such a common mathematical plane for all impressions, then it is certainly not easy to conjecture where it lies. Fortunately, we have at our command the measurements in this respect of two of the greatest observers the world has ever seen: those of Frauenhofer and Helmholtz. Frauenhofer, the first to make experiments in this realm found a few moments irreconcilable with the supposition of a fixed plane of delineation; these he could not explain.

For the dioptric apparatus of the eye we can use the so-called reduced eye of Listing. In an eye of this kind, as is well-known, a single refracting surface is taken with a radius of curvation of 5,1248 mm, which separates water on the concave side from air on the convex. For purposes of reckoning such an eye replaces the human eye with sufficient accuracy. Now Frauenhofer experimented with red light which answers to his line C, and violet answering to his line G. He had already determined that these rays had for water an index of refraction of 1,331705 and 1,341285 respectively. For parallel red rays the focusing point lies on the axis of our reduced eye 20,574 mm behind the vertex of the refracting surface; for parallel violet rays the focus lies 20,140 mm behind this area. Hence the focal planes of these two colors are 0,434 mm distant from each other. (Helmholtz Ph. O. §13). If the violet focal plane is to coincide with the red, the violet rays must needs come from a distance of 713 mm in front of the refracting surface. For this reason, Frauenhofer supposed that one must see the violet illumined object most distinctly at this distance; but in fact he had to bring it to a distance of 685 mm. He took note of the variation but could not explain it. Helmholtz too carried out similar experiments and likewise ascertained this deviation. He could not explain it either, but he supposed that it depended upon a difference in the refracting power of the eye and of water, although according to all measurements, they are not to be distinguished. Matthiessen also reached these results (Ph. O. a. a. O.)

We will presuppose that there is only a slight difference or none at all between the refracting power of the eye and of water. In this case the violet image in Frauenhofer's eye must have lain 37 μ behind the red. Frauenhofer's experiments were extremely exact. The data of his lines C and G make possible the exact determination of the distance between the two images.

Helmholtz does not give with exactness the parts of the spectrum which he compared; he merely says "violet and red." Let us assume that he used Frauenhofer's line C for red and the extreme violet with a refraction index of 1,3425; then the distance between the two images was 30 μ. The measurements of Matthiessen give about 40 μ. So the observations of all three agree very well, and on the supposition that the power of refraction of the eye is very nearly the same as that of water, we notice that the violet focal plane lies behind the red at a distance of the length of the outer segments of the cones. In a series of experiments with colors of the spectrum I was able to demonstrate the above results very well, and also that the other colors (yellow and green) consequently lie between these limits.

On the ground of these proofs then we will assume that a red image lies in a plane which intersects the large disks, a violet one in a plane which intersects the smallest disks; the other colors form planes intersected by the resonant disks corresponding to them. Here we have to deal with a physiological constant magnitude in the human eye that corresponds to an anatomically physiological magnitude, viz., the length of the outer segments.

Von Gräfe declared, that in aphacia there was a certain range of accomodation though very short. Donder, on the other hand, says: "The accomodation line of Czermaks which is mistakenly connected with the length of the rods depends upon this: it is caused by the lack of symmetry of the dioptric apparatus of the eye and is a function of the length of the focal power." But in spite of this I believe that Von Gräfe is right, and that the short range of accomodation, if one may call it so, really is caused by the different levels of the disks.

In the following we will consider the disks as elastic bodies, each of which has its own period of vibration, and which are capable of taking up this period or a great number of them. From their size we expect that these periods will reach over an octave, and in fact we find that visible light includes from 395 to 760 billion vibrations. In physics it sometimes happens that a coincidence arises not from chance but from a common law. In all probability pure *chances* happen very seldom; *e. g.* Maxwell found that the velocity of a disturbance in an electromagnetic medium agreed exactly with that of light. Later experiments in that line have proved that it was no chance, but identity of the phenomena.

To be continued.

A CRITICISM OF "FAITH AND THE FOURTH DIMENSON."

WILLIAM H. JOHNSTON.

FOR POPULAR ASTRONOMY.

A reading of "Faith and the Fourth Dimension" suggests to me that, in making public his ideas on that subject, Professor Jacoby has failed to appreciate the obligations imposed by his position. As a representative of the intellectual life, he owes it to his station to confine his utterances to a subject in which his reason can withstand his prejudice and in which his knowledge of the facts justifies an expression of opinion. That he has not so confined himself will be made evident by a consideration of his article.

The author's efforts are devoted to showing that "it is possible for science, like religion, to believe something not logically proven." Grant his contention that science takes things on faith; does it follow that science is, therefore, like religion? One man believes that the stars influence human character; another believes that space is three-dimensional in points. Neither can prove his case; but, surely, they are not equally credulous. In other words, believing one thing without proof is not necessarily on par with accepting some other thing without proof. Hence, religious faith is not necessarily the same as scientific faith; and since Professor Jacoby has not shown that they are alike, he is not justified in saying that one resembles the other.

Let us, now, look to the accuracy of some of the facts. According to our author, Lobachevski has shown "that Euclid's demonstrations are not in accord with the extreme requirements of rigid logic." As a matter of fact, the rigor of Euclid's logic is questioned no more to-day than it was two thousand years ago; for in mathematics "no new development can undo the work of previous developments or substitute new in place of old results." (Herman Schubert: On the Nature of Mathematical Knowledge.)

In particular, we are expected to believe that Lobachevski's theorem regarding the sum of the angles of a triangle conflicts with Euclid's angle theorem. If we draw a triangle on a sphere, the sum of the angles is not 180°. But who imagines that the theorem is at variance with the one about the plane triangle? And if no one is surprised to learn that a figure on a curved surface does not possess the same properties as a figure on a plane, one ought not to be especially astonished to know that Lobachevski's results differ from Euclid's; for the former's triangle is on a curved surface. "One of the most surprising results of modern geometric investigations was the proof of the applicability of the non-Euclidean geometry to pseudospheres or surfaces of constant negative curvature." (Dr. Karl Fink: A Brief History of Mathematics.)

The next topic which is of interest to us in this connection is the fourth dimension, the domain of "half ridiculous phenomena." An elaborate discussion is hardly necessary here, for a mere suggestion of one phase of the subject as it appears to a mathematician will suffice to show that the fourth dimension is not so much a figment of the mathematical imagination as Professor Jacoby would have us believe. To begin, it is necessary that we realize definitely what we mean when we say that space is three-dimensional in points. An answer involving the terms length, breadth, and thickness is not satisfactory; for, what is the length of space? If we think of a portion of space, what is the thickness of a sphere? Such questions do not occur if we say that space is three-dimensional in points because to locate a point one must know three things about it. These three may be latitude, longitude, and altitude.

Suppose that, instead of limiting ourselves to points and lines, we turn to the geometry of spheres and groups of spheres. From the point of view of such geometry, what is the dimensionality of space? That is, how many things must one know to locate a sphere, which is the element of space? A particular sphere may be fixed by determining its center and radius. Three qnantities fix the former; and hence, four distinguish one sphere from all others. Thus, when we study the geometric properties of groups of spheres, the space of our senses is four dimensional. If, then, the space that we know may be either three or four dimensional, the fourth dimension cannot be any further from reality than the third.

Up to this point we have considered the illogical structure of "Faith and the Fourth Dimension," the erroneous idea of the author regarding Euclid and Lobachevski, and, finally, the writer's limited knowledge of the fourth dimension. There are one or two other matters which might be of interest, but I think enough has been written to justify the statement that Professor Jacoby has not sustained the intellectual standard of his position. I have sought to establish this proposition, not because the article is exceptional, but because it seems likely that

A simple method of determining the radii of curvature is illustrated in Fig. 2. Draw the straight lines $a f$ and $a c$ forming *any* angle at a. With a as a center, and with radii $a b$ and $a d$ respectively equal to the semi-minor and semi-major axes, draw the arcs $b e$ and $d c$. Join $e d$ and through b and c respectively draw $b g$ and $c f$ parallel to $e d$ intersecting $a c$ at g, and $a f$ at f; $a f$ is the radius of curvature at the vertex of the minor axis; and $a g$ the radius of curvature at the vertex of the major axis.

From the similarity of the triangles $a c f$, $a e d$ and $a g b$, the student will see that this construction is in conformity with a demonstration in the calculus, viz., that the radius of curvature at the vertex of an axis is a third proportional to the semi-axes. With these radii (R and r) the osculating circles in Fig. 1 are described.

One of these circles falls wholly *without* the ellipse, while the other falls wholly *within* the curve. It is evident then, that in order to represent an ellipse approximately by arcs of circles, the longest radius should be less than R, and the shortest radius greater than r.

The following empirical construction gives the best result. Lay off $d h$ (Fig. 2) equal to one eighth of $b d$. Join $e h$, and draw $c k$ and $b l$ parallel to $e h$. Take $a k$ for the longest radius ($=R$); $a l$ for the shortest radius ($=r$); and the arithmetical mean, or one half the sum of the semi-axes, for the third radius ($=p$); and employ these radii in the well-known construction for the eight-centered oval.

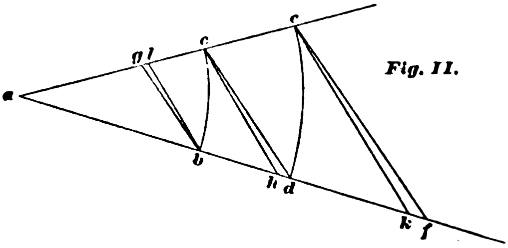


Fig. II.

In case the student may not be familiar with this figure it is illustrated. Let $a b$ and $c d$ (Fig. 3) be the major and minor axes. Lay off $a e$ equal to r, and $a f$ equal to p; also lay off $c g$ equal to R, and $c h$ equal to p. With g as a center and $g h$ as a radius, draw the arc $h k$; with the center e and radius $e f$ draw the arc $f k$ intersecting the former at k. Draw the line $g k$ and produce it, making $g l$ equal to R. Draw k e and pro-

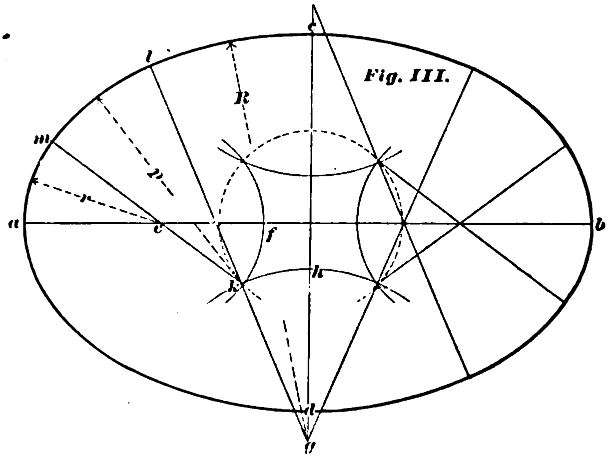


Fig. III.

duce it, making $k\ m$ equal to p. With the center g and radius $g c$ $(=R)$ draw the arc $c\ l$; with the center k and radius $k\ l$ $(=p)$ draw the arc $l\ m$; and with the center e and radius $e\ m$ $(=r)$ draw the arc $m\ a$.

Since the remainder of the work is symmetrical with respect to the axes, the student will need no explanation beyond that which is afforded by the drawing.

Hartford, Conn.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

Part III. (Continued.)

THE NATURE OF THE SOLAR RADIATIONS AND THEIR RELATION TO TERRESTRIAL MAGNETISM AND OTHER METEOROLOGICAL PHENOMENA.

Upon the orbital velocity, represented by $D^{\frac{1}{6}}$, or $P^{\frac{1}{4}}$, depend the rigidity and elasticity of the molecules of all gaseous matter, these quantities being proportional to the square of the velocity and therefore to $D^{\frac{1}{3}}$ and $P^{\frac{1}{2}}$ and, even in the case of that superlatively tenuous matter called the "luminiferous ether," which is at the lowest known, (and the fundamental) temperature in nature, the molecular rigidity and elasticity are very great because, as has been demonstrated, the atoms of each molecule of this transmitting-medium for radiance of all kinds are continually revolving, in their normally circular orbits, with a *linear* orbital velocity equal to 2π times the "velocity of light" which is (according to Professor Newcomb), very approximately, 186,340 miles, per second which expressed in English feet, per second is 9839×10^5 (in *centimeters* 2999×10^7, or 3×10^{10}, very nearly) the orbital velocity being therefore, 6182×10^6 feet, or 1884×10^8 centimeters, per second, these quantities being 2π times the "velocity of light" which is the projection of this orbital, or tangential, velocity of the atoms, upon the diameter of the circular orbits thereof, or upon the diameter of a molecule of the ether,—the velocity of light being, obviously, a radial quantity. The molecules of the atmospheric gases at the Earth's surface are by reason of the compression caused by the terrestrial force of gravity, very much denser and of smaller radius, and possess, therefore, a much higher absolute temperature and pressure (due to the much greater orbital velocity of their component atoms) than the molecules of the fundamental matter, the luminiferous ether the density whereof, relative to that of air under the normal conditions, is extremely low, and the linear orbital velocity of the atoms of the normal atmospheric molecule is proportional to $D_a^{\frac{1}{6}}$; ie., to the sixth root of the density (D_a) of atmospheric air, relative to the density (D_e) of the ether, which, in this connection, is taken as *unity*, D_a being therefore the *reciprocal* of the density D_e. The last named density is, according to my determination, set forth in a preceding part, $5191 \times^{-20}$, or $\frac{1}{1412 \times 10^{13}}$, whence the value of D_a is 1412×10^{13} the logarithm of which is [16.149448] the logarithm of $D_a^{\frac{1}{6}}$ being therefore, this logarithm divided by 6, or [2.691658], the natural number whereof is 491.65, the linear orbital velocity of the atoms of a molecule of atmospheric air being 3040×10^9 feet, or 9266×10^{10} centimeters, per second.

