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WILLIAM W. PAYNE.
H. C. WILSON.

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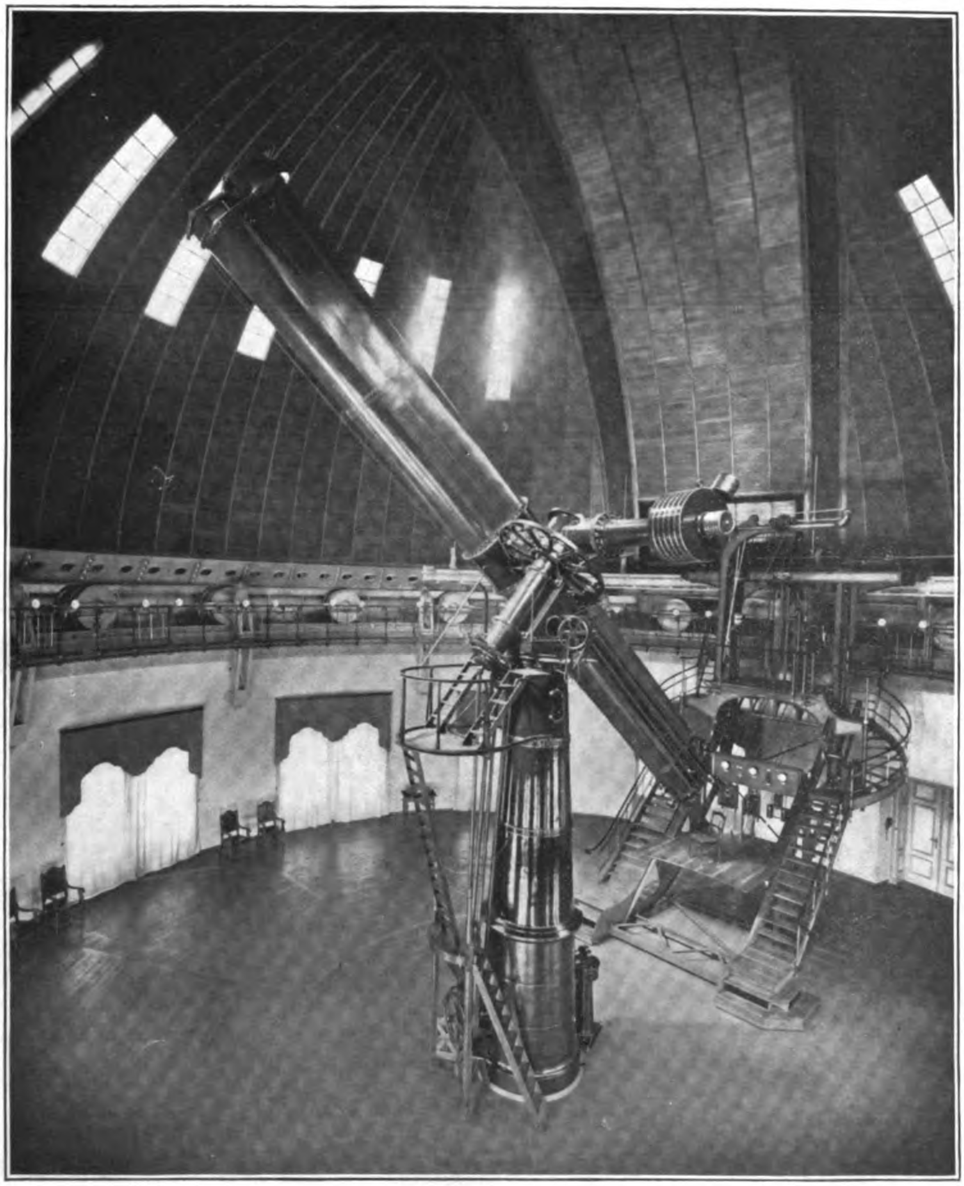
PLATE I.



THE NEW PHOTOGRAPHIC TELESCOPE OF THE ASTROPHYSICAL OBSERVATORY AT POTSDAM.

Popular Astronomy.

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A POSSIBLE EXPLANATION OF THE GEGENSCHEIN.

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY.

Besides the Moon, we know that there must be countless much smaller bodies constantly circling about the Earth, in various directions and at various distances. Owing to collisions, and attractions of the Sun and Moon, some of these bodies are occasionally drawn from their normal orbits and precipitated upon the Earth as meteorites. Those that continue to circulate in direct closed orbits, nearly parallel to the plane of the ecliptic, must all, drawn by tides which they themselves produce, gradually recede from the Earth. When they have receded to something over one million miles their periods of revolution will be just one year, and as soon as they recede beyond that point they will be left behind by the Earth in her orbit, and lost to her as satellites. Henceforward they will be dependants upon the Sun. As they approach this limiting distance, however, their rate of recession will become slower, and accordingly a large proportion of them will be found at about this distance from the Earth, and with periods of about a year.

Any meteorite whose period is just one year will remain at a constant difference of longitude from the Sun. As its period approaches this figure it will be much perturbed of the Sun, and rapidly change its longitude with regard to it, save in one position, that where it is in line with the Earth and Sun, and beyond the former. Here the perturbations will be slight, and consequently the change of position slow, and therefore there will be a greater number of the meteorites collected in this place. In this place, moreover, since they will appear full as seen from the Earth, they will appear at their brightest.

It is therefore suggested that we have here a possible explanation of the Gegenschein, which according to this hypothesis would be an actual body attendant upon the Earth; in short, a sort of cometary or meteoric satellite. Its mass would be small, but its bulk as judged from its angular dimensions would be great, being not far from that of the planet Jupiter.

No meteorite whose period of revolution was one year could remain in line between the Sun and Earth, as it would be drawn away by the former body. There seems to be no question but that some action such as that above described must take place, and therefore that the light of the Gegenschein must be due in part, at least, to this cause, the only question is whether it is wholly due to it; in other words, whether the suggested explanation is adequate to produce the effect observed. A suggestion that the Gegenschein might be of meteoric origin was made by Professor Searle in 1882 (A. N. C II. 266).

It may be pointed out if this hypothesis is correct, that the Moon should produce some effect upon the location of the Gegenschein. Thus, when the Moon, is full the Gegenschein should be slightly to the west of its mean position, and when the Moon is new, it should be somewhat to the east of it. In an article printed for private distribution, but taken in part from POPULAR ASTRONOMY for 1897, Vol. V., p. 178, Mr. Douglass gives the results of an examination of 254 observations of the Gegenschein made chiefly by himself, and concludes that the longitude of the Gegenschein does bear a definite relation to the lunar month. He finds "that observations made before new Moon have a tendency to place the Gegenschein farther east than those made after." Should these observations be confirmed, there would seem to be no doubt that the Gegenschein is a material object attending the Earth in its orbit, and not merely an electrical discharge or a phenomenon produced by remote bodies outside of the orbit of Mars.

HARVARD COLLEGE OBSERVATORY,
December 8, 1899.

THE EULER-LAMBERT EQUATION FOR PARABOLIC MOTION.

ASAPH HALL.

FOR POPULAR ASTRONOMY.

It is well known that the important equation between the time of moving through the arc of a parabola, the two radii vectores, and the chord, was given first by Euler, although for many years it was known as Lambert's equation. This formula was published by Euler in the Memoirs of the Berlin Academy, 1743. It is given in his work on the orbit of the Comet of

March, 1742. Euler gives two demonstrations, and finds in our modern notation the known equation,

$$kt = \frac{1}{6}\left[(r + r' + c)^{\frac{3}{2}} - (r + r' - c)^{\frac{3}{2}}\right] \qquad (1)$$

He gives no plus sign to the second term, which is required when the heliocentric motion is more than 180°. Euler's method of determining the orbit of the comet is to make by trial the computed interval of time agree with the observed interval. He also tries the theory of an ellipse, assuming that the semi parameter is to the perihelion distance as $2 - \alpha$ is to 1 and finds $\alpha = 0.06047$. Euler gives this value of the perihelion distance,

$$q = \frac{(r - r' + c) \,.\, (r - r' + c)}{4\,(r + r') - 4.\left[\,(r + r' - c)\ (r + r' + c)\right]^{\frac{1}{2}}}$$

I do not find that Euler ever made any further use of formula (1). It appears to have been forgotten by the author, and by every one, until it was rediscovered by Lambert, and published by him in his elegant treatise, "*Insigniores orbitae Cometarum Proprietates*," 1761. In article 83 Lambert gives formula (1), with the negative sign only, as Euler had done. He expands (1) in a series according to the ratio $\frac{c}{r + r'}$: and this is the series employed by Encke for the solution of (1).

Equation (1) has been transformed in many ways. A useful method is to divide the equation by $(r + r')^{\frac{3}{2}}$, and write it in the form,

$$\frac{6kt}{(r + r')^{\frac{3}{2}}} = \left(1 + \frac{c}{r + r'}\right)^{\frac{3}{2}} - \left(1 - \frac{c}{r + r'}\right)^{\frac{3}{2}}$$

From the geometrical conditions we may always put

$$\sin\gamma = \frac{c}{r + r'},$$

taking γ less than 90°. Now it is evident that

$$\left(\cos\frac{1}{2}\gamma \pm \sin\frac{1}{2}\gamma\right)^2 = 1 \pm \sin\gamma,$$

and hence

$$\frac{6kt}{(r + r')^{\frac{8}{2}}} = \left(\cos\frac{1}{2}\gamma + \sin\frac{1}{2}\gamma\right)^3 - \left(\cos\frac{1}{2}\gamma - \sin\frac{1}{2}\gamma\right)^3$$

$$= 6\cos^2\frac{1}{2}\gamma\sin\frac{1}{2}\gamma + 2\sin^3\frac{1}{2}\gamma.$$

Or we may write

$$\frac{6kt}{\sqrt{8}.\ (r+r')^{\frac{3}{2}}} = 3\left\{\frac{\cos\frac{1}{2}\gamma}{\sqrt{2}}\right\} - 4\left\{\frac{\sin\frac{1}{2}\gamma}{\sqrt{2}}\right\}^{3}.$$

If therefore we put

$$\frac{6kt}{\sqrt{8}.\ (r+r')^{\frac{3}{2}}} = \sin\psi,$$

the last equation gives by the forms for the sine of a triple arc,

$$\sin\frac{1}{2}\gamma = \sin\frac{1}{3}\psi.\sqrt{2}.$$

Gauss appears to have pointed out this transformation.

CAMBRIDGE, Mass.
1899, Dec. 4th.

PHOTOGRAPHIC EFFICIENCY OF THE CROSSLEY REFLECTOR.

We have been greatly interested in the recent photographic work of Professor J. E. Keeler, Director of Lick Observatory, Mount Hamilton, Cal., which is done by the aid of the Crossley Reflector. This large reflecting telescope was originally made by Calver; it was for some time used by Dr. A. A. Common, of England, who obtained with it some excellent celestial photographs for which he received the Gold Medal of the Royal Astronomical Society in 1884. Later it came into the hands of Mr. Crossley who, after making some improvements upon it, in 1895, presented it to the Lick Observatory while Professor E. S. Holden was Director.

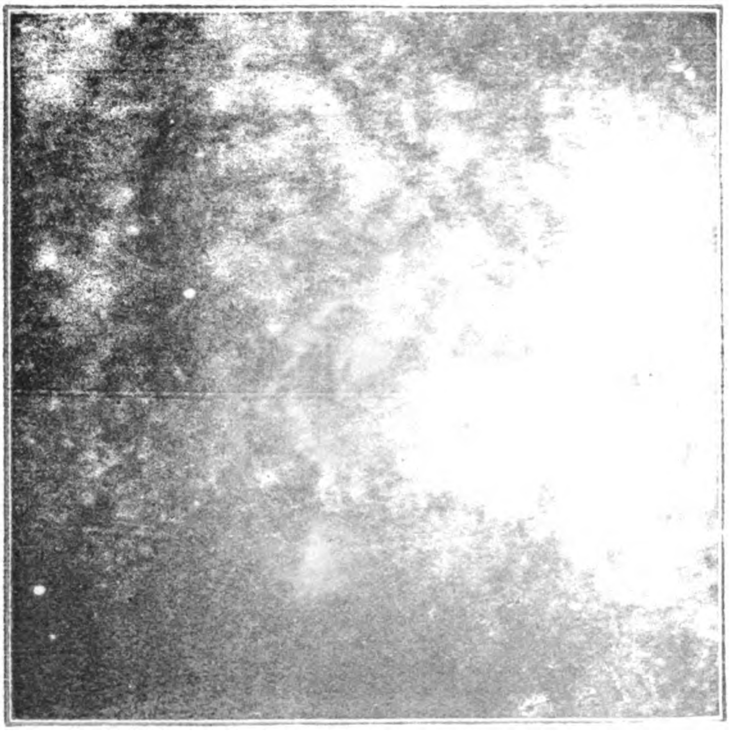
Last May Professor Keeler published a brief account of some photographic work by the aid of this instrument in the *Publications of the Astronomical Society of the Pacific.* That account is so instructive and so useful to any one interested in celestial photography that we give below the article in full.

By permission of Professor Keeler we are able to reproduce one of the finest photographs of Earl Rosse's wonderful spiral (M. 51), sometimes called the "Whirlpool Nebula," we have ever seen. The reproduction in our cut, though carefully done, does not equal the exquisite photograph obtained by Professor Kee-

PLATE II.

THE GREAT SPIRAL NEBULA IN CANES VENATICI.

Photographed with the Crossley Reflector of Lick Observatory.
Exposure 4 hours.



ler with the Crossley reflector. A beautiful lantern slide of that photograph was sent to Dr. Wilson, of Goodsell Observatory, only a few days ago, and our illustration was made from the lantern slide. The size of our cut is one and one-half times that of the picture which appears to be the size of the focal image of the nebula in the Crossley reflector. Of this, however, we are not sure for Professor Keeler has not yet given information on this point.

The picture of this Nebula by Mr. Roberts, of England, will be found in *Knowledge* Vol. 12, (1889) facing page 188. The Roberts' picture was taken April 21, 1889, with a 20-inch silver-on-glass reflector with an exposure of 4 hours. The print is we think by the collotype process. By reading the following account any one will readily understand the advantages which Professor Keeler would have both in size of instrument and locality for work of this kind. Mr. Roberts' picture although enlarged 8 diameters is still a little smaller than that obtained at Mount Hamilton. The enlargement of a photograph so much has undoubtedly both diminished the sharpness of detail and occasioned a loss of the fine contrast and very minute features that may appear in the original negative. The exquisitely delicate mingling of shade and the soft effect of definite color in the Keeler picture is certainly charming to those who love to study good photographic work. Professor Keeler gives reasons for these results in the following article:

"The reflecting telescope has been so little used in this country, since the time of Henry Draper, that a few notes on the photographic efficiency of the Crossley reflector may be of interest to American readers.

The Crossley dome is built on the farther end of a long rocky spur, which extends from the principal summit of Mt. Hamilton toward the south, and is within a few minutes' walk (or climb) of the main Observatory. The mirror, which has a very fine figure, has an aperture of three feet, and a focal length of seventeen feet six inches. The mounting, as compared with the beautifully mounted large refractors of the Observatory, is undoubtedly a rude piece of mechanism, but with sufficient experience of its numerous idiosyncrasies, the observer can obtain negatives with exposures of four hours' duration, with only an occasional failure.

At present the Crossley telescope is being used for photographic observations of nebulæ. For such work the summer months at Mt. Hamilton present almost ideal conditions. The sky is continuously and often brilliantly clear, while the dryness and purity of the air are such that the silvered surfaces retain their brilliancy without any care on the part of the observer. Within the last week, however, the smoke from forest fires (from which there seems to be no escape in even the remotest corners of the Earth) has greatly dulled the brightness of the sky, and has interfered most annoyingly with the photographic work. In the winter months, on the other hand, the conditions are generally bad, on account of storms, snow, fog, or dampness; yet there are many nights, between the spells of bad weather, on which the telescope can be used.

To one who, like myself, has always worked with refracting telescopes, the photographic power of a large reflector is surprising. In this respect, the Crossley reflector does not, of course, surpass any other reflecting telescope of like dimensions, but its photographic "rapidity" is certainly very considerably greater than that of a refracting telescope of the same angular aperture. This is due to the fact that the silvered surfaces absorb less of the chemically active light than the glass lenses of a refractor, and it is noteworthy that this superiority of the reflector becomes more pronounced the finer the atmospheric conditions under which the two classes of instruments are compared. On one of the fine nights which I have mentioned, when the Milky Way shines with astonishing splendor and the whole heavens look phosphorescent, the photographic activity of the reflector is remarkably increased. But the performance of the refractor is not greatly changed, for the reason that the short light-waves, which are transmitted more abundantly by the unusually clear air, are in any case strongly absorbed by glass.

To illustrate the photographic rapidity of the Crossley telescope, I give the following examples of exposure-times in which well-known nebulæ have been photographed:—

The Ring nebula in *Lyra* has been photographed on several occasions, and the results are described in another part of the present number of the *Publications*. It will be seen that the best general representation of the nebula was obtained with an exposure of ten minutes. On this plate the stars are perfectly round and very small. The disc of the central star of the nebula has a diameter of 3″.5; that of the smallest stars shown does not exceed 1″.5. On the same plate is a double star (not resolved) the equal components of which are about 2″ apart, while their magnitude is not less than 17 or 18. It will hardly be observed visually. The central star, which has a visual magnitude of 15.4, according to Burnham. gave a distinct image in one minute.

Photographs of small planetary nebulæ have been made, not only for the purpose of ascertaining the exposure-times required for such objects, but to see what amount of detail can be shown in a surface of such small dimensions. With regard to the latter purpose, it was found that a large amount of detail was shown, but that visual observation with the 36-inch refractor was more satisfactory than photographic observations with the reflector.

In the case of the small but remarkable planetary nebula G. C. 4628 (26″ x 16″), the best general picture was obtained in two minutes, while with the "ansæ," extending outward from and connected with the main nebula, were well shown in ten minutes.

Another planetary nebula which has been photographed is G. C. 4964. Eight images were obtained on the same plate by slightly changing the position of the plate-holder between the exposures, which ranged from two minutes to one second. The images which received exposures of one minute, thirty seconds, and twenty seconds respectively, were the best. A weak image, in which the central star was just visible, was produced in two seconds, and a bare trace of the nebula was visible at the place where the exposure was one second.

The planetary nebula in *Draco*, G. C. 4373, has also been photographed, with quite similar results; and small nebula discovered by Professor Barnard near the star *Merope* is distinctly shown on a negative of the *Pleiades* which was exposed for thirty seconds.

The photographic power of the reflector which is illustrated in the foregoing examples is very advantageous in the case of objects which are of very unequal brightness, as a very full light-action, and consequently softening of contrasts, is obtained with a comparatively short exposure. If, for instance a plate is exposed for ten minutes to such an object as the great cluster in *Hercules*, and rather strongly developed, a negative is obtained which shows very distinctly all the brighter stars. If the plate is exposed for two hours, and is then very lightly developed, the brighter stars appear much as before, but the swarms of minute stars, to which a globular cluster seems to owe its nebulous aspect, also appear on the plate, so that the photograph closely represents the appearance of the cluster as seen in a large telescope. On a photograph of the cluster in *Hercules*, made with the Crossley reflector on July 13th, with an exposure of two honrs, over 5,400 stars were counted within the limits of the cluster. The average diameter of a star disc is 3″.5. A discussion of stars in the cluster, as shown by this photograph, has been made by Mr. Palmer.

With exposures of four hours, stars and nebulæ are photographed which are far beyond the range of the 36-inch refractor. On one plate (3¼ x 4¼ in.) sixteen new nebulæ were found. It would be easy with this instrument greatly to increase the number of known nebulæ; but the discovery of new nebulæ, all of which would necessarily be faint, seems to be much less important than the gain of further information about nebulæ already known. For this reason no search has been made for new objects, though a catalogue will be made in due time of those which have been found in the course of other investigations."

REPORT ON PROGRESS IN NON-EUCLIDEAN GEOMETRY.*

GEORGE BRUCE HALSTED.

"Projective Geometry proper," says Russell, "does not employ the conception of magnitude."

Now it is in metrical properties alone that non-Euclidean and Euclidean spaces differ. The distinction between Euclidean and non-Euclidean geometries so important in metrical investigations, disappears in projective geometry proper. Therefore projective geometry deals with a wider conception, a conception which includes both, and neglects the attributes in which they differ. This conception Mr. Russell calls 'a form of externality.' It follows that the assumptions of projective geometry must be the simplest expression of the indispensable requisites of all geometrical reasoning.

Any two points uniquely determine a line, *the straight*. But any two points and the straight are, in pure projective geometry, utterly indistinguishable from any other point pair and their straight. It is of the essence of *metric* geometry that two points shall completely determine a spatial *quantity*, *the sect* (German strecke). If Mr. Russell had used for this fundamental spatial magnitude this name, or any name but 'distance,' his exposition would have gained wonderfully in clearness. It is a misfortune to use the already overworked and often misused word 'distance'

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* Continued from page 523.

as a confounding and confusing designation for a sect itself and also the measure of that sect, whether by superposition, ordinary ratio, indeterminate as depending on the choice of a unit; or by projective metrics, indeterminate as depending on the fixing of the two points to be taken as constant in the varying cross ratios.

That Mr. Russell's chapter 'A Short History of Metageometry,' contains all the stock errors in particularly irritating form, and some others peculiarly grotesque, I have pointed out in extenso, in *Science*, Vol. VI., pp. 478–491. Nevertheless the book is epoch-making. It finds "that projective geometry, which has no reference to quantity, is necessarily true of any form of externality. In metrical geometry is an empirical element, arising out of the alternatives of Euclidean and non-Euclidean space."

One of the most pleasing aspects of the universal permanent progress in all things non-Euclidean is the making accessible of the original masterpieces.

The marvellous '*Tentamen*' of Bolyai Farkas, as Appendix to which the 'Science Absolute' of Bolyai János appeared, a book so rare that except my own two copies, I know of no copy on the Western Continent, a book which has never been translated, a field which has lain fallow for sixty-five years, is now being re-issued in sumptuous quarto form by the Hungarian Academy of Sciences. The first volume appeared in 1897, edited, with sixty-three pages of notes in Latin, by König and Réthy of Budapest. Professor Réthy, whom I had the pleasure of meeting in Kolozsvár, tells me the second volume is in press, and he is working on it this summer.

Bolyai Farkas is the forerunner of Helmholtz, Riemann, Lie, though one would scarcely expect it from the poetic exaltation with which he begins his great work. "Lectori salutem! Scarce superficially imbued with the rudiments of first principles, of my own accord, without any other end, but led by internal thirst for truth, seeking its very fount, as yet a beardless youth, I laid the foundations of this 'Tentamen.'

"Only fundamental principles is it proposed here so to present, that Tyros, to whom it is not given to cross on light wings the abyss, and, pure spirits, glad of no original, to be borne up in airs scarce respirable, may, proceeding with firmer step, attain to the heights.

"You may have pronounced this a thankless task, since lofty genius, above the windings of the valleys, steps by the Alpine peaks; but truly everywhere are present gordian knots needing swords of giants. Nor for these was this written.

"Forsooth I wish the youth by my example warned, lest having attacked the labor of six thousand years, alone, they wear away life in seeking now what long ago was found. Gratefully learn first what predecessors teach, and after forethought build. Whatever of good comes, is antecedent term of an infinite series."

His analysis of space starts with the principle of continuity: spatium est quantitas, est continuum (p. 442). This Euclid had used unconsciously, or at least without specific mention; Riemann and Helmholtz consciously. Second comes what he calls the *axiom of congruence*, p. 444, § 3, "corpus idem in alio quoque loco videnti, quæstio succurrit: *num loca ejusdem diversa æquaila sint?* Intuitus ostendit, æqualia esse."

Riemann: "Setzt man voraus, dass die Körper unabhängig von Ort existieren, so ist das Krümmungsmass überall constant." See also the second hypothesis of Helmholtz.

Third, any point may be moved into any other; the free mobility of rigid bodies. If any point remains at rest any region in which it is may be moved about it in innumerable ways, and so that any point other than the one at rest may recur. If two points are fixed, motion is still possible in a specific way. Three fixed points not costraight prevent all motion (p. 446, § 5).

Thus we have the third assumption of Helmholtz, combined with his celebrated principle of Monodromy.

Bolyai Farkas deduces from these asumptions not only Euclid but the non-Euclidean systems of his son János, referring to the approximate measurements of astronomy as showing that the parallel postulate is not sufficiently in error to interfere with practice (p. 489). This is just what Riemann and Helmholtz afterward did, only by casting off also the assumption of the infinity of space they got also as a possibility for the universe an elliptic geometry, the existence of a case of which independently of parallels was first proven by Bolyai János when he proved spherics independent of Euclid's assumption. So if Sophus Lie had ever seen the 'Tentamen," he might have called his great investigation the Bolyai-Farkas Space Problem instead of the Riemann-Helmholtz Space Problem.

The first volume of the 'Tentamen' as issued by the Hungarian Academy does not contain the famous appendix. But in 1897, Franz Schmidt, that heroic figure, ever the bridge between János and the world, issued at Budapest, the Latin text of the Science Absolute, with a biography of Bolyai János in Magyar, and a Magyar translation of the text by Suták József.

Strangely enough, though the Appendix had been translated into German, French, Italian, English, and even appeared in Japan, yet no Hungarian rendering had ever appeared. It was Franz Schmidt who placed the monument over the forgotten grave of János, only identified because there still lived a woman who had loved him. Now in this Magyar edition he rears a second monument. The introduction by Suták is particularly able.

The Russians have honored themselves by the great Lobachévski Prize; why does not that glorious race, the Magyars, do tardy justice to their own genius in a great Bolyai Prize?

One other noble thing the Hungarian Academy of Science has just achieved, the publication in splendid quarto form of the correspondence between Gauss and Bolyai Farkas: (Briefwechsel zwischen Carl Friedrich Gauss und Wolfgang Bolyai). It was again Franz Schmidt, who after long endeavors, at last obtained this correspondence from the Royal Society of Sciences at Göttingen, where Bolyai had sent the letters of Gauss at his death. The Correspondence is fitly edited by Schmidt and Staeckel. It gives us a romance of pure science. Gauss was the greater mathematician; Bolyai the nobler soul and truer friend. On April 10, 1816, Bolyai wrote to Gauss giving a detailed account of his son János, then fourteen years old; and unfolding a plan to send János in two years to Göttingen, to study under Gauss. He asks if Gauss will take János into his house, of course for the usual remuneration, and what János shall study meanwhile. Gauss never answered this beautiful and pregnant letter, and never wrote again for sixteen years! Had Gauss answered that letter Göttingen might now perhaps have to boast a greater than Gauss, for in sheer genius, in magnificent nerve, Bolyai János was unsurpassable, as absolute as his science of space. But instead, he joined the Austrian army, and the mighty genius which should have enriched the transactions of the greatest of learned societies with discovery after discovery in accelerating quickness, preyed instead upon itself, printing nothing but a brief two dozen pages.

Almost to accident the world owes the admirable volumes in which Staekel and Engel contribute such priceless treasures to the non-Euclidean geometry. An Italian Jesuit, P. Manganotti, discovered that one of his order, the Italian Jesuit Saccheri, had already in 1733 published a series of theorems which the world had been ascribing to Bolyai. Thereupon, in 1889, E. Beltrami published in the *Atti della reale Accademia dei Lincei*, Serie 4, Vol. V., pp. 441-448, a note entitled 'Un Precursore italiano di Legendre e di Lobatschewski,' giving extracts from Saccheri's book which abundantly proved the claim of Manganotti.

In the same year, 1889, E. d'Ovidio, in the *Torino Atti*, XXIV., pp. 512-513, called attention to this note in another entitled, Cenno sulla Nota del prof. E. Beltrami: "Un Precursore, etc., expressing the wish that P. Manganotti would by a more ample discussion rescue Saccheri's work from unmerited oblivion. Staeckel says the thought then came to him, whether Saccheri's work were not a link in a chain of evolution, the genesis of the non-Euclidean geometry.

In 1893, at the International Mathematical Congress at Chicago, in the discussion which followed my lecture, 'Some Salient Points in the History of Non-Euclidean and Hyper-Spaces,' wherein I gave an account of Saccheri with description of his book and extracts from it, Professor Klein, who had never before heard of Saccheri, and Professor Study, of Marburg, mentioned that there had recently been brought to light an old paper of Lambert's anticipating in points the non-Euclidean geometry, and named in connection therewith Dr. Staeckel. I at once wrote to him and published in the *Bulletin of the New York Math. Soc.*, Vol. III., pp. 79-80, 1893, a note on Lambert's non-Euclidean geometry, mentioning Staeckel's purpose to republish Lambert's paper in the Abhandlungen of the Leipziger Gesellschaft der Wissenschaften. But after this, in January, 1894, Staeckel formed the plan to make of Saccheri and Lambert a book, and associating with him his friend Friedrich Engel, they gave the world in 1895, 'Die Theorie der Parallelinien, eine Urkundensammlung zur Vorgeschichte der nichteuklidischen Geometric.' Strengthened by the universal success of this book, they planned two volumes in continuation. Staeckel takes the volume devoted to Bolyai János and his father. It is to begin with a more complete life of the two than has yet appeared, of course, from material furnished largely by Franz Schmidt.

Then follows the 'Theoria parallelarum' of Bolyai Farkas. interesting as proving that in 1804 Gauss was still under the spell of Euclid.

Then is to follow the Latin text of the immortal Appendix with a German translation. Next comes in German translation selections from the 'Tentamen.' The book concludes with the geometric part of 'Kurzer Grundriss,' the only one of the Bolyai's works printed originally in German. This volume is nearly published and may be expected in a few weeks. The volume undertaken by Engel has just appeared (1899). It is a German translation of Lobachévski's first published paper (1829), 'On the Principles of Geometry,' and also of his greatest work, 'New Elements of Geometry, with Complete Theory of Parallels.' Only from the 'New Elements' can any adequate idea be obtained of the height, the breadth, the depth of a Lobachévski's achievement in the new universe of his own creation.

Of equal importance is the fact that Engel's book gives to the world at last a complete, available text-book of non-Euclidean geometry. There is no other to compare with it.

For the history of non-Euclidean geometry we have the admirable Chapter X., of Loria's pregnant work, 'Il passato ed il presente delle principali teorie geometriche.' This chapter cites about 80 authors, mostly of writings devoted to non-Euclidean geometry.

In my own 'Bibliography of hyper-space and non-Euclidean geometry,' in the *American Journal of Mathematics* (1878), I gave 81 authors and 174 titles. This, when reprinted in the Collected Works of Lobachévski (Kazan, 1886), gives 124 authors and 272 titles.

Roberto Bonola has just given in the *Bolettino di Bliografia e Storia della Scienze Matematiche* (1899), an exceedingly rich and valuable 'Bibliografia sui Fondamenti della Geometria in relazione alla Geometria Non-Euclidea,' in which he gives 353 titles.

This extraordinary output of human thought has henceforth to be reckoned with. Hereafter no one may neglect it who attempts to treat of fundamentals in geometry or philosophy.

AUSTIN, Texas, Aug. 14, 1899.

OBSERVATIONS OF THE BIELIDS OF 1899.

COMMUNICATED BY G. W. MYERS.

FOR POPULAR ASTRONOMY.

Arrangements had been made at this Observatory to observe the Andromid meteors from the 22d to the 27th of Nov., but a densely clouded sky interfered with the work until shortly after seven o'clock on the evening of the 24th, when the clouds broke and cleared away entirely in the course of half an hour. Observation was then begun by the writer, assisted during a part of the evening by two of the students in astronomy, and the following data were obtained. (The times are on the 90th standard meridian; Longitude 5^h 52^m 55^s.)

Time of Count {Begin End	No. of Andromids.	Number per Hour.	Remarks.
8 09 23	22	110	Sky clear. 6th magn. stars visible.
8 23 38	14	56	Sky clear.
8 38 52	12	52	Getting cloudy in the north at $8^{h}\ 50^{m}$
8 52 9 07	08	32	Sky hazy and partly cloudy.
9 07 22	08	32	Sky more than half cloudy.
9 36 10 21	28	37	Quite cloudy $9^{h}\ 35^{m}$–50^{m}. Fairly clear $9^{h}\ 50^{m}$–$10^{h}\ 10^{m}$. Only stars of first three magnitudes visible at $10^{h}\ 10^{m}$–20^{m}. Clouds becoming denser, watch was discontinued.
11 06 41	24	41	Sky clear, seeing fine.

In addition to these results may be mentioned a count of about ten minutes duration (as well as could be estimated), shortly before eight o'clock, which gave twenty meteors.

The third column of the above table shows that, in the part of the swarm encountered by the Earth between half past seven o'clock and midnight, the density decreases quite markedly. The ratio of frequency from the first and second counts or from the first and third, is nearly as two to one, while comparison of the first and last makes the ratio about three to one. It is to be noted that these four counts were made with a clear sky and good seeing in each case. The clouds rising in the north at 8^{h} 50^{m} did not interfere with the third count.

An approximate location of the radiant, from 5 carefully charted trails, gave its position at a point about 2° from γ Androm. on a line toward α Cassiop. This is for the centre of what seemed to be a diffuse area.

The magnitudes and colors of individual meteors all of which are Andromids are given in the following summary:

Magnitude—	—3	—2	—1	0	1	2	3	4	5	6
Number of Meteors—	1	1	0	2	3	14	36	33	18	10
Color—	White		Yellow		Blue					
Number of Meteors—	48		45		10					

The small number of faint meteors seen is undoubtedly due to the fact that the sky was hazy or partly cloudy during more than half the time of observation.

NOTE.—A remarkable meteor, which swept entirely across the sky, was seen at $8^{h}\ 30^{m}\ 50^{s}$, 90th meridian time. It started from a point in Gemini, nearly due east and about 20° above the horizon, and, following approximately the ecliptic, disappeared when at an altitude of 20° and 10° south of west. The meteor moved quite deliberately, leaving a broad, vividly blue trail, persisting about five seconds. The head was yellow, of a magnitude estimated at about — 4, and seemed to pass quite close to the observer, so that sparks could be seen streaming back from it.

The meteor was undoubtedly a Leonid, since it came directly from that point in the horizon where Leo was about to rise.

W. C. BRENKE.

UNIVERSITY OF ILLINOIS,
Dec. 13, 1899.

THE FAILURE OF THE LEONIDS IN 1899.

W. W. PAYNE.

In the December number of the Observatory (English), page 433, a brief account appears, giving some reasons why the great shower of the Leonids which had been quite generally and confidently expected was believed to be less certain than supposed as the time of the display drew near. From this article it is learned that Dr. Johnstone Stoney as early as November 10 gave before the Royal Astronomical Society the result of further researches which made the prediction of the time for the shower less certain than the conclusions he had reached and published some seven or eight months before, in which he claimed that the shower would probably take place November 15 18^h. On Nov. 14, Dr. Stoney published a letter in the "London Times" which gave some of the reasons for a less degree of certainty in regard to the time of prediction. In as much as Dr. Stoney and Mr. Downing were largely responsible for the predictions that appeared early in the year, the letter referred to above is important, and the abstract of it which appeared in the *Observatory* is given below:

" During the great shower of 1866, the position of the point of the heavens from which the meteors appeared to diverge was very carefully observed, and this determination, combined with what Professor Newton had brought to light, enabled the late Professor J. C. Adams to make one of the most brilliant astronomical discoveries of the present century—viz., the discovery of the actual orbit within the solar system which was being traversed by the meteors which are situated in the neighborhood of that part of the stream through which the Earth passed in 1866.

"The actual shift of the node—that is, the amount by which the meteoric orbit has moved sideways along the Earth's orbit—has had considerably more than three times its average amount in consequence of the intense perturbation to which the meteors have been subjected within the last 33 years; and this is not the only respect in which Adam's orbit has been removed from the position in which he found it in 1866. This meteoric orbit then intersected the Earth's orbit. It has since been forced away from the Earth's orbit by the disturbing action of the planets, chiefly of the great planets Jupiter and Saturn. In the position which it now occupies the Earth will pass closest to it upon next Thursday morning, at about 6 o'clock A. M.; and Adams' meteoric orbit will then be as much as 1,300,000 miles distant from the Earth's orbit, that is more than five times further off than the Moon.

"This would be quite enough to carry the stream of meteors quite clear of the Earth if that stream were a mere cylindrical stream like a thread traveling lengthwise through space. But the investigations which we have had to make have brought to light the important fact that the stream where it pierces the plane of the Earth's orbit is not like a thread but more like a long piece of strap or tape traveling forwards in the direction of its length—in other words, the stream is very much wider than it is thick. Its thickness is known, from the duration of the meteoric showers, to be about 100,000 miles; but all that is known of its width is that it is much more. We shall probably not be far wrong if we estimate it as being three or four millions of miles. This very wide and comparatively thin stream of meteors passes obliquely through the plane of the Earth's orbit, and the part of the plane through which it passes has obviously the shape of a long oval or rectangle. We know where one point in this oval is at present—namely the point spoken of above where Adams' orbit pierces the plane of the Earth's orbit—a point which, as we have seen, will be 1,300,000 miles nearer to the Sun than the position which the Earth will reach at 6 A. M. on next Thursday morning. Unfortunately we do not know the length of the longer axis of the oval section, nor its position, further than that its direction originally, that is, 17 centuries ago, lay perpendicular to the Earth's orbit, and that it has since been very slowly shifted by perturbations into a position which slopes towards a part of the Earth's orbit which the Earth will reach sooner than 6 o'clock A. M. on Thursday morning. When the shower of this year takes place, if there is one of the great showers this year, we shall know from the time of its occurrence how much the oval section has turned out of its original position. Meanwhile we can only say that the shower is to be expected before 6 A. M. on Thursday, probably some hours earlier, and possibly, but not probably, so much earlier that the beginning of the shower may be seen from our side of the Earth before dawn on Wednesday morning, It is, however, more likely to come during the daytime or evening of Wednesday, in which case it will not be seen in England, or after 10:30 P M. on Wednesday evening, in which case it will be visible if the weather permit."

In the last issue of this journal we gave a number of reports of observers who watched the November Leonids, with charts showing the work done. We now give considerable more space to the continuance of these reports.

LEONIDS AT NORTHFIELD, MINN.

The Astronomy class at Carleton College, Northfield, Minn., consisting of twenty members, participated in the observations of the Leonid meteors Nov. 15, 17^h to 22^h 1899, Greenwich M. T. The following table gives the times and brightness of individual meteors as observed by students.

No.	G. M. T.		Mag.	No.	G M. T.		Mag.	No.	G. M. T.		Mag.
	h	m			h	m			h	m	
1	16	59	3	10	19	38	4	19	20	39	2
2	18	27	1	11	19	46	3	20	21	18	1
3	18	33	1	12	19	47	2	21	21	20	1
4	19	17	3	13	20	7	1	22	21	19	1
5	19	17	2	14	20	8	1	23	21	25	3
6	19	26	4	15	20	9	2	24	21	30	2
7	19	27	4	16	20	9	2	25	21	51	2
8	19	29	3	17	20	9	2	26	22	30	2
9	19	29	1	18	20	21	2				

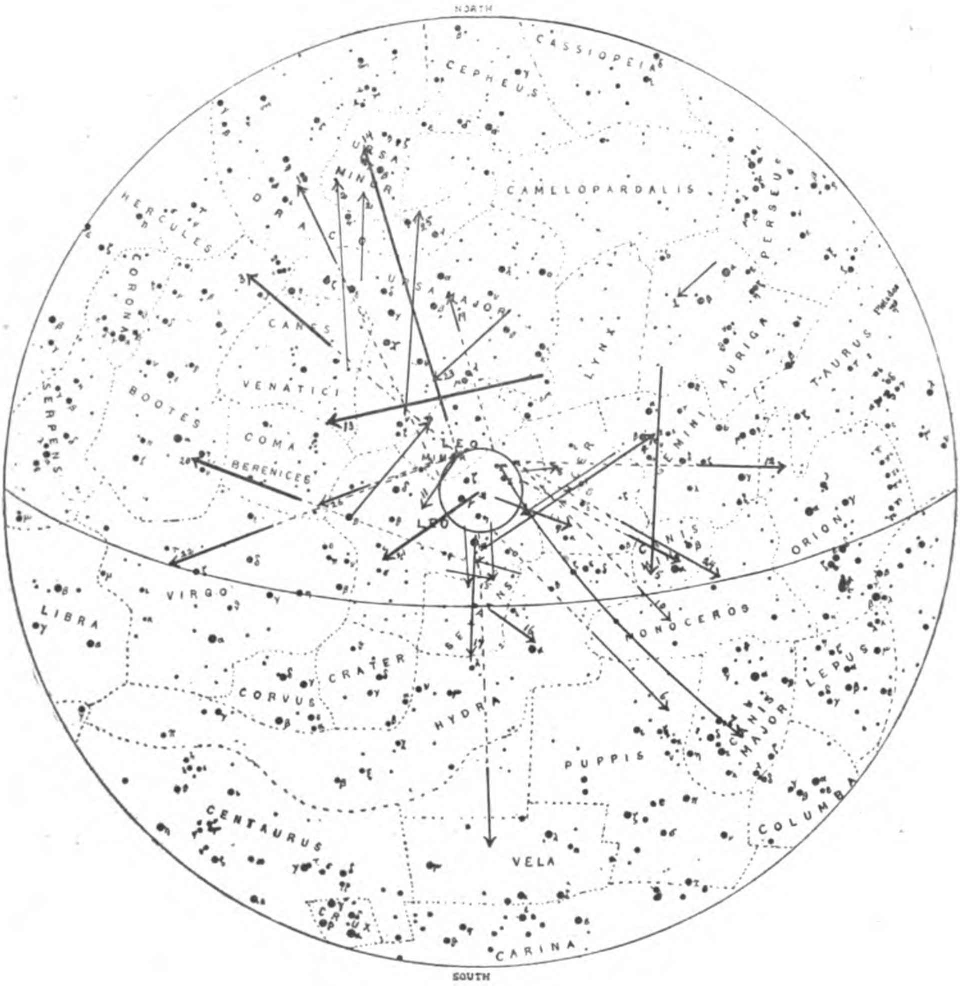
At no time was the sky entirely clear during the night watch. It was partly clouded or covered with haze so that it was difficult to see any meteors except for the brief time they were brightest. All trails were therefore short and correspondingly uncertain in direction. If we add to this the strong moonlight, it is at once evident how unsatisfactory the observations were.

LEONIDS AT BARRE CENTER, N. Y.

On the morning of the 14th the heavens were cloudy, but on the morning of the 15th in a clear sky from 1 A. M. to 4 A. M. I charted nineteen meteors, the most of which could be traced from the Sickle in Leo, their flight was generally very rapid, with exception of two, which first appeared very near Gamma Leonis both were very bright with short trails and one of these showed a very perceptible curve. In no case could any be said to exceed the second magnitude. At 1:30 A. M. a very large meteor far exceeding the brilliancy of Venus at her greatest with a heavy luminous train at a slow rate of motion was seen to emerge from Ursa Major and travel eastward disappearing low in the horizon. I again on the 16th and 17th at midnight resumed my watching till about four o'clock in the morning, but in neither case was a single meteor seen. I prepared to photograph the radiant with a wide angle lens and 5 x 7 plate with camera attached to my 8½ inch Brashear reflector but as no meteors were seen I abandoned the work. I enclose the chart of meteors as seen.

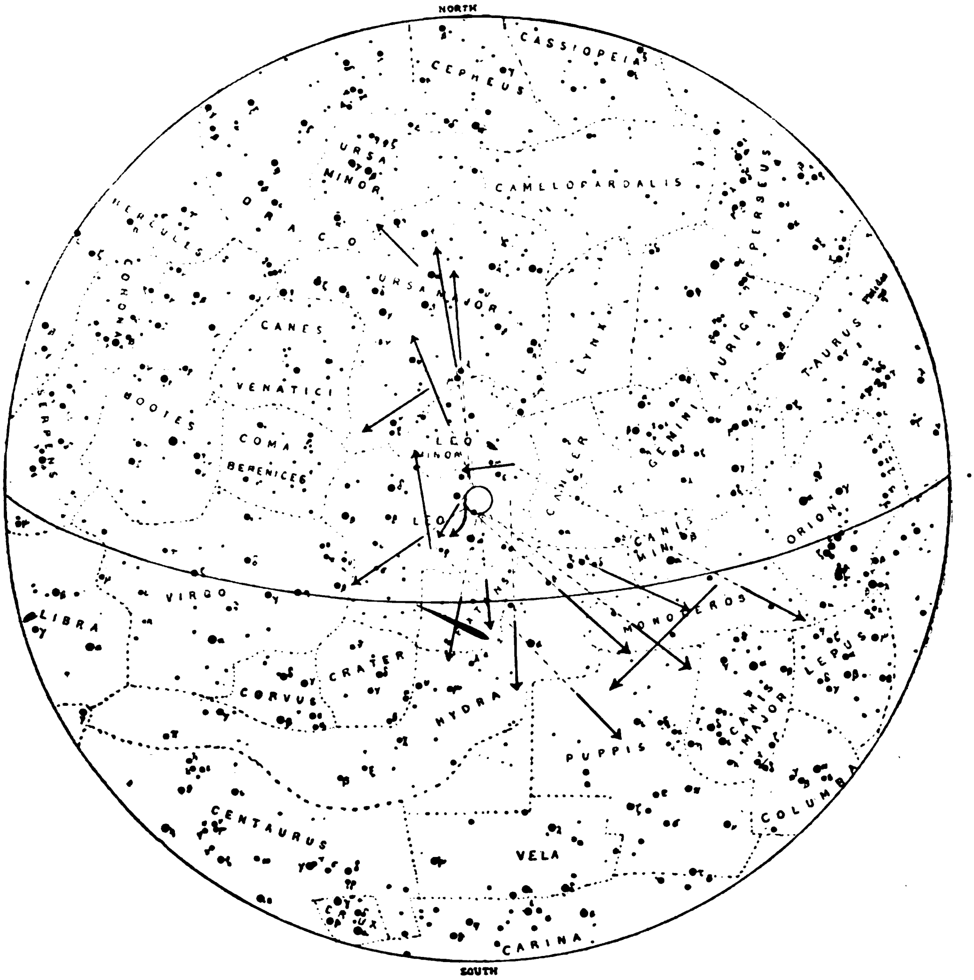
WESTON WETHERBEE.

BARRE CENTER, N. Y. NOV. 19, 1899.



METEORS CHARTED DURING THE LEONID SHOWER.

Nov. 15, 1899, 17^h—22^h Greenwich M. T., by students at Goodsell Observatory, Carleton College, Northfield, Minn.



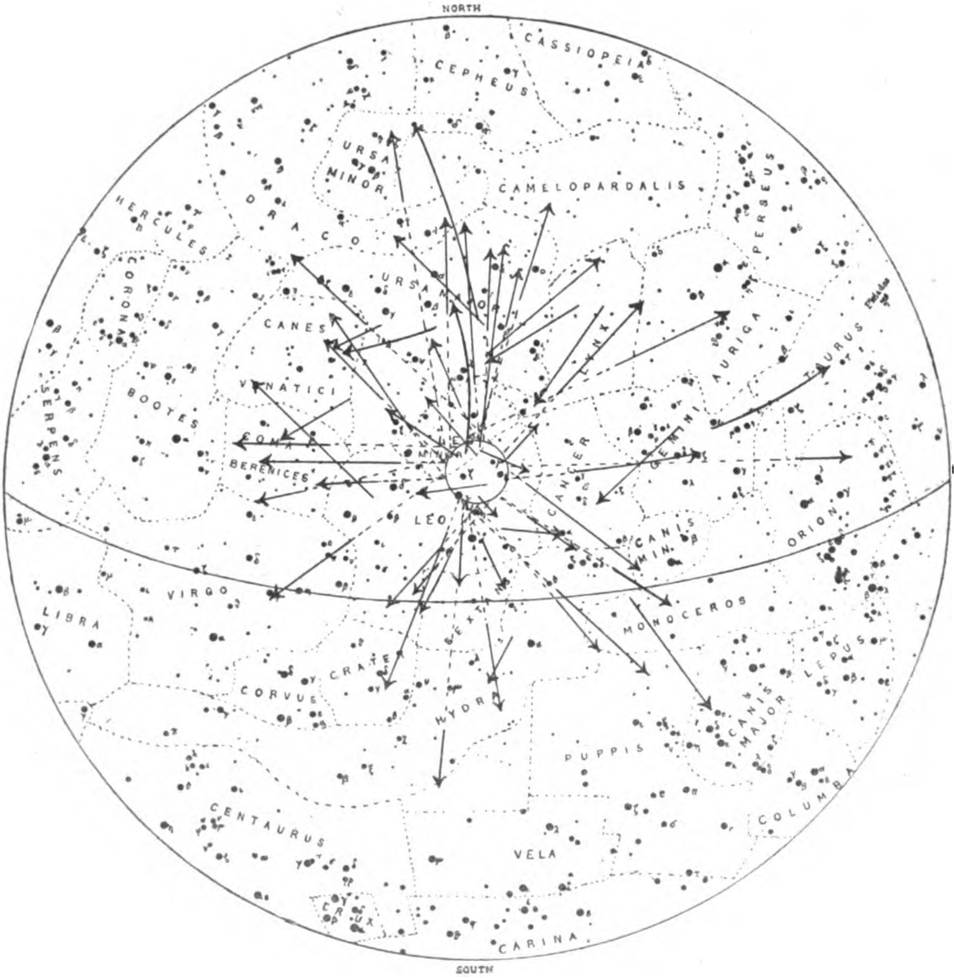
METEORS CHARTED DURING THE LEONID SHOWER.

Nov. 14, 1899, 18^h—22^h Greenwich M. T., by Mr. Weston Wetherbee at Barre Center, N. Y.

LEONIDS AT CRETE, NEB.

Observations of the Leonid meteors were made successfully from this place on the nights of Tuesday, Nov. 14, and Thursday, Nov. 16. On Monday and Wednesday nights it was cloudy as was also the case for about three hours after midnight of Thursday. No careful work was done on Friday night but a few Leonids were reported as seen by casual observers.

A considerable number of the students of Doane College volunteered their assistance for the work and the corps of observers were given detailed instruction in advance in order to secure as satisfactory results as possible. In general the suggestion of Professor Wm. H. Pickering as given in the September and October



METEORS CHARTED DURING THE LEONID SHOWER.

Nov. 14. $18^h 30^m$–24^h Greenwich M. T., by Professor Henry H. Hosford and students at Boswell Observatory, Doane College, Crete, Neb.

number of POPULAR ASTRONOMY were followed. It was arranged that the observers should work in sets of three. In each set one person was to keep an accurate count of all meteors seen, recording the number for each quarter hour; the second observer was to plat on the chart all meteors whose paths were accurately determined, recording the exact time when each was seen and other matters of interest; the third person was to act as time-keeper, comparing his watch each hour with the Observatory clock.

On Tuesday night for about two hours after midnight the sky was partially covered with light, filmy clouds which doubtless prevented the observers from seeing many of the less bright meteors. As the sky became clear the number of meteors seen was much greater. The increase was especially noticeable as the Moon sank toward the western horizon and was obscured by clouds. The total number of meteors counted on Tuesday night was 198, of which 53 were platted as shown on the accompanying chart. Many are noted as showing trains persisting for a few seconds and seven were thought to follow a slightly curved path. In no case was a meteor seen to explode, to change its course abruptly or to leave a train persisting for more than a few seconds. The chart shows six meteors which were quite certainly not Leonids and as many more are doubtful.

Several photographs were taken Tuesday night by a camera mounted on the equatorial telescope but no meteor trails were shown on the plates.

The total number of meteors counted on Thursday night, Nov. 16, between 15^h and $18^h\ 30^m$ was 30. Two of these were not Leonids. Details of the count are given in the following table:

Date.	No.	State of Sky.	Date.	No.	State of Sky.
Nov. 14.			Nov. 14.		
12:30-12:45	0	Hazy. Moon shining.	17:30-17:45	26	Clear.
12:45-13:00	3	"	17:45-18:00	19	"
13:00-13:15	1	"	Nov. 16.		
13:15-13:30	1	"	15:05-15:15	0	½ Cloudy. Moonlight
13:30-13:45	2	"	15:15-15:30	1	"
13:45-14:00	7	Cloudy.	15:30-15:45	1	Clearing.
14:00-14:15	6	Light haze.	15:45-16:00	1	"
14:15-14:30	9	Clear.	16:00-16:15	3	Clear.
14:30-14:45	6	"	16:15-16:30	1	"
14:45-15:00	8	"	16:30-16:45	2	"
15:00-15:15	8	"	16:45-17:00	3	"
15:15-15:30	9	"	17:00-17:15	5	"
15:30-15:45	8	"	17:15-17:30	4	"
15:45-16:00	6	"	17:30-17:45	5	"
16:00-16:15	7	"	17:45-18:00	3	"
16:15-16:30	6	"	18:00-18:15	0	"
16:30-16:45	9	"	18:15-18:30	1	"
16:45-17:00	10	" Moon setting			
17:00-17:15	21	" and clouds			
17:15-17:30	26	" in west.			

HENRY H. HOSFORD.

BOSWELL OBSERVATORY, Doane College, Crete, Nebraska.

LEONIDS AT UNIVERSITY PARK, COLORADO.

The following observations of the meteoric shower were made by the writer, except on the night of Nov. 15-16, when they were made by a corps of volunteer observers. Mountain Time was used as the standard:

Nov. 13: 12:30-13:00; no Leonids; clear.
13:30-14:00; no Leonids; clear.
14:30-15:00; one Leonid; clear.
15:30-16:00; eight Leonids; Moon has set; clear. One of the sixth magnitude glanced.
16:30-17:05; four Leonids; one faint one glanced; clear.

The average brightness was equivalent to that of a star of mag. 3 or 4.

Nov. 14: 17:00-17:35; eleven Leonids; hazy, but stars of mag. 5 were visible. Three or four were brighter than mag. 1, and no one was as faint as mag. 5. The average magnitude was 3.

17:35–18:00; four Leonids; low lying haze spread rapidly toward the zenith, and during the last five or ten minutes the stars in the Sickle were barely visible. One meteor, brighter than mag. 1, dashed across the western sky at a Leonid's pace, but its trail, which lasted perhaps two seconds, passed about five degrees above the Sickle, and it was not counted as a Leonid. The sky was cloudy before 17:00; after that there was no Moon.

Nov. 15: see below.

Nov. 16: 13:00–13:15; no Leonids; hazy so that nothing fainter than mag. 3 was visible.

13:30–13:45: no Leonids; somewhat clearer.

14:00–14:15; no Leonids; only the brightest stars visible. After this it became cloudier and observations were useless.

Nov. 17: 14:15–14:30; no Leonids; observed through a large rift in the clouds.

14:45–15:00; 1 Leonid; an area as large as I could survey was clear.

15:00–16:15; cloudy.

16:15–16:30; no Leonid; large clear area of sky.

16:45–17:00; no Leonid; sky perfectly clear in the vicinity of Leo.

17:15–17:30; no Leonid; sky cloudless.

17:45–18:00; one Leonid; sky cloudless, but light because of approaching dawn.

Nov. 16. The observers were mostly in pairs, one person observing for fifteen minutes while the others rested; the two thus kept a continuous watch upon some part of the sky. Each pair was instructed to face N., or N. E., or E., etc., and to watch a point at an altitude of 45° noting every Leonid seen, and rejecting others. The zenith was also watched by observers recumbent on a mattress. Professor E. B. T. Spencer was in charge of those counting: he rang a bell at each quarter hour, having given a warning signal two minutes previously. Below is a very condensed summary.

Mary C. Traylor and Grace M. Sater faced north and counted five between 13:00 and 15:00. Clouds then intervened. Between 15:00 and 16:15 Miss Traylor faced east and counted four.

Myron A. Pattison and Guy W. McCreery faced east and counted forty-four between 13:00 and 16:45.

Edward Stauffer and Chas. F. Seitter faced north-east and counted fifteen between 13:00 and 15:15. Clouds then came. Between 16:00 and 16:15 Mr. Stauffer counted one.

Fred Winship and Loyd Winship faced the zenith and counted three between 13:00 and 14:30. From 14:30 to 17:00 the zenith was mostly cloudly but seven were counted.

Fred Stover and Earl K. Terry faced south-east and counted sixty-four between 12:45 and 18:30, none being seen during the last fifteen minutes.

Earle Blakeslee and Wayne Blanks watched the zenith between 13:00 and 14:45 and counted six.

Bertha Brooks and Elise C. Jones faced east and counted fourteen between 13:00 and 17:00.

Daniel N Jones and Ervin N. Edgerton watched the area bounded by lines joining Rigel, Betelgeuse, Sirius and Procyon from 13:00 to 14:45 and saw two within the area.

Mr. McReynolds faced south and counted three between 14:00 and 14:15. Between 14:30 and 14:45 he saw one.

CHART OF LEONIDS DRAWN BY JAS. B. WESTHAVER.

Hazel B. Bush noted the exact times of appearance of ten of the brightest, with a stop watch.

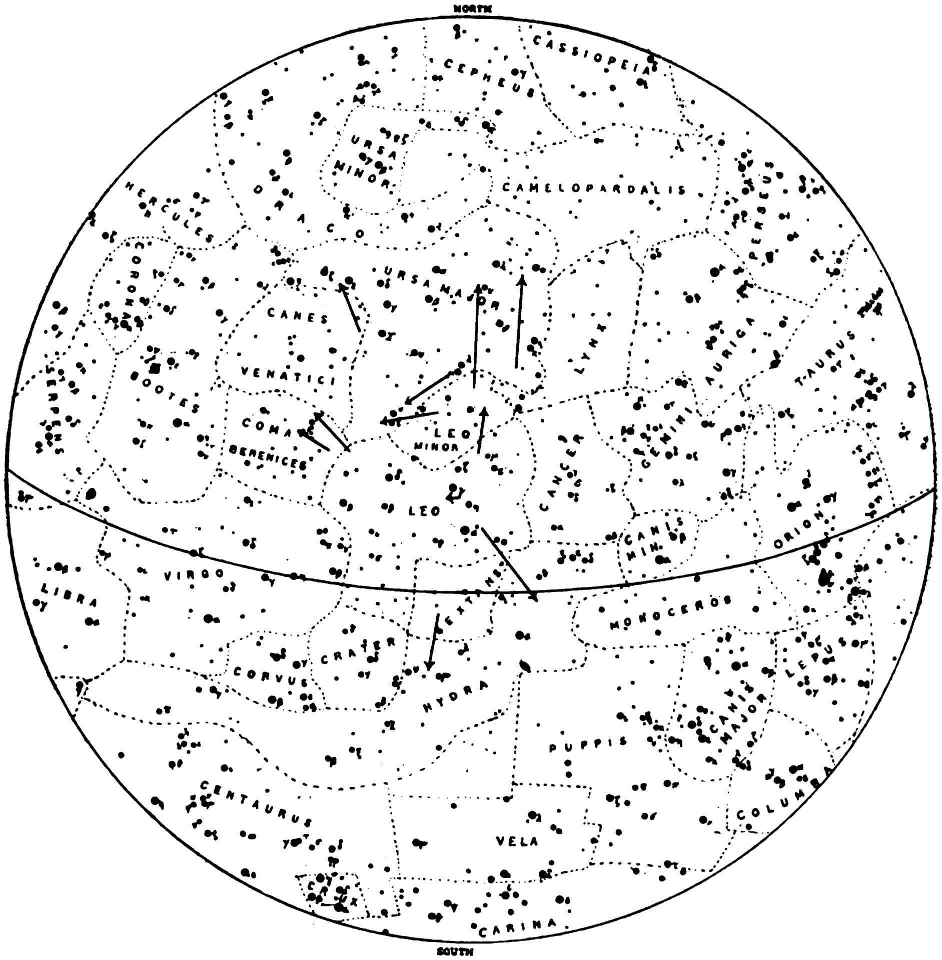
Frank Hiller faced north and saw two between 13:00 and 14:15.

Leonora Colmer faced south-east and observed steadily from 13:30 to 16:45 excepting next to the last quarter hour; she counted thirty-three.

The radiant-point was located by a drawing by James B. Westhaver.

A study of the results shows (1) that the south-east was the most favorable direction to face. (2) that few Leonids were seen before 14^h, on any night; (3) that between 14^h and 17^h on the night of Nov. 15-16 about the same number were visible in each quarter hour, (4) that the average magnitude was about 3.5, (5) that the absence of the Moon did not materially increase the number seen, and (6) that the best time was probably not later than that predicted by Stoney and Downing, and may have been earlier. After making allowance for probable duplicates the number seen at University Park is 180, 150 of which came on the morning of Nov. 16. For about a week prior to Nov. 13 the number of telescopic meteors seen while observing nebulae with the 20-inch refractor was about three every four hours, the field of view being 15′ in diameter. This is judged to be at least three times the ordinary frequency of such objects. But there was no evidence from their direction that they were Leonids. Has any one ever studied these telescopic objects, in order to see whether they are the residue of naked-eye meteors, or distinct minute bodies? HERBERT A. HOWE.

CHAMBERLIN OBSERVATORY, UNIVERSITY PARK, Col.



THE LEONIDS OBSERVED AT THE ROYAL OBSERVATORY IN LISBON, PORTUGAL, Nov. 12-17, Local M. T.

OBSERVATIONS AT LISBON, PORTUGAL.

Name of observers; CR = Campus Rodrigues; O = F. Oom. Post office address: Royal Observatory, Tapada, Lisbon, Portugal. Latitude = + 38° 42′.5; Longitude = 36^m 45^s W. Gr.; Time: Local mean.

Frequency of Meteors.

Date. Observer	R.	Sky.	Began.	Ended.	No.
			h m	h m	
Nov. 12					
O.	S	Clear.	12 0	13 0	0
"	"	"	13 0	14 0	0
"	"	"	14 0	15 0	0
Nov. 13					
O.	"	Cloudy.	12 25	13 0	0
"	"	Overcoat.	13 0	13 30	—
"	"	Cloudy	14 0	14 30	0
"	"	Partly cloudy.	15 0	15 15	0
"	"	" "	16 0	16 30	0
"	"	Cloudy.	17 0	17 30	0
Nov. 14					
O.	"	Cloudy.	12 0	12 30	0
"	"	"	12 30	13 0	2
"	"	"	13 15	13 30	0
"	"	"	14 0	14 30	0
"	"	"	15 0	16 0	1
"	"	Clear.	16 0	16 25	3
"	"	Overcast.	16 30	17 0	—
"	"	Clear.	17 0	18 0	4
Nov. 15					
O.	"	Cloudy.	11 0	12 0	0
"	"	Overcast.	10 0	14 0	—
"	"	Cloudy.	14 0	15 0	0
"	"	Cloudy, hazy.	15 0	16 0	0
CR.	"	Overcast.	16 0	16 30	—
"	"	Cloudy.	17 10	17 30	8
"	"	"	17 30	17 50	1
"	"	"	17 50	18 10	1
"	"	"	18 10	18 25	1
Nov. 16					
O.	"	Overcast.	11 0	12 0	—
"	"	Cloudy.	12 0	13 0	0
"	"	Overcast.	13 0	15 0	—
CR.	"	"	16 0	19 0	—
Nov. 17					
O.	"	Clear.	12 0	13 0	0*
"	"	"	13 15	13 45	0
"	"	"	14 20	14 50	1
"	"	"	15 0	16 0	0
CR.	"	"	16 0	16 30	3
"	"	"	16 30	17 0	0
"	"	"	17 0	17 30	1
"	"	"	17 30	18 0	2

Individual Meteors.

Date. Observer	Time.	Class.	Mag.	Col.	Remarks.
	h m				
Nov. 14					
O.	12 49	1	1	w?	Trail.
"	12 56	1	1	"	Trail.
"	16 0	1	3	"	
"	16 20	n	4	"	
"	16 23	1	2	"	
"	17 30	1	3	"	
"	17 32	1	2	"	
"	17 34	1	3	"	Trail.
"	17 37	1	2	"	Trail.
Nov. 17					
O.	12 37	n	1	"	
"	14 35	1	—1	"	

*** One meteor *not* Leonid : See Individual Meteors, Nov. 17, 12*h* 37*m*.**

C. A. DE CAMPOS RODRIGUES, Director.

LISBON, TAPADA, Royal Observatory,
1899, November 25.

THE MAKING OF PHOTOGRAPHY.*

CHARLES F. HIMES PH. D., LL. D.

This hasty resumé of some of the leading facts in the growth of a branch of science, the history of which practically begins with that of the Institute, to which the occasion more naturally invited than to a display of its achievements, would find its highest justification in the enumeration of its applications. But a very few must suffice. In scientific investigation the eye has been replaced in so many cases by the camera, for observation as well as record, that we begin to inquire what is left for visual observation. This is not for the relief of the eye, but because the photographic plate has so much wider range in time and space. It is capable of observing the instantaneous, and yet of looking without wearying, but with cumulative effect by the hour to catch phenomena to which the eye, with its best aids, is hopelessly blind. It has even been said by an eminent astronomer, that it has added to observing power as much as the invention of the telescope. It has, in fact, revolutionized astronomy. Beginning with the Moon, with which perhaps least has been accomplished, total eclipses of the Sun have yielded up long desired information, otherwise unattainable, so that they, by comparison, approach the character of worked-out fields. Automatic daily observations of the solar surface, with the details of its spots, promise data for determining effects upon terrestrial climate. Nebulæ have been discovered, their form, details and conditions revealed, and fainter extensions, vaster than could be conceived, added. Comets have exhibited wonderful transformations, distortions and internal movements utterly undiscoverable by the best telescopes alone. Asteroids so numerous leave the record of their existence in trails upon the plates that, as has been said by Professor Barnard, they are turned adrift again unless they show some striking peculiarity of orbit. Meteors record their paths on which rests the expectation of precise determination of the radiant. Combined with the spectroscope, binaries of shortest periods are detected, variable stars not only discovered, but classified. The surmises of mathematicians in regard to Saturn's rings are confirmed. Runaway stars are caught. The Parisian astronomer that could

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* Extract from an address. Oct. 2, 1899, on the 75th anniversary of the Franklin Institute, Philadelphia, Pa.

not catch the satellite of Neptune with his telescope, could see it fixed on his photographic plate.

Photography and microscope, too, have gone hand-in hand with a more intimate sympathy even than that between the camera and telescope. Among the earliest amateurs of highest character was a large percentage of experts with the microscope. It was in the decade following the founding of the Institute that the microscope began to assume something of its present character as an instrument of delicacy and precision. In 1831, the factory of Ross was established, and under the stimulus and coöperation of such men as Herschel, Airy, Powell, and more especially Lister, improvements in the optics and mechanics of the microscope were rapidly made, so that at the discovery of photography, microscopy had an entirely modern aspect, and it recognized at once a new ally. Dr. Draper immediately took microdaguerreotypes. From this time the improvements in optical appliances urgently demanded by the microscopist were ably seconded by the photographer, and both combined were largely instrumental in occasioning the marked progress in practical optics, which, in turn, reacted to advance photography and microscopy. Even in the days of slow wetcollodion good work was done with the microscope, and even stereo-photo-micrographs were taken by Professor Rood. The rapid dry-plate, sensitive to all or any desired colors, has nowhere contributed more to the advance of photographic practice than with the microscope. It has become to it only less the observing and recording eye than to the telescope. The intimate connection between the microscope and the camera is also well exemplified in the Institute, where the gifted Zentmayer gave the world its best model for the microscope, and the lens which bore his name long filled a place entirely its own in photography, and when the Government placed the administration of the total eclipse expedition of 1869 in the hands of Professor Morton, then Secretary of the Institute, it was unnecessary to seek further for the complete solution of the then new practical optical questions involved in such an enterprise.

In chemistry, Dr. Crookes, by aid of photo-spectroscopy and orthochromatic plates, has added the metal monium to the list, with its characteristic lines far out in the ultra invisible light, in the phosphorescent glow of yttria under molecular bombardment in vacuo. Meteorological science is enriched by photography. It is pertinent to mention the interesting contributions of W. N. Jennings, of the Institute, to the study of lightning dis-charges, and the work of C. Francis Jenkins in the conversion of a scientific toy into the phantascope, which has found its extension in the kinetoscope, and which earned for him the Cresson medal of the Institute. The kinetoscope, with its miles of photographic films, as exhibited first by our H. R. Heyl, has found applications unanticipated in recording the movements during a solar eclipse and of growing plants, and has gone to the front with the army in Africa. In the industries the applications of photography are of infinite variety in character and importance. It is proposed to furnish cards for the Jacquard loom, and thus make tapestries commonplace. It will furnish water-marks for paper capable of 100,000 impressions. It reproduced the Encyclopædia Britannica at one-third the cost of type. It preserved the valuable MS. copy of Century Dictionary, which was practically uninsurable, in miniature form against loss by fire. It may, in the future, in the same way, find a place to economize shelf-room in our libraries by compressing books that are seldom or never read. Its applications are well known in the copying of inscriptions, even in dark interiors, in the preservation and duplication of valuable documents and papers, in the detection of forgeries, especially by the method of composite photography as developed by Dr. Persifor Frazer, in the furnishing of legal evidence in general, in the detection of criminals, etc. In Canada, 50,000 square miles have been platted by means of the photo-theodolite. In the late war the camera went to the front, and has furnished invaluable records. Apropos of this, it is only necessary to recall Capt. Wise making exposures while charging up San Juan Hill. In the present African war it promises to play an important part in reconnoissance through the telephoto apparatus that accompanies the British forces.

In its purely commercial aspects this subject is one of growing importance. The demands, at present great, are rapidly increasing with new applications and expansion of those now in use. Outside of the industries consuming photographic goods there are at least 1,500,000 amateurs in the United States, generally regarded as gross consumers. The industries supplying photographic wants are necessarily of the most varied character. Companies supplying them are continually increasing their plants. It is difficult to get at the amount of business and profits, but the published statement of one company originating in America, now in England and America, announced a dividend of 20 per cent. in December last, with repeated interim dividends, on a capital of $8,000,000. Other companies show similar prosperity. One article, largely consumed, may be particularly mentioned, which America does not seem able yet to produce of best quality, namely, paper, and it is well for manufacturers to remember that in photography only the best of everything is good enough.—*Journal of the Franklin Institute*, December, 1899.

THE STUDY OF ASTRONOMY.

W. W. PAYNE.

Some time ago we were interested in finding out how generally the elements of astronomy was regularly pursued in the colleges and secondary schools of the United States. The result of a limited inquiry was, that in the colleges the study of astronomy appears very commonly in some courses and good modern textbooks have been adopted very generally. From all that could be learned, however, in regard to the way the study was taught in some colleges, there seemed to be room for improvement.

In the secondary schools the results obtained were astonishing beyond measure. We are not now prepared to make a statistical statement to support the impression on our mind made by it, but it may at present suffice to say that about one-fourth of the high schools in the United States have the study of the elements of astronomy at all in the regular courses of study now pursued. We think this statement will be borne out by a full and complete canvass of such schools in this country.

Some years ago, it was our privilege, by request of Dr. Harper, President of the University of Chicago, to sit with the committee of ten to consider and report on what requirements should be generally adopted as suitable for entrance to college in the branches of physics and astronomy. The committee of ten was made up of representative scholars and teachers of science (if the writer's name be not thought of now) from widely different parts of the United States. In the deliberations of that committee it was very soon apparent that but two members of it had any interest at all in the study of astronomy as a means of preparation to enter college and but for those two persons, it was more than probable that it would have been reported by that committee that the elements of astronomy should not be one of the requirements to enter college in any of its regular courses.

These things are mentioned that it may be known more generally what is a prevailing opinion among representative school men of the worth of this branch of study to find a place in the secondary courses of training. It is a very pertinent question for any educator to ask why this is so. These same committee men referred to above were enthusiastically interested in the study of physics and methods of teaching it in the laboratory, and they were unitedly urgent that more time should be given to this branch, even a whole year in the ordinary high school course. This condition of things could be explained by the facts that these men were teachers of elementary physics and that they had little, if anything, in later years, to do with the branch of astronomy. They did not seem to be informed in regard to the later and the better methods of teaching astronomy in secondary schools and in colleges.

In view of these facts and others like them that might be named, it is important that something should be done to put the study of the elements of astronomy in these grades of instruction on the right basis. No one says that astronomy is not one of the best and the noblest of the sciences. All believe that it should have prominent place in every college curriculum. But where it shall find place, how much time shall be given to it, and when it shall be taught are the minor points which each institution can settle for itself. But the method by which it shall be taught is common ground for all and much careful attention should be given to this side of the matter, and what we have further to say will bear on this point.

1. What ought to be done and what can be done to give elementary astronomy its proper place in courses of study for secondary schools? It is first necessary to bring to the attention of leading teachers and prominent school officers the value and place of astronomy as a disciplinary study. Those who are informed know that the advantages accruing to the student from a pursuit of this study are chiefly intellectual. The experienced teacher who can rightly advise as to the choice of studies, will never place favorable advice in the choice of astronomy as against biology or physics, on the ground that its pursuit and development will have direct bearing to enhance the material interests of mankind. It is not for a moment to be supposed that the discoveries of astronomy will at all compare in practical value with those coming to us from chemistry and electricity for uses in the arts the manufacturing industries of the world that hold so large a place in the public thought of the present time. But it is true, as Professor Young has well and thought-

fully said, that the student may expect his chief profit to be intellectual "in the widening of the range of thought and conception, in the pleasure attending the discovery of simple law working out the most complicated results, in the delight over the beauty and order revealed by the telescope in systems otherwise invisible, in the recognition of the essential unity of the material universe and of the kinship of his own mind with the infinite reason that formed all things and is immanent in them."

The five points made in this statement covering the scope of astronomy and revealing, to some extent, the unique character of the study for scholastic uses, open to view the grand possibilities of the theme. Much more could easily be said in the same line, but that is not necessary or desirable now.

2. How shall astronomy be taught? If we have rightly in mind the value of this branch as a means of training, and have given it proper place in courses of study mapped out for use, then comes the important query how shall this study be taught? As we have said in these pages more than once recently, the teaching of astronomy is now rapidly undergoing a change which is to increase its efficiency and to bring it rapidly and widely to favorable notice in public school instruction. That change is coming in the uses that are to be made of text-books. Too generally the text-book in this branch of study is made the end of the student's effort. When he has learned what the book contains the impression often follows that good progress has been made in gaining knowledge of the subject which may be very far from the truth. Something like what is now called the "laboratory method" will certainly take the place of a large part of the time and effort put forth by an immature student to get the meaning of the author who has written a scholarly book which is more a manual or a ready hand-book in the science than it is a suitable text-book for a novice. The fact is apparent and it has been recently the source of much discussion in the minds of those who teach. The trend of things is towards the inductive idea, or, what is the same thing, the "laboratory method," so called. This means that students should have test exercises, in astronomy, as those in physics now do who go to the laboratory for work, there to fix their knowledge of the principles of this science which is given in the text-book or in the lecture room. It is at once seen that such a step as this will put the student to the test of independent knowledge of the things he can see, chart, or

reason out as compared with what he can learn and remember from a text-book. The difference between these two kinds of knowledge is very great.

(TO BE CONTINUED.)

LECTURE-ROOM DEMONSTRATION OF ORBIT OF BODIES UNDER THE ACTION OF A CENTRAL ATTRACTION.

R. W. WOOD.

Not remembering to have seen any attempt to show experimentally in the lecture room the motion of bodies acted on by a central attractive force varying inversely as the square of the distance in elliptic, parabolic, and hyperbolic orbits, I have made a few experiments with a view of determining how well these curves could be imitated by the motion of a small steel ball around a magnetic pole. The results were so good that I feel warranted in making them known, and believe that the experiment may be found useful in making more cheerful that portion of the course usually rather destitute of pyrotechnics.

The apparatus used was very simple, consisting of a circular glass plate about 40 cm. in diameter, with a small hole in the center through which projected the somewhat conical pole piece of a large electro-magnet (Fig. 1). The surface of the plate was smoked, and it was made level as nearly as possible, the axis of the magnet being of course vertical.

A small, highly polished ball of steel about 5 mm. in diameter (from a bicycle bearing), when projected across the plate, traced its path in the soot and left a permanent record of its motion.

Under these conditions gravity exerts no direct influence on the motion, and we have only the initial velocity and the central attractive force to deal with, together with the loss of velocity due to friction. There are several other circumstances which make the conditions unlike those existing in the case of two gravitating bodies in space, and taking everything into consideration, it is quite surprising what good results were obtained

The ball was blown out of a short piece of glass tubing held in the plane of the plate with varying initial velocities, and curved orbits obtained which were at least good imitations of the ellipse parabola and hyperbola.

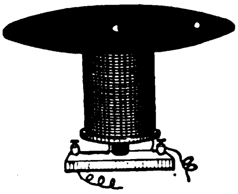

Fig. 1

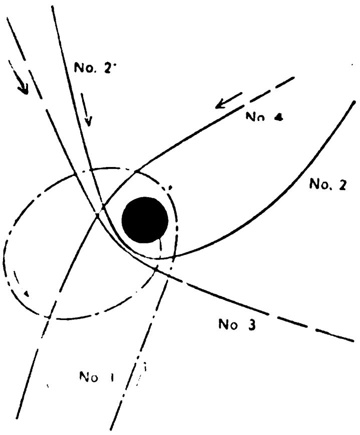

Fig. 2.

Figure 2 is a photograph* of a plate showing all three forms, the black spot in the center being the hole occupied by the magnet pole; the arrows indicate the direction of the motion.

Number 1 was produced with low initial velocity, and is a very fair representation of an ellipse, with the attractive force in one focus. The loss of velocity due to friction caused the ball to "fall into the Sun" after completing one revolution, a one year's existence of the system.

On another trial an ellipse (*spiral*, strictly speaking) was obtained that was almost re-entering, the miss being not more than a couple of millimeters, while in the one figured it was nearly a centimeter.

The right-hand branch of No. 2 resembles a parabola, and was produced by a somewhat higher initial velocity. It will be noticed that the ball moved to its perihelion position in a path rather like a hyperbola, and on rounding the pole, its velocity having been diminished somewhat, moved off in a parabola. It would be more exact probably if we called this curve an ellipse of great eccentricity, since the conditions governing the formation of a parabolic orbit would be difficult even to approximate.

Numbers 3 and 4 are hyperbolæ, produced by still higher initial velocities.

None of the orbits shown in the figure are as perfect as some that have been obtained by accident on other plates. It is quite difficult to make a plate showing all three forms with only four or five trials, as the velocity has to be nicely adjusted; conse-

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* Figure 2 has been reproduced by the engraver from an untouched photograph.—Ed. *Physical Review.*

quently the curves shown in the figure must not be taken as samples of the best that can be produced by a large number of trials.

The hyperbola is of course the easiest to produce, and the parabola the most difficult. Some device for regulating the initial velocity and aim would be conducive to more uniform results.

Polarization of the steel ball is apt to give trouble, and I have obtained some repulsion orbits where the ball turns back before reaching the center, which are very pretty, but not desirable when one is trying to illustrate central attraction. Soft iron balls would be preferable to steel on this account, but they are not on the market so far as I know, and the others answer the purpose well enough.

ASTRONOMICAL PHENOMENA DURING 1900.

ECLIPSES.

In the year 1900 there will be three eclipses, two of the Sun and one of the Moon.

1. **A Total Eclipse of the Sun,** May 28, will be visible as a partial eclipse throughout North America and Europe and in the western part of Asia, the northern part of Africa and the extreme northern part of South America. This is the most important astronomical event which can be predicted for the year, and will be especially interesting to Americans, since the path of totality passes across easily accessible portions of the United States (See POPULAR ASTRONOMY, No. 69, Nov. 1899, for chart of path of totality across the Southern States.)

Doubtless most of the Observatories in this country will send expeditions to observe the eclipse and to obtain all possible data concerning the wonderful corona of the Sun, which can be seen only when the Sun's disc is wholly covered by the Moon. The duration of totality is short in this eclipse; only 2^m 8.8^s at maximum, and that when the shadow falls upon the middle of the Atlantic Ocean. At the most favorable points in the United States totality lasts only about 1^m 30^s, so that there is little time in which to make the very important and very delicate observations which are desired. Photographic and automatic processes will be employed wherever possible, thus reducing the observer's duties to a minimum and making a miscarriage of operations, due to the observer becoming confused, improbable. The great uncertainty in the case is the state of the sky. A cloud of two minutes duration over the Sun would render all preparations useless. A series of weather observations has been undertaken by the U. S. Weather Bureau, during the month from May 15 to June 15 in the last three years, at a large number of points along the path of totality, for the purpose of determining the probability of clear or cloudy weather at those localities. Professor Bigelow's discussion of these observations (POPULAR ASTRONOMY, No. 69,) seems to show that chances are about three to one in favor of clear weather at stations near the Atlantic coast and about six to one in favor of clear weather in the interior of Georgia and Alabama. We may therefore have confident expectation of some good results from all the effort and money which will be expended upon this total eclipse.

The path of totality begins in the Pacific Ocean off the coast of Mexico, crosses northern Mexico and the Gulf of Mexico, passes almost centrally over the city of New Orleans, touches Mobile, Alabama, Raleigh, North Carolina, and Norfolk, Virginia. Across the Atlantic no prominent islands lie in the track of the shadow. It touches land again on the west coast of Portugal, crosses Spain and the Mediterranean Sea, passes over Algiers and several other points on the north coast of Africa and ends near the north end of the Red Sea.

ELEMENTS OF THE ECLIPSE.

Greenwich Mean Time of conjunction in right ascension, May 28, 2^h 57^m $02^s.7$.

Sun and Moon's R. A.	4^h	19^m	47^s 38	Hourly motions $10^s.16$ and $149^s.08$			
Sun's declination	+ 21°	27′	16″.0	Hourly motion	+ 0′	24″.2	
Moon's declination	+ 21	50	17 .4	Hourly motion	+ 2	41 .0	
Sun's equa. hor. parallax			8 .7	Sun's true semidiam.	15	46 .6	
Moon's equa. hor. parallax	58		27 .4	Moon's true semidiam.	15	53 .0	

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.			Longitude from Greenwich.		Latitude.	
		h	m	°	′	°	′
Eclipse begins	May 28	0	12.5	97	49.5 W.	9	59.2 N.
Central eclipse begins		1	14 5	116	38.4 W.	17	50.3 N.
Central eclipse at noon		2	57.0	45	0.4 W.	44	56.8 N.
Central eclipse ends		4	33.5	31	37.1 E.	25	20.6 N.
Eclipse ends		5	35 6	12	29.4 E.	17	32.8 N.

2. A Partial Eclipse of the Moon, June 12, will be visible generally throughout North and South America, Europe and Africa. It will, however, be of almost no importance, since the obscuration will be so very slight, only .001 of the Moon's diameter being covered by the umbra of the shadow at the middle of the eclipse.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, June 12, 15^h 31^m $30^s.0$.

Sun's right ascension	5^h	23^m	$37^s.06$	Hourly motion		$10^s.36$
Moon's right ascension	17	23	37 .06	Hourly motion		145 .04
Sun's declination	+ 23°	11′	16″.1	Hourly motion	+ 0′	09″.0
Moon's declination	— 22	12	57 .2	Hourly motion	+ 0	55 .3
Sun's equa. hor. parallax			8 .7	Sun's true semidiam.	15	44 .8
Moon's equa. hor. parallax	57		29 .7	Moon's true semidiam.	15	39 .2

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich M. T.			Central S. T.		
		h	m	h	m	
Moon enters penumbra	June 12	13	15.0	7	15.0	P. M.
Moon enters shadow		15	24.4	9	24.4	"
Middle of eclipse		15	28.1	9	28.1	"
Moon leaves shadow		15	31.7	9	31.7	"
Moon leaves penumbra		17	41.2	11	41.2	"

Magnitude of eclipse 0.001 (Moon's diameter = 1.0).

3. An Annular Eclipse of the Sun, Nov. 21, will be visible in South Africa and Australia. This will be regarded of little importance, because the

Sun's apparent diameter will be so much greater than that of the Moon that the bright ring of sunlight at central eclipse will wholly overpower the corona.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, November 21, 19^h 22^m 49^s.0.

Sun and Moon's R. A.	15^h	49^m	26^s.34	Hourly motions 10^s.52 and 130^s.97			
Sun's declination	—20°	03′	59″.8	Hourly motion	—	0′	32″.5
Moon's declination	—20	16	25 .8	Hourly motion	—	3	49 .8
Sun's equa. hor. parallax			8 .9	Sun's true semidiam.	16	11	.9
Moon's equa. hor. parallax		55	10 .1	Moon's true semidiam.	15	01	.2

CIRCUMSTANCES OF THE ECLIPSE.

		Greenwich M. T. h	m	Longitude from Greenwich. °	′	Latitude. °	′
Eclipse begins	Nov. 21	16	09.6	21	04.9 E.	1	28.2 S.
Central eclipse begins		17	26.6	2	41.1 E.	5	59.7 S.
Central eclipse at noon		19	22 8	65	49.9 E.	33	19.1 S.
Central eclipse ends		21	12.9	135	19 4 E.	18	26.8 S.
Eclipse ends		22	19.8	116	48.0 E.	13	58.8 S.

OCCULTATIONS.

The *American Ephemeris* gives a list of 105 occultations of stars by the Moon, which will be visible at Washington, and therefore most of them visible throughout the United States, during the year. Among them we notice two of the planet Saturn and one of the planet Uranus which will be generally visible. They are as follows, the times being given in Washington mean time:

			Immersion. h	m	Emersion. h	m	Duration. h	m
Saturn	March	23	13	31	14	38	1	07
Saturn	July	10	10	43	12	5	1	22
Uranus	Oct.	26	5	26	6	39	1	13

The following is the list of occultations of stars visible at Washington during January:

Date. 1900.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
Jan.	8	104 Piscium	7.5	3	41	52	4	56	250	1	15
	11	χ^1 Tauri	4.7	3	28	89	4	28	244	1	00
	11	χ^2 Tauri	6.3	3	31	112	4	22	221	0	51
	13	14 Geminorum	7.2	8	35	122	9	54	250	1	19

THE PLANETS.

The apparent movements of the planets during the year are shown upon the charts Figs. 1, 2 and 3. If the reader will compare these charts with those published in the January numbers of POPULAR ASTRONOMY for the last two years, he may be interested to note the differences as well as the general similarity in the charts. The outer planets describe exactly similar paths among the stars each year, but these paths are further toward the east each year. The inner planets describe the whole circuit of the heavens with the Sun each year, but the position and shape of the loops in their apparent paths vary from year to year.