Although the orbital velocity of the atoms of the mean atmospheric molecule, under the normal conditions, is thus nearly 492 times that of the atoms of the molecules of the luminiferous ether, the velocity of transmission of radiance by these atoms of the comparatively much denser matter of the atmospheric gases, is sensibly the same as when the transmission is through the medium of the atoms of the ether out in space, at an altitude of very approximately 250 miles above the Earth's surface, at which height the matter of the terrestrial atmospheric envelope is in equilibrium, as to density, temperature and pressure, with the tenuous matter of the luminiferous ether, this altitude marking the upper limit of the Earth's atmosphere as determined by an analytical method based upon the principles of my theory of gases, and sufficiently well verified by observational data of several kinds, as will be shown subsequently.

A fundamental analytical expression derived from the principles of my theory is $V_1 = \frac{\lambda}{A}$ in which λ represents wave-length, and A the corresponding amplitude of vibration, in the case of luminous radiation through the transmitting medium, the "velocity of light" being designated by V_1 which is, as is well-known, sensibly a constant quantity. By reason of the greater orbital velocity of the atoms of the atmospheric gases, the "frequency of vibration" is increased in direct proportion and the wave-length λ decreased in the same ratio, when radiation is transferred to the denser molecules of the atmospheric gases under the normal conditions of temperature and density, as is indicated by the well-known expression of the "wave-theory of light"; that is $V_1 = f\lambda =$ a constant, in which f represents the frequency of vibration.

Therefore, the wave-length, (λ) in the case of luminous vibrations through the normal atmospheric molecules, is only $\frac{1}{491.65}$ of that when the transmission takes place through the atoms of the molecules of the ether in outer space, the orbital velocity of these atoms being less than that of the ultimate particles of the standard atmospheric molecules, by that fraction; but, by reason of the greater orbital velocity of the latter atoms, whereby the rigidity of each molecule is increased, any given impulse transferred to an atom of the medium by impact from any ultimate particle of a radiating surface, will deflect this atom from the tangent to its normally circular orbit, at the point of impact, by only the $\frac{1}{491.65}$ part of the deflection that would result from the same—or an equal—impulse or impact directed against a revolving atom of a molecule of the ether, the circular function defining the angle of deflection being the cotangent thereof, which also represents the amplitude of vibration designated by A, which, therefore, in the case of the atmospheric gases aforesaid, is $\frac{1}{491.65}$ of its value when the radiation is through the ether, and since it varies *pari passu* with λ, there results the equation; $V_1 = \frac{\lambda}{A}$ = a constant, which is an expression of the undulatory theory as well as of mine.

This is only one of several links connecting the wave theory of radiation, with the one that I have advanced, mine being, in this respect, a veritable undulatory, as well as corpuscular theory, the Newtonian theory (which was long ago discarded for that of Huygens, when the "criterion" as to the relation between the velocity of light in media of different densities, and the index of refraction was applied) which is corpuscular, being thus corroborated in so far as the nature of the medium, by, and through, which the radiation is propagated, is concerned, the luminous vibrations being those of almost infinitesimal material particles, the atoms—while the motion of these particles is in accordance with the principles of the wave theory advanced by Huygens, the great Dutch scientist of the 17th century.

The values of the linear, orbital velocities of the atoms of the molecules of the atmospheric gases (at the standard absolute temperature, 491.65 degrees, Fahrenheit (32°), and pressure 14.73 pounds (avoirdupois per square inch), which velocities are 3040×10^9 feet, and 9266×10^{10} centimeters per second, should be well noted because they serve as the basis of the greater part of the numerical determinations from the principles of my general theory in regard to the constitution of gases and the nature of radiation through the medium of gaseous matter, and particularly in regard to the constitution and extent of the terrestrial atmosphere, its relation to the luminiferous ether, and the functions that its ultimate particles, or atoms, perform in the processes of radiation and of electric and magnetic action, the "dielectric strength of air", being obtained directly, and simply—as has been demonstrated—from the atmospheric pressure (grams per square centimeter) from which quantity I have derived the several electrostatic, electromagnetic and electrochemical units, in the case of terrestrial magnetism, in absolute measurement according to the C G S system, the results of my investigation, in this connection, leading directly to a knowledge of the very nature of the electric and magnetic forces which have, heretofore, been known only by their effects. It is these results,—the derivation whereof has been set forth and discussed in the preceding number—that have led me to designate my theory as "an electronic theory of matter," in addition to that title which indicates its astronomical aspect.

Reverting to the discussion of electro-magnetic action and the equations pertaining thereto—which are of prime importance in my theory of the nature of the solar radiations—in the October number of POPULAR ASTRONOMY, attention is called to the following facts. The value of the absolute unit of electromotive force, given by equation (ι) on page 502 of that number, is expressed in gram-centimeters, per second, and it represents a tangential force, but it is reducible to a radial quantity through division by 2π, while a further division by the terrestrial force of gravity (g), expressed in centimeters per second the number whereof is 980.7, will reduce it to dynes, per square centimeter, the resulting expression being for the greatest possible number of "lines of force" in that area for unit inducing current, or the maximum magnetic "induction" as it is called. The resulting equation for the maximum induction (I') as derived from the aforesaid equation for unit electromotive force, is $I' = \frac{Pa\, V_1^2}{61620\, d^2}$, in which Pa represents the normal atmospheric pressure in grams per square centimeter, V_1 the velocity of light, and d, the *reciprocal* of the normal molecular diameter, in centimeters, and it should be noticed that this is the significance of the literal factor d in the equations on page 502, while in some other cases, as on page 506 of the November number, it represents the molecular diameter directly.

A solution of the equation for I', aforesaid, with the numerical values of the several literal factors in the right-hand member, taken from the table on page 501 of the November number, gives, roundly, 18,000 as the maximum number of "lines of force" per square centimeter this being only a little greater than the maximum in the case of soft iron which possesses the greatest magnetic "susceptibility" of any known substance, the maximum magnetic induction in this case being 17,500 lines of force per square centimeter, according to the experimental determinations of Rowland. As the inducing current is increased from a low value, the magnetic induction increases, but not pari-passu, or indefinitely, a maximum value being soon reached, when the magnetized metal is said to be "saturated", or in other words, when it cannot have its magnetism further increased by augmentation of the inducing current, all of the atoms of all the molecules in the "interface" being then affected according to my theory in this connection which I think, explains this peculiar and well-known condition of magnetism, in a rational and satisfactory manner.

Under my theory the specific nature of the magnetic and electrostatic forces, particularly in regard to what is called "polarity" which is their distinguishing characteristic, becomes definitely explicable as follows:

As I have pointed out, each normal, undisturbed molecule is composed of a definite number of entirely similar atoms, the number (n) thereof being expressed by $2.\frac{d}{\Delta}$ the diameter of the molecule being designated by d and that of an atom by Δ and all these atoms are equally distributed in each molecule under the normal conditions, and are moving with equal velocity around their respective molecular centers, in all directions, there being as many atoms in one hemisphere of each spherical molecule as in the other, but when by the application any force, mechanical, such as that of friction, percussion or compression; of chemical affinity as in the galvanic cell, or of heat to a sufficiently high degree, this equilibrium of any molecule is disturbed, or destroyed, by the addition of atoms above the normal number, or by subtraction from said number, the molecule having an excess of atoms will be "*positive*" with respect to one in which the atoms are in defect, the latter being "*negative*", a condition of "polarity" being thereby established and there will be a tendency to a restoration of equilibrium by the transfer of atoms from a positive molecule, wherein they are in excess, to a negative one in which they are in defect, the former thus possessing a "potential energy" analogous to that of a coiled spring. There is thereby produced a tension such as that designated by "potential", so that when the recoil takes place in the process of restoration of mechanical equilibrum in the molecules, the latter will be wholly, or partially, broken up by the action, the orbital velocity of their atoms being increased from the normal circular velocity to, or above, a velocity that would send them off in an open curve, a *parabola* or an *hyperbola*.

Complete, and practically instantaneous, dissociation of the atoms of a molecule constitutes a "disruptive discharge"—such as that of static electricity and the lightning flash—while a succession of these discharges, at almost infinitesimal intervals, constitutes a continuous electric current. Since each normal molecule of the medium, under my theory, is practically a spherical shell enclosing the only absolute void in the known universe which,—even as Democritus the philosopher of old has stated,—consists, in the ultimate analysis, of "atoms and a void" the complete disruption of a molecule and collapse of the molecular shell, must be accompanied by detonations varying in loudness and intensity from the feeble crepitations caused by discharges of electricity generated by ordinary electrical apparatus, to the crash of thunder, consequent upon the lightning flash which is caused by the disruption of a long line of atmospheric molecules, the acoustic effects of a complete collapse of a molecule of the gaseous medium being quite analogous to the report that follows the sudden breaking of the bulb of an incandescent electric lamp from which the air has been exhausted as far as possible.

The statements in the immediately preceding paragraphs refer only to the cases in which all the atoms of a molecule are affected by extraneous impulses, the atoms of all the atomic couples dissociated and the molecule completely disrupted, but when a portion only of these atoms in a molecule are affected and the molecule itself is not destroyed, the resultant action is productive of what is called magnetism, and electro-magnetism, where the disturbing force is that of an inducing electric current.

Taking the case of a single layer of molecules, (the thickness whereof is the molecular diameter (*d*)) in most intimate connection with the surface of a bar of soft iron, and forming an "interface" between said surface and the molecules of the medium beyond, it is obvious that, when undisturbed by extraneous forces, all the molecules in this layer are in dynamic equilibrium, each being composed of the same normal number of like atoms distributed equally around the whole molecular surface, and revolving with the same orbital velocity around each molecular center, each molecule being therefore endowed with the same quantity of kinetic energy which is a function of the mass of the atoms and the square of their velocity. Now, let this equilibrum of the molecules be disturbed, either by the vibrations caused by an inductive electric current passing through conductors coiled around the bar, or by frictional, or other, means as in the case of static electricity, it is obvious that some of the molecules must be supercharged above the normal, with atoms expelled from a normal molecule, by reason of increase of orbital velocity, and since the normal number of molecules in the undisturbed layer aforesaid is constant, these ejected atoms must gather, or crowd together, in excess in the molecules at one end of the bar, thereby causing a deficiency at the other end, the former end constituting the positive magnetic pole, and the latter the negative pole. The supernumerary atoms will be forced outward from the positive pole, or end, of the bar, but as all surrounding molecules of the medium are in possession of the normal number of atoms, the only place that these wandering corpuscles or "ions"—as we may call them—can find lodgment is at the other end of the bar which constitutes the negative magnetic pole, where the molecules have less than the normal number of atoms, and are, consequently, deficient in kinetic energy.

The atoms thus expelled at first pass directly outward from the positive pole, or end of the bar, and then curve and move backward along the lines of least resistance, roughly parallel to the axis of the bar to the other end thereof, then re-curving, and moving inward to the negative pole, in the tendency to the restoration of molecular equilibrium in the interface, and there will thereby be established a "magnetic circuit" in a manner quite the same as in the case of the complete disruption of the molecules, that is the cause of electrical action. It is obvious that, under these conditions, if the positive poles of two such bars be brought into juxtaposition, the expelled atoms from each will be directly opposed in the direction of their motion, and a force of repulsion result, whereas if a positive pole be presented to a negative, the outflow of atoms from that end of the bar will coincide with the inflow from the negative pole of the other bar, the reaction obviously being such that the two bars will then experience a force of attraction; in other words like poles repel, and opposite poles attract, each other, which is only a statement of an axiom in Magnetism. The atoms thus moving along the line of least resistance from the positive to the negative end of the bar, constitute what are known as lines of force, and a similar action occurs in the case of induced static electricity, the phenomena whereof are explicable as in the case of magnetic induction aforesaid. It is thus apparent that, under my theory, electrical and magnetic action can be excited only by the application of some extraneous force to the molecules, and therefore that even though there were no wasteful loss, or dissipation, of energy, no more work can be derived from the kinetic energy of the atoms of these molecules—enormous as it is even in a cubic centimeter of gaseous matter—

than is expended upon them, this principle being analogous to, and axiomatic as, the well-known one of thermodynamics, in this respect, which is demonstrated by the working of a heat engine of any kind.

In the case of statical electricity as artificially generated directly by divers apparatuses, and also in that of the conductors on the rapidly revolving armature of a dynamo, the applied forces are those of friction, percussion, and compression, and in the galvanic cell it is that of chemical affinity and its reaction, while in the case of thermo-electricity as generated in the thermopile, and also in that of the solar electro-magnetic radiations, the generating force is that of "heat." As I have demonstrated in the latter case the effective surface, or radiating, temperature of the Sun, (6,700 degrees Fahrenheit absolute) is just above the absolute temperature corresponding to an orbital velocity augmented by the velocity of impact of the atoms of the radiating surface, to the parabolic limit at which the atomic couples of the molecules of the transmitting medium are dissociated, this limiting temperature being 6680 degrees Fahrenheit, and since the density of the transmitting medium in space, which for convenience may be called—as it is—the luminiferous ether is almost infinitesimal as compared with that of the normal atmospheric gases, the density of the latter being, as I demonstrated, 1412×10^{13} times as great as that of the ether, if we take the latter density as the unit in this connection, (reference being made, of course, to volume-density as expressed by $D = \frac{I}{V}$ and not to the density involving the actual mass (M) as expressed by $D = \frac{M}{V}$), as I have demonstrated, the rigidity of a molecule, in so far as it is due to the orbital velocity of the atoms revolving around the molecular center, is a function of the volume density (D) of the molecule, or of mass of gaseous matter composed of these spherical shells, it being proportional to $D^{\frac{1}{3}}$ which represents the square of the relative orbital velocity of the atoms in media of different volume-densities, the orbital velocity itself being proportional to $D^{\frac{1}{6}}$, the numerical value whereof is 491.65 (which is also the absolute temperature, in degrees Fahrenheit, of the standard atmospheric gases under the normal conditions, viz., 32 degrees Fahrenheit) and the square of this, or $D^{\frac{1}{3}}$, is roundly 241,700, the logarithm of which is 5.383312—that of the relative density aforesaid being 16.149936.

A velocity of impact of an atom of a radiating surface, directed against an atom of a molecule of a surrounding gaseous medium (this impact and the resulting additional velocity being imparted primarily to an atom of a molecule in the layer or interface in immediate contact with the radiating surface) and corresponding to an absolute temperature of 6680 degrees Fahrenheit, is just sufficient to dissociate the component atoms of an atomic-couple in a molecule of the atmospheric gases even when at their normal rigidity at a pressure of one atmosphere, or 14,730 pounds per square inch at the Earth's surface, the complete disruption of these molecules and the dissociation of their component atoms by the energy due to the application of a velocity of impact which augments the normal orbital velocity to or beyond the parabolic limit corresponding to the aforesaid absolute temperature, being exhibited in a most striking manner in the case of the voltaic-arc between the carbon points, or poles, of an arc lamp when an electric current of sufficiently high voltage is coursing through the circuit, the temperature of the arc thus formed being very approximately, according to the ordinary Fahrenheit scale, 6220 degrees which is equivalent to the absolute temperature of dissociation of the atoms (6680 degrees) productive of electric action.

Since the orbital velocity of the atoms in each molecule of the luminiferous ether is so much less than in the case of the normal standard atmospheric molecules, it being only $\frac{1}{491.65}$ of the velocity in the latter case, it is obvious that—the molecular rigidity in the case of the ether being only the square of the fraction just stated, that the ethereal molecules will be disrupted by a velocity of impact from the atoms of a radiating surface, corresponding to an absolute temperature much less than that in the case of the limiting absolute temperature at which the atoms of the molecules of the ether are thrown off in parabolic curves, it being only, roundly 3,760 degrees Fahrenheit, or 2,920 degrees less than in the case of the atmosphere as I have determined from the principles of my general theory as to the constitution of gases, the nature of radiance and the law of radiation founded thereon, in the following manner.

In the process of radiation the velocity of impact (v) of an atom of the radiating surface, which impact is longitudinally directed against an atom of the radiating surface which is necessarily a solid (although the radiating material may be very finely divided) the atoms whereof are vibrating longitudinally and impinging upon the circularly revolving atoms of the molecules of the medium in the layer or interface in immediate contact with said surface, the "velocity of impact" (v) of any atom of the surface increases with the absolute temperature of the radiating material, the velocity being added to the normal orbital velocity of the atoms of the medium and the impact deflecting any affected atom from the tangent to its circular orbit at the point of impact, by an angle that may be designated by (χ) which varies with the velocity (v) and thereof with the radiating temperature, degree by degree. The deflection thus caused by the impact, and the increased orbital velocity, throws the atom of the medium from the normally circular orbit into an elliptical one the eccentricity increasing with (v) up to the point at which this velocity of impact is just equal to the normal orbital velocity which is increased thereby to 1.414 times its normal value, when the eccentricity becomes 1 and the orbit parabolic, the ratio of increase aforesaid being $\sqrt{2}$, which expresses the well-known relation between the velocity of a planet at unit distance from the Sun, and the corresponding parabolic velocity at the same distance, as is demonstrated in Analytical Mechanics and Theoretical Astronomy. We know therefrom that if the orbital velocity of the Earth at its present mean distance from the Sun were increased in the aforesaid ratio from nearly nineteen miles per second to nearly twenty-seven miles in the same time, our globe would leave its elliptical, and nearly circular, orbit around the Sun and move off in a parabolic curve that would carry it forever away from the center of gravity of the Sun the attractive force of the latter body being unable to hold the Earth in its closed orbit if our globe were to have its orbital velocity increased to twenty-seven miles per second—which is also the velocity of any comet moving around the Sun, in a parabolic orbit, when at the mean distance of the Earth from the center of gravity of the solar globe. The deflection of the path of the affected atom of a molecule in the layer in contact with the radiating surface, from the tangent to the normally circular atomic orbit at the point of impact, is in the direction of the ray which lies along the diameter of the spherical molecule at that point, the deflected curve extending from this point to the other end of the molecular diameter, 180 degrees distant, where the affected atom delivers up the added velocity of impact (v) to a revolving atom of a molecule farther on in the direction of the ray and contiguous to the affected molecule in the interface aforesaid, this process being extended outward from molecule to molecule by means of the revolving atoms constituting these spherical shells (this being the process known as radiation) the vector-atom, after delivering up its impressed velocity and resultant burden of kinetic energy to the atom in the molecule in advance, returning to its circular orbit and, through the other semi-circle, back to the original point of impact, each atomic orbit becoming again circular until another similar impulse is given from the atom of the radiating surface. When an atom, or a large number of them as is actually the case in a molecule, is so affected, the molecule is deformed, and reformed when the velocity has been delivered up, as aforesaid, to the atoms of a contiguous molecule farther on along the ray. But this process—which is productive of what we know as "heat" and "light"—can continue only up to the parabolic limit, corresponding to a radiating temperature of 6680 degrees Fahrenheit, as aforesaid, in air at normal pressure density, and temperature, and of 3760 degrees Fahrenheit in a medium at the density and temperature of the luminiferous ether, as determined through my theory, and at this point the angle of deflection (χ) of the path of the affected atom from the tangent to its normally circular orbit becomes 45 degrees (the natural tangent and cotangent whereof are each 1) and the affected atoms are thrown off in open curves, the path of each such atom becoming hyperbolic beyond that limit as the respective radiating temperatures are increased, the hyperbolic curve gradually approximating, and finally becoming, a straight line coincident with the diameter of the molecule, the orbital revolution of these atoms becoming then longitudinal vibrations similar to those of the X-rays and others of that type electrically generated, instead of being transverse as are thermal and luminous vibrations which are produced when the atom is thrown from its normally circular orbit into an elliptical one only.

In the case where atoms are expelled from each molecule of the medium affected by the radiation, these expelled atoms eventually recombine in a molecule that possesses less than its normal number—as expressed by $2.\frac{d}{\Delta}$—the dynamic equilibrium of a molecule being destroyed when its atomic components fall below, or rise above, the normal number and restored when recombination takes place in the process just described. As has been pointed out on a preceding page, if only a portion of the component atoms, diatomically arranged in a molecule, are dissociated, the spherical molecular shell yet retains its form, but the molecular kinetic energy thereof is decreased by the reduction of the number of atoms below the normal quantity, the resultant effect being in this case magnetic, or exemplified by the action in the case of a bar of soft iron around which an electrical current is conducted, and by what we know as terrestrial magnetism which results from the partial disruption of the layer of atmospheric molecules contiguous to the Earth's surface, the prime cause of this disruption being the velocity of impact imparted to the atoms of these molecules by the radiation from the Sun, through the molecules of the intervening medium which is called the luminiferous ether, this velocity corresponding to a radiating temperature above that at which the atoms of the molecules are dissociated (6680 degrees Fahrenheit) the effective surface temperature of the Sun being 6700 degrees Fahrenheit according to my determination; but when all the atoms of the molecule are dissociated and all the molecules in unit surface of the molecular layer aforesaid are disrupted, the resultant action is electrical as illustrated by disruptive electrical discharges such as those produced artificially by divers apparatuses and means, for example, the discharges from a frictional electrical machine, a Leyden jar, and in vacuum tubes, such as those of Crookes and Geissler, and in nature by the lightning flash and the aurora borealis or northern lights, as it is commonly known, this last named phenomenon being analogous, in all practical respects, to the phenomena exhibited in the case of discharges—either direct or indirect—in the vacuum tubes aforesaid and these facts enable us to easily comprehend and analyze the specific nature of the solar radiations.

The force of gravity at the Sun's surface is somewhat more than twenty-seven times that of terrestrial surface gravity, so that were the normal temperature the same as that of the atomspheric gases at the Earth's surface, which is taken at 32 degrees Fahrenheit or 492 degrees as measured on the absolute scale, the density of the gaseous envelope immediately surrounding the Sun just above the photosphere and in contact therewith would, by the compression due to the solar surface gravity, be a little more than twenty-seven times that in the similar case of the terrestrial atmospheric gases under the normal conditions which I have taken as the standard, of density (*D*), pressure (*P*), and temperature (T), the relations between these quantities being expressed $P = DT$ whence $D = \frac{P}{T}$. But, according to my determination the maximum absolute temperature of the gaseous matter composing the solar globe, which temperature has been generated by compression of the solar nebula as I have demonstrated in a preceding number (February, 1908) of POPULAR ASTRONOMY is 13,400 degrees Fahrenheit or a trifle more than twenty-seven times the normal temperature of the atmospheric gases aforesaid, so that through the equation last set forth above, the density of that portion of the solar envelope may be regarded as practically in the same condition as the normal atmospheric envelope.

The maximum solar temperature of 13,400 degrees Fahrenheit is that of which I have denominated the "internal temperature" of the Sun, at which temperature there can be no chemical combination whatever as, if free from the compressive action of solar gravitation, all the molecules composed of these atoms would be disrupted, and the atoms exist and move as separate entities endowed merely with mass, motion and inertia as were the primordial components of the fundamental matter known as the luminiferous ether, and such combination can occur only at a level but slightly above the solar surface, where radiation to outside matter at a lower temperature (this matter being that of the planets and their satellites as well as of the comets and other widely diffused matter which is the residuum of the primitive solar nebula which has contracted to the present dimensions and conditions of the Sun) reduces the temperature of the surface matter to, and below, the degree at which these atoms by reason of the consequent decrease of their orbital velocity, fall into elliptical orbits around the focus within the molecule these ellipses having divers degrees of eccentricity varying from zero (in which case the atomic orbits are circular, the matter in this case constituting a gas in its simplest elemental form from the ether up to helium and hydrogen) up to infinity in which case the orbits become straight lines and the orbital revolutions longitudinal, or simple vibrations to and fro, under which conditions these atoms group themselves in divers combinations dependent upon their relative orbital velocities such combinations constituting what is known as solids. This grouping occurs primarily in, or near the surface of the photosphere where the solar matter is free to radiate its heat to the absorbent matter in surrounding space and to cool below the absolute temperature at which such chemical combination becomes possible, this temperature in the case of such elements as carbon, silicon and calcium (which are most important and abundant components of the Earth as well of the Sun's surface matter) being not far below the effective temperature of the more or less solid radiating matter of the solar surface, which is 6700 degrees Fahrenheit according to my demonstration, or one half the maximum temperature which is that of the internal gases not far below the surface, or even intermingled with the finely divided solid matter of vastly higher thermal emissivity, which, grouped in more or less extensive aggregations such as the bright points and filaments of the photosphere, and the calcium and other flocculi above it, constitute the effective radiating matter of the Sun this being well depicted in the illustrations accompanying the paper in the last (November) number of POPULAR ASTRONOMY, by Professor William W. Payne on the subject of "Solar Vortices."

Saint Paul, Minnesota,

To be continued.

THE NORTHERN LIMIT OF THE ZODIACAL LIGHT.*

E. A. FATH.

This investigation was undertaken at the suggestion of Director Campbell in order to determine, if possible, the nature of a faint light which for years has been noticed in the summer along our northern horizon by several observers.

Three hypotheses as to the origin of this light seem to require examination: that it is an aurora; that it is twilight; and that it is the Zodiacal Light.

The observations were begun in July, 1907, but at that time consisted merely in noting whether the light was visible or not. They have been continued during the present summer upon a somewhat more extended scale, but have been made only at intervals when time could be spared from another investigation. In consequence the results are by no means as definite as one might wish. Then, too, the air has been much less clear than usual this summer owing to the forest fires, something less than fifty miles distant.

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* Extracts from Lick Observatory Bulletin, No. 142.

The general appearance of the phenomenon when observed near midnight with a clear sky and no moon is that of a flat arch of light with its maximum of intensity near the north point of the horizon. At that time of night in the early part of July, 1908, the greatest altitude above the northern horizon was 18°. It extended westward about 40° and eastward to the Milky Way and was symmetrical with respect to the meridian. At the extremities it was only a degree or two above the horizon, depending upon the clearness of the air at such a low altitude. When, however, the observations were made before midnight the maximum was always to the west of the north point and after midnight always to the east.

When this much had been established it seemed advisable to note, as accurately as possible, the extent to the east and west of the north point, the altitude and azimuth of the maximum brightness and the greatest altitude to which it could be traced. This greatest altitude was always directly over the maximum. A simple instrument was designed and constructed for observing the horizontal and vertical angles referred to and set up on the roof of the observatory. To simplify matters the zero for azimuth was taken as the north point and azimuth recorded as east or west.

The method of observation was to locate the various parts of the luminous area with reference to the stars; then, pointing to these places, to read the circles to the nearest degree and note the sidereal time. Owing to the faintness of the light any one position might be in error by as much as 5°, but it is not likely that many are out so much as that. The instrument was set up on July 2, 1908, and used whenever possible.