Mercury begins the year in Sagittarius, west of the Sun, and follows a course quite similar to that of last year. Its loop in Pisces is a month earlier and is of a different shape from that described last year, the upper half of the loop being con-

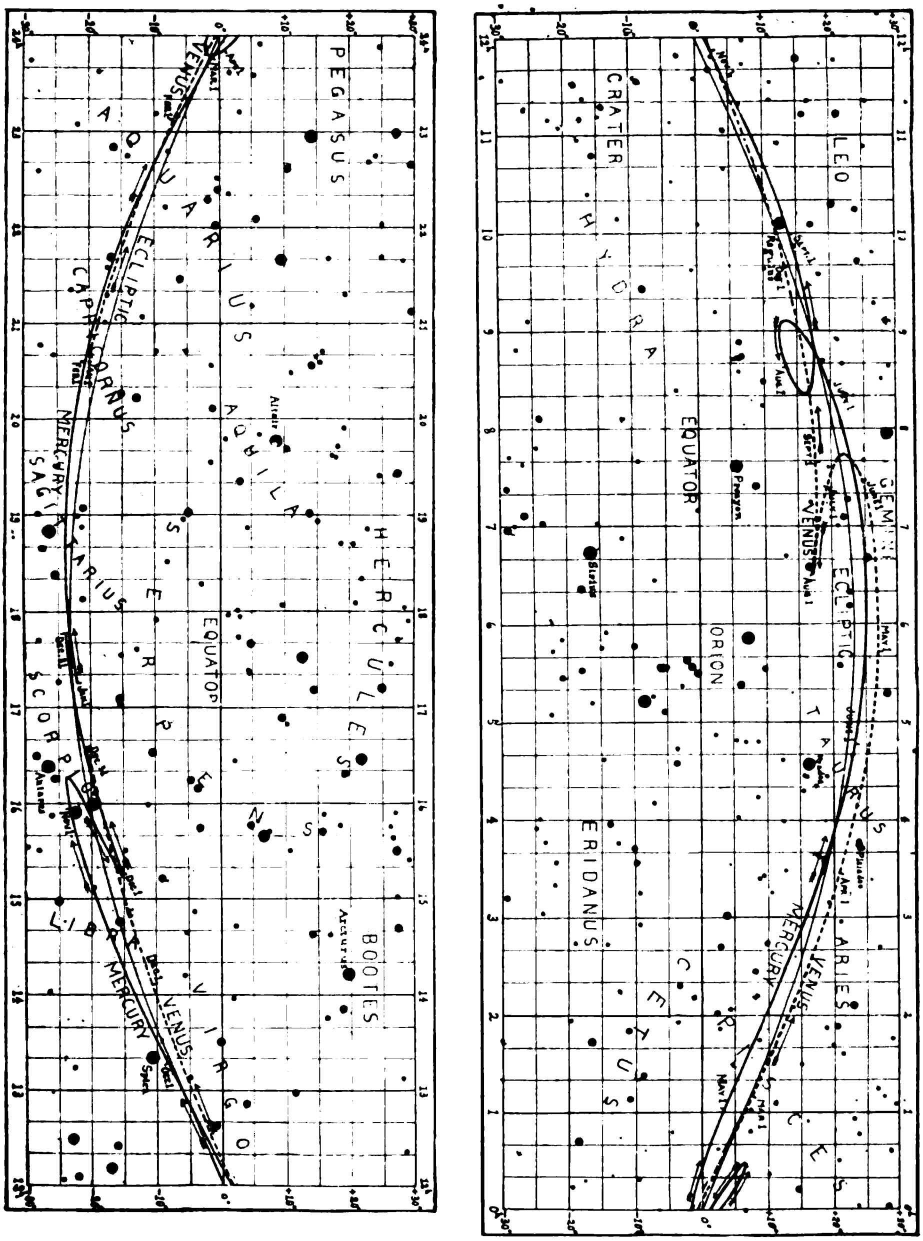


Fig. 1. Chart of the Apparent Paths of Mercury and Venus During 1900.

siderably wider. The loop in Cancer made in July and August is very nearly of the same shape as last year's corresponding curve. The inverted S-shaped curve made in Scorpio in November is wider than that of last year. These different shapes are due to the differing relative positions of Mercury and Earth in their orbits. Their periods being incommensurable, the same combinations of position and motion do not repeat themselves from year to year.

The times when Mercury will be visible to the naked eye and may be therefore called "Evening Star" or "Morning Star," may be derived from the following table, remembering that the planet is visible only from one to two weeks at a time when near greatest elongation from the Sun, and that it is evening star when east of the Sun, and morning star when west of the Sun.

ASPECTS OF MERCURY.

Feb. 9.	Superior conjunction.		
Mar. 8.	Greatest elongation east	18°	16′
Mar. 24.	Inferior conjunction.		
Apr. 21.	Greatest elongation west	27	19
May 30.	Superior conjunction.		
June 4.	Greatest elongation east	26	01
Aug. 1.	Inferior conjunction		
Aug. 19.	Greatest elongation west	18	32
Sept. 13.	Superior conjunction.		
Oct. 29.	Greatest elongation east	23	44
Nov. 20.	Inferior conjunction		
Dec. 7.	Greatest elongation west	20	50

The path of *Venus* will be found upon the same chart with that of Mercury. It begins in Capricorn and follows approximately the course of the ecliptic until June, when for three months it describes a large loop in Gemini. For the remainder of the year the course is again eastward, near the ecliptic. Venus will be "evening star" during the first half of the year and is already very conspicuous for her brilliancy as seen toward the southwest in the early evening. She will continue to increase in brightness until June 1, a month after reaching greatest elongation, east from the Sun 45° 35′, April 28. During the spring therefore Venus will be a splendid object in the western evening sky, situated very favorably for the study of her surface markings. She will come to inferior conjunction July 8 and

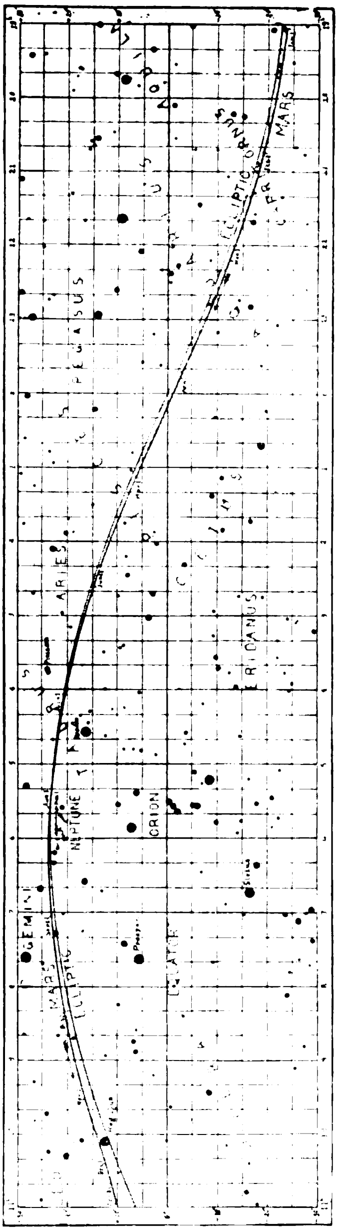


FIG. 2. CHART OF THE APPARENT PATHS OF MARS AND NEPTUNE DURING 1900.

a month later attain her greatest brilliancy as "morning star." Venus will be at greatest westernelongation, 46° 2′, Sept. 17 and will continue to be conspicuous in the morning during the remainder of the year.

Mars moves in a smooth curve without loops, from Sagittarius a little more than half way round the sky, to Leo, following pretty closely the line of the ecliptic. Mars will be at superior conjunction Feb. 9, and will not be in favorable position until autumn, and then only in the morning hours.

Neptune's path is shown upon the same chart with Mars, but upon so small a scale that its shape can scarcely be made out. It moves back and forth practically in a straight line, retrograding from Jan. 1 to March 5, advancing from March 5 to Oct. 1, and retrograding for the remainder of the year. The planet is visible only with telescopes of considerable power.

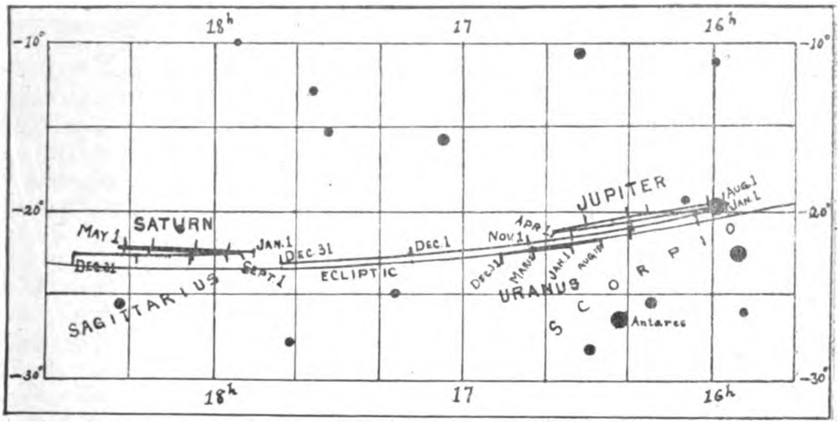


FIG 3. CHART OF THE APPARENT PATHS OF JUPITER, SATURN AND URANUS DURING 1900.

Jupiter, Saturn and ***Uranus*** are near together in Scorpio and Sagittarius. They will be in most favorable position for observation during the summer months. Their apparent paths are almost exactly alike, advancing for three months, retrograding for four months and again advancing for five months.

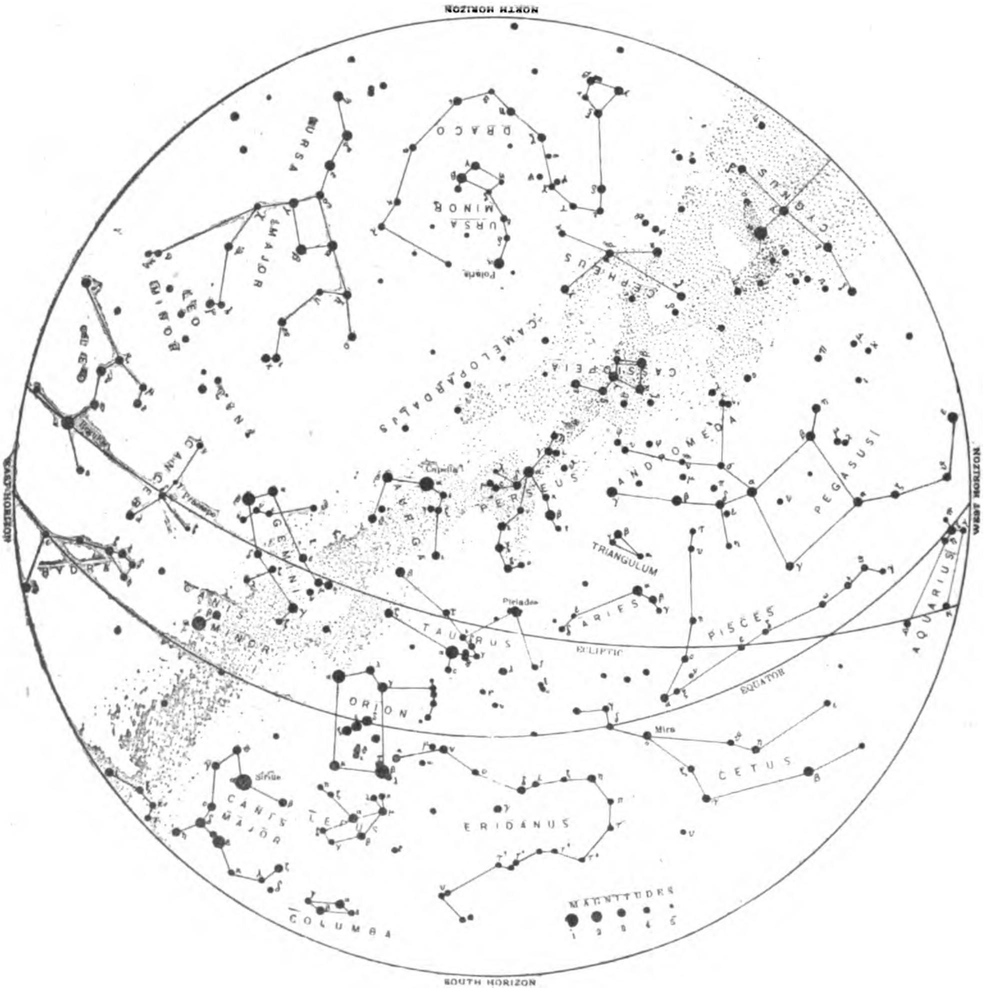
ASTEROIDS

New minor planets will doubtless continue to be discovered by the photographic method. The number now known of these little bodies is over 450, so that their discovery is of much less importance than it was fifty years ago. Most of those found now are extremely faint, but occasionally one is discovered which can be observed with a small telescope. Such an one was found by Charlois at Nice, France, on the night of Dec. 4, 1899, in right ascension $4^h\ 37^m\ 56^s$ and declination north 14° 13′. It was of the tenth magnitude and moving westward 56^s and northward 4′ daily.

The most notable discovery in this line during recent years was that of the asteroid Eros (433) by Witt at Heidelberg Aug. 13, 1898 This planet is extraordinary in the fact that its orbit extends within that of Mars and thus approaches nearer to the Earth than any other of the minor or major planets. An ephemeris of this planet for the months of March, April and May has been communicated to us by Professor H. A. Howe, Director of the Chamberlin Observatory of the University of Denver, Col., and is given on another page.

COMETS.

Three periodic comets are expected to return to perihelion this year. All are faint and can only be seen with a telescope.



THE CONSTELLATIONS AT 9 P. M., JANUARY 1, 1900.

Finlay's comet, discovered in 1886 seen again at its return in 1893, should be at perihelion about the end of February, but will be so unfavorably situated that its rediscovery is doubtful.

The DeVico-Swift comet, discovered in 1844 by DeVico and in 1894 by Edward Swift, son of Dr. Lewis Swift, is due at perihelion in August. It should be in quite favorable position for observation during the summer and autumn. It was however exceedingly faint in 1894, and may be found with difficulty this year.

Barnard's comet 1884 II, which has not been seen at the last two returns, if we except an uncertain observation by Swift in 1895, should be at perihelion in October. Its position will be about as favorable as in 1895, and perhaps a little better, so that there is a possibility of its being found.

No ephemeris of any of these objects is yet at hand.

Brorsen's comet, which has been lost since 1879, should be at perihelion about the close of this year and in fairly good position for observation. The fact, however, that it was not found at the equally favorable opposition of 1890, leads astronomers to think that something has happened to change the course of this comet. Dr. J. R. Hind and Dr. E. Lamp in *Astronomische Nachrichten*, Vol. 137, p. 110, point out that possibly Denning's comet 1894 I may have been a fragment of Brorsen's comet, the two objects having been in nearly the same position in space in February and March, 1881. Denning's comet is due at perihelion in June, 1901.

METEORS.

After the failure of the great Leonid shower to materialize in November last it may be rash to make any more predictions concerning it, but there are several indications that the prediction of last year was a year, possibly two years, early, and that we may look for fine showers in 1900 and 1901. The observations seem to indicate that the maximum of the shower this past year occurred on the morning of Nov. 15, instead of Nov. 16 as predicted by Messrs. Johnstone and Stoney, so that probably the maximum next November will be on the date predicted by Mr. Denning (See POPULAR ASTRONOMY No. 69, Nov. 1899, p. 479).

The Andromede or Bielid shower occurred in 1899 on the night of Nov. 24, and will probably not be noticeable in 1900.

The following table of the radiant points of the more prominent meteoric showers by Mr. W. F. Denning is abstracted from "the Companion to the Observatory" for 1900.

	Radiant.		Meteors.
1900.	R. A.	Decl.	
Jan. 2	230°	+ 53°	Swift; long paths.
Apr. 20	270	+ 33	Swift
May 6	338	− 2	Swift; streaks.
July 28	339	− 12	Slow; long.
Aug. 10	45	+ 57	Swift; streaks.
Oct. 18	92	+ 15	Swift; streaks.
Nov. 14-16	150	+ 22	Swift; streaks.
Nov. 23 24	25	+ 44	Very slow; trains.
Dec 10-12	108	+ 33	Swift; short.

The Perseids, with a maximum on August 10, are visible for a considerable period and the radiant exhibits an easterly motion among the stars, changing from R. A. 20°, Decl. + 51°, July 19, to R. A. 53°, Decl. + 58°, Aug. 16.

Ephemeris of Eros.—The following ephemeris of Eros has been computed with the elements given by Henry Norris Russell in *A. J.* 457.

EPHEMERIS FOR GREENWICH MIDNIGHT.

Date.		α			δ		log Δ
1900.		h	m	s	°	′	
March	1	20	51	35	− 19	1.5	0.40719
	3	20	56	9	18	37.5	0.40543
	5	21	0	39	18	13.1	0.40361
	7	21	5	9	17	48.4	0.40173
	9	21	9	37	17	23.3	0.39977
	11	21	14	3	16	57.8	0.39775

Date.		α			δ			log Δ
1900.		h	m	s		°	′	
March	13	21	18	27	−	16	32.0	0.39566
	15	21	22	49		16	5.9	0.39349
	17	21	27	10		15	39.4	0.39126
	19	21	31	29		15	12.0	0.38896
	21	21	35	46		14	44.5	0.38659
	23	21	40	2		14	18.1	0.38415
	25	21	44	16		13	50.3	0.38164
	27	21	48	28		13	23.3	0.37906
	29	21	52	39		12	54.0	0.37640
	31	21	56	48		12	25.4	0.37367
April	2	22	0	56		11	56.6	0.37086
	4	22	5	2		11	27.5	0.36798
	6	22	9	7		10	58.1	0.36503
	8	22	13	10		10	28.5	0.36201
	10	22	17	12		9	58.7	0.35891
	12	22	21	12		9	28.7	0.35574
	14	22	25	11		8	58.4	0.35250
	16	22	29	9		8	27.8	0.34919
	18	22	33	6		7	57.1	0.34580
	20	22	37	1		7	26.7	0.34233
	22	22	40	55		6	55.0	0.33879
	24	22	44	48		6	23.6	0.33517
	26	22	48	39		5	52.1	0.33147
	28	22	52	30		5	20.2	0.32769
	30	22	56	19		4	48.4	0.32384
May	2	23	0	8		4	16.3	0.31990
	4	23	3	55		3	44.0	0.31589
	6	23	7	41		3	11.5	0.31179
	8	23	11	26		2	38.8	0.30762
	10	23	15	10		2	6.0	0.30337
	12	23	18	53		1	33.0	0.29904
	14	23	22	35		0	59.9	0.29463
	16	23	26	16	−	0	26.6	0.29014
	18	23	29	50	+	0	6.8	0.28557
	20	23	33	36		0	40.4	0.28091
	22	23	37	15		1	14.2	0.27617
	24	23	40	53		1	48.1	0.27134
	26	23	44	30		2	22.3	0.26643
	28	23	48	1	+	2	56.4	0.26143

DANIEL N JONES, JR.

SPECTROSCOPIC NOTES.

In *Science* of Dec. 1 and Dec. 8 abstracts are published of the papers, about a third of them spectroscopic, presented last summer at the first meeting of the Astronomical and Astrophysical Society of America.

The relative photographic brightness of Mars and Jupiter has been measured by Dr. J. Hartmann at Potsdam (*Berlin Sitzungsberichte*, July 20, 1899; *Astrophysical Journal*, Nov.) Using a new type of photometer he finds that for the light of greatest photographic activity (λ 4760 to λ 4110) the surface brightness of Jupiter is almost exactly identical with the surface brightness of Mars, while the surface brightness of the brightest—southwest—portion of the Moon is about one fourth that of either planet. The distance of Jupiter from the Sun was a little less than 3.5 that of Mars; the intensity of illumination, varying as the square of the distance inversely, was consequently for Mars 11.9 that for Jupiter. In order that the surface brightness should be the same for the two planets the reflecting power, or albedo, of Jupiter must for the part of the spectrum under consideration be 11.9 that of Mars. The visual albedo of Jupiter Professor Müller has found to be 2.8 that of Mars, as against Dr. Hartmann's ratio of 11.9 for the violet albedo, while Professor Lohse has found Jupiter's photographic albedo, where the ultra-violet is effective in addition to the violet, to be 18 8 that of Mars. Evidently the violet of Mars is relatively weak, and the ultra-violet very weak; as might be expected from the planet's pronounced reddish color.

In the *Astrophysical Journal* for November Mr. Harrer of the Allegheny Observatory gives the results of his examination of the spectrum of α Orionis during the star's irregular minimum at the past opposition. Comparing his spectrograms of this period with Professor Keeler's spectrograms of 1894 he has detected no change in the number or relative intensities of the lines in the green and yellow of the spectrum.

The American Academy of Arts and Sciences have appropriated the sum of $500 to assist in the construction of a large spectroscope to be used at the Yerkes Observatory by Professor Frost for the determination of motion of stars in the line of sight.

In the choice of officers of the British Astronomical Association Mr. J. Evershed was reëlected for the current year director of the section of spectroscopy.

A summary is given in *Science* of Dec. 8 of the results of Dr. Chase's careful investigation of the refraction of red stars. While the excess of red light in these stars might be expected by its smaller refrangibility to diminish the amount of their general refraction, Dr. Chase agrees with previous observers in finding that the refraction for the red stars is the same as for the other stars.

In the *Astrophysical Journal* for November Professor Campbell reports that he finds variable motion in the line of sight for β Capricorni and v Sagittarii.

In the forthcoming 'Revised Harvard Photometry' a column is promised giving, for each star whose magnitude has been determined, the character of its spectrum; and also, where possible, the photographic magnitude will be given, by comparing which with the visual magnitude the star's color may be determined.

Dr. Wilsing, continuing his investigation of the effect of pressure on spectra, has obtained (*Astrophysical Journal*, November,) by moistening carbon electrodes with water, results for hydrogen analogous to his previous results for other elements.

Professor Hale has recently confirmed and extended his observations of carbon in the Sun's chromosphere (Yerkes Observatory Bulletin No. 12; *Astrophysical Journal*, November,). The green fluting of carbon, terminating at λ 5165 was found in the chromosphere as long ago as September, 1897, the identification of the feeble bright lines of the fluting in the chromosphere being accomplished by first putting the slit of the spectroscope on the Sun's disc and then moving quickly to the Sun's edge, when the dark carbon lines were replaced by bright lines. In Aug. 1899 with the reconstructed spectroscope this green fluting was observed better than before, a large number of bright lines being visible. With perfect conditions and adjustments the yellow fluting, terminating at λ 5635, was seen. The blue fluting, which terminates at λ 4737, could not be seen.

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900.

ALGOL.

	d	h
Feb.	7	17
	10	14
	13	11
	16	8

U CEPHEI.

	d	h
Feb.	1	7
	3	19
	6	7
	8	19
	11	6
	13	18
	16	6
	18	18
	21	6
	23	18
	26	5
	28	17

S VELORUM.

	d	h
Feb.	5	18
	11	17
	17	15
	23	14

λ TAURI.

	d	h
Feb.	8	13
	12	12
	16	10
	20	9
	24	8
	28	7

R CANIS MAJ.

Every 8th min.
$P = 1^d\,3^h.3$

	d	h
Feb.	6	1
	15	4
	24	6

δ LIBRAE.

	d	h
Feb.	4	17
	11	17
	18	17
	25	16
	28	0

U CORONAE.

	d	h
Feb.	1	19
	8	17
	15	15
	22	13
	26	0

RS SAGITTARII.

	d	h
Feb.	0	16
	5	12
	7	22
	12	18
	17	14
	24	20

DM + 45°3062.

	d	h
Feb.	1	6
	5	20
	10	10
	14	23
	19	13
	24	3
	28	17

U OPHIUCHI.

Every 10th min.
$P = 20.1^h$

	d	h
Feb.	5	4
	13	13
	21	23

DM + 12°3557

	d	h
Feb.	2	0
	2	21
	3	18
	4	16
	10	0
	10	21
	11	18
	12	16
	18	0
	18	21
	19	19
	20	16
	26	0
	26	21
	27	19
	28	16

The above ephemeris was computed from the elements given in Chandler's Third Catalogue with three exceptions. For U Cephei, Chandler's revised elements given in No. 396 of the *Astronomical Journal*; for DM. + 12°3557, Luizet's elements given in No. 3596 of the *Astronomische Nachrichten*; for DM. + 45°3062, Pickering's elements given in Harvard College Observatory Circular, No. 44. The long period variables must still await the appearance of an ephemeris in the *Vierteljahrsschrift* or the *Companion to the Observatory*.

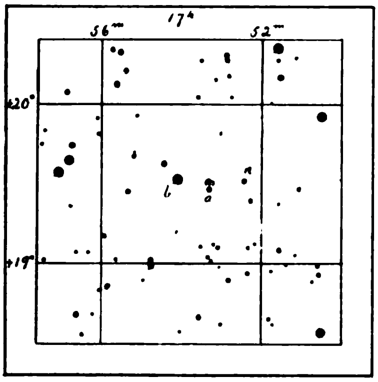
ANDERSON'S NEW VARIABLE IN HERCULES.—This is the first of the new variables noted on page 537 of the December number. The place there given is—

R. A. 17^h 53^m 27.7^s Decl. + 19° 29′ 41″, (1855)
55 24.7 29 20 (1900)

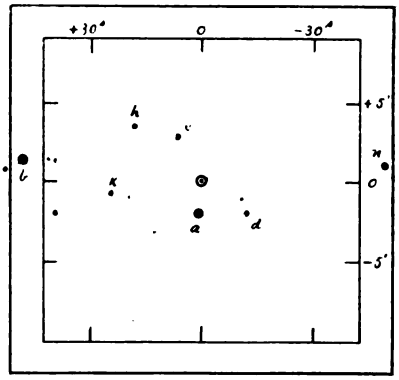
The place was also measured by Dr. Hartwig with the 7-inch heliometer of the Remies Observatory in Bamberg, Germany. He gives as his results in No. 3603 of the *Nachrichten*—

R. A. 17^h 53^m 27.60^s Decl. + 19° 29′ 40.1″, (1855)

Anderson's New Variable in Hercules.
17^h 53^m 27.7. + 19°29′41″ (1855)



Anderson's New Variable. Larger Scale.
17^h 53^m 27.7. + 19° 29 41″ (1855)



The accompanying charts will aid in finding the field, which is 1° south of the 4.5 magnitude star *95 Herculis*. The first chart, on the scale of the DM, gives the stars from the 6th to the 9 5 magnitude within a degree of the variable. The star *a* is DM. + 19°3439, *b* is 19°3494, and *n* is 19°3484. The larger scale chart gives enough of the stars from the 6th to the 12th magnitude within 10′ of the variable to identify it in its fainter stages.

COMPARISON STARS FOR ANDERSON'S NEW VARIABLE IN HERCULES.

	Co-or. from V.					Co-or. from V.			
	R. A.		Decl.	Mag.		R. A.		Decl.	Mag.
	′	″	′			′	″	′	
n	− 11.3	− 48.3	+ 0.5		*k*	+ 5.7	+ 24.2	− 0.7	11.1
d	− 2 9	− 12.1	− 2.0	11.2	*f*	+ 8 1	+ 34 3	− 2 0	10.2
m	− 2.5	− 10.8	− 1.0	12.2	*l*	+ 8.1	+ 34.4	+ 1.4	11.0
a	+ 0.2	+ 0.9	− 2.0	9.5	*b*	+ 10.1	+ 43.0	+ 1.3	6.5
c	+ 1.6	+ 6.8	+ 2.9	10.9	*g*	+ 11.3	+ 47.9	+ 0.8	10.9
h	+ 4.2	+ 18.0	+ 3.5	11.1					

The magnitudes of the comparison stars are merely approximate, for the purpose of identification.

The variation of this star has been somewhat rapid, as the following list of observed magnitudes will show,

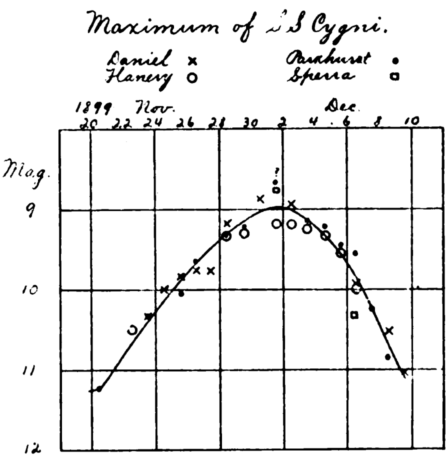
		Mag.				Mag.	
1899	Aug. 22,	9.0	Anderson,		23,	11.9	J. A. Parkhurst.
	24,	9.0	"		28,	12.4	"
	Sept. 17,	9.9	"	Nov.	4,	12.4	"
	Oct. 12,	11.2	J. A. Parkhurst,		8,		"
	17,	11.4	"		to		"
	20,	11.8	"	Dec.	5,	<12	not seen, 5 obs.
	21,	11.9	"				

Dr. Hartwig, in the place above cited, reports a decline of 0.25 magnitude between Oct. 3 and 14.

When these observations are platted it will be seen that there is no check in the rapidity of the decline, and therefore no signs of an approaching minimum. The curve resembles that of Anderson's former discovery in this constellation, 6100 RV Herculis (See POPULAR ASTRONOMY, V, 326), which was followed below the 15th magnitude with the 40-inch Yerkes telescope. (*Astronomical Journal*, No. 456). If this resemblance is confirmed the star may reappear after minimum in the spring of 1900, in position for morning observation.

THE SPECTRUM OF α ORIONIS DURING THE RECENT MINIMUM.—Mr. Henry Harrer, of the Allegheny Observatory, took six spectrograms of α Orionis during the interval 1898 December 24 and 1899 April 5, to seek for any spectral changes which might accompany the recent minimum. These plates were compared with three taken by Professor Keeler with the same instrument and the same adjustment in October and December 1894. The results of this comparison are thus stated by Mr. Harrer in a note in the *Astrophysical Journal* for November 1899. "The comparisons revealed no changes either in the number or relative intensities of the lines. The above six photographs therefore revealed no change in the spectrum of α Orionis within the limits which have been stated." About 130 lines were compared, between λ 5130 and 5655.

ANOMALOUS MAXIMUM OF SS CYGNI.—If any apology were needed for the frequent reference to this variable, it would be furnished by Professor Bailey's discovery of so many examples of this type of variation in the cluster Messier 5, already noted in these columns. But these cluster variables are beyond the reach of an ordinary telescope, while all the changes of SS Cygni can be followed with a moderate aperture, so we must look to this star for most of our knowledge of this type of variation.



The maximum just passed was unique in character. Nothing like it has been seen before, or at least been published, in the light changes of this star. If the form of curve for this maximum depended on the comparisons of a single observer, the report would perhaps be doubted, but the observations of the four are in so satisfactory agreement that the anomalous form of the curve seems well established. The accompanying graphic representation will show at once the form of the curve and the agreement of the observations (Compare curves in V, 271 and 387, VI, 159 and VII, 145). The star had reached normal light after the October maximum on Nov. 6, so that the period of quiescence was only 14 days, the shortest on record. The curve shows a maximum Dec. 1.7, the time of passing 9.35 magnitude during the rise being Nov. 28.1.

The number of observations reported is—

Zaccheus Daniel,	11
David Flanery,	9
J. A. Parkhurst,	41
Wm. E. Sperra,	2
Total,	36

COMET NOTES.

Definite Orbit of Comet 1894 IV, (E. Swift).—In *Astronomische Nachrichten* No. 3606-7 Mr. F. H. Seares gives detailed results of a definitive calculation of the orbit of E. Swift's comet, from all of the published observations. It will be remembered that a similarity was noted, soon after its discovery, between the elements of the orbit of this comet and those of the long lost De Vico comet 1844 I. The previous calculations, although pointing strongly to the identity of the two comets, yet left much uncertainty as to the conclusion to be derived from them. To clear up this uncertainty as much as possible has been the object of Mr. Seares' investigation, and the new determination of the elements of the comet 1894 IV has been a first step in the investigation.

The comet was so faint and the weather so bad that the total number of observations of the comet was only 64 for right ascension and 63 for declination. By comparing these observations with an ephemeris from Mr. Chandler's elements in *Astronomical Journal* No. 338 Mr. Seares formed seven normal places, and after correcting these for perturbations by Jupiter, Saturn, Mars, and Earth, calculated corrections to the elements by a least square solution of differential formulæ.

The definitive elements thus obtained are as follows:

Epoch 1594, Dec. 1.0. Osculation 1894, Dec. 10.0.

$$\begin{array}{l}
M_0 = 8^\circ\ 22'\ 58''.2 \pm 4''.2 \\
\left.\begin{array}{l}
\pi = 345\ 23\ 11.1 \pm 4\ 4 \\
\Omega = 48\ 48\ 23.4 \pm 27.7 \\
i = 2\ 57\ 55\ 8 \pm 1.4
\end{array}\right\} 1900.0 \\
\varphi = 34\ 51\ 37.3 \pm 7.1 \\
\mu = 605''.9999 \pm 0''.0665.
\end{array}$$

These elements place the perihelion passage on Oct. 12, 1894, and make the period 5.855 years. The next perihelion, neglecting perturbations, would be Aug. 20, 1900.

GENERAL NOTES.

It is scarcely necessary to say that the Leonids, though comparatively few in November anywhere, make something of a display in January from the pages of this magazine. Some of the charts present only a few true Leonids, and none a great many in view of what was expected, yet it has seemed best to give many reports from widely different localities in the hope that some useful data may be gained to help in solving some troublesome questions about the real location, dimensions and characteristics of the orbit of the Leonid stream of meteors.

Reports from Leonid Observers.—We have some more reports of Leonids observed in other localities not yet published. We have set aside other matter this month, and given large space to this, for reasons already given above. In presenting other reports later, we have still the same object in view, *viz.*: that of making as full a survey of the observational side as is possible under the circumstances.

The New Photographic Telescope of the Potsdam Astrophysical Observatory.—We have just received a beautiful photograph of the great telescope recently completed for the Astrophysical Observatory at Potsdam, Germany. No description accompanies the photograph and we have seen no reference to the telescope in recent publications except the barest mention that it was in the process of construction and that it was to be a photographic refractor consisting of two telescopes, the photographic objective having an aperture of 80*cm* (= 31.5 inches) and the visual objective having an apertnre of 50*cm* (= 19.7 inches). The photograph (Plate I) shows the telescopes to be in position in the dome and that they have approximately the same focal length. The instrument will be of great value for photographing faint objects, like the smaller nebulae and star clusters, on a scale large enough to show their details of structure plainly. We presume also that a large part of its work will be in connection with the spectroscopic study of the fainter stars.

Orbit of the Fifth Satellite of Jupiter.—The careful and thorough work done in 1898 and 1899 in observing the fifth satellite of Jupiter by Professor E. E. Barnard, with the 40 inch equatorial of Yerkes Observatory, has already received full notice at home and abroad in various scientific publications. His micrometrical observations have made it possible for the mathematical astronomers to study the orbit of this new satellite with confidence that some uncertainties about it will be removed. Years ago, Tisserand called attention to the fact that early observations showed that the orbit of the satellite had eccentricity. This led Professor Barnard to plan a series ot observations of the positions of the satellite that should be as nearly continuous as possible in order to settle this question. One result which he obtains from the work of the last two years is a period of revolution for the satellite which he regards as correct to one one-hundredth of a second of time. The period given in his recent paper on this subject is

$$11^h\ 57^m\ 22^s.647.$$

Tisserand's results from early observations gave a daily motion to the apse line of + 2°.42, and an eccentricity of orbit equal to 0.0073. By Professor Barnard's later observations, it appears that ,Tisserand's daily motion of the apse line is too small, its true value being more nearly + 2°.465, making a complete revolution of the orbit in 4.9 months.

It is suggested by a writer in a late number of *Nature* that "an interesting question may also be settled, by continued observation of this satellite; that is, the distribution of matter at the equator of Jupiter itself, as the motion of the perijove of the satellite does not agree with that deduced from the actual polar compression of the planet." This gives opportunity for more fine micrometrical work by the aid of a large telescope.

The Astronomical Director of the United States Naval Observatory.—The expiration of the time limit for the office of Astronomical Director for Professor William Harkness at the United States Naval Observatory, Washington, D. C., occurred Dec. 17, 1899. His retirement completes the list of those men who have been long in service together in the professorships of mathematics at the Observatory, *viz*: Professors Hall, Frisby, Eastman and Harkness. The time of service of these eminent men at the Observatory has been during a transition period of the character and history of our national astronomical Observatory. When these men came it was little more than a depôt of charts with some astronomical instruments needed for the rating of chronometers and the observations for the Nautical Almanac and the American Ephemeris. The ability of these men in their chosen profession, and in a long and skillful service, faithfully rendered at their respective posts, has, more than anything else, brought the Naval Observatory to a rank worthy of a national name which it noes not yet bear. This transition period has been one of conflict, trouble, jealousy and ill-managment that have defeated much of the best work that might have added largely to the usefulness of the Observatory to astronomy and the country at large. Notwithstanding this these men have lived through it it all, and each and all of them have come to honorable retirement when they were at their best in scientific ability and experience for the performance of professional work to which they have ambitiously devoted their whole lives.

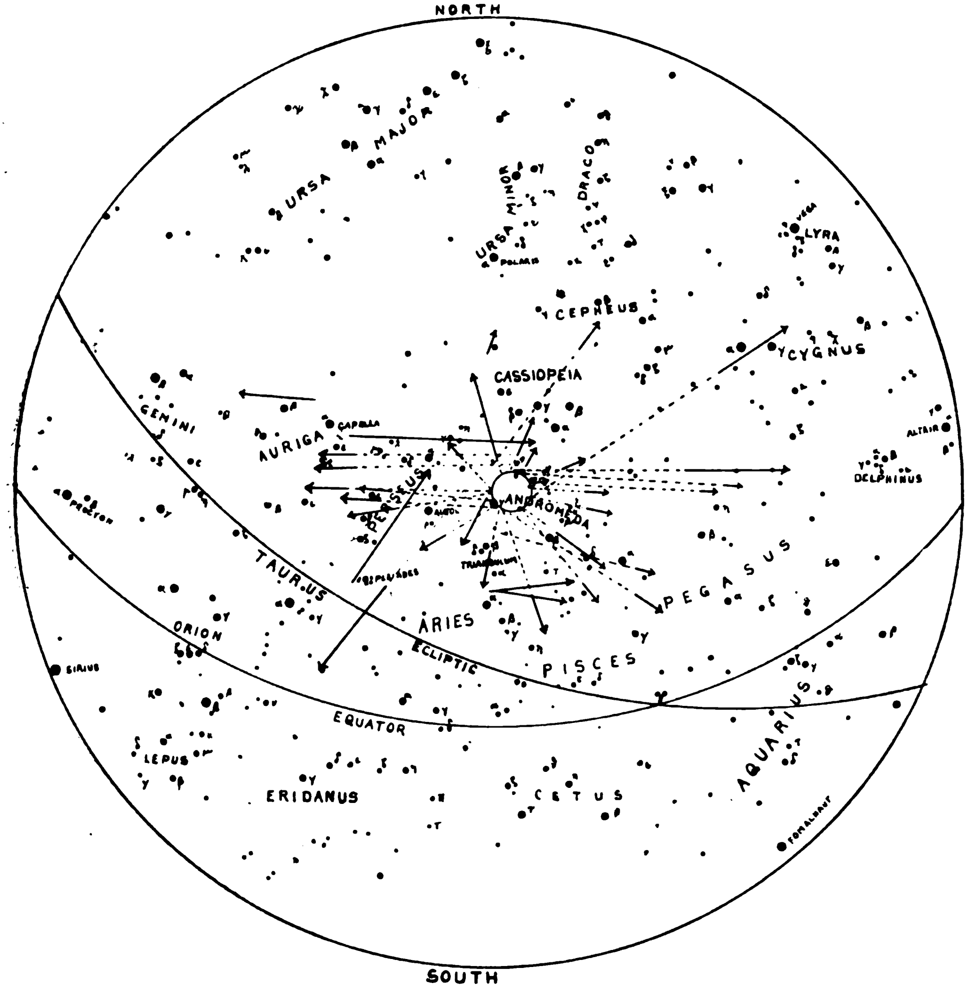
From a recent number of the Washington *Star*, we copy the following statement about Professor William Harkness, who is the last in retirement of the four persons referred to:

"Professor Harkness was born in Scotland, Dec. 17, 1837, and came with his father, who was a Presbyterian minister, to the United States when a mere child. He entered the University at Rochester, N. Y., and graduated in 1858. He studied medicine in New York, became an M. D. in 1862, and enlisted as a surgeon in the Federal army. He resigned that position, was appointed an aid in the United States Naval Observatory in 1863, and became a professor of mathematics the same year.

"His first scientific work was with the the United States monitor Monadnock, in 1864-5 in investigating compasses and iron-clad vessels. On his return he was attached to the Hydrographic Office. While observing a total eclipse of the Sun at Des Moines, Iowa, in 1869, he discovered the 1874 line of the Solar-Corona. In 1871 Professor Harkness was attached to the 'Transit of Venus Commission,' and designed the instruments of the expedition. In 1878 he was placed in charge of the government party which observed the total eclipse of that year at Creston, Wyo. In 1882 he was made executive officer of the 'Transit of Venus Commission,' and reduced the photographic work of the numerous observations taken.

"Among his inventions are the sphereometer caliper, for measuring inequalities of the pivots of astronomical instruments. In 1890 Professor Harkness was made astronomical director of the United States Naval Observatory. In 1897, on the retirement of Professor Newcomb, he was made head of the Nautical Almanac. As a member of various scientific societies, he has contributed numerous reports on mathematical astronomy and the application of mechanics to astronomy. His 'Solar Parallax and its Related Constants" is one of the most important. Professor Harkness has been honored with the degree of A. M., Lafayette College, and with the degree of LL. D. from Rochester University. He will continue his scientific work in Washington in his retirement.

The Andromede Meteors.—The nights of Nov. 22 and 23 were cloudy at Northfield. The 24th was perfectly clear up to 10^h P. M. and a considerable number of meteors were seen by several persons. On account of another engagement systematic watch was not kept until after 10^h.



METEORS CHARTED DURING THE ANDROMEDE SHOWER,

Nov. 24, 1899, by H. C. Wilson and students at Goodsell Observatory.

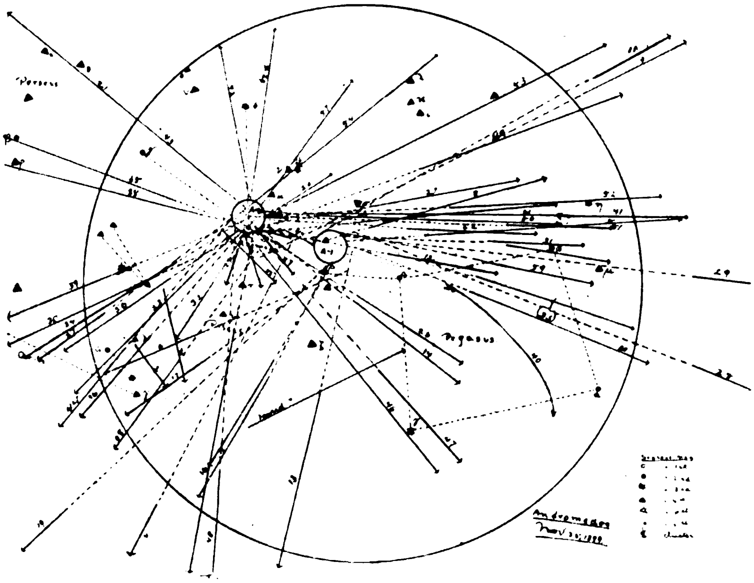
In the first five minutes, one observer counted 10 meteors, all from Andromeda, while the others were getting the apparatus for charting into position. After this the meteors came more slowly and soon clouds covered the sky, lasting until about 11^h, when the sky cleared again and remained clear until the Moon rose. The shower was evidently nearly over at 11 o'clock, for after that, though the sky was perfectly clear, the meteors were very few. The few that were charted between 10 P. M. and 1 A. M. place the radiant about one-third of the way on a line from γ to φ Andromedæ.

On the evening of the 25th watch was kept occasionally but no Andromedes were seen.

The Andromedes.—The Andromedes shower was a fine one for one night. On November 20, 1899 I watched for forerunners. The sky was half overcast. But in spite of that I saw one of the third magnitude at 7.10 of a white color. The 21st, 22d and 23d were cloudy. But on the 24th the sky was excellent. A cloudless and moonless sky. I began observations at 7:00 sharp. I had a table, chair, clock and maps and instruments. I noticed all through the night that the Taurids were also at their best, and I saw eleven in all, while fixing my attention on the constellation Andromeda. They were all bright and four very bright ones. I saw at one time three in one minute all of 0 magnitude. Saw in all sixty-four Bielids during the time between 7:00 and 10:02. Two on different nights. One on the 20th and one on the 25th the only one I saw between 7:00 and 8:30. Most of them were fairly bright. I saw two of 0 magnitude; one in the north-west and another that went through Pegasus and left a two-portioned trail of a green to blue color. This trail lasted two seconds. I had a camera ready, but did not set it because I thought the shower would be better the next night.

To sum up my observations:—

Time.	Mag.	Class	Color.	No.	Remarks.
h m					
7 0	4	A	W	1	
7 3		A(M)	W	2	
7 6		(A)M	W	3	
7 7		A	W	4	
7 10	0	A	G	5	Very brilliant two portioned trail 1 mag. G.
7 14	1	T	W	6	
7 15		A	W	7	
7 17		T	W	8	
7 21	3	A	G	9	
7 22	5	T	W	10	
7 24		A	W	11	
7 28		A	W	12	
7 31	3	A	W	13	
7 31	2	A	W	14	
7 34	3	A	W	15	
7 35	2	T	W	16	Fine trail.
7 36	1	A	R	17	Very swift.
7 36	3	A	W	18	
7 40	4	A	W	19	
7 41	1.5	A	W	20	Trail 2 seconds green.
7 48	3	A	W	21	Very slow.
7 51	4	A	W	22	
7 55	4	A	R	23	
7 57	1	A	G	24	Trail. Whizzing noise.
7 58	2	A	W	25	Very lengthy.
8 1	4	A	R	26	Near radiant.
8 4	4	A		27	
8 12	2-3	A	W	28	
8 12	1	M	G	29	Swift green meteor.
8 17	3	A	G(R)	30	Was two colors.
8 19	3	A	G	31	
8 23	1	A	W	32	Trail 1 second.
8 33	2	A	W	33	Trail 2 seconds
8 35	2	A	W	34	
8 37	2	A	W	35	
8 39	2	A	W	36	
8 40	2	A	W	37	Very faint trail.
8 42	3	A	W	38	
8 42	2.5	A	W		
8 43	4.1	A	W	39	
8 45	3.5	A	W	40	
8 46	3.5	A	W	42	
8 47	4	A	W	43	
8 48	2	A	W	44	Trail 2 seconds.
8 49	3	A	G	45	
8 53	4	A	W	46	
8 54	4	A	W	47	
9 1	3	A	R	48	
9 1	2	A	R	49	
9 4	1	A	R(w)	50	Trail 2 seconds.
9 5	3	A	R	51	
9 7	3	A	R	52	Off map in west.
9 9		A	W	53	
9 11	3	A	R	54	
9 12	1	A	W	55	
9 14	2	A	W	56	
9 19	3	A	W	57	
9 23	1	T	W	58	
9 24	1	A	W	59	Trail 2 seconds.
9 30	1	A	W	60	
9 32	1	A	G	61	
9 33	1	A	Y(R)	62	Faint green trail.
9 34	1	A	G	63	Trail 1-5 second.
9 36	0	A	W	64	Very bright off map.
9 38	3	A	R	65	Went clear across heavens.
9 40	6	A	W	66	
9 41	1	A	W	67	
9 47	3	A	W	68	
9 48	2	A	R	69	
9 51	3	A	W	70	
9 53	5	A	R	71	
10 1	1	A	W	72	Left a two part trail 1 mag.
10 2	3	A	W	73	
10 5	4	A	W	74	
10 6	1	A	W	75	
10 15	0	A	W	76	Green trail.
9 55	1	I	R	77	Went clear across the sky.
9 55	0	T	W	78	
9 55	0	T	W	79	
				80	



The whole number of meteors was 80, consisting of Taurids, Bielids or Andromedes and two shooting stars. I did not, by good luck, sit up until 11:00 or probably the number of meteors would have been perhaps over a hundred. There were two radiants on the map (A–1) and (A–2). The meteors started at first near the star δ and then gradually moved to β Andromedae.

ROBERT M. DOLE.

GLEN ROAD, Jamaica Plain, Boston, Mass.

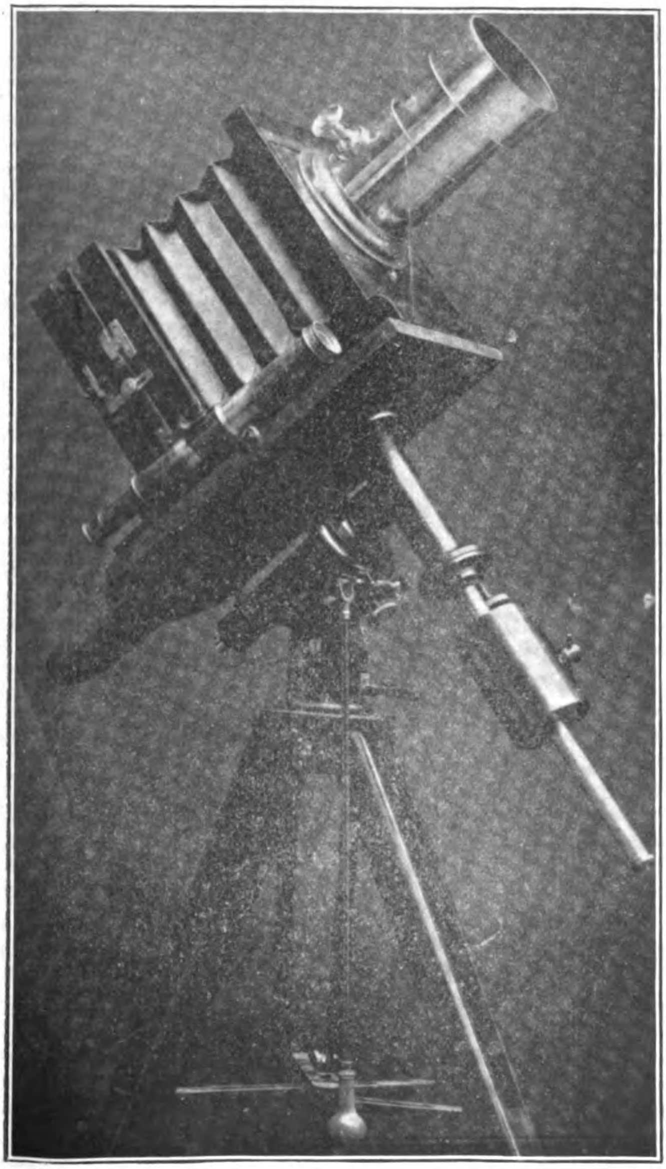
An Interesting Object.—Near 5:30 P. M. on Thursday, Nov. 2, 1899, a hazy light spot, something like a fiery mist, large enough to easily attract attention, made its appearance near the horizon, north of east. This spot became rapidly distinct as it approached, changing from a hazy mist into a redder ball, which changed into a peculiarly beautiful white light, becoming more defined and with a luminous train growing larger and brighter and more beautiful as it slowly glided westward. Its course from the point where it appeared was due west and moving in a straight line almost parallel to the horizon lasted fully one minute. When at about two-thirds of its flight across the sky the ball of light seemed not to explode but rather part into three distinct bodies which moved on in the same path. Gradually the two bodies following separated from the head until at a certain distance which was kept the remainder of their flight. The second ball, smaller than the other two, keeping midway between.

Presently the face of the head light began to dissolve into fiery red flakes that were soon flying about the two bodies following which were almost lost to view but could be distinguished by their whiter appearance. At a point almost due north the lights, while making a short turn from their unvaried straight course, disappeared leaving a very dark curl of smoke. FRED HATCH.

BALDWIN, Kansas.

Leonids at New York City.—It may interest you to hear from your easteern observers of the Leonid meteors, our Mr. Chas. Lembke, Mr. Otis

Wattles and Mr. Holtz of the Goerz Lens Co., Berlin. We stationed ourselves at the Brooklyn Museum of Arts and Sciences, provided with cameras equatorially mounted provided with finder and slow motion in right ascension. The lenses used were 4·4 portrait tube and lenses ground by Chas. Lembke, Jr. The other camera was supplied with a Goerz astigmat wide angle lens.



PHOTOGRAPHIC CAMERA BY GALL & LEMBKE.

Our disappointment was very great, as our station, free from houses or any interference except the brilliancy of moonshine. We have not seen a single meteor neither on Thursday 1 A. M. to 4 A. M., nor the following morning.

GALL & LEMBKE.

The Foucault Pendulum Experiment.—A brief article appears in No. 9 of the Journal of the British Astronomical Association concerning the Foucault Pendulum experiment to show the rotation of the Earth on its axis. This experiment was first performed by Foucault at the Panthéon, in Paris in 1851. From the article, above referred to, it is learned that nearly two centuries before this date, those who were experimenting with the pendulum at Florence had observed the rotation of the plane of oscillation, and that Vincenzo Viviani, the pupil of Galileo, had recorded the observation "in a note which was found amongst his writings relating to the motion of the pendulum but which remained unpublished." The members of the Florence Academy understood this fact thoroughly, but they could not give the reasons for it. The demonstration as we now know was first given by Foucault about two centuries later.

It is easy to perform the experiment in a rough way, now, and it is doubtless done in most colleges of this country which use the laboratory methods in teaching astronomy to any considerable extent. We have at Carleton College shown the rotation of the plane of oscillation with a pendulum only 12 feet long in less than one half hour. We have used a smooth sphere of iron 8 inches in diameter weighing 100 pounds and suspended it with steel wire so as to give a length of about 24 feet. If carefully suspended such a pendulum will swing for two or three hours, and show a deviation of plane of vibration at the rate of 10 degrees per hour, roughly, in latitude 45°, and *always* in the right direction to show rotation of the Earth to eastward. When we could get a chance to swing the pendulum with a length of 100 feet, as has been true in one instance, in the use of the steeple of a large church, the results came out beautifully and with greater accuracy in swings of about one hour periods. To gain accurate results by such an experiment the mounting of the pendulum must be done with very great care.

Lowe Observatory, Echo Mountain, Dec. 9, 1899.—I have read in the November number of POPULAR ASTRONOMY Mr. Herman Davis' description of a lunar rainbow as seen by him. I subscribe to his assertion that they are somewhat rare from my own experience, having during the past 60 years seen but few. This calls to mind a desire I long have felt to learn if many of the readers of your Popular Astronomical Journal ever saw a solar rainbow in the north? I have seen but two, and therefore conclude that the phenomenon is of rare occurrence, in fact, reason teaches that it *must* be rare, for it depends on the simultaneous occurrence of four distinct events: 1st, it must (say in the middle states) occur during the three winter months; 2d, it must take place at noon; 3d, it must be raining in the north; and 4th, the Sun must be shining in the south. As the apex of the bow is low, it also requires to see it an unobstructed northern horizon.

My last and the most conspicuous of the two was seen from the elevated tower of the Warner Observatory in Rochester, N. Y., some eight years ago. In Southern California it so seldom rains a rainbow in any direction is rarely seen. I have seen on a few occasions detached pieces of one, but seldom is one seen entire from horizon to horizon.

LEWIS SWIFT.

Eclipse of the Moon at Des Moines, Ia.—The eclipse of the Moon, Dec. 16, 1899, was observed and enjoyed by a large number of the citizens of Des Moines.

The disappointment in not seeing the expected Leonids, Nov. 12-16, led to skepticism, on the part of some people, as to the calculations and predictions of astronomers, and confidence was in a measure restored by seeing the eclipse occur at the hour predicted.

The first contact was not generally well seen because of clouds near the horizon, but within a very few minutes the arc of the segment of the shadow was plainly visible on the Moon.

While the sky was slightly hazy the entire evening, yet it was sufficiently clear to make the eclipsed Moon a beautiful naked-eye object from 6 to 9 P. M.

At the middle of the eclipse the center of the Moon was quite dark, but the "seas" showed up finely in the finder of the telescope, and Tycho was quite easily seen. The very slightly protruding rough edge of the bright limb was interesting.

The copper hue before, at, and after, the middle of the eclipse was readily noticeable. W. A. CRUSINBERRY.

Leonids at Cleveland, Ohio.—With ten assistants from my astronomy class I watched for meteors from Monday to Friday night inclusive, November 13th to 18th. During this time we had one hour of clear sky on Friday morning. We counted five meteors and photographed three 8 x 10 plates. The weather was most unfortunate and the results obtained here are of no value whatever. I write you personally, not for publication, to let you know that we tried to do our part in watching this shower. CHAS. S. HOWE,

Professor of Astronomy.

CASE OBSERVATORY, Case School of Applied Science, Cleveland, Ohio.

Leonids and Andromedes at Carlisle, Pa.—I beg to make a brief report of recent meteoric observations in this vicinity. Cloudy weather interfered very disappointingly on Nov. 13, 14, 15 and 16th and our party saw but one Leonid, although we kept up our constant watch for hours each night. We were well situated on an elevation away from the glare of the electric lights of town and had charts, etc., ready, but the clouds persisted in intervening.

However, the observations from Andromeda were more encouraging. The number seen on the night of Nov. 22-23 was 89, including one of wonderful brightness going toward and nearly to St. Cygnus. Others were faint by comparison as this big one cast a distinct shadow. The course was straight and the trail was visible for some seconds afterwards.

A party of five of us saw 161 meteors on the following night. These were all from Andromeda, with the exceptions of several Cassiopeids and a very pretty Leonid, the latter going as far west as Polaris at 12.30 A. M. on Nov. 24th. A number of the Andromedes were particularly brilliant and created much enthusiasm. The average was about one per minute. At intervals there would be three or four in rapid succession and in two instances there were two going in the same direction at the same time. The sky was cloudless and all of the constellations were exceedingly clear and distinct. E. N. FOUGHT.

CARLISLE, Pa., Nov. 30, 1899.

The Central Star in the Ring Nebula.—In *Astron. Nachr.*, No. 3607, Mr. W. Stratanoff, of the Tachkent Observatory, Russia, gives the results of a study of some 70 photographs of the Ring Nebula in Lyra, with reference to a variation in the brightness of the central star, which is shown in all photographs, but which is visible to the eye only with the aid of a very large telescope. He finds a variation of only a third of a magnitude and thinks it doubtful if this can be regarded as real. The photographs considered cover the period from 1895 to 1899, and their exposures were from 22^m to $1^h\ 23^m$.

Mr. Stratanoff has also made four long exposures upon this nebula, three of 10^h and one of 20^h duration. These long exposures make the relative magnitude of the central star less, as compared with the stars outside the nebula, than do the short exposures. Mr. Stratanoff suggests that this may be accounted for by supposing the central star to be nebulous, giving upon the plates an image whose intensity increases more slowly than does that of a star proper. He says also that his plates show the contour of this star to be irregular and filamentous, thus differing from the other stars.

Uniformity of Mathematical Symbols.—Professor A. E. Haynes, of the University of Minnesota, has prepared a brief but thoughtful paper recently on the desirability of uniformity in the use of mathematical terms and symbols. Although some of the symbols having two meanings have been long in use, and most are well understood by mathematicians generally; for those who begin the study of this ambiguity, Professor Haynes thinks, is a source of needless confusion that might be remedied.

After indicating how this may be done, he gives some examples of this ambiguity in the following illustrations:

"The word 'cancel' is used, frequently in the same work, in the sense of the striking out of equal factors, and the striking out of numerically equal terms with opposite signs.

The symbol 0 (zero) is used to signify an entire absence of number and an infinitesimally small number.

In many works Naperian logarithms are said to be characterized by the modulus unity, while in others such logarithms are called natural logarithms.

Ratio is defined both as the quotient of the antecedent divided by the consequent, and the consequent divided by the antecedent.

The symbol for multiplication (×) is said to mean 'times,' 'multiplied by' and 'into,' some of which meanings are incorrect, if the multiplier must be an abstract number.

The term parameter is used to signify the double ordinate through the focus of a conic section, and, again, as 'an arbitrary constant entering into an equation of a locus, but which is made variable by hypothesis.'

The base of a system of logarithms is symbolized by *e*, as is also the eccentricity of a conic section.

The word 'decimal' is used with two meanings.

Even the word 'sum' is used with a double meaning While in most cases it is used to signify the aggregate, yet it is also employed to indicate the limit of the sum, as is the case in dealing with an infinite, decreasing geometrical progression.

The word 'limit' as defined, generally excludes the number toward which it constantly approaches, but sometimes it does not.

The word 'pole' as used in analytical geometry, and as used in the theory of functions of a complex variable, has entirely different meanings

The word 'equal,' as used in different works on geometry, is applied to figures having the same magnitude and form, or to those having the same magnitude and unlike form.

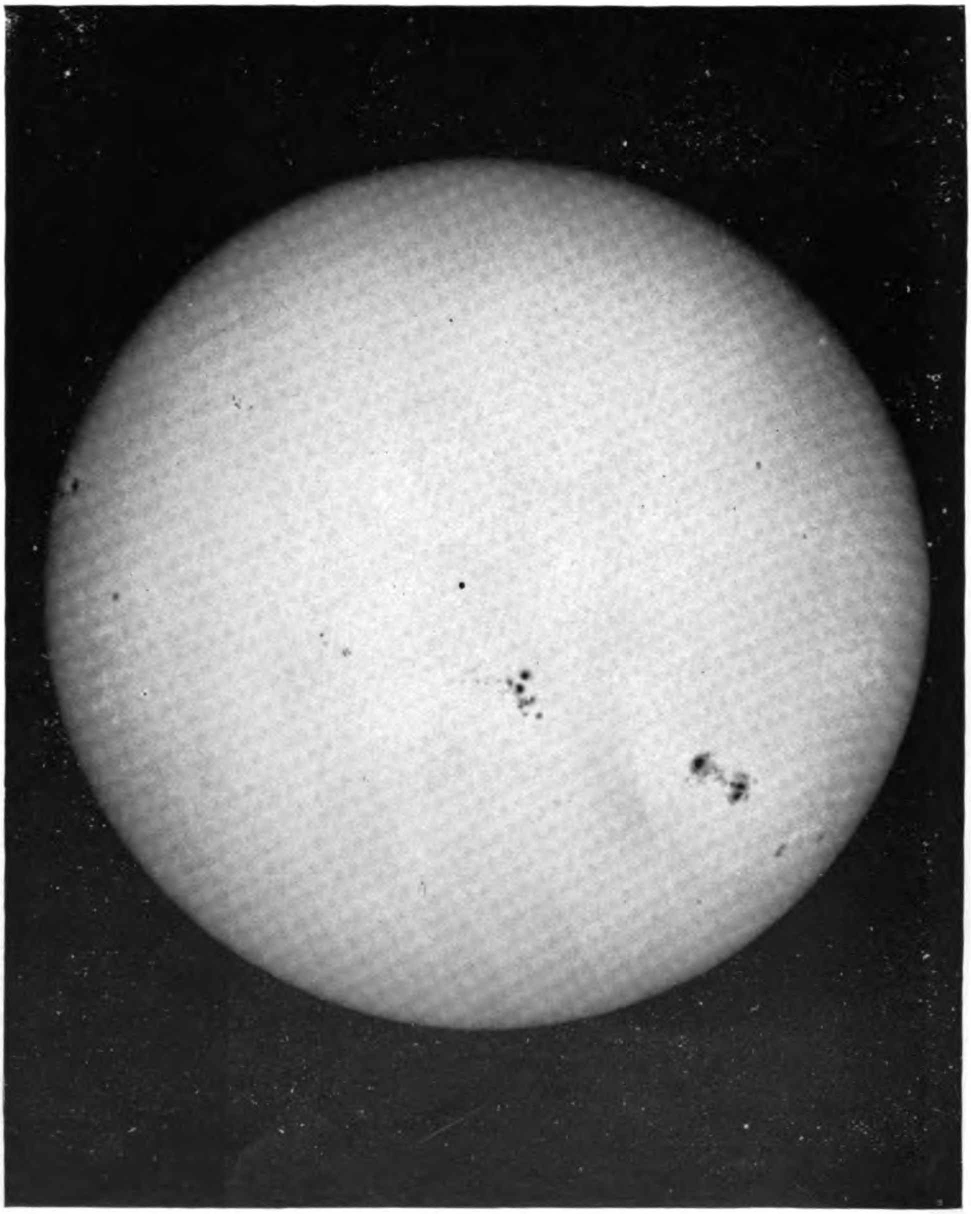
Quadratic equations, involving both the second and first powers of the unknown quantity, and those involving only the second power of the unknown quantity, each have at least two names.

While the Greek symbol (π) is used to express the ratio between the circumference of a circle and its diameter, and also to signify the product of an infinite series of factors.

Spherical degree as used in geometry is an objectionable term, for it signifies area rather than difference of direction."

With these illustrations as a basis Professor Haynes makes a strong appeal for needed revision in mathematical language.

PLATE III.



Photograph of the Sun May 18, 1894.

Taken at Goodsell Observatory.

Popular Astronomy.

Vol. VIII. No. 2. FEBRUARY, 1900. Whole No. 72.

LUNAR CHANGES DURING THE ECLIPSE OF DECEMBER 16, 1899.

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY.

The Moon rose at Cambridge at about 9^h 30^m G. M. T. The first contact of the shadow was at 11^h 45^m, the middle of the eclipse at 13^h 26^m, and the last contact at 15^h 07^m. Magnitude of the eclipse according to the American ephemeris 0.996. My observations with the 15 inch equatorial were confined to a study of four formations, namely, Riccioli, Schröter's Valley, Linné, and the large irregular plain west of Webb. These observations were made with the view of determining if any alterations took place in these objects due to their passage through the Earth's shadow. These same formations had been examined at the time of the eclipse of December 27, 1898, with the same view in mind, as detailed in the *Harvard Observatory Annals*, Vol. XXXII, page 256. On that occasion changes had been suspected in Linné and Webb, but it was felt that the observations required confirmation.

On the present occasion a light veil of cirrus clouds covered the sky, rendering the definition remarkably good for this locality. Before the eclipse the seeing was 6 upon the standard scale, afterwards it was 8. Since the libration carried Riccioli far towards the eastern limb, it was hoped, for reasons given in the article above mentioned, that some evidence of change due to the eclipse might be detected in it. None could be found, however, nor was any alteration observed in Schröter's Valley, nor in the plain near Webb.

At the time of the eclipse of 1898 the seeing was very bad at Cambridge, but fortunately I had requested Mr. Douglass, who was then at Flagstaff, to measure the north and south diameter of Linné upon the five nights of December 25, 26, 27, 28 and 29. He did so, and as a result wrote me "I should say that the crater was smaller on the 27th than on the other four nights, but exhibited a slight increase of size for thirty minutes after totality." That the crater, or more strictly speaking the white spot surrounding it, would be smaller on the 27th than on the other four dates was what I had expected, from observations already made at Cambridge, but what the effect of the eclipse would be upon it was at that time only a matter of conjecture. However, the change was what I had supposed would take place, although Mr. Douglass was at the time unaware of that fact.

During the present eclipse especial pains were taken to repeat these measures with the greatest care possible. The shadow of the Earth reached Linné at 12^h 17^m and left it at 14^h 46^m, duration of obscuration 2^h 29^m. The magnifying power employed was 550 diameters. The white spot was slightly elliptical, the position angle of its major axis being 82° with regard to the Earth's meridian. The ellipticity as measured by the scale of ellipticities was 1.12 before the eclipse, and 1.10 afterwards, these numbers representing the ratio of the major to the minor axis. The following measures of the minor axis were secured. The first two columns of the table give the date and Greenwich Mean Time of the observations, the third gives the number of days since the Sun rose upon Linné, the fourth the quality of the seeing, the fifth the mean difference of the six micrometer readings constituting a single observation, the sixth the residuals, and the seventh the average deviation. The eighth column gives the micrometer reading corrected for the breadth of the threads, the ninth its reduction to arc, and the last the final value, after applying the subjective correction, which in my case amounts to 0″.25.

DIAMETER OF LINNÉ.

Date.		G. M. T.		Days.	S.	Microm.	Residuals.	Av. dev.	Thread.	Arc.	Corr.
1899	d	h	m							″	″
Dec.	13	10	26	5.0	—	0.387	*.003*, .000, .003	0.002	0.340	2.56	2.81
	15	11	00	7.1	4	.373	.008, *.012*, .004	.008	.326	2.46	2.71
	15	11	34	7.1	5	.350	.002, .006, *.007*	.005	.303	2.29	2.54
	16	11	32	8.1	6	.313	*.002*, *.001*, .007	.004	.266	2.01	2.26
	16	11	56	8.1	6.5	.280	*.015*, .002, .014	.010	.233	1.76	2.01
	16	12	02	8.1	6.5	.277	*.003*, *.005*, .009	.006	.230	1.73	1.98
	16	12	17	8.1	—		Linné obscured.		——	——	——
	16	4	46	8.2	—		Linné emerged.		——	——	——
	16	14	54	8.2	8	.293	*.001*, *.005*, .005	.004	.246	1.86	2.11
	16	15	03	8.2	8	.275	.000, .004, *.005*	.003	.228	1.72	1.97
	16	15	44	8.2	8	.270	*.006*, .002, .003	.004	.223	1.68	1.93

As shown in the volume of the Annals above mentioned, the diameter of the white spot about Linné two days after sunrise is 4″, by the eighth day after sunrise it reaches a minimum, and is re-

duced to 2″, and two days before sunset it has increased to about 3″.5. It will be noticed in the above table the first three measures made upon the fifth and seventh days are larger than any of the others.

The first reading made upon the date of the eclipse as compared with its two successors made immediately afterwards, is unaccountably large. This is probably due in part to the inferior seeing, which would have this effect, and in part to accidental errors. Omitting it from consideration for the present, we find that before the eclipse the mean diameter of the spot was 2″.00, immediately after the eclipse it was 2″.11, and soon after that it was reduced to 1″.95. The mean of the first two and the last two is 1″.97, which, subtracted from the reading made immediately after the eclipse is 0″.14, corresponding to 0.17 miles or 0.26 kilometers. That is to say, owing to the eclipse, the white spot surrounding Linné apparently increased in diameter by about one-sixth of a mile. Including the rejected measure, the mean of the five readings, to be compared with that taken immediately after the eclipse is 2″.03, giving an enlargement due to the eclipse of 0″.08.

Although these results certainly cannot be called conclusive, still, they tend to confirm those already obtained by Mr. Douglass during the previous year, both in the fact of the existence of an enlargement, and also in the observation that the effect is of short duration; and perhaps that is all that can be expected, when we consider how small a quantity is involved. There seems to be a strong reason to believe, as has been already stated, that the size of Linné increases as the Sun approaches its horizon, and if this is so, it certainly seems natural to suppose that it should increase in size if the Sun's light were withdrawn from it altogether. At all events that is the effect which has been observed at two different eclipses, by two different observers, one of whom had no personal bias, since he did not know what to expect.

Harvard College Observatory,
December 24, 1899.

CONCERNING THE EARTH'S MOTIONS.

GEORGE S. HODGINS.

FOR POPULAR ASTRONOMY.

The expression, so often used in everyday conversation, "Immovable as the Earth;" is after all, only relatively true, and could not be accepted for a moment, as a scientific statement of fact. Equally open to a little friendly criticism, in this regard, are the well known words, in which Juliet adjures her lover: "O swear not by the Moon, the inconstant Moon, that nightly changes in her circled orb, lest that thy love prove likewise variable." The Moon is, however, not more inconstant than the very globe upon which Juliet stood. Investigation by astronomers has revealed the fact that the Earth is circling and swinging and changing its course in a manner that is well nigh baffling to the understanding.

In the first place our Earth revolves upon its axis, as any school boy knows, just as an orange may be made to rotate round a knitting needle, thrust through its volume. It is, of course, this motion which gives us the endless succession of day and night. If the equator be regarded as a huge wheel, it makes one complete revolution in about 23 hours and 56 minutes. During this period of time, the Sun has moved forward in its course, over a million miles, so that the Earth requires to continue its rotations for 4 minutes longer, in order that it may bring the same meridian, under the central beam of light from the Sun, which shone on it, at the beginning of any one of its rotations. It thus makes the period of rotation 24 hours for each day and night. The period of 23 hours 56 minutes is called the *sidereal* day; and the 24-hour period is the solar day.

Passing on to the annual motion of the Earth round the Sun, we find that this revolution is the one which produces the seasons, in regular succession. The path or orbit of the Earth round the Sun follows a line, which is simply a vast ellipse. The major axis of this ellipse, is given, by some authorities, so as to place the Sun, approximately, three and a half millions miles, nearer one end of the ellipse than the other.

It may be advantageous, just here, to glance at one of the properties common to all ellipses. There are, in every true ellipse, two points, situated on the greater diameter, called foci. An ellipse has been shortly defined, as a plane curve, such that the sum of the distances from any point of the curve, to the two fixed points, is a constant. It may be added, that the two foci, are, of course, always separated by a line of constant length.

The Earth, then, swings round the Sun in a path called an ellipse, the Sun occupying one of the foci. As the Earth swings past the Sun, at the nearer end, one would expect that at this portion of its path, it would receive more heat, than when at the farther end, as it is then about three and a half millions of miles nearer the great source of heat and light. Paradoxical as it may seem, northern countries experience, at this nearer approach to the Sun, their winter season. At the more distant end of the orbit these northern lands enjoy their summer weather. The reason for this lies in the fact that the axis of the Earth is tilted, and makes an angle with the plane of its own orbit of about 66½°. The consequence of this axial tilt is, that when the Earth is closer to the Sun, the rays of heat fall more obliquely on the northern hemisphere, than they do when the Earth assumes its more distant position. The rapidity of the Earth's motion about the Sun has been estimated at about 19 miles per second.

Glancing now, very briefly at another, and more complex motion of our planet, one may say that the above holds good on the assumption that the inclined axis of the Earth always moves parallel to itself, during the entire cycle round the Sun. Though the axis does approach very close to absolute parallelism, all the way round, yet, strictly speaking, it is not so. The tilt of the axis, and the Earth's peculiar shape give rise to a curious and interesting motion, which astronomers have called the *precession of the equinoxes*.

The shape of the Earth is not that of a perfect sphere. It is in reality that of an oblate spheroid, or in other words, it is slightly flattened at the poles and bulges out in the neighborhood of the equator. The polar diameter of the Earth is somewhere about 26 miles shorter than its equatorial diameter. This equatorial protuberance, is at times, above and again below, the line joining the centres of Earth and Sun, owing to the tilt of the axis of the former. The effort of the Sun's attraction, acting along the line of centres, on this protuberant mass, tends to draw the Earth into such a position that the axis of the latter shall be perpendicular to the plane of its orbit about the Sun. This effort, directed upon a rapidly rotating body, like our Earth, causes each pole to describe a circle, traced out in the heavens, in a manner similar to that of a spinning top, whose axis revolves slowly, in a cone. The revolution of the Earth's axis round this circle, which, if the poles be supposed to be prolonged until they reach the stars, above and below the Earth, is a very slow one indeed, and in marked contrast to the rapid diurnal rotation and annual rates of revolution. The complete revolution of the axis, or the precession of the equinoxes, requires a period of no less than 25,827 years.

From this it will be evident that the true polar point in the heavens is slowly and gradually shifting its place among the stars. The star in the northern heavens which we know as Polaris, or the Pole Star, is only a close approximation to the true north point. No one point, therefore, remains permanently as our celestial pole.

It has been calculated by competent authorities, and found, that at the date of the construction of the Great Pyramid of Egypt, in the year 2170 B. C., the pole star of that remote epoch was the first star in the Dragon, more correctly called, α Draconis. At the present time α Ursæ Minoris, or the brightest star in the Little Bear, is the nearest observable point to our true north, and is in more than name, the North Star. In the southern celestial hemisphere, there is no conspicuous star to mark the polar point. The precession of the equinoxes is so called because the equinoxial points on the Earth's orbit revolveslowly around, with the circling poles.

In considering this motion, one is compelled to notice, the modification of it, which is effected through the agency of the Moon's attraction. This modification is called *nutation*, or the nodding of the pole. The path of the Moon is inclined to that of the Earth at an angle of about 5°, and her attraction when above and below the protuberance at our equator, is able to modify the lines traced by the poles, on the heavens, due to the Sun's attraction. The Moon's attractive force, though much less than the Sun's, by reason of her inferiority of mass, is yet very considerable, owing to her comparative proximity to our planet. By the delicate balancing of her power with that of the Sun, it is found that she is able to compel the otherwise circular line, traced by our poles on the heavens, to assume a sinuous form. The deviation from the circle which the Sun would cause our pole to trace, passes as much outside it as it does within, so that the resulting figure is really a scalloped circle, if one may so say; forming an exquisitely beautiful and sinuous line. The period required to make one "nod" in the pole's course is about 18⅔ years. The motion, or rather, modification of motion which we call *nutation*, effects a series of slight undulations in the otherwise theoretical circle, traced by the pole in its "precession."

Next in order comes that motion of the Earth called the *advance of the apsides.* In order to properly consider it, we must here go back to our great ellipse or path of the Earth around the Sun. The apsides are the two points on this ellipse having, respectively the greatest and least distance from the Sun. They are, in fact the ends of the major diameter of the ellipse. When at either of these points, the Earth is said to be, as the case may be, in *perihelion*, when near the Sun, and in *aphelion*, when away from the Sun. These two points together with the whole ellipse or Earth path, move slowly forward in the direction of the Earth's motion.

'The Earth revolves round the Sun in its diurnal motion from west to east, turning upon its axis, just as if it were being rolled over and over, on the outer surface of the Sun. In its annual motion round the central luminary, it moves in exactly the same direction, as if rolled over the Sun's surface. In the same direction also the apsides advance. This motion is caused by the attraction of Jupiter, and the other planets. It amounts to about 1° 23′ per century, so that in about 26,024 years, the advancing apsides would complete one cycle. When computed with reference to time, we find that there is a difference in the length of the year, as measured by the advance of the apsides and that of the sidereal year. This latter is the time required by the Earth, leaving any point in the heavens, and returning to it again. The year measured by this apsidal motion is 4 minutes and 39 seconds longer than the sidereal year, which latter is 365 days, 6 hours, 9 minutes and 10 seconds.

Another modification of the Earth's motion is caused by the *tilting or swaying of the ecliptic.* This is also due to the attraction of our giant neighbor, Jupiter, and his fellow planets. The ecliptic is the name given to the plane of the Earth's orbit. It may be supposed that this plane is extended outward in all directions until its edges touch the fixed stars, exactly like the surface of a level liquid, with the Earth floating, half immersed in it. The Earth's axis stands, as has been said above, at an angle of about 66½° to the ecliptic and it therefore makes the complementary angle of 23½° with a line standing perpendicular to the ecliptic. The ecliptic does not, however, lie motionless like the surface of a level liquid; but is moved up and down, or tilted about a line joining the equinoxial points, just as a table might be tilted up at one end, and down at the other, about a line drawn straight across it, in the middle, from side to side. This tilting up and down, of the ecliptic, will necessarily alter the angles 66½° and 23½° just given. The limits of the tilting motion are from 23° 53′, with the perpendicular line, to 22° 54′, or through an angle of *59′. In the year 2000 B. C. it had the former greater angle, and it is predicted that somewhere about 6000 A. D. the lesser limiting angle will be reached. At the present time the angle is decreasing; though it is very close to 23½°.

The seventh motion, or rather variation of motion in the Earth's course are its *perturbations*. This term is applied to the slight alterations in the elliptic form of the Earth-path, about the Sun. It consists, at one time of a flattening of the curve of the orbit, and at another, of an increase in the degree of curvature as the Earth approaches or recedes from its planetary neighbors. These perturbations can be calculated before hand for each case.

The eighth and last motion of our Earth is through space, together with the Sun and the whole of our solar system. This motion, as far as can be judged up to the present time, is in an apparently straight line. It is in the direction of the star known as π Herculis. The rate of advance along this line is at the prodigious speed of 1,296,000 miles per day. The apparently straight line upon which the Earth, Sun and planets are traveling, has been held by some to be really a curve ot great magnitude, having for its centre, η Tauri, more familiarly known as Alcyone—the brightest star in the Pleiades.

Briefly to recapitulate:—We have traced in merest outline five proper motions of the Earth, viz: The diurnal, the annual, the precession of the equinoxes, the advance of the apsides, and the motion through space. The modifications of motion, if they may be so called, appear to be three in number: nutation, the perturbations and the tilting of the ecliptic. This division is suggested as an easy method of classification, though the reader may prefer, with perfect propriety, to alter the classification for himself. It is, however, a wonderfully complex picture presented by our Earth, as it spins, and circles, nods and sways, rolls and rushes with terrific speed, on through space; never in reality passing through or near the same point again, once it has quitted it. It moves onward with resistless sweep, majestically, without jar or tremor of motion. With no hint of its rapid flight, it hastens on, to its appointed goal, working out its destiny in the appointed way, fulfilling as it goes, the inspired words which tell us that "while the Earth remaineth, seed time "and harvest, and cold and heat, and summer and winter, and "day and night shall not cease."

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* Professor Young, on the authority of J. Herschel, gives the lower limit as 23¼° and the variation not to exceed 1° 20′ from the mean.—Ed.

WORK OF THE BRITISH ASTRONOMICAL ASSOCIATION.*

Roughly, our members may be divided into three classes, viz.: —First, the professional astronomers, connected with established Observatories, and having at their disposal, more or less ample instrumental equipment. Second, amateurs having instruments fitted for serious work and possessing, moreover, a fair amount of experience in the use of such instruments. And third, members who are students of astronomy, but who are either not possessors of instruments at all, or who have not facilities for observational work of an original kind. This third class may possibly be advantageously subdivided as I shall indicate later on.

As regards the first class, the professional astronomers, it is, I am sure, a great satisfaction to us all that we have been able to enroll so many of them in our ranks. A reference to our list of members will show that it includes professional astronomers in nearly every civilized country, men whose names are household words, and the history of whose work constitutes to a great extent the history of the recent progress of our science. It is impossible to overrate the value to our association of the collaboration of these professional astronomers. Their contributions to our publications may be comparatively few, for, as a rule, the accounts of their researches are, almost of necessity, issued through other channels; but we are indebted to them for some very valuable papers, while we have constantly benefitted by their presence at our meetings and by their aid in various ways. Without them the status of our association would certainly not be what it now is.

Next, as to the second class, that consisting of amateurs possessing more or less excellent instrumental equipments. It is this class which has formed the backbone of our observing sections, and to it is due the bulk of the original work which has been recorded in the publications of the association. In the admirable address delivered from this chair last year by our valued Vice-President, Mr. Wesley, special reference was made to the organization of our observing sections, and to the excellent work which those sections have done and are still doing. It will be quite unnecessary for me to go again over the ground which Mr. Wesley covered so thoroughly, but I do wish to strongly endorse the views which he expressed as to the value of the feature which these observing sections have formed in our organization, and as

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* Extract from the Presidential Address, before the British Astronomical Association delivered Oct. 25, 1899, W. H. Maw, President.

to the great debt we owe to the directors by whom these sections have been controlled. Unfortunately we have to mourn the loss during the past year of one of the most valued of these directors, Miss Brown, but if anything could console us for this loss, it is the knowledge that the work which she so ably inaugurated, and which she carried on until the last with such conspicuous ability and enthusiasm, will be continued with the most conscientious thoroughness under the new director, Farther Cortie.

It is satisfactory to know that this second class of our members upon whom we depend so much for original work, is an ever growing one, while year by year it is becoming possessed of more powerful and more perfect instruments. And this brings me to a point on which I wish to say a few words, namely, the influence of the large telescopes, with which some of our more important Observatories are now provided, on the usefulness of the work of amateur observers. In considering this point it must be borne in mind that the great telescopes of the present day are of a very different class from the giant instruments of the past. The great reflectors of Herschel, of Lassell, and of Rosse were all instruments made and used by amateur astronomers, and although they possessed great light-grasp and did some admirable work they were, owing largely to the nature of their mountings, utterly unfitted for the class of observations on which the large telescopes of the present day are chiefly employed. The 36-in. and 60-in. reflectors of Dr. Common may, perhaps, be regarded as the latest of this older class of large telescopes, although it would probably be more just to consider Dr. Common's instruments as forming a connecting link between the giants of the past and present.

In the case of such large refractors as those at Pulkowa, at Washington, at Vienna, at Mount Hamilton, at Nice, at the Yerkes Observatory, and at Greenwich the cost of the telescope itself is but a small portion of the total outlay incurred. Not only must such an instrument be thoroughly well mounted to fit it for modern research work, but it must be protected by a well constructed dome, and in order that every moment of good seeing may be utilized, provision should be made for effecting all movements of both telescope, and dome with the least possible amount of labor to the observer using the instrument. How perfectly this can be done is well shown by the great Yerkes refractor, which, notwithstanding its enormous size and weight, can, with its dome, be so readily handled by the electric motors with which it is provided, that it can be—and is—efficiently used by a single observer through a whole night, without any assistance whatever. It is satisfactory to know that two of our own members, Messrs. Warner and Swasey, were responsible for both the design and construction of this admirably perfect mounting, while the rising floor, which forms such an important feature in the equipment of both the Yerkes and Lick Observatories, and contributes so much to the convenient use of these large telescopes, is the invention of another of our members, Sir Howard Grubb.