1908	Mt. Ham. Sid. T.	Azimuth Eastern End	Azimuth Western End	Maximum		Greatest Altitude
				Altitude	Azimuth	
June 27	18^h 17^m					
	19 47				15° E	
30	18 29					
July 2	18 00		41° W	10°	3 W	16°
	18 45		39 W	10	4 E	18
	19 45		30 W	9	13 E	16
	20 45	81° E	18 W	7	33 E	11
	21 15	81 E	8 W	7	35 E	10

* * * * *

The three hypotheses for the light as mentioned above will now be examined.

The aurora hypothesis does not seem tenable for three reasons: 1st.—The light in question is seen only in the summer, during a period of about two months on either side of the summer solstice.

2d.—The spectroscopic evidence as given by the observations of July 29 and 31. The bright aurora line at λ 5571 could be seen in practically all parts of the sky and was no brighter when the spectroscope was pointed to the maximum of the luminous area than when pointed many degrees away and entirely outside this area. At this time there was no aurora visible as such. That the aurora line, λ 5571, can be seen when there is no visible aurora[1] may have been noted by Vogel[2] although he does not definitely state it. Campbell[3] seems to have been the first to call direct attention to this.

3d.—Columns 3 and 4 of the table show the maximum intensity to move with the Sun.

If the light were twilight it seems reasonable to suppose that the mean of the observations would show the maximum intensity to be on or very near the vertical circle passing through the Sun. Taking all the differences of azimuth from columns 3 and 4, the mean of the 29 observations shows the maximum to be $1^\circ.7$ farther east along the northern horizon than this vertical circle. Such a large difference does not appear accidental. Moreover the observations of July 2, $18^h\ 45^m$, shows that the light could be seen 46° north of the Sun, the Sun being at that time 30° below the horizon and thus 12° lower than the usually assigned limit for twilight. Observations[4] made during the summers of 1907 and 1908 to determine the zenith distance of the Sun at the end of twilight or the beginning of dawn all agree in making the zenith distance of the Sun 108°. The twilight hypothesis, therefore, does not explain the phenomenon satisfactorily.

Of the three hypotheses that of the Zodiacal Light remains.

The observations of July 19, 22, 23, 26, 29, August 27 and 28 show a direct connection between this light and the ordinary

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[1] It seems advisable to call attention to what appears to be a mis-statement in Scheiner's *Spectralanalyse der Gestirne.* On page 343 it is stated "Auch Wright hat häufig die grüne Nordlichtlinie im Spectrum des Zodiakallichtes wahrgenommen, aber nur dann, wenn dieselbe auch an ausserhalb des Zodiakallichtes gelegenen Stellen auftrat, was zuweilen geschah, ohne dass ein Nordlicht direct zu sehen gewesen wäre." In Wright's report of his work on the spectrum of the Zoadiacal Light in *The American Journal of Science*, Series 3, 8, 45, 1874, occurs the statement, "On the other hand, the bright line was never seen when there was no aurora."

[2] "Die helle Linie erschien übrigens an den [three] genannten Tagen an allen Theilen des Himmels, der mit einem matten, lichten Schleier überzogen war, mehr oder weniger intensiv." *Astron. Nach.*, 27, 327, 1872.

[3] *Astrophysical Journal*, 2, 162, 1895.

[4] Not included in the observations taken above.

cone of the Zodiacal Light, a practically straight line forming the northern boundary of both the cone and the light under observation. This connection was also seen from the summit of Mt. Whitney, altitude 14,500 feet, on August 24. (See note at end of paper.) During the summer months the Zodiacal Light can be readily seen at Mt. Hamilton both in the west in the evening and in the east in the morning. The connection was seen with both the western and eastern cones.

The 1°.7 displacement of the maximum of the light to the east of the vertical circle passing through the Sun appears significant. If we assume the axis of greatest intensity of the Zodiacal Light to be in or near the ecliptic, then at midnight at the time of the summer solstice the axis will be perpendicular to the vertical circle passing through the Sun. Before midnight the western angle between the axis and the vertical circle will be less than 90° and after midnight the eastern angle will be less. In general, before the summer solstice the western angle will average less throughout the night than the eastern and vice versa. Now taking two points at the same altitude and symmetrically situated with respect to the vertical circle, the one to the west would average nearer the axis throughout the night for observations before the solstice and therefore be the brighter. In the same way, after the solstice, the eastern one would be the brighter. We might expect, therefore, that before the solstice the maximum observed intensity would be shifted toward the west and after the solstice toward the east. the shift varying with the distance of the Sun from the solstice. Now we find an observed displacement of 1°.7 toward the east and all the observations upon which this observed displacement depends were made after the solstice. An examination of the values in columns 3 and 4 of the table will also show a tendency for the displacement to increase with the time. The observations thus agree with the hypothesis.

The figures in the last two columns of the table aid in the determination of the apparent shape of the light observed. As stated above the figures give the distance from the Sun (in degrees) of the intersection with the ecliptic of the great circle drawn from the point of the greatest observed altitude through the point of greatest eastern or western elongation. The total range of intersections is from 40° to 105°. When the results of the last four columns of the table are plotted, using the Sun as origin and the ecliptic as the axis of abscissas it is seen that the light observed is distributed fairly symmetrically with respect to the Sun. It passes 46° to the north and intersects the ecliptic about 70° on either side. This applies, of course, only to the part north of the ecliptic. Assuming symmetry with respect to the ecliptic also we have the lenticular appearance of the Zodiacal Light. The effect of atmospheric absorption would be to bring the intersections too close to the Sun. The apex of the Zodiacal Light cone can be seen at various distances from the Sun ranging from 40° to over 100°. This agreement between the observed position of the apex and the position of the intersections is as satisfactory as can be expected from the nature of the objects observed.

The observations of August 28 and September 3 together with the results of others made after the reduction of the observations given above lead to the following table of results. The first column gives the distance of the apex of the Zodiacal Light cone from the Sun; the second column the angle made by the north side of the cone with the ecliptic; the last column the latitude of the intersection of the prolongation of the northern boundary of the cone with the great circle passing through the Sun perpendicular to the ecliptic.

		Apex from Sun	Angle with Ecliptic	Latitude
August	28	47°	47°	38°
September	3	45	56	46
	24	76	45	44
	25	81	42	41
	26	80	41	41
	27	80	39	39
	28	79	38	38
	29	82	31	31[5]
	30	81	39	39
October	1	82	39	39
	3	83	46	46
	4	84	55	55
	5	88	39	39
	6	88	45	45

The mean of the results in the last column shows that we should expect the Zodiacal Light to extend 42° north of the Sun if we neglect curvature of the boundary and the effect of atmospheric absorption. The former would decrease and the latter increase the distance. Observations above the northern horizon give 46°.

In the classic volume of observations of the Zodiacal Light by Jones[6] I find that by extending the boundaries of the "diffuse" light they would in many cases exceed latitudes of 45° both north and south of the Sun. The writer has not at present the time

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[5] Given half weight in mean on account of conditions under which the observations were made.

[6] *Observations of the Zoadiacal Light.* Vol. 3 of the Report of the United States Japan Expedition, 1856.

necessary to investigate carefully this great wealth of material and therefore desires only to call attention to the agreement between the observations of Jones and his own.

From the evidence at hand it seems fair to conclude that the phenomenon observed is the Zodiacal Light, and probably the same phenomenon as seen by Herrick,[7] Newcomb,[8] and Barnard.[9] For the sake of completeness the observations should extend over another summer, say from May 1 to August 10. It could then be determined whether the maximum is to the west of the vertical circle passing through the Sun before the solstice and to the east after the solstice. It seems best, however, to publish these preliminary results for the benefit of any who may be interested in the matter of making the necessary observations next summer. It would also be of great value to have observations made at stations in the southern hemisphere from the first of November to the end of January.

In this paper it has been assumed that the axis of the Zodiacal Light is in or very near the ecliptic, in accordance with many observations. Some recent work places the axis in the plane of the Sun's equator. This would materially change the conclusions reached. Mention has also been made of the apex of the Zodiacal Light cone. This is taken as the point of intersection of the two sides of the cone. No real apex is seen at Mt. Hamilton as the cone near the "apex" merges directly into the zodiacal band which can usually be traced across the entire sky.

In conclusion, I wish to acknowledge my indebtedness to Director Campbell for his coöperation and suggestions, and especially for the trouble taken to secure the Mt. Whitney observations under trying circumstances. It is also a pleasure to acknowledge some suggestions from Mr. W. H. Wright, Astronomer in the Lick Observatory.

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[7] *Silliman's Jour. of Science*, 39, 331, 1840.
[8] *Astrophysical Journal*, 22, 209, 1905.
[9] *Ibid.*, 23, 168, 1906.

NOTE.—Director Campbell spent the night of August 24, 1908, on the summit of Mt. Whitney, altitude 14,500 feet, latitude +36° 35′. At the request of the writer he kindly undertook some observations of the Zodiacal Light; it being arranged that the writer should make simultaneous observations at Mt. Hamilton. The Mt. Whitney observations are as follows:

"At 8^h 15^m Pacific Standard Time the Zodiacal Light could be faintly seen in the west. It extended along the ecliptic and then around the northwest horizon almost to the north point. Under β *Urs. Maj.* its altitude was ⅓ that of β. At midnight nothing could be seen along the north horizon. Air exceptionally clear."

The observations at Mt. Hamilton showed nothing further. The smoke from the forest fires doubtless obscured the faint light.

JOHN KROM REES.*

HAROLD JACOBY.

It is the custom to mark the passing of a well-known man with a short notice of biography; and it is not difficult to recite a list of services, enumerate honors and distinctions conferred by public bodies, or recapitulate scientific researches and publications. But to the writer these are cold and hard when said of Rees; to him Rees was known best as a friend—that rare friendship of which the beginning is outside the grasp of memory, the end a green sod.

JOHN KROM REES
Died March 9, 1907

Surely, if there exists a relation adapted better than any other to make one acquainted with the good or bad in any man, it is the relation of a subordinate to his chief. During eighteen long years the writer sat at his work under Rees: in all that time there never came down to him an unkind word; never once did a serious difference of opinion arise. In eighteen years one becomes accustomed to any man; the few like Rees one comes to love. These words will fail signally in their purpose, if they do not convey to his sorrowing family such poor consolation as may come from those who feel and suffer with them.

Rees was but fifty-five on his last birthday; in his short life he had served Washington University as a professor five years, and Columbia University twenty-one. He had been president of the New York Academy of Sciences two years, and secretary of the American Metrological Society fourteen years. For six years he was secretary of the Columbia University Council. He was a fellow of the Royal Astronomical Society of London, a member of the Astronomische Gesellschaft of Leipzig, and in 1901 was

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* *School of Mines Quarterly*, Vol. XXVIII, No. 4.

created a chevalier of the Legion d'Honneur in recognition of his services as one of the judges at the Paris exposition in that year. His principal observational research was a study of the "Variation of Terrestrial Latitudes and the Aberration of Light," made at Columbia University, in coöperation with the Royal Observatory, Naples. This was the first application of the method of simultaneous observations at two stations situated on the same parallel of latitude, but separated widely in longitude. The work was continued from 1893 to 1900: the method has since come into general use; and the International Geodetic Association, which includes all civilized governments, has now established four permanent stations to carry it on.

It was also during Rees's administration that the astronomical department of Columbia University undertook the publication of Rutherfurd's valuable series of star photographs. Through his efforts this enterprise was made possible; he took a keen interest in it, and spared no pains to further the work during a long series of years.

In educational matters Rees was at all times most active. His public lectures were frequent. Characterized especially by lucidity, they always attracted large audiences; people came to hear him again and again. But his most lasting contribution to educational development was his establishment of the Columbia summer school of geodesy. It is probable that he was the first to recognize practical field work in this subject as an indispensable adjunct in the training of civil engineers. Here he was at his best: his point of view always that of the genuine man of science, seeking ever the truth for its own sake; never exalting mere technique at the expense of theoretic perfection; never limiting his exposition of a subject to the side having most value from the financial point of view. Students frequently came back to him in later years; they always spoke of his summer school as the most agreeable memory of their college years. Whenever this occurred, he was a happy man for days.

The following letter from Professor F. R. Hutton shows well the cordial relations that existed between Rees and his professional associates in the days of old Columbia :

"Rees entered the School of Mines in 1872 on graduating from Columbia College. His class was of Rölker, Weller, Leavens and Wright, who have all risen to high standing in their respective specialities. Chemistry figured very largely in the old course of study under Bolton, Waller and Kerns, whom all delight to remember whose memory runs back to those old times.

The buildings were most inadequate and poorly ventilated, but they hummed with a spirit of busy and ever enthusiastic industry. On graduation Rees went at once to his work at Washington University, St. Louis, where he took a very earnest and vital interest in all matters relating to the university. It was while he lived and labored there that the memorable fire occurred in the Southern hotel, from which Rees and his young wife escaped at peril of their lives and lost all their belongings. They descended from windows on ropes.

"Coming to Columbia as assistant to Professor William Guy Peck, Rees had to begin with very small facilities. A wooden structure on the campus, with a small refracting telescope and a time instrument, were all he had, but he rendered most effective service with this apparatus, not only in descriptive astronomy with college students, but in effective coöperation with the schools of the city, where classes were formed for evening visits to the little observatory, sadly interfering with Rees's dear ambition to do real scientific work. But he felt this an obligation he could not slight. It was a great gain when the new buildings and the library at 49th street were erected, giving at least a mechanical elevation above the horizon of the surrounding roofs; but difficulties from smoke and railroad vibrations, caused by heavier engines and increasing weight and number of trains, all stood in the way of any ambition to rival research observatories. It was a dear dream of his to establish a great observatory on the Hudson at some point remote from the interference of metropolitan conditions.

"On the coming of Professor Trowbridge in 1878 the need of geodetic surveying was at once considered and the courses in geodesy for civil engineers established to meet it. These were also made to furnish necessary preliminary training for the summer school with which Rees was so prominently identified. The first schools were held by him at Cooperstown, N. Y,, and continued there until the transfer to Sunapee, N. H., from which place they moved to their present location at Osterville, Mass. The bond between Professors Rees and Peck was a very close and friendly one both during the period of Rees's service as adjunct professor, and later when he was made full professor over the independent department of astronomy."

At times Rees was persuaded to go beyond his quiet field of activity in the university. His most lasting public service to the nation was rendered as secretary of the Metrological Society, in furthering the introduction of standard or railroad time.

The late Dr. F. A. P. Barnard, president of Columbia College, made the following reference to Professor Rees in his testament, dated 1886:

> "I give to my friend, Professor John Krom Rees, the watch known as my Cosmic Time Watch, as a mark of my regard and of my appreciation of his zealous efforts for the promotion of metrological reform and for the introduction of the now established system of public standard time."

Rees's attitude towards the scientific work of others was one of extraordinary modesty. To him the past masters of astronomy were not men; they were demi-gods, to be mentioned in respectful accents and with lowered tones. Even living visible masters of the craft commanded from him a degree of respect such as he could not have offered even to crowned royalties. His own work might be as good as theirs, but he could never see it so.

Another marked characteristic was his extreme delight when visited by any one to whom it was possible to do a favor. This was his pleasure. No trouble was too great or time-consuming; no return, not even thanks, was expected. No man ever had fewer enemies; his friends equaled in number those who knew him. When at last the heavy weight of disease was laid upon him he met it as a man should. No querulous repining; regret only that his work must stop; his solace that others would carry the good work on. Mother earth, that he loved well to measure and compute, will give him sleep; to him the peaceful end is surely a release.

PLANET NOTES FOR JANUARY, 1909.

Mercury will be in conjunction with Uranus on Jan. 1, both planets being then so nearly behind the Sun as to be invisible. Mercury will be at greatest elongation, east from the Sun 18° 26°, on the evening of Jan. 26. This will be a favorable time to see the planet, since it will be relatively bright and well up from the horizon at sunset. It may be caught sight of toward the west, probably within a half hour after sunset.

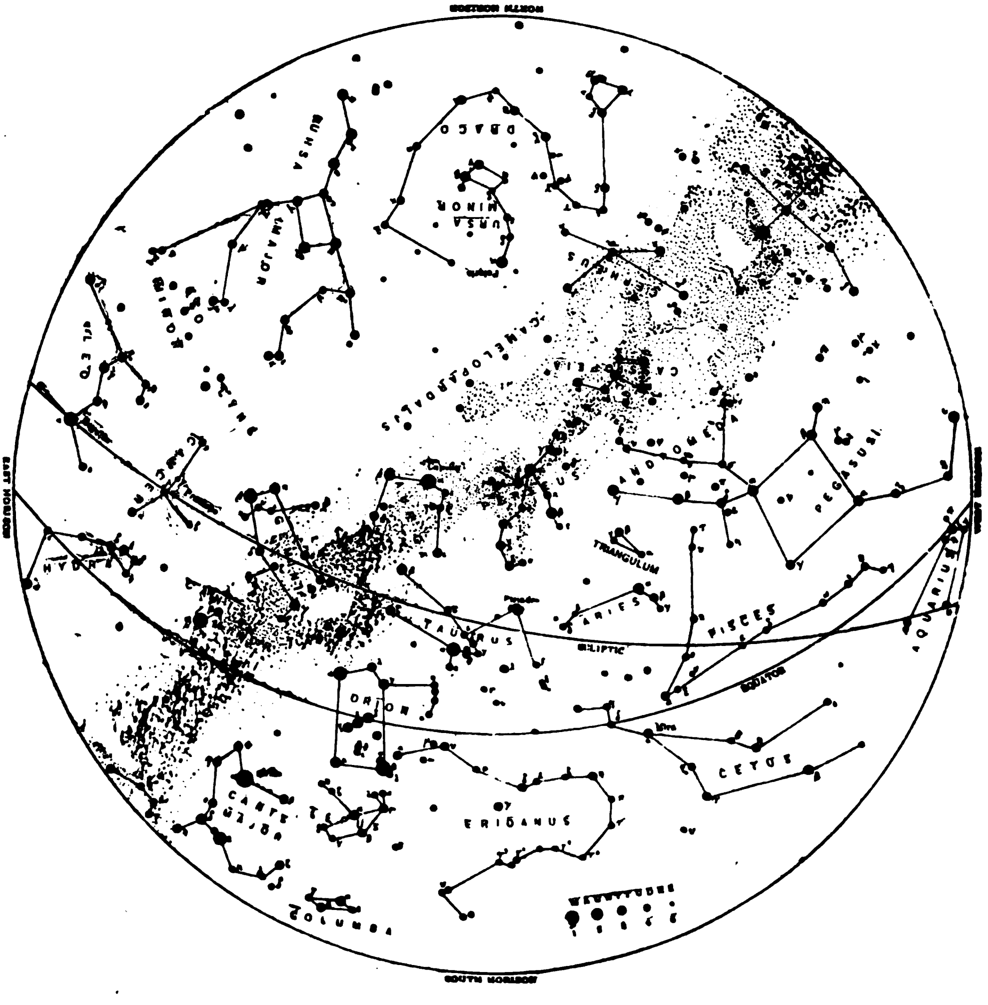
Venus may be seen toward the southeast in the morning for an hour or more before sunrise. Venus and Uranus will be in conjunction on Jan. 30, Uranus being at nearest point 21′ south of Venus.

Mars may seen toward the southeast for about three hours before sunrise. Its altitude is low at best and its apparent diameter small, so the time is not favorable for the study of this planet.

Jupiter is near the meridian, at a good high altitude, at four o'clock in the morning. The planet is in good position for study with the telescope during all of the latter half of the night. Jupiter is in the constellation Leo about fifteen degrees southeast from Regulus and is much brighter than Regulus.

Saturn is near the meridian at sunset and so may be studied in the early evening. Saturn is in Aquarius and will move northeastward into Pisces.

Uranus will be in conjunction, behind the Sun, Jan. 7 and so cannot be studied during this month.



The Constellations at 9:00 p. m., January 1, 1909.

Neptune will be at opposition on the morning of Jan. 6. During this month it may be observed at all hours of the night. The planet is in the constellation Gemini a little south and west from the star δ.

COMET NOTES.

New Ephemeris of the Comet Tempel$_3$-Swift.—In A.N. 4277 Mr. E. Maubant gives corrected ephemerides of this periodic comet extending from Oct. 20 to Dec. 31. The portion for December is given below. Mr. Maubant remarks that in order to represent the observation of Mr. Javelle at Nice on Sept. 29, it is necessary to diminish the mean daily motion of the comet by 0″.38. The correction, he thinks, is too large to be accounted for by inaccuracies in the computation of the perturbations, and he calls attention to the fact that Bossert found it necessary to apply a similar correction to the calculations for the apparition of 1891. It is possible that this comet is subject to a retardation such as Schulhof found for the comet Tempel$_3$ and Lamp for Brorsen's comet.

EPHEMERIS OF COMET TEMPEL$_3$-SWIFT.

[For Paris midnight; perihelion 1908 Oct. 4.528].

Date	α			δ		log r	log Δ
	h	m	s				
Dec. 1	9	31	33	+17°	27′.3		
2		32	07	17	16.5		
3		32	38	17	06.1	0.1381	9 8214
4		33	05	16	53.9		
5		33	28	16	45.9		
6		33	47	16	36.3		
7		34	03	16	27.0	0.1463	9.8215
8		34	15	16	17.9		
9		34	23	16	09.1		
10		24	28	16	00.6		
11		34	29	15	52.4	0.1547	9.8218
12		34	26	15	44.5		
13		34	29	15	36.9		
14		34	10	15	29.5		
15		33	56	15	22.5	0.1631	9.8224
16		33	39	15	15.7		
17		33	18	15	09.3		
18		32	54	15	03.1		
19		32	26	14	57.3	0.1715	9.8236
20		31	54	14	51.7		
21		31	19	14	46.4		
22		30	41	14	41.4		
23		30	00	14	36.6	0.1799	9.8156
24		29	15	14	32.2		
25		28	27	14	28.0		
26		27	36	14	24.1		
27		26	43	14	20.4	0.1884	9.8286
28		25	46	14	17.0		
29		24	47	14	13.9		
30		23	45	14	11.0		
31	9	22	40	+14	08.4	0.1968	9.8328

Comet Morehouse.—Professor E. B. Frost, Director of the Yerkes Observatory, calls attention to the recent increase of brightness of Morehouse's Comet and writes on October 29:—

"It was visible to the naked eye, and three or four degrees of tail could readily be seen in a small field glass. Three spectrum plates were obtained with the Zeiss ultra-violet doublet and objective prism by Mr. Parkhurst with some assistance from me. Two of these had exposures of one hour. No continuous spectrum was perceptible, whence we may reach the important inference that last night the comet's light was very largely intrinsic. Seven bands were very conspicuous as knots on the plate. I am measuring the spectra this morning, but have no doubt that they will prove to show the ordinary hydrocarbon spectrum."

The photographs taken last night at the Harvard Observatory, show a tail at least nine degrees in length, and much longer than on previous nights.

Astronomical Bulletin, No. 343, EDWARD C. PICKERING.
Harvard College Observatory, Oct. 31, 1908.

Approximate Ephemeris of Comet *c* 1908.—The following approximate ephemeris of Comet *c*, computed by Dr. Smart, is taken from *The Observatory* for November, 1908. It shows that the comet will move steadily southward during the winter reaching the south polar regions of the sky during March. During the first half of January it will be invisible because of its being behind the Sun.

EPHEMERIS OF COMET *c* 1908.

Greenwich Midnight	R. A.	Decl.	Greenwich Midnight	R. A.	Decl.
Dec. 11	18^h 50^m 0^s	−12° 56′	Mar. 8	18^h 10^m 00^s	−65° 49′
15	18 50 0	−15 06	12	17 49 12	−69 59
28	18 49 55	−21 34	16	17 14 20	−74 02
1909			20	16 12 44	−77 37
Jan. 15	18 49 20	−30 08	24	14 30 16	−79 38
19	18 49 08	−32 05	28	12 31 00	−78 55
23	18 48 56	−34 07	Apr. 1	11 06 08	−75 45
27	18 48 40	−36 11	5	10 17 52	−71 27
31	18 48 20	−38 20	9	9 50 08	−66 47
Feb. 4	18 47 48	−40 38	13	9 35 52	−62 06
8	18 46 52	−43 04	17	9 23 52	−57 38
12	28 45 36	−45 40	21	9 16 40	−53 21
16	18 43 44	−48 26	25	9 13 20	−49 30
20	18 41 04	−51 24	29	9 11 08	−46 08
24	18 37 12	−54 36	May 3	9 09 56	−42 59
28	18 31 52	−58 06	7	9 09 40	−40 10
Mar. 4	18 23 20	−61 50	11	9 10 04	−37 38

Brightness 3.1 on Feb. 1, 3.0 on March 1, 2.4 on April 1 and 0.9 on May 1.

Comet *c* 1908 (Morehouse).—This comet continues to exhibit wonderful changes from night to night. On Oct. 28 the writer noted it for the first time as visible to the naked eye. On this night only the head of the comet and a very little of the tail could be seen, but on Oct. 29 it was quite conspicuous and the tail could be traced for about 6° length with the unaided eye. On Oct. 30 the tail was fainter, scarcely visible to the eye at all. On Nov. 13 and 17 the head of the comet was scarcely visible, and the tail not at all, to the naked eye, but on Nov. 20 the head was quite bright and the tail could be caught by averted vision for a length of four or five degrees. The photographs on these dates show that the tail was from twelve to fifteen degrees long and full of marvelous details of structure.

The following ephemeris for the first days of December is taken from *A. N.* 4276.