But by the time a refractor of this kind has been erected and equipped the outlay upon it will have become so large, that it would be utter folly to use the instrument for work other than that for which its great power renders it specially fitted. The result of this is that our modern giant telescopes are, with few exceptions, employed, not in doing work which was formerly done by smaller instruments, but in doing work which formerly could not be done at all. Such for instance, is the bulk of stellar spectroscopic work including determinations of velocity in the line of sight, the measurement of close double stars, the spectroscopic examination of nebulæ, the discovery of new planetary satellites, and similar matters. We see, therefore, that the establishment of these powerful telescopes has been accompanied by the development of new fields of research, and that the work which was formerly done—and can still be well done—by instruments of moderate size, has not been reduced. On the other hand, many professional astronomers have withdrawn from the work which they formerly did with the instruments then available, and they have thus left to amateur observers the continuance of their former labors.

We thus see that there is ample work for the members forming our observing sections and that such work, if faithfully carried out and recorded with judgment and discrimination, is calculated to be of great and permanent value.

This brings me to a somewhat delicate point on which it is, I think, my duty to say a few words:—I mean the character of the reports of our observing sections. Now the report of a section may be of two kinds, namely, it may be a simple record of all the work done by the members of that section; or it may be a digest of the facts which the labors of the section have elicited. A report of the first kind possesses the advantage that it gives full credit for the work of individual observers, and so far acts as an encouragement to further efforts; but one is apt to rise from the perusal of such a report with a very confused idea of what it all means, and as a document for reference it certainly leaves much to be desired. A report of the second kind, on the other hand, if carefully drawn up by an observer having special experience in the matters dealt with, such as the director of a section naturally possesses, is a work not merely of great present interest, but of permanent value, and adds materially to the standing of the society by which it is published. If our funds were abundant we might, no doubt with advantage, give our sectional reports a dual character, publishing more or less in full the records of individual observations, and adding a digest of the facts deduced by the director from those observations. In this way we should be imitating the procedure of a Royal Commission, which accompanies its report by a reprint of the evidence on which that report is founded. But, unfortunately, our funds are far from being abundant, and we are, therefore, bound to practice strict economy, and to endeavor to spend our money so that it may be of the greatest benefit to our members generally. It is thus eminently desirable that our sectional reports should be of the character of digests of facts prepared by the directors, and that the engravings should be only such as are required to illustrate these facts and render clear points which can not be so well explained verbally. I fear that the adoption of this course may lead to some disappointment of individual workers, and to the non-publication of many admirable drawings which, if our funds allowed, we should be most desirous to reproduce. I hope, however, that members of sections will see the necessity of the course I have foreshadowed, and that they will, at all events for the present, be content with a less full record of their individual work than that to which they may possibly deem they are entitled.

And this brings me to another point, namely, the mode of recording the work of our sections. While it is at present impossible for us to print anything like full records of the work of individual observers, it is eminently desirable that such records should be available for future reference. In order that this end may be conveniently attained, however, it is essential that the reports of the observers forming any section should be sent to the director in some uniform style, and written on paper of a standard size. The selection of the form of the individual reports is, of course, to a great extent a matter to be decided by the directors of sections; but I think that all directors might agree as to a uniform size and character of paper, and I would suggest ruled foolscap would be as convenient as any. Every report of an observation, however brief, should be written on paper of the standard size, the writing being on one side only, and a broad margin being left on the left-hand side of each page for the addition of marginal notes or cross references by the director. I happen to have had through my hands the individual reports received by more than one of our directors of sections, and I have been struck by the great amount of extra labor which is but too often thrown upon the director of a section by the varied character of the notes of observations sent to him. When such notes are contained in letters of all sizes, written on both sides of the paper, and often mixed up with other matter, one cannot wonder that the task of unearthing and digesting the facts is one which a director is not greatly inclined to undertake. On the other hand, individual notes on sheets of uniform size can be readily classified, and after the preparation of the director's reports they can be conveniently collected and preserved in pamphlet cases in our library for future reference. Altogether I would strongly urge the consideration of this point on our directors of sections.

I have now to deal with the third class of our members, namely, those who are either non observers or who, if they observe at all, are provided with a very limited instrumental equipment. This is a very large and important class, and it may, as I have already hinted, be conveniently sub-divided into at least two sections, one comprising those who already possess a considerable knowledge of astronomy, and the other consisting of those who are more or less beginners in the study of our science. To both these sections our Association should be of considerable service, while both, on the other hand, can materially aid the objects which the Association has in view.

To our members forming the first sub-division much really useful work is open. In the first place they may render valuable aid to our observing sections. Nominally, of course, our sections should consist of actual observers, but as I have already pointed out, observations can only be estimated at their full value when carefully arranged and compared, and I see no real reason why the ranks of our observing sections should not include members who, although not observers themselves, are competent to discuss and compare the observations of others. It has to be borne in mind, too, that such discussions of observations as I am here referring to, should not be confined to the examination of new observations only; on the contrary, it should include comparisons with past published records, for it is only by such comparisons that the true lessons of many new observations can be learned. The questions of the periodicity of the changes in the markings on Jupiter is a case in point.

Such aid to the work of the observing sections as I am foreshadowing would also include the calculation of cometary and double star orbits; the preparation from the records of double star observations of lists of pairs appearing to demand special attention; the examination and comparison of records of variable stars; the examination of lunar photographs and their comparison with older charts and drawings; the comparison of old and new planetary observations, and much other work of a cognate kind. How valuable may be the aid to astronomical progress rendered by researches of this class, carried out by one who is not himself—or herself—an observer is admirably shown by the writings of one of our own members, Miss Clerke, whose books and papers we all so greatly value. Altogether, I feel certain that the collaboration of competent non-observing members would be welcomed cordially by the directors of most of our observing sections.

Then, again, there are other directions in which the class of members with whom I am now dealing can do useful work. Some may strike out original lines of mathematical or geometrical investigation, as has been done by Mr. Whitmell, whose papers contributed to our "Journal" aid us so much in realizing aspects of the solar system regarded from other planets than our own; others may take up optical matters and assist in the perfecting of our telescopes and spectroscopes, as Mr. Thorpe, while still others may afford to our hard-working editor much needed assistance in his preparation of those abstracts of foreign astronomical publications which form so valuable a feature in our "Journal." I have, however, I think, said enough to show the fact of not possessing an observatory or instrumental equipment is no bar to the accomplishment by competent members of work of real value to our Association and to astronomical science generally.

I have now finally to deal with the second section of the third of the three classes into which I have ventured to divide our members. This section, it may be remembered, consists of those who are commencing the study of astronomy. I will not call these members "learners," because that is really not a distinctive term. An astronomer devoted to his science never ceases to be a "learner" however eminent he may become; and, in fact, with the growth of knowledge comes inevitably the growth of the conviction that great as has been the progress of astronomical discovery we have as yet only touched the fringe of that great science whose possibilities are as limitless as space itself. Using then, for the want of a better, the term "beginners" to denote the class of members of which I am now speaking I wish before concluding this address—already I fear protracted to an undue length—to offer a few remarks on the manner in which I consider that the study of astronomy can be most advantageously commenced.

In the first place, however, let me comment briefly on certain complaints—for the most part very mildly expressed—which have from time to time reached me from beginners as to the character of the contents of our publications. These complaints assume that inasmuch as the promotion of the study of astronomy is one of the chief objects of our Association, that therefore our "Journal" should be devoted largely to the explanation of elementary astronomical facts. Now this is such an untenable—and I should have thought obviously untenable—assumption, that I should not have referred to it, had I not had evidence that it is somewhat widely held, but held, I believe, unthinkingly. The proper object of our "Journal" is not to afford elementary astronomical information, which can far better be obtained from text books, but to record progress and to supplement text books by keeping our members fully informed with regard to new discoveries and current astronomical work. Such elementary information as beginners require is to be sought not in our "Journal" but in our library, while our "query box" affords a ready means of obtaining explanations on points which text books may not make clear.

I trust that the remarks which I am about to make on the commencement of the study of astronomy will not lead anyone to suppose that I in the least underrate the value of the numerous popular works on our science, or the admirably illustrated magazine articles dealing with astronomical subjects, of which so many have appeared during recent years. On the contrary, I believe such books and articles have done great good, and have, by the interest they arouse, caused many additions to be made to the ranks of amateur astronomers. But the beginner who, wishing to study astronomy, confines his attention solely to such writings as I have just referred to is much in the position of a man who thinks he can become a soldier by reading glowing accounts of hard won victories. Such a beginner, who has had his imagination stirred by the examination of beautifully reproduced photographs of comets, or nebulæ, or lunar views, is apt to experience more or less severe disappointment when he is shown these objects through a telescope of moderate size. Not having had experience in observing, he misses much detail which even such an instrument can show, and realizing how far what he sees falls short of what he had been led to expect, he is apt to jump to the conclusion that observational astronomy, at all events, offers few attractions to those who have not at command an expensive instrumental equipment.

Now this conclusion is an utter mistake, a fact which the beginner who approaches the study of astronomy in the proper spirit will soon recognize. It has to be borne in mind that, great as are the attractions of modern astro-physical research, the real basis of our science is that which is sometimes called by way of distinction "gravitational astronomy." It has further to be borne in mind that the earlier astronomers working with instruments of a very elementary kind obtained a considerable knowledge—which was in many respects really remarkable for its approximate accuracy—as to the motion of the heavenly bodies, and as to the phenomena presented by the chief members of our solar system. Now, what was done in the olden times can be done in the present day, and I wish to prominently direct the attention of beginners to the fact that by the employment of quite simple apparatus they may make observations which will bring home to them, in a way which mere reading can never do, a knowledge of many astronomical phenomena which they will find to be, not only of immediate interest, but of great value to them in their further studies.

What I wish to urge, therefore, is, that those commencing the study of astronomy should not be content with reading only, but should work in the open air, faithfully and systematically recording their observations, however elementary these may be. I lay great stress on this latter point, because unrecorded observations have, as a rule, little educational value. The mere fact of describing in writing any observation, however simple, which has been made is of immense assistance in securing completeness and accuracy. Of course, the country offers greater facilities than towns do for this out-of-door work, but there are few towns where access cannot be had to some convenient site giving a fairly clear horizon and sufficiently free from traffic to allow of star maps being referred to without serious inconvenience. Naturally the beginner's first endeavor will be to identify the brightest stars, and trace out approximately the confines of the various constellations. Continuing this study, he will gradually acquire a knowledge of the paths followed by the stars in their courses from rising to setting, and obtain a clear idea of the position of the apparent axis of this motion. As time goes on, he will further notice that the constellations he has identified set earlier and earlier each evening, and that other constellations previously unseen will come into view on the eastern horizon, Further, he will notice that the path followed by the Moon in her course through the sky not only differs at different parts of lunation, but varies for any given part of a lunation at different seasons of the year. As his knowledge of the sky progresses, he will be able to identify any bright planets which may be visible, and to observe their changes of position with regard to the adjacent stars, changes which he will do well to note in his sketch-book for future reference and consideration. Now the beginner who has learned these elementary facts by actual observations of the sky, and has subsequently, by the aid of his text-books, mastered the reasons for what he has observed, will have made a very fair start in the study of astronomy, and he will, I venture to think, have acquired a far keener interest in the motions of the heavenly bodies than he would have possessed if he had confined his attention solely to books, or if his open-air observations had not been of a systematic character. He will also find that by the aid of some very simple home-made instruments, such as a cross-staff, a rude form of transit instrument, and other similar appliances, he will be able to make observations which serve to still more impress upon his mind the facts he has been learning. Of course, such observations must be crude and wanting in accuracy, but they will, nevertheless, be found to serve a very useful educational purpose.*

To the beginner who has taken up the study of celestial motions, an endless number of problems will suggest themselves for examination, and it will be found that the solution of these problems will afford work which is not only of great immediate interest, but will lead to the acquirement of knowledge of considerable future value.

It has been often said that "Learners should not be ashamed to ask questions." This is quite true in a certain sense, and no beginner should be ashamed to acknowledge that he has much to learn. But the practice of asking questions is not one to be advocated, except within certain strict limits. The beginner who gets

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* Beginners desiring to take up the study of astronomy on the lines here advocated will derive considerable assistance from two American books recently published, viz., "A New Astronomy for Beginners," by Professor David P. Todd, and "A Laboratory Manual in Astronomy," by one of our own members, Miss Mary E. Byrd.

into a difficulty and immediately asks for aid to get out of it, is not likely to make any great progress. It is the battling with difficulties, the habit of regarding a problem from various points of view, and the practice of "getting at the bottom of things," which impresses truths and principles on the mind, and a few facts so learned are worth ten times the number acquired by the question and answer method.

The statement I have just made appears to me to apply with special force to the use of instruments. Many present have no doubt been struck, as I have, by the character of numerous queries respecting the use and adjustment of instruments which, from time to time appear in print. These questions suggest the idea that those proposing them are of opinion that scientific instruments should be made on the "You-touch-the-button-and-we-do the-rest" principle, and that their employment should require no special knowledge on the part of the user. Now this is a frame of mind which is much to be deprecated. Nothing is more essential to secure the best results with any instrument than a clear comprehension of the principles on which such instrument is constructed. It is only by the possession of such knowledge that the user of a telescope, a spectroscope, or other astronomical appliance can determine whether or not any defect in performance is due to a radical fault in such instrument or to a comparatively trivial fault in adjustment. For this reason I would thoroughly urge beginners, when they take up actual observing, to study carefully the theory of any instrument they may employ, and make themselves familiar with its principles and construction. Were this more generally done. much disappointment and loss of time would be saved, and instrument makers would be spared many unjust complaints and much worry.

I am afraid that my remarks on the section of our members which I have classed as "beginners," have run to an undesirable length, but it must be remembered that the "beginners" of to-day are those from which we shall at an early date expect work which will promote the interests and strengthen the position of our Association, and any suggestion which may aid in their training may thus possibly be regarded as excusable.

In conclusion I may quote a passage from the works of Bacon, which was written to have a wide significance, but which appears to me to apply with peculiar force to the science to which we are all devoted. Says the great philosopher:—"Knowledge "is not a couch whereon to rest a searching and restless spirit; "nor a terrace for a wandering and variable mind to walk up "and down with a fair prospect; nor a tower of state for a "proud mind to raise itself upon; nor a fort or commanding "ground for strife and contention; nor a shop for profit or sale; "but a rich storehouse for the glory of the Creator and the relief of man's estate."

THE STUDY OF ASTRONOMY. II.

W. W. PAYNE.

In the last number of this publication (p. 24) we began to say some things about the study of astronomy, as the same is now pursued. It was there pointed out that the writer believes some important changes are now being made both in regard to the method of teaching, and, in studying the elements of this branch of science. It was said that representative school men who have been occupied in teaching branches kindred to astronomy have been so interested in the so-called "laboratory methods that they have quite forgotten that elementary astronomy is a branch of general physics, and that the methods that serve well in elementary chemistry and the elements of natural philosophy must equally well apply to astronomy. Not only this, but the further and more serious complaint must be made, that these same school men in science who are offering and requiring schemes of study in the secondary schools, and strongly urging them publicly, very generally exclude from these schemes the study of elementary astronomy altogether. They do this for two reasons: The first is because they want more time for laboratory work in elementary physics and chemistry. Some are claiming that this laboratory work in elementary physics should be extended over the time of a full year continuously to cover necessary themes and to do the work as it ought to be done. But those instructing in chemistry say no to this, and claim that two-thirds of this time is ample for the work of chemistry in such schools, and that teachers of physics should be satisfied with so large a change in their favor as that which has come into practice recently.

The second reason why elementary astronomy is dropped from the courses of study in the secondary schools is because those who form these courses say the subject is too difficult for students in those schools, and, therefore those who want to study elementary astronomy should wait until they reach college. The writer of this article would never have believed that any leading superintendent or high school teacher in a country town would have made such a public statement as this, if he had not heard it with his own ears. Much less would he have believed that the instructors in some of our large cities should be found advocating the same thing for the same reason.

Now, certainly one of two things is plainly evident, wherever such reasoning is allowed to prevail; either the superintendents or teachers or both do not themselves know enough of elementary astronomy to teach it, or they do not know *how* to teach it. For no one who is at all observant can have failed to notice that nothing interests the old and the young alike, as much as the simple rehearsals of a little knowledge of the Moon, Sun, planets, stars and meteors. Miss Mary Proctor, of New York, is largely employed in giving public talks to children about astronomical subjects for compensation and interested adults are often found in these gatherings. We know that students of astronomy in all parts of the United States are giving familiar talks on astronomy to audiences including persons of all ages with acceptance and very general favor. Almost every week country papers published in California, Pennsylvania, Massachusetts, Iowa, Illinois, or some other states come to us with marked articles, showing that the readers of POPULAR ASTRONOMY have been setting forth some important matters of current astronomical interest for interested readers in their respective rural localities. For the same reason, viz: the popular interest in elementary themes of astronomy, associations have sprung up in the United States, Canada and England partly for the study of what people do not generally get in the secondary schools and, of course, partly for the purpose of keeping abreast with the progress of astronomy in later years.

Now, what does all this mean? To our mind it plainly means that our secondary schools, and some of our colleges and academies are not giving to the branch of elementary astronomy the attention it should receive. Our teachers are not informed as they should be. They do not generally know how to teach elementary astronomy as it should be taught.

Enough has been said to call attention to the widespread interest in the themes of elementary astronomy for all classes of people, and, also, to indicate how very far from the truth, the statement is which claims that elementary astronomy is a branch too difficult for the grasp of the students in secondary schools. If this be true, it is certainly necessary that instructors in these schools look into this matter more thoroughly, that they prepare themselves to judge of the value of elementary astronomy as an important theme for place in their courses of study, and above all, that they prepare themselves to teach the branch in all grades of instruction, including the high school and those above it which are not entered by examination, at least, in the elementary part of the subject.

This last part of the instructor's qualification for his work is all important. We believe that the root of the difficulty which has brought about present lethargy, conscious inability and manifestly weak judgment on the part of prominent school men and instructors lies in the fact that teachers have not known how to instruct well, if they have some knowledge of the branch of elementary astronomy. We wish to offer some suggestions on ways and means to this end. This brings us to the unfinished point we were considering in our last when we found that all our space was taken. In continuing the thought of how to teach the elements of astronomy we may illustrate this in several ways. The first, because it is as simple as any, is the celestial sphere and the fixed stars. In our first volume of POPULAR ASTRONOMY is found a series of articles by Professor Winslow Upton, Director of Ladd Observatory of Brown University, Providence, R. I., who has taken great pains to write out a course of study of the constellations in a way to make it easy for any interested student or teacher to inform himself fully and well about the bright stars and the constellations that may be seen by common observers. There is no question in our mind, whether or not a teacher of elementary astronomy thould know the constellations familiarly, and the stars of the first and second and, at least, some of the third magnitude at sight. That much is so easy to learn and the information is so useful in many ways, that we need only to mention the matter, that any teacher who has not thought about it will at once see the advantages. If teachers should ask their pupils what bright stars are visible at particular hours of the early evening and at what places in the sky they may be seen, ordinary high school students would surely be interested in looking after the stars, and probably they would be anxious to learn the names of such as should attract their attention, and if the teacher can not impart this information readily and certainly, that teacher must rightly take a lower place in that student's estimation than he should hold.

Again, suppose some bright student should ask the instructor at what time Vega or Sirius passes the meridian on a given day, it ought not to be difficult for any teacher to give an approximate answer that would fully satisfy the bright student, and also furnish the natural opportunity of saying something about the ways in which astronomers know how to get very accurate answers to all such interesting questions. This kind of thought and work, for and with students in the simplest lines of observation will certainly quicken and deepen an interest that will always make instruction easy and very delightful. Those who have tried it know that these statements are not overdrawn; such know that they are but the common and the natural results that flow from the use of natural and rational methods of study.

When the publication of POPULAR ASTRONOMY was begun a few years ago, a great deal of expense was incurred and much valuable aid was given freely from very competent sources in order to bring before teachers of astronomy in college, academy and the high school just such methods of instruction as we have have been hinting at in what has gone before. We secured the series of articles from Professor Upton who is an acknowledged authority on star-charting. He has since published an excellent star atlas neatly printed by Messrs. Ginn & Co., of Boston, Mass.

Before the Upton articles were completed we began the publication of the large colored star-charts which were reduced from the planisphere published by the Poole Brothers of Chicago in 1894, and each month a map of the constellations was presented in POPULAR ASTRONOMY, appropriate to the time, until a complete series of twelve covering an entire year had been given. Messrs. Poole Brothers, who own the plate and still have this excellent planisphere on sale, made the step of publishing these large colored star-charts possible to us, by themselves most generously incurring all the expense of reduction and the printing of the charts in colors. We have lately learned that the Poole planisphere has had considerable sale in the colleges and universities of this country and also abroad. We greatly wonder that it has not had larger sale in the colleges and academies and the leading high schools, for it is certainly a very meritorious piece of work. We have used the planisphere with elementary classes in astronomy for several years and we know of its value.

We have one hundred copies of volumes I and II of POPULAR ASTRONOMY, in pamphlet form, so as to accommodate teachers of the elements of astronomy who may wish to try the plan suggested above in regard to this one theme, the celestial sphere and the constellations. These volumes are selling for $2.50 when whole sets are furnished. In order to induce teachers to try this plan we will sell them to teachers, and teachers only, for one dollar each, one or both, as long as they last. We have made a fuller and more complete statement in one of our advertising pages of this number.

Those schools that are provided with a good field glass or a small telescope may do some interesting work in the study of the Moon. In this the most useful guide we know of is the map of the Moon recently published by the Poole Brothers of Chicago. Great care and skill have been used in the engraving of this map to get its many different features related in a scale that should give the most correct impression of the lunar surface as a whole, and also, to represent the individual markings in such way, as to satisfy good photographs and visual observations as far as possible. We think no one can understand the difficulty of such an undertaking who has not tried it. We personally know the artist, Mr. J. A. Colas, of Chicago, and we are fully informed of the labor expended on the plate before satisfactory results could be reached; having before him for imitation for a long time the best photographs of the Moon that could be obtained, in order to transfer to the plate the delicate transition of shade that was shown in the photographs, and, as far as possible to soften the errors of contrast in light and dark shading, which always appear even in the best photographs.

Knowing all this and more about the way in which the Poole Map of the Moon was made, our readers will not wonder that we became interested greatly in this piece of astronomical work as a means of illustration in teaching the elements of astronomy to classes in Carleton College. Whether we use the field glass, the small telescope or the large one, this excellent map of the Moon is our reference and the little pamphlet of twenty-four pages that goes with it, as a key to its numbers, contains a catalogue of more markings than those given by Webb or Proctor. The plan is to look at the Moon with the instrument, use the guide and the map as references for name and location and such other facts as are cited or easily obtained from other sources if desired.

Our experience is that students become so interested in study and observation in this way that they want, and find time for, more hours of study of particular themes than is required. It is never necessary to urge requirements in order to secure work enough to make what is sometimes called a passing grade in the study, as college language sometimes puts it.

Next time we want to say something about other simple apparatus to aid in illustrative study of the elements of astronomy.

THE CORONA OF THE SUN AS SEEN BY E. MILLER, MAY 3d, 1899, THERE BEING NO ECLIPSE OF THE SUN.

E. MILLER,

FOR POPULAR ASTRONOMY.

Professor C. A. Young, perhaps the most competent authority upon solar phenomena, writing about the Sun's corona, says—" We must evidently wait awhile for the solution of the problems presented by the beautiful phenomenon. Possibly the time may come when some new contrivance may enable us to see and study the corona in ordinary daylight, as we now do the prominences. The spectroscope, indeed, will not accomplish the purpose, since the rays and streamers of the corona give a continuous spectrum; but it would be rash to say that no means will ever be found for bringing out the structures around the Sun which are hidden by the glare of our atmosphere. Unless something like this can be done, the progress of our knowledge must be very slow, for the corona is visible only about eight days in a century, in the aggregate, and then only over narrow stripes on the Earth's surface, and but from one to five minutes at a time by any one observer."

Sir Robert S. Ball, in "The Story of the Sun," says—"Such is an outline of the facts known to us with regard to the corona; and it must be admitted that our information is at present of a somewhat meagre description. We can only hope that the attempts to photograph the corona without having to wait for a total eclipse may ultimately prove successful.

Doubtless many of our perplexities would vanish if a series of observations taken at brief intervals were certainly available. We might then expect to gain information regarding the changes in the corona, which it seems absolutely certain are in progress. We might expect, too, that some satisfactory evidence might be forthcoming as to the actual character of the material to which the coronal light is due."

In Langley's splendid book, "The New Astronomy," we read—"Outside all is the strange shape which represents the mysterious corona, seen by the naked eye in a total eclipse, but at all other times invisible even to telescope and spectroscope, and of whose true nature we are nearly ignorant from lack of opportunity to study it." On page 40, the same author says—"The Sun went out as suddenly as a blow-out gas jet, and I became as suddenly aware that all around there had been growing into vision a kind of ghostly radiance, composed of separate pearly beams, looking distinct each from each, as though the black circle where the Sun once was, bristled with pale streamers, stretching far away from it in a sort of crown. This was the mysterious corona, only seen during the brief moments while the shadow is flying overhead."

The French astronomer, Flammarion, says in his "Popular Astronomy," "What, then, is the corona? It is probably a region in which is found a variable quantity of detached particles, partially or wholly vaporized by the intense heat to which they are exposed. But how can these particles be supported in these burning heights? To this question we are already able to give three replies: (1). The matter of the corona may be in a state of permanent projection, being composed of substances incessantly darted out by the Sun and falling back on him. (2), The coronal substance may be more or less supported in the solar heights by the effect of a calorific or electrical repulsion. (3), Finally the corona may be due to clouds of meteors, aerolites circulating around the Sun in his immediate vicinity. All these explanations are perhaps in part true." In Proctor and Ranyard's "Old and New Astronomy" we read as follows: "But it is evident on the one hand that no simple theory can be advanced in explanation of the phenomena of solar appendages manifestly complex and varied, and on the other that the details of coronal structure and of coronal phenomena present problems far too difficult to be as yet solvable."

Miss Clerke in her "History of Astronomy during the Nineteenth Century," says—"The corona is properly described as a solar appendage, and may be conjecturally defined as matter in a perpetual state of efflux from and influx to our great luminary, under the stress of electrical repulsion in one direction and of gravity in the other. Its constitution is of a composite character. It is partly made up of self-luminous gases, chiefly hydrogen, and the unknown substance giving the green ray, "1474;" partly of white-hot solid or liquid particles, shining with continuous light, both reflected and original. The coronal materials must be of inconceivable tenuity, since comets cut their way through them without experiencing sensible retardation. Summing up what we have learned about the corona during some forty-five minutes of scrutiny in as many years, we may state, to begin with, that it is *not* a solar atmosphere. It does not gravitate upon the Sun's surface and share his rotation, as our air gravitates upon and shares the rotation of the earth; and this for the simple reason that there is no visible growth of pressure downward in its gaseous constituents; whereas, under the sole influence of the Sun's attractive power, their density should be multiplied many million times in the descent through a mere fraction of their actual depth."

It is easily seen from the preceding extracts that the corona of the Sun has been visible only on those rare occasions when solar eclipses are total; and the very short period of time during which a total eclipse lasts at any given point upon the Earth's surface, renders any examination of the corona a very difficult operation. Since the introduction of the camera and the spectroscope, as adjuncts in all solar research, the amount of time and labor devoted to such work has been multiplied more than twofold. All the great observatories of the world are systematically engaged in trying to solve the mystery of the corona. Mountain peaks, clear skies, and rare atmospheres, have been sought for, and expensive trips to far away lands have been undertaken, in order to determine once for all what this wonderful thing may be which persists in withholding from the inquisitive eye its secrets and its nature. Men have gone half way round the globe to witness for one, two or six or seven minutes at most, the most beautiful object visible in the solar system. The question naturally arises—is it possible, or will it *ever* be possible, for the human eye, with or without any kind of instrument, and at *any* time to look upon and examine at leisure, such a glorious appendage as that of the Sun's corona? Will this nineteenth century, so full of splendid achievement in every field of scientific research, add to its other honors that of having made it possible, in the absence of a total eclipse, to see the corona? All efforts hitherto made have been without avail, have utterly failed.

In 1866, Mr. Lockyer, and in 1868, Janssen, made it possible for one to see at any time of the day when the Sun is above the horizon, and not obscured by clouds, the so-called "protuberances" or "prominences," that up to that time had been considered as mysterious as the corona is now. Miss Clerke says—"The eclipse of 1868 is chiefly memorable for having taught astronomers to do without eclipses, so far, at least, as one particular branch of solar inquiry is concerned. Inspired by the beauty and brilliancy of the variously tinted prominence-lines revealed to him by his spectroscope, Janssen exclaimed to those about him, "Je verrai ces lignes-là en dehors des eclipses!" On the following morning he carried into execution the plan which formed itself in his brain, at the time of the eclipse.

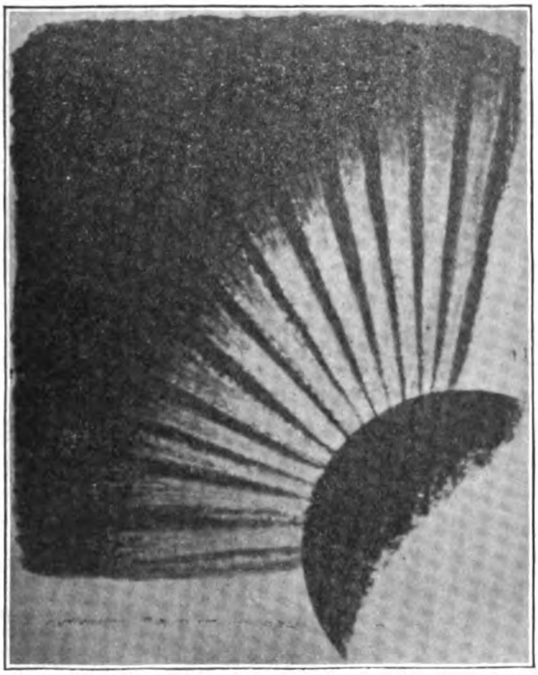
More than a year ago an idea took possession of my brain that there must be some method by which the corona of the Sun may be rendered visible at any time between sunrise and sunset, atmospheric conditions being favorable. In the latter part of April, 1899, I secured three strips of pine lumber, each about six or seven feet long, and of a uniform thickness of three-fourths of an inch. The strips were fastened to the outside of the tube of a Clark telescope of six inches object glass, separated from each other by a distance of 120°. Ordinary wrapping twine was used with which to make the strips secure and firm in their position. They were so placed that about three feet of each one was allowed to project beyond and in front of the object glass. This done, a card board, sufficiently heavy, was cut into the form of a circular disc of seven inches diameter. Upon the inside of the circumference of the disc, and as close to the limb as possible three small holes were pierced, through which pieces of fine, flexible wire were put, and these were tied around the pine strips. By this arrangement the card-board disc—an artificial moon—could be securely heid in position, and by slipping the wires forward or backward, as might be necessary, the disc could be made to hide completely the entire face of the Sun. It was expected and hoped that the effect would be the same as in the case of a true solar eclipse, that is, that the solar appendages would be revealed. All things being ready, the telescope mounted firmly upon the tripod, the pine strips fastened, and the card-board moon put at a suitable distance from the object glass, on the afternoon of May 3d, 1899, the first trial was made, an observation was taken. The face of the Sun being completely obscured, bright radiations were seen to issue from the limb of the artificial moon in great numbers. These radiations were carefully scrutinized, but it was soon made apparent that they were nothing but streaks of light of a decidedly brassy appearance, reflected from the inside of the telescope, the barrel of which was made of brass. The card-board moon was now shifted to a point a little farther away from the object glass. The result was still the same, the brassy streaks, and all else. During all this time, and in spite of every effort to prevent it, the barrel of the telescope was flooded with light that poured into it from the surrounding atmosphere. Just here seemed to be the difficulty, the light came into the telescope apparently from everywhere past the limb of the false moon.

For over an hour, slight changes were made in the position of the false moon, at intervals of from five to six minutes each, at one time to a place nearer the object glass, at another to a point further away, but all to no effect, the results were invariably the same, save that the brassy streamers were modified accordingly. Matters were becoming monotonous and rather disheartening, so much so that the question arose whether the observation should be prolonged, or given up as a flat failure. The determination to succeed, or know the reason why success should not be attained, prolonged the work for some time longer. The time passed in shifting the false moon, readjusting the pine strips, keeping the telescope in proper position, straining the eye in order to see the sight should a revelation be made, yet nothing was seen but the brassy reflections from the telescope itself, which seemed to be dancing and laughing as if in very mockery at every attempt to succeed. More than two hours had passed, and the goal to be reached was apparently as far off as ever. The observer was quite disheartened and discouraged, and about ready to give up in despair. In such a frame of mind, and quite willing to give it up as a bad job, suddenly and unexpectedly the false moon, for some reason or other, changed its position slightly, so that apparently its surface and the surface of the object glass were no longer parallel to each other. Whether the lack of parallelism was a fact or not, cannot now be determined. The effect produced was that the barrel of the telescope seemed to be completely filled with absolute darkness, the brassy streamers vanished, and along the upper right-hand limb of the false moon appeared in all their beauty and soft light the coronal streamers. There was no mistaking the vision. It was the genuine corona itself, "a thing of beauty," and a glorious recompense for the time and labor that had been expended.

An attempt to change the position of the telescope so as to hold the Sun in the field, resulted in destroying the vision, and the coronal streamers disappeared from view. The following is a fac simile of a hand made drawing of the corona as seen on the afternoon of May 3d, 1899. It is not a complete coronal form, for the reason that the cardboard disc extended beyond the limb of the Sun, and prevented a view of the streamers other than as represented.

Several cardboard discs, one six inches in diameter, one seven, and another eight inches in diameter, were made and used at varying distances. A great many obstacles had to be met and surmounted in preparing for the work, and great care had to be exercised in handling the apparatus. The telescope used was mounted on a tripod, and was exposed to the action of the wind.

There was no driving clock attachment, so that every movement had to be made by the observer, thus rendering the labor so much the more difficult. Other observations were taken in May and in June, but on account of ill health, the observations had to be suspended during the summer, and there has been no opportunity since to resume them.



OBSERVATION OF SUPPOSED CORONA OF THE SUN WITHOUT AN ECLIPSE.

But that the corona of the Sun was seen on the 3d of May, 1899, a day upon which there was no eclipse of the Sun, either partial or total, can scarcely admit of doubt. There is a possibility that it may have been a vision of something else, an optical illusion, an "ignis fatuus," or a dream.

At the moment when the picture was sketched, the "apparition" was situated in the vicinity of one of the poles of the Sun, and not in the plane of the Sun's equator, and so clear and well defined was the shape, and so different from all other appearances, that the conclusion reached by the observer was that it was the corona itself. To be sure, he may have been mistaken, but he thinks not, and it is unfortunate that the observation of

May 3d, has not as yet been corroborateq by other observations. The work will be resumed in the near future.

The difficulty in the case consists not in making an artificial Moon, attaching it to a telescope, and locating it at a proper distance from the object glass, but in flooding the barrel of the telescope with absolute darkness. When that is done, all other difficulties will seem but trifles and will vanish at once. The light of the Sun that fills the surrounding atmosphere is the great foe to anything like success and seems to bid defiance to every attempt. Shut out that light, exclude it entirely from the interior of the telescope by means of a conical hood that will extend some distance over the barrel of the telescope and forward as far perhaps as the false moon, or further, and with the conveniences and appliances of a modern Observatory, the result may be safely predicted—the corona will be made visible.

In conclusion, if the corona was seen, upon the day mentioned, when there was no eclipse of the Sun, as described in the foregoing, I think I am justified in saying that the same thing can be done again and again, upon any clear day, during the hours of sunshine, no clouds interfering and other atmospheric conditions being suitable, and the question as to the possibility of astronomers seeing and studying the greatest mystery of the Sun at any time will be settled once for all.

UNIVERSITY OF KANSAS, Lawrence, Kansas.

THE TOTAL SOLAR ECLIPSE OF MAY 28, 1900.

Reprint from *Science*.

The committee on the total solar eclipse of May 28, 1900, appointed at the Second Conference of Astronomers and Astrophysicists, presents herewith a preliminary report.

The aim of the committee has been:

1. To asertain the opinion of astronomers regarding the best means of securing coöperation, the most important classes of observations and the best means of making them, and the plans of the various eclipse parties.
2. To collect other information likely to be useful to persons planning to observe the eclipse.

For the purpose of securing information on the various points referred to in paragraph (1) a circular letter was addressed to American astronomers. From an examination of these replies it appears:

1. That there is a general willingness to coöperate with the committee in securing thorough observations of the eclipse phenomena and effective distribution of stations along the line of totality.

2. That, in the opinion of those from whom the replies were received, the most important observations include studies of the minute structure of the corona, both visually and by means of large scale photographs; photography of the flash spectrum and determination of the wave-length of the green coronal line; measurement of the heat radiation of the corona; photographic search for an intra-mercurial planet.

3. That several institutions, including the Princeton, Lick, Naval, Goodsell, Chabot, Flower and Yerkes Observatories, will probably be represented by well-equipped parties, while a considerable number of astronomers with good instrumental equipment will take part as individuals.

4. That no general appeal to the public for funds is required, as each institution will endeavor to secure the amount necessary for its work.

5. That the work already planned includes observations of contacts, photography of the corona with large and small cameras; visual and photographic observations of the spectrum of the Sun's limb and of the corona; visual examination of the details of the coronal structure; measurement of the brightness of the sky at different distances from the Sun; search for an intra-mercurial planet; and observations of the shadow bands.

A preliminary report on the weather conditions along the line of totality has been prepared by the Weather Bureau, at the request of the committee. From this it appears that interior stations are probably to be preferred to those on the seacoast, in spite of the shorter duration of the total phase. The full report of the Weather Bureau, which will soon be published, will contain much valuable matter, including maps of the eclipse track, showing location of towns and railways; information regarding hotel accommodations, desirable sites, etc.

It is understood that the Naval Observatory will issue instructions to observers, and that a map of the eclipse track will be published by the Nautical Almanac Office. The Treasury Department has made arrangements by which the instruments of foreign parties will be admitted free of duty.

The committee, if authorized by the conference to continue its work, will be glad to receive and publish further information from eclipse parties regarding their plan of observations and location of stations.

Extracts from the replies of various astronomers were appended to the report, but need not be reproduced here, as they have been published in the *Astrophysical Journal.* The committee was continued in office.

The committee appointed at the Second Conference to act in reference to the questions at issue regarding the United States Naval Observatory also reported that the opinions of astronomers regarding that institution, which had been obtained in response to a circular letter, had been communicated to the Secretary of the Navy. This report is not reproduced here, as it is practically superseded by the official report of a Board of Visitors appointed by the Secretary of the Navy to visit, examine and report upon the Naval Observatory. The recommendations of this official report have been given in full in *Science.*

The first meeting of the Astronomical and Astrophysical Society of America adjourned at noon, September 8th.

EDWIN B. FROST, Acting Secretary.

YERKES OBSERVATORY, Williams Bay, Wis.

PACKING INSTRUMENTS FOR TRANSPORTATION.

SABRA C. SNELL.

FOR POPULAR ASTRONOMY.

The repeated experiments of Professor Todd, of Amherst College, in transporting delicate apparatus over great distances make valuable the method of packing he has been led to adopt. His experience is that the safest packing material is cork saw dust closely confined in cloth bags of various shapes and sizes.

This cork may be obtained from any dealer in Malaga grapes. It should be looked over to remove all foreign substances, then washed and thoroughly dried. That as little water as possible be absorbed; put not more than two or three quarts at a time into three or four times as much lukewarm water; press it under and rub between the hands till the whole has been treated; the dirt thus loosened will mostly sink, while the cleased cork floats. Skim off carefully and squeeze or drain, till dry enough to spread in the Sun. If one is possessor of old fashioned quilting frames, nothing is better; set up in a sunny room, with a large square of cotton cloth stretched over them, they furnish space for spreading a bushel at once under most favorable circumstances. The drying process should be very thorough, and to insure this, it is safe to heat the cork in large flat pans in an oven after it feels perfectly dry to the touch. Any moisture remaining in the pores is thus drawn out.

The bags are made of firm cotton, closely stitched and filled nearly as hard as a pincushion. Mostly small sizes are serviceable, but for packing a large lens, two squares, each divided into several compartments, furnish good protection. Also, if it is desired to put tubes within others, long bags, a few inches only in width, filled and bent into rings, serve to separate them.

The elasticity of the cork, together with the possibility of almost perfect freedom from dust, make it for this use superior to any other substance yet tested.

GROWTH OF A GREAT AMERICAN OBSERVATORY IN TWENTY YEARS.*

The financial condition of the Harvard College Observatory has undergone a great change during the last twenty years. The invested capital on August 31, 1877, was $173,908.67, and for the preceding year yielded an income at the rate of 6.36 per cent. The total receipts of the Observatory were $14,359.55. On July 31, 1898, the invested capital was $825,699.30, and for the preceding year yielded an income at the rate of 4.37 per cent. The total receipts were $46,175.46. Accordingly, during this time the principal has increased about four and a half times, while the income has increased three times, although the rate of interest has diminished by nearly one-third. This remarkable growth in our resources has been attained in a great measure through the Visiting Committee of the Observatory. When appointed Director in 1877, I showed that a small addition to the income would greatly increase the efficiency of the work. The Committee accordingly secured by subscription the sum of $5,000 a year, for five years, from seventy-two persons. While nearly all the members of the Committee took part in this work, its success was due to the unremitting efforts of three persons, Mr. Alexander Agassiz, Chairman, Mr. J. Ingersoll Bowditch, and Mr. William Amory. At the end of the five years the Observatory seemed to be poorer than before, since we had learned how much could be accomplished by a moderate increase in its

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* Report of Professor E. C. Pickering Director of Harvard College Observatory to the Board of Overseers of Harvard College May 1899. The article is his, the title ours.—[Editor.

means. Accordingly, a second subscription of $50,000 was undertaken by the Committee, the Rev. James Freeman Clarke, Chairman, also taking an active part. Not only was this sum obtained but the indirect results were even greater. Two gentlemen were asked to subscribe and both declined. It afterwards appeared that each made his will at about that time, and within a fortnight of each other, each leaving his entire fortune for astronomical purposes. Both of these sums, forming two of the largest bequests that have ever been made to astronomy, have now come into the possession of the Observatory. Mr. Robert Treat Paine, for forty-one years a member of this Committee, bequeathed his entire fortune, amounting to $323,557.86, to this Observatory. Mr. Uriah A. Boyden left his property to Trustees, to coöperate with some institution, for the purpose of establishing an astronomical station at a high altitude and under the most favorable atmospheric conditions. One of the Trustees, Mr. James B. Francis, visited the observatories all over the United States, and was strongly advised to coöperate with the Lick Observatory, or with the Smithsonian Institution, but after a long correspondence and numerous interviews I was able to satisfy him that the means we had already secured would enable us to carry out Mr. Boyden's wishes better here than could be done elsewhere. Accordingly, this bequest, exceeding two hundred thousand dollars, also came to the Observatory. The next addition to our resources is one of the most important that we have received, in its objects, its results, and its amount. A member of this Committee, Mrs. Henry Draper, desiring to develop and extend the work so skillfully begun by her husband, established here the Henry Draper Memorial. Her gift of $10,000 a year has enabled the spectra of the stars to be studied photographically, as was first done successfully by Dr. Draper, on a scale which has not been attempted elsewhere, and with results which in number and importance render it perhaps the most widely useful department of the Observatory. A Memorial has thus been established, in the most appropriate manner, which perpetuates the memory of the founder of this department of science. Without the Paine and Boyden Funds it is doubtful if the work of the Henry Draper Memorial could have been conducted more advantageously at Harvard than elsewhere. Each of these funds aids the other, and greatly assists in securing new donations. Thus, when Miss Bruce of New York was asked to give us a photographic telescope of the largest size, it was easy to show that we had here appliances to attain with it the best possible results. Her gift of $50,000 has furnished us an instrument for photographic research, far more powerful than any now existing elsewhere. Several other bequests have been received, the largest and latest of them, the Haven Fund, amounting to $45,000. With the Boyden, Draper, and Bruce photographic telescopes many thousand photographs were obtained, which are of the greatest value, but if destroyed could never be replaced. Yet for several years we were obliged to store them in the wooden buildings of the Observatory, where they were liable to destruction in a few hours at any time, by fire. Again the Visiting Committee came to our assistance, and largely through the efforts of the Chairman, Mr. George O. Shattuck, $15,000 was raised by subscription, and a fire-proof building was erected in which the photographic plates are safely stored, examined, and measured.

The Observatory has thus grown by successive steps until it now has organized departments for research, some of which are at least equal to those of any other Observatory, either public or private, even including those maintained by the governments of England, France, Germany. and Russia. The work of the Observatory has increased more rapidly than its means. The number of assistants has increased from six to forty. During the first thirty years of its existence four volumes of its Annals were published and distributed, and three or four more were partially completed or ready for distribution. The total number of volumes is now forty. Besides the Station at Cambridge, the Observatory maintains a permanent Astronomical Station at Arequipa, Peru, where the atmospheric conditions are much better than at other observatories, with perhaps two or three exceptions.. It also maintains seven meteorological stations in Peru, including the highest in the world, that on El Misti, elevation 19,200 feet. By coöperation with the Blue Hill Meteorological Observatory, the excellent results obtained at the three stations of that Observatory are published in our Annals.

The scientific work of the Observatory since its establishment has been in the direction of the physical properties of the stars rather than in merely measuring their positions. This line has been especially pursued for the last twenty years, and has developed fields of work that have not been taken up elsewhere. The station in the southern hemisphere enables researches on the northern stars to be extended to the south pole, permitting all stars in the sky to be studied according to a uniform system. Thus, after measuring with the meridian photometer all the northern stars visible to the naked eye, the instrument was sent to Peru and similar measures were made of the southern stars. All stars north of — 40°, of the magnitude 7.5 and brighter, have since been measured, besides several thousand stars of the eighth and ninth magnitude. About nine hundred and thirty thousand settings of about forty-five thousand stars have been made with the meridian photometer since 1879, and a more powerful instrument now enables stars of the thirteenth magnitude to be measured. Measures are also made of the light of faint stars every clear evening with the 15-inch Equatorial telescope.

Measures of position have not been neglected. The observations of a zone of 8,627 northern stars with the Meridian Circle. in connection with twelve other observatories, have been completed, and the results published occupy seven volumes of the Annals. The observations of a similar zone of southern stars are completed and good progress has been made in their reduction. Several photographic telescopes are kept in constant use, both in Cambridge and Arequipa, throughout the whole of every clear night. As a result about eight thousand photographs are taken every year, and the entire collection of nearly a hundred thousand plates are carefully studied by about a dozen assistants. These plates show the spectra of all the stars in the sky brighter than the tenth magnitude. They also furnish charts showing the condition of the entire sky several times every year, and contain a history of the visible universe during the last ten years. A striking illustration of the value of this collection is shown in the recently discovered planet Eros, which comes nearer to the Earth than any other known celestial body except the Moon. Its nearest approach occurs every thirty-seven years, the last time being in 1894, when no visual observations were obtained, since it was not discovered until five years later. Its path from October 1893 to May 1894 is shown by fifteen of our photographs, each of which also gives its position with an accuracy equal to that of a meridian circle. The laborious computation required in this search for Eros has been made for this purpose by Mr. S. C. Chandler. No photograph of Eros was obtained in 1893, at any other observatory. Other even more interesting objects may yet be discovered, and are doubtless contained on our photographs, since the latter cover the entire sky for the last ten years.

The results here described have been attained by rigorous economy, in spending money only to obtain results, and in no case for display. No money is expended on architectural effect, and in the buildings and instruments appearances are always sacrificed to efficiency. The salaries, especially those of the younger assistants, are much lower than their services deserve.

A serious question now arises regarding the future of the Observatory. It has attained a position among the great Observatories of the world. This position, I believe, it should maintain, and I believe that Harvard University, and the people of the United States, desire that it should do so. If the Observatory is to do the work it did twenty years ago, its means are more than ample. If it is to do its present work, and maintain its present position, there must be no diminution in its income, but rather a steady, if gradual, increase. Unfortunately, the gradual falling off in the rate of interest affects a large portion of the resources of the Observatory. For this reason the income has been diminishing at the rate of a thousand dollars a year, for the last six years, and we are far from reaching the lowest point. One per cent. in the rate of interest means a loss to the Observatory of about ten thousand dollars a year. A diminution in income means abandoning work already undertaken, losing assistants at the very time when they have attained their greatest usefulness since their salaries cannot be gradually increased, and postponing the reduction and publication of observations already made. Such a course is the worst possible economy. Delay in publication often means a great increase in expense if material accumulated by one person must later be put into the hands of another, and often, as has frequently happened at other Observatories, a loss of the entire work.

In view of the wide interest in astronomy, and its numerous and generous patrons in this country, there are doubtless many persons who would gladly meet this need if it were properly brought before them. Unfortunately, the legacy tax of the United States, amounting in some cases to fifteen per cent. of an entire bequest, is likely to discourage gifts to science, instead of inducing donors to give during their lives.

As a remedy for these difficulties, it is suggested that the attention of the public be called to these facts by publication, and that the statement be made that it is desired to increase the capital of the Observatory by $200,000, to compensate for the loss of income due to falling off in the rate of interest. If this amount cannot be obtained the sum of $50,000, if expended during the next ten years, would provide for the reduction and publication of a large part of the material now on hand.

A PHOTOGRAPH OF THE SUN.

H. C. WILSON.

The photograph of the Sun shown in Plate III was taken May 18, 1894, at 4^h 41^m Central Standard Time with the 8-inch Clark refractor. This telescope is provided with a third lens placed in front of the visual objective to correct it for the photographic rays. It is also provided with two amplifiers by Brashear and Hastings, one throwing up the solar image to approximately 3½ inches, the other to 7 inches diameter. The greater amplifier was used for this picture, which has been reduced in the process of engraving.

The photograph was taken at a time not far from the maximum of the Sunspot period, and a large number of spots are shown upon the plate. Seven groups lie in the zone south of the solar equator and two very small groups in the zone north of the equator. The solar equator is inclined about 20° to the horizontal in this picture, being tilted down on the right and up on the left hand, and passes a little above the center of the disc, the solar latitude of the center of the disc being approximately — 2°. The row of five prominent groups of spots thus lie on a line nearly parallel to the solar equator.

The most prominent of the groups, in the lower right portion of the disc is about 60,000 miles long and of half that width. It has three marked centers of disturbance, or umbræ, and a comparison of this photograph with one taken on the next day, shows that the whole group was in a state of violent change. Surrounding the group of dark spots on all sides are irregular areas of white faculæ. Scattered patches of like character are to be seen at several points near the east and west edges of the disc, generally in connection with the dark spots but sometimes entirely separated from them. The area covered by the white faculæ is as a rule much greater than that covered by the dark spots.

The group just below the center is remarkable for the number of small separate dark spots which it contains. The photograph taken on the next day shows many of these run together, while the larger spots are more intense and changed in form, so that the change in one day is quite noticeable.

To the left and a little below the center of the disc is a group of less prominent spots, the leader of which is rather large and has four umbræ forming a parallelogram. On the next day these four umbræ had united into one very black pear-shaped umbra, with the large end toward the right, making this group almost as remarkable as those which precede it.

Nearer the left edge of the picture is a single almost round spot, in the upper part of a large group of faculæ. Higher on the left, quite near the edge of the disc, a conspicuous dark spot may be seen, having a white cloud or facula on its left and apparently over it. Another umbra lies to the left of this, almost lost in the dark shading due to absorption of light by the solar atmosphere, which produces its greatest effect at the edge of the disc. Almost exactly at the left edge of the disc, wholly lost in the print but plainly seen in the negative, two large spots are just coming into view. The rotation of the Sun once in 26 days carries the spots across the disc approximately from east to west, so that these spots on the next day are well in view.

Many finer details which cannot be brought out in the engraving, such as the fine mottling or grain of the solar surface, are to be seen in the photographic print and still better in the negative.

SPECTROSCOPIC NOTES.

The important Potsdam investigation of the spectra of 528 stars (*Untersuchungen uber die Spectra von 528 Sternen.* H. C. Vogel und J. Wilsing. *Potsdam Publicationen No. 39*) is the subject of an appreciative review in the *Astrophysical Journal* for December, where the chief results are more accessible than in the original memoir. The stars under investigation are mostly of Class I, to which the photographic method with the ordinary plates is well adapted, and the list includes all the brighter stars of that class. The instrument employed was one of moderate power only, sufficient to give photographs suitable for comparison and classification. Class I is thus subdivided:—

Ia1. Spectra containing only strong hydrogen lines.

Ia2. Spectra containing strong hydrogen lines, and faint metallic lines, with *K* a sharply defined line.

Ia3. Spectra containing strong hydrogen lines, numerous metaliic lines, with *K* strong and usuallv a diffuse band.

Ib. Spectra containing strong hydrogen lines, helium lines, and some metallic lines.

Ic1. Spectra containg bright hydrogen lines.

Ic2. Spectra containing bright hydrogen lines, and bright helium lines, and perhaps other bright lines.

The distribution by number is, Ia1, 44; Ia2, 168; Ia3, 68; Ib 100; Ic1, 3; Ic2, 2; together with a few given as intermediate between various classes. The spectra of the two stars of Ic2 belong also to Ia2 by reason of the presence of helium lines. The review summarizes the section of the work devoted to a discussion of stars with remarkable spectra,—such as φ Persei, γ Cassiopeiæ, β Lyræ, P Cygni,—and closes with an account of the companion of the Potsdam with the Harvard results and classification.

Herr Belopolsky contributes to the *Astrophysical Journal* for December the results of his investigation at Pulkova of the spectrum of P Cygni. In this star, which shows the hydrogen and other lines both bright (Ic2 in the Potsdam classification) and dark, the bright lines are seen to be about in coincidence with the comparison lines, while the dark lines are strongly displaced toward the violet. Herr Belopolsky finds a bright and dark line in the star's spectrum corresponding to each of the several comparison air lines due to nitrogen.

In the *Observatory* for December, Mr. Newall announces his confirmation of Professor Campbell's discovery that Capella is a spectroscopic binary; and states that before Professor Campbell's note on the subject had been received in England he had presented a short preliminary note to the Royal Astronomical Society to announce the binary nature of the star.

Dr. Wilsing describes in the *Astrophysical Journal* for December the Potsdam photographic photometer, with which his measures of the relative albedo of Mars and Jupiter were made.

In the conferring of the British new year's honors, Captain William deW. Abney, whose researches in photography are well known to students of the science, and who was the first to photograph the infra-red of the solar spectrum, was designated a Knight Commander of the Bath (K. C. B.).

In his letter to the Board of Visitors to the Naval Observatory at Washington Professor Brown, writing in anticipation of his recent appointment to the position of Astronomical Director of the Observatory, states that the necessary accessories have been provided to enable the Naval Observatory to join in the work of determining motions of stars in line of sight, and that such observations are now a part of the routine work of the Observatory. He expresses his opinion that the time of the 26-inch telescope should be divided equally between this work and micrometric measures.

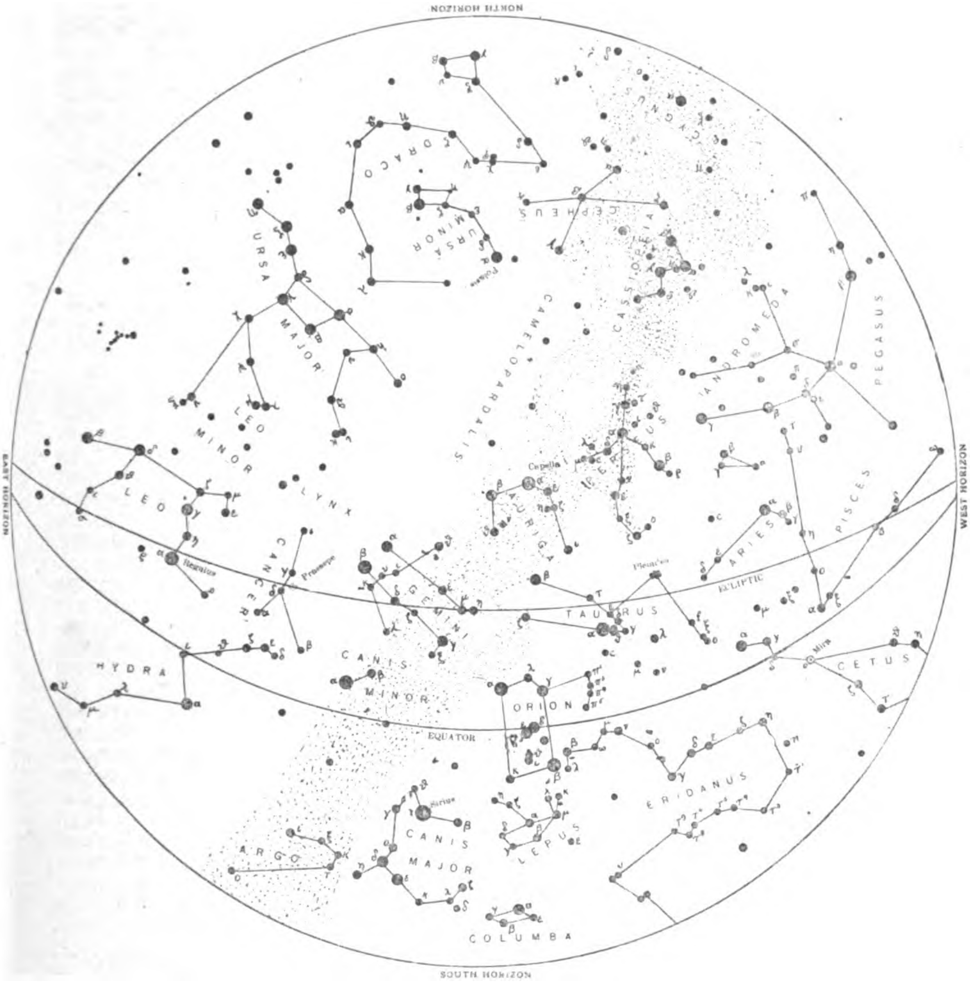
The *Astrophysical Journal* for December contains a short note by Professor Young on his original mistaken identification of the corona line with the 1474 chromosphere line. He states that his plan of placing the micrometer wire on the corona line, at the last moment, to fix its position was frustrated both in 1870 and in 1878 by the premature ending of totality.

PLANET NOTES FOR FEBRUARY.

H. C. WILSON.

Mercury will be behind the Sun during this month, passing superior conjunction Feb. 9, and coming out so as to be visible as evening star in the last days of the month. Mercury passes Mars on the morning of Feb. 3, when both planets will be invisible.

Venus is exceedingly brilliant now in the early evening, and may be seen with the naked eye at any time in the afternoon if one knows just where to direct the eye. Her position is becoming more favorable all the time and her brightness steadily increasing, while she now outshines many fold any of the stars. Observations, however, must be made early in the evening, preferably before sunset, for Venus sets at about 8 o'clock on Feb. 1 and at about 9 o'clock at the end of the month.



THE CONSTELLATIONS AT 9 P. M., FEBRUARY 1, 1900.

Mars was at conjunction with the Sun Jan. 15 and moves so slowly, relative to the Sun, that he will not be observable for several months.

Jupiter will be at quadrature, 90° west from the Sun, Feb. 28, and so may be observed in the morning an hour or two before sunrise. The altitude of Jupiter will, however, be too low for favorable observations.

Saturn may also be seen in the morning toward the southeast but in less favorable position than that of Jupiter, so that most of us will wait until the spring and summer months for our study of this wonderful planet.

Uranus is in Scorpio between Jupiter and Saturn (see chart in Jan. 1900 No. of POPULAR ASTRONOMY, p. 39), and so to be seen under the same unfavorable conditions.

Neptune is the only planet which can be seen in the evening at a high altitude. This planet requires a powerful telescope to show its disc, but it may be seen and its movement noted with a telescope of three or four inches aperture. It is to be found in the region northeast of the star ζ Tauri, R. A. Feb. 1, $5^h 36^m 12^s$, Decl. + 22° 3′; Feb. 28, R. A. $5^h 35^m 2^s$, Decl. + 22° 4′.

The Moon.

		Phases.	Rises.			Sets.		
			(Central Standard Time at Northfield; Local Time 13m less.)					
			h	m		h	m	
Feb.	6	First Quarter..............	10	42	A. M.	2	09	A. M.
	14	Full Moon.....................	6	11	P. M.	7	17	"
	22	Last Quarter.................	1	23	A. M.	10	33	"
Mar.	1	New Moon....................	6	32	"	6	47	P. M.

Occultations Visible at Washington.

				IMMERSION.			EMERSION.				
Date. 1900.		Star's Name.	Magnitude.	Washington M. T.		Angle f'm N pt.	Washington M. T.		Angle f'm N pt.	Duration.	
				h	m	°	h	m	°	h	m
Feb.	2	19 Piscium	4.9	10	34	105	11	12	218	0	38
	4	104 Piscium	7.5	12	10	47	12	52	288	0	42
	5	27 Arietis	6.3	10	35	118	11	21	223	0	46
	6	τ^1 Arietis	5.3	8	16	52	9	24	291	1	08
	6	65 Arietis	6.0	9	16	50	10	16	298	1	00
	7	χ^1 Tauri	4.7	11	32	94	12	36	272	1	04
	7	χ^2 Tauri	6.3	11	36	115	12	35	251	0	59
	11	5 Cancri	6.3	13	50	169	14	33	241	0	43
	13	*h* Leonis	5.7	9	51	85	11	05	334	1	14
	15	p^2 Leonis	5.4	12	13	139	13	40	291	1	27
	16	B.A.C. 4006	6.1	15	31	162	16	37	262	1	06
	17	*q* Virginis	5.7	13	34	152	14	51	275	1	17
	21	δ Scorpii	2.6	18	49	37	19	35	335	0	46
	22	15 Ophiuchi	7.3	12	12	65	12	59	317	0	47
	22	22 Ophiuchi	6.7	17	17	44	18	11	327	0	54
	24	31 Sagittarii	7.0	16	39	142	17	18	209	0	39

VARIABLE STARS.

J. A. PARKHURST.

Maxima and Minima of Long Period Variables.

MAXIMA.

1900 Feb.

	Mag.	Day.
845 R Ceti	8.2	1
1635 R Reticuli	7	16
2445 W Monocerotis	8.8	28
2776 W Puppis	9.5	2
2857 U Puppis	8.8	27
3495 *l* Carinæ	3.7	27
(3879 RR) Hydræ	8.5	6

MINIMA.

1900 Feb.

	Mag.	Day.
466 U Piscium	14.7	15
782 R Arietis	12	16
893 U Ceti	12	8
980 V Persei	10	8
2528 R Geminorum	13.5	9
2625 V Geminorum	13	23
2676 U Monocerotis	7.1	25

MAXIMA.

1900 Feb.

		Mag.	Day.
3890	W Leonis	9	17
5037	RR Virginis	11	27
5174	RS Virginis	8.2	6
5504	S Coronæ	7.0	28
5644	Z Libræ	11	23
5758	X Herculis	6.1	17
5795	W Scorpii	10.6	20
5830	R Scorpii	10	9
5955	R Draconis	7.6	15
6794	R Lyræ	4.0	9
6892	RX Sagittarii	9.9	7
6900	W Aquilæ	7.5	26
7106	S Vulpeculæ	8.7	13
7260	Z Aquilæ	8.9	16
7456	RR Cygni	8.4	5

March.

		Mag.	Day.
103	T Andromedæ	8.0	16
114	S Ceti	7.5	12
494	R Sculptoris	6.6	20
715	S Arietis	9 5	15
1222	R Persei	8.5	22
1383	T Eradini	7 2	26
1582	S Tauri	9.7	21
1717	V Tauri	8.9	7
2583	L Puppis	3.5	14
2676	U Monocerotis	8.6	15
2780	T Geminorum	8.4	17
3567	V Leonis	8.6	28
4471	T Canum Venaticor.	8.7	31
4511	T Ursæ Majoris	7.3	14
4521	R Virginis	7 3	3
4896	T Centauri	5.9	8
5438	Y Libræ	8.5	14
5566	RU Libræ	8.5	26
5617	U Libræ	9	11
5752	RZ Scorpii	7.8	18
5950	W Herculis	8.2	30
6225	RS Herculis	8.0	25
6512	T Herculis	7.7	24
6682	X Ophiuchi	7.9	7
6794	R Lyræ	4.0	27
6921	S Sagittarii	9.8	13
7085	RT Cygni	7 3	5
7257	R Sagittæ	8.6	18
7431	S Delphini	9.1	29
8324	V Cassiopeæ	7.5	7

MINIMA.

1900 Feb.

		Mag.	Day.
2742	S Geminorum	< 13.5	8
2976	V Cancri	12	19
3495	*l* Carinæ	5.2	13
3825	R Ursæ Majoris	12.9	23
4557	S Ursæ Majoris	10.9	8
6100	RV Herculis	< 15	12
7252	W Capricorni	< 14.7	24
7571	V Capricorni	14 ?	6
7999	X Aquarii	13	25
8068	S Lacertæ	< 12	28

March.

		Mag.	Day.
146	T Sculptoris	10.0	14
1577	R Tauri	13.0	18
2690	X Puppis	9.6	7
3477	R Leonis minoris	13	8
3495	*l* Carinæ	5.2	21
3637	S Carinæ	9.1	17
3994	S Leonis	< 13	7
4425	X Centauri	12.4	13
4596	U Virginis	12.5	31
4826	R Hydræ	9.7	25
4940	W Hydræ	8.0	14
5095	R Centauri	9.3	27
5249	V Libræ	12.2	20
5430	T Libræ	< 14.7	13
5758	X Herculis	7.0	21
6132	R Ophiuchi	< 12	27
6549	W Lyræ	12	18
6794	R Lyræ	4.7	5
6899	U Draconis	< 13	15
7106	S Vulpeculæ	9.5	26
7242	8 Aquilæ	11.3	18
7257	R Sagittæ	10.1	2
7754	W Cygni	6.4	11
8373	S Pegasi	13	6

AUTHORITIES FOR THE ABOVE EPHEMERIS. The dates for the ephemeris of long-period variables are taken from M. Loewy's ephemeris as published in the *Companion to the Observatory* for 1900. The magnitudes are taken from Chandler's Third Catalogue for the stars contained in it, for the remainder they are taken from later announcements in the *Astronomical Journal*, or from personal observations. For the Algol-stars, the ephemeris for S Velorum and RS Sagittarii was computed from the elements in Chandler's Third Catalogue; for W Delphini from the same source; for + 12° 3557 from Luizet's elements in No. 3596 of the *Nachrichten*; for + 45° 3062 from Professor Pickering's elements in No. 3581 of the *Nachrichten*. The data for the rest of the Algol-stars were taken from M. Loewey's ephemeris in the *Companion to the Observatory*, but the times there given are not the ordinary Astronomical Time, reckoning from noon to noon, but reckoned from the previous midnight, as for civil time, so that 12^h must be subtracted from the times as above given, to reduce to Greenwich Time. This matter was evidently overlooked by the editors of the *Companion*, for the statement is made in the introduction, "Greenwich Mean Time is used in all cases, and the astronomical day is reckoned from noon to noon as in previous years."

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900 March.

U CEPHEI.

	d	h
Mar.	3	17
	8	17
	13	16
	18	16
	23	16
	28	15

ALGOL.

	d	h
Mar.	11	18
	14	15
	17	12

λ TAURI.

	d	h
Mar.	8	17
	12	16
	16	15
	20	13
	24	12

S. CANCRI.

d	h
6	18
16	5
25	17

R CANIS MAJ.

Every 3d min.
$P = 1^d 3^h.3$

	d	h
Mar.	3	13
	6	23
	10	9
	13	19
	17	4
	20	14
	23	24
	27	10
	30	20

S VELORUM.

	d	h
Mar.	1	12
	7	10
	13	9
	19	7

δ LIBRAE.

	d	h
Mar.	2	20
	7	12
	16	19
	21	11
	30	18

U CORONAE.

	d	h
Mar.	5	9
	8	20
	12	7
	15	18
	19	5
	22	16
	26	2
	29	13

U OPHIUCHI.

Every 4th min.
$P = 20.1^h$

	d	h
Mar.	2	0
	5	8
	8	17
	12	1
	15	10
	18	18
	22	3
	25	11
	28	20

W. DELPHINI.

	d	h
Mar.	18	19
	23	15

RS SAGITTARII.

	d	h
Mar.	1	16
	6	11
	8	21
	13	17
	18	13
	25	19
	30	15

+ 12°3557

Mar.	6	21
	7	19
	8	16
	14	21
	15	19
	16	16

+ 45°3062.

	d	h
Mar.	5	6
	9	20
	14	10
	19	0
	23	13
	28	3

SS CYGNI. The abnormal maximum which was described in the January number of this magazine, has evidently made no interruption in the regular order of procedure with this remarkable star, for it rose suddenly to a maximum of the usual type some time between 1899, Dec. 30, and 1900, Jan. 1. Mr. Sperra fixed the above limits. I found it normal Dec. 29 and bright, about 8.6 magnitude Jan. 1.5. Mr. Flanery found it bright Jan. 2. This rise is about a week earlier than the ephemeris time given in Vol. VII, page 149, a correction quite comparable with those deduced from late maxima. In the table at the top of page 47 in the January number there should be 14 observations by J. A. Parkhurst, instead of 41.

DENSITIES OF ALGOL-TYPE VARIABLES. In the *Astrophysical Journal* for December, 1899, there are two interesting articles on the above subject, by Alexander Roberts and Henry Norris Russell. Mr. Russell says in introduction: "It is possible in the case of an Algol-star, assuming the eclipse theory of its variation, and a circular orbit, to deduce a limiting value for its mean density from its period and the duration of its light-variation, any uncertainty as to the result being due to the uncertainty in the ratio between these two quantities, which is, as a rule, not yet very accurately determined." His results for "the seventeen known Algol-variables" are as follows—

Star.	Maximum Density.
320 U Cephei	0.098
1090 β Persei (Algol)	0.139
1411 λ Tauri	0.142
2610 R Canis Maj.	0.366
3055 X Carinae	0 261
3109 S Cancri	0 035
3416 S Velorum	0.061
5374 δ Librae	0.058
5484 U Coronae	0.137
5949 R Arae	0.145
6189 U Ophiuchi	0.298
6442 Z Herculis	0.728
6546 RS Sagitarii	0.086
7399 W Delphini	0.170
7488 Y Cygni	0.212
+12°3557	0.320
+45°5062	0.076

Mr. Roberts confines his attention to four stars whose elements are found from his own numerous observations at Lovedale, South Africa.

His results are in part—

3416 S Velorum, Bright star 0.61, Faint star, 0.03.
3055 X Carinae, Assuming equal masses, 0.125.
—— Lac 5861, Assuming equal densities, 0.14.
6546 RS Sagittarii, Bright star, 0.16, Faint star 0.21.

COMET AND ASTEROID NOTES.

Holmes' Comet.—In *Astronomische Nachrichten* No. 3610, Mr. H. J. Zwiers gives an extension of his ephemeris of Holmes' comet from Jan. 1 to Feb. 12, 1900. He says that he does not think that the comet can be observed in the second half of February. It is very doubtful whether the comet can be seen in the first half of the month. It has been exceedingly faint at best during this apparition, and its theoretical brightness is waning rapidly. No observations have been reported except with the most powerful telescopes.

Ephemeris of Holmes' Comet, *d* 1899.

1900		R. A.			Dec.			τ (Aber.)	log Δ
		h	m	s	°	′	″	d	
Feb.	1	2	35	52.32	+39	27	36.6	0.01500	0.414920
	2		37	02.99	39	24	12.0	.01510	.417635
	3		38	14.56	39	20	54.0	.01519	.420339
	4		39	27.01	39	17	42.5	.01529	.423033
	5		40	40.32	39	14	37.4	.01538	.425716
	6		41	54.46	39	11	38.5	.01548	.428387
	7		43	09.43	39	08	45.8	.01557	.431047
	8		44	25.10	39	05	59.1	.01567	.433696
	9		45	41.75	39	03	18.3	.01576	.436332
	10		46	59.06	39	00	43.2	.01586	.438956
	11		48	17.11	38	58	13.8	.01595	.441568
	12	2	49	35.88	+38	55	49.8	0.01605	0.444167

Tempel's Second Comet *c* 1899 (1873 II.)—This comet was observed at Lick Observatory by Professor Aitken on 10 nights, from Aug. 11 to Sept. 26. "In August and early in September the comet nucleus was very sharp, and the comet bright—easily visible in a 3½-inch telescope. On Sept. 26 it was faint enough to be difficult with the 12-inch refractor."

The same comet was also observed on twenty nights from July 11 to Sept. 9 with the transit circle of the Royal Observatory, Cape of Good Hope.

New Elements of Eros (433).—In *Astronomische Nachrichten* No. 3609 E. Millosevich gives elements of Eros based upon all available observations from Nov. 1898 to April 1899, combined into seventeen normal places.

Epoch and Osculation. Oct. 31.5, 1900, Berlin mean time.

$$\begin{array}{rl} M &= 304^\circ\ 23'\ 59''.7 \\ \left.\begin{array}{r} \pi \\ \omega \\ \Omega \\ i \end{array}\right. & \left.\begin{array}{l} = 121\ \ 09\ \ 22.0 \\ = 177\ \ 38\ \ 41.6 \\ = 303\ \ 30\ \ 40.4 \\ = \ \ 10\ \ 49\ \ 38.9 \end{array}\right\}1900.0 \\ \varphi &= \ \ 12\ \ 52\ \ 48.2 \\ \mu &= 2015''.12740 \text{ (Period 643.14 days).} \\ \log a &= 0.1638027 \end{array}$$

An epemeris for the next opposition is given, extending from Sept. 1, 1900, to Jan. 31, 1901. The brightness of the planet will increase from 11.0 mag. Sept. 1 to 8.4^m Dec. 30 and after that diminish slowly.

Elements of Asteroid 1899 EY.—A supplement to *Astronomishe Nachrichten*, No. 3612, gives elements by Otto Knopf of the asteroid discovered by Charlois on Dec. 4, 1899, which was noted as being exceptionally bright for a newly discovered asteroid.

Epoch Jan. 0.0, 1900, Berlin mean time.

$$\begin{array}{rl} M &= 345^\circ\ 32'\ 15''.3 \\ \left.\begin{array}{r} \omega \\ \Omega \\ i \end{array}\right. & \left.\begin{array}{l} = \ \ 3\ \ 32\ \ 19\ .9 \\ = 89\ \ 46\ \ 43\ .3 \\ = 15\ \ 22\ \ 20\ .0 \end{array}\right\}1900.0 \\ \varphi &= \ \ 5\ \ 13\ \ 16.4 \\ \mu &= 651''.293 \\ \log a &= 0.490821 \end{array}$$

The orbit is not very eccentric ($e = 0.09$) and the distance from the Sun is greater than the average for the asteroids, so that the brightness of this planet is not due to a near approach to the Earth but to relatively great size or albedo.

An ephemeris for the first few days of February follows. The brightness on Feb. 9 is calculated to be 10.2 magnitude.

		R. A.			Dec.		log *r*	log *Δ*
		h	m	s	°	′		
Feb.	1	4	10	44	+ 18	50.4	0.4500	0.3623
	3		11	19	+ 19	01.9		
	5		11	59	+ 19	13.5	0.4499	0.3719
	7		12	46	+ 19	25.0		
	9	4	13	39	+ 19	36.6	0.4498	0.3814

GENERAL NOTES.

Western Australia.—Meteorological report is received from Perth Observatory, for year 1898, W. E. Cooke, Gov. Astronomer. It is a very full report with 24 full page colored maps.

The Solar Parallax.—In *Comptes rendus* (Vol. 129, pp. 986-993) M. Bouquet de la Grye gives the results of a discussion, of the observations by the various French expeditions which observed the Transit of Venus in 1882. In this discussion an important fact is brought out which may not have come to the attention of observers very generally. It is the fact that the time of external contacts is influenced by the size of the telescope. In the case of internal contact the author does not find any difference due to size of instrument.

With large telescopes, observations show $p = 8''.7996$
" small " " " $p = 8\ .8068$

From these results the mean parallax comes out 8″.80 from the visual observations of the French parties. The photographic results are not yet known.

In 1888, Professor Young stated in the first edition of his General Astronomy that the solar parallax is very nearly 8″.80. Twelve years has not changed the value.

Duplicity of *r* Tauri.—Professor G. W. Hough in *Astronomical Journal*, No. 474, states that the fourth magnitude star *r* Tauri probably has a close companion of the ninth magnitude, the position angle being north preceding and the distance from 0″.15 to 0″.4. He infers this from an observation of an emersion of the star from behind the disc of the Moon, Oct. 21, 1899, when the star reappeared first as a star of the ninth magnitude and after an interval of rather more than one second flashed out in full brightness. He examined the star on one good night with the 18½-inch refractor of Dearborn Observatory, but failed to see the companion.

To Observe the Solar Eclipse in Africa.—On Jan. 15, Mr. Percival Lowell, of Lowell Observatory, Flagstaff, Arizona, and Professor David P. Todd, of Amherst College Observatory, left in the *St. Paul*, for Africa to observe the total solar Eclipse of May 28, 1900. Mr. Lowell's many friends will be glad to learn of the improved condition of his health which allows him to undertake such a sea voyage. After a fortnight in London they will go to Paris, Nice, Marseilles, and perhaps to Rome and Milan. Then they sail for northern Africa to find in Algeria or in Tripoli some suitable point in the path of totality for the observations of the eclipse desired.

The British Astronomical Association Expedition to Observe the Total Solar Eclipse.—We have just received information regarding the proposed expedition of the British Astronomical Association to observe the total solar eclipse of May 28, 1900, in Spain and Algeria, northern Africa. An extract from the circular received from London will interest some American readers:—

"Subject to a sufficient number of passages being actually taken before January 31, the following arrangements have been made for the proposed expedition to Spain and Algeria.

The Royal Mail Steamer, "Tagus," (5,545 tons, 7,000 H. P.) or a sister vessel, will be engaged for the exclusive use of the Members of the British Astronomical Association and friends introduced by them, and will start from Southampton at 6 P. M. on Friday, May 18, and the following itinerary will be adopted:—

Leave Southampton	6 P. M.	Friday	18th May.
Arrive Cadiz	6 A. M.	Tuesday	22d "
Leave "	8 A. M.	"	" "
Arrive Alicante	noon	Wednesday	23rd "
Leave "	4 P. M.	"	" "
Arrive Algiers	6 A. M.	Thursday	24th "
Leave "	6 P. M,	Tuesday	29th "
Arrive Alicante	6 A. M.	Wednesday	30th "
Leave "	9 A. M.	"	" "
Arrive Gibraltar	7 A. M.	Thursday	31st "
Leave "	noon	"	" "
Arrive Lisbon	10 A. M.	Friday	1st June
Leave "	7 P. M.	"	" "
Arrive Southampton	7 A. M.	Monday	4th "

It is expected that the Members of the Association will divide themselves into three pricipal groups:—

1st. Those observing the Eclipse in the interior of Spain.
2nd. " " " " at Alicante or neighborhood.
3rd. " " " " in Algeria, where the ship will act as an Hotel for all those who wish to use it in that capacity.

The first party will, it is expected, break up into two chief sections—those who will alight at Cadiz and rejoin the ship at Alicante, and those who, alighting also at Cadiz, will rejoin the ship at Gibralter."

The Leonids in India.—Miss Moulton's report of observations of the Leonids and the Andromedes is full and interesting. We regret that we have not space for it all and the chart kindly furnished. The following extracts are made:

"On the night of the 14th and morning of the 15th the record is as follows:

Time.	Meteors.	Leonids.
1:00–3:30	29	10
3:30–3:50	9	7
3:50–4:5	17	9
4:05–4:20	13	6
4:20–4:35	20	11
4:35–4:45	23	11
4:45–5:	24	8
5: –5:15	14	7
5:15–5:20	20	11
5:30–5:37	10	4
Total	179 of which	84

I watched from 11 till 5:45. The bright Moon made much difference with the number seen, undoubtedly. At 2:35 was a bright fire ball, leaving a trail of greenish yellow light behind' and at 5:01 there were two more like it.

On Monday, the 27th, I watched for Andromedes. This is the result:

	Meteors.		Andromedes.
8:30– 9:15	13	of which	5
9:15–10:10	12		3
10:10–10:40	6		1
10:40–11:20	14		1
11:20–11:40	12		3
	Total 57	of which	13 were Andromedes.

On Tuesday, Nov. 28:

8:30– 9:15	15		1
9:15–10:05	11		1
10:05–10:30	10		1
	36	of which	3 were Andromedes.

MARY ETTA MOULTON.

WAI, SATARA DISTRICT, India, Dec. 7, 1899.

Density of Variable Stars of the Algol Type.—The last number of the *Astrophysical Journal*, Dec., 1899, contains two very interesting brief articles on this subject. Both writers, Mr. Alexander Roberts, of Lovedale, South Africa, and Mr. Henry Norris Russell, of Princeton University, attempt to obtain, from the data of the light variations of the stars, maximum limits for the densities of the stars as compared with our Sun. The Algol Variables are assumed to be exceedingly close double stars whose components eclipse each other at regular intervals. Mr. Roberts finds the densities of the two components separately using the formulae

$$\text{Density of (1)} = \frac{(0.0092)^3}{p^3\,t^2}\left(\frac{m_1}{m_1+m_2}\right);$$

$$\text{Density of (2)} = \frac{(0.0092)^3}{q^3\,t^2}\left(\frac{m_2}{m_1+m_2}\right);$$

in which t is the periodic time in years, m_1 and m_2 are the masses of the components, and pr and qr are their respective diameters, r being the semi-major axis of the orbit. Since $\frac{m_1}{m_1+m_2}$ and $\frac{m_2}{m_1+m_2}$ must always be less than unity, practical upper limits for the densities are given by the expressions

$$d_1 = \frac{(0.0092)^3}{p^3\,t^2} \text{ and } d_2 = \frac{(0.0092)^3}{q^3\,t^2}.$$

The constant 0.0092 is not explained by the writer but we assume it to be the diameter of the Sun in astronomical units.

Treating four southern stars which he has had especially under observation Mr. Roberts obtains the following results:

	Period. t			Duration of Minimum.		p	q	d_1	d_2
	d	h	m	h	m				
X Carinæ	0	13	00	6	30	0.71	0.71	0.25	0.25
S Velorum	5	22	24	14	50	0.17	0.46	0.61	0.03
Lal. 5861	0	14	32	7	16	1.0	1.0	0.27	0.27
RS Sagitarii	2	9	59	10 7	40 00	0.48	0.44	0.16	0.21

If the masses of the two components in each were assumed to be equal, then $\frac{m_1}{m_1 + m_2}$ and $\frac{m_2}{m_1 + m_2}$ would each be one-half and each of the densities given above would be divided by two. The average density of these four stars would then be 0.13 or only one-eighth that of the Sun.

Mr. Russell attempts only to find the average density of each system, but by a different method reaches very similar results. He finds as an expression of the upper limit of density

$$\rho \leqq \frac{3K}{\pi t^2 \sin^3 \frac{\pi d}{t}}$$

in which t is the period of the variability, d the duration of light variation, and $\frac{3K}{\pi}$ is found from the density of Earth (5.53) to be 44.1. The results for 17 stars are as follows:

No. in Chandler's Catalogue.	Name.	t in hours.	d in hours.	Limit of Density.
320	U Cephei	59.82	10.	0.098
1090	B Persei	68.81	9.15	0.139
1411	λ Tauri	94.87	10.	0.142
2610	R Canis Maj.	27.26	5.	0.366
3055	χ Carinæ	13.00	6.5	0.261
3109	S Cancri	227.63	21.5	0.035
3416	S Velorum	142.40	15.2	0.061
5374	δ Libræ	56 85	12.	0.058
5484	U Coronæ	82.85	9.75	0.137
5949	R Aræ	106.21	10.3	0.145
6189	U Ophiuchi	20.13	5.1	0.298
6442	Z Herculis	95.82	5.3	0.728
6546	RS Sagittarii	57.93	10.4	0 086
7399	W Delphini	115.35	10.	0.170
7488	Y Cygni	71.90	8.	0.212
	DM. + 12°3557	21.35	5.	0.320
	B. D. + 45°3063	109.75	13.	0.076

The Corona of the Sun Visible Without an Eclipse.—From an article elsewhere published in this number it will be seen that Professor E. Miller, of the University of Kansas, has been trying to make visual observations of the Corona of the Sun without the aid of the Moon at time of total solar eclipse. He feels quite sure that he has succeeded in the attempt, and definitely and clearly states how it was done. He would have made more observations if it had been possible then or since for him to do so. We are sure, from correspondence and from the language of the article, that he feels the need of more evidence to substantiate the large and wonderful claim that he makes, than has yet been secured. We are also sure that our readers will say, that there must be some mistake about this single observation, and some cause for the peculiar phenomenon which he saw, that is yet unexplained and that the picture is not one of the Corona, although it looks somewhat like that which should appear in the polar regions of the Sun. We are anxious that Professor Miller shall have the full benefit of the earliest announcement possible to him, for any such notable discovery as it *may be possible* to make in this way. We urge him to try again and so learn, by varied trials, whether he can see the Corona in this way beyond a reasonable doubt.

Modern Astronomy.—Messrs. Wm. Wesley and Son, scientific booksellers and publishers, 28 Essex Street, London, England, have recently issued a scientific and natural history book circular (No. 135), which deals with modern astronomy in a helpful way. It is nothing less than a classified catalogue of books and pamphlets on modern astronomy. It embraces the literature on the subject since 1800, including the libraries of Edwin Dunkin, Rev. A. Freeman, J. R. Hind, A. Marth and E. J. Stone. The classification of the catalogue appears under 35 heads making the reference to any astronomical theme very easy and certain. Under these heads are classified 2240 books and pamphlets treating of subjects comprising the whole range of modern astronomy during the 19th century. Under each separate head the authors' names are alphabetically arranged and printed in heavy-faced type so as to be very easily caught by the eye as the index list is scanned. We do not know of any catalogue compilation in the interest of general astronomy that is so complete and useful generally, as this new Wesley catalogue, for the period of time it covers.

Honor for Dr. Wm. R. Brooks.—We have failed to notice, as promptly as we should have done, the deserved honor which has again been conferred on Dr. William R. Brooks of Smith Observatory, Geneva, N. Y. He has recently received the Lalande prize awarded by the Paris Academy of Sciences. In the language of the award it is bestowed "for numerous and brilliant astronomical discoveries." American astronomers are having their share of honors dispensed by the foreign learned societies. Congratulations to Dr. Brooks.