	R. A.	Decl.	log r	log Δ	Brightness
Nov. 29	18^h 50^m 24^s	−5° 31′.9	0.0217	0.2068	4.52
30	50 22	−6 12 .6			
Dec. 1	50 21	−6 52 .5			
2	18 50 19	−7 31 .6			

		R. A. (h)	R. A.	Decl.	log *r*	log Δ	Brightness
Dec.	3	18	50m 18s	−8° 10′.0	0.0098	0.2230	4.43
	4		50 17	−8 47 .7			
	5		50 16	−9 24 .8			
	6		50 14	−10 01 .2			
	7	18	50 13	−10 36 .9	9.9992	0.2375	4.35

H. C. WILSON.

Comet of 69 B. C. and Donati's Comet.—In *A. N.* 4277 Mr. H. H. Kritzinger gives the results of his investigations in regard to the identity of Donati's comet of 1858 with one observed by the Chinese in the year 69 B. C. He reaches a negative conclusion in regard to the comet of 69 B. C. but finds that another great comet observed by the Chinese in the year—146 (147 B. C.) might possibly be identified with Donati's comet. The elements computed for Donati's comet admit of a period all the way from 1879 to 2040 years.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

136.1907 Andr.

	d	h
Jan.	12	17

U Cephei

	d	h
Jan.	1	1
	3	13
	6	1
	8	13
	11	1
	13	13
	16	0
	18	12
	21	0
	23	12
	26	0
	28	12
	30	23

Z Persei

	d	h
Jan.	1	4
	4	5
	7	6
	10	8
	13	9
	16	10
	19	12
	22	13
	25	15
	28	16
	31	17

RY Persei

	d	h
Jan.	5	20
	12	17
	19	13
	26	10

RZ Cassiop.

	d	h
Jan.	1	1
	2	6
	3	10
	4	15
	5	20
	7	0
	8	5
	9	10
	10	15
	11	19
	13	0
	14	5
	15	9
	16	14
	17	19
	18	23
	20	4
	21	9
	22	13
	23	18
	24	23
	26	3
	27	8
	28	13
	29	17
	30	22

RX Cephei

	d	h
Jan.	12	1

Algol

	d	h
Jan.	3	7
	6	4
	9	1
	11	22
	14	19
	17	16
	20	12
	23	9
	26	6
	29	3

RT Persei

	d	h
Jan.	1	11
	2	7
	3	3
	4	0
	4	20
	5	17
	6	13
	7	9
	8	6
	9	2
	9	23
	10	19
	11	15
	12	12
	13	8
	14	4
	15	1
	15	21
	16	18
	17	14
	18	10
	19	7
	20	3
	21	0
	21	20
	22	16
	23	13
	24	9
	25	5
	26	2
	26	22
	27	19
	28	15
	29	11
	30	8
	31	4

λ Tauri

	d	h
Jan.	1	20
	5	19
	9	18
	13	16
	17	15
	21	14
	25	13
	29	12

RW Tauri

	d	h
Jan.	1	18
	4	12
	7	7
	10	1
	12	20
	15	14
	18	8
	21	3
	23	21
	26	16
	29	10

RV Persei

	d	h
Jan.	2	20
	4	19
	6	18
	8	18
	10	17
	12	17
	14	16
	16	15
	18	15
	20	14
	22	13
	24	13
	26	12
	28	11
	30	11

RW Persei

	d	h
Jan.	8	11
	21	16

RS Cephei

	d	h
Jan.	13	9
	25	19

RY Aurigæ

	d	h
Jan.	3	2
	5	19
	8	13
	11	6
	14	0
	16	17
	19	11
	22	4
	24	22
	27	15
	30	9

RZ Aurigæ

	d	h
Jan.	1	20
	4	21
	7	21
	10	21

RZ Aurigae
d h
13 22
16 22
19 23
22 23
25 23
29 0
RW Geminorum
Jan. 1 10
4 6
7 3
10 0
12 21
15 17
18 14
21 11
24 8
27 5
30 1
RW Monoc.
Jan. 1 0
2 22
4 20
6 18
8 15
10 13
12 11
14 9
16 6
18 4
20 2
22 0
23 21
25 19
27 17
29 15
31 12
RU Monoc.
Jan. 1 4
2 1
2 23
3 20
4 18
5 15
6 13
7 10
8 8
9 5
10 3
11 0
11 22
12 19
13 17
14 14
15 12
16 9
17 7
18 5
19 2
20 0
20 21
21 19
22 16

RU Monoc.
d h
23 14
24 11
25 9
26 6
27 4
28 1
28 23
29 20
30 18
31 15
R Canis Maj.
Jan. 1 3
2 7
3 10
4 13
5 16
6 20
7 23
8 7
9 2
10 5
11 9
12 12
13 15
14 18
15 22
17 1
18 4
19 8
20 11
21 14
22 17
23 21
25 0
26 3
27 6
28 10
29 13
30 16
31 19
Y Camelop.
Jan. 2 13
5 20
9 3
12 11
15 18
19 1
22 9
25 16
28 23
RR Puppis
Jan. 6 22
13 8
19 19
26 5
V Puppis
Jan. 1 8
2 19
4 6
5 17
7 3
8 14

V Puppis
d h
Jan. 10 1
11 12
12 23
14 10
15 21
17 8
18 19
20 6
21 17
23 3
24 14
26 1
27 12
28 23
30 10

X Carinæ
Jan. 2 2
3 4
4 6
5 8
6 10
7 12
8 14
9 16
10 18
11 20
12 22
14 0
15 2
16 4
17 6
18 8
19 10
20 12
21 14
22 16
23 18
24 20
25 22
27 0
28 2
29 3
30 5
31 7

S Cancri
Jan. 3 0
12 11
21 23
31 11

S Velorum
Jan. 1 9
7 7
13 5
19 4
25 2
31 1

RR Velorum
d h
Jan. 2 8
4 4
6 1
7 21
9 18
11 14
13 11
15 7
17 4
19 0
20 21
22 17
24 14
26 10
28 7
30 3

SS Carinæ
Jan. 2 9
5 17
9 0
12 7
15 14
18 21
22 5
25 12
28 19

Z Draconis
Jan. 1 12
2 22
4 6
5 15
6 23
8 8
9 16
11 1
12 10
13 18
15 3
16 11
17 20
19 4
20 13
21 22
23 6
24 15
25 23
27 8
28 16
30 1
31 10

SS Centauri
Jan. 2 0
4 11
6 23

SS Centauri
10
Jan. 9 22
11 9
14 21
16 8
19
21 20
24 7
26 19
29 5
31 17

δ Libræ
Jan. 2 9
4 16
7 0
9 8
11 16
14 0
16 8
18 16
20 23
23 7
25 15
27 23
30 7

U Coronæ
Jan. 1 10
4 20
8 7
11 18
15 5
18 16
22 3
25 13
29 0

R Aræ
Jan. 1 18
5 4
9 14
14 0
18 10
22 21
27 7

UZ Cygni
Jan. 3 15

143.1907 Andr.
Jan. 3 11
6 5
8 23
11 18
14 12
17 6
20 1
22 19
25 13
28 8
31 2

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

104.1907
Cassiopeiæ
d h
Jan. 3 10
7 12
11 14
15 16
19 17
23 19
27 21
31 22

RW Cassiop.
(−5 19)
Jan. 15 12
28 7

RX Aurigæ
(−4 0)
Jan. 8 13
20 4
31 19

Y Aurigæ
(−0 18)
Jan. 4 1
7 21
11 18
15 15
19 11
23 8
27 4
31 1

T Monoc.
(−9 23)
Jan. 24 13

W Geminorum
(−2 2)
Jan. 1 20
9 18
17 16
25 14

ζ Geminorum
(−5 0)
Jan. 9 21
20 1
30 5

RU Camelop.
(−9 12)
Jan. 3 9

RU Camleop.
d h
Jan. 25 15

V Carinæ
(−2 4)
Jan. 7 2
13 18
20 11
27 4

T Velorum
(−1 10)
Jan. 4 23
9 15
14 6
18 21
23 13
28 4

W Carinæ
(−1 0)
Jan. 5 22
10 7
14 16
19 1
23 10
27 19

S Muscæ
(−3 11)
Jan. 5 13
15 5
24 21

T Crucis
(−2 2)
Jan. 6 15
20 2
26 20

R Crucis
(−1 10)
Jan. 5 15
11 10
17 6
23 2
28 22

S Crucis
(−1 12)
Jan. 2 20
7 13
12 5
16 22

S Crucis
d h
Jan. 21 14
26 7
31 0

RZ Centauri
Jan. 1 11
2 9
3 8
4 6
5 5
6 3
7 2
8 0
8 23
9 21
10 20
11 18
12 17
13 15
14 14
15 12
16 11
17 9
18 8
19 7
20 5
21 4
22 2
23 1
23 23
24 22
25 20
26 19
27 17
28 16
29 14
30 13
31 11

W Virginis
(−8 5)
Jan. 14 8
31 15

V Centauri
(−1 11)
Jan. 3 21

V Centauri
d h
Jan. 9 9
14 21
20 9
25 21
31 9

R Triang. Austr.
(−1 0)
Jan. 2 9
5 18
9 4
12 13
15 22
19 8
22 17
26 3
29 12

S Triang. Austr.
(−2 2)
Jan. 4 10
10 18
17 2
23 9
29 17

S Normæ
(−4 10)
Jan. 9 1
18 19
28 13

RV Scorpii
(−1 10)
Jan. 4 18
10 20
16 21
22 23
29 0

Y Lacertae
(−1 10)
Jan. 3 14
7 21
12 5
16 12
20 20
25 4
29 11

δ Cephei
h d
(−1 10)
Jan. 6 6
11 15
16 23
22 8
27 17

V Lacertae
(−1 16)
Jan. 4 1
9 1
14 0
19 0
23 23
28 23

X Lacertae
Minimum
Jan. 3 7
9 3
14 14
20 1
25 11
30 24

SW Cassiop.
Jan. 6 3
11 16
17 5
22 18
28 7

RS Cassiop.
(−1 19)
Jan. 1 12
7 19
14 2
20 9
26 17

RY Cassiop.
(−7 10)
Jan. 6 18
18 21
31 1

Approximate Magnitudes of Variable Stars on November 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.		R. A. 1900.	Decl. 1900.		Magn.	Name.		R.A. 1900.	Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
X Androm.	0	10.8	+46	27	12.0*d*	Y Cephei	0	31.3	+79	48	9.2
T Androm.		17.2	+26	26	9.6 *i*	U Cassiop.		40.8	+47	43	11.6 *i*
T Cassiop.		17.8	+55	14	8.0	V Androm.		44.6	+35	6	11.2 *i*
R Androm.		18.8	+38	1	8.9*d*	RR Androm.		45.9	+33	50	12.5*d*
S Ceti		19.0	− 9	53	10.0 *i*	W Cassiop.		49.0	+58	1	8.6

Approximate Magnitudes of Variable Stars on Nov. 1, 1908—Con.

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A 1900		Decl. 1900		Magn.
	h	m	°	′			h	m	°	′	
U Androm.	1	9.8	+40	11	<12	RS Gemin.	6	55.2	+30	40	12.2*d*
S Piscium		12.4	+ 8	24	<12.0	V Can. Min.	7	1.5	+ 9	2	8.9
S Cassiop.		12.3	+72	5	11.0*d*	R Gemin.		1.3	+22	52	8.9
U Piscium		17.7	+12	21	11.4 *i*	R Can. Min.		3.2	+10	11	9.7 *i*
R Piscium		25.5	+ 2	22	<12.5	RR Monoc.		12.4	+ 1	17	10.2 *i*
RU Androm.		32.8	+38	10	<12.5	V Gemin.		17.6	+13	17	9.0
Y Androm.		33.7	+38	50	<12.4	S Can. Min.		27.3	+ 8	32	9.6*d*
X Cassiop.		49.8	+58	46	10.6 *i*	T Can. Min.		28.4	+11	58	9.2 *i*
U Persei		53.0	+54	20	9.0 *i*	Z Puppis		28.3	−20	27	<12
R Arietis	2	10.4	+24	35	<12	U Can. Min.		35.9	+ 8	37	11.5 *i*
W Androm.		11.2	+43	50	10.0*d*	S Gemin.		37.0	+23	41	<12.5
Z Cephei		12.8	+81	13	<14	T Gemin.		43.3	+23	59	9.0
o Ceti		14.3	− 3	26	3.8*d*	U Puppis		56.1	−12	34	11.6
S Persei		15.7	+58	8	8.8	R Cancri	8	11.0	+12	2	9.3*d*
R Ceti		20.9	− 0	38	80. *i*	V Cancri		16.0	+17	36	8.6 *i*
U Ceti		28.9	−13	35	7.3	RT Hydrae		24.7	− 5	59	8.4 *i*
RR Cephei		30.4	+80	42	10.5*d*	U Cancri		30.0	+19	14	<12.5
R Trianguli		31.0	+33	50	9.0 *i*	X Urs. Maj.		33.7	+50	30	<12
T Arietis		42.8	+17	6	9.3*d*	S Hydrae		48.4	+ 3	27	9.4 *i*
W Persei		43.2	+56	34	9.4*d*	T Hydrae		50.8	− 8	46	8.5 *i*
U Arietis	3	5.5	+14	25	<12	T Cancri		51.0	+20	14	8.5 *i*
X Ceti		14.3	− 1	26	10.7*d*	W Cancri	9	4.0	+25	39	9.3 *i*
Y Persei		20.9	+43	50	8.6 *i*	X Hydrae		30.7	−14	15	10.0
R Persei		23.7	+35	20	9.5 *i*	Y Draconis		31.1	+78	18	14.0*d*
Nov. Per. 2		24.4	+43	34	12.6	R Leo. Min.		39.6	+34	58	8.3 *i*
S Fornacis		41.9	−24	42	8.5	RR Hydrae		40.4	−23	34	10.8
T Tauri		16.2	+19	18	9.8	R Leonis		42.2	+11	54	6.0 *i*
W Eridani	4	7.3	−25	24	<12	Y Hydrae		46.4	−22	33	7.3
R Tauri		22.8	+ 9	56	<12	V Leonis		54.5	+21	44	12.4*d*
W Tauri		22.2	+15	49	9.0	R Urs. Maj.	10	37.6	+69	18	9.8*d*
S Tauri		23.7	+ 9	44	<12	W Leonis		48.4	+14	15	<12.5
T Camelop.		30.4	+65	57	12.5	S Leonis	11	5.7	+ 6	0	<12.5
RX Tauri		32.8	+ 8	9	<12	R Comae		59.1	+19	20	<12.5
X Camelop.		32.6	+74	56	9.6 *i*	SS Virginis	12	20.1	+ 1	19	8.0
V Tauri		46.2	+17	22	<12.5	T Can. Ven.		25.2	+32	3	11.8
R Orionis		53.6	+ 7	59	<12.0	T Urs. Maj.		31.8	+60	2	9.8*d*
R Leporis		55.0	−14	57	7.9	RS Urs. Maj.		34.4	+59	2	10.0 *i*
V Orionis	5	0.8	+ 3	58	12.2*d*	S Urs. Maj.		39.6	+61	38	8.4 *i*
T Leporis		0.6	−22	2	8.4	T Urs. Min.	13	32.6	+73	56	9.0 *i*
R Aurigae		9.2	+53	28	9.0 *i*	R Can. Ven.		44.6	+40	2	8.8 *i*
S Aurigae		20.5	+34	4	8.6 *i*	U Urs. Min.	14	15.1	+67	15	8.7 *i*
W Aurigae		20.1	+36	49	9.0 *i*	S Bootis		19.5	+54	16	12.0 *i*
S Orionis		24.1	− 4	46	8.0 *i*	V Bootis		25.7	+39	18	8.1
T Orionis		30.9	− 5	32	10.5 *i*	R Camelop.		25.1	+84	17	8.2 *i*
S Camelop.		30.2	+68	45	10.2*d*	R Bootis		32.8	+27	10	10.0*d*
RR Tauri		33.3	+26	19	11.1*d*	S Coronae	15	17.3	+31	44	12.4
U Aurigae		35.6	+31	59	9.5	S Urs. Min.		33.4	+78	58	9.6 *i*
RZ Aurigæ		42.9	+31	39	11.0	R Coronae		44.4	+28	28	6.0
U Orionis		49.9	+20	10	10.6*d*	X Coronae		45.2	+36	35	11.2*d*
— Orionis		50.0	+20	9	10.0	V Coronae		46.0	+39	52	11.8*d*
Z Aurigæ		53.6	+53	18	10.1 *i*	Z Coronae		52.2	+29	32	11.0*d*
X Aurigae	6	4.4	+50	15	8.5	RR Herculis	16	1.5	+50	46	8.6
SS Aurigae		5.6	+47	47	14.0*d*	U Serpentis		2.5	+10	12	13.0*d*
V Aurigae		16.5	+47	45	11.0 *i*	RU Herculis		6.0	+25	20	8.0
V Monoc.		17.7	− 2	9	9.6*d*	W Coronae		11.8	+38	3	10.4*d*
S Lyncis		35.9	+58	0	12.2*d*	U Herculis		21.4	+19	7	9.3*d*
X Gemin.		40.7	+30	23	11.0*d*	SS Herculis		28.0	+ 7	3	10.5*d*
W Monoc.		47.5	− 7	2	10.0	W Herculis		31.7	+37	32	10.6*d*
Y Monoc.		51.3	+11	22	11.0 *i*	R Draconis		32.4	+66	58	7.3 *i*
X Monoc.		52.4	− 8	56	13.5	S Herculis		47.4	+15	7	7.5
R Lyncis		53.0	+55	28	9.6 *i*	RV Herculis		56.8	+31	22	10.3