Occultations During the Eclipse of Dec. 16, 1899.—Below are given the local mean times of disappearance of a number of faint stars, observed with the twenty-inch refractor of the Chamberlin Observatory, the magnifying power being 200. The position angles are from the north point of the limb toward the east. As the Observatory has not received the European list no attempt has been made to identify the stars. The position of the Observatory is given in the American Ephemeris, under the heading Denver.

Magnitude.	Position Angle.	Mean Time.			Notes.
	°	h	m	s	
9.5	80 or 90	6	0	58.9	Good.
10.5	90	6	2	49.4	Poor.
7	70	6	7	32.6	Good.
10	70	6	16	22 9	Pretty good.
9.5	75	6	27	1.4	
11	65	6	27	46.4	Rather poor.
10	65	6	29	1 9	Good.
10	55 ±	6	29	5.8	Good.
11	53	6	34	44.4	
10.5		6	36	22.6	
10.5	0	6	40	25.3	Uncertain.
10.5	60	6	54	0.8	Time late, from faintness of star.
10	45	6	56	35.2	Pretty good.
10.5	65	7	3	36.3	Pretty good.
8	75	7	24	10.8	Bad, because of brightness of Moon.
8	15	7	32	21.0	Pretty good.

HERBERT A. HOWE.

UNIVERSITY PARK, Colorado.

Solar Eclipse, May 28, 1900.—Phases for Latitude 37° 30′ N. Longitude, 94° 16′ W ($6^h\ 17^m\ 4^s$), which point is near Lamar, Barton Co., Mo.

Eclipse begins	$6^h\ 37^m\ 19^s$	Central Time. A. M.
Greatest Observation	$7^h\ 39^m\ 36^s$	
Eclipse ends	$8^h\ 48^m\ 24^s$	
Duration	$2^h\ 11^m\ 5^s$	

Nearest approach of centres of Sun and Moon 410″.
Magnitude .7878. Sun's diameter unity.

	POSITION ANGLE.	
First Contact	25°	South of West.
Last Contact	49′ 28″	North of East.
	On the Sun's disc.	

Calculation by ORRIN E. HARMON.

LIBERAL, Barton Co., Mo.

Staff of the United States Naval Observatory.—The following changes in the personnel of the Observatory have taken place during the fiscal year:

Capt. Charles H. Davis, U. S. N., reported for duty as superintendent on November 1, 1898, relieving Commodore Robert L. Pythian, U. S. N., who was detached on that date.

Lieut. Charles C. Marsh, U. S. N., reported for duty on January 26 and was assigned to the department of nautical instruments, but was detached on January 30, 1899.

Lieut. A. N. Mayer, U. S. N., in charge of the departments of nautical instruments and chronometers and time service, reported for duty on September 16, 1898, and was detached on June 20, 1899.

Lieut. Ben W. Hodges, U. S. N., reported for duty on June 28, 1899, and was assigned to the departments of nautical instruments and chronometers and time service.

Computer M. E. Porter was detached from the transit circle and sent to the time service on July 15, 1898.

Prof. John R. Eastman was retired for age July 29, 1898, but on account of the Spanish war he remained on duty at the Observatory until October 12, 1898. He was originally appointed as aid on November 7, 1862, and was promoted to be professor of mathematics, United States Navy, February 17, 1865.

Mr. Aaron N. Skinner was promoted from assistant astronomer to professor of mathematics, United States Navy, on July 30, 1898. He has served continuously at the Observatory since March 28, 1870, when he was appointed an aid.

Mr. John N. James, electrician, resigned July 31, 1898.

Mr. R. H. Charles was appointed to be electrician August 1, 1898, vice Mr. John N. James, resigned. Mr. Charles was originally appointed as engineer February 17, 1898.

Mr. Frank B. Littell was promoted from computer to assistant astronomer on August 6, 1898.

Computer W. S. Eichelberger was transferred from the Nautical Almanac Office to the Observatory on August 15, 1898.

Mr. George H. Peters was appointed photographer on August 15, 1898, vice Charles T. Fellows, deceased.

Mr. William F. Gardner, instrument maker, died December 11, 1898. He was first employed in the Observatory on September 8, 1864, and was promoted to be instrument maker on November 1, 1866.

Mr. J. W. Davison, employed in the library, left the Observatory on February 3, 1899, and his place was supplied by Kenneth B Turner, formerly employed in the Treasury Department, with whom he had exchanged positions.

Professor T. J J. See reported for duty at the Observatory on March 2, 1899.

Professor H. M. Paul was detached from the Observatory on March 3, 1899.

Mr H. C. Cleve reported for duty as instrument maker on March 7, 1899, vice William F. Gardner, deceased.

Professor Edgar Frisby, U. S. N., was retired for age May 22, 1899. He was originally appointed as an aid on June 22, 1868, and was promoted to be professor of mathematics, United States Navy, June 11, 1878.

Rapid Change on the Surface of the Sun.—Caroline E. Furness in charge of the Observatory at Vassar College, Poughkeepsie, New York, was examining the surface of the Sun, with the telescope, Jan. 22, at about 3 o'clock in the afternoon, and noticed an interesting change going on at one point in the surface. When first looked at the solar surface was everywhere clear of spots. Fifteen minutes later, a very small spot was seen near the central region. The image of the Sun was thrown upon a screen and made about fifteen inches in diameter. The spot then appeared like a pin head. While watching it closely a second fainter one appeared near it, and presently two or three attendant darkenings which looked very much like the ordinary nodules, except that they were dark enough to stand out quite conspicuously against the mottled disc of the Sun. In ten minutes these dark bodies had faded so as to be scarcely visible, and only the first spot remained. As the Sun was low the observations could not be continued longer, and the next morning there was no trace of any disturbance.

It is true that important changes in the solar surfaces are contantly going on, yet it is somewhat rare to notice those that are so peculiar and so rapid.

Beman and Smith's Plane and Solid Geometry.—This book is a revision of one published by the same authors in 1895. The distinctive features of it are the retention of a minimum of formal proofs as models, and a maximum of unsolved and unproved propositions as exercises. The authors are fully aware of the late strong tendency to break away from the formal proofs of Euclid and Legendre, and to substitute for them methods of work calculated to lead the student to independent discovery. These authors do not believe that the best results in scholarship are to be gained in this way, but rather, that the student should be well started in the ways of geometrical thinking, by the use of good models of reasoning and some exercise in applying mathematical language to geometrical figures. When the student has some acquaintance these ways of elementary thinking, then the teacher may safely begin to exercise or tax the learner gradually and progressively on the side of training which is sometimes called invention or discovery.

In this we think these authors judge wisely. We believe they are right.

The ideas of modern geometry that simplify the ancient methods find deserved place in this revision. The free use of various kinds of symbols to abbreviate definitions and proofs is in full keeping with modern ways that are in general favor. The manifest gain in this way of writing is the advantage in holding the attention of the student, while he is trying to master a given course of reasoning, or to gain knowledge of an unfamiliar principle or concept. Clear and concise expression has great value if it be not so brief as to be ambiguous. The eminent and scholarly Loomis of Yale, years ago, used to call his students back to demonstrations in geometry a second time often, and say "now, have given those proofs in the best way possible! Try again."

As far as we have had opportunity to examine this book, it appears to be work very well done. It is expected that the publishers will do their work well, for Messrs. Ginn & Company always do their part admirably.

Holden's Elementary Astronomy.—This new book is published by Messrs. Henry Holt & Company, and is one volume in the elementary course of the American Science series which is being issued by the same publishers. It is a beginner's text-book and contains 446 pages with ample illustration, which is neat, well-chosen and not obtrusive. The book is a condensation of two others written by Professors Newcomb and Holden about twenty years ago for this same science series. Though a condensation in matter, it is entirely re-written and many new illustrations added which makes the book to well represent the state of the present advancement of astronomy in phases most useful for elemental study. We are pleased to notice how aptly and well the author has presented in illustration and happy expression the more difficult topics that must receive some attention even in an elementary text-book. One illustration of this is a cut representing the fall of rain in which a man, a horse and a train of cars are running at different rates of speed. The drops appear to be falling vertically over adjacent houses, obliquely against the man, and more and more so against the horse and the more rapidly moving train. It is a most delicate art to illustrate well, especially if the theme is a hard one to comprehend in the most favorable light that may be shed upon it. This is certainly true in the case of the aberration of light.

Another excellent illustration is the two page cut of the Moon with numbers and names on the picture, and outside on the same page, are found 189 names of objects referred to and located on the map in the proper quadrant to which each one belongs. This scheme is an admirable key to guide anyone in elementry stuy of the lunar surface.

The later ways of presenting the themes of elementary astronomy by what is called the "laboratory" or the inductive method has reeeived some attention in this new book. It is done by means of lists of review questions, and cuts of simple apparatus which may be made easily by any one. This kind of exercise is made quite prominent and the teacher is expected to use his own judgment in emphasizing this part of the training exercise. From a perusal of the full and carefully written introduction, one will readily understand how important the author deems this kind of work. Professor Holden has prepared a first rate text-book and the publishers have done their part well. Teachers will examine it with interest and profit.

Scientific Thought of the Nineteenth Century is the title of an address, delivered before the Connecticut Academy of Arts and Sciences October 11, 1899, by Wm. North Rice. The purpose of the address was to call attention to a "single, broad, general aspect of the intellectual history of our age." In brief, it was to show how largely general ideas which make a distinction between the scientific and unscientific view of nature have wrought during the nineteenth century.

The first of these ideas is the extension of the universe in space. The unscientific mind looks upon the celestial bodies as belonging to the Earth, and as relatively small and near to it. The scientific mind knows that the stellar universe stretches away into illimitable space which outreaches all finite power or imagination to measure it.

Another idea is the extension of the universe in time. The unscientific mind does not know that the universe has a history. To such thought it is only chaos. To the scientific mind the universe is a cosmos. Its forces are not discordant however much they appear so. Polytheism is not a part of religion, for the scientific mind knows that this universe is dominated by a supreme unity, imminent in all things in time and space.

A third idea is the unity of the universe. To the unscientific mind the processes of nature are thought of as acting independently and often in discordant way, To the scientific mind the boundless complexity is pervaded by one system of law, intelligible, formulable throughout all its measureless extension in space and time.

The extension of the universe in space had its growth mainly in earlier times. The Greek geometers learned the approximate size of the Earth and the distance of the Moon. The Copernican system of astronomy as modified by Kepler gave the true idea of the solar system; the discovery of Neptune greatly increased its size, and the known distances of a few stars show the vast magnitude of the stellar universe as it is now approximately measured.

The extension of the universe in time was known to some extent in the time of Pythagorus from a study of the changes in the crust of the Earth, but Hutton's Theory of the Earth, in an important sense marked the beginning of modern theorizing as to the time from the study of Geology.

In this century is found the chief development of astronomy in regard to the history of the solar system. The work of Laplace, Kant, Swedenborg and Newton laid the foundation and the building thereupon has been large and amazingly rapid.

The author then speaks of spectrum analysis, conservation of energy, modern chemical philosophy and finally lauds lavishly the idea of evolution as the greatest intellectual achievemnt of our age. In one of his rhetorical flights, he sees "the author of that sublime Hebrew psalm of Creation, preserved to us in the first chapter of Genesis" as "evolutionist in his way," because he says "let the earth bring forth, let the waters bring forth." The idea, he thinks, is growth and not manufacture.

In the last paragraphs of the address the author professedly goes outside the realm of science to speak of Theology, the Church and the immanence of God. He fairly speaks of the influence of science on religious thought in such a way as not to disturb Christian faith in a real revelation. But when he implies the existence of such an imminent "Intelligence" in nature that there is no room for the "Carpenter God" of the old Theology as he chose to call Christ, then our instructor in Theology is assuming much that he evidently does know. That is unscientific assumption. That is begging the question more than Darwin and Huxley ever did when they honestly thought they had proved the origin of life in matter. Mr. Rice should review his logic before he makes another attempt of this kind.

Variables.—The following variables, though of small magnitude, were found with a four inch telescope without circles by the aid of the charts published in POPULAR ASTRONOMY.

The period of W Lyræ* is unknown and its variations seem to be of an irregular nature.

Oct. 11th, 1899.	W Lyræ is of 12th mag.
22d	It is of 10th mag.
23d	Do.
28th	It is about 9th mag.
31st	Of 10th mag.
Nov. 1st	Do.
4th	Of 9th mag.
6th	Do.
21st	Nearly 8.6 mag.
22d	Slightly decreased.
Nov. 29th, 1899.	About of 9 mag.
30th	Do.
Dec. 1st	Do.
2d	Do.
3d	Do.
5th	Do.
6th	Do.
17th, 18th and 19th	it was fully equal to adjacent star of 8.6 mag.

After this it was hidden from view at dusk by neighboring buildings but it is to be hoped that other observers traced its variations to a later date.

Madam Ceraski's† new Algol variable in Cygnus was observed as follows, the comparison stars being those so conveniently furnished by Mr. J. A. Parkhurst:

Nov. 2d, 1899.	Barely visible in a high power.
4th	Nearly of 8.6 mag.
6th	Do.
21st	Do.
22d	Brighter than 9.6 mag. perhaps about 9th.
29th	Midway between the comparison stars of 8.6 and 9.6 mag.
30th	Do.
Dec. 1st	Do.
2d	Do.
3d	Of 9 6 mag.
5th	Brighter than 9 6
17th	Of 9.6 mag.
19th	Brighter than 9.6.
Dec. 20th	Do.
21st	Do.
22d	Nearly of 8.6 mag.
23d	Do.
24th	Of about 9 mag.
25th	Do.
26th, 6:30 P. M.	Invisible in a low power but in a high power it seems to be scarcely 12th mag.
27th, 7 P. M	It is very nearly of 8 6 mag.
Jan. 3d, 1900.	It is of 9th mag.
4th	Do. Night hazy.
5th	Do. Do.
8th	Of about 10th mag.

SAN FRANCISCO, January, 1900. ROSE O'HALLORAN.

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WM. W. PAYNE,
Northfield, Minn., U. S. A.

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* The period of W Lyræ is quite well known, and is more regular than the average long period variable. Since its discovery by Anderson in 1896, it has been observed at least once in every week by either Mr. P. S Yendell, Zaccheus Daniel or J A. Parkhurt. For their results see *Astronomical Journal* No. 388, 397, 412, 426, 434, 456, 458, 465, 473 Dr. Hartwig gives the period as 200 days; the result from 3 maxima and 5 minima obsrved at Marengo is 197 days.

† In case of Algol-type variables, like the above Ceraski star, the time of observation should be given to the hour and minute.

Popular Astronomy.

Vol. VIII. No. 3. MARCH, 1900. Whole No. 73.

VARIABLE STARS OF THE ALGOL TYPE.

H. C. WILSON.

The interesting articles referred to in the last number of POPULAR ASTRONOMY, on the Densities of the Algol Variables, by Messrs. Alexander Roberts and Henry Norris Russell*, led the writer to brush up his knowledge of this class of variable stars, and it was thought that some of the results of his study might be put in such form as to be interesting to the readers of the magazine. What is written is therefore presented with no claim to originality or a thorough study of the subject. We venture to hope, however, that it may be of use in putting clearly before the minds of perhaps some of the professional astronomers as well as of the average reader, the problem of interpreting the varying light of these peculiar stars.

These variables are regarded as exceedingly close double stars, whose light variation is caused by the eclipse of one star by the other. The planes of their orbits must be nearly parallel to the line of sight from the Earth to the star, so that each star in the course of a revolution will pass between the Earth and the other star, cutting off its light in part or wholly, just as the Moon eclipses the Sun. The parallel will be much better if we can imagine two suns close together, revolving about each other so swiftly that every few days or hours the one passes in front of the other. When they are separated, side by side, we receive the light from the whole hemisphere of each of them, and their combined light is at a maximum. When they are so nearly in line with the Earth that the disc of one appears to overlap that of the other, part of the light of the more distant star is cut off and their combined light is diminished. If the stars are equal in diameter and the one passes directly in front of the other, for a moment there is a total eclipse of the more distant star and the eye receives only the light of the nearer one. If the orbit be circular, under these conditions there are two equal minima of the star during each revolution, the intervals between them are equal and the periods of waning and increase of light are equal.

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* *Astrophysical Journal* Vol. X, p. 308-318.

Under the same conditions, if the two stars are of equal surface brightness, the greatest diminution of their total light will be 0.8 of a magnitude, for in case of a total eclipse of either by the other only half of their total light will be cut off. Since a star of a given magnitude on Argelander's scale is approximately 2.5 times as bright as one of the next lower magnitude, to divide its light by 2 would reduce its magnitude by $2/2.5 = 0.8$.

In case the two stars are of equal surface brightness but of unequal diameters, the light at either minimum, if the eclipse be central, is very nearly equal to that from the larger star and hence the diminution of light will be less than 0.8^m. So when the components are of equal surface brightness, there can be no very marked minima. If the difference in size is very great the minima will be scarcely noticeable.

On the other hand, when one of the stars is darker than the other, the minima will be unequal, and may be so unequal that one will not be observable at all, while at the other the star may become nearly or quite invisible.

When the orbit of one star about the other is elliptic, as is usually the case, there are two minima which may be equal or unequal according to the inclination of the orbit and the relative brightness of the component stars. The intervals between the two minima of each revolution are generally unequal; the exception being when the major axis of the ellipse lies in the line of sight from the Earth to the star.

The figures, which we have prepared, will perhaps enable the reader to understand more clearly the statements already made, and prepare the way for those which wiil follow. In Fig. 1, Plate IV, we will suppose the circle A to represent a bright star, and B a smaller or darker star, both revolving in circular orbits around their common center of gravity C. Let EA be a portion of the line of sight from the Earth to the star. If this line of sight lie in the plane of the orbits $AA'A''$ and $BB'B''$, it will be clear that every time B passes the position B_2B_8 it must be projected in perspective against A, as shown in Fig. 2, Plate IV, obscuring a surface area of A whose projection is equal to the projection of the earthward surface of B. Also when A reaches A'', B will be at B'' and will be wholly obscured by A. Between those positions as at $A'B'$ the stars will send their combined radiation earthward.

It will be easier to study the relative movements of the two stars if we transfer the center of movement to the center of the bright star and ascribe the whole change of position to the lesser star. The orbit of B about A will then be the larger circle $B_1B_6B_9$.

This circle represents truly the relative movement of *B*, for clearly AB_5 is equal both in length and direction to $A'B'$, and $A''B''$ has its counterpart in the line between AB_7 and AB_8. The angular movement of *B* is the same in both cases, but its linear velocity in the relative orbit is the sum of the real velocities of *A* and *B*.

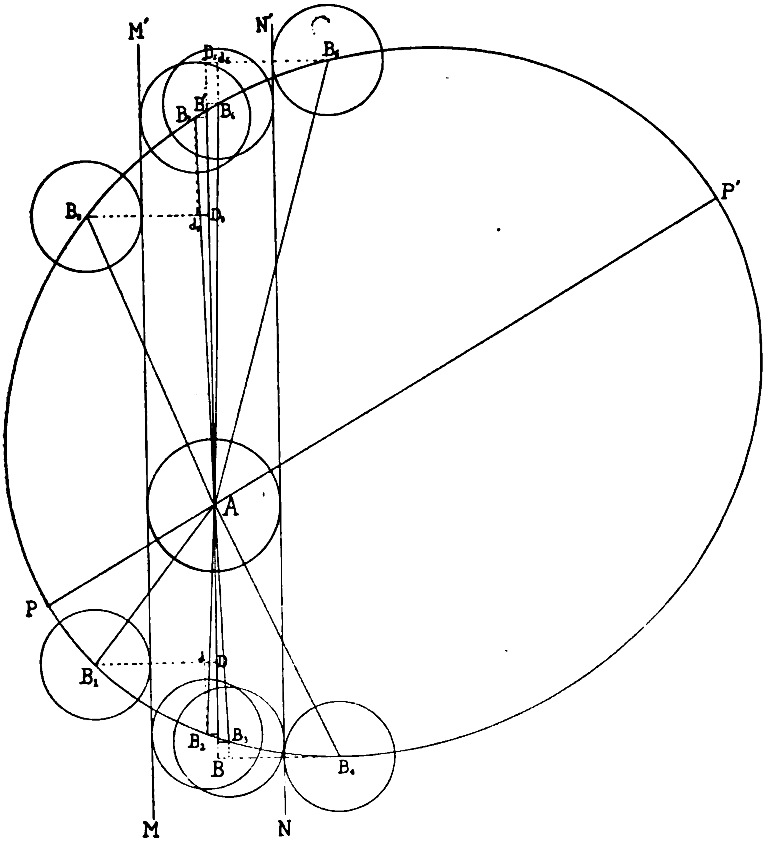

FIG. 3. ELLIPTIC ORBIT OF AN ALGOL VARIABLE.

Using then the larger circle and regarding *A* as stationary, we may draw the parallel lines *MN* and *M'N'* tangent to the disc of *A* as the limits of a cylinder within which *B* must enter in order to eclipse *A* on the one hand or be eclipsed on the other. Supposing the eclipse to be central and taking no account of the atmospheres of the stars (a most important omission), as soon as *B* reaches the position B_1, tangent to *MN*, the light begins to wane; slowly at first, then more rapidly, as the longer chords of *B* encroach upon *A*, then more slowly until at B_2, the whole disc of *B* overlaps that of A and the light is at a minimum. The minimum will continue, practically stationary, until B reaches B_3, tangent to $M'N'$, when the increase of light will begin, the order of change being the reverse of that of the waning, ending at B_4. From B_4 to B_6 the light will be constant, but from B_6 to B_9 a secondary minimum will occur, the light of B being cut off by A, waning from B_6 to B_7, stationary from B_7 to B_8 and increasing from B_8 to B_9. From B_9 to B_1 the light will remain constant again. Thus one will readily see that a variable of this class should have two minima and that generally the two minima should be unequal. Only in case the two stars are of equal surface brightness can the two minima be equal. In that case the brightness at both minima is practically that of the star A, for at the primary minimum B gives about as much light as it cuts off from A, while at the secondary minimum the light is wholly that of A.

The reader must understand that these stars are so distant from the Earth that they are mere points as seen through the most powerful telescopes and that the distance between the components is far below the limit of measurement with a micrometer. No one of them has ever been seen double in a telescope. Very little therefore can be determined with reference to their orbits. The fact of their being double was a mere inference from the phenomena of their light variations, until a few years ago. In 1888-9, Professor Vogel,* by a series of photographs of the spectrum of Algol proved that that star was moving away from the Earth before each minimum at the rate of 24.4 miles per second and was approaching at the rate of 28.5 miles per second after each minimum, proving conclusively that it was revolving about a center of gravity under the control of a force from a dark companion.

The other variables of this type are all fainter than Algol and their orbital motions have not, so far as I am aware, been determined spectroscopically, so that we must confine ourselves to what can be learned from their light changes and the similarity of these changes to those of the one known to be binary.

First, then, let us connect the light curve of Algol at minimum with the orbital velocity determined by Vogel. For about 59 hours Algol's light is practically constant, shining as a star of 2.3 magnitude. Nearly five hours before minimum it begins to decline, slowly at first then more rapidly, until at minimum its magnitude is about 3.4. It then increases in the reverse order of

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* *Astronomische Nachrichten*, No. 2947.

its decline, a very little more slowly perhaps, recovering its normal brightness in a little less than five hours, the total duration of the light change being about $9^h\ 45^m$. The curve of those changes, as determined by Dr. Scheiner from all available observations during the last two centuries, is shown in Fig. 4. Supposing the transit of the companion star to be central over the primary and the orbit to be circular, it is evident from Fig. 1 that the sum of the diameters of the two stars is equal to the line B_1B_4, or the sum of their radii is one-half of that line. Representing the radius of A by a, that of B by b and that of the orbit by R, the duration of light variation by d and the total period of the variable by p,

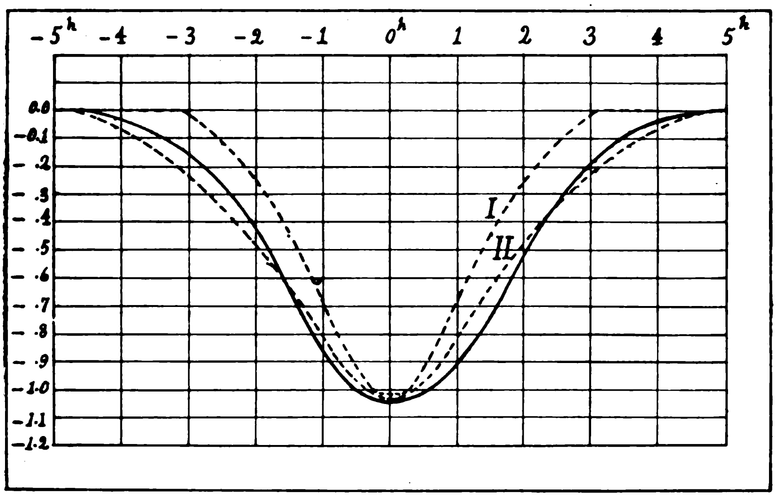

FIG. 4. LIGHT CURVES FOR ALGOL.

$$a + b = R \sin \frac{1}{2}\ B_1AB_4 = R \sin \frac{1}{2}\ \frac{2\pi d}{p}. \qquad (1)$$

If the orbit be elliptic, as in Fig. 3,

$$a + b = r_1 \sin (v_0 - v_1) = r_4 \sin (v_4 - v_0) \qquad (2)$$

where r_1, r_4, v_1 *and* v_4 are the radii vectores and the true anomalies of the points B_1 and B_4, and v_0 the true anomaly of the point B, which can be computed by the usual elliptic formulæ when the elements are known.

Confining ourselves to the circular orbit, which is very nearly true in the case of Algol, and adopting Vogel's mean orbital velocity 26.3 miles per second and Chandler's period $2^d\ 20^h\ 48^m\ 55^s = 247{,}735^s = 68.814^h$ we have

$$R_c = \frac{26.3 \times 247,735}{2\pi} = 1,040,000 \text{ miles};$$

that is, the principal star is about one million miles from the center of gravity of the system. Assuming, from the loss of light at a minimum of about 1 magnitude, that the surfaces are in the ratio of 1.00 to 0.60, we should have for the ratio of the diameters of the stars 1 to 0.78; and for their volumes 1 to 0.475 or approximately 0.5. Again assuming, what may or may not be true, that their densities are equal, their masses will be in proportion to their volumes and their distances from the center of gravity will be as 1 to 2. So we may take in round numbers for the distance of the primary star from the center of gravity 1,040,000 miles, for the distance of the satellite from the center of gravity 1,040,000 ÷ 0.475 = 2,190,000 miles, and for the distance of the center of the satellite from the center of the primary star 3,230,000 miles. The sum of their radii then becomes

$$a + b = R \sin \frac{d}{p}.\ \pi = 3,230,000 \sin \left(\frac{9.75}{68.81} \times 180^\circ\right) =$$

$$1,390,000 \text{ miles.}$$

Dividing the sum in the ratio of 1 to 0.78 we have $a = 781,000$ miles and $b = 609,000$ miles.

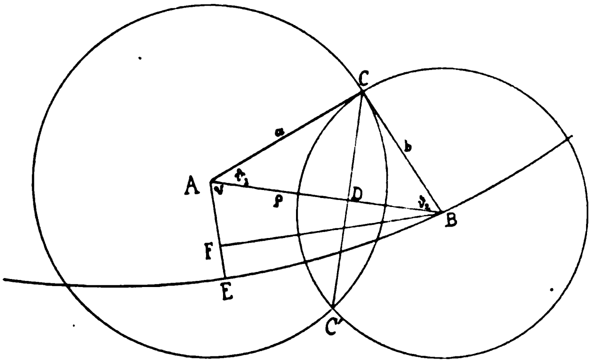

FIG. 5.

Let us now see how these dimensions of the two stars will satisfy the light curve. In Fig. 5 let *BE* be the projection of a portion of the orbit of the satellite *B* near conjunction with *A*. If the transit were central, the distance *AE* would be zero; in general it is $R \sin i$, where i is the inclination of the line of sight to the plane of the orbit. In the case of Algol the light is not stationary for any noticeable length of time at the minimum, so that the transit cannot be central. Let us assume that the inclination is just enough to cause the disc of B to wholly enter upon that of A, producing internal tangency at minimum; then

$$R \sin i = a - b \text{ and } \sin i = \frac{a-b}{R}. \qquad (3)$$

Let $\rho =$ the projection of AB and $u =$ the angle BAE, then at any moment

$$\rho = \sqrt{R^2 \cos^2 u \sin^2 i + R^2 \sin^2 u} \qquad (4)$$

If t represent the time occupied by the satellite in passing from E to B

$$u = \frac{t}{p} \times 360^\circ. \qquad (5)$$

The area from which the light is cut off at any moment is the sum of the two segments between the chord and the two arcs CC'. The segments are the differences between the corresponding sectors and triangles ACC' and BCC'. The areas of the sectors are

$$\text{Sector } ACC' = \pi a^2 \left(\frac{2\theta_1}{360^\circ}\right) \text{ and Sector } BCC' = \pi b^2 \left(\frac{2\theta_2}{360^\circ}\right)$$

in which θ_1 and θ_2 represent the angles BAC and ABC respectively. The areas of the triangles are

$$\varDelta ACC' = a^2 \sin \theta_1 \cos \theta_1 = \frac{a^2 \sin 2\theta_1}{2} \text{ and}$$

$$\varDelta BCC = b^2 \sin \theta_2 \cos \theta_2 = \frac{b^2 \sin 2\theta_2}{2}.$$

From these we obtain for the area of the eclipsed portion of the primary star

$$S = \frac{a^2}{2}\left(\frac{2\theta_1}{57.3^\circ} - \sin 2\theta_1\right) + \frac{b^2}{2}\left(\frac{2\theta_2}{57.3^\circ} - \sin 2\theta_2\right). \qquad (6)$$

The angles θ_1 and θ_2 may be found by the formulae

$$\cos \theta_1 = \frac{\rho^2 + a^2 - b^2}{2a\rho} \text{ and } \cos \theta_2 = \frac{\rho^2 - a^2 + b^2}{2b\rho}. \qquad (7)$$

If the loss of light be considered proportional to the area of the covered part of the disc and the satellite gives no appreciable light we may express the ratio of the brightness at any moment to the normal brightness by

$$L = 1 - \frac{S}{\pi a^2} \qquad (8)$$

and the loss in magnitudes by

$$\Delta m = \frac{10}{4} \log L. \qquad (9)$$

By the aid of these formulae I computed the values of Δm for Algol for the five hours before and after minimum, with the values a = 781,000 miles and b = 609,000 miles. In the computation, however, I expressed a and b in terms of R by dividing each by 3,230,000. R then became unity in the formulae and $a = 0.2415$ and $b = 0.1885$. The values of Δm found agreed exactly with those computed in a similar manner by Dr. J. Wilsing† and are represented by the lower dotted curve *II* in Fig. 4. It will be noted that this curve nowhere deviates more than 0.10 magnitude from the observed light curve. The small deviation is however systematic and larger than the errors of the observed curve. Dr. Vogel considered that the observations could be better represented by supposing the two stars to be smaller in diameter but surrounded by extensive atmospheres, the absorption of which changes the character of the curve. He estimated the radii of the two stars as $a = 530,000$ and $b = 415,000$ miles. The upper dotted curve *I* in Fig. 4 represents the light changes, which I have computed with these dimensions of the stars, neglecting the effect of their atmospheres. The duration of the light change would be only 6^h 30^m and there would be a stationary period of a half hour or more at the minimum.

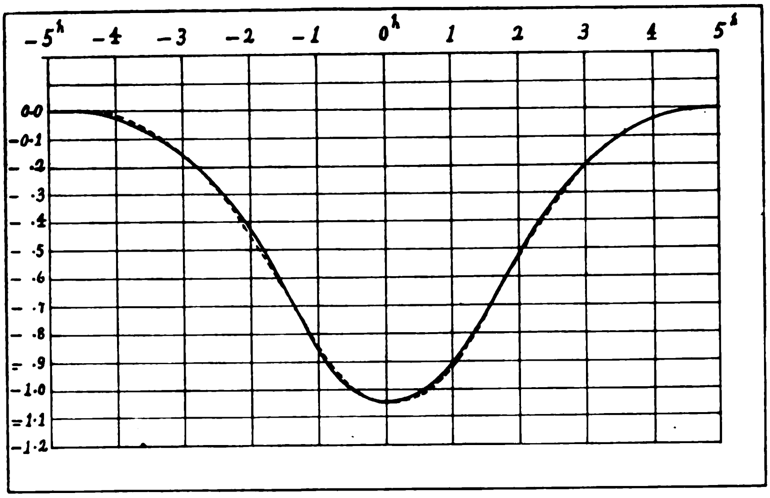

FIG. 6. WILSING'S COMPUTED LIGHT-CURVE OF ALGOL.

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† *Astronomische Nachrichten* No. 2960.

Dr. Wilsing by using Vogel's radii of the stars and assuming that the atmospheres surrounding the stars extended to the limits which in our first computation we gave to the stars themselves, *i. e.* to 781,000 miles and 609,000 miles from the respective centers, was able to represent the observed light curve in all parts within 0.02 magnitude, the coefficient of absorption which he deduced being only one-fortieth of that of the Earth's atmosphere. In Fig. 6 I have platted his final values, in which he made a small correction for the eccentricity of the orbit, which he found to be 0.011, together with the observed light curve. The dotted line here coincides so closely with the smooth line that it was difficult to draw them so as to show both. No more complete representation of observation by theory could be asked for.

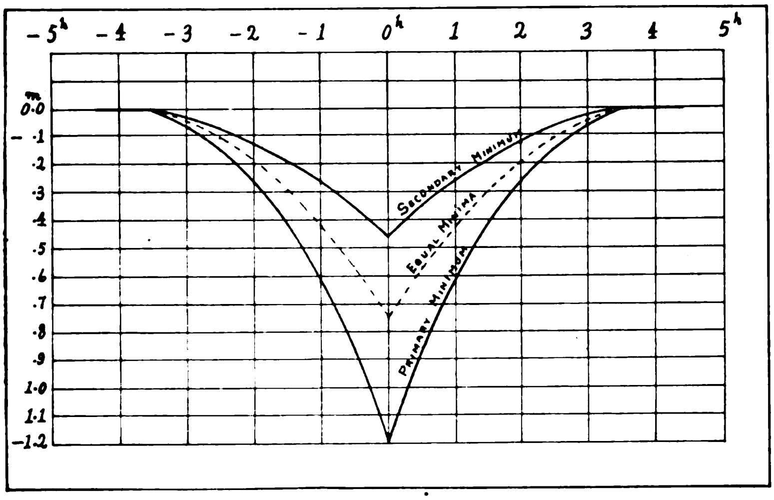

FIG. 7. THEORETICAL LIGHT-CURVES.

In the first part of his investigation Dr. Wilsing takes up the question of the possibility of two such bodies existing in so close proximity and shows that the deformation of one of the bodies by the attraction of the other amounts to only one-ninetieth part, which is much less than the flattening of Jupiter by its own rotation. He also shows that if the satellite shines by reflected light only, its brightness cannot be more than $\frac{1}{50}$ of that of the primary star and therefore it could have no influence upon the light curve. That its light is very feeble is evident from the fact that Algol has no secondary minimum. Dr. Plassman* thinks he has observed slight changes in the light of Algol be-

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* *Astronomy and Astrophysics* Vol XI, p. 419.

tween minima. These changes are very slight and must be explained in some other way than by the eclipse theory, for he finds two secondary minima, neither of them anywhere midway between the primary minima.

In Fig. 7 I have drawn some theoretical curves, which, though having no basis in actual observation, may assist in comprehending the problem. The dotted curve was computed on the hypothesis of two stars, without atmospheres, equal in diameter and intensity of surface luminosity, revolving about each other, or rather their common center of gravity, at the distance of the components of Algol. The curve is the same for both minima. The two smooth line curves were computed on the same hypothesis as above, with the exception that surface intensity of one of the stars is twice that of the other. The transits are supposed to be central in each case and the diameters 1,060,000 miles. The sharp points of the curves at minima can be rounded off either by assuming atmospheres or by supposing the eclipses to be only partial. The symmetry of the curve before and after minimum may be destroyed either by eccentricity of the orbits of the stars or by elongation of the bodies themselves, provided that elongation be not exactly parallel to the line joining their centers. In Fig. 8 the smooth curve represents the light variation, during an entire revolution, of two stars of equal intensity of surface illumination and equal diameters, revolving tangent to each other. This is an impossible case, for the mutual attractions of the two bodies would destroy their spherical figure and cause the contiguous portions to merge, forming figures perhaps like the ellipsoid of Jacobi, the dumb-bell or the apioid of Poincaré, figures which have been shown to be of at least temporary stability of equilibrium[*]. The curve bears so

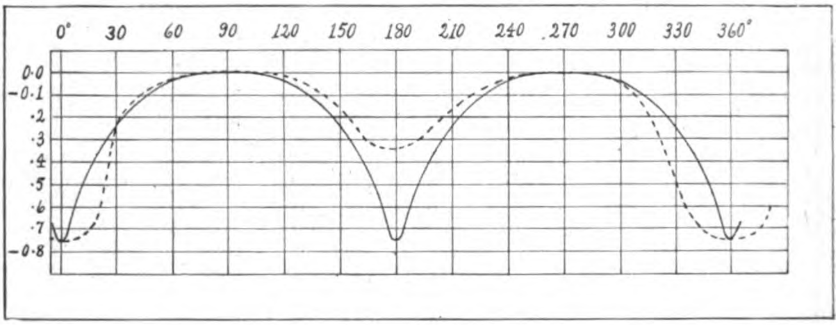

Fig. 8. Light-curve of Equal Stars in Tangency, and of β Lyræ.

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[*] See Popular Astronomy, Vol. III, pp. 489-519.

much resemblence however to the curve of β Lyrae, which I have drawn as the dotted line in the same Figure, that it would seem that by proper assumptions as to the forms, distance, intensity and atmospheres of the two components, the variations of that star and all of its class might be represented on the eclipse theory. In this class of variables the light change is not confined to a relatively short portion of the period, near minimum, but is continuous throughout the whole period. This would be the result with the Algol variables if the components should be near enough together for their atmospheres to blend.

Dr. Chandler has shown† that the period of Algol is variable, having decreased, with several fluctuations, up and down, from $2^d\,20^h\,48^m\,58^s.0$ to $2^d\,20^h\,48^m\,51^s.1$ during the last century. He attempts to account for this change by the attraction of a second dark body in the system, and is inclined from his study of the problem to regard the mass of this second companion as greater than that of the bright star. We should thus have the anomaly of a bright satellite revolving about a dark primary body, which is certainly a very interesting cosmological problem, much as we may doubt its possibility. From an investigation of the proper motion of Algol, Dr. Chandler thinks he has found evidence of this orbital motion of the bright star, and that its period is about 131 years and the semimajor axis of the orbit $1''.33$. There are also slight indications of disturbances by still other hypothetical dark companions, in other words perhaps of a complex planetary system akin to the solar system. M. Tisserand, however, denies the necessity of assuming the dark primary body and shows that the observed change of period can be accounted for by the attraction of a smaller dark body, if one or both of the close companions are flattened by rotation. His theory also requires the presence of the third member, and possibly more, of the system.

Similar irregularities in the length of period are found in the case of several others of the Algol-type variables, and suggest the same explanation, so that we may, perhaps, naturally conclude that motions like those shown to exist in the case of Algol, and furnishing evidence of complex planetary systems, somewhat similar to that of the Sun, are not rare exceptions but possibly the rule in the stellar universe.

There is another irregularity in the light changes of certain of these stars, however, which seems more difficult of explanation

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† *Astronomical Journal* Vols. VII, p. 180; IX, p. 121. See also POPULAR ASTRONOMY Vol. V, p. 302.

and almost fatal to the satellite theory. That is well shown in the light curve of U Ophiuchi in Fig. 9; a distortion of the curve shortly after minimum, due to something which checks the recovery of light for a time. This retardation is so slight that, if it were noticed in one star or by one observer alone, it might be regarded as due to some fault in the observing. But it seems to be characteristic of several of the Algol stars and Chandler speaks of noticing the same tendency in Algol. It must, therefore, be taken into account in any theory which is to explain the changes of these peculiar stars.

LIGHT CURVE OF U OPHIUCHI.

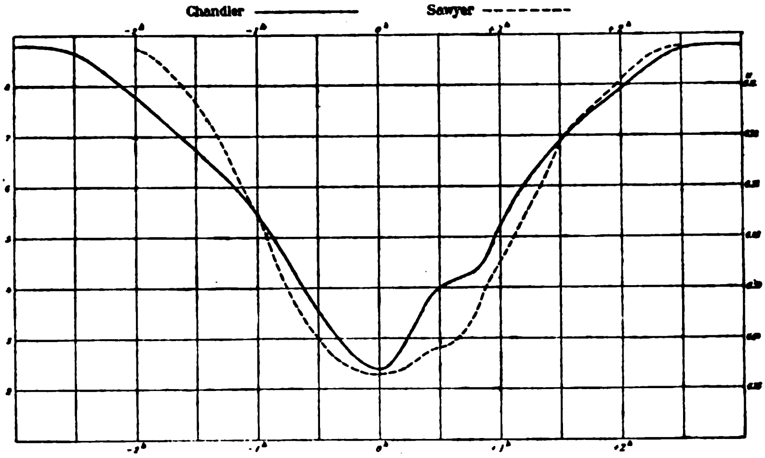

FIG. 9.

In order to obtain any idea of the absolute masses of the bodies, we must know their actual distances or parallaxes and the elements of their orbits. Rough approximations to their maximum densities, however, as compared with the Sun, may be obtained even when these are lacking, from the data of the light variations. Assuming the law of gravitation to be the same in other systems as in our own, when two bodies have satellites, the ratio of their masses is determined by the proportion*

$$M + m : M_1 + m_1 :: \frac{r^3}{t^2} : \frac{r_1^3}{t_1^2} \qquad (10)$$

in which M and M_1 are the masses of the primary bodies, m and m_1 the masses of the satellites, r and r_1 the distances of the satellites from their respective primaries, and t and b their periodic times. From this

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* Young's General Astronomy. p. 342.

$$\frac{M_1+m_1}{M+m}=\frac{t^2\,r_1^3}{t_1^2\,r^3}. \tag{11}$$

Adopting the mass of the Sun as unity and neglecting that of the Earth, since it is insignificant in comparison, expressing the time in units of a year, and taking the Earth's mean distance from the Sun as 93,000,000 miles, we have

$$M_1+m_1=\frac{r_1^3}{t_1^2\,(93{,}000{,}000)^3}. \tag{12}$$

Since the density of a body is its mass divided by its volume, the density of a star and that of the Sun will be in the proportion of their masses divided by the cubes of their diameters, or

$$\delta_a : \delta_s :: \frac{M_a}{a^3} : \frac{M}{s^3} \tag{13}$$

where δ_a is the density of the star, δ_s that of the Sun, a and s their diameters and M_a and M their respective masses. In units of the Sun's mass and density

$$\delta_a=\frac{s^3}{a^3}\,M_a \tag{14}$$

If δ represent the average density of the two components of a binary, whose diameters are a and b

$$\delta=\frac{s^3}{a^3+b^3}\,(M_a+M_b\,). \tag{15}$$

Substituting the second member of equation (12) for $(M_a+M_b\,)$ and 866,400 miles for s, we obtain

$$\delta=\frac{\left(\dfrac{866{,}400}{93{,}000{,}000}\right)^3 r_1^3}{t_1^2\,(a^3+b^3)}=\frac{(0.0093)^3\,r_1^3}{t_1^2\,(a^3+b^3)}. \tag{16}$$

Evaluating (16) for Algol, taking Vogel's dimensions of the system, we get

$$\delta=\frac{(0.0093)^3\,(3{,}230{,}000)^3}{\left(\dfrac{68.81}{24\times 365.25}\right)^2(1{,}061{,}000^3+830{,}000^3)}=0.249\,;$$

that is, the average density of the components of Algol is only one quarter of that of the Sun.

If we should include the atmospheres in the volumes of the stars, which is what we must do when we have no other data than the light curve, in the case of Algol a^3+b^3 would be $(1{,}562{,}000^3+1{,}218{,}000^3)$ and we should obtain $\delta=0.078$.

In formula (16) let $a=pr_1$ and $b=qr_1$. Then

$$\delta = \frac{(0.0093)^3}{t_1^2(p^3 + q^3)}. \tag{17}$$

The values of p and q may be found from the light variations of the star. In Fig. 1

$$B_1D = \frac{1}{2}(a + b) = r_1 \sin \frac{1}{2} B_1AB_4 = r_1 \sin \frac{\pi d}{t_1},$$

and

$$D_2D = \frac{1}{2}(a - b) = r_1 \sin \frac{1}{2} B_2AB_3 = r_1 \sin \frac{\pi c}{t_1}.$$

in which t_1 is the total period of the variable, d is the duration of the change of light, and c is the period during which the light remains constant at minimum. Adding and subtracting, we have

$$a = r_1 \left(\sin \frac{\pi d}{t_1} + \sin \frac{\pi c}{t_1}\right)$$

$$b = r_1 \left(\sin \frac{\pi d}{t_1} - \sin \frac{\pi c}{t_1}\right).$$

Dividing by r_1,

$$\left.\begin{aligned} p &= \left(\sin \frac{\pi d}{t_1} + \sin \frac{\pi c}{t_1}\right), \\ q &= \left(\sin \frac{\pi d}{t_1} - \sin \frac{\pi c}{t_1}\right). \end{aligned}\right. \tag{18}$$

If the star has no interval of constancy at the minimum, c is zero and p and q are equal. Formula (17) then becomes

$$\delta = \frac{(0.0093)^3}{2t_1^2 \sin^3 \frac{\pi d'}{t_1}},$$

and if we express t_1 and d in hours instead of years

$$\delta = \frac{(0.0093)^3 \times 24^2 \times 365.25^2}{2t_1^2 \sin^3 \frac{\pi d}{t_1}} = \frac{30.9}{t_1^2 \sin^3 \frac{\pi d'}{t_1}} \tag{19}$$

This will give Mr. Russell's formula if we multiply it by 1.39, the density of the Sun in units of the density of water.

If p and q are unequal we may obtain maximum estimates of the densities of the individual stars in the following manner.

Dividing equation (14) by (15)

$$\delta_a : \delta = (a^3 + b^3)\, M_a : a^3\, (M_a + M_b)$$

Hence

$$\delta_a = \frac{(a^3 + b^3)\, \delta}{a^3} \left(\frac{M_a}{M_a + M_b}\right)$$

and substituting for δ its value from (16) and cancelling r_1, as in (17)

$$\delta_a = \frac{(0.0093)^3}{p^3\, t_1^2} \left(\frac{M_a}{M_a + M_b}\right) \qquad (20)$$

In like manner

$$\delta_b = \frac{(0.0093)^3}{q^3\, t_1^2} \left(\frac{M_b}{M_a + M_b}\right) \qquad (21)$$

Now the fractions $\frac{M_a}{M_a + M_b}$ and $\frac{M_b}{M_a + M_b}$ must always be less than unity, no matter how small one of the masses may be, and if one of these fraction approaches unity the other must approach zero. If the masses are equal the two fractions each become equal to ½. Hence if we substitute unity for the final factors in equations (20) and (21) we shall have as maximum expressions for the densities of the component stars,

$$\delta_a = \frac{(0.0093)^3}{p^3\, t_1^2} \text{ and } \delta_b = \frac{(0.0093)^3}{q^3\, t_1^2} \qquad (22)$$

These are Mr. Roberts' formulae, except that he has 0.0092 instead of 0.0093 in the numerators of the expressions.

If in these formulae we express t_1 in hours instead of years they will be a little more convenient for use. We have then

$$\delta_a = \frac{61.8}{p^3 t_1^2} \text{ and } \delta_b = \frac{61.8}{q^3 t_1^2} \qquad (23)$$

which correspond with (19).

As an example of the working of the formulae let us take X Carinae, which Mr. Roberts finds to vary very regularly. It is constant for 6½ hours at 7.8 magnitude, declines in 3¼ hours to $8^m.6$ and recovers in 3¼ hours. As there is no constant period at maximum and the fall is just 0.8 magnitude or one-half the total light, we may consider this as a binary of two equal components, the total period being 26 hours with equal minima at equal intervals. We have then $t_1 = 26^h$, $c = 0$, $d = 6.5$, whence $p = 0.707$ and $q = 0.707$.

Therefore, $$\delta_a = \frac{61.8}{p^3 t_1^2}\left(\frac{M_a}{M_a + M_b}\right) = 0.259 \left(\frac{M_a}{M_a + M_b}\right)$$

and $$\delta_b = \frac{61.8}{q^3 t_1^2}\left(\frac{M_b}{M_a + M_a}\right) = 0.259 \left(\frac{M_b}{M_a + M_b}\right);$$

or, if the masses be assumed equal, the densities of both stars equal 0.130 of the Sun's density.

A most remarkable result is obtained in the case of S Velorum, a southern star, the normal magnitude of which is 7.8, but which sinks at minimum to 9.3 and remains constant at the minimum for 6½ hours. The elements of its variation are

	d	h	m	s
Total period	5	22	24	23
Descending period		4	10	0
Constant at minimum		6	30	0
Ascending period		4	10	0

It is evident that the fainter star is larger than the brighter one and thus totally eclipses the latter for 6½ hours. There ought to be a noticeable secondary minimum, but Mr. Roberts makes no reference to any observations of it. If the orbit be circular we have

$$t_1 = 142^h.41 \qquad d = 14^h.63 \qquad c = 6^h.50$$

$$p = \sin 18^\circ.4 + \sin 8^\circ.2 = 0.46 \text{ (for faint star).}$$

$$q = \sin 18^\circ.4 - \sin 8^\circ.2 = 0.14 \text{ (for bright star).}$$

$$\delta_a = \frac{61.8}{p^3\, t_1^2} = 0.03 \text{ (for faint star).}$$

$$\delta_b = \frac{61.8}{q^3\, t_1^2} = 0.61 \text{ (for bright star).}$$

Thus the maximum limit for the density of the faint star is only one-thirtieth that of the Sun.

Considering the orbit as possibly elliptic Mr. Roberts finds the following expressions for the densities, letting e equal the eccentricity and θ the angle between the line of apsides and the line of sight:

$$\text{Density of bright star} = 0.61 \left(\frac{\sqrt{1-e^2}}{1+e\cos\theta}\right);$$

$$\text{Density of faint star} = 0.031 \left(\frac{\sqrt{1-e^2}}{1+e\cos\theta}\right);$$

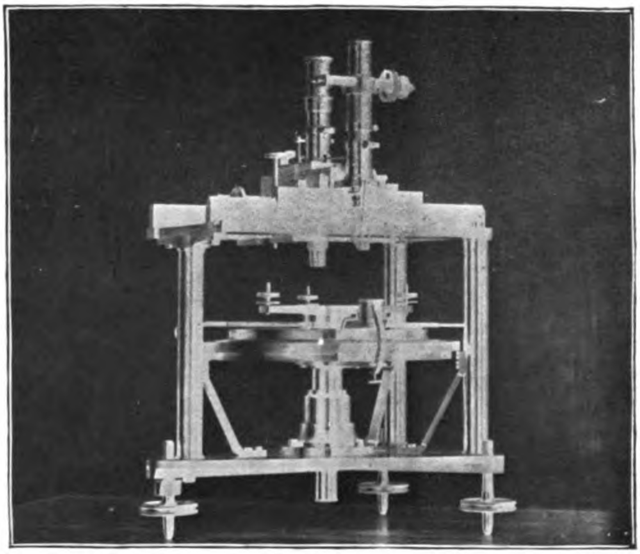
"The relation between the diameters of the stars and the axis-major of the orbit precludes a higher eccentricity than 0.5, for any greater value would mean collision at periastron passage. Also it is evident that the greatest value of the density is obtained when $\theta = 180^\circ$. Considering now the value of the eccentricity to be the greatest possible; and eclipse to take place at periastron, then the greatest possible values of the densities of the two stars become

Bright star	3.17
Faint star	0.16.

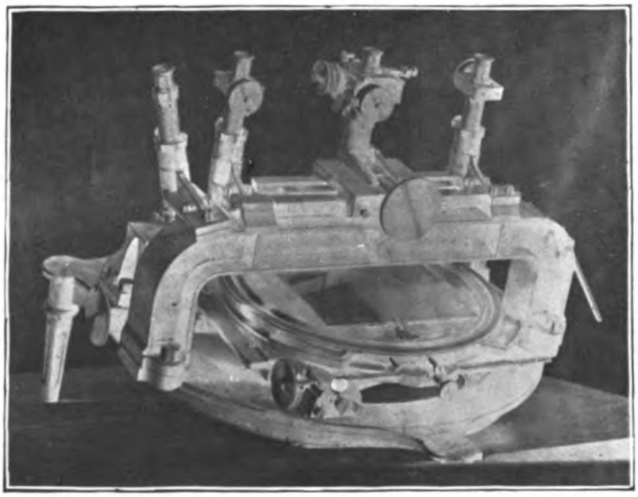
That both these values are far too great is certain. They assume a high eccentricity. The regularity of the light curve is directly against this assumption. They assume a value of the mass of either star infinitesimally small. But with every possible combination of mass, position in orbit and eccentricity, the density of the faint star is still exceedingly small."

PLATE V.

MACHINES FOR MEASURING ASTRONOMICAL PHOTOGRAPHS.



THE RUTHERFURD.



THE REPSOLD.

THE RUTHERFURD PHOTOGRAPHS.

FLORA B. HARPHAM.

FOR POPULAR ASTRONOMY.

Photography claims the respectable age of twenty decades, though astronomical interest in its development took a practical turn only at the beginning of the last six of the twenty. When the experimenters were at a loss to find a solvent for the salts of silver on the undarkened portion of their plates which would at the same time leave untouched the darkened parts, Sir John Herschel led them out of their difficulty by suggesting the use of hypo-sulphite of soda for the double purpose of fixing and clearing. The suggestion proved valuable and the obstacles which had hindered the development of photography practically disappeared. The substitution of glass as a support for the sensitizing salts and the adoption of collodion as a medium to hold the chemicals upon the glass plate rendered the success of photography assured. The modern "dry plate" has been evolved of late years but the old collodion or "wet process" gave exceedingly fine results.

If Sir John the chemist made the suggestion which helped so much the material development of the new art, Sir John the astronomer was equally quick to realize the advantage of this aid to progress. He advised the use of the sensitive plate for the self-registry of Sunspots and lived long enough to see photography bid fair to outrival the slower and less reliable method of eye obsevation of objects to which it is adapted. Before his death many photographs had been taken, not only of the Sun and Moon, but also of the stars and star spectra.

Among those who entered with enthusiasm upon the new lines of investigation was a young man of New York, Lewis M. Rutherfurd. By a fortunate combination of circumstances, just when photography became serviceable, he was enabled to give up his law practice and devote his whole energy to scientific investigation. During his course at Williams College, he had given much time to chemistry and physics and shown also great mechanical skill. He accordingly planned his work along these lines, spent several years in study and travel in Europe, and returned home with the intention of devoting himself to astronomical and optical investigation. He built an Observatory in the garden of his home and began the work which he continued for twenty years and which made his name well known in the scientific circles of Europe and America.

Mr. Rutherfurd was obliged to construct his own instruments. While engaged in spectroscopic work, he devised a ruling engine which produced interference gratings unequalled until Professor Rowland's ruled surfaces appeared. In the investigation of star spectra Mr. Rutherfurd discovered the amount of correction necessary to convert an achromatic object glass into a photographic lens. By means of this discovery, he constructed a large photographic telescope of eleven inches diameter, and later a still larger one of thirteen inches. From the time of the completion of his first telescope, Mr. Rutherfurd was indefatigable in his astronomical activity. He used, of course, the wet plate process and became expert in the delicate manipulations necessary to ensure sharp negatives full of detail. His photographs of the Moon, especially, are scarcely surpassed in their exquisite definition even by the modern appliances of the great Observatories of today. In the twenty years of his photographic activity he took a large number of plates of the Sun, Moon, star groups and spectra, and received many acknowledgements of their excellence. He had the satisfaction of seeing his long labor appreciated by the scientific world and realized that the success of his work had much to do with the practical development of astronomical photography. He was firmly convinced of its value and labored unweariedly to prove its excellence. He originated the method and introduced its practical working; he devised and constructed the first measuring micrometer for photographs and caused a large number of measures of his plates to be executed in his study under his own supervision. When his health failed, he carried the machine and plates and measurer with him to the south, that the work which he had planned should not be interrupted. In the year 1890, he gave to Columbia University nearly fifteen hundred of his finest negatives together with his telescope, measuring micrometer and entire Observatory equipment.*

Through the courtesy of Professor Rees, Director of the Observatory, a photograph of the Rutherfurd measuring micrometer and of the modern Repsold machine accompany this article. The essential parts of both machines consist of a microscope micrometer, a graduated circle and a graduated scale. In the Rutherfurd machine a second microscope is rigidly attached to the frame of the first for the purpose of reading the scale when the micrometer threads of the first microscope are bisecting a star. The two microscopes move parallel to each other along

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* Lewis M. Rutherfurd, by John K. Rees, *Astronomy and Astro-Physics*, Oct., 1892.

the length of the plate, but a transverse motion in its frame is also possible to the first microscope, thus allowing it to move across the plate as well as lengthwise. By this device, any star on the plate may be brought under the micrometer threads. The plate rests upon a glass circle and the circle upon three levelling screws. When the glass circle is rotated, the plate is carried around with it. Outside the glass circle is a fixed graduated silver circle read by a microscope which records the position angles from the central star. The plate is set into the machine in such a position that the central star will remain under the microscope when the plate is rotated. The scale reading is noted for the central star and the micrometer is then moved over any other star, the scale microscope recording the reading for the second star also. The difference of the readings gives the distance between the stars. Although the machine will permit the measurement of either rectangular or polar coördinates, Mr. Rutherfurd preferred the latter and all the measures made under his supervision are in the form of distances and position angles from the central star. The distances are obtained as just described, but to find the position angle it is necessary to know the "zero of position" as the point is called from which the angles are measured. This is determined by Mr. Rutherfurd's method of exposing the plate. He took two impressions of all the stars and three impressions of the brighter ones. After the first impression was made, he screened the plate from the starlight and moved the telescope slightly westward, thus throwing the second impression east of the first. When this second impression was completed, the clock was disconnected from the telescope and the stars were allowed to pass across the plate, the bright ones leaving a fine, black line to record their course. It required a very bright star to trace this line which extended from the eastern image back through the western and across the plate to the third image; for when the stars had approached the edge of the plate, the clock was again started and the telescope was held long enough to permit the brighter stars to leave a third impression. This last image was called the "trail" and marked the direction of increasing right ascension, thus giving the needed "zero of position" for the angles.*

Mr. Rutherfurd's custom of placing a known star in the centre of his photographic plate was one of the best evidences of the excellence of his method. For the fundamental problem in the re-

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* Reduction of Photographic Observations, Dr. B. A. Gould. Nat. Acad. of Sciences, Vol. IV.

duction of photographic measures is to deduce the right ascension and declination of the stars in the sky from their measured coördinates on the plate. This requires that the position of the origin of coördinates should be known. This origin coincides with the foot of the perpendicular let fall from the optical centre of the object glass upon the plate. The photographic plate is a plane surface and upon it is projected that portion of the celestial sphere represented by the stars which dot the surface of the photograph. The plate may be regarded as a tangent plane, and the point on the plate which represents the point of tangency is the foot of the perpendicular let fall from the centre of the object glass. Mr. Rutherfurd so adjusted his plate in the holder that the image of the central star should lie approximately at the foot of this perpendicular. And as he always selected for the central star one which is well known, the position of the origin of the coördinates was thus determined.

The modern Repsold measuring machine differs from the Rutherfurd only in its details. The photograph of the Repsold shows a plate in the machine in position for measurement. One of the three legs of the machine has been removed, allowing the frame to fall forward until it rests upon its edge, thus placing the plate at an angle to the plane of the supporting table, in which position it is more conveniently measured. Instead of moving the measuring micrometer both longitudinally and transversely as in the Rutherfurd machine, the longitudinal motion is communicated to the plate itself by means of the large screw of the machine which moves the plate-carrying casting along a guiding cylinder. The microscope moves transversely along a carriage at right angles to the cylinder and parallel to the scale. By means of these two motions any star on the plate may be brought under the micrometer threads and its position noted by the scale, the difference of the scale readings for the star and the central star giving its distance from the latter. One microscope reads both the star and the scale, as the lever lifts the microscope through a small angle. After setting the micrometer threads upon a star, the micrometer is turned upon the scale by means of this small angular motion and the distance of the star from the nearest division of the scale is measured directly by the graduated head of the micrometer screw. In either rectangular or polar coördinates, the distances are measured in this manner, but the position angle from the central star is obtained from the reading of the graduated circle on the outer edge of the casting which carries the plate. In the

Repsold machine the orientation of the plate is a simpler process than that described above for the Rutherfurd. By means of the slow motion screw the plate is moved until both the central star and its trail will remain under the micrometer threads during a motion of the plate along the cylinder. By turning the graduated circle ninety degrees and clamping the plate in this position, the direction of increasing right ascension is found to be very nearly parallel to the scale. It will not be exactly parallel, owing to the diurnal motion of the star during the exposure of the plate, the size of the small angle between the two depending on the declination of the star. After the circle reading is corrected for this small angle, the central star will then lie approximately at the origin of the coördinates, the positive axis of X will point toward the east and the positive axis of Y toward the north; the final small correction necessary to place the origin at the foot of the perpendicular let fall from the centre of the object glass is found later by a least square solution from the measures themselves.

Mr. Rutherfurd's gift of his instruments to the university was accompanied by the volumes containing the measures which he had caused to be executed. Most of these were as yet unreduced. As early as 1865, however, he had prevailed upon his friend, Dr. Benjamin A. Gould, to take sufficient time from the duties of an active professional life to enable him to reduce some of the measures in order to test the accuracy of the photographic method. Dr. Gould selected for this purpose the measures of the group of the Pleiadès, being influenced to this choice by the fact that a heliometer determination of their relative positions had been made by Bessel. The accuracy of these heliometer positions would give a severe test of the photographic reduction.

In the selection of the formulas for these reductions, Dr. Gould followed the general outline for the reduction of heliometer measures.* He wished to consider also in his discussion the sources of possible errors, such as a motion of the collodion film by shrinkage or expansion, the effect of irregularity in the motion of the clockwork guiding the telescope, the distortion of the images near the edge of the field, and the errors of measurement caused by the different aspects of the stars in different positions of the plate in the measuring machine, inasmuch as the images vary in density and it is difficult for the eye to select the exact centre. At the time of Dr. Gould's discussion the method was new and some

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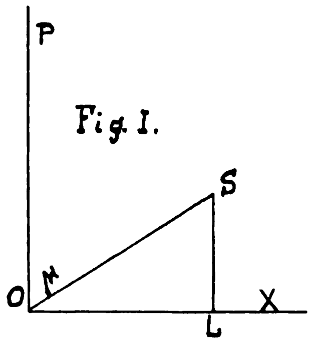
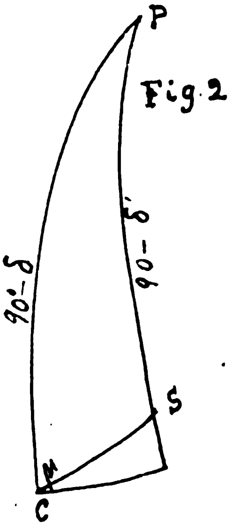
* Reduc. of Phot. Observations, B. A. Gould, Nat. Acad. of Sciences, Vol. IV.

fear was felt, especially in the matter of durability, lest the photographic plate would hold its usefulness for only a comparatively short period. But Dr. Jacoby has shown, by a remeasurement and discussion of some of the Pleiades plates twenty years after the photographs were taken, that the film does not deteriorate from age and its records may therefore be relied upon.*



In the formulas of reduction, Dr. Gould considered the relations of the parts of the spherical triangle formed upon the sky by the north pole, a star, and the point in the sky corresponding to the centre of the plate. In Figure 2, *PS* is the polar distance of the star, *PC* is the polar distance of the point corresponding to the centre of the plate, *CS* is the distance, η, of the star from *C*, the angle *SPC* is the difference in right ascension between the star and the centre, and the angle *PCS* is the position angle, μ, of the star.

In the plane triangle considered in Figure 1, *PO* is the projection of the meridian *PC*. *OS* is the projection of the distance η. *POS* is the position angle μ which remains unchanged since *PC* and *CS*, being arcs of great circles are projected upon the plane surface as straight lines which are the tangents of the circles; *OL* and *SL* are the measured x and y of the star upon the plate. Then, considering the ordinary trigonometrical formulas of the spherical triangle, from Figure (1) 2



$$\sin\eta\sin\mu = \cos\delta'\sin(\alpha'-\alpha)$$
$$\sin\eta\cos\mu = \cos\delta\sin\delta' - \cos\delta'\sin\delta\cos(\alpha'-\alpha)$$
$$\cos\eta = \sin\delta\sin\delta' + \cos\delta\cos\delta'\cos(\alpha'-\alpha)$$

and from Figure (2,) 1

$$x = \tan\eta\sin\mu$$
$$y = \tan\eta\cos\mu$$

$$\text{whence } x = \frac{\cos\delta'\sin(\alpha'-\alpha)}{\sin\delta\sin\delta' + \cos\delta\cos\delta'\cos(\alpha'-\alpha)}$$

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* Permanence of Rutherfurd Phot. Plates. Harold Jocoby, Ann. of New York Acad. of Sciences, Vol. IX.

$$y=\frac{\cos\delta\sin\delta'-\cos\delta'\sin\delta\cos(\alpha'-\alpha)}{\sin\delta\sin\delta'+\cos\delta\cos\delta'\cos(\alpha'-\alpha)}$$

From these equations the approximate values of $(\alpha'-\alpha)$ and $(\delta'-\delta)$ may be obtained in terms of x and y which have been measured upon the plate, or in terms of distance and position angle if they are preferred. Rigorous values of $(\alpha'-\alpha)$ and $(\delta'-\delta)$ may be derived from these same equations by expansion into a series of ascending powers of x and y.

These formulas of Dr. Gould are identical with the modern formulas of Sir Robert Ball and Dr. Arthur Rambaut with the exception of the factor r which is the radius of the sphere to which the plate is tangent, r being equal to the equivalent focal length of the telescope.* The reduction to the final form for logarithmic computation differs in the latter also from that of Dr. Gould, but his satisfactory results, when compared with Bessel's heliometer determination of the Pleiades positions, speak well for both the Rutherfurd photographs and the method.

In the reductions, the measures are first freed from instrumental errors depending upon the division errors of the scale, errors of the micrometer screw and runs. Upon every plate are a few, at least, known stars. After correcting the measures for refraction and multiplying the measured coördinates by the scale value in seconds of arc, the corrected coördinates will agree very nearly with the differences obtained by subtracting the catalogue position of the central star from that of each of the other known stars. The difference is caused, aside from the errors of observation, by the fact that the origin does not lie exactly at the foot of the perpendicular, by the inexact orientation of the plate, by a possibly incorrect scale value, etc. All these errors are small and by a comparison of the measured positions of the known stars with those deduced from the catalogue, a series of equations of condition is formed whose solution will give the needed corrections to these quantities. The measured coördinates of the unknown stars are then multiplied by these corrected values of the scale, orientation, etc., and from these corrected coördinates are deduced the final differences of right ascensions and declinations.

The photographic plate gives the relative positions of the stars as they appear at the moment when the photograph is taken. As the same region of the sky is photographed on different dates,

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* Relative positions of 223 stars in the cluster of χ Persei as determined photographically, Sir Robert Ball, LL. D., F. R. S., and Arthur A. Rambaut, M. A., D. Sc. Trans. Royal Irish Acad. Vol. XXX, pt. IV.

the right ascensions and declinations deduced from each plate must be referred to the beginning of some selected year, usually the year of the plate or the middle year of the series, in case the photographs extend over several years. To refer the stars to this selected epoch, a correction for aberration must be applied to the apparent right ascensions and declinations given by the plate to reduce them to the true, and a further correction for nutation and precession to reduce them to the mean right ascensions and declinations at the beginning of the year of the plate. To bring these to the beginning of another year, the annual precession is applied for the number of years required. The mean of all the values reduced to the same epoch gives the final right ascensions and declinations.

Since Mr. Rutherfurd's gift to the university, many of the plates have been measured and reduced and catalogues made of the stars. The work is still going on but even with rapid measurement, it will require years for the complete reduction of all the star photographs. Before his death Mr. Rutherfurd had the satisfaction of seeing the work well under way. He had the further gratification of seeing the field in which he was a pioneer well occupied by trained workers. In 1886 he was invited to attend the international conference which met at Paris for the purpose of considering the charting of the entire heavens by means of photography. Although prevented by failing health from attending, Mr. Rutherfurd was an interested observer of the action of that conference and approved the great undertaking which, when completed, will be a valuable legacy to the astronomers of future generations.

UNIVERSITY OF COLUMBIA,
February 1, 1900.

THE STUDY OF ASTRONOMY. III.

W. W. PAYNE.

In the January issue of this publication, (p. 24), we referred to the lack of interest manifested by leading teachers and educators in the study of elementary astronomy and offered some reasons why so general a view should prevail. We also tried to point out the disadvantage, if not harm, that has arisen from such an erronious view.

In the last number, (p. 75) more was said in regard to this same point, giving a few illustrations of what has seemed to the writer strong evidence to sustain the position taken, and then began the reference to what is claimed to be improved methods of study and instruction for college and secondary schools. We called attention to the usefulness of simple observation of some heavenly bodies, saying that such work, if properly arranged and followed up by teacher and student, will always awaken an interest in study that it may not be easy to secure in any other way. Not only so, but if the plan is persistently followed, and faithfully used, step by step, will surely lay the foundation of a habit of observation that will be of life-long value to its possessor, because having eyes to see he has acquired the power to grasp more than others when he looks at anything worthy of attention.

The next point made was the advantage of good illustration. In this the thought is that the student shall get his eyes and mind away from the words of the book, which is rightly his guide for the statement of principle, fact or definition; so as to get a different and a firmer impression in mind of the thing he is to comprehend, without the necessity of learning words out of a book which may not convey meaning enough in themselves to hold them easily.

In the study of the Moon a good chart is desirable, indeed necessary for the best results, if the instructor has not the advantage of a small telescope. In illustrating the Sun, our experience in the use of large photographs has been very satisfactory. Such pictures show the photosphere in detail, so that there can be no doubt concerning its lack of continuity, its faculæ, its spots, large and small, in their varying structure, something of the filaments of the penumbra, the bridges of the umbra, the rotation of the Sun from day to day, by the apparent movement of the spots across the disc, the direction of the solar axis in the same way, and the difference of intensity of the light of the Sun from its limb and its central regions. These and many other things are easily seen by inexperienced eyes if the collection is large enough to include the different phases of solar activity that will cover at least one half of a rotation period when the spot conditions are favorable. We have not yet made a complete series of these pictures, though we have prepared enough of them so that the main points desired are illustrated and others have been easily inferred from what could be seen from the partial series. Some teachers have used a series of Sun-spot drawings to some extent, though no drawings can so well show the conditions of spots as is possible with photography. If any instructor should care to make a comparison of a series of such drawings with photographs that are now made almost daily, those by Father Sistini and published first by Lieut. M. F. Maury, Director of the United States Naval Observatory, in the publications of that institution for the year 1847, and printed in 1853. They will be found in Vol. III, appendix A. That number of these publications and others preceding it are comparatively scarce and may not be easily obtained. The drawings are beautiful specimens of art and the engravings show a degree of skill worthy of high commendation. I have no doubt but that those desiring copies of this work as a means of illustration, or for library uses might obtain them at small expense by writing to Professor J. G. Hagan, S. J., of Georgetown College Observatory, Georgetown, District of Columbia.

A still more effective way for the study of the Moon and the Sun is by the aid of lantern slides under a strong light. It may be thought too expensive to provide secondary schools with a good stereopticon and an oxy-hidrogen light for the sake of illustrations in the department of science, but it seems to us that it is wise economy to do this, not only for the science work, but also because the same apparatus can be effectively used in illustrating art and literature studies and even those of language and history. The time is coming and we hope soon, when eye, ear and pencil will more equally share in making mental impressions than has been true in the past, except in some particular branches of study more highly favored in method than others.

The lantern slide furnishes the best means of study of the surface of the planets, because it is easy to make these slides from the current, scientific publications that issue regularly from the leading Observatories of the world, and the persons having such facilities can certainly know and get the very best information and the best results in print almost as soon as it is published.

The character of these drawings is such as to command attention. It is generally true that the best modern astronomical work comes from Observatories that are endowed and have a number of observers in their respective organizations who are trained men in special lines. When any piece of work is completed, or reaches a stage of advancement that knowledge of it will be useful to others, or of general popular interest, it will not generally be difficult to secure such information for publication in channels that are safe for its dissemination. This has been particularly true of all recent, astronomical work for the last twenty years. When Schiaparelli made his notable discoveries in regard to the canals of Mars in 1887-8, it was soon known from one end of the world to the other. Not long after a fine colored map of the entire surface of the planet was published, so that knowledge of what was supposed to be discovered was very widely known and definitely within the reach of astronomers. The same was true of Professor Asaph Hall's brilliant discovery of the satellites of Mars in 1877, of Mr. Barnard's matchless victory in the capture of Jupiter's fifth satellite, of Mr. Lowell's remarkable discoveries regarding the surface markings on the planet Mars, and for like astonishing results in the study of the surfaces of the planets Mercury and Venus.

These are a few instances relating to the studies of the Moon, Sun, and planets which must interest teachers who desire to have within reach the latest and the best information possible, for the work they, themselves, wish to do for the persons or classes they are appointed to instruct. We have recently published in these pages the fine charts of the markings on the surfaces of the planets Mercury and Venus; also, within the last two years much pertaining to the planet Mars, and good illustrations of the surface views of the planet Jupiter by Professor G. W. Hough of Dearborn Observatory, Evanston, Ill., who probably has done more extended and careful work in observing that planet than any other American astronomer.

Now, if professors in the colleges and instructors in the secondary schools would take up this matter systematically and thoroughly, there can be no question regarding the large results—very unexpectedly large results—that will follow such an undertaking.

We will try to furnish the lantern slides and the large photographs as indicated elsewhere in our advertising pages, as promptly as possible after the wishes of those desiring them are known, and give such other sources of information as we have to aid in carrying out the plan suggested in these articles. If the order for slides or photographs should be large, some delay may be necessary to secure the material, because we use only that which is fresh from the makers and it takes about ten days to secure new photographic supplies from Philadelphia or St. Louis.

We have been interested and encouraged, not a little, in the way some prominent teachers have regarded this series of brief articles so far. A considerable number have already ordered the first two volumes of POPULAR ASTRONOMY at the low price of *one dollar each*, to professors and teachers, for the purpose of trying this plan. We believe the investment is a wise one. Next time we will speak of other work possibly reaching the comets, stars, and the nebulæ.

THE TWENTIETH CENTURY*.

Years *ab urbe condita* (A. U. C.) are years counted out from the supposed date of the foundation of the City of Rome. These years are given according to Varro, the greatest authority on that chronology; but the old calendar of the Romans fitted the years like a bad clock fits the time. The calendar was sometimes too fast, sometimes to slow. Not only was the calendar a bad fit for the course of the years, but it was made a foot ball of by political factions, who, being trusted with its occasional correctness, sometimes put it on and sometimes put it back, in order to facilitate their electioneering tricks, and with only secondary regard for keeping the calendar in beat with the course of the seasons.

Some forty-seven years before Christ, Julius Cæsar—the then Dictator of Rome, and one of the greatest men of antiquity—the man who did Britain the service of conquering it twice, and introducing to it the Roman language, laws, and civilization—had his attention called to the vast inconvenience of this state of the Roman calendar, which was then some three months too fast, and indicated the time of spring when the season was really midwinter. He added some ninety days to the calendar for the year 46 B. C., and made that year of the calendar to extend over 445 days, which, in effect, put back the calendar some 90 days. Julius Cæsar then made the year 45 B. C.† to commence on the first of January, on the day of a new Moon. In order also to make the calendar keep better time, he took up the odd quarter of a day by making every fourth year into what we now call a leap-year. This was one of the great services done by Julius Cæsar to the world, and the calendar thus defined with a year of 365 days, but with every fourth year of 366 days, was called the Julian calendar. The seventh month of the year was named Julius, in honor of Julius Cæsar.

The precise length of the real year was not then known; but subsequently the continual revolution of the seasons showed that the Julian calendar was a little too slow. This was because, as we now know, the length of the year is 365¼ days *minus* 11^{m} $12^{s}.43$. Every recurring leap-year, therefore, left the Julian calendar nearly 45^{m} behind time. But the Julian year was very nearly the real year, and it was so vast an improvement upon the former calendar that the years from the 1st of Janu-

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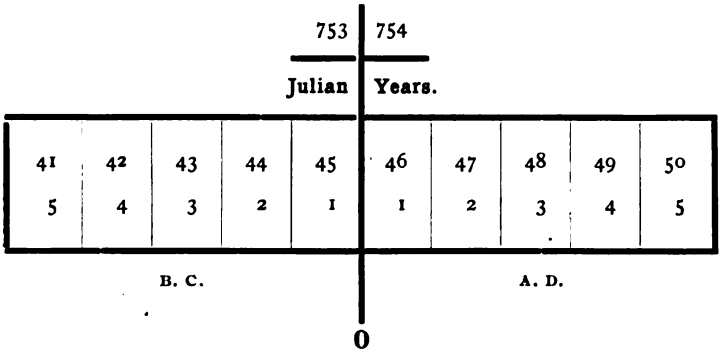
* By Dr. James Edmunds in the *English Mechanic*, 1900, Jan. 28.

† [709 A. U. C.—EDS.]

ary of the first Julian year (45 B. C.) were regarded as the Julian era. Now, the diagram shows that decade of Julian years which covers the period from the end of the 40th Julian year to the end of the 50th, each year being indicated by a space which represents the interval *in time* covered by that particular year. According to the chronology of Varro, the 45th and 46th years of the Julian era were more or less contemporaneous with the 753rd and 754th years from the foundation of Rome. These years are indicated in the diagram by the two top numbers.

Ab Urbe Condita (*Varro*).



				753	754				
				Julian	**Years.**				
41	42	43	44	45	46	47	48	49	50
5	4	3	2	1	1	2	3	4	5
		B. C.					A. D.		

Nativity.

The end of the 45th Julian year was the date adopted by the Monk Dionysius Exiguus in the year A. D. 527 as the commencement of the Christian era. It therefore follows that the 45th Julian year was the first year before the commencement of the Christian era, and that the 46th Julian year was the first year after the commencement of the Christian era. The decade of years of the Julian era from 41 to 50 inclusive was thus contemporaneous with the first five years before Christ (B. C.). and the first five years after Christ (A. D.). If, now, the diagram be considered by the light of this explanation, and the spaces be regarded as representing the respective years, it should be easy to see " what it is that we are talking about."

The putting in of the leap-years of the Julian era fell into the hands of the priests. They blundered over it, and for the first 36 years of the Julian calendar they put in a leap-year every third year instead of every fourth year. The priests managed this by something like the method of Lord Dundreary, who discovered that whether he had ten fingers on his two hands—or nine, or eleven—depended solely upon whether he counted his fingers forwards or backwards, and where he left off before he summed them up. Whether the priests began, as some sages of this day do, with a zero year, I do not know. But they counted both extremes, as was the custom in Rome, and so made every three years into four. The result was that in the 37th Julian year, the Emperor Cæsar Augustus discovered that the calendar was too slow by three days, and he then ordered that the next three leap-years should be omitted. Now the next three leap-years would have been 40, 44, and 48 of the Julian era, and these were all reduced to 365 days each. It was not till the fourth leap year, the fifty-second Julian year, and the seventh of the Christian era, that another year of 366 days was let into the calendar. Thus it came about that leap-years were non-existent in the Julian calendar at the commencement of the Christian era.

Owing to the Julian calendar, with its leap-years, proving too slow for the years by an annual interval of $11^{m}\ 12^{s}.43 = 44^{m}\ 49^{s}.72$, or nearly 45 minutes every leap-year, the calendar had got twelve days behind the true season of the year in the time of Pope Gregory. By that time the true length of the year was more accurately known, and Pope Gregory then put the calendar on ten days, so as to correct it for the days it had fallen behind, while, in order to make the calendar in future to keep better time with the revolutions of the Earth round the Sun, he ordained that all the centurial leap-years, except such as were divisible by 400, should be left out. This was in 1582. The Julian calendar, thus further corrected, thenceforth was very unfairly called the Gregorian calendar. What the Monk Dionysius Exiguus had done in 527 was simply to steal the Julian Era. Its first 45 years he cut off, and its 46th he called the first of the Christian era. Otherwise it remained the Julian calendar. And all that Pope Gregory had done was to partly make those further corrections in the number of leap-years which the Julian calendar in its working for centuries had shown to be necessary. The Catholic countries in general at once adopted the New Style (N.S.) of Pope Gregory. This reformed calendar was ten days in advance of other nations, and the unreformed calendar, for the sake of distinction, had to be denoted as Old Style (O.S.). England, being a Protestant country, did not then adopt Pope Gregory's New Style, nor his omitted leap-years. But in 1752 England did this by Act of Parliament (24 Geo. II. c. 23). Russia, being under the sway of the Greek or Eastern church, has even rejected the reformed calendar till this day. Christmas Day, which we held on our Dec. 25, was therefore in Russia the

13th of December. Again, owing to the 1900th year with us having its leap-year omitted, while in Russia it is still a leap-year, as ordained by Julius Cæsar, their calendar will be 13 days behind time on their first of March, 1900. Anglo-Russian documents therefore have to carry two dates in order to avoid confusion. The dates will appear thus:—

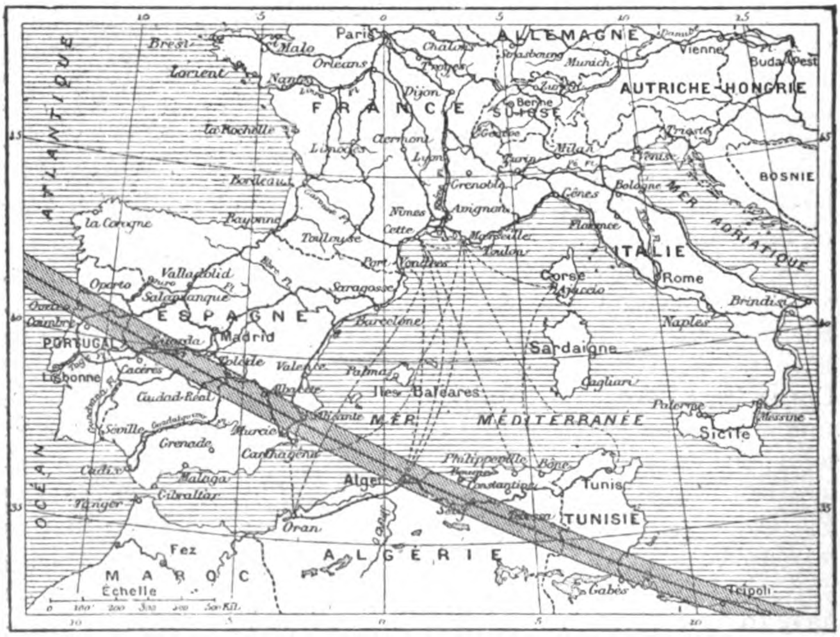
Thursday, 1900, March $\frac{2 \text{ O.S.}}{15 \text{ N.S.}}$.

Reverting now to our diagram, it will be evident that the years B. C. are merely a retrospective method of labelling time, and that, in counting the years B. C., we count backwards, and in each year we unavoidably begin with the 31st of December, and end with the 1st of January. The years A. D. we count forwards, precisely as we count the years of a man's age, and the early calendar A. D. we regard precisely as we regard the calendar to-day. It is, therefore, evident that the 100th year has to be completed before the 1st century is finished, and that the 1900th year has to be completed before the 19th century is finished. When we come to nineteen hundred *and* one we shall have completed the 19th century and entered upon the first year of the 20th.

As to the sticklers for the precise moment of the real Nativity, we know neither the day nor the month of the Nativity. Historians, moreover, are agreed that Christ must have been born prior to February in the fourth year B. C. But whether Christ were born five years before the date now in use for the commencement of the Christian era, or were born five years after it, or had never been born at all. makes not a particle of difference. Our calendar has been determined by an English Act of Parliament, and it would be alike impracticable and futile for us now to attempt to alter it. Nor does the naming nor dating of our era have anything to do with the number of years which have to be allotted to a century. If a cheque for £100 be misdated, that makes no difference to the number of sovereigns which the payee is entitled to at the bank counter. So, in order to complete a century, we must finish up its 100th year to the last moment.

THE APPROACHING TOTAL ECLIPSE OF THE SUN.

The astronomers of both Europe and America are now busy in making arrangements to observe the total eclipse of the Sun which will occur on the 28th of next May. As usual, our American cousins are better off than we are, for they can observe the eclipse without going out of their own country. British astronomers will have to travel to Spain or Portugal. The eclipse path stretches from the west of New Orleans to Algiers and N. Africa on the east. The local times and conditions at certain points along this path are thus given in the "Local Particulars" published by the *Nautical Almanac* Office:—



MAP OF ECLIPSE PATH 28 MAY 1900.*

Position W. of New Orleans.
Long. 90° 6′ W., Lat. 30° 4′ N.

		Local Mean Times.					Central Standard Mean Times.				Sun's Altitude.
		d	h	m	s		d	h	m	s	°
Eclipse begins	May	27	18	26	13	May	27	18	26	37	18
Totality begins	"	27	19	29	42	"	27	19	30	6	30
Totality ends	"	27	19	31	0	"	27	19	31	24	
Eclipse ends	"	27	20	43	10	"	27	20	43	34	46

Duration of Totality 1^m 17^s.8.

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* From the January Bulletin de la Societé Astronomique de France.

Angle from N. point of	first contact, 104° towards the W. last contact, 76° towards the E.	for *direct* image.
Angle from Vertex, of	first contact, 40° towards the W. last contact, 145° towards the E.	

Position near Union Point, Georgia.
Long. 83° 5′ W., Lat. 33° 29′ N.

	Local Mean Times.					Central Standard Mean Times.					Sun's Altitude.
		d	h	m	s		d	h	m	s	°
Eclipse begins	May	27	19	0	25	May	27	18	32	45	25
Totality begins	"	27	20	7	52	"	27	19	40	12	39
Totality ends	"	27	20	9	24	"	27	19	41	44	
Eclipse ends	"	27	21	26	16	"	27	20	58	36	55

Duration of Totality, 1^m 32^s.

Angle from N point, of	first contact, 104° towards the W. last contact, 76° towards the E.	for *direct* image.
Angle, from Vertex, of	first contact, 41° towards the W. last contact, 139° towards the E.	

Position south of Cape Henry, Virginia.
Long. 76° 5′ W., Lat. 36° 42′ N.

	Local Mean Times.					Central Standard Mean Times.					Sun s Altitude.
		d	h	m	s		d	h	m	s	°
Eclipse begins	May	27	19	36	35	May	27	19	40	55	33
Totality begins	"	27	20	48	7	"	27	20	52	27	47
Totality ends	"	27	20	49	53	"	27	20	54	13	
Eclipse ends	"	27	22	11	2	"	27	22	15	22	62

Duration of Totality, 1^m 45^s.6.

Angle from N. point, of	first contact, 103° towards the W. last contact, 78° towards the E.	for *direct* image.
Angle from Vertex, of	first contact, 44° towards the W. last contact, 130° towards the E.	

Position near Ovar (Portugal).
Long. 8° 38′ W., Lat. 40° 50′ N.

	Local Mean Times.					Central Standard Mean Times.					Sun's Altitude.
		d	h	m	s		d	h	m	s	°
Eclipse begins	May	28	2	8	35	May	28	2	43	7	56
Totality begins	"	28	3	27	10	"	28	4	1	42	42
Totality ends	"	28	3	28	43	"	28	4	3	15	
Eclipse ends	"	28	4	38	42	"	28	5	13	14	30

Duration of Totality, 1^m 33^s.6.

Angle from N. point, of	first contact, 89° towards the W. last contact, 93° towards the E.	for *direct* image.
Angle, from Vertex, of	first contact, 137° towards the W. last contact, 38° towards the E.	

Position S. W. of Talavera de la Reina (Spain).
Long. 5° 10′ W., Lat. 39° 47′ N.

	Local Mean Times.					Central Standard Mean Times.					Sun s Altitude.
		d	h	m	s		d	h	m	s	°
Eclipse begins	May	28	2	29	18	May	28	2	49	58	53
Totality begins	"	28	3	46	2	"	28	4	6	42	39
Totality ends	"	28	3	47	29	"	28	4	8	9	
Eclipse ends	"	28	4	55	38	"	28	5	16	18	26

Duration of Totality, 1^m 27^s.4

Angle, from N. point, of	first contact,	88° towards the W.	for *direct* image.
	last contact,	94° towards the E.	
Angle, from Vertex, of	first contact,	140° towards the W.	
	last contact,	38° towards the E.	

Position west of Puerto del Inferno (Spain).
Long. 1° 43′ W., Lat. 38° 38′ N.

	Local Mean Times.				Central Standard Mean Times.				Sun's Altitude.
	d	h	m	s	d	h	m	s	°
Eclipse begins	May 28	2	49	40	May 28	2	56	32	49
Totality begins	" 28	4	4	28	" 28	4	11	20	35
Totality ends	" 28	4	5	49	" 28	4	12	41	
Eclipse ends	" 28	5	12	9	" 28	5	19	1	23

Duration of Totality, $1^m 21^s.5$.

Angle, from N point, of	first contact,	87° towards the W.	for *direct* image.
	last contact,	94° towards the E.	
Angle, from Vertex, of	first contact,	143° towards the W.	
	last contact,	38° towards the E.	

Cape de Sta. Pola (Alicante) Spain.
Long. 0° 30′ W., Lat. 38° 13′ N.

	Local Mean Times.				Central Standard Mean Times.				Sun's Altitude.
	d	h	m	s	d	h	m	s	°
Eclipse begins	May 28	2	56	47	May 28	2	58	47	48
Totality begins	" 28	4	10	52	" 28	4	12	52	34
Totality ends	" 28	4	12	11	" 28	4	14	11	
Eclipse ends	" 28	5	17	55	" 28	5	19	55	21

Duration of Totality, $1^m 19^s.4$.

Angle, from N. point, of	first contact,	87° towards the W.	for *direct* image.
	last contact,	94° towards the E.	
Angle, from Vertex, of	first contact,	144° towards the W.	
	last contact,	38° towards the E.	

The accompanying map of the line of totality will show the parts of Spain, Portugal, Algeria and Tunis from which this eclipse can be observed. It will be seen that the track, after leaving Spain near Alicante, crosses the Mediterranean and enters Africa close to Algiers.

We may be perfectly certain that the astronomers of the United States and France will man the beginning and the end of the line quite efficiently. It is clear, therefore, that the attention of British astronomers with serious work to do will be directed to the observing stations in Spain and Portugal.

The weather chances were stated by Professor Arcimis in a former number of *Nature*,[*] and may be considered excellent.

There are many branches of work, such as securing photographs of the corona, in which amateurs may do good service. For them the well-found steamers leaving Marseilles may make the coast near Algiers more convenient.—*Nature*, Dec. 28, 1899.

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[*] Vol. lix. p. 439.

ORIGIN OF THE LUNAR FORMATIONS.*

Various theories have been advanced at different times to explain the origin of the lunar craters, but the chief difficulty that astronomers have heretofore met has been to account for the gigantic scale upon which they are formed. In the series of experiments presently to be described, artificial craters have been constructed resembling those found at present upon the Moon. Since in the earlier experiments no recourse is had to capillary action, or to the explosion of gases, there seems to be no natural limit set to the size of the formations that may be produced by this method, either naturally or artificially. In the explosive experiments described later other features are illustrated. I should state that this investigation was suggested by a letter from Mr. J. B. Hannay, published in *Nature*, 1892, Vol. XLVII, p. 7. In it he describes some minute craterlets naturally produced in solidifying iron slag It seemed to me worth while to repeat these experiments, and to obtain if possible some substance more readily manipulated than melted iron. The substance which I found best suited to the purpose was paraffine. This material melts at so low a temperature that it can be readily handled in the viscous form, while at the same time it becomes quite hard and firm at ordinary temperatures. Like the materials composing the crust of the Earth, it contracts on solidifying, the change in volume in both cases being rather large.

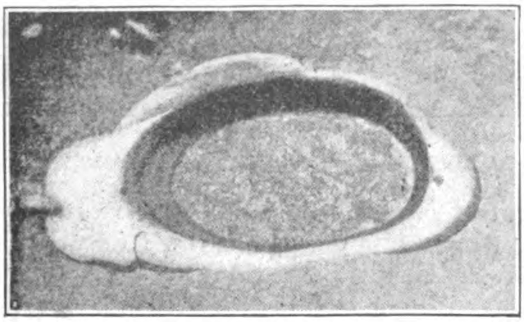

FIG. 14.

The paraffine was melted in an enamelled ware pan, measuring three and a half inches deep by eight in diameter, over a small spirit lamp. By employing a small source of heat the paraffine

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* From Vol. 32, pt. 2 of the Annals of Harvard College Observatory, by William H. Pickering.

was melted locally above the flame, and soon formed a little hole in the surface crust measuring about one quarter of an inch in diameter. That portion of the liquid in contact with the bottom of the pan was at a much higher temperature than that above it, and was forced upwards by the heat, rapidly enlarging the hole formed in the crust above it. The hole retained its circular or elliptical form, and continued to enlarge as long as the hot liquid was brought in contact with it. As soon as it had reached a convenient size the lamp was extinguished, and the cooling process begun. As the lower regions of the paraffine cooled they contracted, and the liquid surface dropped, leaving a smoothly cut elliptical pit (Figure 14)*. The sides were at first quite shelving, but by reheating the fluid once or twice they became steeper, and even overhung in some places. Probably a rapid cooling at the surface, and a more rapid contraction of the fluid, obtained by using a larger reservoir, would accomplish the same result. If the contraction is allowed to proceed too far, however, the floor of the crater pit becomes concave, and may even be broken through by the pressure of the atmosphere.

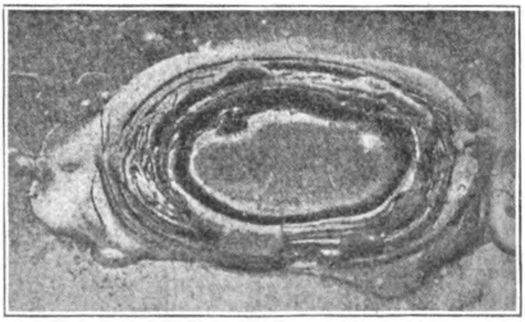

FIG. 15.

In Mr. Hannay's letter he refers to the former very powerful influence of the tides upon the liquids contained within, and upon the surface of the Moon. This tidal action was imitated by inserting a brass tube one inch in diameter and twelve inches long in the paraffine when it was first melted. The tube was fitted with a wooden piston packed loosely with cotton flannel. By working this piston up and down, the melted pariffine could be made alternately to rise and fall inside the craters formed by it, and the cooling process could be hastened when desired by blow-

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* Number of Figure in Vol. 32, pt. 2, H. C. O. Annals.

ing upon the liquid surface. Craters (Figures 15 and 16) were formed in the same manner as the first one, excepting that after extinguishing the lamp the tidal action was brought into play, alternately pumping the liquid up to the rim of the crater, where it partially solidified, leaving a little ring of solid parffine, and then drawing it down again into the interior, where it soon partly remelted, preparatory to a renewed elevation. This tidal action was continued until the fluid became quite viscous, solidifying into little hills and ridges inside the crater, and later as the hardening surface was dragged out of shape bv the pumping of the liquid below it, little cracks were formed around the edges and across the bottom of the crater, like the rills seen in similar situations upon the Moon.

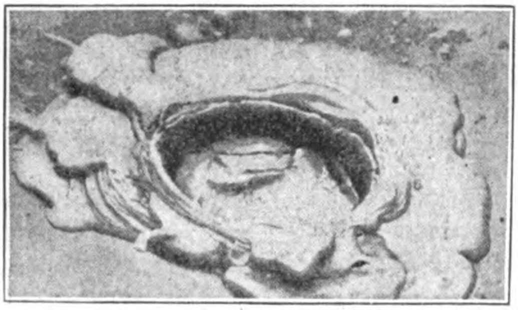


FIG. 16.

If now, we raise the piston high enough, and wait for air to get underneath it, we may force this down into the melted paraffine. The result is an explosion, in which the paraffine may shoot up several feet in the air. If care is taken, however, the jets may be confined to the height of a few inches. A cone is soon formed (Figure 17), and the liquid paraffine trickles down the slopes in miniature lava streams. As the cooling process goes on the paraffine comes out in bubbles, like soap suds, which break and rapidly build up the cone. If the process is continued further, partially solid lumps of paraffine are projected into the air, falling down upon the outer slopes of the cone. The crater now gradually narrows, and if care is not taken will soon become clogged. With care many well known volcanic phenomena may be repeated, such, for instance, as the shifting of crater to one side, and the formation of a succession of crater rings and semi-circles. Also the bursting out of new craters near the base of the original cone. Indeed, the investigator is likely to perform this experiment involuntary, if he permits the main vent to get partially clogged, and applies too much heat below. The introduction of air seems to transport us at once from lunar to terrestrial scenes, although in the case of the Earth the tides of course have nothing to do with the matter, their place being taken by irregularly recurring explosions of steam.

FIG 17.

Applying now the results of our experiments to the case of the Moon, we may conceive that the order of formation was somewhat as follows. We will start with the Moon in the form of a liquid or viscous sphere, revolving about the Earth, and close to its surface. Under these circumstances the tides would be of enormous power, and quite unlike in magnitude anything at present existing upon the Earth. Those constituents of the Moon having the least specific gravity would float upon the surface and soon solidify, forming a thin crust. Whether this occurred before or after the solidification of the central core through pressure is of no consequence. As it solidified the crust would contract, forming cracks, which would be enlarged at points into circular holes or craters by the hot liquid interior, while the remaining portions of the crack would become filled with fluid from the interior, which would slowly harden and become part of the continuous surface. We have an illustration this very process arrested in the act, in the case of the great rill of Hyginus, and the small craters distributed along its length. Hyginus is probably a later formation, however, as, if the crust had been thin, the process would have been completed, the craters enlarged, and the rill filled up.

When the process first began, numerous comparatively small holes would form one after another. These holes would continue to enlarge, retaining their circular form, as the hot liquid was forced through them, until the action was stopped by a sufficiently thick crust forming upon the liquid surface. In the mean time the tremendous tides engendered by our Earth, coursing through the imprisoned liquid interior, would fracture the thin and brittle crust in fresh places, where the same process would be repeated. When the crust was thin the enlargement of the crater would proceed rapidly, and the aperture might attain considerable dimensions before the restraining crust was formed, but as the original crust thickened, and the passage connecting the aperture with the liquid interior lengthened, we should find that the craters formed would be smaller, but more numerous. We should thus expect, in general, that the older the crater the larger it would be, and that the smaller craters would impinge upon the larger ones, and not *vice versa*. An examination of the lunar surface shows this to be the case. The older and larger craters, like Clavius, Albategnius, and many others near the south pole, are pitted and sometimes almost concealed by numerous smaller and later craters, while craters of more moderate size, like Tycho and Copernicus, are comparatively free from such intrusions.

It can be shown that the maximum surface tension exerted by the Earth upon the Moon is exerted upon the great circle forming the limb, and tends to separate the two hemispheres with a force which at the mean distance of the two bodies amounts to a tension of 9.6 pounds on the square inch. When the Moon was at one-tenth of its present distance from the Earth, this tension would have been one thousand times as great, and would have been sufficient to shatter it to pieces had it then existed in the solid form. If, however, it were fluid or viscous, as we have supposed, the effect would have been merely to produce an enormous tide, as has been shown by Professor Darwin. In the mean time, if the Moon revolved rapidly on its axis, so that all portions of its surface were presented successively to the Earth, this maximum strain would be felt successively by all portions of its surface, the tendency being to separate, or crack it, in a meridional direction. We should thus expect to find that the earlier formations would have a tendency to lie in lines in a north and south direction. This we find actually to be the case with the craters that we have been discussing, particularly the larger ones. This fact has been pointed out by Webb, Neison and others.

The craters of this early period, of which Copernicus is the characteristic example, would be moulded by the enormous tides into forms resembling Figures 15 and 16. The interior surface of one crater, Wargentin, apparently solidified when the tide which filled it reached to its very rim. The aperture connecting it with the interior had in some way evidently become clogged, and the fluid which had formed the crater was caught as it were in the act, to serve as a clue and perpetual illustration of the process of construction to all future generations. Another crater, Mersenius, has a conspicuously convex interior. This was the case at first with the paraffine crater represented in Figure 15, but subsequent cooling caused it to become concave. If the floors of the lunar craters when they solidified were in general convex, it is evident that the subsequent solidification of the fluid beneath them would tend to make the floor level, thereby producing a compression of the surface, which might well result in the formation of a central peak or ridge. If the paraffine model had been constructed upon a larger scale, and the contraction of the fluid beneath it had been allowed to proceed more slowly, it is thought that this result might have been obtained. As it was, a tendency to form small ridges was noticed. In Figure 16 the internal surface of the crater was artificially broken, thereby producing the central mound.

As the cooling process continued, regions deeper down solidified and contracted. The upper layers, having now become completely solid, would not contract at the same rate, with the fall of temperature, and the result would be that the surface of the Moon, instead of being too small, would now be too large for its interior. When this "critical epoch" occurred, the formation of craters would for a time almost cease. The result would be a local subsidence with a considerable local evolution of heat, although the temperature of the Moon as a whole would still continue to diminish. If the heat so developed were sufficient to overcome the latent heat of solidification a considerable portion of the subsident area might be melted, while portions of the original crust carrying their ancient craters with them, would sink slowly beneath the liquid surface, the process of destruction continuing as long as the supply of heat lasted.

In the mean time the Moon would have receded much farther from the Earth, and the tides would have accordingly greatly diminished in their intensity. The subsident areas would in general be large in extent, such as the Maria Imbrium, Serenitatis, and Crisium. The darker color of their floors would seem to indicate that they were formed from another kind of material, which, coming from a considerable depth, had united and mixed with the lighter colored molten matter which had formed the original surface. In these *maria* we often see the outlines of old crater rings which have been partially melted down and absorbed in the subsequent eruption of melted matter from the interior. Since in all cases the melting progresses outward from a centre, we see why it is that these large seas, like the smaller craters, all retain the approximately circular shape. In some cases where the original crust has subsided, it has melted in the thinnest places only, such as the bottoms of the deepest craters. Thus Plato probably had originally an interior like that of Copernicus, but the melting process which destroyed the bottom was not carried far enough to ruin its walls also, as was partially done in the case of many of the older craters. The elevation of the surfaces of the *maria* probably indicates their relative age, the lower ones being formed last.

(TO BE CONTINUED.)

SPECTROSCOPIC NOTES.

The approaching total eclipse of the Sun May 28, 1900, will be elaborately observed, and should yield some valuable spectroscopic results. As the path of totality passes through such an accessible district in this country the number of well equipped expeditions should be unusually large, while with favorable weather there should be a host of general observers. With New Orleans, Mobile, Raleigh, and Norfolk in the path of totality, thousands can hope to see the corona with no greater inconvenience than going out of doors; while not a few will regard a view of the corona ample reward for traveling a considerable distance.

The probability of a clear sky at the time of totality, as shown by weather observations covering a number of years, varies considerably for different parts of the path. The best prospect for good weather is in the highest elevation in northern Georgia and eastern Alabama, decreasing gradually toward the Gulf coast in one direction and the Atlantic coast in the other. The path of totality on land in this hemisphere is so long that even with a general storm it will be quite possible to have clear weather for a part of the path, and with this in view the extreme southwest should not be altogether neglected. Local fog or flying clouds may add interest and excitement. In case of partial cloudiness in any district observers should be scattered; for this, without diminishing the chances of any individual, increases vastly the probability that the eclipse will be seen by some at least of the party.

For the powerful spectroscopes of various types there will be work in plenty, in the accurate determination of the revised position of the corona line; possibly in the measurement of the velocity of rotation of the corona; and in the study of the flash spectrum at the instants of beginning and end of totality. With the most modest spectroscope the gaseous character of the corona may be shown, and the relative brightness of the weak continuous spectrum may be studied.

The European and African end of the path of totality, passing through Portugal (Coimbra), Spain (Alicante), and Algiers, will be occupied by a number of parties and many general observers. Baron de la Baume Pluvinel on behalf of the French Astronomical Society has visited Spain to ascertain the weather prospects at various points and to arrange for the accommodation of intending visitors. The British Astronomical Association in case a sufficient number express an intention of going will arrange an expedition much after the character of the one to Vadso, Norway, in 1896. A steamer will be chartered to leave Southampton May 18, and after touching at Cadiz to land observers for the centre of Spain, and at Alicante to land those who expect to observe at that point, the ship will proceed to Algiers May 24, and will remain there till after the eclipse; leaving Algiers May 25, touching at Alicante, Gibraltar, and Lisbon, will arrive at Southampton June 4.

The prizes announced by the French Academy of Sciences for 1900 include the Janssen prize, a gold medal, for the most important discovery in physical astronomy.

The report of the Superintendent of the United States Naval Observatory states that the difficulties involved in using a lens only visually corrected for photographing star spectra have been remedied by the insertion of a correcting lens of 2.09 inches aperture, which alters the minimum focus from λ 5270 in the yellow-green to λ 4341 in the violet.

The variable star 2852 V Puppis has recently been studied by Mr. A. W. Roberts at Lovedale, South Africa (*Astronomical Journal* No. 477). He assigns it to the Algol class with a period of 1.5 days. In 1886 Mr. Stanly Williams supected variation and suggested a period of 4.2 days. In 1896 Professor Pickering found the star to be a spectroscopic binary with a period, about double that given by Mr. Roberts, of 3.115 days. Mr. Roberts' observations are consistent with the assumption of the two components, slightly unequal in brightness, revolving in an orbit nearly circular and only slightly inclined; the distance between the surfaces of the stars being less than their semidiameter.

PLANET NOTES FOR MARCH.

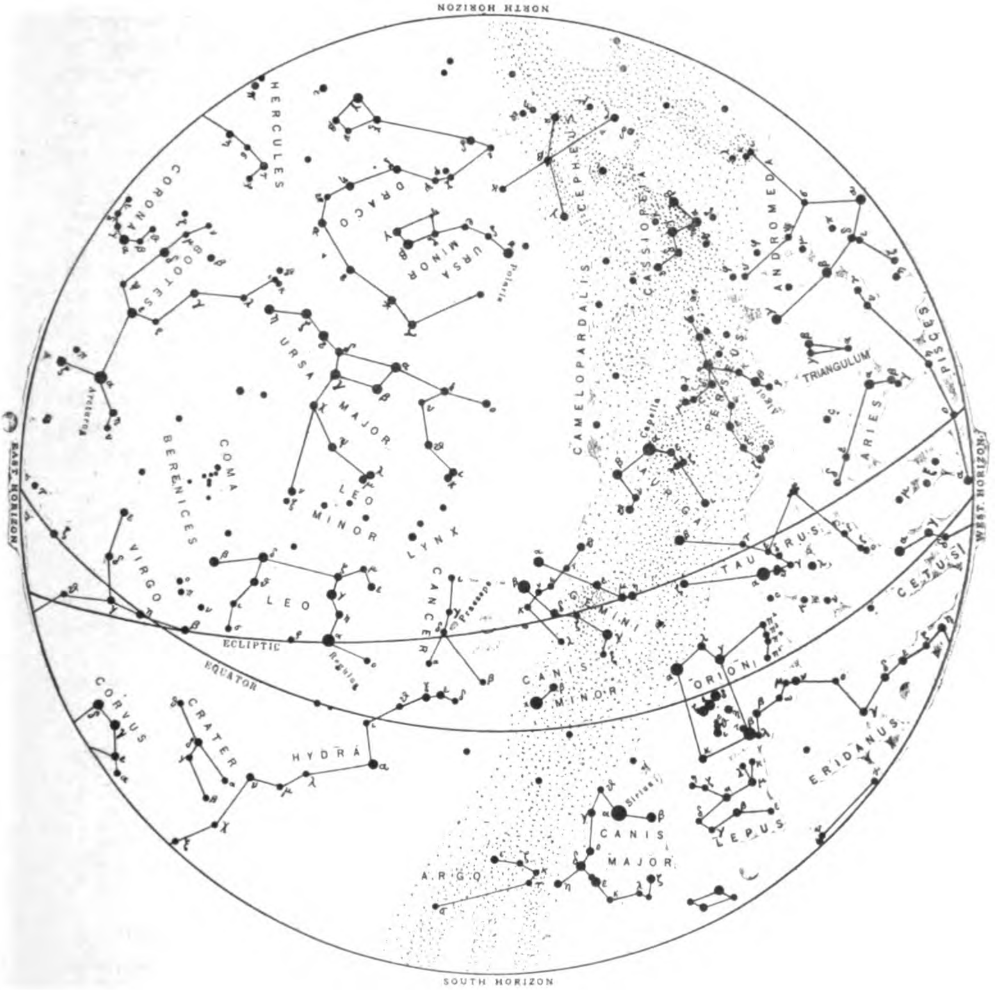
H. C. WILSON.

Mercury is now visible as "evening star" and will continue to be visible to the naked eye for a couple of weeks. Look toward the western horizon about seven o'clock. Mercury is brighter than any star in the vicinity, and ruddy in color because of its low altitude. The planet will be at greatest elongation east from the Sun, 18° 16′, on March 7. On the 24th Mercury will be at inferior conjunction and a couple of weeks later become visible as morning star.

Venus lights up the western sky in the evening with her brilliant rays, causing opaque objects to cast quite perceptible shadows in her light. One can easily see this planet with the naked eye in full sunlight, at any time during a clear afternoon, when once her place is pointed out. Venus disc is gibbous, about half way between the quarter and full phases, and is waning quite rapidly in phase while her light is increasing because of her approach to the Earth.

Mars is morning star but too nearly in line with the Sun to be observed.

Jupiter can be seen in the morning toward the south, but at a low altitude, so that it is not worth the while losing sleep to study the planet.



THE CONSTELLATIONS AT 9 P. M., MARCH 1, 1900.

Saturn and *Uranus* also are toward the southeast in the morning, not far from Jupiter, but at low altiudes. Uranus will be at quadrature March 3 and Saturn in the same aspect on March 25.

Neptune will be at quadrature east of the Sun on the 14th, and may be observed in the early evening, in the constellation Taurus: R. A. March 15, 5^h 35^m; Decl. + 22° 5′. It will move very slowly eastward, being now at the turn of the western loop in its annual path.

The Moon.

		Phases.	Rises.		Sets. (Central Standard Time at Northfield; Local Time 13m less.)	
			h	m	h	m
Mar.	7	First Quarter..............	10	09 A. M.	1	59 A. M.
	16	Full Moon....................	7	06 P. M.	6	29 "
	23	Last Quarter................	1	10 A. M.	10	13 "
	30	New Moon....................	5	27 "	6	55 P. M.

Occultations Visible at Washington.

Date. 1900.		Star's Name.	Magnitude.	IMMERSION. Washington M. T.		IMMERSION. Angle f'm N pt.	EMERSION. Washington M. T.		EMERSION. Angle f'm N pt.	Duration.	
				h	m	°	h	m	°	h	m
Mar.	5	δ Arietis	4.0	11	25	57	12	09	293	0	44
	13	14 Sextantis	6.6	12	38	167	13	36	258	0	58
	14	36 Sextantis	6.6	7	11	51	7	40	5	0	29
	14	55 Leonis	6.2	15	36	88	16	34	323	0	58
	14	57 Leonis	6.9	16	08	141	17	06	269	0	58
	23	Saturn	...	13	31	100	14	38	260	1	07

The occultation of Saturn will be visible only in the eastern part of the United States, and there it will be so close to the horizon that the immersion will be almost hopeless of observation. In Europe and Africa the conditions will be much more favorable.

VARIABLE STARS.

J. A. PARKHURST.

Maxima and Minima of Long Period Variables.

1900 April.

MAXIMA.

		Mag.	Day.
434	S Piscium	8 6	29
1981	S Camelopardalis	8.4	16
2100	U Orionis	7.0	17
2735	U Canis minoris	8.7	30
3244	S Pyxidis	8.3	3
3264	W Cancri	9.6	13
3425	X Hydrae	8.4	30
—	- Virginis	8	6
4849	R Canum Ven.	6.4	2
5465	R Trianguli Austr.	6.7	5
5583	X Librae	9.7	9
5675	V Coronae	7.4	12
5776	X Scorpii	10.0	10
5831	S Scorpii	9.7	23
6062	RR Scorpii	7.3	5
6225	RS Herculis	8.0	2
7045	R Cygni	7.0	1
7118	X Aquilae	8 6	16
7192	Z Cygni	7.8	2
7404	R Microscopii	8.0	1
7448	W Aquarii	8.0	6
7450	V Aquarii	8.1	10

MAXIMA, Con't.

		Mag.	Day.
7468	T Aquarii	7.2	20
7560	R Vulpeculae	8.0	1
—	- Pegasi	9	9
7792	SS Cygni	8.5	14?
7907	U Aquarii	9.7	25
8600	R Cassiopeae	6.0	27
	MINIMA.		
243	U Cassiopeae	<15	11
973	T Arietis	9.5	28
806	*o* Ceti	9	10
1805	V Orionis	<13	6
2478	R Lyncis	<13	29
3186	T Cancri	9.9	20
4492	Y Virginis	12.2	30
5338	U Bootis	12.8	2
5677	R Serpentis	13	6
6044	S Herculis	12	4
6849	R Aquilae	11.2	4
6943	T Sagittae	9.6	27
7428	V Cygni	13.5	20
7456	RR Cygni	9.5	29

NOTES TO LONG PERIOD EPHEMERIS.

1) The dates are taken from Dr. Hartwig's ephemeris in Vol. 34 of the *Vierteljahrsschrift*, part 4. The star numbers and magnitudes are taken from Chandler's Third Catalogue, with a few exceptions.

2) The Star —— — Virginis is at $12^h\ 39^m\ 54^s$, + 4° 56′.1, (1855).

3) The star —— — Pegasi is at $21^h\ 14^m\ 8^s$, + 13° 50′.3, (1855). See No. 3521 of the *Nachrichten* and Nos. 457, 465 and 473 of the *Astronomical Journal.*

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900 April.

U CEPHEI.

	d	h
April	4	15
	9	14
	14	14
	19	14
	24	13
	29	13

ALGOL.

	d	h
April	17	13
	23	7

R CANIS MAJ.

Every 8th min.
$P = 1^d\ 3^h.3$

	d	h
April	1	14
	10	16
	19	18
	28	20

S. CANCRI.

	d	h
April	3	17
	22	16

S VELORUM.

	d	h
April	23	22
	29	20

δ LIBRAE.

	d	h
April	1	14
	2	22
	8	14
	10	21
	15	13
	17	21
	22	13
	24	21
	29	12

U CORONAE.

	d	h
April	1	12
	4	23
	8	10
	11	21
	15	8
	18	18
	25	16

U OPHIUCHI.

Every 10th min.
$P = 20.1^h$

	d	h
April	4	21
	13	6
	21	16
	30	1

RS SAGITTARII.

	d	h
April	4	11
	6	21
	11	17
	16	13
	18	23
	23	19
	28	15

DM. + 45°3062.

	d	h
April	1	17
	6	7
	10	20
	15	10
	20	0
	24	14
	29	3

DM. + 12°3557.

April	1	16
	2	14
	3	11
	7	22
	8	19
	9	16
	10	14
	11	11
	15	22
	16	19
	17	16
	18	14
	19	11
	23	22
	24	19
	25	17
	26	14
	27	11

W. DELPHINI.

	d	h
April	11	20
	16	16

AUTHORITIES FOR ALGOL-TYPE EPHEMERIS—The times for the above ephemeris are taken from Dr. Hartwig's paper in the *Vierteljahrsschrift* with the following exceptions:

1) For R Canis Majoris, S Velorum and RS Sagittarii they were computed from the elements in Chandler's Third Catalogue.

2) For DM. + 12°3557 Luizet's elements, in No. 3596 of the *Nachrichten* were used.

CORRECTION TO THE ALGOL-TYPE EPHEMERIS IN THE FEBRUARY NUMBER.—As noted at the top of page 100, the times for part of the ephemeris were expressed in *civil* time instead of *astronomical* time, but through an error in making up the form the correction was separated from the ephemeris, so that there was danger of its being overlooked. A note from the editors of the *Observatory* gives the source of the original error in the adoption of *civil* time in the French *Annuaire du Bureau des Longitudes* from which the ephemeris was taken.

VARIABLE STAR SECTION OF THE BRITISH ASTRONOMICAL ASSOCIATION.—Col. Markwick has lately been appointed Director of this Section. He is an accomplished variable star observer and doubtless the Section will flourish under his direction. The following item from his introductory address will interest American observers. "Out of 165 observations of maxima and minima reviewed in the last 6 numbers of the *Journal* (of the British Astronomical Association) 135 were made in America."

VARIABLES IN THE REVISED EDITION OF YOUNG'S GENERAL ASTRONOMY.—A considerable improvement is seen in the light-curves of typical variables, over those given in the first edition. Notably that of Mira corresponds with that given by Dr. Nyland, which was reproduced in Vol. VI, page 413 of this Journal.

SS CYGNI.—In spite of generally unfavorable weather the maximum noted in the February number, page 100, was observed well enough to determine its character. The rise occurred between Dec. 31 and Jan. 2, the maximum about Jan. 7, at 8.4 magnitude, and normal light was reached about Jan. 19, giving a typical long maximum. If the abnormal maximum described in the January number be left out of account, the previous normal period lasted 55 days, just about the usual length. The abnormal maximum has evidently not disturbed the usual order. The number of observations of the January maximum reported so far are as follows;

Zaccheus Daniel	6,	J. A. Parkhurst	10,
David Flanery	1,	W. E. Sperra	4.

U GEMINORUM.—Mr. Sperra has published his observations of the January maximum in No. 476 of the *Astronomical Journal*, showing that the rise took place between 1899 Dec. 30 and 31. In connection with the observations of Mr. Daniel and the writer it is seen that the maximum was passed about Jan. 2 and normal light was reached Jan. 7 or 8. Mr. Daniel is following the star through its normal light with the 10-inch refractor of the Bucknell Observatory.

ANDERSON'S NEW VARIABLE IN HERCULES, which was charted on page 45 of the January number, was found fainter than the 13th magnitude by Mr. Daniel 1899 Nov. 23 and 28. It afterwards rose rather rapidly, for on Feb. 1 I found it only two or three steps fainter than the comparison star *a*, whose DM magnitude is 9.0. The star is thus seen to have a considerable range and a fairly rapid rate of variation. Its place for 1900 is—

R. A. $17^h\ 55^m\ 25^s$, Decl. $+ 19° \ 29'\ 20''$,

thus bringing it into good position for morning observation.

A NEW ALGOL-TYPE VARIABLE.—Professor W. Ceraski, director of the Moscow Observatory, prints the following note in No. 3614 of the *Nachrichten*.

"From a study of the photographs taken by my assistant, M. Blajke, Madam L. Ceraski has found a new variable in the position,

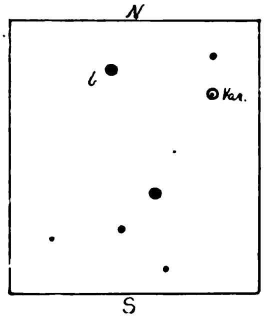
R. A. 19^h	40^m	$59^s.7$	Decl. $+ 32°$	$21'$	$6''$,	(1855)
19	42	33 .4	$+ 32$	27	34	(1900)

The position was found from one of the plates, the coördinates of the fundamental stars being taken from the Leyden Zones.

Studying other photographs of the same region, M. Blajke has found that the star was invisible on 4 plates, and on 15 it was constant in light, making it probable that it belongs to the Algol-type.

On the 16th of December of this year, at $5^h\ 3^m$, Moscow Mean Time, M. Blajke found the star fainter than usual, the minimum had taken place a few hours before and it was approaching normal light.

New Algol-type Variable
$19^h 41^m 0^s$, $+32° 21'.1$ (1855)
Ceraski's Chart.



From all the proceding a period of $6^d\ 0^h\ 9^m.4$ has been deduced, a minimum occurred 1399 December 15, $23^h.3$, Greenwich Mean Time, the error in the minimum may reach $\frac{1}{2}^h$, that of the period will probably not exceed $0^m.1$.

The accompanying chart shows the variable and neighboring stars."

Scale of the charts.* The chart given by Ceraski is about 7′ by 8′. Its relation to the DM chart can be seen by the stars *a* and *b*, which are lettered on both. The DM chart also contains the variable χ Cygni at $19^h\ 45^m\ 0^s$, $+ 32°\ 33'.0$, which is now rising towards maximum.

The plates on which the star was constant† in light were taken—

1)	1895	Sept.	24	$11^h\ 50^m - 13^h\ 32^m$,	Moscow Mean Time
2)	1895	Oct.	12	6 45 − 11 45	" " "
3)	1898	May	12	11 50 − 13 35	" " "
4)	1898	July	29	12 20 − 13 25	" " "

The variable is usually about the 10th magnitude, at minimum it is 12th magnitude or fainter.

For some time the minimum will take place during daylight, when it cannot be observed.

COMET AND ASTEROID NOTES.

Comet *a* 1900 (Giacobini).—A faint comet was discovered by Giacobini at Nice on Jan. 31 in the constellation Eridanus about 10° directly south of the star *α* Ceti. Its motion is northwesterly and rather slow. No elements reached us until Feb. 28, when the elements and ephemeris by Perrine, given below, were received by telegram from John Ritchie, Jr., Boston, Mass. As seen in our 16-inch telescope in moonlight, Feb. 5, the comet was exceedingly faint and difficult to observe. Bad weather and the lack of an ephemeris prevented later observations.

ELEMENTS OF COMET *a* 1900 BY C. D. PERRINE.

$T =$ April 29.08, 1900 Gr. M. T.
$\omega = 24°\ 37'$
$\Omega = 40\ \ 25$
$i = 146\ \ 25$
$q = 1.3289$

EPHEMERIS.

		R. A.			Dec.		Light.
		h	m	s	°	′	
Feb.	26	2	10	32	+1	43	0.85
Mar.	2	2	05	36	2	56	
	6	2	01	52	4	07	
	10	1	58	32	+5	15	0.82

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* The second cut was lost by engraver or in transit.

† NOTE. This seems to be an error for "invisible," as printed it is "invariable."

The date of the first observation used in the computation was Feb. 3 and the interval from the first to the second more than 10 days, and from the second to the third 5 days. The elements, therefore, ought to be fairly reliable. The comet according to the ephemeris is now in the neck of Cetus and will soon enter Aries.

New Elements of Asteroid 1899 EY.—Mr. Otto Knopf gives new elements of this planet, in *Astronomische Nachrichten*, No. 3621, based on observations on the dates Dec. 7 and 29 and Jan. 21.

Epoch 1900 Jan. 0.0 Berlin M. T.

$$\left.\begin{array}{l} M = 19^\circ\ 43'\ 24''.0 \\ \omega = 322\ \ 58\ \ 41\ .4 \\ \Omega = 89\ \ 55\ \ 39\ .0 \\ i = 15\ \ 13\ \ 23\ .9 \end{array}\right\} 1900.0 \qquad \begin{array}{l} \varphi = 4^\circ\ 28'\ 33''.5 \\ \mu = 668''.1835 \\ \log a = 0.433407 \end{array}$$

With these he has computed the following ephemeris, for Berlin, midnight:

	R. A. h	m	s	Dec. °	′	log r	log Δ	Mag.
Mar. 5	4	31	03	+21	49.1	0.4544	0.4418	10.7
7		32	58	22	00.0			
9		34	57	22	10.9	0.4547	0.4506	10.8
11		37	00	22	21.6			
13		39	06	22	32.2	0.4550	0.4592	10.8
15		41	16	22	42.7			
17		43	29	22	53.1	0.4553	0.4675	10.9
19		45	46	23	03.3			
21		48	06	23	13.4	0.4556	0.4756	10.9
23		50	29	23	23.3			
25		52	55	23	33.0	0.4559	0.4834	11.0
27		55	24	23	42.5			
29	4	57	56	23	51.9	0.4562	0.4909	11.0
31	5	00	31	+24	01.1			

GENERAL NOTES.

We are delayed, again, in getting some important illustrations ready for this issue. We know our subscribers would be better pleased if we were able to issue our publication earlier. We are trying to catch up, and still hope to do so for the April number.

Beginning of the Twentieth Century.—It is astonishing to see how thinking people are confused about the beginning of the twentieth century. There can be no uncertainty about this, if it is remembered that there is no zero year in our calendar before the Christian era, at its beginning or since. Year 2 did not begin until the end of year 1, year 20 did not begin until the end of year 19; hence year 1901 will not begin until the end of year 1900. We are not yet in the twentieth century.

The Nebulae of the Pleiades.—Two fine specimens of the recent work of the Crossley Reflector in photographing the Nebulae of the Pleiades have just come to hand by favor of Professor James E. Keeler, Director of the Lick Observatory, Mount Hamilton, California. One of these positives is the Maia Nebula, and the other is the Merope Nebula. The dark background of each positive covers a space of 5 inches square in each picture. One or both of these fine pictures will appear in our next number.

Rays from Bright Stars in Photographs.—Professor E. E. Barnard, of Yerkes Observatory, Williams Bay, Wisconsin, was a visitor at the February meeting of the Royal Astronomical Society, London, England. While the work of reflecting telescopes was under discussion, Professor Barnard was asked for his views, being cordially welcomed and addressed as an authority on stellar photography. In reply he said: "I have not had experience in the use of the reflecting telescope, but I have generally had the impression that it is not at all comparable with the refractor, especially for visual work; but the things that have been done in the last few years in the way of astronomical photography with the reflector have led me to think that when properly mounted, as Mr. Christie has said, it is the better instrument for taking nebulæ. It is far better than the refractor for that work. I was much interested in the very beautiful picture of the Pleiades, and there was one thing I was rather struck with. I do not know exactly what is the reason, but there seems to be a total absence in this particular picture of the objectionable rays from the brighter stars that are seen in the photographs made with the reflector. I do not know how these are got rid of, but I believe it is due to the supports of the small mirror. I should be glad to have a little more information on this subject. I should like to know why the bright stars in the field are not accompanied by nebulosity and how these rather objectionable defects have been got rid of."

In reply to this Dr. Common said: "It is the fact that two supports (to the small mirror) produce four rays, three produce six, but four produce four. So you can have four supports with less injury to the image than with three."

We learn from a friend that Professor Barnard sailed for America, Feb. 24.

Comet *a* 1900 (Giacobini).—On the afternoon of February 1, I received a telegram from Professor Edward C. Pickering, announcing the discovery of this comet. The following night being clear and dark, I observed the new comet with the ten inch Clark telescope of the Bucknell Observatory. The comet was pretty faint. I could just glimpse it with the three inch finder, but my four inch refractor showed it very distinctly. In the ten inch refractor, it appeared small and round with a strong central condensation. No train was seen, but a nucleus was suspected. I saw the comet again on February 2, but the conditions were not so good as they were on the previous night. Since that time, I have not seen it, owing to clouds and moonlight. No observations for position could be made because the micrometer is not in working order.

BUCKNELL UNIVERSITY, Lewisburg, Penn., ZACCHEUS DANIEL.
1900 February 16.

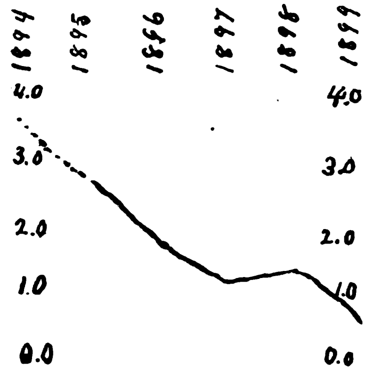
Dawn of the Twentieth Century.—"The first people to live in the twentieth century will be the Friendly Islanders, for the date-line, as it may be called, lies in the Pacific Ocean just to the east of their group," writes John Ritchie, Jr., in the January Ladies' Home Journal, of "Where the next century will really begin." "At that time, although it will be already Tuesday to them, all the rest of the world will be enjoying some phase of Monday, the last day of the nineteenth century [December 31, 1900]. At Melbourne the people will be going to bed for it will be nearly ten o'clock; at Manila it will be two hours earlier in the evening; at Calcutta the English residents will be sitting at their Monday afternoon dinner, for it will be about six o'clock; and in London, 'Big Ben,' in the House of Commons, will be striking the hour of noon. In Boston, New York and Washington half the people will be eating breakfast on Monday morning, while Chicago will be barely conscious of the dawn. At the same moment San Francisco will be in the deepest sleep of what is popularly called Sunday night, though really the early dark hours of Monday morning, and half the Pacific will be wrapped in the darkness of the same morning hours, which become earlier to the west, until at Midway or Brooks Island it will be but a few minutes past midnight of Sunday night."

Five Years of Sun Spots.—Late in the fall of 1894 our telescope was mounted. Soon afterward we began observing sun spots, and making record of the number seen at each observation.

The record has many breaks, as to its continuity, but possibly it is worth preserving.

The record which is given below was begun Jan. 1, 1895 and closed the last of Dec., 1899.

	No. of Observations.	Average No. of Spots.
1895	123	24
1896	100	15
1897	76	10
1898	105	11
1899	38	6



SUN SPOT CURVE.

DRAKE UNIVERSITY, Des Moines, Ia.

W. A. CRUSENBURY.

Mme. Ceraski's Second Algol Variable.—Another remarkable variable star of the Algol class has been discovered by Mme. Ceraski, and is announced in the *Astron. Nach.* 151, 223. The position for 1900 is R. A. = 19^h $42^m.7$, Decl. = + 32° 28′. From an examination of the Draper Memorial photographs of this star, it appears that while the star has its full brightness on 45 of them, on several of the early photographs it is so faint that they must have been taken when the star was near minimum. The Moscow photographs furnish the means of determining the period from an interval of four years, the Harvard photographs increase this interval to nine years. The following table gives, in the first seven lines, the results derived from the Harvard photographs; the next four, the results of the Moscow photographs; and the last line gives the estimate of M. Blajko. The times of minima as found by Professor Ceraski may be expressed by the formula J. D. 2,415,004.971 + $6^d.0065$ E. Measures of four Harvard photographs when the star had its full brightness gave the photographic magnitudes, 11.00, 10.80, 10.74, and 10.79; mean 10.83. The value of E, derived from the above formula; the year, month and day; the Greenwich Mean Time of the middle of the exposure; the corresponding time expressed in Julian Days and decimals; and the duration of the exposure in minutes are given in the first five columns of the table. The sixth column gives the photographic magnitude, and the seventh, the phase computed by means of the formula mentioned above. The error in the ephemeris is given in the eighth column, and is derived from an approximate light curve. It appears that the period is too long by about $0^m.6$, and if this correction is applied, the errors have the values given in the ninth column. The tenth column gives the mean photographic magnitude, during the entire time of exposure, derived from the corrected ephemeris and light curve.

E.	Date.			G. M. T.		J. D.	Ex.	Magn.	Phase.	O–C.	O–C′.	C. M.
	y	*m*	*d*	*h*	*m*		*m*					
− 580	1890	6	2	16	32	1521.689	27	11.81	+ .488	+ .25	+ .01	11.7
− 570	1890	8	1	14	20	1581.597	13	12.75	+ .331	+ .24	+ .02	12.7
− 570	1890	8	1	14	57	1581.623	20	12.22	+ .357	+ .16	− .06	12.5
− 557	1890	10	8	11	53	1659.495	10	< 12.4	+ .145	. .	. .	12.8
− 508	1891	8	8	16	07	1953.672	20	< 11.7	+ .003	. .	. .	12.1
− 443	1892	9	2	14	44	2344.614	16	10.96	+ .522	+ .18	.00	11.0
− 325	1894	8	11	15	07	3052.630	10	10.90	− .228	+ .13	−.01	10.9
− 257	1895	9	24	10	11	3461.424	102	< 12	+ .124	. .	. .	12.9
− 254	1895	10	12	6	45	3479.281	300	< 12	− .039	. .	. .	12.5
− 97	1898	5	12	10	12	4422.425	105	< 12	+ .085	. .	. .	12.9
− 84	1898	7	29	10	22	4500.432	125	< 12	+ .008	. .	. .	12.9
− 0	1899	12	16	3	33	5005.106	125	Ft.	+ .135	. .	. .	12.5

It appears from this table that while the formula of Professor Ceraski satisfies all the later observations, it is not confirmed by the early observations. For instance, according to this formula the star should have had nearly its full brightness on the first three photographs. On the other hand, all the observations are satisfied by the corrected formula, in which the period is $6^d\ 0^h\ 8^m.8$. As soon as we obtain accurate observations of subsequent minima, these combined with the photographs taken in 1890, will give a much more precise formula. A comparison of the sixth and tenth columns shows that the observed and computed magnitudes differ in one case only by more than one tenth. A slight defect partially covers the image of the variable on the second plate taken August 1, 1890, and thus renders the measured value too bright. The period differs so little from exactly 6 days that for a long time the minima cannot be observed in certain longitudes. Accordingly, while valuable observations may be obtained next autumn in Europe, or better still in Asia, minima cannot be observed in America until the following year.

Five stars of the Algol class, S Cancri, U Cephei, W Delphini, + 45°3062, and the star here discussed are especially interesting, owing to the large variation in their light, which amounts to about two magnitudes in each case. It is remarkable that two of these were found by Mme. Ceraski, and one by her distinguished husband. EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY Circular No. 47.
February 12, 1900.

Leonids Seen at Scott Observatory, Park College, November, 1899.—November 13. Sky was overcast with heavy clouds from midnight till daylight. No meteors were visible.

November 14. A heavy fog overhung the landscape from midnight till two o'clock, when it began to settle down, though a thin haze prevailed all over the sky till half past four o'clock, Central Standard Time. From that time till dawn, which came about six o'clock, the sky was reasonably clear. For the record made, see annexed pages.

November 15. Thin hazy clouds prevailed all night. At times these were so dense that not even the Moon was visible through them; then, again, stars as bright as Regulus or Aldebaran would show dimly; and, very rarely, γ and ϵ Leonis would show quite distinctly. Stars of fifth magnitude could not be seen at any time during the night.

November 16. Heavy clouds spread over the sky. Rain came once and lightning played frequently. The clouds began to break away about half past five o'clock, and for a few minutes, once just before 5:30 and again just before six o'clock, the "sickle" in Leo came into view.

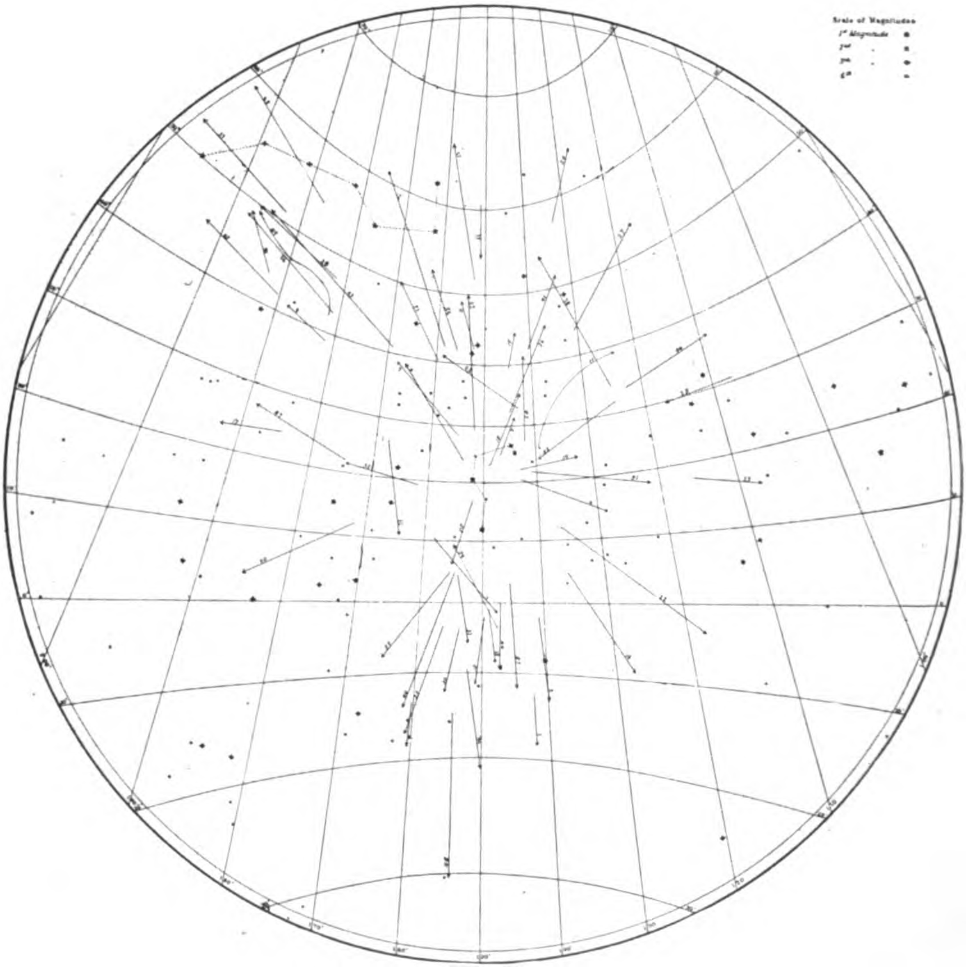


CHART OF LEONIDS.

By Professor S. P. Brackett, Park College, Mo., Nov. 13-16, 1899.

November 17. The sky was tolerably clear from midnight till three o'clock and from that time till full daylight as clear as it could possibly be.

On all these nights a large force of watchers, composed of students in the Junior class of Park College, volunteered their services and assisted the writer in carefully kept observations. Probably, in all, a dozen small meteors, nearly or quite all distant from the radiant, were ignored and no record kept of them. Some of these came from the direction of the radiant but most of them did not. The writer most gladly attributes a large portion of the success (small as it was on account of clouds) to the efficient help rendered by the young ladies and gentlemen of the student body, Juniors and Seniors in Park College. The following is the record:

Scott Observatory is in Lat. + 39° 03′ 18″ and Long. 94° 41′ 26″ W.

TUESDAY NIGHT.

Time. h	m	s	Color.	Mag.	Leonid or Not.	Time. h	m	s	Color.	Mag.	Leonid or Not.
14	08	45	B	3.5	L	16	56	25	R	2	L
	17	08	B	3	L		57	28	Y	2	L
	17	27	B	5	L		58	15	R	2	L
	38	02	B	5	?	16	59	48	R	5	N
	39	55	B	3	N	17	00	10	B	4	L
	45	05	B	2	N		03	00	R	3	L
	45	07	B	2.2	L		05	30	R	2	L
	46	03	Y	3.3	N		06	25	B	3	N
	47	02	B	5	L		07	07	B	2	L
	55	04	B	4	L		08	45	R	2	L
14	59	03	B	4	L		09	27	B	2	L
15	01	40	R	2	N		10	01	B	3	L
	02	06	B	3	L		11	48	B	1.5	L
	03	59	B	3	N		12	02	B	6v	L
	04	01	B	3	N		12	40	Y	4	L
	04	45	R	1	L		15	03	B	4	L
	06	07	B	3	L		15	05	B	2	L
	08	05	R	2	N		15	10	Y	2	L
	12	59	Y	3	N		15	21	B	1.5	L
	14	20	B	4.5	L		15	46	B	− 2	N
	18	08	B	6	L		15	55	R	1	L
	18	41	R	2.5	L		16	30	B	5	L
	19	06	B	5	L		17	02	B	2	L
	20	11	B	6	L		18	10	B	− 1.5	L
	21	20	R	1	L		18	15	R	4	L
	22	25	B	4	N		20	05	B	− 2	L
	23	04	R	4	L		20	16	B	3	L
	30	21	R	3	N		20	50	Y	5	N
	36	00	B	3	L		21	04	B	1	L
	45	04	B	− 1	L		21	16	Y	3	N
	47	17	B	4	L		21	45	B	3.5	L
	50	42	R	2	N		22	04	B	3	N
	52	03	B	3	L		22	19	Y	4	L
15	52	05	B	2	L		23	00	B	4	N
16	08	02	Y	4	N		23	07	B	6	L
	10	12	B	4	L		24	03	B	2	L
	13	01	B	5	L		24	05	B	4	N
	17	13	B	5	L		25	32	B	− 2	L
	20	07	R	5	?		25	45	B	− 3	L
	22	25	R	2.5	L		28	05	B	5	L
	30	45	R	2	L		29	01	B	6	?
	31	05	B	2	L		30	14	B	− 2	L
	34	11	B	5	L		30	25	B	3	L
	35	50	Y	5	L		31	20	B	− 2	L
	37	06	RY	3	L		32	20	B	1	L
	37	45	B	3.5	L		32	45	Y	4	L
	40	03	B	6	L		33	41	R	5	L
	46	55	Y	4	L		34	05	R	2	L
	47	00	RY	2	L		34	36	B	4	L
	48	01	B	5	L		35	05	Y	4	L
	48	35	R	2.5	L		36	55	B	3	L
	50	01	B	3	L		36	57	B	2	L
	52	26	B	4	L		37	45	Y	4	N
	54	02	B	4	L		38	25	B	− 2	L
16	55	49	B	3	L	17	39	06	Y	3	L

Time.			Color.	Mag.	Leonid or Not.	Time.			Color.	Mag.	Leonid or Not.
h	m	s				h	m	s			
17	40	14	B	2	L	17	49	08	B	5	L
	40	25	R	3	L		52	15	B	3	L
	41	03	B	5	N		52	24	B	3	L
	42	06	B	2	L		54	01	B	4	L
	42	55	B	3	L		55	13	B	1.5	L
	43	41	B	2	L		56	34	Y	1	L
	44	00	B	5	L		56	52	R	3	L
	44	31	B	5	N		57	03	B	2	L
	44	47	Y	5	L		58	04	B	1	L
	46	03	B	6	L	17	59	11	B	5	L
	47	25	B	4	L	18	01	03	B	3	L
	48	32	B	2	L		02	01	B	5	L

WEDNESDAY NIGHT.

Time.			Color.	Mag.	Leonid or Not.	Time.			Color.	Mag.	Leonid or Not.
h	m	s				h	m	s			
13	45	29	B	3	L	14	42	34	B	3	L
	55	55	B	3	L		48	08	B. R.	1	L
14	02	20	B	2	L		50	18	B	3	L
	06	22	B	4	L		52	15	B. R.	– 2	N
	10.	32	R	5	N		36	04	B	2	L
	19	45	R	3	L		58	17	R	4	N
	21	14	R	4	N	14	58	56	B	5	L
	21	43	R	3	N	15	03	48	B	3	N
	21	45	R	3	L		11	24	B	4	N
	22	54	R	4	L		11	25	Y	4	L
	23	05	B	4	L		20	41	Y	3	N
	24	53	B	4	L		41	53	B	2.5	L
	25	46	R	5	L	16	06	10	Y	2	L
	27	32	B	5	L		09	05	B	6	L
	28	25	B. G.	3	L		12	16	Y	1	L
	30	03	B	4	L		17	06	B	6	L
	30	15	Y	2	L		18	35	Y	6	L
	31	53	R	4	L		19	31	B	5	L
	32	15	R	3	L		19	34	R	2	L
	33	04	B	4	L		23	11	B	2	L
	33	23	Y	1	N		23	25	B	4	L
	33	38	B	3	L		25	51	R	1	L
	33	44	B	4	L		47	44	B	4	N
	35	17	B	3	L	16	59	19	R	5	N
	36	19	Y	4	L	17	01	45	bg	1	L
	36	33	R	4	N		03	47	R	4	L
	37	10	B	2	L		04	38	Y	4	L
	38	46	B	4	L		08	51	B	4	L
	41	24	R	5	L		23	15	B	4	L
	41	27	B	4	L	17	31	53	B	4	L
14	42	19	B	3	L						

THURSDAY NIGHT.

Cloudy till nearly dawn.

Time.			Color.	Mag.	Leonid or Not.	Time			Color.	Mag.	Leonid or Not.
h	m	s				h	m	s			
17	49	48	B	– 1	L	17	26	49	R	4	L

FRIDAY NIGHT.

Time.			Color.	Mag.	Leonid or Not.	Time.			Coror.	Mag.	Leonid or Not.
h	m	s				h	m	s			
13	09	17	R	4	N	14	00	07	B	3	N
	11	42	R	3	?		01	12	Y	3	N
	33	10	R	1	L		29	35	Y	1	N

Time.			Color.	Mag.	Leonid or Not.
h	m	s			
14	40	01	B	4	L
	44	32	B	3	N
	56	39	B	3	L
15	11	04	B	1	L
	31	47	B	3	L
	34	58	Y	1	L
	37	39	R	2	N
	40	46	B	3	L
	43	54	B	3	L
	44	19	B	1	L
	45	21	R	6	N
	51	05	B	1	L
15	52	00	B	2	L
15	52	09	B	4	L
16	00	01	B	2	N
	16	09	B	3	L
	19	30	B	4	L
	24	48	B	4	L
	26	49	R	4	N
	32	51	Y	2	L
	34	43	B	2	L
	45	04	B	4	L
17	01	09	B	4	N

Meteors seen Tuesday night	134
" " Wednesday night	61
" " Thursday night	2
" " Friday night	29
Total	226

Probably from a dozen to twenty meteors fell, but so far from the radiant that no record was kept of them.

F. P. BRACKETT.

Bulletin of Geography.—"Bulletin of the American Bureau of Geography" is the name of a new publication which is issued under the direction of Edward M. Lehnerts of the State Normal School, Winona, Minn. The first number of this quarterly magazine, which is dated for March, 1900, presents a very creditable appearance. The number of associate editors and the contents of this initial number certainly give promise of large usefulness in its chosen field.

We are especially interested in the article under the title "The points of the compass, and the seasons in teaching Geography in the grades," by Professor John M. Holzinger. His simple illustrations of prominent constellations of stars, and a method of copying and relating bright stars in them is worthy of notice.

Popular Articles on Astronomical Subjects.—The unusual interest in popular articles on astronomical subjects is very noticeable in recent years. In view of this it has seemed to us wise to give larger place to them in the future. In the past two things have stood partially in the way of this: (1) The need of students more or less advanced in the study of astronomy who have asked for, and have needed, such articles as Dr. J. Morrison, of Washington, has furnished from time to time; and (2) the difficulty of getting good popular matter. We have partly overcome these hindrances.

Queries and Short Answers.—1. Please inform one who wishes to know something about Astronomy, what book or books would be best to get.

C. B. T.

Answer. For a beginner, Todd's Stars and Telescopes published by Little, Brown & Co., Boston; Holden's Elementary Astronomy, Henry Holt & Co., New York; Howe's Elements of Descriptive Astronomy, Silver Burdett & Co., Chicago; Howe's Study of the Sky, Flood and Vincent, Meadville, Penn.; Young's Lessons in Astronomy, Ginn & Co., Chicago, are a few of the recently published good books. Prices can be obtained by writing to the publishers.

2. Does the top of a wagon wheel, when rolling on the ground, go faster than the bottom?

H. S.

A. Yes, if the motion of the two points is thought of in relation to a line parallel to the ground. No: if thought of in relation to the center of the wheel.

3. If a stick two feet long, and three inches in diameter at one end, be shaved down to a true point at the other end, then balanced it on a knife-edge, and cut into two pieces on the line of balance, which part will weigh the more?

A. Each part weighs the same.

4. Does the Mississippi river run up hill? It does, if the law of gravitation is true. E.

A. It certainly is true that the mouth of the Mississippi river is farther from the center of the Earth than its source; just how much we do not now stop to inquire, but when the effect of the rotation of the Earth and other conditions that enter into its structure are considered, the fact that the river runs south and not north no more disproves the law of gravitation than if it run north, unless it can be shown certainly that the law of gravitation requires the river to flow northward instead of southward. The attempts that have been recently made to disprove the law of gravitation in this way that we have seen depend on very weak and faulty mathematics. It is like trying to polish a diamond point with a broad ax. Well-meaning students need instruction in mathematics.

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All correspondence and all remittances should be sent to

WM. W. PAYNE,
Northfield, Minn., U. S. A.

Popular Astronomy.

Vol. VIII. No. 4. APRIL, 1900. Whole No. 74.

THE VARIATION OF LATITUDE AT NEW YORK, AND A DETERMINATION OF THE CONSTANT OF ABERRATION FROM OBSERVATIONS AT THE OBSERVATORY OF COLUMBIA UNIVERSITY.

J. K. REES.

FOR POPULAR ASTRONOMY.

In 1892 the Columbia University Observatory completed its arrangements with Professor Em. Fergola, Director of the Royal Observatory at Capodimonte, Naples, for making a series of observations to study the variation of latitude. The Naples Observatory was selected because its latitude differed only 3 minutes of arc from that of the Observatory at Columbia. The regular Observatory of the University was then situated in the middle of the block bounded by 49th and 50th Streets and Madison and Fourth Avenues, New York City. This Observatory was on top of the library building of the University, and within 250 feet of the New York Central and New Haven Railroad tracks. In 1892, the trustees of the University purchased the new site on Morningside Heights, occupied at that time by the Bloomingdale Insane Asylum. The Director of the Observatory was able to interest the authorities of the Asylum, and although the property did not at once pass under the control of the trustees of Columbia, the Asylum trustees allowed the building of a little latitude Observatory on the grounds. The new site was further north than the old Observatory and also provided a place not disturbed by railroads. Here was erected in the fall of 1892 a small circular building of brick about twelve feet in diameter, having in its roof a proper slit for meridian observations. In the building was placed a zenith telescope built by Wanschaff, of Berlin, under the general direction of Dr. Albrecht, of Potsdam. Dr. Albrecht also consented to examine the instrument before it was shipped. The Wanschaff zenith telescope has an aperture of 80 millimeters, and a focal length of 1 meter. It is provided with two latitude levels. The illumination is electric. The instrument was in place and ready for observation about April 1st, 1893. Inasmuch as all of the officers connected with the Observatory were charged with daily work in the Uni-

No.	Name.	Mag.	Approximate Right Ascension 1875.			Declination. 1875.		
			h	m	s	°	′	″
	Group I.							
1	10 Camelopardi	4.0	4	52	18.38	60	15	22.871
2	ι Tauri 102	5.0		55	37.51	21	24	33.418
3	λ Aurigæ 15	5.0	5	10	21.05	39	59	7.306
4	ρ Aurigæ 20	5.8		12	57.62	41	40	37.881
5	17 Camelopardi	6.0		18	22.13	62	57	33.609
6	119 Tauri	5.0		24	53.07	18	29	56.730
7	ξ Aurigæ 30	5.0		44.	22.21	55	40	29.184
8	139 Tauri	5.3		50	14.27	25	56	9.812
9	2 Lyncis	4.6	6	8	35.58	59	3	10.456
10	μ Geminorum 13	3.0		15	23.89	22	34	31.892
11	ν Geminorum 18	4.6		21	32.44	20	17	20.780
12	8 Lyncis	6.0		26	15.72	61	35	15.588
13	ζ′ Geminorum 43	Var.		56	41.66	20	45	5.658
14	17 Lyncis	7.0		58	25.41	60	59	8.508
	Group II.							
15	— Draconis (Pi. XII : 255)	6.	12	56	53.80	64	16	55.500
16	— Comæ Ber. (Pi. XII : 283)	6.7	13	3	39.15	17	30	56.709
17	20 Canum Venaticorum	4.6		11	56.14	41	13	52.193
18	23 Canum Venaticorum	5.6		14	42.77	40	48	25.799
19	83 Ursæ Majoris	5.4		35	59.70	55	18	53.429
20	3 Bootis	6.0		40	54.99	26	19	48.062
21	υ Bootis 5	4.3		43	26.87	16	25	7.516
22	i Draconis 10	5.0		47	46.91	65	20	28.665
23	α Draconis 11	3.3	14	1	0.35	64	58	25.662
24	20 Bootis	5.0		13	50.29	16	52	49.744
25	— Bootis (Pi. XIV : 156)	6.0		34	17.27	54	33	51.853
26	34 Bootis	5.2		37	55.76	27	3	36.690
27	— Bootis (Pi. XIV : 178)	5.5		40	12.70	15	39	28.971
28	2H Ursæ Minoris	5.0		55	36.13	66	25	50.798
	Group III.							
29	ζ Draconis 22	3.0	17	8	25.72	65	52	7.124
30	— Ophiuchi (Pi. XVII : 94)	6.1		18	55.75	15	43	16.331
31	λ Herculis 76	4.8		25	41.17	26	12	22.406
32	ν′ Draconis 24	4.7		29	42.95	55	16	13.085
33	z Herculis 88	6.0		46	47.08	48	25	43.411
34	— Herculis (Pi. XVII : 347)	6.1		56	1.67	33	13	9.913
35	b Herculis 99	5.0	18	2	16.83	30	32	42.835
36	— Draconis (Groom. 2549)	6.3		17	0.48	51	17	36.321
37	42 Draconis	5.1		25	37.39	65	29	10.324
38	— Herculis (Poulk. 2621)	6.4		31	32.59	16	5	33.331
39	— Draconis (Groom 2658)	6.0		39	50.60	62	37	31.854
40	— Herculis (Pi. XVIII : 203)	5.9		43	26.00	19	11	24.217
41	48 Draconis	6.0		54	38.16	57	38	58.554
42	— Vulpeculæ (Bradley 2409)	5.4	19	1	25.64	24	3	29.697
	Group IV.							
43	f′ Cygni 59	5.3	20	55	34.46	47	2	1.149
44	υ Cygni 66	4.3	21	12	46.73	34	22	22.158
45	70 Cygni	5.1		22	15.56	36	34	27.286
46	ρ Cygni 73	4.1		29	16.80	45	2	23 302
47	16 Pegasi	5.3		47	22.54	25	20	15.817
48	13 Cephei	6.1		50	41.12	56	1	10.983
49	— Lacertæ (Pi. XXI : 405)	5.3	22	0	58.29	44	24	24.270
50	1 Lacertæ	4.6		10	31.28	37	7	36.349
51	25 Cephei	6.1		14	8.02	62	10	41.109
52	39 Pegasi	6.0		26	33.09	19	35	10.771
53	— Lacertæ (Groom. 3919)	6.1		48	22.90	39	42	39.015
54	ο Andromedæ 1	3.6		56	10.39	41	39	16.161
55	2 Cassiopeiæ	5.8	23	4	23.78	58	39	18.234
56	υ Pegasi 68	4.6		19	8.52	22	42	58.030
57	6 Lacertæ	5.	22	25	5.57	42	28	58.777
58	8 Lacertæ 2d	6.		30	18.71	38	59	16.172

versity, it made it impossible for one person to do all the work of observing. Moreover, during the summer the Astronomical Department conducts a summer class which occupies nearly the whole time of two of the three officers. It was decided, therefore, to divide the work of observing among three persons, and observations were made every clear night. During the first year and a half all observers lived about three miles away from the latitude Observatory, and it was necessary to make arrangements to sleep at the Asylum. Dr. Lyon, the superintendent of the Asylum, gave us every facility and comfort. Later on when the Asylum buildings were torn down to make way for the new University buildings, other arrangements had to be made.

In December, 1895, the latitude Observatory had to be moved to make way for one of the University buildings. The new resting place was several hundred feet north and west of the first position, to which it was connected by a carefully executed survey.

The two Observatories here and in Naples, being on very nearly the same parallel of latitude, were able to use the same stars. Four groups of stars were selected, seven pairs of stars in each group, and they were so arranged that the observations could be made for a determination of the constant of aberration by Küstner's method. The foregoing table gives the list of stars observed.

From May 1st, 1893, to July 1st, '94, the observations were made every clear night. After the latter date it was decided to observe four clear nights each half month, whenever possible. All of the observations were made by J. K. Rees, H. Jacoby, and H. S. Davis.

For the purpose of reduction our observations were divided into four series as follows:

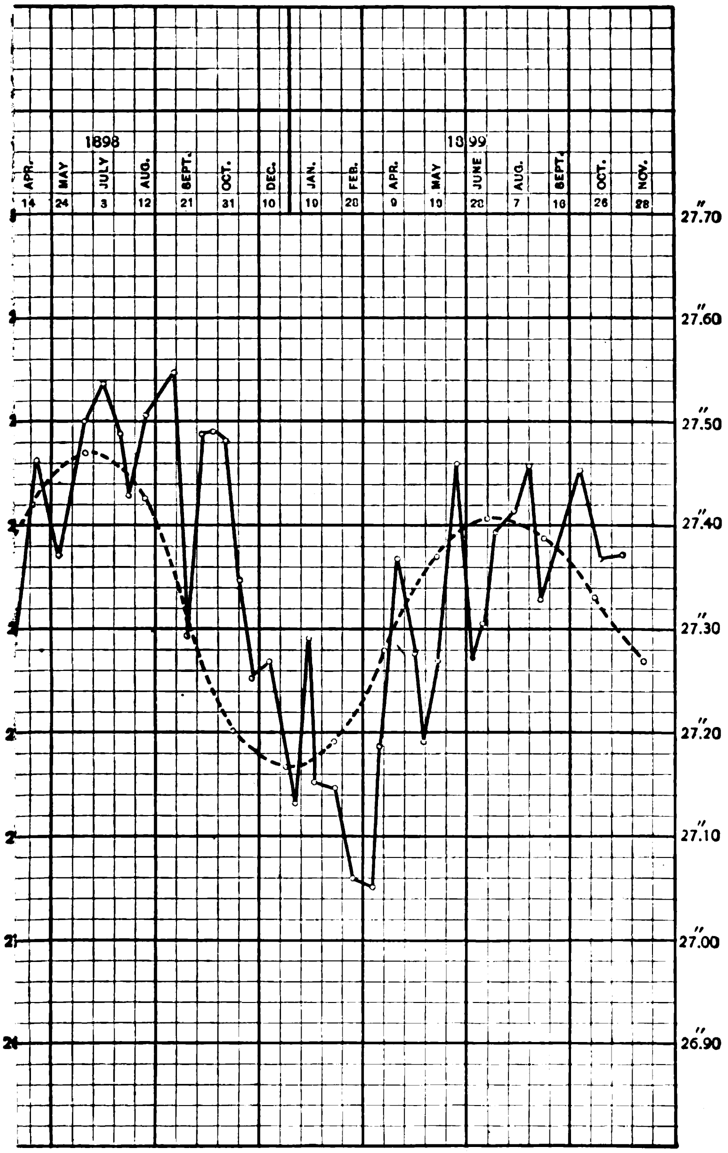
Series A.	April 24, 1892 to July, 1894	818	pairs	by	Rees.
		302	"	"	Jacoby.
		654	"	"	Davis.
" B.	July 1894 to Jan. 1896	771	"	"	Rees.
		310	"	"	Davis.
" C.	Jan. 1896 to Jan. 1898	1065	"	"	Rees.
		774	"	"	Davis.
" D.	Jan. 1898 to Dec. 1899	951	"	"	Rees.
		873	"	"	Davis.
	Total pairs	6518			

This table shows the individual observers to have measured:

Rees	3605	pairs
Jacoby	302	"
Davis	2611	"
Total	6518	

Date.	φ	$\varphi - \varphi_0$.	No. Pairs.
1893			
May 9	27.222	− .082	77
19	.144	− .160	44
27	.162	− .142	42
June 8	.178	− .126	59
17	.198	− .106	45
28	.259	− .045	32
July 8	.262	− .042	30
19	.177	− .127	38
26	.141	− .163	46
Aug. 6	.029	− .275	46
Oct. 6	.377	+ .073	31
15	.244	− .060	43
30	.241	− .063	44
Nov. 9	.111	− .193	46
20	.204	− .100	48
Dec. 3	.232	− .072	18
11	.255	− .049	28
23	.302	− .002	43
1894			
Jan. 2	.192	− .112	36
11	.168	− .136	65
23	.198	− .106	61
Feb. 2	.214	− .090	56
12	.148	− .156	59
24	.193	− .111	86
Mar. 5	.234	− .070	68
21	.083	− .221	51
April 1	.192	− .112	33
11	.199	− .105	65
23	.218	− .086	83
May 2	.153	− .151	89
12	.225	− .079	62
29	.216	− .088	50
June 8	.079	− .225	68
17	.193	− .111	64
July 1	.114	− .190	34
16	.120	− .184	38
Nov. 15	.226	− .078	39
29	.274	− .030	43
Dec. 18	.367	+ .063	25
1895			
Jan. 2	.305	+ .001	20
15	.412	+ .108	53
Feb. 2	.380	+ .076	39
14	.332	+ .028	40
26	.425	+ .121	35
Mar. 10	.500	+ .196	18
21	.346	+ .042	24
April 8	.298	− .006	30
20	.353	+ .049	48
May 7	.354	+ .050	44
18	.213	− .091	47
June 4	.184	− .120	28
13	.257	− .047	51
July 5	.217	− .087	45
16	.286	− .018	23
28	.222	− .082	46
1895			
Aug. 10	27.295	− .009	19
23	27.103	− .201	46
Sept. 15	26.943	− .361	26
Oct. 1	.996	− .308	38
18	27.111	− .193	55
Nov. 5	.119	− .185	50
18	.063	− .241	36
Dec. 2	.070	− .234	41
1896			
Jan. 14	.474	+ .170	37
28	.476	+ .172	54
Feb. 11	.542	+ .238	45
22	.600	+ .296	41
Mar. 5	.560	+ .256	42
17	.627	+ .323	37
28	.464	+ .160	21
April 9	.477	+ .173	37
19	.367	+ .063	33
May 5	.513	+ .209	56
18	.532	+ .228	27
June 4	.551	+ .247	47
20	.554	+ .250	30
July 1	.501	+ .197	48
12	.437	+ .133	31
31	.458	+ .154	47
Aug. 19	.379	+ .075	57
Sept. 9	.331	+ .027	23
26	.240	− .064	27
Oct. 13	.135	− .169	35
25	.142	− .162	53
Nov. 10	.193	− .111	59
23	.118	− .186	23
Dec. 5	.232	− .072	37
15	.314	+ .010	15
28	.219	− .085	27
1897			
Jan. 8	.345	+ .041	23
25	.214	− .090	41
Feb. 5	.387	+ .083	28
18	.362	+ .058	53
28	.378	+ .074	55
Mar. 10	.452	+ .148	38
23	.283	− .021	10
April 25	.583	+ .279	41
May 21	.565	+ .261	73
June 1	.376	+ .072	16
17	.573	+ .269	48
July 2	.595	+ .291	44
20	.597	+ .293	26
Aug. 4	.522	+ .218	70
Aug. 22	.639	+ .335	44
Sept. 30	.503	+ .199	97
Oct. 16	.324	+ .020	13
Nov. 4	.361	+ .057	38
16	.254	− .050	20
1897			
Nov. 26	.089	− .215	37
Dec. 10	.193	− .111	13
26	27.100	− .204	22
1898			
Jan. 10	.205	− .099	33
26	.139	− .165	43
Feb. 10	.177	− .127	53
Mar. 1	.246	− .058	88
17	.169	− .135	25
April 4	.285	− .019	33
19	.461	+ .157	22
May 12	.365	+ .061	69
26	.429	+ .125	28
June 13	.501	+ .197	64
26	.539	+ .235	59
July 12	.488	+ .184	75
26	.430	+ .126	23
Aug. 12	.506	+ .202	32
Sept. 6	.549	+ .245	47
17	.295	− .009	28
Oct. 2	.488	+ .184	45
15	.490	+ .186	42
Nov. 1	.485	+ .181	59
15	.354	+ .050	40
Dec. 1	.251	− .053	48
14	.264	− .040	28
1899			
Jan. 14	.138	− .166	36
23	.291	− .013	44
Feb. 3	.151	− .153	28
23	.146	− .158	35
Mar. 13	.060	− .244	24
26	.055	− .249	16
April 6	.189	− .115	28
26	.366	+ .062	48
May 9	.275	− .029	29
14	.194	− .110	39
29	.267	− .037	61
June 16	.459	+ .155	11
30	.275	− .029	46
July 14	.309	+ .005	48
25	.391	+ .087	21
Aug. 12	.418	+ .114	51
22	.458	+ .154	42
Sept. 4	.322	+ .018	63
30	.397	+ .093	31
Oct. 17	.451	+ .147	35
Nov. 5	.361	+ .057	51
24	.369	+ .065	53
Mean	27.304		

The record shows that observations were taken on 758 nights.


1898
1899
APR. 14
MAY 24
JULY 3
AUG. 12
SEPT. 21
OCT. 31
DEC. 10
JAN. 19
FEB. 28
APR. 9
MAY 19
JUNE 28
AUG. 7
SEPT. 16
OCT. 26
NOV. 28
27.70″
27.60″
27.50″
27.40″
27.30″
27.20″
27.10″
27.00″
26.90″

Po

The computations give the following table* and curve which show the variation of latitude.

The curve required by Dr. S. C. Chandler's formula (*Ast. Jour.*, No. 446) is shown in the dotted line. From 1896 the observed epochs of maxima and minima follow the computed in time.

Dr. Chandler writes me that "on account of the different combinations of the observers participating at various times, there are doubtless constant differences of zeros in the observed curve at different epochs, which would bodily shift the latter up or down, over certain intervals. However the noticeable systematic differences of the observed and computed curves (notably from 1896 to 1898 where the observed epochs of maxima and minima distinctly follow the computed in time) are undoubtedly real, as well as extremely interesting. In my opinion they are referable to the fact that the annual ellipse is not stationary, but that its line of apsides is retrograding several degrees annually, as I have pointed out in my articles in various places (see especially *Ast. Journal* No. 446 where I have summed up the evidence). Of course the law of this revolution is not yet sufficiently demonstrated to justify its being incorporated in the formula which is hence based on a constant position of the ellipse ($\omega = 39°.6$); that is, the inclination of the major axis of the annual ellipse is assumed as 40° east of Greenwich, although the evidence is sure that it is backing around, so that it is now (1898-99) somewhat west of Greenwich. The fuller and more satisfactory investigation of this phenomenon must await the accumulation of two or three years' observations. By 1902 or 1903 I think it can be clearly apprehended, and formulated; not before. Another interesting fact is that your later observations confirm what your and other series earlier indicated, namely, that the dimension of the fourteen months' circular motion has progressively diminished since 1890. This is so well established that it was embodied in the formula some years ago." Nearly every element entering into this motion of the pole is variable.

The four series of observation gave the foregoing values of the Aberration Constant:

Series A.	20.″4566	weight 18
B.	20. 4525	" 16
C.	20. 4695	" 26
D.	20. 4704	" 27

Taking the probable error of a single latitude observation as

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* The previous publications will be found in *The Astronomical Journal* Nos. 401, 451, 474. In these papers the mean latitude is taken for each series and not, as in this case, for the whole time.

0″.16 gives Constant of Aberration 20″.464 ± 0″.006.

Fergola obtained a value, corresponding in time to our Series A, of 20″.53, using the same stars and the same methods of reduction.

Harkness in his work on "The Solar Parallax and its related Constants" (1891) gives the values of the constant of aberration determined between the years 1817-1888, and from his discussion of these values gets 20″.466 ± 0.011. Newcomb in 1895 published his book on "Astronomical Constants" in which he gave the values of the aberration constant down to 1894. He divided the results into two classes: A, standard Pulkova determinations, and B, other determinations. The separate results he weighted and obtained

Mean result from A	20.493 ± 0″.011
" " " B	20.463 ± 0 .013

The first result is almost "identical with that found by Nyrén" in 1883: this was 20″.492 ± 0″.006 and was not included in list A or B.

These results were all obtained on the assumption of a constant latitude. Dr. Chandler has rediscussed and obtained quite different results. The Paris Conference of May 1896 adopted the value of 20″.47.

Doolittle's results gave him a mean value of 20″.580 from observations made 1896-1898: Fergola obtained, as stated above, at Naples the value 20″.533. Finlay at the Cape of Good Hope obtained the value 20″.57 and at Berlin and Strassburg have been obtained the values 20″.511 and 20″.475.

The value 20″.47 corresponds to the value of solar parallax of 8″.8033, while 20″.53 gives 8″.7773.

The differences in the various results obtained indicate plainly that we must wait some time longer for a definitive value of the aberration constant.

PHOTOGRAPHS OF THE ZODIACAL LIGHT.

A. E. DOUGLASS.

FOR POPULAR ASTRONOMY.

The experiments which resulted in the accompanying photographs of the zodiacal light were the outcome of long continued interest in the subject of the gegenschein and zodiacal light and a desire to render less fatigueing and more accurate the observation of those faint lights. Contours of the zodiacal light drawn by hand on about two hundred different nights had shown the defects and difficulties of that method of recording observations. Perhaps the chief of the defects was the almost invariable interference of stellar light; yet that was not the only important one, for the very first result of these photographs was to show that in estimating a visual contour one is apt to mistake ease in distinguishing the zodiacal cone at any given point for actual intensity at that point and therefore the contours of equal brightness are prolonged along the axis too far away from the Sun and horizon light. After seeing the photographs this erroneous tendency was actually found to exist.

The inherent difficulties in the old method lie in the long time required to get perfectly acquainted with standard reference stars and the advantage, that amounts almost to necessity, in making records in the dark. Even an old hand at this work will frequently be obliged to make use of some star whose name he does not know and will have to describe its place, as well as that of the zodiacal light, on paper which he can barely see resting in his hand.

The first effort to improve upon the method of observation consisted in designing a machine which could automatically record the contours directly on a star map, and a rough model of this contrivance gives entire promise of success. But as this was not put into actual practice attempts were made to succeed by photography. Many attempts have been in this line elsewhere, but without success. Of these one was by myself while in South America (in 1891, I think) and another has since then been made at that same station. The early work at Flagstaff was equally without result. But after repeated trials success was at once attained when the very simple idea of using ordinary positive visual eyepieces, which combine very short focus with relatively large aperture, occurred to me and was tested and from that time on constantly improving results have been obtained. The most successful lens and the one by which the illustrations for this article were taken, is a combination lens, put together and mounted by Mr. Cogshall, who has done practically all of the photographic work. This lens seems to give a combination of flat and large field and very great light-transmission that surpasses any other apparatus that we have tried, and among those tried the one marked "Clark; Special" in the list below is a "solid" achromatic lens cut on the Fraunhofer curves. The following list describes briefly the various lenses tried by Mr. Cogshall and gives a summary of our experiments:

Make.	Focus.	Aperture.
St. Louis house; name unknown	16 inches	2 inches.
Same, with telescope lens to shorten focus	10 "	2 "
Rochester Optical Co. Rap. Rect	8 + "	¾ "
H. & E. J. Dale, London. (A hand camera)	5 + "	¾ "
" W. A. C. Pinhole" Camera	3 "	¼ "
Zeiss Planar Series Ia. By Bausch and Lomb	1⅜ "	5/16 "
Eyepiece; Brashear	1 "	½ "
" "	1 "	¼ "
" "	1 "	⅛ "
" "	½ "	¼ "
" "	⅜ "	⅛ "
" Clark	2 "	¼ "
" "	2 "	⅜ "
" "	2 "	½ "
" " "Special"	2 + "	⅜ "
"Combination;" part made in Paris and part by Clark; combined by W. A. C	1.3 "	½ " or 0.4 (⅜) for best work.