Approximate Magnitudes of Variable Stars on Nov. 1, 1908—Con.

Name.		R. A. 1900.	Decl. 1900		Magn.	Name.		R. A. 1900.	Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
Z Ophiuchi	17	14.5	+ 1	37	8.8*d*	WX Cygni	20	14.8	+37	8	10.6 *i*
RS Herculis		17.5	+23	1	11.2*d*	U Cygni		16.5	+47	35	9.7*d*
RU Ophiuchi		28.1	+ 9	30	11.5*d*	RW Cygni		25.2	+39	39	8.2
RS Ophiuchi		44.8	— 6	40	11.4	RU Capricorni		26.7	—22	2	<12
T Draconis		54.8	+58	14	10.0	Z Delphini		28.1	+17	7	11.2 *i*
— Draconis		54.7	+58	14	11.2	ST Cygni		29.9	+54	38	11.8*d*
RY Herculis		55.4	+19	29	10.0	Y Delphini		36.9	+11	31	13.7
V Draconis		56.3	+54	53	11.8 *i*	S Delphini		38.5	+16	44	10.9*d*
T Herculis	18	5.3	+31	0	8.4 *i*	V Cygni		38.1	+47	47	11.8*d*
W Draconis		5.4	+65	56	11.0 *i*	Y Aquarii		39.2	— 5	12	11.2 *i*
X Draconis		6.8	+66	8	<12.6	U Capricorni		42.6	—15	9	12.1*d*
RY Ophiuchi		11.6	+ 3	40	11.2 *i*	T Delphini		40.7	+16	2	<13.7
W Lyrae		11.5	+36	38	12.0*d*	V Aquarii		41.8	+ 2	4	8.4
SV Herculis		22.3	+24	58	14.0*d*	W Aquarii		41.2	— 4	27	10.6*d*
T Serpentis		23.9	+ 6	14	9.8 *i*	V Delphini		43.2	+18	58	13.4*d*
RZ Herculis		32.7	+25	58	12.5*d*	T Aquarii		44.7	— 5	31	13.0*d*
X Ophiuchi		33.6	+ 8	44	8.8	RZ Cygni		48.5	+46	59	13.4*d*
RY Lyrae		41.2	+34	34	11.6	X Delphini		50.3	+17	16	10.6*d*
RW Lyrae		42.1	+43	32	11.4	UX Cygni		50.9	+30	2	11.2
RX Lyrae		50.4	+32	42	12.0 *i*	R Vulpeculae		59.9	+23	26	8.4*d*
ST Sagittarii		55.9	—12	54	14.0	V Capric.	21	1.8	—24	19	<12.5
Z Lyrae		56.0	+34	49	13.3*d*	TW Cygni		1.8	+29	0	11.4 *i*
RT Lyrae		57.8	+37	22	12.4*d*	X Capricorni		2.8	—21	45	11.0 *i*
R Aquilae	19	1.6	+ 8	5	6.4 *i*	X Cephei		3.6	+82	40	10.0 *i*
V Lyrae		5.2	+29	30	<13.6	RS Aquarii		5.8	— 4	27	12.4 *i*
RX Sagittarii		8.7	—18	59	13.2*d*	Z Capricorni		5 0	—16	35	11.6*d*
RW Sagittarii		8.1	—19	2	10.3*d*	R Equulei		8.4	+12	23	11.8*d*
S Lyrae		9.1	+25	50	<13.8	T Cephei		8.2	+68	5	8.4
RS Lyrae		9.3	+33	15	11.4 *i*	RR Aquarii		9.8	— 3	19	10.7*d*
RU Lyrae		9.1	+41	8	11.0	X Pegasi		16.3	+14	2	12.0 *i*
U Draconis		9.9	+67	7	13.5*d*	T Capricorni		16.5	—15	35	10.6 *i*
W Aquilae		10.0	— 7	13	12.9	Y Capricorni		28.9	—14	25	<13
T Sagittarii		10.5	—17	9	11.0*d*	S Cephei		36.5	+78	10	9.4*d*
RY Sagittarii		10.0	—33	42	7.3	RU Cygni		37.5	+53	52	8.3
R Sagittarii		10.8	—19	29	13.0*d*	RR Pegasi		40.0	+24	33	<13
S Sagittarii		13.6	—19	12	<13	V Pegasi		56.0	+ 5	38	10.4*d*
Z Sagittarii		13.8	—21	7	12.6*d*	U Aquarii		57.9	—17	6	11.2 *i*
TZ Cygni		13.4	+50	0	10.8*d*	RT Pegasi		59.8	+34	38	9.5 *i*
U Lyrae		16.6	+87	42	10.6	T Pegasi	22	4.0	+12	3	12.0 *i*
T Sagittae		17.2	+17	28	9.4	Y Pegasi		6.8	+13	52	10.4 *i*
TY Cygni		29.8	+28	6	12.6*d*	RS Pegasi		7.4	+14	4	<13
R Cygni		34.1	+49	58	10.6*d*	X Aquarii		13.2	—21	24	<11.6
RT Aquilae		33.3	+11	30	13.6*d*	RT Aquarii		17.7	—22	34	9.4
RV Aquilae		35.9	+ 9	42	<13 6	RV Pegasi		21.0	+29	58	9.0
RT Cygni		40.8	+48	32	10.8 *i*	S Lacertae		24.6	+39	48	<12.4
TU Cygni		43.3	+48	49	13.0*d*	R Lacertae		38.8	+41	51	<12.4
X Aquilae		46.5	+ 4	13	8.5 *i*	S Aquarii		51.8	—20	53	12.4
χ Cygni		46.7	+32	40	12.2*d*	RW Pegasi		59.2	+14	46	13.8*d*
RR Aquilae		52.4	— 2	11	12.6*d*	R Pegasi	23	1.6	+10	0	8.8*d*
RS Aquilae		53.7	— 8	9	11.4 *i*	V Cassiop.		7.4	+59	8	9.6 *i*
Z Cygni		58.6	+49	46	9.0 *i*	W Pegasi		14.8	+25	44	8.8
SY Aquilae	20	2.3	+12	39	12.2	S Pegasi		15.5	+ 8	22	12.4*d*
S Cygni		3.4	+57	42	11.8 *i*	R Aquarii		38.6	—15	50	10.0
R Capricorni		5.7	—14	34	10.8 *i*	ST Androm.		33.8	+35	13	9.2 *i*
S Aquilae		7.0	+15	19	10.0 *i*	Z Cassiop.		39.7	+56	2	13.2*d*
RU Aquilae		8.0	+12	42	13.5 *i*	RR Cassiop.		50.7	+53	8	<12.2
W Capricorni		8.6	—22	17	<13	Z Aquarii		47.1	—16	25	8.6
Z Aquilae		9.8	— 6	27	10.3	V Ceti		52.8	— 9	31	11.2 *i*
RS Cygni		9.8	+38	28	8.5	R Casssiop.		53.3	+50	50	8.0 *i*
R Delphini		10.1	+ 8	47	13.6*p*	Z Pegasi		55.0	+25	21	10.0 *i*
RT Capricorni		11.3	—21	38	8.0	Y Cassiop.		58.2	+55	7	<13
SX Cygni		11.6	+30	46	11.0*d*						

The letter *i* denotes that the light is increasing; the letter *d* that the light is decreasing; the sign $<$, that the variable is fainter than the appended magnitude.

The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Vassar, Mt Holyoke, Whitin, Swartz and Harvard Observatories.

New Variable Stars 139 and 140.1908.—In A.N. 4272 Prof. W. Ceraski announces two new variables discovered by Mme. L. Ceraski upon the Moscow photographic plates. Their places are as follows:

	α 1855 h m s	δ 1855 ° ′ ″	α 1900 h m s	δ 1900 ° ′ ″
139.1908 Lyræ	18 30 19	+46 01	18 31 35	+46 03
140.1908 Sagittarii	18 41 05.6	−16 52 53	18 43 41.8	−16 50 07

The former varies from about $10^{\rm m}$ to below $11^{\rm m}.5$ and the period is probably long. The latter is B. D.—16° 5041 and on three photographs taken Sept. 27, 1899, July 23 and Aug. 20, 1906, appears of the same brightness, about $7^{\rm m}.5$ while on a fourth plate obtained Sept. 18, 1906, it is about $0^{\rm m}.8$ fainter.

New Variable 141.1908 Draconis.—This is announced by Prof. W. Ceraski in A.N. 4277. From 22 photographs taken at Moscow during the years 1904–1908 the range of variation appears to be between the 10th and 12th magnitudes and the period perhaps about twelve months. Its position is

1855 $\alpha = 17^{\rm h}\ 30^{\rm m}\ 53^{\rm s}$ $\delta = +54°\ 02'$
1900 17 31 49 +54 00

New Variable 142.1908 Cassiopeiæ.—In A.N. 4277 Mr. Sigurd Enebo calls attention to a star near the variable SX (142.1907) Cassiopeiæ, which during the winter of 1907–08 must have been below magnitude 10.5. On Aug. 5, 7, 9, 13 and 15 last it was not noticed during the observations of SX, but on Aug. 20 it was estimated at $9^{\rm m}.4$ and on Sept. 8 at $9^{\rm m}.6$. Since that time it has been reckoned as below $10^{\rm m}.0$ Its color on Aug. 20 was strong red. Its position is

1855 $\alpha = 0^{\rm h}\ 02^{\rm m}\ 36^{\rm s}$ $\delta = +54°\ 04'\ 24''$
1900 0 04 55 +54 19 26

On Oct. 15 its brightness was estimated at about $11^{\rm m}.0$. The star is the third of four faint stars which follow each other in a straight line, only a few seconds apart in right ascension.

Algol.—In A.N. 4278 Mr. Charles Nordmann gives the results of his observations of six minima of β Persei (Algol), from which he concludes that the ephemerides of Algol in "Annuaire du Bureau des Longitudes" require a correction of about $-53^{\rm m}$. These ephemerides agree with those published in POPULAR ASTRONOMY so that the minima of Algol may be expected to occur about an hour earlier than predicted in our tables.

Antalgol Variable ST Virginis.—In A.N. 4277 Dr. E. Hartwig gives as elements of this variable

$$\text{Max.} = 2418121.4146 + 0.^{\rm d}41139.$$

It is of the antalgol type remaining at minimum about five hours and at maximum only ten minutes. The range of variation is from about 10.5 to 9.1 magnitude. The place of the star is

1855 $\alpha = 14^h\ 20^m\ 12^s.44$ $\delta = -0^\circ\ 14'\ 52''.1$
1900 14 22 30.98 —0 27 07.4

Sixteen New Variables in the Harvard Map, Nos. 4 and 13.—In the Harvard College Observatory Circular No. 140 Prof. Pickering gives a list of sixteen new variables discovered by Miss Cannon in examining the photographic plates covering the region of the Harvard Map, Nos. 4 and 13. In A.N. 4275 these are given the numbers 44 to 59.1908.