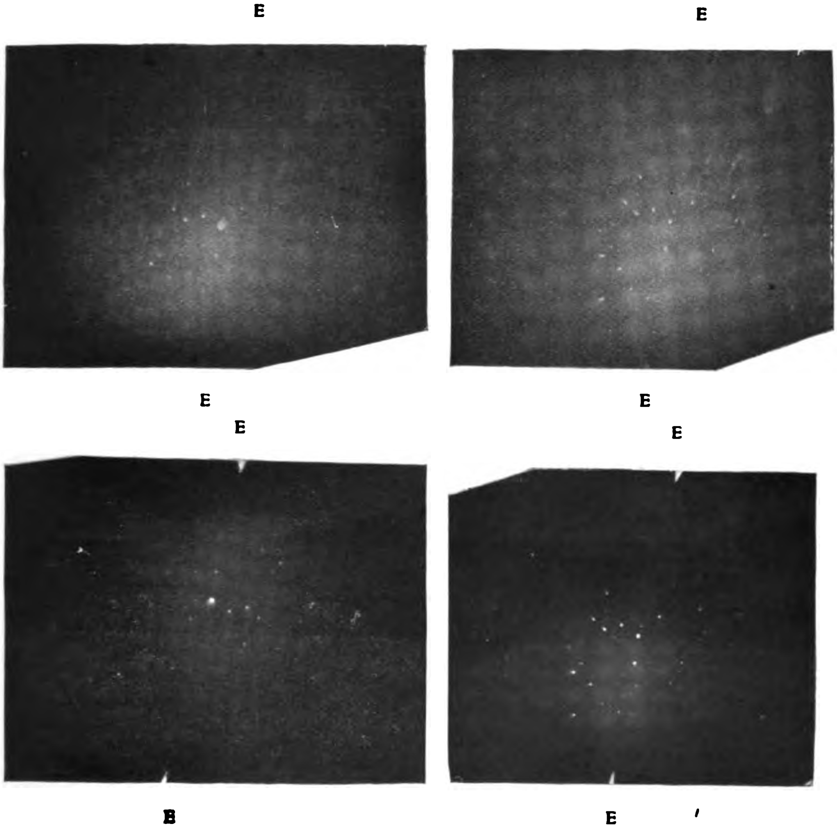
After obtaining real photographs the first step was to make sure that there was no deception. Some of the views taken as long ago as May, 1899, were really exceedingly good but had some trifling defect, which threw a slight doubt on their genuineness. But they were repeated many times. Finally a very thorough test for ghosts or other concentration of light in the fields of the chief lenses used, was made by trial exposures on such objects as landscapes and ruled paper, by daylight, the side of a house by moonlight, and the sky, by day and by night. No genuine irregularity or concentration of light could be found in the fields over an area considerably greater than the entire portion of sky shown in our illustrations, and the photographs were therefore accepted as real. (Let me here explain that while taking the photograph of October 7, a pasteboard tube supporting the lens, projected too far inside the camera and cut down the field; this effect shows conspicuously in the original negative.)

The first conclusions drawn from these photographs are that the axis of greatest density is very indefinite and that the photographic contours of the apex of the zodiacal cone are far more rounded in form than the visual ones are usually represented; and, as stated above, I am inclined to think this same roundness is really true of the visual outlines.

Another conclusion and one of much interest to the experimenter, is one that cannot be derived from our illustrations but has been found to hold true on other photographs. It is that with this form of camera the zodiacal light makes an impression on the sensitive plate more readily than equally bright regions of the Milky Way.

The horizon light does not appear to effect these photographs.

PLATE VIII.



October 7^d 16^h 20^m — 17^h 15^m

October 14^d 16^h 15^m — 17^h 20^m
and October 15^d 16^h 16^m — 17^h 20^m

PHOTOGRAPHS OF THE ZODIACAL LIGHT IN LEO.

The letter E at the top and bottom of each photograph indicates the direction of the Ecliptic.

POPULAR ASTRONOMY, No. 74. Lowell Observatory, 1899.

Of course they are not allowed to continue when the horizon light is very strong. Nor am I sure that the atmospheric absorption materially affects the intensity of the light near the horizon, since lessened exposure on the lower edges will account for the faintness in that region.

Finally in these photographs of the zodiacal light in Leo, at a distance of about 8° from the ecliptic, the intensity of the light fades much more rapidly on the southern side than on the northern. This effect may be partly due to atmospheric absorption but as the axis of the cone in this instance is inclined over 70° to the horizon, I am inclined to believe this a real effect due to the form and position of the great lenticular mass of particles which cause the zodiacal light.

LOWELL OBSERVATORY,
February 26, 1900.

ATTRACTION AND THE FIGURE OF THE EARTH.

W. W. PAYNE.

From time to time so many questions are asked about the law of gravitation, its history, its development and its applications, that it has seemed best to try to answer some of them, in a general way, and in popular language, for the benefit of some readers who have not the knowedge of the higher mathematics that will enable them to read the works of standard authors on these difficult themes.

We have decided to do this now because we have seen lately, more then ever before, something of the waste of time and money, by people of good minds, who apparently have not pursued the branches of mathematics and physics far enough to fit them for the study of such questions, either for their own benefit or for the instruction of others; much less are they qualified to write books on new theories of attraction, or to set up claims that the law of gravitation is not true, because some of its applications are not proved, or seem to be false, as determined by methods of algebra, geometry and trigonometry.

The history of the law of gravitation is so closely connected with that of the figure of the earth that the consideration of the one necessarily involves that of the other; so we begin with a brief account of the views held by some ancient people of renown about the shape or figure of the earth.

In very early times the prevailing view seems to have been that the surface of the earth was flat; that the earth itself was bounded by an ocean of unknown extent, and that the great sea was limited by the visible horizon; that the sun rose in the morning out of this great ocean and each evening set in it. It is but natural to think that the first people of earth should believe that the relation of things on so large a scale as that visible to the eye should indeed be exactly as they appear, and that the earth and the heavens were the whole of the universe.

The Chaldean opinion of the shape of the earth was, however, unexpectedly peculiar. They believed that it was like the half of an orange, with the curved side upwards, but it does not appear on what the flat side of the orange rested. The Chaldean astronomers supported their belief, as they supposed, by scientific argument, as we are told in Lenormant's Chaldean Magic, page 150. Such proofs as they could frame would not be certain, however, because the scholars of those times did not have sufficient knowledge of physical laws for a sound basis in reasoning on such questions. Some writers are inclined to make an exception to this view in the case of the Chinese whose definite records of eclipses go back as far as 800 B. C., because they knew, it is claimed, that the sun and the heavenly bodies were visible to people towards the east sooner than to those further west. This they must have known could only be due to the curvature of the earth. This view is somewhat strengthened from naked-eye observations of the sky, day or night. These early people must have noticed its spherical shape by day, and they would also observe the daily motion of prominent star groups, we call constellations, around a particular point in the heavens, which we now call the celestial pole; but whether or not they would infer the globular form of the earth from these motions, and from the change of altitude of the stars above the horizon to one traveling north or south, has been a matter of some doubt. It seems to us that thinkers and acute observers, at almost any time in human history could have inferred so much, when we remember some of the astonishing things they did learn under very unfavorable circumstances. And yet we are in doubt about this, if we go back in history no further than about 600 years, in the time of boasted learning among the ancient Greeks. Thales of Miletus, 640 B.C., Anaximander, 570 B. C., and Anaxagoras, 460 B. C., all claimed that the earth was cylinderical in shape, its height being three times its diameter. They found place for all the land and water of the earth on the upper base of the cylinder. Plate, 400 B. C., said the earth is a cube; but Aristotle of Thrace, 384 B. C., was probably among the first of the early scholars to advance the theory that the earth is a sphere..

The reader of history knows that Egypt was in the lead, in these early days, in most scholarly pursuits. Before the founding of the Ionian school, which was the beginning of the study of mathematics under the Greek influence, Thales was pursuing the studies of geometry and astronomy in Egypt, so it becomes of interest to learn what we may about the opinions held by the Egyptians regarding the form of the earth.

About thirty-five years ago a so-called hieratic papyrus which forms part of the Rhind collection in the British Museum was satisfactorily read. This writing throws some light on the advancement of the Egyptians in very early times in arithmetic and geometry. It is believed by those who have read it, that this manuscript was written by an Egyptian priest, named Ahines, somewhere between 1700 B. C. and 1100 B. C., itself being only a copy, with corrections, of an older writing whose date was about 3400 B. C. The title of this old manuscript is "Directions for Knowing All Dark Things." For a brief review of the arithmetic and geometry there presented, see Ball's Short Account of the History of Mathematics, p. 3, and following. From Ball's review, it is evident that the knowledge of these two branches of mathematics in Egypt was sufficient 2000 years B.C. to have led scholars of that time to make useful applications of them to the study of the figure of earth, if their minds had been so directed. But it is one thing to have knowledge of a principle in mathematics, as proved by a course of reasoning, as a proposition is demonstrated in plane geometry, but it is quite another and a different thing to be able to apply a principle so learned to its concrete uses, though it be simple in kind, and sometimes quite obvious in relation. As we read of the early history of the Egyptians, this seems to be strikingly true in what they know of elementary science—so much so that it is hard to account for the utter lack of ability to apply their reasoning powers to the study of the shape of the Earth, when they had done so well in the elements of pure science and philosophy.

It may be possible to explain part of this enigma by the fact that the scholars of those very early times were the priests whose influence with the people was very large, and whose privileges secured to them by the ruling classes were exceptionally great. These priests were much occupied with idolatrous worship, which filled Egypt with it massive temples, its numberless objects of worship, and its endless ceremonies. These things being so, they would hinder rather than promote the advance of truth or science in any important way. In proof of this we have only to remember that there were gods for the Sun, dawn, sky, Earth, water, storm, and indeed as many other things on the Earth, under it, and in the heavens, as one may be pleased to enumerate. The god, Varuna, who was king of the sky, is especially interesting to us just now, because we read that,

"Varuna stemmed asunder the wide firmanent; he lifted up on high the bright and glorious heaven; he stretched out apart the starry sky and the Earth." * * * * "This Earth, too, belongs to Veruna, the king of this wide sky with its ends far apart. The two seas (the sky and the ocean) are Veruna's loins."*

These are a few sentences from the sacred songs of the Vedas, which were chanted often by Egyptian priests in the ears of the people 1500 years B. C. They were written in Sanskrit, until recently almost an unknown language, which we now learn bears a near relation to our own English tongue. The people who joined in such worship were the ancestors of Aryan races, the great family to which the Anglo-Saxon belongs. We are interested in the early thoughts of their intellectual life and growth, especially because we learn from the above quotations, and others like them, that they believed the Earth was something like a cylinder in form, for its "ends were far apart." This seems to be the source of the belief later held by the Greek civilization, for it was the same thing in the time of Anaximander, and modified only a little by Plate, to that of a cube, because, philosophically, the cube was a more perfect figure.

When we come to the later Indian pictures, ideas seem to be a little more concrete and less poetical, and strangely enough, when we learn that the Earth was then thought of as a large shell supported by "Elephants (representing strength), the elephants being supported on a tortoise, (which represented infinite slowness)." We are not told on what the tortoise rested; it doubtless needed none, for it moved infinitely slow.

This must suffice for the early views of the form of the Earth. We next consider the spherical hypothesis.

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*See The Dawn of Astronomy, Ch. I., by Norman Lockyer.

ORIGIN OF THE LUNAR FORMATIONS.*

The characteristic difference between the *maria* and the larger craters, like Clavius, Ptolemy, and Schickard, is that every crater is surrounded by a high mountain ridge. In the case of the older and larger craters, when not too far destroyed by subsequent melting, the interior of the walls show a terraced structure due to the past tidal action. The *maria*, on the other hand, are usually surrounded by low shores. When they are high, as in the case of Crisium and Humorum, the shore is a plateau rather than a mountain range, although the northeastern boundary of Humorum is somewhat mountainous for a short distance. The northern boundary of Mare Imbrium is distinctly a plateau, and the only apparent exception to the general rule seems to be in the case of the Apennines and Caucasus. But even here it appears that these ranges originally formed the edge of a plateau that has been somewhat tipped out of its former horizontal position. According to this view, therefore, the Apennines and Caucasus are merely the curved edge left to the original solid surface by the molten flood, which, welling up from the interior, melted and destroyed everything before it, as long as the supply of heat caused by the local subsidence lasted. Portions of the original surface, only partially destroyed, are seen in the regions about Archimedes and Autolycus.

As soon as the surfaces of the *maria* had solidified, fresh compression of their molten interiors began, and a second era of crater formation was inaugurated. These craters necessarily differed from those of the earlier period in one respect, however, and that was that while the walls of the earlier craters were light colored, those of the secondary period were of the same color as the material of the surrounding *mare*. Thus, of two craters located side by side in the middle of a *mare*, one may be light and the other dark. In such a case the former one survived the flood, the latter was formed subsequently to it. This secondary period seems to have extended to the present time, for, as we have already seen, small craters are even now being constantly produced, as in the case of the interior of Plato. Some craters, like Aristarchus, and certain small craterlets, are intensely brilliant; but this is an extraneous circumstance, as we shall presently see, having no bearing on the age of the crater.

The hypothesis is frequently maintained that the *maria* were originally covered with water. There seems to me no sufficient

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* Continued from page 153.

evidence to be found in support of such a conclusion. As shown in my paper published in *Astronomy and Astro-Physics* for 1892, Vol. XI, p. 778, it is probable that the lunar atmosphere was never very dense, perhaps not exceeding one inch in pressure. Under these circumstances the evaporation from any large body of water exposed to the Sun's rays would be very rapid, and the condensation at night equally so. This more than tropical precipitation could hardly have failed to leave very conspicuous evidence of its former existence in denuded slopes and deep ravines. Moreover, the *maria*, although frequently in communication, are placed at very different levels, as has been often pointed out. As the water gradually dried up, or was absorbed, and the upper seas emptied into the lower ones, channels would have been cut connecting them. Nothing of the sort is seen, however, although these would be the most favorable regions in which to observe them. In short, the evidence of the action of water upon the Moon is certainly very much less marked than upon the Earth, and seems quite inadequate to support the hypothesis that the *maria* were ever flooded.

The lunar craters may be divided according to their appearance into six classes, distributed into two periods. *Craters of the first period.* These all have bright walls. (a) Unaltered craters. These have high sharp walls with rough interiors. Copernicus, Tycho, Arzachel. (b) Partially submerged craters. These have sharp walls but smooth interiors, which may be either dark or light. Plato, Archimedes, Ptolemy, Schickard. (c) Softened craters. The whole crater floor and walls seem to have been softened and flattened. Posidonius, Cassini, Gassendi. (d) Submerged craters. Only portions of the rims of these craters show above the surface of the *maria*. Large crater near Flamsteed. Numerous craters in nearly all the *maria*. *Craters of the second period.* All craters having dark walls belong to this class. (e) Dark craters shaped like Copernicus, but on a much smaller scale, rising in several of the *maria*. Lambert and other craters in Mare Imbrium. (f) Craters with smooth floors and walls, the latter having low exteriors and deep interiors. Most of the smaller craterlets found in the *maria* belong to this type. Helicon, Bessel, and Horrocks are among the larger examples.

Owing to the sinking of the convex surface of the *mare* a compression will arise, and ridges be formed. These are usually concentric, as in Maria Imbrium, Humorum, and Procellarum, but sometimes they pass through or near the centre, as in Mare Serenitatis. When these ridges have sharp crests they become less able to resist the internal compression, and craterlets often force their way through in such places. This compression, as we have seen, is the probable cause of the central ridge or peak found in many of the unaltered lunar craters, the weight of the surrounding mountain wall being an efficient aid in producing the requisite compression. As in the case of the ridges in the *maria*, a craterlet is sometimes found in the summit of the central peak. Under these circumstances the appearance is occasionally quite similar to that of the smooth, high, truncated cone of a terrestrial volcano, as in the case of Timocharis; nevertheless, I do not believe that volcanoes proper are to be found upon the Moon. Certainly no evident instances of such formations have ever been clearly seen. Nor is it evident how the necessary explosive force could be obtained, unless we assume the former presence of large bodies of water upon the Moon.

Besides the generally recognized *maria*, there are several simiiar smaller formations which have not as yet received any special designation. The most important one is of about the same shape and size as the Mare Crisium, but of rather lighter color. It is situated nearly due west of it, and is only brought into view under a favorable libration. Another is situated south of Mare Humorum and west of Schickard. Had the melting of the original surface been a little more complete, it would undoubtedly have been designated as a *mare*. On the other hand the large nameless plain southeast of Schiller is clearly a ruined crater, perhaps the largest to be found upon the Moon. Another small unnamed *mare* is situated southwest of Humorum, between it and Tycho. The very elongated crater of Schiller is really composed of a series of craters, the dividing walls between which have been broken down by internal heat.

Among the most important of the smaller formations upon the Moon are the rills. The rills proper, as distinguished from the river beds already described, are undoubtedly cracks in the lunar surface, formed at a time when it was too small for the interior, but when the fluid contents was so far removed from the surface that but little of it was able to escape and relieve the pressure. The rills are therefore of comparatively recent formation. They are rarely if ever found among the primary formations, unless these have been melted or softened by the subsequent application of heat. They are never found near the poles where the tidal action is small, although seen near other parts of the limb. Only three minute rills, therefore, are found in the Mare Frigoris, although they abound in the other *maria*. The most northern rill known is in latitude + 57°, north of Aristoteles, the most southern one is in latitude — 35° south of Ramsden. They are particularly numerous in the southeastern quadrant of the Moon, and comparatively rare in the southwestern. They are frequently concentric with some *mare* or partially submerged crater. Striking illustrations of this are found just to the west of Mare Humorum where three concentric systems of rills occur. The appearance of this *mare* is as if a thin skin had formed over the liquid surface, and had then been broken and crumpled, and drifted to the eastern side. Towards the centre and on the western side of Humorum are some long ridges, the western one concentric with the *mare* and the rills. On the eastern side are some deep rills also concentric with the *mare*. The paraffine crater, Figure 15, shows a minute ridge stretching from the nearer side towards the centre. Later a rill formed upon the further side concentric with the crater, thus showing that the surface was subjected first to compression as the floor of the crater fell, and later to tension as it contracted and receded from the crater walls.

The direction of the rill in many cases bears no apparent relation to the surrounding formations, and seems to be the result of a general contraction of the lunar crust. When it traverses a crater it is often evident that the latter is the earlier formation, as in the case of Hippalus. On the other hand, in the case of Ramsden the crater seems to have been formed later. Some extremely broad and deep concentric rills are found in the interior of Wurzelbauer. The appearance of a crumpled skin seen in the Mare Humorum is also found in other formations, as in J. Herschel.

An extremely rough and broken surface is found just to the north of Sinus Iridum. Few craters are to be seen, and it looks as if it might have been a part of the original surface of the Moon, before it had been pitted with craters or fused into *maria*. But what makes this region particularly interesting is that we have here a clear view of a section of the surface some two miles in depth, cut by the melted lava that formed the Sinus Iridium. An examination of this section shows a nearly vertical wall, in places perhaps overhanging, apparently composed chiefly of objects like huge boulders, measuring several thousand feet in diameter, but separated from one another here and there by interstices forming caves of surprising dimensions. As seen under favorable conditions, at Arequipa, the appearance was not unlike that of a piece of wood broken squarely across the grain.

The structure of the wall is entirely different from that of the Apennines, which bound the Mare Imbrium on the west. Neither does it resemble the smooth sloping terraced interiors of the larger craters.

Among the more noteworthy of the minor lunar features may be mentioned the following formations. To the north and also to the south of Copernicus are found a number of spindle-shaped cuts in the surface, like very elongated craters. They are on the average about two miles long by half a mile broad, and very much resemble in shape the mark that a bullet might make in penetrating obliquely a somewhat vicous surface. Scattered among them are a number of smooth rounded mounds, some circular and some elongated. Some of the latter look as if they would exactly fit into the spindle-shaped cuts. Similar cuts are found in Cassini. To the north and west of Copernicus are a series of irregular elongated markings formed in part of craterlets, and due perhaps to the escape of gases through the formerly viscous surface from a submerged crack or rill. Similar markings are found to the southeast of Schiller. A little over one diameter due east of Gassendi is a curious ring of isolated elevations surrounding a central peak. A little north of Cavalerius is situated a very striking black peak.

A series of well marked parallel grooves each groove several miles in width, forms a characteristic feature of certain portions of the Moon's surface. They are well seen in the vicinity of Pallas, and lie in a northeast and southwest direction. They extend from somewhat to the north of Hyginus as far south as Albatagnius. A less marked series of parallel grooves lies southeast of Sinus Iridium, and another near the south pole. A large ruined nameless crater of oval shape, and exhibiting a curious spiral arrangement of supporting ridges is to be found lying between Wurzelbauer and Heinsius. Although lava streams are not usually clearly defined upon the Moon, one may be seen where Wargentin overflowed its crater on the northeast, flooding the surrounding region. This overflow probably prevented the lava from rising higher in the adjoining crater north of Phocylades, whose interior is on the same level as the surface of Wargentin, and several hundred feet higher than the level in Phocylades proper.

The last feature that we shall refer to upon the Moon is the system of bright streaks conspicuously surrounding six of the larger crater formations, and also visible around many of the smaller craters. In the *Astronomische Nachrichten*, Vol. CXXX,

p. 225, I pointed out certain facts regarding these streaks, derived from my observations made at Arequipa, of which the following are the most important. Hundreds of these streaks exist upon the Moon, but in the great majority of instances they are found to issue from minute intensely white craterlets. These craterlets are seldom over 1″ in diameter, and are usually much less. The streaks are very brilliant where they issue from the craterlet, but broaden and grow fainter as they recede from it. Their maximum breadth seldom exceeds 5″, and their length usually varies from 10″ to 50″. Those streaks which do not issue from minute craterlets usually lie upon or across ridges, or in other similarly exposed situations. Frequently a number of the craterlets producing streaks are found to be arranged in the same direction in which the streaks lie. In such a case, before one streak comes to an end another will begin, thus forming a nearly continuous white band. A few of these white bands extend for over one thousand kilometers. The nature of the individual streaks is seen very clearly in the crater Pitatus. It is also well shown in Copernicus, but does not become clearly visible there until the thirteenth day after new Moon. The combination of the streaks to form a white band is most readily studied in the conspicuous marking stretching from Tycho to Mare Nectaris. Under favorable atmospheric conditions it can be seen in the two parallel bands extending from Tycho towards Kepler, and in the band stretching from Menelaus across the Mare Serenitatis.

The visibility of the streaks can be studied very satisfactorily from photographs. They become visible in general about twelve hours after sunrise and brighten for one or two days. They remain visible until about the same period before sunset. Latitude has little if any effect on the time of their appearance. They are probably due to the same cause that produces the variable white markings and spots in Plato and about Linné and Schröter's Valley.

Since the pressure of water vapor at the freezing point is 4.6 mm., it is manifest that, unless the pressure of the lunar atmosphere exceeds this figure, water cannot exist upon the surface of the Moon at all in a liquid state, no matter what the temperature may be. Above the freezing point its condition will be wholly gaseous, below the freezing point it may be wholly gaseous, or it may be partly solid and partly gaseous. Since it is doubtful if the pressure of the lunar atmosphere exceeds 0.5 mm., it is clear that water as such cannot at present exist upon the surface of the Moon. There is no reason, however, why the white markings above mentioned may not be due to ice crystals, either suspended in the air or deposited upon the ground. That the white substance cannot be frozen carbonic acid is certain, on account of the enormous pressure that would be involved, even at extremely low temperatures, to keep it in the solid form. Whether the increase and diminution in size of the white markings, and their transportation from place to place is due to the bodily transference of the crystals by means of the lunar winds and the subsequent melting of the crystals, or whether the water is transported in the gaseous form and later deposited as hoar frost, is not as yet determined, but I am inclined to believe, from the appearances noted about Schöter's Valley and about Messier, that actual clouds due to ice crystals really exist upon the Moon. That so rare an atmosphere should be able to transport the ice crystals at all seems at first sight very remarkable, but it is possible that the crystals are very minute, as would indeed probably be the case when condensed in such an atmosphere. In considering the plausibility of the explanation that the white substance causing the bright streaks and craters is really hoar frost, an idea which was, I believe, first suggested by Mr. Ranyard, (Knowledge, 1890, Vol. XIII. p. 130,) we may call to mind the observations already described in the section devoted to Linné. It was there pointed out, not only that the white area was diminishing in size from year to year, but also that there was a large periodic variation from day to day, the micrometric measurements showing that as lunar midday approached the spot grew smaller, reaching a minimum soon afterwards, and then again increased in size with the approach of night, much as the polar caps of the Earth increase and diminish with the seasons.

In order to obtain a satisfactory explanation of the bright streaks, we may start with the observed fact that those craterlets producing streaks which are situated in the vicinity of a prominent streak centre, as Tycho, for instance, are distributed not quite uniformly, but with a tendency to take the form of radial bands. It is very evident that when those craterlets near the center become active, they will give rise to a wind blowing away from Tycho in all directions. As this wind proceeds outwards, it will be reinforced by the wind from the various active craterlets that it encounters upon the way; there will therefore, in general, be no opportunity for diverse currents, and the bright streaks must necessarily lie radially as we observe them. As we have seen in the previous chapters, the activity of the craterlets sometimes, as in the case of Schröter's Valley, begins shortly after sunrise and ends before sunset. In the case of Linné, on the other hand, the activity apparently lasts for a short time into the night.

If the supply of ice crystals is limited, as must certainly be the case upon the Moon, and the country over which they are blown is rough, they will settle almost exclusively in the crevices and hollows between the rocks. Moreover, this tendency will be further increased, as we see upon the Earth, since the Sun will tend to evaporate those in the more exposed situations. Since the shadows are perfectly black upon the Moon, the crystals upon which the Sun does not shine will reflect no light. Therefore at sunset and sunrise the bright streaks should be comparatively inconspicuous, showing best under a high illumination. The phenomenon should be quite independent of the position of the Earth, upon which depends the phase of the Moon. This we find to be the case, since the streaks first appear clearly a few days after sunrise, regardless of other circumstances as to whether the Moon is a crescent, gibbous, or full. Moreover, if we view the dark side of the Moon three or four days after the Moon is new, the bright streaks will be clearly seen by earthlight, although invisible both before and after, at sunset and sunrise. When the crystals are exposed to the Sun they will appear bright even at sunrise, as in the case of Aristarchus. In the crater of Messier, on the other hand, they do not begin to form until the Sun is well up, so that the interior does not become bright until three or four days after sunrise.

The streaks are sometimes extremely narrow. Thus, in 1893, six were seen radiating from invisible craterlets situated upon the lower slopes of Dionysius. The streaks measured from twenty to forty kilometers in length, appeared absolutely straight, and could have been but a few hundred meters in breadth. They have not been seen in Cambridge. Occasionally we find streaks flowing towards Tycho, even in its immediate vicinity. A most striking instance of this occurred in Clavius, where, upon January 30, 1893, I saw two minute craterlets situated side by side, one sending its streak away from Tycho and the other directly towards it.

It is sometimes stated as proving the total absence of a lunar atmosphere that no clouds ever obscure the Moon's surface, but that all its features are at all times perfectly clear and distinct. This statement is certainly erroneous. The Moon's atmosphere probably is full of clouds. Wherever we see a bright streak, there a few days after sunrise will be found a cloud, and it is chiefly their conspicuous presence, combined with the lack of shadows, that at the time of full Moon makes the lunar detail in certain regions so difficult to distinguish. In other regions, over the *maria*, for instance, and strikingly over the floor of Plato, where the bright streaks do not extend, far more detail can be seen at full Moon than during any other portion of the lunation.—*Annals of Harvard College Observatory, Vol. XXXII, Part II.*

NON-EUCLIDEAN GEOMETRY.

GEORGE BRUCE HALSTED.

FOR POPULAR ASTRONOMY.

In writing of "The Wonderful Century," Alfred Russel Wallace says of all time before the seventeenth century: "Then, going backward, we can find nothing of the first rank except Euclid's wonderful system of geometry, perhaps the most remarkable mental product of the earliest civilizations."

But of late all men of science and intelligent teachers have been hearing more and more of non-Euclidean geometry, and are naturally anxious to know how these new doctrines are related to the traditional geometry which they were taught and perhaps now are teaching.

The new departure is absolutely epoch-making, but fortunately it has intensified admiration for that imperishable model, already in dim antiquity a classic, the immortal *Elements* of Euclid.

But without assumptions nothing can be proved, and Euclid stated his assumptions with the most painstaking candor. He would have smiled at the suggestion that he could ever claim for his conclusions any other truth than perfect deduction from assumed hypotheses.

And so his system is forever safe. Each one of his axioms may turn out to be inconsistent with external reality; each of his fundamental assumptions may be replaced in our final explanation of the space in which we live and move; in reference to our space, all his theorems may be shown to be only approximations; and yet his work will remain a perfect piece of pure mathematics, the exact, eternal geometry of Euclidean space.

For two thousand years no one ever doubted the truth of any one of this set of axioms, far the most influential in the intellectual history of the world, put together by Euclid in Egypt, but really owing nothing to the Egyptian race, nothing to the boasted lore of Egypt's priests.

The Papyrus of the Rhine, belonging to the British Museum, but given to the world by the erudition of a German Egyptologist, Eisenlohr, and a German historian of mathematics, M. Cantor, gives us more knowledge of the state of mathematics in ancient Egypt than all else previously accessible to the modern world. Its whole testimony confirms with overwhelming force the position that geometry as a science, strict and self-conscious deductive reasoning, was created by the subtle intellect of the same race whose bloom in art still overawes us in the Venus of Milo, the Apollo Belvidere, the Laocoön. But though for twenty centuries the truth of the axioms of the Greek geometer remained unquestioned, there was one of them of which the axiomatic character was doubted even from far antiquity. Elementary geometry was for two thousand years as stationary, as fixed, as peculiarly Greek as the Parthenon. But among Euclid's assumptions is one differing from the others in prolixity, whose place fluctuates in the manuscripts.

Peyrard, on the authority of the Vatican MS., puts it among the postulates, and it is often called the parallel-postulate. Heiberg, whose edition of the Greek text is the latest and best (Leipzig, 1883-1888), gives it as the fifth postulate.

James Williamson, who published the closest translation of Euclid we have in English, indicating, by the use of italics, the words not in the original, gives this assumption as eleventh among the Common Notions.

Bolyai speaks of it as Euclid's Axiom XI.

Todhunter has it as twelfth of the Axioms.

Clavius (1574) gives it as Axiom 13.

The Harpur Euclid separates it by forty-eight pages from the other axioms.

It is not used in the first twenty-eight propositions of Euclid. Moreover, when at length used, it appears as the inverse of a proposition already demonstrated, the seventeenth, and is only needed to prove the inverse of another proposition already demonstrated, the twenty-seventh.

Geminos of Rhodes (about 70 B. C.) speaks of it as needing proof. The astronomer Ptolemy (A. D. 87-165) tried his hand at proving it.

The great Lambert expressly says that Proklas demanded a proof of this assumption because when inverted it is demonstrable.

The Arab Nasir-Eddim (1201-1274) tried to demonstrate it.

No one had a doubt of the necessary external reality and exact applicability of the assumption. Until the present century the Euclidean geometry was supposed to be the only possible form of space-science; that is, the space analyzed in Euclid's axioms was supposed to be the only non-contradictory sort of space.

But could not this assumption be deduced from the other assumptions and the twenty-eight propositions already proved by Euclid without it? Euclid demonstrated things more axiomatic by far. He proves what every dog knows, that any two sides of a triangle are together greater than the third.

Yet after he has finished his demonstration, that straight lines making with a transversal equal alternate angles are parallel, in order to prove the inverse, that parallels cut by a transversal make equal alternate angles, he brings in the unwieldy assumption thus translated by Williamson (Oxford, 1781).

"II. And if a straight line meeting two straight lines make those angles which are inward and upon the same side of it less than two right angles, the two straight lines being produced indefinitely will meet each other on the side where the angles are less than two right angles."

As Staeckel says, "it requires a certain courage to declare such a requirement, alongside the other exceedingly simple assumptions and postulates."

In the brilliant new light given by Bolyai and Lobachevski, we now see that Euclid understood the crucial character of the question of parallels.

There are now for us no better proofs of the depth and systematic coherence of Euclid's masterpiece than the very things which, their cause unappreciated, seemed the most noticeable blots on his work.

Sir Henry Savile, in his Praelectiones on Euclid, Oxford, 1621, p. 140, says: "In pulcherrimo Geometriae corpore duo sunt naevi, duae labes . . . " etc., and these two blemishes are the theory of parallels and the doctrine of proportion; the very points in the Elements which now arouse our wondering admiration.

But down to our very nineteenth century an ever renewing stream of mathematicians tried to wash away the first of these supposed stains from the most beauteous body of Geometry.

The attempts may be divided into three classes: First, those in which is taken a new definition of parallels. Second, those in which is taken a new axiom different from Euclid's. Third, the largest and most desperate class of attempts, namely, those which strive to deduce the theory of parallels from reasonings about the nature of the straight line and plane angle. Hundreds of mathematicians tried at this. All failed. That eminent man, Legendre, was trying at this, and continually failing at it, throughout his very long life. Thus the experience of two thousand years went to show that here some assumption was indispensable. Every species of effort was made to avoid or elude it, but without success. From a letter of Gauss we see that in 1799 he was still trying to prove that Euclid's is the only non-contradictory system of geometry, and that it is the system regnant in the external space of our physical experience. The first is false; the second can never be proven.

Yet even in 1831 the acute logician, De Morgan, accepted and reproduced a wholly fallacious proof of Euclid's assumption, recently republished, Chicago, 1898.

A like pseudo-proof published in *Crelle's Journal* (1834) deceived even our well known Professor W. W. Johnson, who translated and published it in the *Analyst* (Vol. III, 1876, p. 103), saying, "this demonstration seems to have been generally overlooked by writers of geometrical text-books, though apparently exactly what was needed to put the theory upon a perfectly sound basis."

The most interesting and perhaps the most extended of such attempted proofs was by the Italian Jesuit Saccheri, born the fifth of September, 1667, who joined the Society of Jesus at Genoa, on the twenty fourth of March, 1685. He became teacher of grammar in the Jesuit "Collegio di Brera," where the teacher of mathematics was Tommaso Ceva, a brother of the well known mathematician, Giovanni Ceva (1648-1737), who published in 1678 at Milan a work containing the theorem now known by his name.

Saccheri was in close scientific communion with both brothers and received his inspiration from them. He used Ceva's ingenious methods in his first published work, 1693, solutions of six geometric problems proposed by Count Roger Ventimiglia. His attempt at proving the parallel-postulate in his last work, "Euclid vindicated from every fleck," which received the "Imprimatur" of the Inquisition the thirteenth of July, 1733, that of the Provincial of the Jesuits the sixteenth of August, 1733. Saccheri died the twenty-fifth of October, 1733.

All preceding attempts were alike in trying to give a direct positive proof of the postulate; all were alike in the assumption open or hidden, conscious or unconscious, of an equivalent postulate.

Saccheri tries a wholly new way, and thus his book marks an epoch. He never doubted the absolute necessary truth of Euclid's postulate, and so he thinks that the two alternatives, possible if it be taken as not true, must each lead to some contradiction, to some absurdity. He tries the reductio ad absurdum. Ninety years later, 1823, Bolyai Janos reached the astounding conviction that these alternatives lead not to any contradiction but to the "science absolute of space," a generalization of Euclid's universe. In a letter dated the third of November, 1823, written in the Magyar language, and fortunately preserved for us at Maros Vásárhely in Hungary, Bolyai János writes to his father, Bolyai Farkas: "I have discovered such magnificent things that I am myself astonished at them. It would be damage eternal if they were lost. When you see them, my father, you youself will acknowledge it. Now I cannot say more, only so much: *that from nothing I have created another wholly new world.*"

Suppose we take a few steps into this new universe on the path which opened before Saccheri without his every suspecting whither it led.

1. If two points determine a line it is called a straight.

2. If two straights make with a transversal equal alternate angles, they have a common perpendicular.

3. A piece of a straight is called a sect.

4. If two equal coplanar sects are erected perpendicular to a straight, if they do not meet, then the sect joining their extremities makes equal angles with them and is bisected by a perpendicular erected midway between their feet: [Proved by folding the figure over, along the third perpendicular].

5. Considering figures where the right angles made by the equal perpendiculars may be said to be not alternate,, and where no two perpendiculars to the same straight meet, the equal angles made with the joining sect at the extremities of the two equal perpendicular are either right angles, acute angles, or obtuse angles. Distinguish the three cases as hypothesis of right, hypothesis of acute, hypothesis of obtuse.

6. According to these three hypotheses respectively, the join of the extremities of the equal perpendiculars is equal to, greater than, or less than the join of their feet. [Saccheri, Prop. III. Translated by Halsted in the *American Mathematical Monthly*].

7. Inversely, according as the join of the extremities is equal

to, or less than, or greater than the join of the feet, the equal angles will be right, or obtuse or acute. [S. P. IV].

8. Corollary. In every quadrilateral containing three right angles and one obtuse, or acute, the sides adjacent to this oblique angle are less than the opposite sides, if this angle is obtuse, but greater if it is acute.

9. The hypothesis of right, if even in a single case it is true, always in every case it alone is true. [S. P. V.].

10. Assuming the principle of continuity, and referring only to figures where no two perpendiculars to the same straight meet; The hypothesis of obtuse, if even in a single case it is true, always in every case it alone is true. [S. P. VI.].

11. With like limitation; The hypothesis of acute, if even in a single case it is true, always in every case it alone is true. [S. P. VII.]

12. The sum of the angles of a retilineal triangle is a straight angle in the hypothesis of right, is greater than a straight angle in the hypothesis of obtuse, is less than a straight angle in the hypothesis of acute. [S. P. IX].

13. The excess of a triangle is the excess of the sum of its angles over a straight angle. The deficiency of a triangle is what its angle sum lacks of being a straight angle.

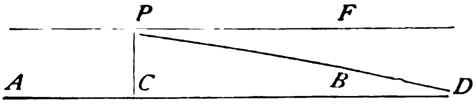
14. Two triangles having the same excess or deficiency are equivalent.

15. Even with the assumption that two straights cannot intersect in two points, the three hypotheses give rise to three perfect systems of geometry, the hypothesis of right to Euclid, the hypothesis of acute to Bolyai-Lobachevski, the hypothesis of obtuse to Riemann.

16. In the hypothesis of acute the straight is infinite. Two coplanar straights perpendicular to a third diverge on either side of their common perpendicular. The angle-sum of any rectilineal triangle is less than a straight angle.

17. In Euclid and Bolyai, parallels are straights on a common point at infinity.

In Bolyai, from any point *P* drop *PC* a perpendicular to a given straight *AB*.



If *D* move off indefinitely on the ray *CB* the sect *PD* will approach as limit *PF* copunctal with *AB* at infinity. *PF* is said to be at *P* the parallel to *AB* toward *B*.

PF makes with *PC* an angle *CPF* which is called the angle of parallelism for the perpendicular *PC*. It is less than a right angle by an amount which is the limit of the deficiency of the triangle *PCD*. On the other side of *PC* an equal angle of parallelism gives us the parallel at *P* to *BA* toward *A*.

Thus at any point there are two parallels to a straight.

A straight has two distinct separate points at infinity.

Straights through *P* which make with *PC* an angle greater than the angle of parallelism and less than its supplement do not meet the straight *AB* at all, not even at infinity.

18. A straight maintains its parallelism at all its points. [Lobachèvski, Geometrical Researches on the Theory of Parallels, Translated by Halsted, § 17].

19. If one straight is parallel to a second, the second is parallel to the first. [L. § 18.].

20. Two straights parallel to a third toward the same part are parallel to each other. [L. § 25].

21. Parallels continually approach each other. [L § 24].

22. The perpendiculars erected at the middle points of the sides of a triangle are all parallel if two are parallel. [L. § 30.]

23. If the foot of a perpendicular slides on a straight, its extremity describes a curve called an equi-distant curve or an equi-distantial.

An equidistantial will slide on its trace.

24. A circle with infinite radius is not a straight but a curve, called the boundary curve, which is a plane curve for which all perpendiculars erected at the mid-points of chords are parallel. [L. § 31]. It is an equi-distantial whose base line is infinitely removed.

Circles, boundary-curves, equi-distantials cut at right angles a system of copunctal straights, of parallel straights, of perpendiculars to a straight, respectively.

Three points determine one of these curves; that is through any three points not co-straight will pass either a circle, a boundary-curve, or an equi-distantial, and only one such curve.

Any triangle may be inscribed in one and only one of these curves.

25. Boundary-surface we call that surface generated by the revolution of a boundary-curve about one of its axes.

Principal plane we call each plane passed through an axis of the boundary-surface.

Every principal plane cuts the boundary-surface in a boundary-curve.

Any other plane cuts the boundary-surface in a circle.

Boundary-triangles whose sides are arcs of the boundary-curve on the boundary-surface have the same interdependence of angles and sides and the same angle sum as rectilineal triangles in Euclid.

Geometry on the boundary-surface is the same as the ordinary Euclidean plane geometry. [L. § 34].

26. Triangles on an equidistant surface are similar to their projections on the base plane; that is, they have the same angles and their sides are proportional.

27. In the hypothesis of obtuse, a straight is of finite size, and returns into itself.

This size is the same for all straights. Any two straights can be made to coincide.

Two straights always intersect.

Two straights perpendicular to a third intersect at a point half a straight from the third either way.

28. A straight in the hypothesis of obtuse does not divide the plane into hemiplanes.

Starting from the point of intersection of two straights and passing along one of them over a certain finite sect, we come again to the intersection without having crossed the other straight.

This sect is the whole straight, and so a straight has not really two sides.

There is one point through which pass all the coplanar perpendiculars to a given straight. It is called the pole of that straight, and the straight is its polar.

A pole is half a straight from its polar. A polar is the locus of coplanar points half a straight from its pole. Therefore if the pole of one straight lies on another straight, the pole of this second straight is on the first straight.

The cross of two straights is the pole of the join of their poles.

The equidistantial is a circle with center at the pole of its basal straight.

Three straights each perpendicular to the other two form a tri-rectangular triangle. It is self-polar, each vertex being the pole of the opposite side.

29. In the hypothesis of obtuse, any two straights enclose a plane figure, a digon.

Two digons are congruent if their angles are equal.

30. In the hypothesis of obtuse, all perpendiculars to a plane meet at a point, the pole of the plane. It is the center of a system of spheres of which the plane is a limiting form when the radius becomes equal to half a straight.

Figures on a plane can be projected from similar figures on any sphere which has the pole of the plane for center. They have equal angles and corresponding sides in a constant ratio depending only on the radius of the sphere.

Geometry on a plane is therefore like two-dimensional spherics, but the plane corresponds to only a hemisphere.

The plane is unbounded but not infinite. It is finite in extent. The universe is unbounded but not infinite. It is finite in extent, or content, or volume.

Now of these three possible geometries of uniform space, Euclid's has the unexpected disadvantage that it can never be proved to be the system actual in our external physical world. To establish Euclid, it would be necessary to show that the angle-sum of a triangle is *exactly* a straight angle; and no measurements can ever reach exactitude.

To prove one of the others, we have only to show that the sum of the angles of some triangle is *less than*, or *greater than* a straight angle, which may conceivably be done even by inexact measurements.

What changes ought to be made in teaching elementary geometry in consequence of these later discoveries and the principles of the non-Euclidean geometries?

We are given a new criterion for questions of method, of exposition. For example, surface spherics attains a new importance.

When properly founded and expounded, pure spherics, two-dimensional spherics, while giving all the old results and laying the foundation for spherical trigonometry, gives also a picture of the planimetric part of Riemann's geometry, and becomes a touchstone for detecting the fallacies and assumptions in the many pseudo-proofs accepted in the past, such as attempts to found parallelism on direction, attempts to prove all right angles equal, etc.

As another example, we see a new stress laid on the incalculable advantages, educational and scientific, of Euclid's procedure in deducing from three assumed constructions every other construction before he uses it in any demonstration. The glib method of *supposed* solutious to all desired problems, of hypothetical constructions, is now seen in its deformity and danger.

Euclid says, under the heading "Postulates:"

"I. It is assumed, that a straight line may be drawn from any one point to any other point.

"II. And that a terminated straight line [a sect] may be produced in a straight line continually.

"III. And that a circle may be described with any center and radius."

From these Euclid rigidly deduces every problem of construction he wishes to use. Says Helmholtz: "In drawing any subsidiary line for the sake of his demonstration, the well-trained geometer asks always if it is possible to draw such a line. It is notorious that problems of construction play an essential part in the system of geometry. At first sight these appear to be practical operations, introduced for the training of learners; but in reality they have the force of existential propositions. They declare that points, straight lines, or circles, such as the problem requires to be constructed, are possible under all conditions, or they determine any exceptions that there may be."

Euclid's first three propositions are problems.

The most popular American geometry, Wentworth's, (1899), puts Euclid's two first postulates on page 8, and the third postulate a whole book later, and then never has a single problem of construction until page 112, where he says: "Hitherto we have supposed the figures constructed."

Meantime, on page 88, he gives as a "theorem:" "Through three points not in a straight line, one circumference, and only one, can be drawn.

He gives as his "Proof. Draw the chords *AB* and *BC*. At the middle points of *AB* and *BC* suppose perpendiculars erected. These perpendiculars will intersect at some point *O*, since *AB* and *BC* are not in the same straight line."

Now the tremendous existential import of the problem, to draw a circle through three non-costraight points, will be recognized when I say that in general it is not possible. In the Lobachevski geometry not every triangle has its vertices concyclic. Granting that every three points must be costraight or concyclic, we prove the parallel-postulate.

Of the possible geometries we cannot say *a priori* which shall be that of our actual space, the space in which we move.

The hereditary geometry, the Euclidean, is underivable from real experience alone, and can never be proved by experience. Euclidean space is, at least in part, a creation of the human mind. Its adequacy as a subjective form for experience has not yet been disproved. It can never be proved.

The realities which with the aid of our subjective space form we understand under motion and position, may, with the coming of more accurate experience, refuse to fit in that form.

Our mathematical reason may decide that they would be fitted better by a non-Euclidean space form.

Comparative geometry finally overthrows that superficial method which pretends to found a logically sound exposition of geometry on "direction," undefined.

For more than 20 years Wentworth gave his definition "A straight line is a line which has the same direction throughout its whole extent." (1877, Def. 8. 1886, p. 4; 1888, § 17).

At last he discards his aged error, and takes the definition of non-Euclidean geometry, "a straight is the line determined by two points" (1899, §§ 36 and 46).

Though the Bolyai and the Riemann geometries are founded on the straight, yet to say in them of two straights that they have the same direction has no ordinary meaning, since in Riemann every two straights cross and inclose a space, while in Bolyai every two parallels continually approach each other.

So as to direction, Wentworth has reformed, after 20 years in the land of nod.

But he still says, 1899, § 49, "A straight line is the shortest line that can be drawn from one point to another."

Now a relation of equality or inequality between two magnitudes must have some foundation, and be capable of some intelligible test. In the traditional geometry the foundation of all proof by Euclid's method consists in establishing the congruence of magnitudes.

To make the congruence evident, the geometrical figures are supposed to be applied to one another, of course without changing their form and dimensions. But since no part of a curve can be congruent to any piece of a straight, so, for example, no part of a circle can be equivalent to any sect from the definition of equivalent magnitudes as those which can be cut into pieces congruent in pairs.

In any comparison of size by congruence, we must be able to place one of the magnitudes or portions of it in complete or partial coincidence with the other. No such direct comparison can be instituted between a straight and a line no piece of which is straight. Thus the whole of Euclid's *Elements* fails utterly to institute or prove any relation as regards size between a sect and an arc joining the same two points. The operation of measurement we cannot effect, rigorously speaking, either for curves or for curved surfaces, since the unit for length is a sect, and the unit for area, the square on that sect. In fact, however little may be the parts of a curve, they do not cease to be curved, and consequently they cannot be compared directly with a sect; just as parts of a curved surface are not directly comparable with portions of a plane.

We cannot even affirm that any ratio exists between a circle and its diameter until after we have made some extra-Euclidean and post-Euclidean assumption at least equivalent to the following:

No minor arc is less than its chord; and no arc is greater than the sum of the tangents at its extremities. If the curve be other than a circle we assume that on it one can always take two points so near that the arc between these points is not less than its chord, nor greater than the broken line formed by the two tangents touching its extremities. Some such assumption is, in fact, necessary, but it destroys by itself the primitive idea of measuring curves with straights.

Dahamel gives the assumption the following form: The length of a curve shall be the limit toward which the length of a broken line made up of consecutive chords of that curve approaches, when the number of chords is increased in such a manner that the chords all approach zero as limit.

Thus the evaluation of the length of a curve represents not at all an attempt at rectification strictly; but it has for aim the finding of a limit to which another magnitude would approach.

In geometry one proves that as the subdivisions are increased and the sides tend toward the limit zero, the perimeter of the polygon inscribed in a circle increases, circumscribed decreases, toward the same limit, which then is assumed for the magnitude of the circle.

Therefore when Phillips and Fisher, of Yale, give as their definition of a straight (1898, p. 4, § 7. Def.) "A *straight line* is a line which is the shortest path between any two of its points," they pass through and beyond Euclid's *Elements* to give us his simplest element; they institute a comparison not only with circular arcs, but also with all curves known and unknown; they presuppose a foreknowledge of all lines in a definition of the simplest line. Is it still needful to say this is grossly bad logic, bad pedagogy, bad mathematics.

The scientific doctrine of evolution postulates a world independent of man, and teaches the outcome of man from lower forms of life in accordance with wholly natural causes. In this world of evolution experience is a teacher, but man is a creator, and the mighty examiner is death.

The puppy born blind must still be able, guided by the sense of smell, to superimpose his mouth upon a source of nourishment. The little chick, responding to the stimulus of a small bright object, must be able to bring his beak into contact with the object so as to grasp and then swallow it. The springing goat that misjudges an abyss is lost.

So too with man. His ideas must in some way correspond to this independent world, or death passes upon him an adverse judgment.

But it is of the very essence of the doctrine of evolution that man's metric knowledge of this independent world, having come by gradual betterment and through imperfect instruments, for example the eye, cannot be absolute and exact.

The results of any observations are always with certain definite limitations as to exactitude and under particular conditions.

Man the creator replaces these results by assumptions presumed to have absolute precision and generality, such as, for example, the so-called axioms of Euclid.

If two natural hard objects, susceptible of high polish, be ground together, their surfaces in contact may be so smoothed as to fit closely together and slide one on the other without separating. If now a third surface be ground alternately against each of these two smooth surfaces until it accurately fits both, then we say that each of the three surfaces is approximately plane, is a piece of a plane.

If one such plane be made to cut through another, we say the common line where they cross is approximately a straight.

The perfect, the ideal plane is a human creation under which we seize the imperfect data of experience.

If three approximate planes on real objects be made to cut through a fourth approximate plane, then the three approximate straights are formed on this fourth plane, and in general they are found to intersect, and the figure they make we may call an approximate triangle.

Such triangles may vary greatly in shape. But no matter what the shape, if we cut off the six ends of any two such, and place them side by side on a plane with their vertices at the same point, the six are found with a high degree of approximation just to fill up the plane about the point. If the whole angular magnitude about any point in a plane be called a perigon, then we may say that the six angles of any two approximate triangles are found to be together approximately a perigon.

Now does the exactness of this approximation to a perigon depend only on the straightness of the sides of the original two triangles, or also upon their size?

If we know with absolute certitude that the size of the triangles has nothing to do with it, then we know something that we have no right to know according to the doctrine of evolution, something impossible for us ever to have learned evolutionally.

Yet before the epoch-making ideas of Bolyai János and Lobachevski, everyone supposed we were perfectly sure that the angle-sum of an actual approximate triangle approached a straight angle with an exactness dependent only on the straightness of the sides and not at all on the size of the triangle.

But if in the mechanics of the world independent of man we were absolutely certain that all therein is Euclidean and only Euclidean, then Darwinism would be disproved by the reductio ad absurdum.

All our measurements are finite and approximate only.

The mechanics of actual bodies in what Cayley called the external space of our experience, might conceivably be shown by merely approximate measurements to be non-Euclidean, just as a body might be shown to weigh more than two grams or less than two grams, though it never could be shown to weigh precisely, absolutely two grams.

The outcome of the non-Euclidean geometry is a new freedom to explain and understand our universe and ourselves.

MERCURY AS A NAKED EYE OBJECT.

W. F. DENNING.

Rarely visible, and always difficult to observe satisfactorily in a telescope, this planet is yet a most attractive object to the unaided eye. Not receding to a greater distance than 28° from the Sun, he is, however, never above the horizon in England for a longer period than two and a quarter hours before sunrise, or for a similar interval after sunset. When an evening star in the spring months or a morning star in the autumn season, he may often be caught and watched for an hour or so, shining with a sparkling, rosy lustre, and presenting much the same aspect as a fixed star.

To secure a view of Mercury forms one of the earliest and greatest ambitions of the amateur astronomer. Among his first books there will sure to be a copy of Mitchell's "Orbs of Heaven," or Dick's "Celestial Scenery," and on reading the statement that Copernicus never succeeded in seeing Mercury, he resolves that he will do his best to catch a glimpse of this elusive little "Messenger of the Gods." After some vain attempts he finally succeeds, and it is not too much to say that the spectacle sometimes excites and gratifies the observer more than any other subsequent event in his astronomical career. Who is there among us who does not remember the thrill of pleasure incited by the first detection of this fugitive orb, and the conscious pride with which we realized that we had commenced our celestial work by achieving a feat which had been denied to the greatest astronomer of the sixteenth century?

But, as a matter of fact, there seems to be considerable doubt whether Copernicus ever really complained of failure to see Mercury. There is evidence to show that he never expressed himself in the manner quoted in many of our popular text-books. There may, it is true, have been some ground for the statement, but it is well known that a biographer has only to introduce a special incident of the kind alluded to, or to unduly color some expression, and whether on doubtful evidence or not, it is liable to be copied and recopied by subsequent writers without any investigation until it becomes generally accepted as a fact. But admitting for the moment that Copernicus really failed to discern Mercury, he seems to have had very good reason for it. His residence was at Thorn, in Prussia, and through the valley near ran the River Vistula, over which were frequent fogs which obliterated objects near the horizon.

This tradition about Copernicus and Mercury has certainly, however, enhanced the interest with which the planet is regarded as a naked-eye object. The beautiful white lustre of Venus—incomparably brighter than the aspect of Mercury—the stronger and steadier, yellowish light of Jupiter, or the conspicuous ruddy hue of Mars may present a more striking appearance in the sky than the twilight-veiled splendor of Mercury, but there is something about the sparkling lustre of the latter orb, hovering fugitively on the brow of the horizon, which forms an attraction peculiarly its own.

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On reference to my note-book I find that I obtained naked-eye views of Mercury on 102 occasions between February, 1868, and December, 1899. But the planet was very rarely looked for here at the morning apparitions, and not always at really favorable spring elongations. If an observer with good sight made it a point to secure as many unassisted eye observations of this object as possible, he might be successful on about twelve occasions in a year. In a finer climate than ours, the planet may, of course, be more frequently seen. I think that some disappointments in regard to finding Mercury are due to the fact that observers scan the heavens at or after the time of maximum eastern elongations, instead of during a week or more preceding them. The phase and apparent brilliancy decrease rapidly at these periods. I have occasionally noticed Mercury as a very brilliant object about ten or twelve evenings before his greatest elongation, while at the date of his elongation he has appeared quite faint, and a few evenings later, become practically invisible, though above the horizon for about two hours after sunset.

My observations in various years have led me to the following conclusions regarding the visibility of the planet at the evening apparitions:—

(1) The greatest brightness of the planet is attained ten or twelve days prior to his greatest elongation.

(2) In February and March the planet may sometimes be caught twenty minutes after sunset, in April thirty minutes after sunset, and in May forty minutes after sunset. The stronger twilight towards midsummer occasions the difference.

(3) The duration of his visibility to the naked eye is about 1^h 40^m in March, 1^h 30^m in April, and 1^h 20^m in May. On a very exceptional occasion it is possible these limits may be exceeded.

(4) The planet is a conspicuous object, and certainly much brighter than a 1st mag. star. In February, 1868, I considered that his lustre vied with that of Jupiter, then only 2° or 3° distant. In November, 1882, he appeared brighter than Sirius. In 1876 he looked more striking than Mars, then 13° distant, but the latter planet was faint and at a considerable distance from the Earth.

The greatest number of naked eye observations of Mercury at the same elongation was obtained at Bristol in spring of 1876, when the planet was seen on thirteen different evenings. When Venus is near Mercury at a favorable time, she affords an excellent guide to the identification of the latter. But errors have often been induced, and either Venus or Jupiter has been mistaken for Mercury on many occasions. In April, 1898, Venus was near Mercury, and some people, including a few regular astronomical observers, readily saw Venus and believed (and still ardently believe) that they were looking at Mercury.

The albedo, or reflecting capacity of the planet, is rated exceedingly low, being only 0.11, whereas Mars is 0.27, Saturn 0.50, and Venus and Jupiter 0.62. This is remarkable when we consider the occasional striking brightness of the small planet in a region of the sky full of strong twilight. By telescopic comparisons of the disc of Mercury with other planets, it is, however, easily seen that the former is relatively feeble in brilliancy. On May 12, 1890, I viewed Mercury and Venus in the same field of view of a 10-inch reflector, and remarked that the brilliant silvery light of Venus contrasted strongly with the much duller hue of Mercury. The probability is that the latter object is provided with a much thinner atmosphere than that which envelopes his sister planet. There are undoubted markings visible on Mercury, but they are nothing like the peculiar representations of them which have been published in the last few years. The extreme difficulty of obtaining satisfactory views of the planet furnishes the principal reason why his rotation period still awaits accurate determination.

Nature, March 1, 1900.

THE LUNAR ATMOSPHERE.

In the light of the observations already described, we now seem justified in concluding that the Moon is surrounded by an atmosphere. Indeed, nearly all the volcanic phenomena described in this volume involve the escape of imprisoned gases. The visual and photographic observations of the occultation of Jupiter, described upon pages 82 and 83, indicate that upon the sunlit side of the Moon this atmosphere is filled to a height of about six kilometers, or four miles, with some absorbing medium, which is absent upon the dark side. These same observations upon Jupiter show that the gaseous tension at the lunar surface is so slight that the refraction 2 H is less than 0″.5. Since it was necessary to give very short exposures, the photographs could not be taken upon a larger scale than 5″ to a millimeter. The 13 inch telescope was employed, but with a larger aperture and consequently more light it would be possible to take the negatives upon a larger scale, and thus obtain more accurate results.

Upon the night of October 13, 1897, the moon, which was full upon October 10, occulted Alcyone in the Pleiades. As seen from Cambridge the star disappeared behind the bright limb at a point near Anaximander, or about twenty degrees to the east of the north pole. Time of disappearance 12^h 35^m G. M. T. The micrometer thread had previously been set to coincide with the star and its brightest companion p (Bessel). P. A. 289°, Distance 117″. The stars were carefully watched as they approached the limb of the Moon, but not the slightest deviation in the position angle due to lunar refraction could be detected. At the time of the disappearance of Alcyone, *p* was still about 15″ from the Moon's limb. Alcyone reappeared from behind the dark limb at $13^h 15^m$. The micrometer had not been moved in the mean time, and the coincidence of its thread with the two stars was still found to be exact. The position angle of the thread was now changed by 0°.2. The effect upon the stars was quite marked, and it is very certain that any such displacement of the stars with regard to the thread would have been noticed. It was found that a change of 0°.1 would hardly have been seen, although it might have been. Since the distance between the stars was 117″, and the distance from the companion to the limb was 15″, the line joining the two stars was inclined at an angle of 7° to the surface of the Moon. A change of 0°.1 would therefore correspond to a displacement of Alcyone by lunar refraction of 0″.2.

Since the force of gravitation upon the surface of the Moon is but one-sixth as great as it is upon the Earth, the distance that we should have to ascend in the Moon's atmosphere to reduce the pressure by one-half is six times as great as the distance to which we must ascend above the surface of the Earth. In the case of the Earth this distance is three and one-half miles. To reduce the pressure of the lunar atmosphere by one-half we should have to ascend twenty-one miles, or about 17″ at the Moon's limb as seen from the Earth. Since at the disappearance of Alcyone *p* was still 15″ above the Moon's limb, the lunar refraction would displace it about one half as much as it did its primary. Therefore, if the change of position angle of the stars did not exceed 0°.1, the effect of the lunar refraction $2H$ could not exceed 0″.4 upon the bright side of the Moon.

This observation is really a repetition of one that I made at the Lowell Observatory in 1894, with the same result. The instrument employed in the present observation was the 15-inch equatorial, with a magnification of 550. The two fainter companions of Alcyone were both watched during the occultation, although they were seen with too much difficulty to obtain results of the highest accuracy had it been necessary to use them in the research. The photographic magnitudes of Alcyone and its three companions, according to these annals, Vol. XVIII, pp. 158, 159, are 3.42, 6.64, 8.14 and 8.69.

In the *Astrophysical Journal* for 1897, Vol. VI, p. 421, is given a list of twelve observations made between May 8 and October 3, 1897, by Professor Comstock, of occultations of stars observed with a filar micrometer. All of his observations were of immersions on the dark side of the Moon. From them he concludes that upon the dark side the maximum permissible value of 2 H is 0″.2.

When observing occultations of stars with the filar micrometer, if the direction of the line joining the stars is nearly parallel to the occulting limb, their refraction should be measured, as in the above case, by means of the observed position angle. If the line joining the stars is nearly perpendicular to the limb, the refraction should be measured by determining the variation, if any, in the distance between the two stars. In either case the most accurate results can be obtained when the star is occulted near the north or south limb of the Moon. Under these circumstances we have more time in which to make the observation, and we have less trouble from the irregular running of the telescope, as the threads then lie in an approximately east and west direction. It is believed that greater accuracy would be obtained if one could measure the distance between two stars rather than if one were obliged to measure their position angle.

TABLE LXII.

LIST OF WIDE DOUBLE STARS AND CLUSTERS OCCULTED BY THE MOON.

No.	Object.	Magn.		P. A.	Dist.
				°	″
1	77 Piscium	5 9	6.8	82.7	32.8
2	ζ "	4.2	5.3	63.7	23.5
3	Pleiades				
4	χ Tauri	5 7	7.8	25.3	19 3
5	62 "	6 2	8	289.7	28.9
6	τ "	5	7.2	212.4	62.9
7	B. A. C. 1562	6	7	158.6	78.8
8	15 Geminorum	6	8	205.4	33.2
9	ν "	4 2	8	329.1	112.6
10	20 "	6	6 9	209.8	20
11	ζ "	4	7.2	351.6	93.6
12	Praesepe				
13	α Leonis	1.5	8.4	306.6	176.9
14	83 "	6.3	7 3	150.	29.6
15	τ "	5	7	169 6	94.8
16	B A. C. 4134	5.9	6 4	196 3	20.1
17	α Libræ.	3	6		
18	23 Scorpii	4.1	7	336.8	40.8
19	σ "	3	8	271.2	20.4
20	6523 (M S) Sagitarii (cum.) Near B. A. C. 6088				
21	M 25 Sagittarii (cum.)				
22	σ Capricorni	5	8.3	177.2	55.8
23	β "	2.5	6	267.1	205.3
24	o^2 "	6.3	6.8	239.9	21.8

In the preceding table, which has been deduced from "Celestial Objects for Common Telescopes," by T. W. Webb, is given a list of those double stars sometimes occulted by the Moon, whose distance exceeds 20″ and whose fainter component is brighter than magnitude 8.5. A few clusters of brilliant stars are also included.

Bearing in mind the most favorable conditions, that the stars should lie in a nearly north and south direction, that they should not be too far apart, and that the companion should not be too faint, we may select B. A. C. 4134 as decidedly the most favorable star for this investigation. After it follow, in the order of their desirability, 20 Geminorum, 23 Scorpii, 83 Leonis, and χ Tauri. The investigation is perhaps more likely to lead to a positive result if the disappearance takes place behind the bright limb of the Moon, as on account of the higher temperature an atmosphere is more likely to be found upon that side. The Moon should therefore be past the full. If the occultation is a grazing one, however, so that the relative motion of the Moon's limb and the star is slow, disappearances and reappearances can be observed with nearly equal accuracy, and the age of the Moon is unimportant.—*W. H. Pickering in H. C. O. Annals, Vol. XXXII, Part II.*

SPECTROSCOPIC NOTES.

The total eclipse of May 28 is now so near at hand that most of the subjects for study have been decided upon and many of the preparations for observation have been completed. The observations of recent eclipses will be repeated with care; and unless some substantial advance is scored this will at least have to be reckoned a less productive eclipse than the last three.

Probably the most extended study will be devoted to matters spectroscopic. The flash spectrum at the instants of beginning and end of totality will be further investigated, both photographically and visually, with various types of instrument, but especially with the prismatic camera. The question of the precise position of the corona line, made so interesting by the results of the last eclipse, will receive attention, the instrument being primarily the slit spectroscope. The distribution of 'coronium,' requires further study, and valuable work may be done with apparatus no more complex than a binocular with a direct vision prism before one of the glasses. The rotation of the corona, as shown by minute displacement of the corona line, can be studied better a year later, when totality will be much longer.

Among the opportunities for observation not distinctly spectroscopic are, large scale photographs of the corona with lenses of great focal length; with instruments of moderate size short exposure photographs to get the detail of the inner corona, and long exposure photographs to get the extension of the outer corona; measurement of the heat radiation of the corona; naked eye drawings of the corona, preferably of some limited portion of the corona only; telescopic examination of the corona, particularly in the neighborhood of the prominences; the polarization of the light of the corona; estimation of the total light of the corona.

Aside from the study of the Sun itself there are, a photographic search for intra-mercurial planets; determination of the brightness of Mercury with the whole of the disc illuminated, as at this eclipse Mercury will be nearly at superior conjunction; and a search, if the sky be dark enough, for a satellite of Mercury.

Intending observers who are not accustomed to thinking of eclipse matters would do well to consult some report of diversified eclipse observations, such as Sir Norman Lockyer's papers in *Nature*, or the Report of the Expedition of the British Astronomical Association to the Indian Eclipse; or some detailed explanation of possible observations, such as Professor Hale's "Eclipse Problems" (*Astrophysical Journal*, Jan. 1900), or Mr. Maunder's "Eclipse Suggestions" (*Journal British Astronomical Association*, Vol. 10, No. 4). But any observer in selecting his work is distressingly conscientious if he arranges a program which does not permit a plain view, at least momentary, of the corona.

Dr. Ambronn, in his elaborate *Handbuch der Instrumentenkunde*, devotes 44 pages out of 1264 to "*spectralapparate*;" vol. 2, chap. 14, pp. 725-768. The compilation and description of spectrum apparatus there given is avowedly less exhaustive than for other types of astronomical instruments. The first of the three sections of the chapter contains, briefly, a discussion of dispersion, achromatism, and the character of the spectrum lines; a description of prism systems employed, including compound and direct-vision prisms; and a statement of the theory of the cylindrical lens. In the second and longest section the various types of spectroscopes are enumerated and briefly described: The objective prism, the ocular direct-vision spectroscope; the slit spectroscope, with its various arrangements of slit and of index or micrometer, and in its variety of forms, as the star spectroscope of precision of the usual form, the half-prism spectroscope, and the grating spectroscope. The third section describes briefly the spectrograph, including the spectro-heliograph.

In a paper communicated to the Royal Astronomical Society (*Observatory*, January), Professor Barnard, describing his attempt to determine whether the faint nucleus of the ring nebula in Lyra is of the same constitution as the nebula, states that in the 40 inch telescope of the Yerkes Observatory the nucleus comes to focus 0.06 inches farther out than a star, while a planetary nebula comes to focus 0.26 inches farther out than a star.

Professor Campbell and Mr. Newall (*Observatory*, February) agree in finding for the period of the spectroscopic binary Capella 104 days. The two components, one of the solar type, the other of the type of Procyon, are found to be nearly equal in mass. The results for the velocity are from Professor Campbell's observations + 31 kilometres per second for the system, the component of the solar type ranging from + 4 to + 57 km.; from Mr. Newall's observations + 27 km. per second, the solar component ranging from 0 to + 54 km. per second.

A few pages later in the same number occurs the statement that several negatives of the spectrum of Capella, taken at the Washington Observatory, were rejected on account of the duplication of the spectrum lines, supposed to be due to some defect in the spectroscope.

Among the miscellaneous researches described in the *Harvard Observatory Annals*, Vol. 33, is an account of some observations on nebulae by Professors Pickering, Searle Upton and Wendell. Table III gives the general character of spectrum of about 100 nebulae, as determined by a direct vision prism used without a slit. The spectra are described as gaseous, continuous, gaseous with a faint continuous background, or chiefly continuous with a faint gaseous spectrum.

Professor Deslandres, using the great telescope of the Meudon Observatory with spectroscope specially designed for the measurement of motion of stars in the line of sight, finds the velocity of δ Orionis variable (*Comptes Rendus*, Feb. 12). The spectrum of this star shows little more than the lines of hydrogen and helium, which are broad and diffuse. The lines, further, seem to be variable in width, and are unsymmetrical. While the character of the lines precludes measures of great accuracy, Professor Deslandres regards the evidence for marked variation in velocity as adequate, and gives 1.92 days as a period agreeing with his observations.

Sir Norman Lockyer, *Proceedings of the Royal Society*, No. 422, adduces strong evidence for the presence in the Orion stars of the element silicon, or, to use his term, silicium. Several coincidences are found of lines of the element with lines of the star spectra. The lines of silicium may be divided into three sets, behaving differently as the electrical conditions are varied, and of these sets of lines one predominates in β Orionis, another in γ Orionis, and the third in ζ Orionis. The particular set of lines predominant in each star is that which is required by the author's previous conclusion that these stars are at different temperatures, β Orionis the coolest, γ Orionis intermediate, and ζ Orionis the hottest of the three.

PLANET NOTES FOR APRIL.

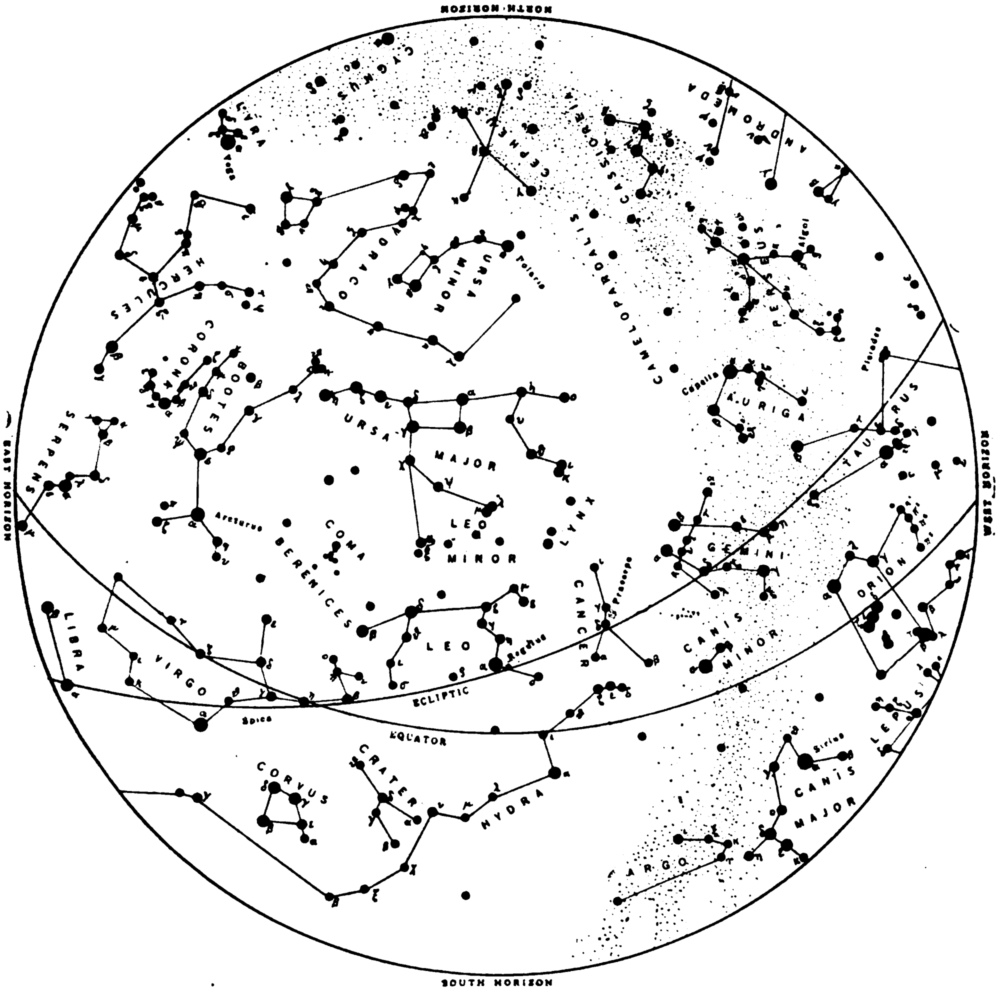
H. C. WILSON.

Mercury is now morning star, and will be visible to the naked eye during the latter half of the month. The planet will be at greatest elongation, west from the Sun 27° 19′, April 21. Mercury and Mars will be in conjunction April 3, but both will then be hidden in the glare of the Sun. Doubtless many were able to identify Mercury during the first two weeks of March, for it was quite conspicuous about a half hour after sunset.

Venus and the crescent moon will be in conjunction on the evening of April 2. In South America an occultation of Venus by the Moon will be visible at this time. Venus has been steadily moving northward as well as eastward, so that her position is very favorable for afternoon and evening observation. The planet will reach greatest elongation east from the Sun, 45° 35′, April 28. The phase of the planet is slightly gibbous, but will reach the quarter phase at the end of the month. Venus is at present approaching the Earth, so that her apparent brightness rapidly increases in spite of her diminishing phase.

Mars is morning star, but will not be in position for observation during this month.

Jupiter is approaching opposition, but is seen at such a low altitude in this country that observations will be of little value. The observers in South America and Africa, on the other hand, will see the planet to the best advantage. Jupiter and the Moon will be in conjunction April 18. Jupiter rises at about midnight at the beginning of the month, and about 10 o'clock P. M. at the end of April.



THE CONSTELLATIONS AT 9 P. M., APRIL 1, 1900.

Saturn rises in the southeast about an hour and forty minutes later than Jupiter, and may be seen in the morning hours of darkness. Its position is equally unfavorable with that of Jupiter for us, and will be equally favorable for southern observers during the summer months. The Moon will be in conjunction with Saturn on the morning of April 20, at 9^h 39^m Washington mean time, and in the northwestern part of the United States an occultation may be witnessed.

Uranus is near Jupiter in the constellation Scorpio.

Neptune is at a good altitude in the western sky in the early evening, but is, of course, not visible to the naked eye. Neptune will be in conjunction with Venus on the morning of April 30, but the planets will be too far apart in declination, Neptune 4° 39′ north of Venus, for the one to be made use of in identifying the other.

The Moon.

(Central Standard Time at Northfield; Local Time 13m less.)

		Phases.	Rises. h	m	Sets. h	m
April	6	First Quarter......	10	52 A. M.	2	04 A. M.
	14	Full Moon....................	7	01 P. M.	5	25 "
	22	Last Quarter................	1	22 A. M.	11	26 "
	28	New Moon....................	4	28 "	7	04 P. M.

Occultations Visible at Washington.

Date. 1900.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
April	5	15 Geminorum	7.0	5	54	182	6	10	202	0	16
	11	e Leonis	5 3	17	08	94	17	59	304	0	51
	14	85 Virginis	6.5	16	40	181	16	57	208	0	17
	22	8 Aquarii	6.8	13	47	31	14	32	297	0	45

VARIABLE STARS.

J. A. PARKHURST.

Maxima and Minima of Long Period Variables.

MAXIMA, May 1900.

		Mag.	Day.
466	U Piscium	9.7	9
678	U Persei	7.7	29
782	R Arietis	8.3	18
869	R Fornacis	8.5	18
2258	V Aurigæ	9.2	8
2266	V Monocerotis	6.3	21
2376	S Lyncis	9	4
3493	R Leonis	6.0	5
4377	T Virginis	8.4	11
5511	RS Libræ	8	28
5593	W Libræ	9.8	26
5770	R Herculis	8.6	6
5931	S Ophiuchi	8.7	20
6100	RV Herculis	9.3	21
......	... Aquilæ	9	28
7252	W Capricorni	10.6	22
7435	Y Aquarii	8.8	25
7455	U Capricorni	10.5	10
7571	V Capricorni	9	6
7659	T Capricorni	9 3	10
7733	Y Capricorni	10	6
7909	S Piscis Aust.	9.0	16
8153	R Lacertæ	8 8	13
8597	V Ceti	9.0	19

MINIMA, May 1900.

112	R Andromedæ	< 12.8	18
518	R Piscium	< 13	16
845	R Ceti	13 5	9
2539	R Canis Minoris	9 7	15
4521	R Virginis	9.8	17
4557	S Ursæ Majoris	10.8	18
5157	S Bootis	12.8	24
5237	R Bootis	11.8	20
6449	T Draconis	11.7	17
6871	V Lyræ	< 12	11
8591	V Cephei	6 9	6

MAXIMA, June 1900.

		Mag.	Day.
62	S Sculptoris	6.5	15
107	T Cassiopeæ	7.5	27
267	V Andromedæ	8 7	13
401	U Sculptoris	8.7	5
893	U Ceti	7.1	10
1116	X Ceti	9.3	30
2080	R Columbæ	7.9	17
2528	R Geminorum	7.2	10
2684	S Canis Minoris	7.6	6
2742	S Geminorum	8.5	15
2976	V Cancri	7 3	9

MINIMA, June, 1900.

......	... Hydræ	8.5	1
3825	R Ursæ Majoris	7.1	9
4471	T Canum Ven.	8.7	13
4596	U Virginis	7.9	27
4896	T Centauri	5.9	7
5430	T Libræ	9.7	26
5501	S Serpentis	8.2	13
5583	X Libræ	9.7	28
5887	V Ophiuchi	7.3	3
6905	R Sagittarii	7.5	9
6943	T Sagittæ	8.5	16
7120	χ Cygni	5.3	13
7260	Z Aquilæ	8.9	26
7404	R Microscopii	8.0	5

MINIMA June, 1900.

7577	X Capricorni	10.0	3
7792	SS Cygni	8.5	11?
7896	V Pegasi	8.2	23
8068	S Lacertæ	7.7	21
8369	W Pegasi	8.1	17
......	... Cassiopeæ	9.4	16

MINIMA, June 1900.

294	W Cassiopeæ	11.4	23
1623	T Camelopardalis	<12	18
5494	S Libræ	< 13	26
5955	R Draconis	12.5	29
6512	T Herculis	10.7	18
7560	R Vulpeculæ	13	15

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900 May.

U CEPHEI.

	d	h
May	4	13
	9	12
	14	12
	19	12
	24	11
	29	11

S VELORUM.

	d	h
May	11	17
	17	15
	23	14
	29	12

δ LIBRAE.

	d	h
May	1	20
	6	12
	8	20
	13	11
	15	19
	20	11
	22	19
	27	11
	29	18

U OPHIUCHI.

Every 10th min.

$P = 20.13^h$

	d	h
May	8	10
	16	20
	25	5

U CORONAE.

	d	h
May	2	14
	9	11
	12	22
	16	9
	19	20
	26	18

+ 12°3557.

	d	h
May	1	22
	2	20
	3	17
	4	14
	5	11
	9	22
	10	20
	11	17
	12	14
	13	12
	17	22
	18	20
	19	17
	20	14
	21	12
	25	22
	26	20
	27	17
	28	14
	29	12

Z HERCULIS.

Even epochs.

	d	h
May	2	16
	6	15
	10	15
	14	15
	18	14
	22	14
	26	14
	30	14

Odd epochs.

	d	h
May	4	15
	8	15
	12	15
	16	15
	20	14
	24	14
	28	14

+ 45°3062.

	d	h
May	3	17
	8	7
	12	21
	17	10
	22	0
	26	14
	31	4

W. DELPHINI.

	d	h
May	5	21
	10	16
	29	22

Y CYGNI.

Even epochs.

	d	h
May	3	16
	6	16
	9	16
	12	16
	15	16
	18	15
	21	15
	24	15
	27	15
	30	15

Odd epochs.

	d	h
May	1	18
	4	18
	7	18
	10	18
	13	18
	16	18
	19	18
	22	18
	25	18
	28	18

AUTHORITIES FOR THE EPHEMERIS.—These are the same as in the March number except that the times for Y Cygni and Z Herculis are also taken from Dr. Hartwig's paper in the *Vierteljahrsschrift.*

RECENT PUBLICATIONS ON VARIABLE STARS.—A number of important articles on this subject have appeared since the last month's notes, deserving more extended notice than can be given here. The following sketches will give some idea of their contents.

MIRA AND R LACERTAE.—In number 3622 of the *Nachrichten* Professor Deichmüller, of Bonn, gives his observations of Mira, covering the three maxima of 1887, 1888, and 1889, being the last three in the previous visibility-period, those of the four or five years following 1889 falling too near the Sun to admit of good determination. In connection with the date of each observation the author gives the comparison stars used, the brightness of the variable in steps, (the scale used agreeing closely with that of Argelander) and the conditions of seeing when at all doubtful. The results were as follows:

Dates of Observations.	No.	Date of Max.	Steps.
1887 Oct. 11 to 1888 Jan. 1	16	1887 Nov. 3.0	20
1888 Aug. 10 to 1888 Dec. 8	40	1888 Sept. 19.5	32
1889 July 31 to 1889 Oct. 5	10	1889 Aug. 20	27

Graphic representations of the light curves are given, showing at a glance the different types of maxima. The author calls attention to the importance of recognizing these different types, and of publishing the observations in sufficient detail to show them. A request is made that any unpublished observations be either published or communicated to him, as Mr. Guthnick, of Bonn, has undertaken a definitive reduction of this variable.

The same author gives his observations of R Lacertae in detail, covering the time from 1899 June 4 to Oct. 10, showing a principal maximum 1899 July 16.0, at 8.70 magnitude. The light curve is given, showing the rise from 12.0 magnitude to maximum and the decline to the same point. A chart of the field is given, and also a comparison with the elements derived from three well determined maxima in 1883, 1892 and 1899. The resulting elements of maximum are:

1899 July 15.8 + $299^{d}.90$ E.

The corrections to these elements given by the three mentioned date of maxima, are only — 0.2, + 0.7, and — 0.2 days, respectively.

These two papers are excellent examples of what reports of variables should be, and are recommended as models to be followed.

OBSERVATIONS OF VARIABLES BY ARGELANDER, SCHONFELD AND SCHMIDT.—Professor Pickering has done a valuable service to astronomy by printing, in Vol. XXXIII of the Harvard Annals, three series of observations of variables reduced with photometric values of the magnitudes of the comparison stars. The series made by Argelander includes about 4000 hitherto unpublished comparisons made between 1869 and 1871. These results are combined with his earlier work, done 1838 and 1867 and published in volume VII of the Bonn Beobachtunen. During this interval from 1838 to 1871, 16 long period variables were followed, making perhaps the most important series in existence.

Of scarcely less importance are the observations made by Schönfeld between 1853 and 1859, relating to 32 variables of long period. The relative brightness of the comparison stars used was determined with great care by Schönfeld, and a comparison with the photometric magnitude gives as the value of one step or "grade," 0.09 magnitude. The corresponding value in Argelander's work was 0.14 magnitude.

The work of Schmidt at Athens was done between 1845 and 1879, and is remarkable for the continuity of measures which the climate of Athens enabled him to secure. Of the many thousand of operations, only those are published which relate to his long period variables, thirteen in number. It should be a warning to modern observers that of eighty-two comparison stars for these variables, Schmidt only left data for identifying thirty-four, and many of these are uncertain. The value of a "grade" expressed in photometric magnitudes is found to be 0.22. More than 7500 observations of the thirteen variables by this industrious observer are published.

The value of these old observations increases with age, since by combining them with modern comparisons our knowledge of the variations of the stars becomes more complete and accurate from year to year. Their reduction with photometric values of the comparison stars insures homogenity in the results, and the convenient form in which Professor Pickering has published them add greatly to their value.

ANOTHER NEW VARIABLE.—In No. 3618 of the *Nachrichten*, Rev. Thomas D. Anderson announces the discovery of a variable, not in the *DM*, in the place—

R. A. 17^h $55^m.6$, Dec. + 54° 51′ (1855)

Its observed magnitudes were—

1899	Nov.	14,	9.4
1900	Jan.	7,	10.2
		26,	10.4

He gives the approximate places of the following comparison stars, which are not in the *DM*:

	Mag.		1855		
a	9.6	17^h	$53^m.9$,	+ 54°	51′
b	9 8	17	53 .9,	54	44
c	10.6	17	54 .1,	54	37
d	10.3	17	55 .3,	54	41

The variable is nearly in line between the following two *DM*. stars—

+ 54°1925	7.0^m	17^h	54^m	39.10^s	+ 54°	40′	49″
+ 55 2003	9.0	17	56	58 2,	55 .	2	39

The magnitudes and positions of the two *DM* stars are taken from the Gesellschaft Catalogues.

On the evenings of March 2 and 6 a 10.5 magnitude star was found near the indicated place and its position found from the two *DM* stars proved to be

R. A. 17^h	55^m	35.7^s,	Dec. + 54°	50′	8″,	(1855)
	56	28.6 ,		49	52 ,	(1900)

There is a 12th magnitude star $2^s.5$ following and 1′ 17″ south. If the stars given are platted it will be easy to recognize the field, which lies 2° south and ½° following the 4th magnitude star ξ Draconis.

THE NEW CERASKI ALGOL-TYPE VARIABLE.—In justice to the writer it should be stated that he did not see the proof of the chart or note concerning this star, given on pages 158 and 159 of the March number, or some of the printed errors would have been corrected.

COMET AND ASTEROID NOTES.

Photographic Search for Comet 1892, (Barnard).—During the summer and autumn of 1899, from July 10 to October 14, Dr. Schwassmann, at Heidelberg, Germany, executed a quite extensive photographic search for this comet, which though very faint visually was discovered by Barnard in 1892 upon a photograph of the Milky Way. Dr. Schwassmann took 25 photographs on 19 nights, with average exposures of about two hours, selecting the field of the photograph by means of an ephemeris computed by M. Coniel, published in the *Bulletin Astronomique.* The plates each covered an area of about 100 square degrees. No trace of the comet was found, while stars of the 13th magnitude and fainter were photographed. Dr. Wolf in speaking of this remarks the few comets which are found, considering the large number of wide field photographs which are now being taken for the purpose of following the asteroids and of obtaining pictures of the Milky Way. It must be inferred from this that the number of telescopic comets is much smaller than it is usually assumed to be.

Elements and Ephemeris of Giacobini's Comet (1900 *a*).—The following system of elements is based on the observation made at Nice by Javelle on February 3 and my own observations of February 16 and 21.

$$\begin{array}{rlll} T & \multicolumn{3}{l}{\text{1900 April 29.0781 Greenwich Mean Time.}} \\ \omega & 24^\circ & 36' & 56''.6 \\ \Omega & 40 & 24 & 38.8 \\ i & 146 & 25 & 22.2 \\ \log q & \multicolumn{3}{l}{0.123476} \end{array} \left.\vphantom{\begin{array}{l}a\\b\\c\end{array}}\right\} 1900.0$$

Residuals, $O - C$.

$$\begin{array}{ll} \Delta\lambda' \cos\beta' & -0''.4 \\ \Delta\beta' & +0.1 \end{array}$$

CONSTANTS FOR THE EQUATOR OF 1900.

$$\begin{aligned} x &= r[9.970123] \sin(v + 79^\circ\ 15'\ 59''.5) \\ y &= r[9.999348] \sin(v + 168\ \ 3\ \ 35.9\ ) \\ z &= r[9.559528] \sin(v + 69\ \ 57\ \ 41.8\ ) \end{aligned}$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1900.	True α.			True δ.		log Δ.	Br.
	h	m	s	°	′		
Feb. 26.5	2	9	52	+ 1	43.0	0.297	0.85
March 2.5		5	38	2	56.6		
6.5	2	1	53	4	7.2	0.320	0.83
10.5	1	58	34	5	15.2		
14.5		55	37	6	21.2	0.339	0.81
18.5		52	57	7	25.2		
22.5		50	32	8	27.6	0.354	0.82
26.5		48	19	9	28.8		
30.5		46	15	10	29.2	0.364	0.83
April 3.5		44	18	11	28.9		
7.5		42	26	12	28.2	0.369	0.85
11.5		40	36	13	27.5		
15.5		38	47	14	27.0	0.370	0.87
19.5		36	56	15	27.0		
23.5		35	3	16	27.8	0.366	0.91
27.5		33	6	17	29.8		
May 1.5		31	0	18	33.2	0.356	0.95
5.5		28	46	19	38.4		
9.5		26	18	20	45.7	0.342	1.00
13.5		23	36	21	55.7		
17.5		20	34	23	8.6	0.323	1.06
21.5		17	9	24	25.0		
25.5		13	16	25	45.6	0.299	1.14
29.5	1	8	47	27	10.6		
July 1.5	23	40	41	42	11.3	0.131	1.81
Aug. 1.5	19	33	28	+ 41	14.4	0.077	1.68

The unit of brightness is that on February 3.

The comet is between 10th and 11th magnitude and has a faint nucleus.

MOUNT HAMILTON, California. C. D. PERRINE.

1900 March 2.

New Asteroid 1900 FA.—This was discovered by Charlois at Nice, Feb. 22, $9^h\ 30^m.0$, Nice, M. T., R. A, $9^h\ 30^m\ 44^s$; Dec. $+22°\ 32'$. Its daily motion was west 17′ and north 1′, and its brightness 12.2^m.

EPHEMERIS OF ASTEROID 1899, EY.

[Continued from March number.]

	R. A.	Decl.	Log *r*.	Log Δ.	Mag.
April 2	$5^h\ 03^m\ 09^s$	+ 24° 10.1	0.4565	0.4982	11.0
4	5 49	24 18.9			
6	8 32	24 27.5	0.4568	0.5052	
8	11 17	24 35.9			
10	14 05	24 44.1	0.4572	0.5119	
12	16 55	24 52.1			
14	19 47	24 59.8	0.4575	0.5183	
16	22 41	25 07.4			
18	25 37	25 14.7	0.4578	0.5245	
20	28 35	25 21.7			
22	31 35	25 28.5	0.4582	0.5304	
24	34 37	25 35.0			
26	37 41	25 41.3	0.4585	0.5361	
28	40 47	25 47.3			
30	43 54	25 53.1	0.4589	0.5415	
May 2	47 03	25 58.6			
4	50 13	26 03.8	0.4592	0.5466	
6	53 24	26 08.8			
8	5 56 37	+ 26 13.5	0.4596	0.5514	11.3

Elements and Ephemeris of Asteroid (434) Hungaria.—In *Astronomische Nachrichten* No. 3624, Dr. A. Berberich gives elements of this planetoid depending upon 29 observations in 1898. The elements represent the observations very closely.

ELEMENTS.

Epoch March 5.0, 1900, Berlin Mean Time.

$$\left.\begin{array}{l} M = 244^\circ\ 34'\ 15''.3 \\ \omega = 122\ \ \ 55\ \ \ 42.3 \\ \Omega = 174\ \ \ 39\ \ \ 17.4 \\ i = \ \ 22\ \ \ 30\ \ \ 32.0 \end{array}\right\}1900.0 \qquad \begin{array}{l} \varphi = 4^\circ\ 15'\ 30''.9 \\ \mu = 1308''.6777 \\ \log a = 0.2887826 \end{array}$$

EPHEMERIS.

Berlin Midnight.	R. A. h m s	Decl. ° ′	Log *r*.	Log Δ
April 4	11 51 34	+ 9 26.3	0.2988	0.0110
6	50 05	10 05.1		
8	48 41	10 42.5	0.2981	0.0172
10	47 23	11 18.3		
12	46 11	11 52.4	0.2973	0.0248
14	45 06	12 24.7		
16	44 07	12 55.3	0.2966	0.0337
18	43 15	13 24.0		
20	42 32	13 50.8	0.2958	0.0436
22	41 56	14 15.7		
24	41 28	14 38.8	0.2950	0.0542
26	41 08	15 00.0		
28	40 55	15 19.5	0.2943	0.0654
30	40 50	15 37.2		
May 2	11 40 54	15 53.1	0.2935	0.0771

The asteroid will be of about the twelfth magnitude during this month.

GENERAL NOTES.

We are again about on time in mailing this month's number, and we expect hereafter to publish early enough, so that all home subscribers will receive POPULAR ASTRONOMY before the first day of the month for which it is published. Foreign subscribers should be reached during the first week of the same month.

The Origin of the Lunar Surface Formations.—We have given considerable space this month and last to Professor William H. Pickering's studies of the origin of the lunar surface formations recently published in the Annals of Harvard College Observatory. His results are very suggestive and instructive.

Variation of Latitude at New York.—Professor J. K. Ree's valuable paper on the variation of latitude at New York is so well and plainly written, that those who have no experience in this kind of delicate astronomical work will readily see from it how the wonderful facts it discloses have been learned.

Professor C Piazzi Smyth.—The well known Professor C. Piazzi Smyth, for forty years Astronomer Royal of Scotland and professor of astronomy in Edinburgh, died on February 21, at the age of 81 years. When our publication of the *Sidereal Messenger* began in 1882, Professor Smyth was the first from Europe to extend congratulations. His genial letter is well remembered to this day, after nearly two decades of years.

Photographic Search for Intra-Mercurial Planets.--Being personally interested in the settlement of the intra-Mercurial planet question, the announcement that Professor W. H. Pickering is going to visit the path of totality of the eclipse of May 28, with a peculiar and ingenious photographic device for the purpose of searching for them photographically, pleases me greatly. My faith that the two objects seen by me at the Denver eclipse in 1878 were intra-Mercurial planets, has never been weakened by the failure of others to find them at subsequent eclipses, for, having no faith in their existence, no one with a proper eye-piece has made the attempt.

At the time, I hastily estimated that their direction from the sun was s. w. Since then I have visited the precise spot where my telescope was planted, to get, with perhaps greater accuracy, the directions of the four cardinal points. My conclusion was that s. of w. was a better estimate than s. w. I hope Bailey's beads will be observed with care, for their cause is a mystery. At Denver they extended half around the moon, at each end appearing like minute angular dots, increasing in size to the middle, but all of the same shape, and had one-half of them been bent over and superimposed on the other, they would have agreed in number, size and shape. At another total eclipse, in Northern California, they bore not the least resemblance to any previously seen, appearing like the letter a, of the Morse telegraphic alphabet, a dot and a dash, thus, .— .— .— extending half around the moon's circumference. I admit that at the Denver eclipse they appeared like notches in the Moon's limb, but she has no such sinuosities of elevations and depressions as to present the appearance observed.

LOWE OBSERVATORY, Echo Mountain, Cal. LEWIS SWIFT.

The Variable Star *o* Ceti (Mira) 1899.—During the past maximum of *o* Ceti only about thirty observations were secured, owing to a greater frequency of cloudy nights, and interruption by sickness and death in the family.

The observations indicate that the maximum occurred between September 18th and 25th, 1899, when the variable was only about the 4th magnitude.

Compared with the brilliant maximum of 1898, the contrast was quite noticeable in the recent apparition of this " wonderful " variable.

Date. 1899.	Central Time.	Mag.	Remarks.
August 28th	2:15 A. M.	4.3	First observation of Mira for the present apparition. Moon in last quarter. Variable is not as bright as Delta Ceti.
September 1st	2:00 A. M.	4 3	No decided change.
2d	11:15 P. M.	4.3	No change.
4th	12:10 A. M.	4.3	Cannot detect much change yet.
6th	1:00 "	4.2	A trifle brighter.
10th	2:30 "	4.1	About same as δ Ceti now.
11th	2:30 "	4.1	About same as δ Ceti, possibly trace brighter.
12th	3:00 "	4.1	No apparent change.
14th	2:00 "	4.1	No change.
18th	3:45 "	4.0	Nearly full bright Moon. Mira appears about same as α Piscium, certainly brighter than δ now.
21st	3:00 "	—	Brilliant moonlight, too near for careful comparison, but Mira appears much brighter than on 18th but this is probably owing to a tendency to estimate this variable much brighter in strong moonlight.
25th	12:05 "	4.0	About same as α Piscium.
25th	10:15 P. M.	4.0	Same as morning observation.
27th	1:00 A. M.	4.2	Trace fainter than δ Ceti this morning.
28th	10:00 P. M.	4.2	Slightly fainter than δ.
29th	10:00 "	4.3	Not as bright as δ Ceti, slightly brighter than ξ^2 Ceti.
October 2d	3:00 A. M.	4 4	Same as ξ^2 Ceti now.
4th	11:00 "	4.4	No change.
5th	10:30 "	4.3	Seems brighter than ξ^2 Ceti tonight.
11th	10:00 "	4 6	Brighter than Nu Ceti, not as bright as ξ^2 Ceti.
13th	10:00 "	4.6	Moon in first quarter. No change.
16th	11:00 "	4.5	Moon nearly full, and variable appears brighter, would estimate it as but a trace fainter than ξ^2 Ceti tonight.
29th	9:30 "	5.4	Good observation. Not as bright as V Ceti.
30th	10:45 "	5 4	Very good observation, same as last night.
November 1st	10:00 "	5.4	No apparent change.
2d	10:00 "	5.4	Slightly inferior to V Ceti.
4th	10:30 "	5 4	No change.
5th	10:00 "	5.4	Good observation, no change.
19th	7:30 "	6.5	About same as 71 Ceti now.
1900			
January 21st	6:30 "	8.5	Good observation, Mira is now about same magnitude as star of 8.5 mag. in same field of view with 4 inch telescope and $\frac{3}{4}''$ eye-piece, according to Durchmusterung chart.

Comparison stars used,—δ Ceti = 4.13 ξ^2 = 4.4 α Piscium = 4.0
71 Ceti = 6.5 Nu Ceti = 4.9 V Ceti = 5.06

ALTA, IOWA, March 15th, 1900. DAVID E. HADDEN.

Report of the Board of Visitors.—We have received an anonymous communication with the above title, which is a malignant attack on the report of the Board of Visitors, who were appointed to consider the present organization and management of the United States Naval Observatory, a few months ago. The report was prepared after much deliberation by the Board of Visitors—Messrs. Comstock, E. C. Pickering and Hale, and seemed to be a fair and reasonable document, meeting the wants of the situation as well as could be expected under the circumstances. It was not, in all respects, what we had hoped it would be, yet. probably the plan proposed is a better one for the present time.

We do not believe there is any real ground for the shameful attack which has been made upon the report, and the visitors personally, by some one who, presumablv, knows the situation well, and has taken this way to neutralize the manifest influence of this movement, which will certainly succeed in due time.

The author of this attack has industriously circulated it at home and abroad, and this is the reason we give it any attention. We know all the visitors personally, and we believe them to be gentlemen wholly above insinuations of this kind. As for the anonymous writer of those charges, it is best for him that he keep in the dark.

The Errors of Star Photographs.—Three significant papers by H. H. Turner, Savilian Professor at Oxford, England, published some time ago in the Monthly Notices of the Royal Astronomical Society, have just come to hand as reprints of those articles. The full title of the first and second papers is "On the Errors of Star Photographs Due to Optical Distortion of the Object Glass with Which the Photograph is Taken." Of the third, "On the Curvature of Star Trails on the Photographic Plates as a Means of Investigating Optical Distortion."

It will be remembered that in 1887 an International Conference assembled at Paris to consider the construction of a chart of the heavens by photography. Almost the first question asked was, "With what kind of an instrument should the work be done?" The reflector, the refractor with acromatic object glass and the photographic doublet were fully considered, and the simple photographic refractor was finally chosen. No astronomer in 1887 knew much about astronomical photography, and the best in the conference were timid in the choice of the kind of telescope to be recommended, or the methods of work by which this large task should be prosecuted. The fears about optical distortion were general, and early opportunities have been sought to test the real value of photographic work in this and other essential particulars. These papers bring out quite satisfactory results in an exhaustive examination of the Oxford plates and those by Professor E. C. Pickering, of Harvard College Observatory, taken with Bruce photographic doublet at Arequipa.

The gratifying results of these papers are, that the early fears about distortion, which caused much discussion in the outset, are found to be largely groundless, and the advantages of getting a large field are now claimed to be "too obvious to need explanation." This is almost unexpected evidence of the high precision of the modern photographic telescope, as well as increased confidence in photographic methods in stellar astronomy.

Total Eclipse of the Sun May 28, 1900.—A useful pamphlet of 32 pages published under the direction of the Superintendent of the U. S. Naval Observatory, Capt. C. H. Davis, has just been received. It contains suggestions and data to assist in the observation of the total solar eclipse of May 28, 1900. It was prepared by Professor H. D. Todd, Director of the Nautical Almanac, and S. J. Brown Astronomical Director of the Naval Observatory.

The pamphlet treats quite fully of

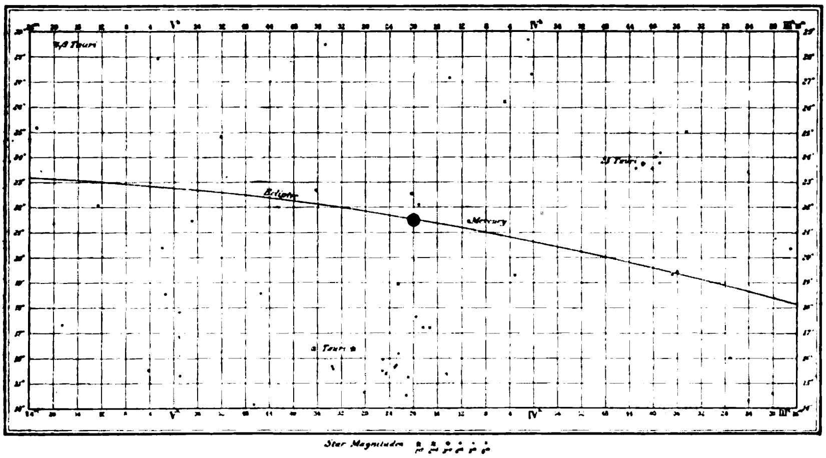
1. Sketches of the corona with the naked eye.
2. The Moon's shadow bands.
3. Photographs of the corona, and
4. Telescopic oservations.

The last part contains the ordinary astronomical data with a series of very good charts as follows:

1. A plate of the geographical limits and path of totality as taken from the Nautical Almanac.

2. A large chart of the stars and planets in the neighborhood of the Sun during the time of totality as given in reduced scale below:

PLANETS AND STARS IN THE VICINITY OF THE ECLIPSED SUN MAY 28, 1900.



3. A large chart showing the path of totality across Mexico and Texas with the hours of progress printed in red.

4. A large chart showing the path of totality across the United States, through Louisiana, Mississippi, Alabama, Georgia, the Carolinas and Virginia.

It is reported that extensive preparations are being made at the United States Naval Observatory for photographing and observing the total eclipse of the Sun. Astronomical Director D. J. Brown said recently: "If the weather is favorable we expect to secure some fine observations of the phenomena."

Two government stations will observe the eclipse, one in South Carolina and one in Georgia. There may be a branch station as far south as Union Springs, in Alabama, a place directly under the line of totality.

Professor Brown said that the Observatory is asked many questions in regard to the eclipse, indicating the wide-spread interest manifested in scientific circles in the approaching event.

A party of Eastern scientists will come to Washington some days prior to the 28th of May and will accompany the Observatory corps South, some going to Georgia and others remaining in South Carolina.

Brief Review of Solar Observations September to December 1899.—(Continuation from October 1899. P. A.) SEPTEMBER. The marked decrease in the number and size of Sun spots, and the frequency of days without spots noted in August, continued during the first three weeks of September, with the exception of occasional sporadic pores on five or six days. From the 24th to the close of the month, several small but active groups were on the disc, one of which suddenly appeared, and another rapidly increased between the 25th and 26th, this outbreak was coincident with a brief display of Aurora on the evening of the 25th.

OCTOBER.—There were eighteen spotless days during the month of October. No spots were visible during the first three weeks, except a few dots, but on the 23rd a fairly large and interesting group appeared at the East limb. With the spectroscope the region between the large spots of the group was much disturbed, the Ha line being reversed at many points. Unfortunately cloudy weather prevented further observations until the 29th, when the group was a small train and fast diminishing, being reduced to a mere dot as it approached the West limb.

NOVEMBER.—Sun spots were small, few and uninteresting during the month of November. There were only eight spotless days, all of which were in the first decade.

DECEMBER.—Owing to sickness and death in the family, and more or less cloudiness, observations were seriously interrupted this month. Between the 12th and 20th a couple of small groups were present, but they faded out before reaching the West limb, and the disc was nearly free from spots during the remainder of the month.

The following table exhibits the numerical results of the observations for the above four months:

Months. 1899.	Number of Observing Days.	Average Number of			Average Number	
		Groups.	Spots.	Faculæ.	Groups North Latitude.	Groups South Latitude.
September	27	0.8	3.4	1.4	0.1	0.7
October	22	0.5	4.3	1.4	0.1	0.4
November	18	0.9	3.3	0.9	0.3	0.6
December	9	1.0	2.8	1.2	0.4	0.6

Compared with the year 1898, there has been a decided diminution in the average number of groups, spots and faculae during the past year, while the total number of spotless days has increased from 30 in 1898 to 108 in the year 1899.

In the table below is given the annual average results for the years 1891 to 1899, inclusive:

Years.	Number of Days of Observation.	Average Annual Number of			Total Number of Spotless Days.
		Groups.	Spots.	Faculæ.	
1891	257	2.9	14.9	3.6	24
1892	205	5.6	34.0	4.1	0
1893	177	6.6	36.6	4.1	0
1894	139	5.6	30.0	3.4	0
1895	149	5.2	30.5	3.5	0
1896	197	3.2	17.8	2.9	5
1897	198	2.2	11.0	2.3	29
1898	234	2.1	11.0	2.4	30
1899	259	1.1	4.8	1.5	108

ALTA, IOWA, March 20th, 1900. DAVID E. HADDEN.

Queries and Short Answers.—5. If a man celebrates his twentieth birthday when he is nineteen years old to the minute, why should he not celebrate the twentieth century the moment we are 1900 years from the given starting point? H. M. S.

Answer. He certainly should celebrate the beginning of the twentieth century when "we are 1900 years from the given starting point." The trouble seems to be to get the starting point right. The first year of the first century did not end until that year was completed; the last year of that century was not completed until the end of the 100th year. So, also, the end of the 1900th year will be the end of the 19th century. If our querist will read the article on page 140, March number, he will see how to begin the reckoning.

6. What name is given by astronomers to the spectrum of the layer of gases immediately above the photosphere of the Sun? S. G.

Answer. It is sometimes called the "flash" spectrum, because of the sudden change of the ordinary solar spectrum to one of bright lines. The discovery of this important fact was made by Professor C. A. Young of the Princeton University in 1870 while observing the Spanish eclipse of the Sun. He says, (article 319 of his General Astronomy) "The lines of the solar spectrum, which up to the final obscuration of the Sun had remained dark as usual, with the exception of a few belonging to the spectrum of the chromosphere, were suddenly "reversed," and the whole length of the spectrum was filled with brilliant-colored lines which flashed out quickly and then gradually faded away in about two seconds —a most beautiful thing to see. The name, *flash*, probably came from the suddenness of the reversal of the lines, and the use of the word by Professor Young n the description of this singularly beautiful sight.

7. Who is the publisher of Wm. Peck's Constellations?

Answer. About information of the book, Wm. Peck's Constellations, I can say that I bought, a few years ago, of G. P. Putnam's Sons, 27 and 29 West 23 St., N. Y., a copy of the Popular Handbook and Atlas of Astronomy by William Peck, Astronomer, Edinburgh. In the preface to this book Mr. Peck says: "In a condensed form there is presented the author's investigation as to the origin of the constellations, which at some future time he hopes to elaborate in a special work. C. A. H.

The inquiry is probably for William Peck's Constellations, a book which Silver, Burdett & Co., of Boston handle. This is a thin book.

In Mayer and Miller's Catalogue No. 169, No. 1359 is Peck, W. The observers Atlas of the Heavens containing catalogues of the accurate positions, magnitudes, etc., of over 1400 double stars, star clusters or nebulae, etc., London, 1898. Mks 21. This is evidently Peck's larger work. H. A. H.

We do not publish any book called "Constellations" by William Peck. We have, by him, A Popular Handbook and Atlas of Astronomy, designed as a complete guide to a knowledge of the heavenly bodies, and as an aid to those possessing telescopes, containing 44 large plates, and numerous illustrations, diagrams, etc., price $5.50, net. This we can supply, if desired.

G. P. PUTNAM'S SONS.

Memoria Sobre el Eclipse Total de Sol.—The Astronomical Observatory of Madrid, Spain, has issued a pamphlet of 107 pages, for benefit of those who are to observe the total eclipse of May 28. It is provided with beautifully colored charts and suggestions, directions and useful data for the contemplated observations. The pamphlet is a creditable piece of work.

On a Class of Particular Solutions of the Problem of Four Bodies, is the title of an interesting mathematical paper recently published by F. R. Moulton, of the University of Chicago. It is encouraging to see the young men pressing the mathematics into service in the needed astronomicai investigations when astrophysics can do very little.

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All correspondence and all remittances should be sent to

Wm. W. Payne,
Northfield, Minn., U. S. A.

PLATE IX.

The Merope Nebula in the Pleiades.

Crossley Reflector, Lick Observatory.

(Exposure 4 hours.)

Popular Astronomy.

Vol. VIII. No. 5. MAY, 1900. Whole No. 75.

THE TOTAL ECLIPSE OF MAY 28, 1900.

WILLIAM H. PICKERING,

FOR POPULAR ASTRONOMY.

It does not appear to the writer that direct photographs of the solar corona have very much scientific importance. He is inclined to believe that their chief value is an aesthetic one. If well taken, they form attractive souvenirs of what is undoubtedly one of the grandest celestial phenomenon on which the eye of man has ever rested. It is this aesthetic enjoyment attained, which it seems to him will constitute the chief gain of the majority of the expeditions which will view the eclipse this next May.

If photographs are of little value, it may safely be said that drawings are worse than useless, since it is quite impossible during the brief time available during totality to represent, with the least pretentions at accuracy, even a very restricted area of the corona. Meanwhile, the time spent in looking at the paper might much more profitably be expended in watching the eclipse itself. It is therefore recommended to those who visit the eclipse region at their own expense, to spend but little time in attempts at scientific work. Probably the most valuable thing that can be done by the average person, especially if off the central line, is to note the duration of totality. This may best be done with a stop watch, but any watch furnished with a second hand may be used, and an effort should be made to determine the time correctly, within half a second. An accurate description of the location of the station should be prepared as described in the recent publication of the Naval Observatory, and sent to the proper authorities.

For those who are so fortunate as to be within the darkened region, one of the grandest features to be seen will be the on-rush of the Moon's shadow. It approaches with approximately the speed of a cannon ball, and is a very striking phenomenon. Since, however, it comes from the west, while the Sun is in the east, one cannot watch both at the same time, and it is recommended to those who are seeing a total eclipse for the first time to be satisfied with watching the shadow depart at the end of totality, and not miss the flash of the corona at the instant totality comes on.

Each observer should have some aid to the eye-sight, if it is only an opera glass. Great care should be taken not to dazzle the eyes by watching the Sun too long during the partial phase, not only on account of the danger of straining the eye-sight, but also because if the eyes are dazzled the corona will be less well seen. A combination of red and green glasses, or red, green and blue, makes a satisfactory shade for the eyes, and it can hardly be too dark. During totality no shade will be needed.

If a sheet be spread on the ground one may watch the shadow bands which appear for a few seconds before and after totality. They are still sometimes erroneously spoken of as diffraction bands, although, of course, they have really nothing whatever to do with diffraction itself. They are due to atmospheric waves occurring a few thousand feet above the Earth's surface at the contact of two currents of air flowing with different velocities. Their direction and speed are dependent on the wind, and have no connection with the Moon's motion or shadow. We may produce the phenomena at will any cold night, by opening a window near an electric arc light, when the shadow of the rising hot air currents may be seen cast on a sheet of paper.

During totality it is so dark that first and second magnitude stars appear, but stars of the third magnitude are seldom if ever visible to the naked eye. I have never seen it so dark that there was even the slightest difficulty in reading the time from a watch of ordinary size. Those interested in the matter will find various suggestions both for visual and photographic observations given in the Harvard Annals, Vol. XVIII, p. 109.

Although, as remarked at the beginning of this paper, little of scientific value can attach to direct photographs of the corona, still many observers will wish to bring away with them some reminder of their trip, however inadequate it may be to represent the grandeur of the phenomenon witnessed. In order to obtain the best results the following facts should be borne in mind: The diameter of the image of the Moon is about one one-hundredth of the focus of the lens. The brightest part of the corona is about one-fiftieth of the photographic brightness of the full Moon. The faintest part of the corona, which is equal in brightness to that of the surrounding sky, is about the same as that of the sky at evening, when second magnitude stars first become visible. The Moon itself is absolutely black, and no one has as yet succeeded in seeing or photographing any detail upon it.

This blackness of the Moon in comparison with the sky is not a contrast effect, as might at first be supposed, but is a real phenomenon, as is shown by photography. It is not generally recognized, I believe, that it indicates that the general illumination of the heavens surrounding the corona is due to a source of light beyond the Moon. That is to say, this general illumination is not due to the light of the inner corona reflected from our atmosphere, nor yet to the illumination of our atmosphere by the bright regions of the Earth's surface outside of the Moon's shadow, but is due to the reflection of the Sun's light from the countless small bodies revolving about it, and lying chiefly inside of the Earth's orbit.

It has been found at Harvard that upon the average night, when the object is sufficiently brilliant, as in the case of the Moon and brighter stars, better definition is obtained with a photographic telescope of fourteen feet focus when aperture is cut down to 3.5 inches, than with either larger or smaller apertures. During totality the seeing is likely to be worse than during the night at Cambridge, therefore for most purposes we may take three inches as the maximum size desirable for photographic use. It is only with instruments of very long focus that a larger size is necessary, and we are then liable to secure inferior definition, together with a lack of contrast on account of the large scale employed.

Nearly all the detail of the corona lies in a radial rather than a tangential direction. The brightness of the corona varies rapidly radially, but only slightly at right angles to this direction. Therefore, if we wish to bring out the radial structure, we must use a plate giving great contrast, but in so doing we limit ourselves to a zone of small breadth surrounding the Moon. Inside of this zone the corona is over exposed, outside of it the corona is under exposed. On the other hand, if we use a plate having great range but little contrast, the whole corona may be shown upon it properly exposed, but little detail will be seen in any portion of its area. Efforts have been made to overcome this difficulty by shutters especially devised to vary the exposure in different portions of the field. In any case the photographer is advised to use a plate giving great contrast, which is equivalent to using a very slow plate, such for instance as is used for lantern slides and process work.

With an ordinary telescope, whose focus is sixteen times its aperture, an exposure of two seconds will give a very satisfactory picture of the inner corona. If one is provided with a mounting driven by clock work the longer the focus the better. If no clockwork is employed, and the focus is as much as four feet, the exposure should not exceed one second, or the trailing of the image will become apparent. For the best results in photographing the outer corona a slow plate is imperative. With a doublet whose focus is six times its aperture, an exposure of ten seconds is about right. One must not make the mistake of giving too long an exposure, or the plate will be over-exposed, and little contrast secured. It is probable that the outermost regions of the corona that we can observe can best be photographed with a lens of only a few inches focus. Thus, in 1886, with a lens of eight and a half inches focus, the corona was traced for 90′ from the Moon's limb, although all distinct detail ceased at a distance of 60′ (Harvard Annals, Vol. XVIII, p. 108). This is believed to be the greatest extent of corona shown by photography up to that time, and it has only recently been exceeded by photographs taken during the Indian eclipse of 1898, when a similar lens was used. All the plates should be backed with suitable varnish to prevent reflection from the rear of the plate. A water color backing is of no use, since the index of refraction of the drying medium must equal that of the glass.

HARVARD OBSERVATORY, Cambridge, Mass.,
March 26, 1900.

S. W. BURNHAM'S NEW DOUBLE-STAR CATALOGUE.* A REVIEW.

R. G. AITKEN.

FOR POPULAR ASTRONOMY.

"A general catalogue of all the double stars discovered by me from time to time during the past twenty-five years has long been needed by those interested in this field of astronomical research, and by reason of the special interest attached to many of these remote sidereal systems, it has become more and more important to bring the scattered material together in order to intelligently pursue the investigations which promise to so much increase our knowledge of the great universe beyond the solar system." These words, taken from Mr. Burnham's introduction, give the raison d' être of the work ot which, at the request of the editor of POPULAR ASTRONOMY, I am glad to write this review.

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* [Publications of the Yerkes Observatory, Volume I, 1900. A General Catalogue of 1290 Double Stars discovered from 1871 to 1899 by S. W. Burnham. Arranged in order of Right Ascension with all the micrometrical measures of each pair, by S. W. Burnham, Chicago. The University of Chicago Press, 1900.

The merit of the volume from the mechanical stand-point will appeal to all who are interested in good book-making. The large open quarto page is well adapted to such a work, and the clear type, the wide margins and the almost complete absence of typographical errors combine to make it attractive to the eye. An excellent view of the Yerkes Observatory forms a fitting frontispiece, and the introduction is illustrated by good engravings of the great 40-inch refractor of that Observatory and of the three telescopes with which the greater part of Mr. Burnham's work has been done—the famous 6-inch refractor, the 18½-inch of the Dearborn Observatory and the 36-inch of the Lick Observatory.

In this introduction, Mr. Burnham gives an account of the beginning of his astronomical work, which will be of interest to many who may not see his volume. "When in London," he says, "about 1861, I purchased one of the cheap astronomical telescopes introduced about that time. It had a nominal aperture of three inches, but was without a finder, and had only the simple alt-azimuth mounting with a common table tripod. It was supplied with a terrestrial, as well as astronomical, eyepiece and while it was a good instrument for landscape use, it was of little value for astronomical purposes. Some years later I obtained a 3¾-inch telescope, with an English object-glass, mounted equatorially by Fitz on a portable stand. This was just good enough to be of some use, and poor enough, so far as its optical power was concerned, to make something better more desirable than ever. In 1869 I accidentally met Mr. Alvan G. Clark in Chicago . . . . . and made some inquiries of him about a small equatorial. This interview resulted in my ordering from the celebrated firm of Alvan Clark and Sons an equatorial of six inches aperture. I told them what I wanted and what I wanted it for. Every detail was left entirely to their judgment, stipulating only that its definition should be as perfect as they could make it, and it should do on double stars all that it was possible for any instrument of that aperture to do. In due course of time this instrument was delivered, and was set up in an observatory prepared for it in the mean time. My attention for some reason or other, which I am unable to explain, had been almost exclusively directed to double stars previous to this while using the smaller telescopes referred to. This preference was not in any sense a matter of judgment as to the most desirable or profitable department of astronomical work, or the result of any special deliberation upon the subject. It came about naturally, without any effort or direction upon my part."

With this instrumental equipment and an astronomical library consisting principally of the first edition of Webb's Celestial Objects for Common Telescopes, Mr. Burnham began his work. His first new double star (β 40) was found on April 27, 1870. By correspondence with other observers, both amateur and professional, by queries in the columns of the *English Mechanic*, but principally by the laborious process of *copying the lists of double stars* from various publications loaned him by different astronomers, he managed to increase his knowledge of the work of previous discoverers in this field to such an extent that in 1873 he was able to publish a catalogue of 81 double stars which he confidently believed to be new.

This modest little list of stars found by an amateur with a six-inch telescope, forms a striking contrast to the present volume, issued as the first publication of a great Observatory, with its 1290 stars, and its summary of thousands of measures, the work of many of the best observers and most powerful telescopes of modern times. Yet the early publication contained the promise and potency of the larger work, for an analysis of its 81 stars shows that 40 of them are separated by distances of 2″ or less—4 of them being well under 1″—and that 9 are naked eye stars. Thus two characteristics of the β stars were at once manifest. The third characteristic of all of Mr. Burnham's catalogues, also holds for this first one, for at least 15 of the 81 stars have now given evidence of being physical systems.

It is a matter for congratulation that Mr. Burnham refused to be discouraged by the belief which seems to have been general amongst astronomers in 1870, that the field of double-star discovery had been exhausted by the Herschels and Struves. Even so well informed a man as the Rev. T. W. Webb, writing in 1873, after the first three catalogues of β stars had been published, said: "It will hardly be possible for you to go on for any great length of time as you have begun, because the number of such objects is not interminable, and every fresh discovery is one less to be made. Still, what you have already done is so much more than any man now living has accomplished, that your high position as an observer is fully secured." After quoting this passage Mr. Burnham remarks: "Since that time more than one thousand new double stars have been added to my own catalogues, and the prospect of future discoveries is as promising and encouraging as when the first star was found with the six-inch telescope."

It is not my purpose to enter into the detailed history of Mr.

Burnham's labors in this field. As is well known, he continued his work of discovery with the six-inch glass, and such larger instruments as became available, until he had published 19 separate catalogues, containing 1274 objects. While preparing the present volume he added 8 pairs found with the 40-inch telescope and recovered 8 others, previously overlooked, from his old observing books. This brings the total to 1290; but 13 stars were later found to be identical with previously known pairs, and their numbers, with the number 444, accidentally omitted, do not appear in the General Catalogue. One thousand, two hundred and seventy-six pairs are therefore given; 133 of these consist of additions of closer or more difficult components to previously known double stars, and 291, nearly one-fourth of the whole, are bright enough to be visible to the naked eye.

The arrangement of these stars in the General Catalogue leaves nothing to be desired. They are given in the order of right ascension (for 1880.0) with all the measures of each pair to the end of the year 1899. The measures are mean results, giving the date, the position-angle, the distance, the observer, and the number of nights on which complete measures were made—"in many instances the angle has been measured on a greater number of nights than that given here." A sufficient number of the estimates of relative magnitude made by different observers is given to fix this quantity with all necessary accuracy. The notes to each pair state the telescope with which it was found, the character of the relative motion, if any, the amount and direction of the proper motion of the primary from meridian observations, if it has been determined, and in the cases of the more interesting stars, a more complete discussion, with the data of orbits, when such have been computed, and other information of value to the observer or computer. In this connection diagrams are freely used. Finally, a complete reference list of the original publications of measures is appended to each star.

But one who reads the book carefully cannot fail to notice Mr. Burnham's moderation in the way of descriptive writing, and his economy in the use of adjectives, especially of those in the superlative degree. One notes these facts with a distinct sense of pleasure, for what is wanted in a work of this kind is the description and history of each star as complete as possible, but in compact form.

In his Introduction, Mr. Burnham shows that all the leading double star catalogues prior to 1870 contained only 680 stars with distances not exceeding 2″. His own discoveries have added not less than 690 to this class. If we extend the comparison to some more recent catalogues, we shall find that 248 of Hough's 622 stars, and 162 of See's 500 have measured distances of 2″ or less. Neither catalogue will compare with Burnham's in the proportion of close pairs. We cannot speak with certainty of Innes' stars for hardly any of them have been measured, but apparently about 200 of the 300 pairs fall into this category. If we assume 300 other pairs—a very liberal estimate—of this class as the contribution of all other observers to the present time, the β stars still give us 30 per cent of all known close double stars.

The significance of this statement—aside from its testimony to the keen observing powers of their discoverer—lies in the fact that the class of close double stars yields by far the greater proportion of physical systems, and practically all the binary stars of short period. In the present state of our knowledge, the period of revolution of a double star, in its most interesting and most important feature, and the shorter the period, the higher the interest. Some hundreds or thousands of years hence, when the accumulated observations of generations of astronomers have furnished sufficient data for the determination of a large number of orbits, greater interest may attach to other elements—the eccentricity, for instance. But even so, it is obvious that the stars in rapid motion will yield the necessary observations in the shortest time; and the great importance of the β stars is due to the fact that many of them are already recognized as binaries of very short period, and that many others give evidence of being in rapid motion.

Mr. Burnham lists 185 pairs (about 14 per cent of all the β stars) that have so far given more or less evidence of being physical systems. He warns us that this list is only provisional. In some cases the relative motion is too small to make the nature of the change certain; many other stars have been observed at but two epochs, separated in some instances by only 5 or 6 years; and about 40 pairs have not been re-measured since discovery. 16 of the last named number are the late additions, and a few others may ultimately prove to be single. How many binaries may later be added from these three classes it is of course impossible to say. An examination of the 185 pairs at present enumerated as physical systems, shows that 41 of them are included largely on the ground of possessing a common proper motion, though there is also slow relative change. These pairs are all at least moderately close—several of them very close. 52 other pairs are relatively fixed, but possess a common proper motion. Only seven of these are as wide as 10″, and 33 of them are closer than 5″. For all the pairs under—say 5″—a common proper motion is sufficient evidence of physical connection through an attracting force similar to, if not identical with, that of gravitation. When the angular separation of the two stars is great, we cannot speak so confidently, but even then the best we can do is note the pair as *probably* a physical system, leaving definitive classification to the future.*

No one will question the correctness of Mr. Burnham's classification of the stars just mentioned except perhaps in a few instances where the amount of the proper motion is very small—as for example β 63 and β 1090. But the other stars, those that show decided relative change are of far greater interest. Some of these also possess common proper motion and in but few cases is the orbital nature of the motion in doubt. In at least 27 of these pairs, the motion has been so rapid that the period of revolution is almost certainly less than 50 years; and there are fully a dozen more very interesting systems with moderately short periods. The observations of the next few years will in all probability considerably increase the numbers in both of these classes.

A review of all the double stars for which orbits with periods of less than 50 years have been computed, shows that the great Σ catalogue has contributed five—only one of which, Σ1728, has a period of less than 30 years. The *O* Σ lists add two—*O* Σ 269 (49 years), and the remarkable system of δ Equulei, which needs only 11.5 years for a revolution; and the discoveries of Alvan Clark and Alvan G. Clark, three more (adopting Zwiers' period for Sirius), all with periods over 30 years. The 19 year period star ζ Sagittarii, discovered by Winlock, brings the total number of short-period binaries, exclusive of the β stars, to eleven, only three of which complete a revolution in less than 30 years. It is probable that Procyon, 95 ceti, and ε Hydrae *AB*, discovered respectively by Schaeberle, Alvan Clark and Schiaparelli, will later be added to this number.

Turning now to the β stars, we find κ Pegasi (11.42 years), the most rapid binary whose period is accurately known, five pairs with periods between 15 and 30 years, and two more with periods under 40 years. For these stars orbits have been compu-

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[* In this connection see Burnham's article "The Binary Systems" in POPULAR ASTRONOMY No. 34.]

ted. We have also β 555 and β 639, which are certainly very rapid, and many other systems (*e. g.* β 552, β 648, β 962, β 1077, etc.), whose periods will prove to be short.

Mr. Burnham's opinion of the value of double star orbits based on short arcs is well known, and it is therefore not surprising to find that he has computed but two orbits for his General Catalogue. For β Delphini (β 151) he finds a period of 26.70 years—a year shorter than that assigned to it by See—and for 85 Pegasi (β 733) a period of 25.7, which is 1.7 years longer than the one given by See. The other elements also vary somewhat from See's, the semi-major axis and inclination of both orbits being considerably smaller. Of β 416, for which five orbits, with periods ranging from 25 to 35 years, have been computed, Mr. Burnham says: "While the general form of the apparent orbit is fairly well indicated, an investigation of this time could give only a provisional value. A revolution will soon be completed, and then a reliable determination of the elements can be made."

This conservatism also prevents him from making any more definite statements with regard to such stars as β 524 and β 612 than that orbits have been computed, but are uncertain; that the motion is rapid, and that the measures of the next few years will probably furnish data for reliable conclusions.

Of β 395, Mr. Burnham writes: "See, using the measures to 1897.67, has computed the orbit and found a period of 16.3 years (*A. N.* 3455). This assumes a change of about 180° between 1891 and 1897. From the slow motion in angle and distance between the date of discovery and the last measure in 1891, it seems very probable that in all the observations the companion star should be put in the same quadrant. . . . . There is no question of the binary character of this pair, but if the change has been in a gradual approach of the two components, as seems most likely, the period will not be a short one." And of β 883, for which Glasenapp has found a period of 16.88 years, and See one of 5.5 years, he writes (Appendix, p. 293): "A recent examination of all the measures of this star leads to the conclusion that the most probable period is about seventeen years. It is certain that the measures of 1891.97 to 1899.78 are properly adjusted as to quadrants, and that the angular motion in 7.8 years is only 110°.

All these matters are questions to be settled by the observer, and answers should be forthcoming in a very few years. Meanwhile, the most satisfactory attitude, and, in my opinion, the one most conducive to real progress, is the conservative one which Mr. Burnham takes.

I cannot close this review without calling attention to a matter that does not strictly relate to the β stars:

It has long been known to double star observers that Mr. Burnham is in possession of more extensive and more accurate knowledge of the bibliography of double star astronomy than any other man living; and that he has used his knowledge in compiling a complete catalogue of all double star discoveries and measures. In the introduction to his present volume he refers to this, saying that the catalogue, which is arranged in proper form for printing, "has all the time been kept posted to date, by the addition of all new material as soon as printed, and many unpublished discoveries and observations." He adds: "Whether it will ever assume other than the present manuscript form remains to be seen."

The publication of such a catalogue would do for all double stars what his present volume does for the β stars. Nothing else could do so much to stimulate research and to direct observers to fruitful fields of labor. It appears to me to be the most urgent need of double star astronomy today, and I am confident that I voice the sentiment of double star observers everywhere in expressing the hope that the means may soon become available to put this work—the result of years of patient labor, into the permanent form now assumed by the General Catalogue of the β Stars.

LICK OBSERVATORY, University of California.
March 6, 1900.

THE LATE CATHERINE WOLFE BRUCE.

W. W. PAYNE.

It is no easy thing to choose fitting words to refer to the close of any life on Earth, much more is it difficult to offer a right and worthy tribute to the memory of one like Miss Catherine Wolfe Bruce, who, for noble cause, the world of science has learned to love for what she was and for what she did.

In what follows it is plain that her intelligent generosity knew no limits of race or country, and so science the world over mourns a common loss. Her kind and thoughtful care lightened many a burden in her own land, awakened new zeal in needful research, and helped to finish many a task when patience and other resources were nearly gone.

Too much will not be said in honor of such gentle and unpretentious worth; for, of such kind is greatness that lives on in unfailing strength and beauty, through the finite and changeful here into the blessed real and eternal yonder.

Miss Bruce was born Janury 22, 1816. Her home was No. 810 Fifth avenue, New York City, at which she was during her last long illness. She passed away March 13, 1900.

We are indebted to a friend for a brief notice of the sad news which appeared in a recent issue of the New York *Tribune*, as follows:

"Miss Catherine Wolfe Bruce deserves more than the ordinary obituary record, for she was a woman of the highest character, of many and varied accomplishments, and had contributed nobly of her means to the cause of charity, of education and of science. The George Bruce Free Library she built, established and endowed, and it is today one of the most flourishing branches of the free library system. Her benefactions to the cause of astronomy are known all over the world, and her name is identified with many important advances in that science. She corresponded with eminent professors here and in Europe, and was the recipient of distinguished honors for her interest and service. A gold medal was presented to her by the Grand Duke of Baden, and she enjoyed the signal distinction of having her name given to a newly discovered asteroid.* Upward of $200,000 has been her contribution to the science she loved. Her charitable gifts and those of private benevolence need not be mentioned here.

"Miss Bruce was the daughter of George Bruce, the famous type-founder, whose work has stood the test of time and change, and is still in use at the present day. Naturally, Miss Bruce was interested in the art of printing—that 'art preservative of all arts,' as she was fond of quoting. It has been said that Miss Bruce was an accomplished woman. She had made a study of painting, and was a painter herself. She knew Latin, German, French and Italian, and was familiar with the literature of those languages. She wrote and published in 1890 a translation of the Dies Aræ. For many years she was an invalid, and deprived of that society which her talents and character well fitted her to adorn. She was always patient and uncomplaining, and entirely resigned to the will of the Almighty Disposer of Events. She has left a gracious memory of good and generous deeds and an impressive example of noble womanhood."

In answer to our request a personal friend has favored us with a list of the generous benefactions made by Miss Bruce to advance the interests of astronomy. It is a pleasure to publish the entire list:

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* No. 323.

GIFTS TO ASTRONOMY.

June 19, 1889	—Harvard College, on account	$ 25,000
July 29, 1889	—Harvard College, in full	25,000
Sept. 25, 1890	—Professor Hirsch, Neuchatel Inter. Geodetic Association,	500
Oct. 1, “	—Professor W. W. Payne, Carleton Observatory	250
“ 6, “	—Professor Simon Newcomb, Washington Nautical Almanac	500
“ 9, “	—Dr. Ludwick Struve	500
“ 9, “	—Dr. David Gill, Cape Good Hope	500
“ 9, “	—Professor J. C. Adams, London	500
“ 9, “	—H. H. Turner, Oxford	500
“ 13, “	—Henry A. Rowland, Baltimore	500
“ 13, “	—Professor E. S. Holden, Lick	500
“ 25, “	—Professor J. J. Astrand, Norway	150
“ 25, “	—Dr. J. Plassmann, Warrendorf, Germany	100
“ 25, “	—Professor H. Bruns, Leipsic, Germany	500
Nov. 7, “	—Professor A. Safârik, Prague	450
“ 7, “	—Professor Lewis Swift, Warner Observatory, Rochester,	50
“ 9, 1891	—Harvard College.	500
June 1, 1892	—Dudley Observatory, Albany, Professor Lewis Boss	25,000
Oct. 10, 1893	—Dudley Observatory, Albany, Professor Lewis Boss	10,000
Ap’l 17, 1894	—Professor Max Wolf, Heidelberg	10,000
May 3, 1895	—Chamberlin Observatory, H. A. Howe	1,000
“ 15, “	—Edw. S. Holden, Lick	500
Sept. 13, “	—E. E. Barnard, Lick Observatory	500
Nov. 22, “	—George E. Hale, Astrophysical Journal	1,000
Mar. 19, 1896	—Professor L. Weinck, Prague	300
June 8, “	—Mary W. Whitney, Vassar Observatory	350
“ 23, “	—Leo Brenner, Manora Observatory, Lussinpiccola, Istria,	1,650
July 28, “	—Edw. S. Holden	1,000
Dec. 7, “	—Vassar College, Maria Mitchel Memorial	1,000
Feb. 2, 1897	—Professor L. Weinck, Prague Royal Observatory	1,000
Ap’l 16, “	—H. A. Howe, Astronomical purposes Chamberlin University, Denver	2,600
May 17, “	—J. K. Rees, Columbia University (publication)	1,500
July 22, “	—E. E. Barnard, Yerkes Observatory, Photo-Telescope	5,500
“ 22, “	—E. E. Barnard, Observatory	1,500
“ 26, “	—Edw. C. Pickering, for printing J. G. Hagen’s charts of Variable Stars, in five series, Georgetown College Observatory, D. C.	1,750
Sept. 2, “	—F. R. Ziel, Secretary and Treasurer Astronomical Society of the Pacific Ednowment Bruce Medal	2,750
Nov. 26, “	—Professor Rees, Columbia University, to pay salary of computors for one year	1,600
Jan. 4, 1898	—Professor Dr. L. Weinck	500
Mar. 4, “	—E. E. Barnard, publication Double Stars	1,500
May 31, “	—Herman S Davis, Reduction Piazzi’s Observations	575
June 7, “	—Columbia University, salary Dr. Hill, Celestial Mechanics, for five years	5,000
“ 24, “	—Yerkes Observatory, salary Professor Frost, Astrophysics, five years	15,000
Aug. 19, “	—Astronomical Clock for J. G. Hagen (remitted Professor Pickering)	500
Sept. 28, “	—H. A. Howe, salary for one year	2,000
Oct. 13, “	—J. K. Rees, Telescope Hellsingfors Observatory	2,500
“ 13, “	—J. K. Rees, to pay salary of computors for one year	1,500
“ 13, “	—Herman S. Davis, Reduction of Piazzi’s Observations	600
Dec. 19, “	—Simon Newcomb, salaries Computors Ultra Neptunian Planet	600
Mar. 17, 1899	—Publication of Father Hagen’s Chart (Remitted Professor Pickering)	1,400
Ap’l 5, “	—J. K. Rees, Columbia College, for measurement and discussion of Astronomical Photographs	10,000

Sept. 8,	"	—George E. Hale, for Spectograph for Yerkes Observatory,	2,300
" 14,	"	—H. A. Howe, salary for one year	2,000
" 27,	"	—William R. Brooks, manufacturing Astronomical Instruments	300
Nov. 29,	"	—Beloit College, Department Astronomy	1,500
			$174,275

A NOTE ON A SUPPOSED EARLY CONJUNCTION OF PLANETS.

W. H. S. MONCK.

FOR POPULAR ASTRONOMY.

The late Mr. John Williams, in his *Observations of Comets*, (extracted from the Chinese Annals), published in 1871, gives some interesting details as regards early Chinese Astronomy which he had carefully studied. One of these relates to the conjunction of planets to which I refer.

"In the Chinese Annals it is recorded that in the reign of Chuen Kuh, the grandson of Hwang Te, in the spring of the year, on the first day of the first Moon, a conjunction of five planets occurred in the heavens in Ying Shih. Zing Shih, or as it is more usually denominated Shih, is one of the 28 stellar divisions, determined by α, β and other stars in Pegasus, extending north and south from Cygnus to Piscis, Australis, and east and west 17 degrees, and compasing part of our signs Capricornus and Acquarius. The Emperor, Chuen Kuh, is said to have reigned 78 years, from B. C 2513-2436, and to have died in his 97th year; and from modern computations (I believe by Bailly, the French astronomer), it has been asserted that a conjunction of the five planets actually did take place about the time and within the limits indicated, *i. e.* on the 29th of Februry, 2449 B. C., being the 65th year of Chuen Kuh. Should this on further investigation prove correct, it will afford a strong presumption of the authenticity of the early Chinese annals, as there is no appearance of these astronomers having been at any time able to compute the places of planets so far back; and the account is to be found in works published long before any intercourse with Europeans had taken place."

The length of Chuen Kuh's reign is a little startling, and leaves a good deal of scope for such a conjuction, and if really observed, it seems strange that the first comet in Mr. Williams' catalogue should be in B. C. 611, or more than 1800 years after the conjunction of planets had been observed. But, turning to a well known work on the subject, Mr. G. F. Chambers' *Handbook of Astrono-*

my, I find (Vol. I. pp. 70-1) that he speaks of the conjunction as one of Mars, Jupiter, Saturn and Mercury, and says that Desvignoles and Kirch computed that such a conjunction actually did take place on February 18th B. C. 2446, between 10° and 18° of Pisces. Williams, however, though he may have made a slip in the date, when citing Bailly from memory, is very unlikely to have misrepresented the Chinese annals as stating that there was a conjunction of the five planets if only four were mentioned (and these four, it would seem, specified if Chambers be correct). Chambers consulted both Bailly and the original memoirs of the two computers in question. He goes on, however, to mention a third computer, de Mailla, who places the same four planets together with the Moon in conjunction between 15° and 27° Pisces on the the 9th of February, B. C. 2441. But the Chinese observers would hardly have described the Moon as a fifth planet, and it will be noticed that Venus, the brightest of all the planets is represented as being on both occasions conspicuous by her absence. But three conjunctions of the remaining four planets in February, 2441 B. C., 2446 B. C. and 2449 B. C., in the same part of the sky are, I apprehend, simply impossible. If one of these conjunctions took place the other two did not. Even if a conjunction of four planets would satisfy the Chinese record, can we rely on its occurrence, when three computers give us three inconsistent dates?

But some other dates given by Mr. Williams are rather startling. The system of reckoning by cycles of 60 years was introduced, he states, by the Emperor Hwang Te, who reigned for 100 years, from 2698 B. C., to 2598 B.C. Chuen Kuh was his grandson. The time that elapsed between the accession of the grandfather and grandson was just 185 years, after which it will be recollected the latter reigned for 78 years, making 262 or 263 years from his grandfather's accession to his death. Mr. Williams does not give any particulars as to Chuen Kuh's immediate successor, but it seems that the Emperor Zaou, also reigned for 100 years, from 2356 B. C. to 2256 B. C. I presume the length of Zaou's reign was taken into consideration in computing the time when Chuen Kuh lived. The impartial reader will, I think, entertain a very strong suspicion that the whole of this historical chronology is fabulous; that very probably there never was any such Emperor as Chuen Kuh; that if he really existed, the date of his reign is extremely uncertain; and consequently that the conjunction of planets was not recorded by any observer, but arrived at by computing backwards, in the very same way that the European astronomers of the 18th century arrived at a similar result.

The Chinese astronomers also computed a conjunction for some date between 2513 B. C. and 2436 B. C., and then following the current but fabulous history, ascribed it to the reign of Chuen Kuh. The problem was probably suggested by an observed conjunction of three or four planets in this region of the sky. A rough computation would enable an astronomer to calculate the dates when the same planets had come together in the same part of the sky during past ages, and then the question was, at which of these dates were the remaining planets, or one of them, also to be found in same constellation? This was computed, but very probably computed erroneously. Such I believe was the history of this conjunction.

THE TOTAL SOLAR ECLIPSE, MAY 28, 1900.

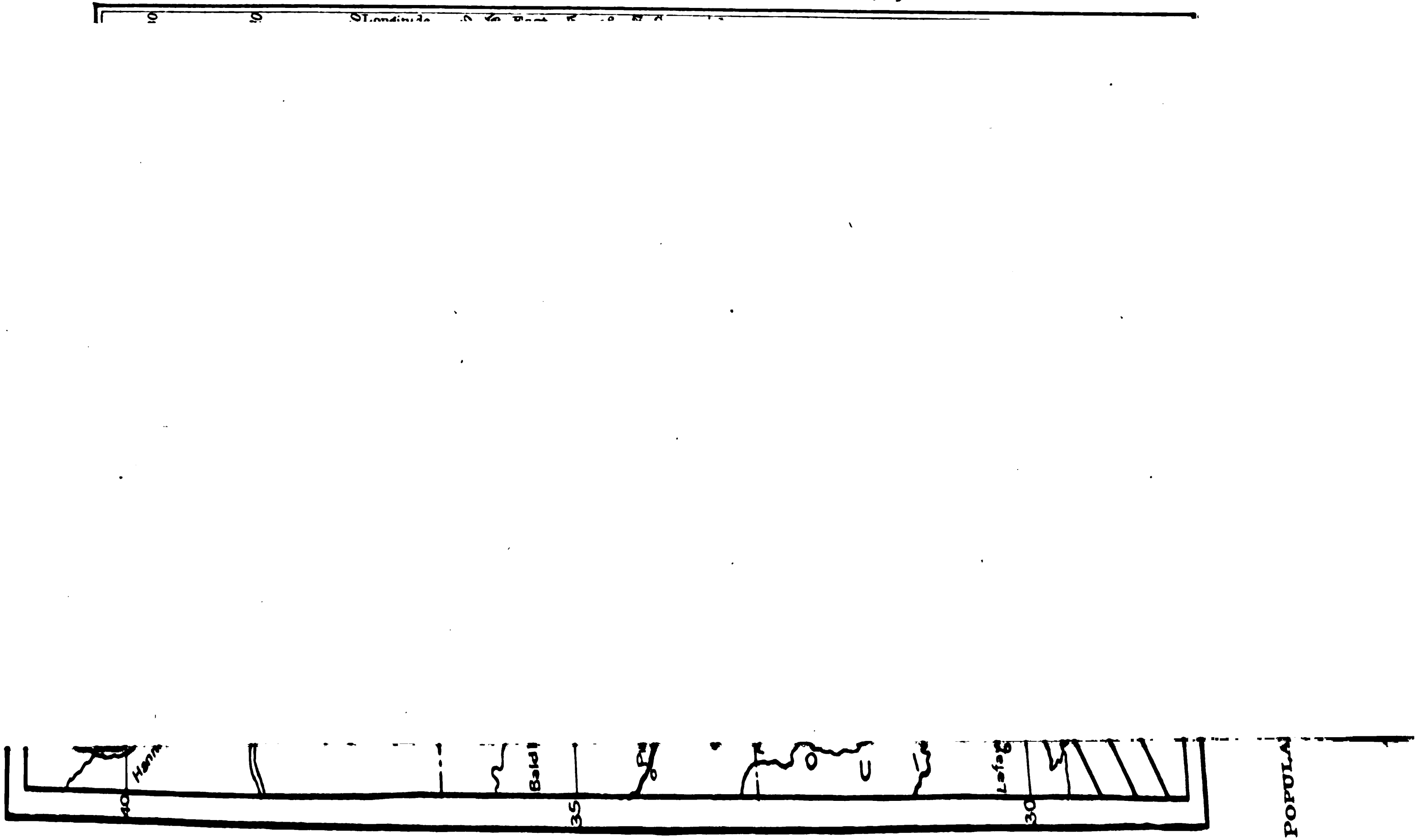
H. C. WILSON.

The great astronomical event of the year, at least so far as can be predicted, is to be the total eclipse of May 28, which will be visible in accessible regions, both in America and Europe.

In Europe the path of totality passes across Spain and Portugal, touching a number of easily accessible cities. It also crosses the northern coast of Africa, the two large cities, Algiers and Tripoli, lying near the central line. Many European expeditions will occupy stations along this portion of the path of the Moon's shadow. The eclipse committee of the British Astronomical Association have undertaken a steamer excursion to Spain and Algeria. The steamer proposed will carry 189 passengers, and the cost to one making the entire trip to Algiers and remaining on board during the stay is to be 22*l.* 10*s.* At latest reports, the war in South Africa makes it somewhat doubtful whether the requisite number of persons will go to make the excursion a success.

In the United States, as may be seen from the accompanying charts, the path of totality crosses the southern states from New Orleans, La., to Norfolk, Va. It is crossed by railroads at many points, and the great railroad centers of the various states, New Orleans, La., Mobile and Montgomery, Ala., Atlanta, Macon and Augusta, Ga., Columbia, S. C., and Raleigh, N. C., lie either within or near the course of the shadow. The investigations of the Weather Bureau (see POPULAR ASTRONOMY Nov. 1899) point to stations in Alabama and Georgia as the most likely to be free from

CHART I.—TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.



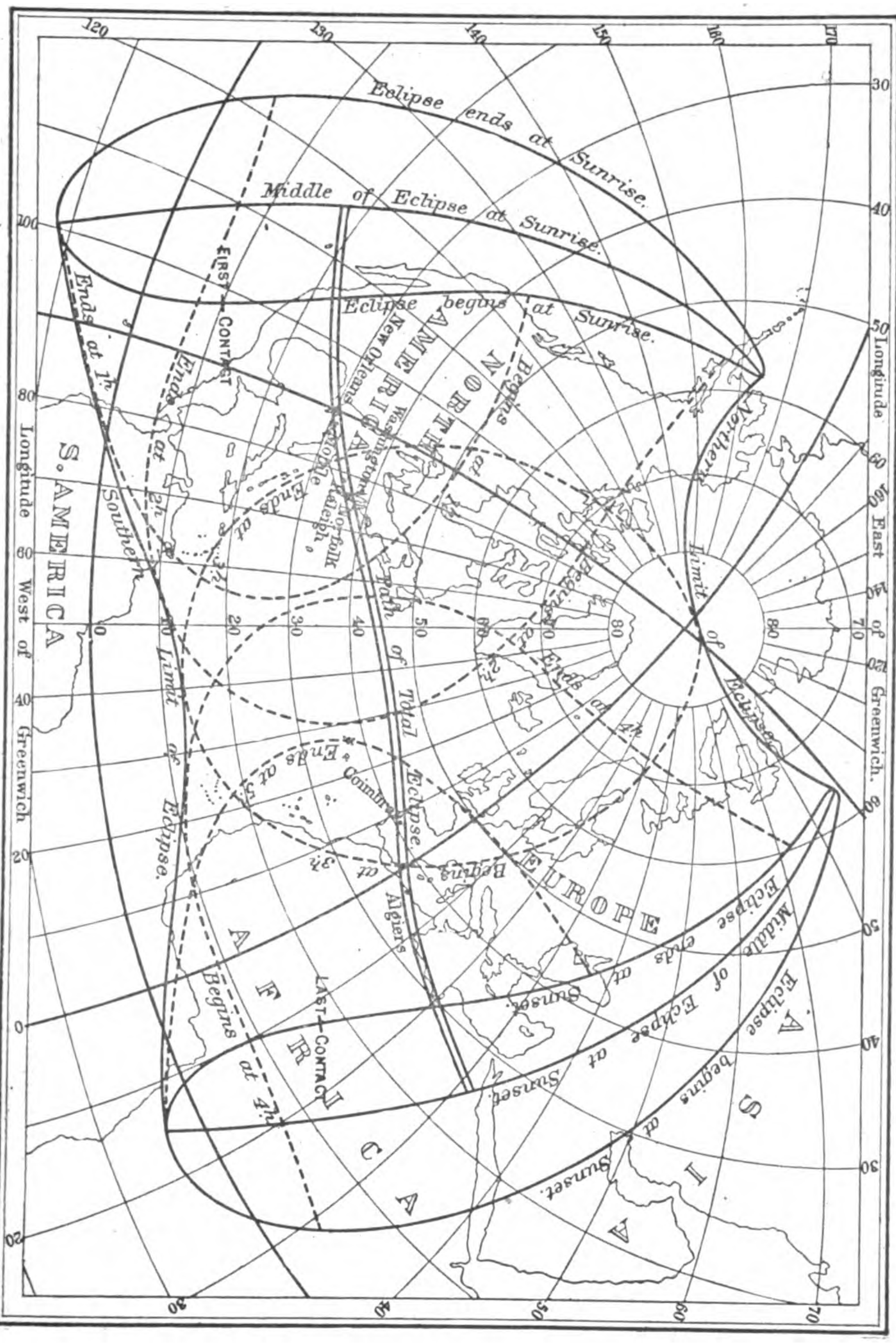


CHART I.—TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.

NOTE.—The hours of beginning and ending are expressed in Greenwich Mean Time.

clouds, so that doubtless most scientific parties from a distance will endeavor to locate in those states. There will be, however, many local parties all along the line, who will witness the wonderful phenomena of the total eclipse and try to collect data for the scientific study of the mystery of the Sun's surroundings.

A few will go to Mexico, where the path of totality crosses four lines of railway, about 170 miles north of Zacatecas, 100 miles south of Saltillo, 100 miles south-east of Monterey and on the Texan border about 100 miles north-west of Matamoras. Here, however, the eclipse will occur early in the morning, totality coming between six and seven o'clock A. M., and lasting less than a minute.

At New Orleans the eclipse begins at 6:25 A. M., is total at 7^h 30^m and ends at ends at 8^h 43^m A. M. Totality lasts 1^m 12^s. As the 6^h meridian from Greenwich passes through New Orleans, local and standard time there agree.

On the Atlantic coast, near Norfolk, Va., the eclipse will begin at 7^h 37^m, will be total at 8^h 49^m, totality lasting 1^m 40^s, and will end at 10^h 11^m A. M., local time.

From these statements one can easily judge of the altitude of the Sun at the intermediate stations, and of the conditions under which the eclipse may be observed, barring bad weather.

Chart No. 1, accompanying this paper, shows that the eclipse will be partial over nearly the whole of North America, a little of South America, the whole of Europe, the northern part of Africa and a little of the western part of Asia. Observers who are unable to go to the path of the total eclipse, although missing the grand spectacle of the corona, will yet be able to witness the partial covering of the Sun by the dark Moon, and may contribute something useful to science by noting the exact moments of the beginning and end of the eclipse. It will be necessary for this that the latitude and longitude of the place of observation be carefully determined, and that the errors of the time pieces used be found within a quarter of a second. The time is telegraphed each day. from the U. S. Naval Observatory, over the Western Union telegraph lines, and on that day the signals will doubtless be more than usually correct. Observers may thus find the errors of their time pieces by carrying them to the nearest railway station and comparing them with the clock at Washington.

Chart No. 2 (reprinted from Professsr Bigelow's paper, POPULAR ASTRONOMY, Nov. 1899), shows the path of totality across the United States, and most of the stations along the path.

According to the larger map issued more recently by the U. S.

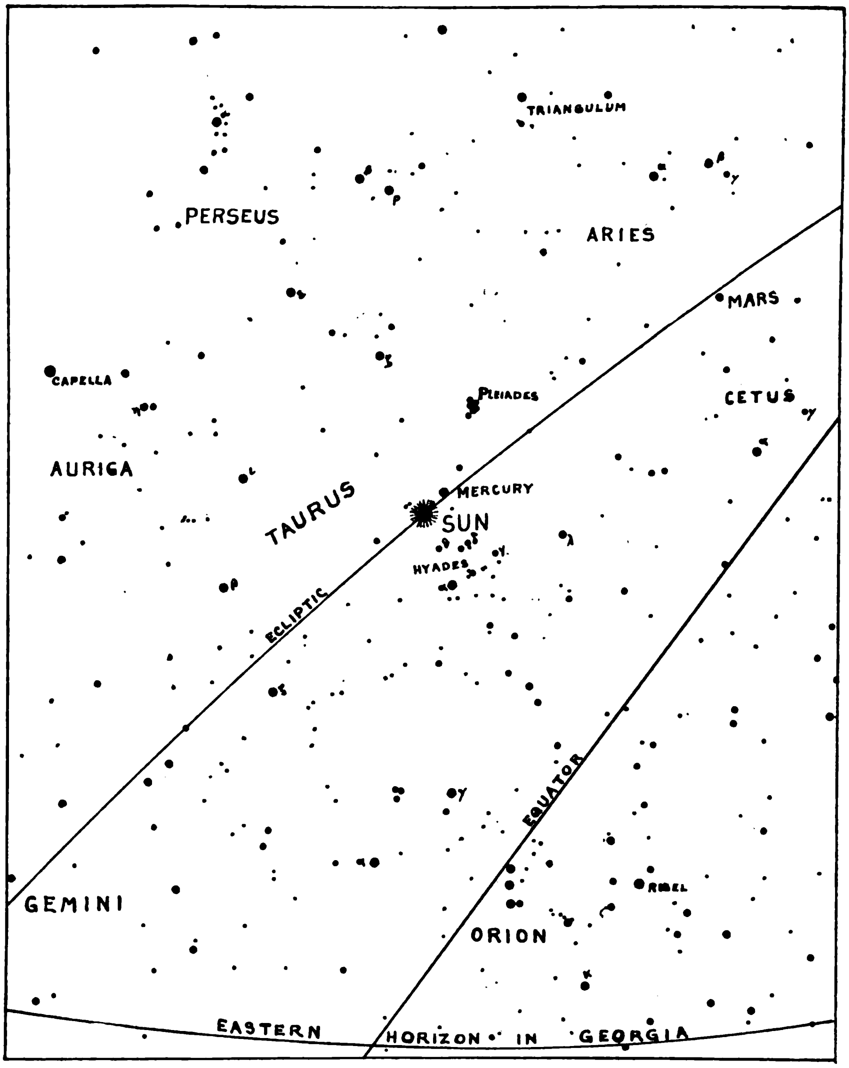


CHART III.—THE STARS IN THE VICINITY OF THE SUN, MAY 28, 1900.

Naval Observatory, this chart is not quite exact, the center line of the path of total eclipse being drawn approximately five miles too far south at New Orleans, and about the same distance too far north near Norfolk.

Chart No. 3 shows the position of the Sun among the stars at the time of the eclipse. The line at the bottom of the chart represents the eastern horizon as seen in Georgia, about the middle of the path across the United States, longitude 83°, latitude 33° 30′, the Sun's altitude there being about 40° at the time of totality. The faintest stars given on the chart are of the fifth magnitude, but it is probable that these will not be visible to the naked eye. It is doubtful whether the darkness during this short totality will be sufficient to render anything fainter than the third magnitude visible. Mercury may be seen a little way above the Sun, and Mars also, well up toward the meridian. The Hyades and Pleiades, the nearest groups of stars to the Sun, may possibly be recognized, but are more likely to be overpowered by the brilliancy of the corona.

The eclipse supplement to the American Ephemeris, 1900, contains many admirable suggestions to observers of the eclipse under the headings: 1. Sketches of the corona with the naked eye. 2. The Moon's shadow bands. 3. Photographs of the corona. 4. Observations of the times of the contacts.

As the suggestions under the first two heads can be followed by many persons with the slightest of equipment, we give them here, taking issue with Professor W. H. Pickering (See page 225), on the usefulness of this kind of work. Good photographs of the corona will always have great scientific value, for only by these can the intricate details of the coronal structure be accurately depicted, and thus its laws of formation and change be studied. Photography, however, fails in some respects and needs to be supplemented by careful eye observations and drawings.

I.—SKETCHES OF THE CORONA WITH THE NAKED EYE.

The duration of totality will be short, varying from 1^m 12^s in the neighborhood of New Orleans to 1^m 40^s near Norfolk. Preliminary preparations therefore should be carefully made, and the necessary skill and quickness acquired by practice on artificial models. Those who expect to make a sketch of the corona unaided will have to confine their attention to sketching the outlines or to some other particular feature, otherwise there will result hasty and inaccurate work. Co-operation of groups of from two to five sketchers, as practiced in the last eclipse in India, 1898, is strongly commended by the successful drawings then made.

In any case, whether sketching singly or in co-operation with others, there should be prepared a diagram to form the basis of the drawing of the corona. A sheet of paper of convenient size, about 9 by 12 inches, should have drawn upon it a black disk 1¼ inches in diameter to represent the Moon, with straight lines radiating from the center at angles of 30°. The positions of the various parts of the corona, as seen projected against the sky, are best referred to a vertical line obtained by mounting a plumb line so that it is seen hanging over the Moon's center. The diagram upon which the drawing is to be made is to be placed upon any convenient support, so that the line marked "Top" "Bottom" shall be in the plane of the plumb line, the top part corresponding to the top of the string.'

Others might find it more easy to estimate the angular positions by dividing the diagram into four quadrants, as the actual position of the parts of the corona as seen in the sky will have to be estimated from the vertical plumb line and an imaginary horizontal line perpendicular to the plumb line.

For the benefit of those who may wish to try the co-operative plan of sketching, the following hints with but little modification are taken from the report of the British Astronomical Association on "Indian Eclipse, 1898."

"HINTS FOR MAKING DRAWINGS OF THE CORONA.

"1. The party should consist of at least five persons—four to sketch details of single quadrants, and one (the leader) to sketch rapidly the general features of the corona. The leader will then be able to correct and supplement the work of the quadrant sketchers, when producing the combined sketch. This must be done on the same day, immediately after the eclipse, in consultation with the whole party; and all the drawings should be photographed as soon as completed. The drawings themselves, even if faulty, should not be touched after completion.

"2. The party should practice together beforehand, each one sketching his own proper quadrant from a corona drawing suspended at the angular height of the Sun. The time of exposure of the drawing should be slightly less than the known duration of the eclipse. By rotating the drawing it may be made to serve for four sketches. The drawing must be well illuminated and clear, but must not be large. The Sun and Moon are small objects to the eye, and a large drawing would not give useful practice.

"3. Experience shows that Mr. Green's suggestion as to materials, white chalk on purplish blue paper, is an admirable one. For practicing, brown paper serves very well if blue paper is scarce.

"4. It is important always to practice on the same scale as the final sketch is to be made. It has been found that a silver half dollar ($1\frac{3}{16}$ inches in diameter), is a very convenient size for the black body of the Moon, and this may be always at hand. A circle, being drawn around the half dollar is bisected vertically and horizontally, and the diameters are produced across the paper. The sketcher has a plumb line (a bunch of keys at the end of a string will do), with which he divides his model corona vertically as he looks up at it, and he guesses at the corresponding horizontal division. His quadrant thus fixed, he proceeds to sketch it. When the time is called .the leader redraws all four quadrants in one combined sketch, and by comparison with the original, the habitual faults of the sketchers are detected, and in the course of a few practices will disappear.

"5. The position of any planet or high-magnitude star very near the Sun at the time of eclipse should be accurately ascertained, and its distance measured in terms of the Moon's diameter (taken as half a degree), as these facts when made familiar to the whole party will check the supposed direction and extent of any long streamers of the corona.

"6. On eclipse day the sketchers should avoid fatiguing their eyes by too much observation of the preceding partial eclipse, and should rest the eyes for the last five minutes before totality, absolutely. It would be well to close them for the last minute, and open them by a signal at totality. Attention should be paid to the extreme extent and to the color of the corona at the moment of beginning to draw, when the eye is at its freshest, and consequently is better able to observe these points than after gazing at the very bright inner parts of the corona."

It should not be inferred from the emphasis laid upon the number five that co-operation between two or three observers would not have an advantage over the method of making a sketch unaided.

II.—THE MOON'S SHADOW BANDS.

The Moon's shadow is bordered by diffraction bands of alternate light and shade, which are visible on any white background, and last about a minute before and after totality. At the eclipse expedition to the Caroline Islands in 1883 they were successfully observed, and the simple method adopted there is recommended. A white sheet, table spread, or another large piece of white cloth, is spread upon the ground and securely fastened, the edges lying north and south and east and west. The observer should be provided with a long rod, which he will lay upon the sheet either parallel or perpendicular to the shadow bands as they move rapidly across the sheet, in order to get their direction. A similar one should be used for the line succeeding totality, as the directions differ widely. Measure as accurately as practicable the direction of the two positions of the rods, using a compass or other instrument in order to get their azimuth or bearing. A second observer, provided with a watch should try to count the number of bands per minute, and estimate carefully their distance apart in inches as they move across the white surface. In the report upon this phenomenon, in giving the direction of the rods with reference to the compass points, it should be stated whether they were placed parallel or perpendicular to the lines.

THE STUDY OF ASTRONOMY III.

W. W. PAYNE.

The brief articles before given in the January and Februry numbers of this publication have spoken of the views of some prominent school men about making elementary astronomy a part of the courses of study in the secondary schools, the methods of teaching astronomy where it is pursued; the marked changes that are now being introduced, sometimes known as the "inductive" or the laboratory methods; and the means of illustration so necessary in all ways of teaching astronomy. This last point is deemed so important that we promised to say more about it, and would have done so in our last number, but for the failure of engravers to reproduce the fine illustration of the Merope nebula which is given as the first plate in this number. In our last, we referred to the help which photographs of celestial objects gives in the study of details, which cannot be obtained so well in any other way. We printed some cuts of enlarged photographs of the Sun and Moon that our readers might get a fuller idea of the value of this means of illustration that could not be so well realized without them. We also referred to special ways of studying the details of sun-spots by the aid of the best drawings that have come to our notice. In that connection we should have said more about the study of the prominences and faculae by the aid of photographs obtained when the spectroscope is used in connection with the telescope. It is known, probably, to most of our readers, that very fine views of the prominences may be had in this way, and that both prominences and faculae can be photographed. The pictures that have been already obtained with some special forms of instruments are such as to give promise of useful results in the study of some important solar phenomena. There is certainly photographic power enough in the *H.* and *K.* region of the spectrum for much aid in pushing our knowledge further in regard to some conditions of solar activity.

We desire to call attention again to the work of Professor J. E. Keeler, Director of Lick Observatory, Mount Hamilton, California, in photographing some faint nebula by the aid of the Crossley reflector.

The picture which is our first plate, is the Merope nebula. This nebula fills a vast region of space around the star of the Pleiades, called Merope. The original negative was exposed four hours, on a fair night, but not one of the best. Professor Keeler says that the positive (from which our plate is made) does not show the small nebula, which is sometimes spoken of as Barnard's new Merope nebula, but that it does appear on the original negative. The positive was an enlargement of the original negative to four diameters, and our plate is the same size as the positive.

Our readers who are acquainted with the names and relative positions of the naked-eye stars in this group, will easily get the scale of the picture by noting the place of the apparently bright star above and to the right of Merope, in the midst of the nebula. That star is given in Young's cut, Fig. 229, p. 553 of the last edition of General Astronomy, as one of two faint stars nearly halfway between Merope and Electra. The other fainter star in the same direction from Merope, just on the edge of the plate, is another star in the little triangle shown in the cut above referred to. The space covered by this plate as represented on the cut would be a little more than one square inch; or about twenty minutes of arc each way, less than one-eighth of the area in the sky which the naked eye stars of the Pleiades seem to enclose.

If we now look at the beautiful plate in its details, we are able to get a glimpse of some of the wonders of this remarkable group of stars which have been a source of careful study by scholars in recent years.

The first thing noticed in regard to the central star, Merope, is the many rays of light that extend outward in all directions. We called attention to this in a brief paragraph in the March issue of this publication. As there said, we suppose the rays are due to the supports of the small mirror in the tube of the telescope. But the chief thing of interest is the structure of the nebulous matter surrounding Merope. It is at once seen that the exterior matter is not related to Merope as a center, in any such way as the nebulous masses appear to be in the great Andromeda nebula. There the nebulosity seems to fall into rings, more or less distinctly outlined, suggesting, possibly, rotary motion of the whole mass. We do not say that this ring formation gives more than a hint of the condition of the nebula in regard to motion. This may or may not be the explanation of the rings that present so much of interest in detail, now so well seen in photographs of long exposure. In the Merope nebula the nebulous masses do not seem to be related. They are in streaks, straight and curved, in parallel lines that fade off gradually into faint streamers or dim, irregular patches soon lost to view, because they cannot be further followed by the power of the sensitive plate to catch the distant outlines, rather than the supposition that the end of their nebulosity has been reached. In this plate, and in other pictures of this nebula, the filiamentary structure of the main mass is very distinctly given. As we look at it thoughtfully we are reminded of the penumbra of great and active sun-spots, especially where the motion of the granular masses is somewhat evenly directed towards the umbra of the sun-spot. Can these striated forms in the nebulous masses mean motion? If so what kind of motion? The fact that some of them point one way and others another way, while the different systems of rays appear to be occupying the same space nearly is another most perplexing thing.

We mention a few of these interesting details to call attention to the great value of good photographs in the study of astronomy, and especially so if one is charged with the responsibility of giving instruction to students.

This must appear more strongly evident, when we remember that the largest telescope now in use will not present to the experienced observer so fine a view of the Merope nebula as that which is shown in Professor Keeler's fine negative, from which our cut by three or four intermediate processes has been obtained. Still more is it astonishing to us, when we remember that only a few years ago there was very lively discussion among prominent astronomers about the existence of any Merope nebula at all. In 1882 Professor Barnard of Yerkes Observatory, then at Nashville, Tenn , observed the nebula and made a drawing of it, which was published in the May number of the *Sidereal Messenger*. That drawing was then and is now correct for the brighter part of the nebula. But the things we now get by photography have so grandly surpassed all visual work, that it is no wonder that astronomers are enthusiastic over the new and later methods of study.

We very much wish to bring to the attention of all engaged in instruction in the elements of astronomy the great advantage of having good large scale photographs as a means of illustration. We have recently sent out about fifty of these pictures to those ordering them, and it is a pleasure to us to know that in all cases the teachers receiving them have been very free in their words of commendation and satisfaction. Putting the price of these large astronomical pictures at 75 cents each, barely covers the cost, so the undertaking is certainly not renumerative to us.

We have just received from Dr. William Huggins and Lady Huggins of London, England, the finest volumes of spectroscopic work we have ever seen in print. It is their own work for years past, and it is most beautifully and perfectly executed, in representing spectra of celestial objects by the aid of photography. If we may get permission to reproduce some of these spectra in this publication, we will further tell our readers what may be done by photography on a large scale to illustrate the work of the spectroscope for the purpose of aid in instruction.

PHOTOGRAPHING THE CORONA.

W. B. FEATHERSTONE.

FOR POPULAR ASTRONOMY.

One of the greatest obstacles to obtaining satisfactory photographs of a solar eclipse is the uneven brightness of the corona. The parts near the Sun are so much brighter than the outlying streamers, that when the latter have been given sufficient exposure, the central portion of the plate has lost all detail from overtiming. The reverse is also true, so that a plate exposed for the inner corona and prominences shows but a trace of the outer corona and none of the fainter detail.

Some very good negatives have been made by the use of non-halation plates, and by manipulating the plate during development, but it would, of course, be much better if the entire plate could be normally exposed at the start.

The following simple device comes very near making this possible, and can be used with a telescope or camera of any size.

Theoretically it does not provide for a perfectly even exposure, as does Mr. Burckhalter's apparatus, but it does so approximately, and this is all that can be accomplished with any device of the kind until the relative brightness of the corona at different distances from the Sun has been more accurately determined.

In the diagram LL' is the objective, PP' the sensitive plate and M the center of the Moon's image. The points BB' are distant two lunar radii from the Moon's limb.

Suppose a circular disc DD', be supported in the position shown, and that its diameter be such that it just occults the lens when viewed from *M*.

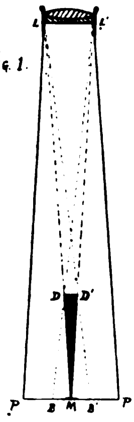


Fig. 1.

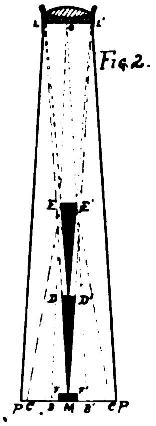


Fig. 2.

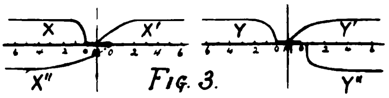


Fig. 3.

Now gradually move the eye from *M* toward the edge of the field. The illumination increases as more of the lens becomes visible, until at *BB'* the plate is exposed to the full aperture. Outside of this point the corona is so faint that there is no danger of overexposure.

When the disc is in the position *DD'*, the prominences and the corona near the Moon's limb will be photographed by less than one-half of their normal light, while the plate at *BB'* and beyond, is exposed to the full aperture of the lens. (Curve *X'*, Fig. 3).

If *DD'* be moved toward *M*, the limb of the Moon will receive less illumination, while the normally-lighted area will extend inside of *BB'* and the light will be cut off less gradually (Curve *X'*, Fig. 3), while the reverse will occur if the disc be moved toward the lens. (Curve *X''*).

A second disc in the position *EE'*, Fig. 2, would cause the partially lighted region to extend into the outer corona (*CC'*), and would also modify the light-gradient for the inner corona, while the prominences would receive the same light as before. (Curve *Y'*, Fig. 3). If, however, it should be placed between *DD'* and the sensitive plate, it would serve to cut off still more light from the region of the Moon's limb, (Curve *Y*), and if it be desired to secure photographs before or after totality, a disc in the position *FF'* would effectually shield the plate from the intense light of the photosphere. (Curve *Y''*).

These discs may be mounted on a rod coincident with the optic axis of the camera and so arranged as to be readily adjusted from the outside. The rod should be supported at the end nearest the objective, so that its supports will not affect the image on the plate.

Instead of the round discs, a disc with serrated edges could, of course, be used, the size and shape of the notches corresponding to the estimated brightness of the corona at different distances from the Sun, but in practice it will be found that the discs must be placed so close to the plate for the best results, that a stationary disc of any shape other than round will be sure to leave its silhouette in the picture.

Moreover, by using two or three circular discs, almost any gradation of light can be produced. The diameter of the discs and their relative positions will depend on the dimensions of the camera, but the diameter will usually be between $\frac{f}{40}$ and $\frac{f}{60}$ or 1½ to 2 times the diameter of the Moon's image, and the fundamental position *DD'* can be determined by placing the eye in the center of the field, when the disc should just occult the objective.

Another arrangement, described below, is to be preferred for several reasons. It not only limits the light from the brighter portion of the corona, but can also be made to act as a shutter, giving a graduated exposure to suit almost any condition.

The disc (*GG'*, Fig. 4), which is a trifle larger than the lens, is kept just outside of it, thus darkening the camera, until the plate is ready for exposure. It is then to be gradually moved to the position shown in the figure. As it recedes from the lens, first the outer corona, then the inner corona and prominences come into view, the relative amount of light from each depending upon the position of the disc and also upon the rate of speed with which it is moved to and from its position.

The disc should be mounted centrally on a rod (*R*, Fig. 5), coincident with the optic axis of the objective, and this rod may be supported by a double tripod arranged to fit over the lens-cell or telescope tube, (*TT'*, Fig. 5). The occulting disc should then have the form of a conical shell (*HH'*) to admit of its fitting closely over the objective.