Provisional Designation		Harvard Number	BD		R.A. 1900			Decl. 1900		Mag.	
			°		h	m	s	°	′		
44.1908	Aurigæ	3086	+39	1225	5	08	14	+40	01.0	9.3	10.1
45.1908	Aurigæ	3087	. . .		5	35	02	+38	53.2	9.5<12	
46.1908	Tauri	3088	+13	971	5	39	23	+13	31.9	8.5	9.4
47.1908	Tauri	3089	. . .		5	43	12	+19	02.0	10.0<15	
48.1908	Tauri	3090	+28	921	5	45	49	+28	05.2	9.4	11.0
49.1908	Aurigæ	3091	+45	1202	5	49	42	+45	29.1	9.3	10.3
50.1908	Orionis	3092	+13	1034	5	50	11	+13	40.2	9.7	10.7
51.1908	Geminorum	3093	+24	1056	5	54	33	+24	28.1	9.3	10.3
52.1908	Geminorum	3094	+22	1146	5	56	35	+22	14.7	9.5	11.0
53.1908	Orionis	3095	. . .		5	57	16	+16	22.3	9.5<12	
54.1908	Geminorum	3096	+11	1187	6	02	32	+22	37.9	9.0	10.0
55.1908	Lyncis	3097	+61	887	6	20	24	+61	37.1	9.2	9.9
56.1908	Geminorum	3098	. . .		6	22		+20	37	9.6	10.5
57.1908	Camelop.	3099	. . .		6	23	40	+67	06.0	10.6<11.6	
58.1908	Camelop.	3100	. . .		7	04	09	+73	29.7	9.8	10.9
59.1908	Ursæ Maj.	3101	+65	613	8	01	41	+65	31.6	9.2	10.1

Notes.—44.1908 period probably short. 45.1908 Maxima = J. D. 2416791 + 452 E. 47.1908 variation resembles that of R Coronae Borealis. 48.1908 period short. 49.1908 nature of light curve not indicated. 50.1908 Algol type. 51.1908 Algol type? 52.1908 period short. 53.1908 period probably long. 54.1908 period probably short. 55.1908 character of light curve not indicated. 56.1908 probably Algol type. 57.1908 period unknown. 58.1908 probable Algol type. 59.1908 type unknown.

Variable Star Note.—From an observation by Leon Campbell with the 24-inch reflector on October $19^d.619$, G. M. T. the variable star 31.1907,—Aurigae was found to be bright, magn. 10.8.

The variable star SS Cygni, 213843, has been undergoing remarkable changes during the past month. On Sept. 15 it had reached a maximum of magn. 8.3, of the type known as Anomalous. On Oct. 6 it had decreased to magn. 11.0, and on Oct. 12 it was increasing in brightness and of the magnitude 10.5; while on Oct. 19 it appears to have attained the magn. 10.0. In other words, the variable had not reached its usual minimum magnitude, 11.8, before it started to increase again.

EDWARD C. PICKERING.

Astronomical Bulletin No. 341,
Harvard College Observatory, October 20, 1908.

GENERAL NOTES.

A Central Eclipse of the Sun will occur on December 23, but will be invisible in the Northern Hemisphere. It will be annular at the beginning and end and will be total in the middle. The path of the central line of eclipse will pass across South America, crossing Chili, Argentine Republic and Uraguay, perhaps touching a corner of Brazil. Thence its course will be wholly over the waters of the southern Atlantic and Indian Oceans. The duration of totality will be only eleven seconds at the most. As a partial eclipse the beginning may be observed all along the southeast coast of South America from the mouth of the Amazon down, in the southern point of Africa and the Island of Madagascar. For the elements of the eclipse see POPULAR ASTRONOMY No. 151, January 1908, page 48.

Photographic Observations of Comet Morehouse. Beginning with the night of October second Comet Morehouse has been photographed here on every clear evening; these photographs have been made with a photographic doublet of nine inches aperture, with a ratio of aperture to focal length of 1 to 5, which has been recently installed in the observatory here.

The instrument was built by the John A. Brashear Company and is a part of the astronomical equipment presented by William C. Sprove to Swarthmore College.

This comet has been whimsical in its behavior, so much so, that, one could not predict with any degree of confidence what, on any one night, the shape of its tail might prove to be.

A most striking change occurred during the twenty-four hours beginning at eight o'clock Washington mean time October fourteenth. A photograph made on the night of the fourteenth showed the comet with a quasi fan-shaped tail. It was not symmetrical, but was much brighter on one side, and there issued from the head and seemingly from various parts of the tail long, thin, straight, and nearly parallel rays. The appearance of the tail on the night of October 15 is well shown in a photograph, the negative of which I exposed from 7:00 to 8:30 o'clock Washington Mean time. I exposed a second plate on the same night from 9:20 to 10:20. Both plates showed the straight narrow tail joined to the head of the comet as well as the long broad irregular ribbon-like tail the beginning of which was at some distance from the head of the comet. The first negative, which was exposed longer and which was made when the altitude of the comet was greater showed thin straight rays apparently issuing from points in the comet's tail, resembling somewhat those of the night before. A comparison of the two plates showed that the beginning of the tail (*i. e*, the part nearest the head of the comet) was moving faster among the stars than the straight tail that was joined to the head of the comet.

At the beginning of the broad tail, I selected two condensations, the one on that side of the tail which was in the direction in which the comet was moving, I called condensation one, and the other at nearly the same distance from the head but on the opposite side of the tail I called condensation two. These condensations are easily identified on both plates. Both were farther from the head on the second plate than on the first, the first having moved a distance of 5′ 45″.5 of arc and the second a distance of 5′ 34″.

On the night of the sixteenth Mr. Walter R. Marriott exposed a plate for one and one half hours beginning at seven thirty. The condensations were found on this plate, though owing to the fact that they had changed their shape somewhat they could not be so certainly identified as on the preceding night. Condensation one on this plate was 1° 17′ 47″ farther from the head than it was on the first plate exposed on the fifteenth and condensation two had moved in the same time through an arc of 1° 16′.

Comet Morehouse.
October 15.

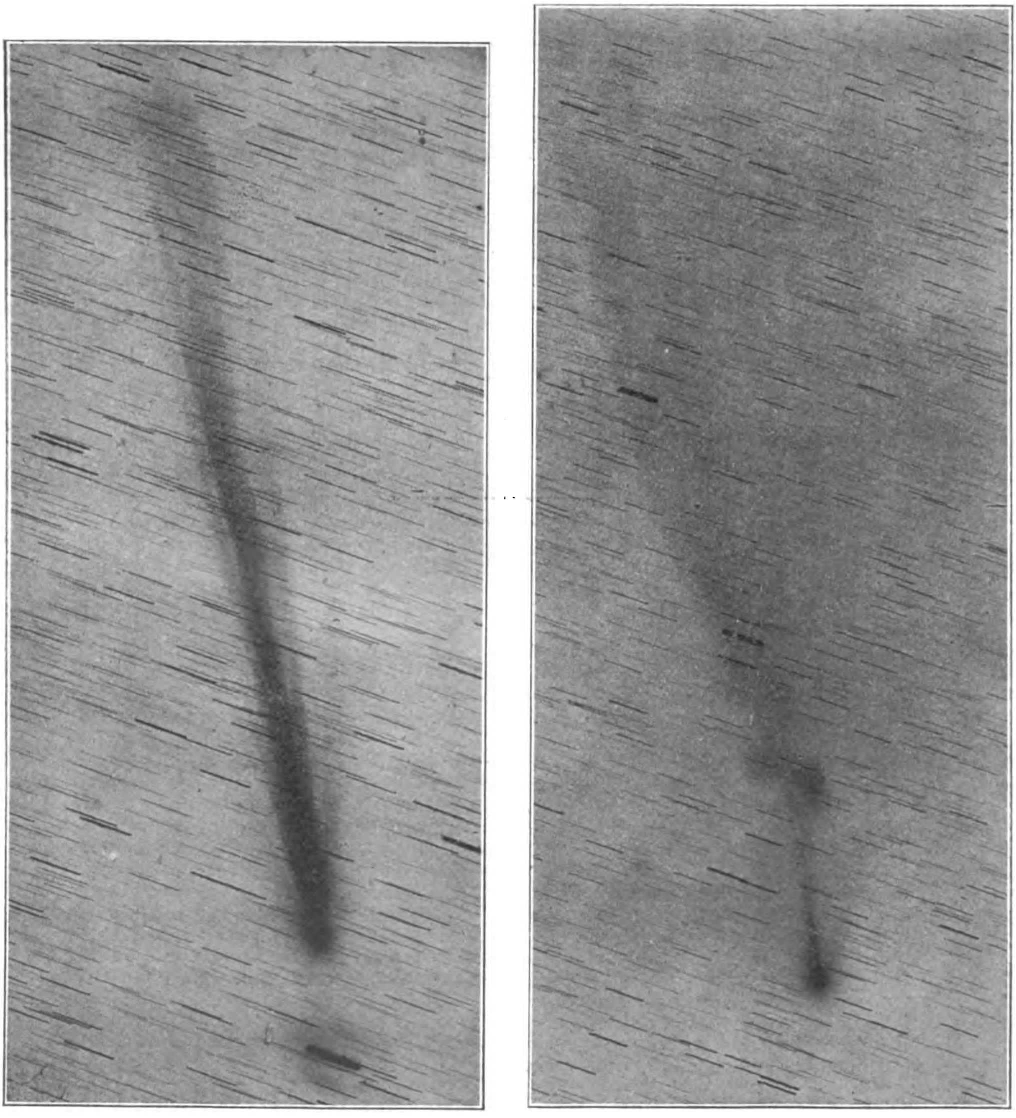
No traces of the condensations, nor of any part of the broad ribbon-like tail could be found on a plate exposed on the seventeenth.

If we assume that the tail of the comet is in the direction of the radius vector of the comet from the Sun, condensation one had receded from the head of the comet, 224,000 miles, and condensation two about 247,000 miles in two and one half hours on the night of the fifteenth. This requires an average velocity of 89,600 and 99,000 miles per hour respectively.

A comparsion of the first plate of the fifteenth with that of the sixteenth shows that the average velocity of the two condensations for 24½ hours was 142,000 and 129,000 miles per hour respectively.

It is probable that the tail of the comet deviates enough from the radius vector, to modify slightly these velocities.

Swarthmore, Pa. JOHN A. MILLER.



No. 1, Oct. 14, '08, exposed 7^h 44^m to 9^h 46^m E.S.T. No. 2, Oct. 15, '08, exposed 8^h 0^m to 9^h 30^m E.S.T.

COMET MOREHOUSE PHOTOGRAPHED BY REV. JOEL H. METCALF.

The Pope and the Comet. *A Reply to Mr. Dean.*

1. The first sentence in my article is *dis*junctive, not *con*junctive, writers on Halley's comet bring in the bull OR the bells OR the prayers. When Mr. Dean pleads guilty to the third, I do not therefore commit him for the first and second.

2. Yes, my article was inspired and hastened by his. I judged him to belong to that large class of readers who see one or two or all three of these statements about Callixtus III almost everywhere in magazines and newspapers, and never hear them contradicted, and therefore never even suspect them to be false, and then propagate them bona fide.

3. Mr. Dean will find a previous similar allusion to this comet story on page 239 of No. 144 of this journal, April 1907. As the article in which this allusion occurs, was reprinted from *Knowledge* and *Scientific News*, and later also appeared in the *Scientific American*, and as similar articles have also been copied by our local Sunday newspapers, I had good reason to conclude that the error had already crept into many other publications, and would keep on spreading unless it was checked by a timely article in a magazine as important as POPULAR ASTRONOMY.

4. That Callixtus III ordered the bells to be rung at noon or introduced the prayer called the Nagelus, is not at all as certain as writers would have us believe. If he did, neither the bells nor the prayer had any connection with the comet, and that is the point at issue. Nor did he add the comet invocation to the litanies or the Angelus. In one word, no historical proof has ever been advanced which would connect Callixtus III with Halley's Comet.

5. Present day writers rarely mention the bull. When they do, they always prefix the phrase "it is said." But many former writers really did believe that the pope issued a formal bull against the comet, and that he ordered bells to be rung to frighten it away. Mr. Dean will find in Fr. Gerard's article (mentioned by me on page 482 in my article) quotations and references which I do not wish to perpetuate.

Creighton University, WILLIAM F. RIGGE.
Observatory, Omaha, Nebraska.

Photographic Films. For some time past European astronomers have been interested in the study of photographic films to obtain knowledge of their elementary structure. The object of this study has been to learn, if possible, whether or not the discordances in the measures of photographic plates in determining exact star places were due to something else than mere errors of measurement.

C. D. Perrine has given in No. 143 of the Lick Observatory Bulletin, some results of a study of the grain and structure of photographic films the summary of which we give as follows:

"The conclusion drawn this investigation is that practically all the large discordances found in the positions of the stars derived from photographs can be traced to the *structure* of the star image itself due to vacant lanes and other irregular arrangements of the silver grains.

It is earnestly hoped that the manufacturers of photographic plates, and others who may have the necessary facilities, will make a strong effort to produce a more uniform structure of sensitive films suitable for original exposures. At the present time I am inclined to believe that such a result is even of greater importance than increased sensitiveness. Could the size of the grain be reduced also, an improvement in positions could hardly fail to result to say nothing of the manifold other ways in which scientific photography could be helped.

It is encouraging to find such strong evidence that practically all the trouble is in one place, and particularly that the telescope, seeing, etc., appear to introduce but slight errors.

It may not be out of place to emphasize the experience of many astronomers that fair sized black images of stars usually give better positions than can be obtained from very small, faint ones."