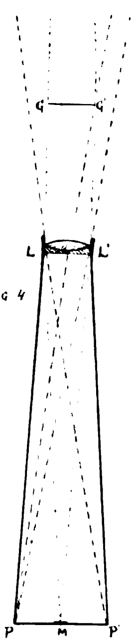


Fig 4

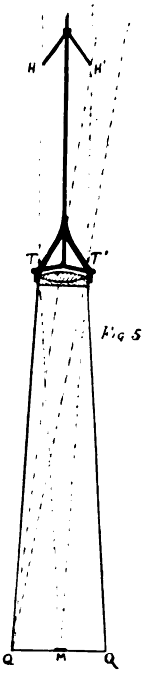


Fig 5

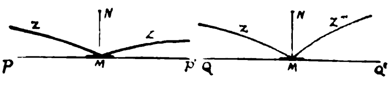


Fig 6

With the disc in the position *GG'*, Fig. 4, the relative amount of light reaching any part of the sensitive plate, is roughly indicated by the curve *Z*, Fig. 6, where *PP'* represents the plate, *M* the Moon's image, and *MN* the height of the curve should all of the light reach the plate.

With the disc at *HH'*, the curve would be somewhat steeper (*Z'*), while it becomes much flatter as the disc is moved toward the lens (*Z''*). If a more rapid increase of light toward the outer corona is desired, the disc may be moved farther still from the lens and the light curve will approximate *Z'''*.

Other modifications of the light curve can be produced by moving the disc back and forth at a variable speed or by changing its position several times during the same exposure. The edges of the occulting disc may also be notched or serrated, but in that event it must either be revolved during exposure or kept quite close to the lens; otherwise its outline will appear on the negative.

For every short exposure the movements of the disc may be actuated by a spring and bulb release, arranged similar to the ordinary pneumatic shutter.

CHICAGO, ILL.,
March 20th, 1900.

MIGHT A COMET STRIKE THE EARTH.

REV. FREDERICK CAMPBELL.

FOR POPULAR ASTRONOMY.

What a comet is and whence it comes are questions still waiting to be answered. This seems the more wonderful when we consider that stars, which exhibit but mere points of light, are fairly understood, while a comet stretching its magnificent tail from zenith to horizon still presents an enigma. That the most conspicuous part of a comet is the less substantial part is accepted as true; the bright head, however, may enclose solid matter, as solid as the globe of a planet. And this suggests the query, what might happen if a comet should stike the earth:

Is a collision between a comet and the earth possible? There is no reason to doubt it. The planets move in concentric orbits about the Sun, their speed imparting to them a centrifugal force which keeps them away from the Sun and from each other, while the Sun's attraction on the other hand prevents their slipping away into the space and thus crossing each other's paths; hence we are safe from collision with the planets. The Moon, too, is always kept at the safe distance of about 240,000 miles; hence she does not threaten our globe. But comets are strangers. They come from outside the solar system. They are here on a visit and do not know the ways of the family. And their path is very different from those followed by the planets. If it be in the same plane with the planets, instead of its being a great and nearly even circle about the Sun, it appears first as almost a straight line toward the Sun, bending more and more rapidly about that body, however, until the direction has been reversed; and now, following a similar path, the comet hastens away to more or less nearly the same region of the heavens from which it came, and so, having left the solar system, disappears from view. In making this journey the comet has crossed the orbits or paths of all the planets. It has not stopped to see whether the planets were due at the crossing points at the time when itself was coming. There are no signals to prevent both trains from trying to cross at the same moment, and if they do, something will happen. If the planet in question be the Earth, the Earth will in such a case be struck.

But if a comet struck the Earth, then what? Even if a comet's head be solid, it is not large, and there being twice as much water as land on our globe, the probabilities would be two to one that the comet would be lost in the bosom of the ocean. There being also vast stretches of uninhabited land, the probabilities greatly increase that the part of the Earth struck by the comet would be without population. Besides this, if the comet should strike where man dwells, the catastrophe would probably be only a local one, like that produced by an earthquake or a cyclone.

The next thing to give assurance is that the Earth is surrounded by a buffer in the form of an atmosphere, which reaches probably two hundred miles or more in every direction into space. If any foreign body be making for the Earth, it must first pass through this and be retarded by it. The heat generated by this concussion with our atmosphere consumes most of our meteors, so that they are turned into gas and seldom reach the ground in solid form. Even in the immensely cold spaces of the heavens, while still many millions of miles from the Sun, as they approach that central body, its slight heat vaporizes comets so as to generate what we call their "tails." This demonstrates how readily they are turned into thin gas, and suggests how the vastly greater heat developed by concussion with the Earth's atmosphere might speedily consume them in their very act of endeavoring to impinge upon the Earth.

Now, it is known that when a comet enters our solar system it is not making for a planet, but for the Sun. The Sun is the center of attraction for a visiting comet as well as for the various planets. A comet may indeed come from any possible direction, and thus not cross any of the orbits of the planets; but supposing it to cross the orbit of the Earth, as it might; that orbit is like a race track, about 560,000,000 miles around, which distance the Earth travels in one year. The Earth is flying over this course at the rate of 1,100 miles per minute. Let any one compute what are the probabilities of its being struck by a single body, moving with perhaps equal speed, which chances to cross its track. The Earth is but a speck of matter, while the nucleus of a comet is much smaller. Two boys throwing balls at each other might better expect that the balls would meet in the air; yet, what boys have the skill to bring this to pass? As Professor Newcomb says, firing a gun at random in the air might better be expected to bring down a bird than that it should be feared that a comet would ever strike the Earth.

The improbability of collision is the greater in view of the fact that comets, which make for the Sun, succeed in getting away again without a collision. We have had comets nearer the Sun than the nearest of all the planets, and yet they have harmlessly swung about that body and fled back into space. How much less, then, can they be expected to impinge upon the Earth. The Earth itself periodically draws many thousands of miles nearer the Sun, but as surely withdraws into space once more, and always unharmed. God has endowed the heavenly bodies with a momentum which, while it sometimes appears threatening, is really their safety. The nearer a comet approaches the Sun, it is hurried more and more rapidly so that it is less and less possible for the Earth's attraction so to deflect it from its course as to produce a collision. Had we no atmosphere to retard its movement, a cannon ball fired at a speed of seven miles a second would keep up a perpetual orbit about the Earth. Perrine's comet in 1896 was estimated to be approaching at the rate of 1,600,000 a day, which is about eighteen miles a second—more than twice as great as necessary to ensure that a cannon ball will not touch the ground. What probability, therefore, that the more swiftly coursing comet will strike the Earth?

The probability of collision with the comet's head is small, because the head itself is small. The tail presents a far larger degree of probability of collision. But so thin is the matter making up the tail that the faintest stars can be seen through a million miles of it. This is evidently generated like steam from the comet's head. But there is more danger in a smoky day in the manufacturing districts of Chicago and Pittsburg than there is in passing through the tail of a comet. Of the lost Biela's comet, Professor Newcomb says: "It had seemingly vanished, not into thin air, but into something of a tenuity compared with which the thinnest air was as a solid millstone." He also declares that "the amount of matter really necessary to make the most splendid tail is so extremely small that a comet might lose it a hundred times over without becoming perceptibly smaller." As a matter of fact, the Earth has probably a number of times passed through a comet's tail, as in 1861, when the only visible effect was a singular phosphorescent mist.

Beyond and above all these considerations, we may well assure ourselves that, while we are under a reign of law, all laws are God's, and no law supersedes His sovereign will. No student of either the Bible or history can believe for one moment that the world's and man's existence in this world are without a plan. Nor can any careful observer believe for one moment that that plan has yet been fulfilled, so far as the human race is concerned. God will hold things in place till the Earth is redeemed. When the end comes, it will be within His power, if He so choose, to produce all its startling conditions by the simple effacing of a single law, namely, that of centrifugal force; this is what keeps all the worlds safely apart. If this law were suspended, gravity would have full sway, and all the worlds would rush together in a series of awful concussions which would literally fulfill the Word which says, "The heavens shall pass away with a great noise, and the elements shall melt with fervent heat; the Earth also, and the works that are therein shall be burned up." Happy are we if, in the midst of all the possibilities and certainties of the universe in which we dwell, we can say, "Nevertheless, we, according to His promise, look for new heavens and a new Earth, wherein dwelleth righteousness."

BROOKLYN, N. Y., 428½ Clinton Street.

THE MOON HOAX.

S. A. MITCHELL.

FOR POPULAR ASTRONOMY.

Throughout all ages of the world's history, there has been a tendency in the human mind to grasp after the new, the sensational and the mysterious; and to foster this inclination, there have always been plenty of men ready and willing to devote their time to the making of so-called new and wonderful discoveries.

Astronomy, the most ancient of all the sciences, has been singularly free from attempts to pander to this craving on the part of man. The human mind, as a rule, has regarded reverently the discoveries in astronomy, but some instances of sensationalism have crept even into this grand old science.

While looking through the Struve library, which was obtained by Columbia University not long since, I ran across a pamphlet which is thoroughly interesting, although the matter contained is extremely surprising. This is the celebrated "Moon Hoax." This work obtained a great notoriety about the middle of the century, and in the hope that it may still be interesting to astronomers, these few pages are written.

Early telescopic observations of the moon were conducted with the confident expectation that the moon would be found to be an inhabited world, and that much would soon be learned of the manners and appearance of the Lunarians. With each increase of telescopic power a new examination was made, and it was only when the elder Herschel's great reflector failed to show any inhabitants on the face of the moon, that men began to look in doubt and think that perhaps the examination was hopeless. Herschel, himself, seemed to be of the opinion that the moon was inhabited, for, after describing the relations, physical and seasonal, that prevailed on the surface of the moon, he adds: "There only seems wanting, in order to complete the analogy, that it should be inhabited like our earth."

When Sir John Herschel carried his giant reflector to the Cape of Good Hope, the hope was renewed that he might be able to tell us something about the inhabitants of the moon. In fact, so confidently was this hope entertained, that when the "Moon Hoax" appeared about this time, purporting to be "*Great Astronomical Discoveries*, lately made by Sir John Herschel, LL. D., F. R. S., &c., at the Cape of Good Hope," there were many people who took every word of these wonderful discoveries in good faith, and were firmly convinced that the moon was inhabited.

The full title of this extraordinary little pamphlet is: "The Moon Hoax; or, The Discovery that the Moon has a Vast Population of Human Beings, by Richard Adams Locke." New York, 1859. The publisher tells us that it was first published in the "New York Sun" in August and September 1835, and that the interest in the discovery was so intense that the circulation of the paper augmented five fold, and these articles, in fact, were the means of giving the journal a permanent footing as a daily newspaper. "Nor did this multiplied circulation of the paper satisfy the public appetite. The proprietors of the journal had an edition of 60,000 published in pamphlet form, which was sold off in less than a month."

It seems best to let this unique little book tell its story as nearly as possible in its own language. The author, Locke, tells us that he is "indebted to Dr. Andrew Grant for the almost exclusive information concerning the facts." Dr. Grant was the "pupil of the elder, and for several years past, the inseparable coadjutor of the younger Herschel, the amanuensis of the latter at the Cape of Good Hope, and the indefatigable superintendant of his telescope during the whole period of its construction and operation."

The story is told, in part, as follows:

"We are assured that when the immortal philosopher to whom mankind is indebted for the thrilling wonders now first made known, had at length adjusted his new and stupendous apparatus with a certainty of success, he solemnly paused several hours before he commenced his observations, that he might prepare his own mind for discoveries which he knew would fill the minds of myriads of his fellow-men with astonishment, and secure his name a bright, if not transcendant conjunction with that of his venerable father, to all posterity. And well might he pause! From the hour the first human pair opened their eyes to the glories of the blue firmament above them, there has been no accession to human knowledge at all comparable in sublime interest to that which he has been the honored agent in supplying. Well might he pause! He was about to crown himself with a diadem of knowledge which would give him a conscious pre-eminence above every individual of his species who then lived, or had lived in the generations that are passed away. He paused ere be broke the seal of the casket which contained it. To render our enthusiasm intelligible, we will state at once that by means of a telescope of vast dimensions, and an entirely new principle, the younger Herschel, at his Observatory in the Southern Hemisphere has already made the most extraordinary discoveries in every planet of our solar system; has discovered planets in other solar systems; has obtained a distinct view of objects in the moon, fully equal to that which the unaided eye commands of terrestrial objects at a distance of a hundred yards; and has affirmatively settled the question whether this satellite be inhabited.

The elder Herschel, several years before his death, conceived it practicable to construct an improved series of parabolic and spherical reflectors, which, unite all the meritorious points in the Gregerian and Newtonian instruments, with the highly interesting achromatic discovery of Dollond. His plan evinced the most profound research in optical science, and the most dextrous ingenuity in mechanical contrivance; but accumulating infirmaties, and eventually death, prevented its experimental application. His son, Sir John Herschel, was so fully convinced of the value of the theory, that he determined upon testing it at whatever cost. Within two years of his father's death he completed his new apparatus, and adapted it to his father's telescope. He found that the magnifying power of 6,000 times, when applied to the moon, which was the severest criterion that could be accepted, produced, under these new reflectors a focal object of exquisite distinctness, free from every achromatic obscurity, and containing the highest degree of light which the great speculum could collect from that luminary. Yet the advance he had made in the knowledge of this planet, though magnificent and sublime, was thus but partial and unsatisfactory. A law of nature, and the finitude of human skill, seemed united in inflexible opposition to any further improvement in telescopic science, as applicable to the known planets and satellites of the solar system, for unless the sun could be prevailed upon to extend a more liberal allowance of light to these bodies, and they be induced to transfer it for the generous gratification of our curiosity, what adequate substitute could be obtained? Telescopes do not create light, they cannot even transmit unimpaired that which they receive. That anything further could be derived from human skill in the construction of instruments, the labors of his illustrious predecessors, and his own, left the son of Herschel no reason to hope.

The limits of discovery in the planetary bodies, and in this one especially, thus seemed to be immutably fixed. But about three years ago, in the course of a conversational discussion with Sir David Brewster on the invincible enemy of powerful magnifiers, the paucity of light, Sir John diffidently inquired whether it would not be possible to effect a *transfusion of artificial light through the focal object of vision!* Sir David, somewhat startled at the originality of the idea, paused awhile, and then hesitatingly referred to the refrangibility of rays, and the angle of incidence. Sir John, grown more confident, adduced the example of the Newtonian reflector, in which the refrangibility was corrected by the second speculum, and the angle of incidence restored by the third. "And," continued he, "why cannot the illuminated microscope, say the hydro-oxygen, be applied to render distinct, and, if necessary, even to magnify the focal object?" Sir David sprang from his chair in an ecstacy of conviction, and leaping half-way to the ceiling exclaimed, "Thou art the man!" Each philosopher anticipated the other in presenting the prompt illustration that, if the rays of the hydro-oxygen microscope passed through a drop of water containing the larvæ of a gnat and other objects invisible to the naked eye, rendered them not only keenly but firmly magnified to dimensions of many feet; so could the same artificial light, passed through the faintest focal image of a telescope, both distinctify [to coin a new word for an extraordinary occasion], and magnify its feeblest members. The only desideratum was a recipient for the focal image which should transfer it, without refranging it, to the surface on which it was to be viewed under the revivifying effect of the microscopic reflectors. In the various experiments made in the few following weeks, the co-operative philosophers decided that a medium of the purest plate glass was the most eligible they could discover. It answered perfectly with a telescope which magnified 100 times, and a microscope of about thrice that power.

Sir John Herschel then conceived the stupendous fabric of his present telescope. The power of his father's instrument would still leave him distant from his favorite planet nearly forty miles, and he resolved to attempt a greater magnifier. Sir John had submitted his plans and calculations in adaptation to an object glass of twenty-four feet in diameter; just six times the size of his venerable father's. For casting this ponderous mass, he selected the large glass house of Messrs. Hartly & Grant (the brother of our invaluable friend, Dr. Grant), at Dumbarton. The material chosen was an amalgamation of two parts of the best crown with one of flint glass, the use of which, in separate lenses, constituted the great achromatic discovery of Dollond. It had been found, however, by accurate experiments, that the amalgam would as completely triumph over every impediment, both from refrangibility and discoloration, as the separate lenses. Five furnaces of metal, carefully collected from productions of the manufactory, in both kinds of glass, and known to be respectively of nearly perfect homogeneous quality, were united by one grand conductor to the mould; and on the third of January, 1833, the first cast was effected. After cooling eight days the mould was opened, and the glass found to be greatly flawed within eighteen inches of the center. Notwithstanding this failure, a new glass was more carefully cast on the twenty-seventh of the same month, which on being opened during the first week in February. was found to be immaculately perfect, with the exception of two slight flaws so near the line of its circumference that they could be covered by the copper ring in which it was desired to be enclosed.

The weight of this prodigious lens was 14,826 pounds, or nearly seven tons, after being polished; and its estimated magnifying power was 42,000 times. It was therefore presumed to represent objects on our lunar surface a little more than eighteen inches in diameter, provided its focal image of them could be rendered distinct by the transfusion of artificial light. It was not, however, upon the mere illuminating power of the hydro-oxygen microscope, as applied to the focal pictures of this lens, that the younger Herschel depended for the realization of his ambitious theories and hopes. He calculated largely upon the almost illimitable applicability of this instrument as a second magnifier, which would supersede the use and infinitely transcend the powers of the highest magnifiers in reflecting telescopes.

So sanguinely did he calculate upon the advantages of this splendid alliance, that he expressed confidence in his ultimate ability to study even the entomology of the moon in case she contained insects upon her surface!

Having witnessed the completion of this great lens, his next care was to construct a suitable microscope, and the mechanical frame-work for the horizontal and vertical action of the whole. His plans in every branch of his undertaking having been intensely studied, even to their minutest details, were easily and rapidly executed. He awaited only the appointed period at which he was to convey his magnificent apparatus to its destination, the Cape of Good Hope.

The ground plan for the mounting is in some respects similar to that of the Herschel telescope in England. The observatory is a wooden building fifty feet square and as many high, with a flat roof. This is brought by means of parallel circles of railroad iron to the required position with respect to the lens. * * * * The lens, which is inclosed in a frame of wood, and braced to its corners by bars of copper, is suspended upon an axis between two pillars which are nearly as high as those which supported the celebrated quadrant of Uleg Beg, being one hundred and fifty feet. Between the pillars is a double capstan for hoisting the lens from its horizontal line to the height required by its focal distance when turned to the meridian, and for elevating it to any intermediate degree of altitude that may be needed. Having no tube, it is connected with the observatory by two horizontal levers, which pass beneath the floor of the building from the circular base of the pillars. * * * * The field of view, therefore, whether exhibited on the floor or on the wall of the apartment, has a diameter of nearly fifty feet, and being circular it has an area of 1875 feet.

It was about half-past nine on the night of January 10th, the moon having advanced within four days of her mean libration, that the astronomer adjusted his instruments for the inspection of her eastern limb. The whole immense power of the telescope was applied, and to its focal image about one-half the power of the microscope. We gazed upon the shores of the Mare Nubium of Riccoli; but why he so termed it, unless in ridicule of Cleomedes, I know not, for fairer shores never angels coasted on a tour of pleasure. A beach of brilliant whitesand, girt with wild castellated rocks, apparently of green marble, varied by chasms occuring every two or three hundred feet, with grotesque blocks of chalk or gypsum, and feathered or festooned at the summit with the clustering foliage of unknown trees, moved along the bright wall of our apartment until we were speechless with admiration. The water, wherever we had a view of it, was nearly as blue as that of the deep ocean, and broke in large white billows upon the strand. Our panting hopes were soon to be blest with specimens of conscious existence, for, beneath the shade of the luxurious trees we beheld our first animal. It was of a bluish color, about the size of a goat, with a head and beard like him, and a single horn, slightly inclined forward from the perpendicular. The female was destitute of the horn and beard, but had a much longer tail. It was gregarious and chiefly abounded on the acclivitous glades of the woods. In elegance of symmetry it rivaled the antelope, and like him it seemed an agile sprightly creature, running with great speed, and springing from the green turf with all the unaccountable antics of a young lamb or kitten. This beautiful animal afforded us most excellent amusement. Frequently, when attempting to put our fingers upon its beard, it would suddenly bound away into oblivion, as if conscious of our earthly impudence; but then others would appear, whom we could not prevent nibbling the herbage, say or do what we would to them.

We soon came across a beautiful valley, and found a large branching river, abounding with lovely islands, and water birds of numerous kinds. A species of gray pelican was the most numerous, but a black and white crane, with unreasonably long legs and bill, was also quite common. Near the upper extremity of one of these islands we obtained a glimpse of a strange amphibious creature, which rolled with great velocity across the pebbly beach, and was lost sight of in the strong current which set off from this angle of the island. We were compelled, however, to leave this prolific valley unexplored, on account of clouds which were evidently accumulating in the lunar atmosphere, our own being perfectly translucent. But this was of itself an interesting discovery, for more distant observers had questioned or denied the existence of any humid atmosphere in this planet. The moon being low in her descent, Dr. Herschel decided that it was useless to carry our labors further, especially as our minds were actually tired with the excitement of the high enjoyment we had partaken.

Our next night of observation was a beautiful clear night, and we set to our work filled with expectancy. While gazing at the landscape in the Valley of the Unicorn we were thrilled with astonishment to perceive four successive flocks of large-winged creatures, wholly unlike any kind of birds, slowly descend from the cliffs and alight upon the plain. These were first noticed by Dr. Herschel, who exclaimed, "Now, gentlemen, my theories against your proofs. We have here something worth looking at. I was confident that if ever we found beings in human shape, it would be in this longitude, and that they would be provided by their Creator with some extraordinary powers of locomotion." Introducing a lens of higher power, we perceived that certainly they *were* like human beings, for their wings had now disappeared and their attitude in walking was both erect and dignified. By our lens, we could bring them to an apparent proximity of eighty yards. They averaged four feet in height, were covered, except on the face, with short and glossy copper-colored hair, and had wings of thin membrane, without hair, lying snugly upon their backs, from the top of the shoulders to the calves of the legs. The face, which was of a yellowish flesh color, was a slight improvement upon that of the large orang outang, being more open and intelligent in its expression, and having a much greater expansion of forehead. The mouth, however, was very prominent, though somewhat relieved by a thick black beard upon the lower jaw, and by lips far more human than any species of the simia genus. In general symmetry of body and limbs, they were far superior to the orang outang. The hair on the head was a darker color than that of the body, closely curled, but apparently not woolly, and arranged in curious semi-circles over the temples of the forehead. Their feet could be seen as they were alternately lifted in walking, but, from what we could see of them in so transient a view, they appeared thin and very protuberant at the heel. Whilst passing across the canvas, and whenever we afterwards saw them, these creatures were evidently engaged in conversation, their gesticulation, more particularly the varied action of their hands and arms, appeared impassioned and emphatic.

Turning from these creatures, we surveyed the shores of the Mare Serenetatis, which is nearly square, being about 330 miles in length and width. This sea has one most extraordinary peculiarity, which is a perfectly straight range of hills, certainly not more than five miles wide. This singular ridge is perfectly *sui generis*, being altogether unlike any mountain chain either on this earth or on the moon itself. Our lens brought it within the small distance of 800 yards. Nothing we had hitherto seen more highly excited our astonishment. Believe it, or believe it not, it was one entire crystallization! Its edge through its whole length of 340 miles is an angle of solid quartz crystal, brilliant as a piece of Derbyshire spar just brought from a mine, and containing scarcely a fracture or a chasm from end to end!

But our eyes were still further gladdened by the sight of more inhabitants. These seemed to be of the same species as our winged friends, and having adjusted the instrument for a more minute examination, we found that nearly all the individuals of several large groups we saw were of a larger stature than the former specimens, less dark in color, and in every respect an improved variety of the race. They were chiefly engaged in eating a large yellow fruit like a gourd, sections of which they divided with their fingers, and ate with rather uncouth voracity, throwing away the rind. They seemed eminently happy, and even polite, for we saw, in many instances, individuals sitting nearest these piles of fruit select the largest and brightest specimens and throw them archwise to some opposite friend or associate who had extracted the nutriment from those scattered around him, and which were frequently not a few. While thus engaged in their rural banquets, or in social converse, they were always seated with their knees flat upon the turf, and their feet brought evenly together in the shape of a triangle, and for some mysterious reason or other, this figure seemed to be an especial favorite among them; for we found that every group or social circle arranged itself in this shape before it dispersed, which was generally done at the signal of an individual who stepped into the center and brought his hands over his head in an acute angle. At this signal each member of the company extended his arms forward so as to form an acute horizontal angle with the extremity of the fingers. But this was not the only proof that they were creatures of order and subordination. * * * * But although evidently the highest order of animals in this lovely valley, they were not its only occupants. The most attractive of the quadrupeds was a tall white stag, with lofty spreading antlers, black as ebony. We several times saw this beautiful creature trot up to the parties of semi-human beings, and brouse the herbage close beside them, without the least manifestation of fear on its part or notice on theirs. This universal state of amity among all classes of lunar creatures, and the apparent absence of every carniverous or ferocious species, gave us the most refined pleasure and doubly endeared to us this lovely nocturnal companion of our larger, but less favored world.

During the month of March we were able to get some more observations, and while looking at the noble valleys at the foot of Atlas we found a very superior species of Lunarian. In stature they did not exceed those last described, but they were of infinitely greater personal beauty, and appeared in our eyes scarcely less lovely than the general representation of angels by the more imaginative schools of painters. Their social economy seemed to be regulated by laws and ceremonies like the former beings seen, but their works of art were more numerous, and displayed a proficiency of skill quite incredible to all except actual observers. I shall therefore let the first detailed account of them appear in Dr. Herschel's authenticated natural history of this planet."

This is the "Moon Hoax," with its flowery descriptions of planet and animal life on our satellite.

How much of these "discoveries" did the people back in the thirties and forties believe? This we can guage by quoting a few of the press criticisms as given in the contemporary daily New York papers:

"No article, we believe, has appeared for years that will command so general a perusal and publication."—*Daily Advertiser.*

"It appears to carry intrinsic evidence of being an authentic document."—*Mercantile Advertiser.*

"It is quite proper that the *Sun* should be the means of shedding so much light on the *Moon* "—*N. Y. Evening Post.*

"The account of the wonderful discoveries in the moon are all probable and plausible, and have an air of intense versimilitude." —*N. Y. Times.*

This hoax was published in serial form in the *Sun* from August 25 to 31st, inclusive.* About the same time there appeared three French translations at ' aris, one at Bordeaux, and Italian trans-

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* The writer has seen the original copies of the "Sun" containing the "Great Astronomical Discoveries," &c.

lations at Parma, Palermo and Milan. A "second edition" of this pamphlet was published in London, 12mo., 1836.

The authorship of this article was attributed to Richard Adams Locke, at that time the editor of the *New York Sun*. But besides the great fluency of style and the masterful command of the English language shown by the "Moon Hoax," there is evinced in this article so accurate a knowledge of astronomical facts, even to the most scientific details, that it is evident none but an astronomer of more than ordinary ability could have written it. This Locke certainly was not. After severing his connection with the *Sun*, Locke edited the *New Era*, and soon after, there appeared in this periodical another hoax, "The Lost Manuscript of Mungo Park," also by Locke. This, however, while showing the same peculiarities in style as the "Moon Hoax," lacked greatly the bold and daring conception in the plot of the latter, and as a result secured very little notoriety. It would seem, therefore, that there had been some bolder and more learned spirit than Locke's which had conceived the plot of the "Moon Hoax," and supplied the editor of the *Sun* with the astronomical facts necessary for the construction of the article. Dr. Andrew Grant, alluded to in the text, seems to be as evanescent as the lunarians. But who, then, with such an idea and the knowledge for its development, would be content to give it to another and remain himself unknown? And what could be his reason for so doing? We seem to find this man in the person of M. J. N. Nicollet, a noted French astronomer, who, for some unknown cause, had been compelled to leave France and seek refuge in America. This astronomer, in connection with MM. Brousseaud and Bouvard, was the author of an important memoir, "Sur la Libration de la Lune;" and in Amer. Phil. Soc. Trans., Vol. VIII, 1842, pp. 306-310, we have a work of his, published under the title of "Observations Made at Several Places in the United States." With Nicollet as the author, we find an explanation of the precise astronomical knowledge shown in our article, and especially the frequent use of the term "libration" in his descriptions of the moon. But we do not see any apparent reason why Nicollet should be willing to allow another to appear as the author of any of his articles. There are, however, a couple of stories about him which perhaps will throw a little light on this question. One story is that Nicollet was a fugitive from Paris, taking some money that did not belong to him, and that his "Moon Hoax" was published in America, simply for the purpose of earning him some money, and being a Frenchman, he obtained Locke's help to put the story into polished English. Another, and a more probable story is, that by his hoax, Nicollet endeavored to entrap his enemy, the astronomer, Arago, in which he succeeded, Arago circulating the wonderful story through Paris until Nicollet, in a letter to M. Bouvard explained the hoax. With this for a motive, it can be easily seen that Nicollet would not care to have the hoax appear over his signature, or allow any hint as to his identity to appear in the article.

It thus appears almost an assured fact that Nicollet, through the medium of Locke, was the real author of the "Moon Hoax," and that it is to him we are indebted for these very interesting "astronomical discoveries."

COLUMBIA UNIVERSITY,
March 15, 1900.

NON-EUCLIDEAN GEOMETRY.

GEORGE BRUCE HALSTED.

FOR POPULAR ASTRONOMY.

In writing of "The Wonderful Century," Alfred Russel Wallace says of all time before the seventeenth century: "Then, going backward, we can find nothing of the first rank except Euclid's wonderful system of geometry, perhaps the most remarkable mental product of the earliest civilizations."

But of late all men of science and intelligent teachers have been hearing more and more of non-Euclidean geometry, and are naturally anxious to know how these new doctrines are related to the traditional geometry which they were taught and perhaps now are teaching.

The new departure is absolutely epoch-making, but fortunately it has intensified admiration for that imperishable model, already in dim antiquity a classic, the immortal *Elements* of Euclid.

But without assumptions nothing can be proved, and Euclid stated his assumptions with the most painstaking candor. He would have smiled at the suggestion that he could ever claim for his conclusions any other truth than perfect deduction from assumed hypotheses.

And so his system is forever safe. Should each one of his axioms turn out to be inconsistent with external reality; should each of his fundamental assumptions be replaced in our final explanation of the space in which we live and move; in reference to our space, should all his theorems be shown to be only approximations; yet his work will remain a perfect piece of pure mathematics, the exact, eternal geometry of Euclidean space.

For two thousand years no one ever doubted the truth of any one of this set of axioms, far the most influential in the intellectual history of the world, put together by Euclid in Egypt, but really owing nothing to the Egyptian race, nothing to the boasted lore of Egypt's priests.

The Papyrus of the Rhind, belonging to the British Museum, but given to the world by the erudition of a German Egyptologist, Eisenlohr, and a German historian of mathematics, M. Cantor, gives us more knowledge of the state of mathematics in ancient Egypt than all else previously accessible to the modern world. Its whole testimony confirms with overwhelming force the position that geometry as a science, strict and self-conscious deductive reasoning, was created by the subtle intellect of the same race whose bloom in art still overawes us in the Venus of Milo, the Apollo Belvidere, the Laocoön.

But though for twenty centuries the truth of the axioms of the Greek geometer remained unquestioned, there was one of them of which the axiomatic character was doubted even from far antiquity. Elementary geometry was for two thousand years as stationary, as fixed, as peculiarly Greek as the Parthenon. But among Euclid's assumptions is one differing from the others in prolixity, whose place fluctuates in the manuscripts.

Peyrard, on the authority of the Vatican MS., puts it among the postulates, and it is often called the parallel-postulate. Heiberg, whose edition of the Greek text is the latest and best (Leipzig, 1883-1888), gives it as the fifth postulate.

James Williamson, who published the closest translation of Euclid we have in English, indicating, by the use of italics, the words not in the original, gives this assumption as eleventh among the Common Notions.

Bolyai speaks of it as Euclid's Axiom XI.

Todhunter has it as twelfth of the Axioms.

Clavius (1574) gives it as Axiom 13.

The Harpur Euclid separates it by forty eight pages from the other axioms.

It is not used in the first twenty-eight propositions of Euclid. Moreover, when at length used, it appears as the inverse of a proposition already demonstrated, the seventeenth, and is only needed to prove the inverse of another proposition already demonstrated, the twenty-seventh.

Geminos of Rhodes (about 70 B. C.) speaks of it as needing proof. The astronomer Ptolemy (A. D. 87-165) tried his hand at proving it.

The great Lambert expressly says that Proklos demanded a proof of this assumption because when inverted it is demonstrable.

The Arab Nasir-Eddin (1201-1274) tried to demonstrate it.

No one had a doubt of the necessary external reality and exact applicability of the assumption. Until the present century the Euclidean geometry was supposed to be the only possible form of space-science; that is, the space analyzed in Euclid's axioms was supposed to be the only non-contradictory sort of space.

But could not this assumption be deduced from the other assumptions and the twenty-eight propositions already proved by Euclid without it? Euclid demonstrated things more axiomatic by far. He proves what every dog knows, that any two sides of a triangle are together greater than the third.

Yet after he has finished his demonstration, that straight lines making with a transversal equal alternate angles are parallel, in order to prove the inverse, that parallels cut by a transversal make equal alternate angles, he brings in the unwieldy assumption thus translated by Williamson (Oxford, 1781):

"II. And if a straight line meeting two straight lines make those angles which are inward and upon the same side of it less than two right angles, the two straight lines being produced indefinitely will meet each other on the side where the angles are less than two right angles."

As Staeckel says, "it requires a certain courage to declare such a requirement, alongside the other exceedingly simple assumptions and postulates."

In the brilliant new light given by Bolyai and Lobachevski, we now see that Euclid understood the crucial character of the question of parallels.

There are now for us no better proofs of the depth and systematic coherence of Euclid's masterpiece than the very things which, their cause unappreciated, seemed the most noticeable blots on his work.

Sir Henry Savile, in his Praelectiones on Euclid, Oxford, 1621, p. 140, says: "In pulcherrimo Geometriae corpore duo sunt naevi, duae labes . . . " etc., and these two blemishes are the theory of parallels and the doctrine of proportion; the very points in the Elements which now arouse our wondering admiration.

But down to our very nineteenth century an ever renewing stream of mathematicians tried to wash away the first of these supposed stains from the most beauteous body of Geometry.

The attempts may be divided into three classes: First, those in which is taken a new definition of parallels. Second, those in which is taken a new axiom different from Euclid's. Third, the largest and most desperate class of attempts, namely, those which strive to deduce the theory of parallels from reasonings about the nature of the straight line and plane angle. Hundreds of mathematicians tried at this. All failed. That eminent man, Legendre, was trying at this, and continually failing at it, throughout his very long life. Thus the experience of two thousand years went to show that here some assumption was indispensable. Every species of effort was made to avoid or elude it, but without success. From a letter of Gauss we see that in 1799 he was still trying to prove that Euclid's is the only non-contradictory system of geometry, and that it is the system regnant in the external space of our physical experience. The first is false; the second can never be proven.

Yet even in 1831 the acute logician, De Morgan, accepted and reproduced a wholly fallacious proof of Euclid's assumption, recently republished, Chicago, 1898.

A like pseudo-proof published in *Crelle's Journal* (1834) deceived even our well known Professor W. W. Johnson, who translated and published it in the *Analyst* (Vol. III, 1876, p. 103), saying, "this demonstration seems to have been generally overlooked by writers of geometrical text-books, though apparently exactly what was needed to put the theory upon a perfectly sound basis."

The most interesting and perhaps the most extended of such attempted proofs was by the Italian Jesuit Saccheri, born the fifth of September, 1667, who joined the Society of Jesus at Genoa, on the twenty-fourth of March, 1685. He became teacher of grammar in the Jesuit "Collegio di Brera," where the teacher of mathematics was Tommaso Ceva, a brother of the well known mathematician, Giovanni Ceva (1648-1737), who published in 1678 at Milan a work containing the theorem now known by his name.

Saccheri was in close scientific communion with both brothers and received his inspiration from them. He used Ceva's ingenious methods in his first published work, 1693, solutions of six geometric problems proposed by Count Roger Ventimiglia. His attempt at proving the parallel-postulate is his last work, "Euclid vindicated from every fleck," which received the "Imprimatur" of the Inquisition the thirteenth of July, 1733, that of the Provincial of the Jesuits the sixteenth of August, 1733. Saccheri died the twenty-fifth of October, 1733.

All preceding attempts were alike in trying to give a direct positive proof of the postulate; all were alike in the assumption open or hidden, conscious or unconscious, of an equivalent postulate.

Saccheri tries a wholly new way, and thus his book marks an epoch. He never doubted the absolute necessary truth of Euclid's postulate, and so he thinks that the two alternatives, possible if it be taken as not true, must each lead to some contradiction, to some absurdity. He tries the reductio ad absurdum. Ninety years later, 1823, Bolyai János reached the astounding conviction that these alternatives lead not to any contradiction but to the "science absolute of space," a generalization of Euclid's universe. In a letter dated the third of November, 1823, written in the Magyar language, and fortunately preserved for us at Maros Vásárhely in Hungary, Bolyai János writes to his father, Bolyai Farkas: "I have discovered such magnificent things that I am myself astonished at them. It would be damage eternal if they were lost. When you see them, my father, you youself will acknowledge it. Now I cannot say more, only so much: *that from nothing I have created another wholly new world.*"

Suppose we take a few steps into this new universe on the path which opened before Saccheri without his ever suspecting whither it led.

1. If two points determine a line it is called a straight.
2. If two straights make with a transversal equal alternate angles, they have a common perpendicular.
3. A piece of a straight is called a sect.
4. If two equal coplanar sects are erected perpendicular to a straight, if they do not meet, then the sect joining their extremities makes equal angles with them and is bisected by a perpendicular erected midway between their feet: [Proved by folding the figure over, along the third perpendicular].
5. Considering figures where the right angles made by the equal perpendiculars may be said to be not alternate, and where no two perpendiculars to the same straight meet, the equal angles made with the joining sect at the extremities of the two equal perpendiculars are either right angles, acute angles, or obtuse angles. Distinguish the three cases as hypothesis of right, hypothesis of acute, hypothesis of obtuse.

6. According to these three hypotheses respectively, the join of the extremities of the equal perpendiculars is equal to, greater than, or less than the join of their feet. [Saccheri, Prop. III. Translated by Halsted in the *American Mathematical Monthly*].

7. Inversely, according as the join of the extremities is equal to, or less than, or greater than the join of the feet, the equal angles will be right, or obtuse, or acute. [S. P. IV].

8. Corollary. In every quadrilateral containing three right angles and one obtuse, or acute, the sides adjacent to this oblique angle are less than the opposite sides, if this angle is obtuse, but greater if it is acute.

9. The hypothesis of right, if even in a single case it is true, always in every case it alone is true. [S. P. V.].

10. Assuming the principle of continuity, and referring only to figures where no two perpendiculars to the same straight meet; The hypothesis of obtuse, if even in a single case it is true, always in every case it alone is true. [S. P. VI.].

11. With like limitation; The hypothesis of acute, if even in a single case it is true, always in every case it alone is true. [S. P. VII.]

12. The sum of the angles of a rectilineal triangle is a straight angle in the hypothesis of right, is greater than a straight angle in the hypothesis of obtuse, is less than a straight angle in the hypothesis of acute. [S. P. IX].

13. The excess of a triangle is the excess of the sum of its angles over a straight angle. The deficiency of a triangle is what its angle-sum lacks of being a straight angle.

14. Two triangles having the same excess or deficiency are equivalent.

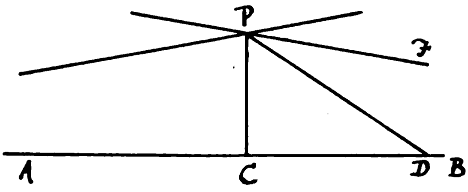
15. Even with the assumption that two straights cannot intersect in two points, the three hypotheses give rise to three perfect systems of geometry, the hypothesis of right to Euclid, the hypothesis of acute to Bolyai-Lobachevski, the hypothesis of obtuse to Riemann.

16. In the hypothesis of acute the straight is infinite. Two coplanar straights perpendicular to a third diverge on either side of their common perpendicular. The angle-sum of any rectilineal triangle is less than a straight angle.

17. In Euclid and Bolyai, parallels are straights on a common point at infinity.

18. In Bolyai, from any point P drop PC a perpendicular to a given straight AB.

If D move off indefinitely on the ray CB the sect PD will ap-



proach as limit *PF* copunctal with *AB* at infinity. *PF* is said to be at *P* the parallel to *AB* toward *B*.

PF makes with *PC* an angle *CPF* which is called the angle of parallelism for the perpendicular *PC*. It is less than a right angle by an amount which is the limit of the deficiency of the triangle *PCD*. On the other side of *PC* an equal angle of parallelism gives us the parallel at *P* to *BA* toward *A*.

Thus at any point there are two parallels to a straight.

A straight has two distinct separate points at infinity.

Straights through *P* which make with *PC* an angle greater than the angle of parallelism and less than its supplement do not meet the straight *AB* at all, not even at infinity.

19. A straight maintains its parallelism at all its points. [Lobachévski, Geometrical Researches on the Theory of Parallels, Translated by Halsted, § 17].

20. If one straight is parallel to a second, the second is parallel to the first. [L. § 18.].

21. Two straights parallel to a third toward the same part are parallel to each other. [L. § 25].

22. Parallels continually approach each other. [L. § 24].

23. The perpendiculars erected at the middle points of the sides of a triangle are all parallel if two are parallel. [L. § 30.]

24. If the foot of a perpendicular slides on a straight, its extremity describes a curve called an equi-distant curve or an equidistantial.

25. An equidistantial will slide on its trace.

26. A circle with infinite radius is not a straight but a curve, called the boundary curve, which is a plane curve such that all perpendiculars erected at the mid-points of chords are parallel. [L. § 31]. It is an equi-distantial whose base line is infinitely removed.

27. Circles, boundary-curves, equi-distantials cut at right angles a system of copunctal straights, of parallel straights, of perpendiculars to a straight, respectively.

Three points determine one of these curves; that is through any three points not co-straight will pass either a circle, a boundary-curve, or an equi-distantial, and only one such curve.

Any triangle may be inscribed in one and only one of these curves.

28. Boundary-surface we call that surface generated by the revolution of a boundary-curve about one of its axes.

Principal plane we call each plane passed through an axis of the boundary-surface.

Every principal plane cuts the boundary-surface in a boundary-curve.

Any other plane cuts the boundary-surface in a circle.

Boundary-triangles whose sides are arcs of the boundary-curve on the boundary-surface have the same interdependence of angles and sides and the same angle sum as rectilineal triangles in Euclid.

Geometry on the boundary-surface is the same as the ordinary Euclidean plane geometry. [L. § 34].

29. Triangles on an equidistant surface are similar to their projections on the base plane; that is, they have the same angles and their sides are proportional.

30. In the hypothesis of obtuse, a straight is of finite size, and returns into itself.

This size is the same for all straights. Any two straights can be made to coincide.

Two straights always intersect.

Two straights perpendicular to a third intersect at a point half a straight from the third either way.

A straight in the hypothesis of obtuse does not divide the plane into hemiplanes.

Starting from the point of intersection of two straights and passing along one of them over a certain finite sect, we come again to the intersection without having crossed the other straight.

This sect is the whole straight, and so a straight has not really two sides.

There is one point through which pass all the coplanar perpendiculars to a given straight. It is called the pole of that straight, and the straight is its polar.

A pole is half a straight from its polar. A polar is the locus of coplanar points half a straight from its pole. Therefore if the pole of one straight lies on another straight, the pole of this second straight is on the first straight.

The cross of two straights is the pole of the join of their poles.

The equidistantial is a circle with center at the pole of its basal straight.

Three straights each perpendicular to the other two form a tri-rectangular triangle. It is self-polar, each vertex being the pole of the opposite side.

In the hypothesis of obtuse, any two straights enclose a plane figure, a digon.

Two digons are congruent if their angles are equal.

In the hypothesis of obtuse, all perpendiculars to a plane meet at a point, the pole of the plane. It is the center of a system of spheres of which the plane is a limiting form when the radius becomes equal to half a straight.

Figures on a plane can be projected from similar figures on any sphere which has the pole of the plane for center. They have equal angles and corresponding sides in a constant ratio depending only on the radius of the sphere.

Geometry on a plane is therefore like two-dimensional spherics, but the plane corresponds to only a hemisphere.

The plane is unbounded but not infinite. It is finite in extent. The universe is unbounded but not infinite. It is finite in extent, or content, or volume.

Now of these three possible geometries of uniform space, Euclid's has the unexpected disadvantage that it can never be proved to be the system actual in our external physical world. To establish Euclid, it would be necessary to show that the angle-sum of a triangle is *exactly* a straight angle; and no measurements can ever reach exactitude.

To prove one of the others, we have only to show that the sum of the angles of some triangle is *less than*, or *greater than* a straight angle, which may conceivably be done even by inexact measurements.

What changes ought to be made in teaching elementary geometry in consequence of these later discoveries and the principles of the non-Euclidean geometries?

We are given a new criterion for questions of method, of exposition. For example, surface spherics attains a new importance.

When properly founded and expounded, pure spherics, two-dimensional spherics, while giving all the old results and laying the foundation for spherical trigonometry, gives also a picture of the planimetric part of Riemann's geometry, and becomes a touchstone for detecting the fallacies and assumptions in the many pseudo-proofs accepted in the past, such as attempts to found parallelism on direction, attempts to prove all right angles equal, etc.

As another example, we see a new stress laid on the incalculable advantages, educational and scientific, of Euclid's procedure in deducing from three assumed constructions every other construction before he uses it in any demonstration. The glib method of *supposed* solutions to all desired problems, of hypothetical constructions, is now seen in its deformity and danger.

Euclid says, under the heading "Postulates:"

"I. It is assumed, that a straight line may be drawn from any one point to any other point.

"II. And that a terminated straight line [a sect] may be produced in a straight line continually.

"III. And that a circle may be described with any center and radius."

From these Euclid rigidly deduces every problem of construction he wishes to use. Says Helmholtz: "In drawing any subsidiary line for the sake of his demonstration, the well-trained geometer asks always if it is possible to draw such a line. It is notorious that problems of construction play an essential part in the system of geometry. At first sight these appear to be practical operations, introduced for the training of learners; but in reality they have the force of existential propositions. They declare that points, straight lines, or circles, such as the problem requires to be constructed, are possible under all conditions, or they determine any exceptions that there may be."

Euclid's first three propositions are problems.

The most popular American geometry, Wentworth's, (1899), puts Euclid's two first postulates on page 8, and the third postulate a whole book later, and then never has a single problem of construction until page 112, where he says: "Hitherto we have supposed the figures constructed."

Meantime, on page 88, he gives as a "theorem:" "Through three points not in a straight line, one circumference, and only one, can be drawn.

He gives as his "Proof. Draw the chords *AB* and *BC*. At the middle points of *AB* and *BC* suppose perpendiculars erected. These perpendiculars will intersect at some point *O*, since *AB* and *BC* are not in the same straight line."

Now the tremendous existential import of the problem, to draw a circle through three non-costraight points, will be recognized when I say that in general, it is not possible. In the Lobachevski geometry not every triangle has its vertices concyclic. Granting that every three points must be costraight or concyclic, we prove the parallel-postulate.

Of the possible geometries we cannot say *a priori* which shall be that of our actual space, the space in which we move.

The hereditary geometry, the Euclidean, is underivable from real experience alone, and can never be proved by experience. Euclidean space is, at least in part, a creation of the human mind. Its adequacy as a subjective form for experience has not yet been disproved. It can never be proved.

The realities which with the aid of our subjective space form we understand under motion and position, may, with the coming of more accurate experience, refuse to fit in that form.

Our mathematical reason may decide that they would be fitted better by a non-Euclidean space form.

Comparative geometry finally overthrows that superficial method which pretends to found a logically sound exposition of geometry on "direction," undefined.

For more than 20 years Wentworth gave his definition "A straight line is a line which has the same direction throughout its whole extent." (1877, Def. 8. 1886, p. 4; 1888, § 17).

At last he discards his aged error, and takes the definition of non-Euclidean geometry, "a straight is the line determined by two points" (1899, §§ 36 and 46).

Though the Bolyai and the Riemann geometries are founded on the straight, yet to say in them of two straights that they have the same direction has no ordinary meaning, since in Riemann every two straights cross and inclose a space, while in Bolyai every two parallels continually approach each other.

So as to direction, Wentworth has reformed, after 20 years in the land of nod.

But he still says, 1899, § 49, "A straight line is the shortest line that can be drawn from one point to another."

Now a relation of equality or inequality between two magnitudes must have some foundation, and be capable of some intelligible test. In the traditional geometry the foundation of all proof by Euclid's method consists in establishing the congruence of magnitudes.

To make the congruence evident, the geometrical figures are supposed to be applied to one another, of course without changing their form and dimensions. But since no part of a curve can be congruent to any piece of a straight, so, for example, no part of a circle can be equivalent to any sect from the definition of equivalent magnitudes as those which can be cut into pieces congruent in pairs.

In any comparison of size by congruence, we must be able to place one of the magnitudes or portions of it in complete or partial coincidence with the other. No such direct comparison can be instituted between a straight and a line no piece of which is straight. Thus the whole of Euclid's *Elements* fails utterly to institute or prove any relation as regards size between a sect and an arc joining the same two points. The operation of measurement we cannot effect, rigorously speaking, either for curves or for curved surfaces, since the unit for length is a sect, and the unit for area, the square on that sect. In fact, however little may be the parts of a curve, they do not cease to be curved, and consequently they cannot be compared directly with a sect; just as parts of a curved surface are not directly comparable with portions of a plane.

We cannot even affirm that any ratio exists between a circle and its diameter until after we have made some extra-Euclidean and post-Euclidean assumption at least equivalent to the following:

No arc is less than its chord; and no minor arc is greater than the sum of the tangents at its extremities. If the curve be other than a circle we assume that on it one can always take two points so near that the arc between these points is not less than its chord, nor greater than the broken line formed by the two tangents touching its extremities. Some such assumption is, in fact, necessary, but it destroys by itself the primitive idea of measuring curves with straights.

Duhamel gives the assumption the following form: The length of a curve shall be the limit toward which the length of a broken line made up of consecutive chords of that curve approaches, when the number of chords is increased in such a manner that the chords all approach zero as limit.

Thus the evaluation of the length of a curve represents not at all an attempt at rectification strictly; but it has for aim the finding of a limit to which another magnitude would approach.

In geometry one proves that as the subdivisions are increased and the sides tend toward the limit zero, the perimeter of the polygon inscribed in a circle increases, circumscribed decreases, toward the same limit, which then is assumed for the magnitude of the circle.

Therefore when Phillips and Fisher, of Yale, give as their definition of a straight (1898, p. 4, § 7. Def.) "A *straight line* is a line which is the shortest path between any two of its points," they pass through and beyond Euclid's *Elements* to give us his simplest element; they institute a comparison not only with circular arcs, but also with all curves known and unknown; they presuppose a foreknowledge of all lines in a definition of the simplest line. Is it still needful to say this is grossly bad logic, bad pedagogy, bad mathematics.

This same Yale geometry blunders horribly on p. 23, where it says: "In fact, Lobatchewsky in 1829 proved that we can never get rid of the parallel axiom without assuming the space in which we live to be very different from *what we know it to be through experience.*

Lobatchewsky tried to imagine a different sort of universe in which the parallel axiom would not be true. This imaginary kind of space is called *non-Euclidean* space, whereas *the space in which we really live* is called *Euclidean*, because Euclid (about 300 B. C.) first wrote a systematic geometry of our space."

The scientific doctrine of evolution postulates a world independent of man, and teaches the outcome of man from lower forms of life in accordance with wholly natural causes. In this world of evolution experience is a teacher, but man is a creator, and the mighty examiner is death.

The puppy born blind must still be able, guided by the sense of smell, to superimpose his mouth upon a source of nourishment. The little chick, responding to the stimulus of a small bright object, must be able to bring his beak into contact with the object so as to grasp and then swallow it. The springing goat that misjudges an abyss is lost.

So too with man. His ideas must in some way correspond to this independent world, or death passes upon him an adverse judgment.

But it is of the very essence of the doctrine of evolution that man's metric knowledge of this independent world, having come by gradual betterment and through imperfect instruments, for example the eye, cannot be absolute and exact.

The results of any observations are always with certain definite limitations as to exactitude and under particular conditions.

Man the creator replaces these results by assumptions presumed to have absolute precision and generality, such as, for example, the so-called axioms of Euclid.

If two natural hard objects, susceptible of high polish, be ground together, their surfaces in contact may be so smoothed as to fit closely together and slide one on the other without separating. If now a third surface be ground alternately against each of these two smooth surfaces until it accurately fits both, then we say that each of the three surfaces is approximately plane, is a piece of a plane.

If one such plane be made to cut through another, we say the common line where they cross is approximately a straight.

The perfect, the ideal plane is a human creation under which we seize the imperfect data of experience.

If three approximate planes on real objects be made to cut through a fourth approximate plane, then three approximate straights are formed on this fourth plane, and in general they are found to intersect, and the figure they make we may call an approximate triangle.

Such triangles may vary greatly in shape. But no matter what the shape, if we cut off the six ends of any two such, and place them side by side on a plane with their vertices at the same point, the six are found with a high degree of approximation just to fill up the plane about the point. If the whole angular magnitude about any point in a plane be called a perigon, then we may say that the six angles of any two approximate triangles are found to be together approximately a perigon.

Now does the exactness of this approximation to a perigon depend only on the straightness of the sides of the original two triangles, or also upon the size of these triangles?

If we know with absolute certitude that the size of the triananglesangles has nothing to do with it, then we know something that we have no right to know according to the doctrine of evolution, something impossible for us ever to have learned evolutionally.

Yet before the epoch-making ideas of Bolyai János and Lobachevski, everyone supposed we were perfectly sure that the angle-sum of an actual approximate triangle approached a straight angle with an exactness dependent only on the straightness of the sides and not at all on the size of the triangle.

But if in the mechanics of the world independent of man we were absolutely certain that all therein is Euclidean and only Euclidean, then Darwinism would be disproved by the reductio ad absurdum.

All our measurements are finite and approximate only.

The mechanics of actual bodies in what Cayley called the external space of our experience, might conceivably be shown by merely approximate measurements to be non-Euclidean, just as a body might be shown to weigh more than two grams or less than two grams, though it never could be shown to weigh precisely, absolutely two grams.

The outcome of the non-Euclidean geometry is a new freedom to explain and understand our universe and ourselves.

SPECTROSCOPIC NOTES.

Arrangements for observing the total eclipse of May 28 have been so far completed as to insure adequate observation by well equipped expeditions. Most of the large observatories will be represented by observing parties, usually of several trained observers, well reinforced by amateur enthusiasts. The stations are chosen for the most part in North Carolina, Georgia, and eastern Alabama; in fact they are probably less widely distributed than they should be. Given only good weather, valuable results seem certain.

Popular interest in the eclipse and its results is evidently considerable. In view, however, of the importance, beauty, and rarity of the phenomenon, this interest ought, much more frequently than seems now to be the case, to take the form of planning to be present in person in the path of totality.

Mr. J. Lunt, *Proceedings of the Royal Society* No. 425, describes experiments which led him to ascribe certain lines in some of the helium stars to silicon. Like Sir Norman Lockyer he found these lines given off by vacuum tubes under a strong disruptive spark, and traced them to silicon derived from the glass of the tubes. In experiments with silicon tetrafluoride the differences in the behavior of silicon under different circumstances of discharge were exhibited in a striking manner.

Professor Campbell (*Astrophysical Journal*, March) finds a variable velocity in the line of sight for β Herculis. The period of the variation is unknown, but seems to be long.

In the *Astronomische Nachrichten*, No. 3629, Dr. K. Schwartzschild publishes a modification of the method of Professor Lehman Filhés for the computation of the orbit of a spectroscopic binary, by which the labor of the process is abridged.

Publications of Sir William Huggins' Observatory, Vol. I (William Wesley and Son, London) contains Sir William and Lady Huggins' Atlas of Representative Stellar Spectra from λ 4870 to λ 3300. The volume opens with a short history of the Observatory, and contains, with the Atlas, a discussion of the evolutional order of the stars and the interpretation of their spectra.

In the *Astrophysical Journal* for March Professor Campbell gives the theory of the velocity of the Moon in the line of sight. As Venus and Mars are not always available to test the accuracy of measures of radial velocity it is sometimes desirable to obtain spectrograms of the Moon for the purpose. The distance, place of observation to Moon plus Moon to Sun, the change of which is the effective radial velocity of the Moon, may vary at a rate almost as great as two kilometers per second. This motion is divided into several parts, the expression for each of which is so arranged as to be easily computed from data given in the Nautical Almanac. In an example Professor Campbell finds for the computed velocity + 1.14 kilometers for second, and for the measured velocity + 1.46 km. per second.

In his annual report President Eliot of Harvard University states that Mrs. Fleming, whose name appears in the University catalogue as Curator of Astronomical Photographs, is believed to be the first woman who has held an official position in Harvard University.

The February number of the *Monthly Notices of the Royal Astronomical Society* contains the annual report of the Council. The Proceedings of Observatories contain, in a number of cases, reference to spectroscopic work. At the Cape of Good Hope the McClean photographic equatoreal has been used with the slit spectroscope for the study of star spectra, yielding the discovery of oxygen and of silicon in certain stars; the object-glass has now, however, been returned to the maker for correction. At Cambridge the work on star spectra with the Bruce spectroscope has been brought to a conclusion. At Stonyhurst a study of the Sun with a grating spectroscope has shown about the same degree of solar activity in 1899 as in 1898; also, the stellar spectrograph has been used to continue the investigation of possible changes in certain selected stars. At Wolsingham the search for stars with remarkable spectra has been continued with success.

Of the summary of progress of astronomy during the year spectroscopic work is the subject of about one-fourth. The advance in stellar spectroscopy is summarized in a compact article occupying four pages, while two pages are devoted to a review of Sir William and Lady Huggins' Atlas of Representative Star Spectra.

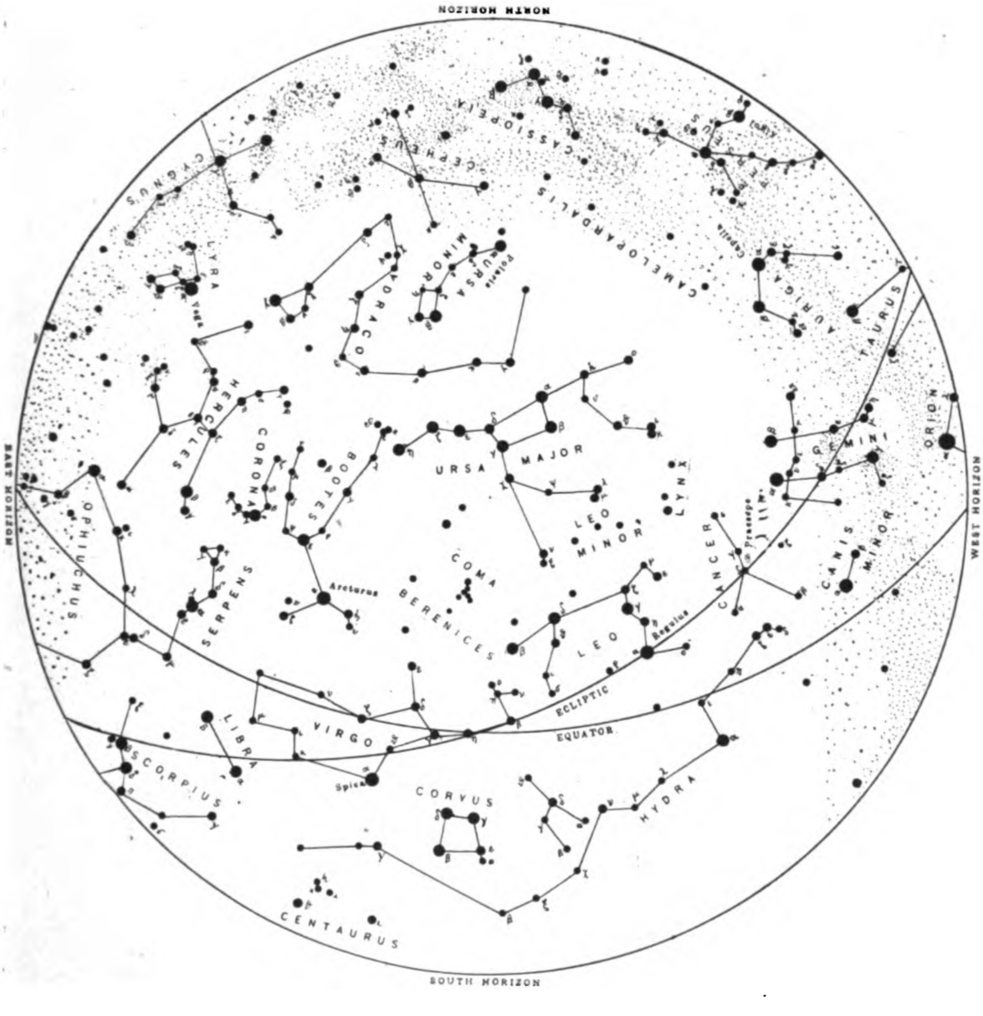
Mr. Wright (*Astrophysical Journal*, March) has computed the orbit of the spectroscopic binary χ Draconis from the results of 28 plates obtained with the Mills spectrograph of the Lick Observatory. For the projection in the line of sight of the major axis he finds 62,000,000 kilometers (39,000,000 miles), with a probable error of 400,000 km. (260,000 mi.); for the eccentricity 0.423, with probable error 0.006; and for the period 281.8 days, with probable error 0.7 days. The spectrum of χ Draconis, resembling that of Procyon, with the $H\gamma$ line of hydrogen well defined and the metallic lines sharp and well separated, was very suitable for measurement.

The death of Miss Catherine W. Bruce removes a very liberal friend of astronomical science, by whose ready and well directed financial aid the construction of much important spectroscopic and photographic apparatus and the prosecution of many valuable researches have been made possible.

PLANET NOTES FOR MAY.

H. C. WILSON.

Mercury is morning star, but too close to the Sun to be observed. At the time of the total eclipse Mercury will be just a little way west from the Sun as shown upon the eclipse chart No. 3, given in this number of POPULAR ASTRONOMY. It will doubtless be visible during totality of the eclipse and observers not in the path of totality might well spend some time in looking for the planet at the time of maximum eclipse. Mercury will then be so near superior conjunction that its disc will be fully illuminated and if those markings which Mr. Lowell's observers at Flagstaff saw so plainly are ever to be seen by others this should be the time. It is true Mercury will be on the farther side of the Sun and and its disc will be small, yet this would only reduce the size of the markings by one-half. For those, therefore, whose time is not occupied with the study of the corona and who have the use of telescopes with apertures of six inches and upwards, it may be well worth the while to study this planet carefully. Mercury will reach superior conjunction on the morning of May 30, being very near perihelion at the same time, and after that will be evening star.



THE CONSTELLATIONS AT 9 P. M., MAY 1, 1900.

Venus has just passed greatest elongation east from the Sun and will this month turn in toward the line joining Earth and Sun. The phase of Venus is now like that of the half Moon and will decrease gradually during the month. The planet, however, will continue to rapidly approach the Earth so that its brilliancy will still increase up to the first of June. Venus, the Moon, the Pleiades and the Hyades made a very pretty group in the western evening sky on

April 2. Venus will be in conjunction with the Moon again on May 2 but the Pleiades and the Hyades will be far down toward the west at that time. Again on May 31 there will be another conjunction of Venus and the crescent Moon.

Mars is morning star about 22° west from the Sun, declination 6° north. Its angular distance from the Sun and its northern declination will steadily increase throughout the summer and so the planet will come into more and more favorable position for observation. Mars will be in conjunction with Mercury on May 3, Mars being 2° north of Mercury. At the time of the total eclipse of the Sun, May 28, Mars will be near the meridian toward the south, and will no doubt be visible to the naked eye at the time of totality.

Jupiter will be at opposition May 27 and so may be best observed during the two hours before and after midnight.

Saturn may be observed between midnight and morning, being seen low in the south or southeast, according to the hour of observation, in the constellation Sagittarius.

Uranus is near Jupiter, in Scorpio, and may be observed at the same hours.

Neptune is now low in the west in the evening, in the constellation Taurus, and practically out of position for observation for the remainder of this year.

Phenomena of Jupiter's Satellites.

Central Standard Time.

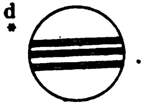
	h	m		
May 1	9	52 P. M.	I	Sh. In.
	10	28 "	I	Tr. In.
2	12	05 A. M.	I	Sh. Eg.
	12	40 "	I	Tr. Eg.
	10	00 P. M.	I	Oc. Re.
5	10	27 "	II	Ec. Dis.
6	1	51 A. M.	II	Oc. Re.
	10	52 P. M.	III	Sh. In.
7	12	48 A. M.	III	Sh. Eg.
	12	57 "	III	Tr. In.
	2	35 "	III	Tr. Eg.
	8	53 P. M.	II	Tr. Eg.
8	2	40 A. M.	I	Ec. Dis.
	11	46 P. M.	I	Sh. In.
9	12	13 A. M.	I	Tr. In.
	1	59 "	I	Sh. Eg.
	2	25 "	I	Tr. Eg.
	9	09 P. M.	I	Ec. Dis.
	11	44 "	I	Oc. Re.
10	8	28 "	I	Sh. Eg.
	8	51 "	I	Tr. Eg.
13	1	01 A. M.	II	Ec. Dis.
	4	07 "	II	Oc. Re.
14	2	49 "	III	Sh. In.
	4	16 "	III	Tr. In.
	8	45 P. M.	II	Tr. In.
	10	33 "	II	Sh. Eg.
	11	09 "	II	Tr. Eg.
16	1	40 A. M.	I	Sh. In.
	1	57 "	I	Tr. In.
	3	53 "	I	Sh. Eg.
	4	09 "	I	Tr. Eg.
	11	02 P. M.	I	Ec. Dis.
May 17	1	28 A. M.	I	Oc. Re.
	8	09 P. M.	I	Sh. In.
	8	23 "	I	Tr. In.
	10	22 "	I	Sh. Eg.
	10	35 "	I	Tr. Eg.
21	10	40 "	II	Sh. In.
	10	58 "	II	Tr. In.
22	1	07 A. M.	II	Sh. Eg.
	1	22 "	II	Tr. Eg.
24	12	57 "	I	Ec. Dis.
	3	12 "	I	Oc. Re.
	9	08 P. M.	III	Ec. Dis.
	10	03 "	I	Sh. In.
	10	07 "	I	Tr. In.
	11	06 "	III	Oc. Re.
25	12	16 A. M.	I	Sh. Eg.
	12	19 "	I	Tr. Eg.
	7	25 P. M.	I	Ec. Dis.
	9	39 "	I	Oc. Re.
29	1	12 A. M.	II	Tr. In.
	1	14 "	II	Sh. In.
	3	36 "	II	Tr. Eg.
	3	42 "	II	Sh. Eg.
30	7	21 P. M.	II	Oc. Dis.
	9	55 "	II	Ec. Re.
31	2	53 A. M.	I	Oc. Dis.
	4	59 "	I	Ec. Re.
	11	51 P. M.	I	Tr. In.
	11	57 "	I	Sh. In.
June 1	12	41 A. M.	III	Oc. Dis.
	2	03 "	I	Tr. Eg.
	2	10 "	I	Sh. Eg.
	2	52 "	III	Ec. Re.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., Eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

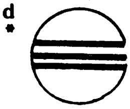
Jupiter's Satellites for May.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

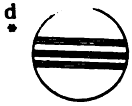
I.



III.



II.



IV.

No Eclipse.

Configurations at 11ʰ 30ᵐ for an Inverting Telescope.

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

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900.

U CEPHEI.

	d	h
June	3	11
	5	22
	8	10
	10	22
	13	10
	15	22
	18	10
	20	21
	23	9
	25	21
	28	9
	30	21

S CANRCRI.

	d	h
June	9	2
	18	14
	28	1

δ LIBRAE.

	d	h
June	3	10
	5	18
	10	10
	12	18
	17	9
	19	17
	24	9
	26	17

U CORONAE.

	d	h
June	9	13
	13	0
	16	11
	19	22
	23	9
	26	19

U OPHIUCHI.

Every 10th min.
P = $20^h.1$

	d	h
June	2	14
	10	23
	19	9
	27	18

Z HERCULIS.

	d	h
June	3	14
July	1	13

2P = $3^d\ 23^h.8$

W. DELPHINI.

	d	h
June	3	17
	8	13
	13	8
	22	23
	27	18

Y CYGNI.

Even min.

	d	h
June	2	15
July	2	14

2P = $2^d\ 23^h.9$

Odd min.

	d	h
May	31	18
June	30	17

2P = $2^d\ 23^h.9$

+ 45°3062.

	d	h
June	4	17
	9	7
	13	21
	18	11
	23	0
	27	14

Maxima and Minima of Long Period Variables.

1900 July.

MAXIMA.

Day.	Star.
3	RT Cygni
4	S Virginis
5	T Columbæ
5	V Geminorum
5	T Pegasi
6	U Bootis
9	V Cassiopeæ
10	S Leonis
12	V Libræ
13	U Lyræ
16	Z Virginis
17	W Lyræ
18	S Aquarii
18	R Ceti

MAXIMA.

Day.	Star.
20	U Cassiopeæ
20	Z Aquarii
20	RR Cygni
20	RZ Cygni
22	S Urase minoris
24	Y Virginis
25	R Capricorni
25	R Virginis
27	S Pegasi
28	W Ophiuchi
30	X Aquarii
31	*o* Ceti (Mira)
31	R Comae

MINIMA.

Day.	Star.
8	Z Ophiuchi
9	V Bootis
11	W Monocerotis
11	S Sagittarii
14	R Persei
19	S Cephei
20	T Cephei
28	S Arietis
29	—Pegasi*

NOTES TO THE EPHEMERIS.—For this month it contains only those stars which are given in Dr. Hartwig's ephemeris in the *Vierteljahrsschrift*, and the long period ephemeris is essentially in the form there given.

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* The star "—Pegasi," whose minimum is given for June 29, is at $21^h\ 16^m\ 15^s$, + 14° 1′.6, (1900).

Additional Notes.

U GEMINORUM.—This star was found normal, 13.4 magnitude, by Zaccheus Daniel, 1900 March 28.57, Greenwich Time, and 9.8 magnitude by the writer, March 30.60. At this writing, April 9, it is still a little brighter than the 11th magnitude, showing it to be a "long" maximum.

SS CYGNI.—The late maximum was covered by 11 observations, 8 by Zaccheus Daniel and 3 by J. A. Parkhurst. It was found normal by Daniel 1900 March 2.91 (*i. e.* 11.2 magnitude); and slightly brighter, about 10.8 magnitude, March 3.50. It was found in full light, 8.46 magnitude, by Parkhurst, March 6.96. It reached normal light about March 23, showing this to be a maximum of the ordinary "long" type, duration 20 days. The strange thing is that the previous maximum, that of 1900 January, was also long. Previous to this, there has been no break in the regular alternation of short and long types, since the two successive short max ma of March and April, 1897, with the exception of the abnormal maximum of 1899 November, which did not interfere (at least immediately) with the regular order.

Report of Rousdon Observatory.*—Observations of long period variable stars during the year 1899, by Sir Cuthbert E. Peek, Bart., M. A., F. R. A. S., C. Grover, assistant.

On 167 nights in 1899 570 magnitude determinations were made. During the 14 years this work has been in progress 6,248 magnitude determinations have been made, each consisting of five visual comparisons. Thus during 1899, 3,420 estimates of brightness have been made.

Instrument used, a 6.4 inch Merz refractor, powers 34, 80 and 132. A 13.5 magnitude star is the limit of vision (on the H. C. O. photometric scale).

About 30 long period variables, mostly circumpolar, are systematically followed, continuously through the year. In 14 years, 245 maxima and 214 minima have been observed.

For 1899.

	MAXIMA.		MINIMA.	
	T.	Mag.	T.	Mag.
T Cass.........	April 17	7.3	Sept. 29	11.3
S "	——	——	June 15	12.7
S Persei	——	——	Dec. 4	10.0
R Aurigæ......	April 17	6.9	——	——
U Orionis......	" 15	6.0	Nov. 26	11.8
R Lyncis.......	Aug. 9	6.5	Jan. 16	13.5
R Urs. Maj....	" 12	7.6	Mar. 4	13.1
T " "	July 3	6.3	" 15	12.6
T " "	——	——	Nov. 15	13.0
S " "	July 20	7.5	April 7	11.6
S " "	——	——	Oct. 30	12.2
S Bootis.......	July 3	8.3	Feb. 1	13.0
S "	——	——	Nov. 20	13.0
R Camelop.....	May 2	8.0	Jan. 6	< 13.0
R "	——	——	Sept. 26	13.6

	MAXIMA.		MINIMA.	
	T.	Mag.	T.	Mag.
R Urs. Min.....	——	——	Sept. 26	10.4
R Draconis....	June 18	7.6	Feb 27	11.9
R "	——	——	Nov. 26	13.3
S Herculis	Sept. 21	6.4	——	——
T Draconis.....	Aug. 16	8.0	Feb. 28	12.1
R Cygni........	Feb. 19	7 3	——	——
χ "	May 22	3.6	1898 Dec. 20	12.6
" "	——	——	1899 Nov. 26	12.0
S "	Mar. 4	10.2	——	——
T Cephei.......	1898. Dec. 28	5.6	June 3	9.5
S "	——	——	May 2	12.6
R Cass.........	June 3	5.8		

During the year 17 maxima and 22 minima have been observed.

Variable Star Notes No. 4, containing observations of *R* and χ Cygni for 10 years, 1887 to 1896, and No. 5. containing U Orionis and S Herculis for 13 years, 1886 to 1898, have been published and distributed.

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* Extract from the *Journal of the British Astronomical Association.*

NEW VARIABLE STARS.

The star BD. + 46°2966 has been found variable from the photograph by Mr. A. Stanley Williams, and confirmed by Prof. Deichmüller. (A. N. Nos. 3629 and 3632). The position of the star is—

R. A. 20^h 28^m 9.7^s, Dec. + 46° 6′ .1, (1855)
29 38.0 10 .2, (1900)

The range so far observed has been from 7.0 to 10.0 magnitude. A period of 31.0 days satisfied the observations of Mr. Williams, but Prof. Deichmüller considers that it may be 15 days. This stamps it as a variable of unusual interest and it should be closely watched.

Rev. Anderson, has found to be variable an anonymous star in the position—

R. A. 20^h 8.5^m, Dec. + 46° 12′, (1855)

The observed magnitudes are—

1900 Jan. 16, 8.8
19, 8.7
1900 Feb. 20, 9.0
Mar. 14, 9.5.

COMET AND ASTEROID NOTES.

Comet a 1900 (Giacobini).—In *Astronomische Nachrichten* No. 3627, Dr. Berberich gives the following approximate ephemeris of Giacobini's comet, which shows that the comet will be nearest the Earth about Aug. 1, but that it will be brightest theoretically about July 1. It will be favorably situated for observation during all of the summer, but will become rapidly fainter in the autumn, because of its recession from the Earth.

EPHEMERIS OF COMET a 1900.

	R. A.		Decl.		log r.	log Δ.	Br.
	h	m	°	′			
April 27	1	33.2	+ 17	28	0.1245	0.3622	0.93
May 29	1	09.0	+ 27	07	0.1483	0.2862	1.18
June 30	23	46.9	+ 41	31	0.2085	0.1376	1.77
Aug. 1	19	36.3	+ 41	20	0.2794	0.0778	1.68
Sept. 2	17	39.2	+ 17	50	0.3472	0.2623	0.53
Oct. 4	17	23.2	+ 5	55	0.4081	0.4316	0.18

Ephemeris of Asteroid (11), Parthenope.

	R. A.			Decl.			log Δ.
	h	m	s	°	′	″	
May 2	16	10	14.9	− 13	36	58	0.1585
6		7	07.9	13	25	29	0.1521
10		3	43.4	13	14	14	0.1468
14	16	00	05.1	13	03	26	0.1427
18	15	56	17.3	12	53	21	0.1399
22		52	24.5	12	44	11	0.1383
26		48	31.6	12	36	11	0.1380
30	15	44	43.5	− 12	29	36	0.1390

Opposition, May 21. Magnitude = 9.1.

GENERAL NOTES.

We have added sixteen pages to the usual size of this publication to print a revise of Professor Halsted's article on Non-Euclidean Geometry. Bad service by an express company makes this necessary.

Goodsell Observatory Eclipse Expedition.—We are now planning for a trip to the line of totality of the eclipse of May 28, 1900, at a point probably in North Carolina. If such a plan should be carried out, the next issue of this publication will be delayed until about the middle of June.

Note Supplemental to Paragraph Ending near Bottom of Page 229.—Since writing that paragraph satisfactory results, as far as contrast is concerned, have been obtained by the use of a strong hydrochinon developer. By this means all the contrast needed can be obtained even on the most rapid plates, without in the least diminishing their rapidity. For my own work I intend to use Seed 27 plates exclusively. Some of the negatives of the inner corona, where plenty of contrast is usually shown, will be developed with rodinal, one part in thirty-two of water. All negatives of the outer corona will be developed with hydrochinon, by Cramer's formula. By this plan, since rapid plates may be used instead of slow ones, the exposures above recommended may be reduced from ten to fifteen times.

CRAMER'S HYDROCHINON DEVELOPER.

I.

Water	25 oz.
Sulphite of Sodium Crystals	3 "
Hydrochinon	½ "
Bromide of Potassium	¼ "

II.

Water	25 oz.
Carbonate of Sodium Crystals	6

Mix equal parts for use, and develop not over six or eight minutes at a temperature of 70°. Carbonate of Sodium Crystals 6 oz. (also called Sal Soda or Washing Soda) are equivalent to 2½ oz. when pulverized and dried. Sulphite of Sodium 3 oz. are equivalent to 1½ oz. when dried or granulated.

WILLIAM H. PICKERING.

MEADOW VIEW, Chatham, N. J., April 16, 1900.

EDITOR OF POPULAR ASTRONOMY:—Will you allow me, through your magazine, to call the attention of readers of my book, "*Star-Names and their Meanings*," to my error in omitting to give his due share of credit to R. T. A. Innes, Esq., of the Royal Observatory at the Cape of Good Hope in the discovery of the new "runaway star" in Pictor. This omission occurred on page 214, and is repeated on page 446 in the remarks on "1830 Groombridge," where I assigned the discovery solely to Professor Kapteyn, making no reference to Mr. Innes.

I exceedingly regret this omission, and all the more as the original announcement by Professor Katepyn in the *Nachrichten*, No. 3466, was explicit as to Mr. Innes' large share in the discovery.

As the latter has sent me the Royal Observatory *Report* for 1897, with the detailed history of the discovery, I transcribe and inclose what Doctor Gill, the Director of the Observatory, has to say on the subject. Some part, or indeed the whole, of this you may think of interest in your columns, for the star in question, as you know, shows the greatest proper motion as yet determined.

RICHARD HINCKLEY ALLEN.

Report of Her Majesty's Astronomer at the Cape of Good Hope to the Secretary of the Admiralty for the year 1897, 1898.—"But by far the more interesting result of this examination has been the discovery of an 8th magnitude star having annual proper motion amounting to nearly 9″ of arc in the great circle, *the largest proper motion yet known.*

In regard to this star (No. 8 of List I.) Kapteyn had remarked—No. 8, 5^h 6^m $40^s.6$, 44° 58′.2, Z. C. V. 243, Mag. 8. 'Certainly missing on two plates.'

On 1897, February 2d, Mr. Innes looked for this star, and found none in the given position, but he found a full yellow star, 8.3 Mag., about 15 seconds in R. A. from the required place. The following day I transmitted to Professor Kapteyn this note of Mr. Innes, with his query 'Do you find the star 5^h 6^m $56^s.0$, 44° 58′ on the C. P. D. plates? It is difficult to think the Z. C. wrong 15^s on two occasions, or that the bright star 5^h 6^m 56^s could have been overlooked. Can this be proper motion?'

On August 24th Kapteyn wrote requesting that the star in question should be again looked up, because the observations now stood thus:

		Mag.	α			δ		
Gould. Z C.	1873.0	8	5^h	6^m	$40^s.6$	— 44°	58′.2	2 obs.
C. P. D.	1890.1	9.2		6	50 .8		59 .5	4 obs.
Innes	1897.0	8.3		6	56 .0		58.0	——

The R. A. agreeing very well on the supposition of a proper motion of $0^s.64$, but not so the Declinations. Could there be a mistake in Mr. Innes' Declination?

On September 22 I replied that there was no doubt that the star C. Z. V. 243 is the star of greatest known proper motion, that Innes' observation of 1897.0 had not been an observation in Declination, because finding no star in the required R. A., he had simply noted the neighboring star differing 15^s in R. A. and having *about* the same Declination as the missing star. But on February 15th he had re-observed the star and found α 5^h 6^m 56^s, δ — 45° 0′.4, and that the estimated motion of the star on one of the catalogue plates made a proper motion of about + $0^s.64$ and — 0′.1 in Declination certain.

On October 27th I forwarded results of two meridian observations of the star made on October 23d and 24th. A preliminary note has been communicated to the *Astr. Nach.*, No. 3464, by Professor Kapteyn. A complete investigation of the proper motion and parallax of this remarkable object will be made at the Cape."

Professor Henry S. Pritchett, Superintendent of the Coast and Geodetic Survey, has resigned his place to accept the presidency of the Massachusetts Institute of Technology of Boston. He was the youngest superintendent that the Coast Survey has ever had, and he has been one of the most capable.—*Scientific American,* April 14.

Rotation of Venus.—A telegram has been received at the Harvard College Observatory from Professor Kreutz at Kiel, Germany, stating that he has information from Professor Backlund, Director of the Observatory at Pulkowa, Russia, that, from a discussion of spectrograms, Belopolsky has found the time of rotation of Venus to be short.

This telegram was distributed to American astronomers April 10. It will be remembered by the reader that there has been considerable dispute between observers of the surface markings of Venus, as to whether the period of rotation is approximately twenty-four hours or is equal to the period of revolution around the Sun, 225 days. We shall await with great interest the details of Professor Belopolsky's observations.

The Total Solar Eclipse of May 28.—So far as known at present, the arrangement of British observing parties is as follows:

OFFICIAL EXPEDITIONS.

Ovar.—The Astronomer Royal will take large scale photographs of the corona, using the Thompson 9 inch object-glass and telephoto concave magnifier to obtain photographs on the scale of 4 inches to the Sun's diameter on 15 by 15 inch plates. The double tube with a 4-inch rapid rectilinear lens of 33-inch focus and a special rapid lens of about 13 inches focus will be used in an attempt to obtain photographs of long extensions of the corona. Mr. Dyson will have in his charge two slit spectroscopes belonging to Capt. Hills and used by him in India in 1898, with which to photograph the spectrum of the flash and of the corona.

Alicante.—Sir Norman Lockyer, who will probably be accompanied by Mr. Fowler and Dr. Lockyer, will be stationed near the central line south of Alicante. The chief instruments to be used here are prismatic cameras, one of which will have an aperture of 6 inches and a focal length of 20 feet.

Algiers.—Professor Turner and Mr. Newall, will be stationed at the Observatory of which M. Trepied is Director. Prof. Turner will have one of the double tubes which have been used in several previous eclipses. One section will be fitted with apparatus for photographing the corona by polarized light, the other will possibly be utilized for taking ordinary photographs of the corona. Mr. Newall will use: (A) a four-prism slit spectroscope for photographing the spectrum (i) of the flash, (ii) of the corona; (B) an objective grating camera for photographing the corona in monochromatic light; (C) a polariscope camera for photographing the corona.

Prof. C. V. Boys and Mr. Wesley will probably be also members of the official party at Algiers.

Mr. Evershed, will proceed to a spot about 20 miles south of Algiers, which is just within the limit of totality. This place is chosen, as it is his purpose to obtain photographs of the "flash" spectrum of as long duration as possible, and near the Sun's pole.

British Astronomical Association Expeditions. Algiers.—Mr. and Mrs. Maunder and family, will take short exposure photographs of the inner corona, and will also take photographs of long exposure for extensions. A prismatic opera glass will be used, if circumstances will allow. Mr. and Mrs. Crommelin, will use a tele-photo lens of about 80 inches, equivalent focal length and aperture 1½ inches to take photographs of the inner corona. They will also observe times of contact, and make sketches at the telescope of detail of the inner corona.—*The Observatory, April,* 1900.

Observatories in the United States having Refracting Telescopes.—From the Congressional Record of April 11, we copy the following list of telescopes in the United States:—

Observatory.	Aperture.	Director.	Location.
	Inches.		
Yerkes (University of Chicago)	40	George E Hale	Williams Bay, Wis.
Lick (University of California). [See also Students' Observatory below.]	36	J. E. Keeler	Mount Hamilton, Cal.
Naval, United States	26	C. H. Davis	Washington, D. C.
Leander McCormick (University of Virginia),	26	Ormond Stone	Charlottesville, Va.
Lowell	24	A. E. Douglass	Flagstaff, Ariz.
Halstead (Princeton University)	23	Charles A. Young	Princeton, N. J.
Chamberlin (University of Denver)	20	Herbert A. Howe	University Park, Colo.
Smithsonian Institution	20	Samuel P. Langley	Washington, D. C.
Northwestern (Dearborn) University	18.5	G. W. Hough	Evanston, Ill.
Flower	18	C. L. Doolittle	Upper Darby, Pa.
Goodsell (Carleton College)	16	Wm. W. Payne	Northfield, Minn.
Lowe	16	Lewis Swift	Echo Mountain, Cal.
Washburn (University of Wisconsin)	15.6	George C. Comstock	Madison, Wis.
Harvard College	15	Edward C. Pickering	Cambridge, Mass.
University of Mississippi	15	Chancellor R. B. Fulton	Oxford, Miss.
Litchfield (Hamilton College)	13.5	S. T. Saunders	Clinton, N. Y.
Columbia University	13	John K. Rees	New York City.
Western University of Pennsylvania	13	F. L. O Wadsworth	Allegheny, Pa.
Detroit (University of Michigan)	12.75	A. Hall, jr	Ann Arbor, Mich.
Morrison	12.5	C. W. Pritchett	Glasgow, Mo.
Emerson McMillin (Ohio State University)	12.5	Henry C. Lord	Columbus, Ohio.
Dudley	12	Lewis Boss	Albany, N. Y.
West Point (United States Military Academy)	12	Professor Peter S. Michie	West Point, N. Y.
Ladd (Brown University)	12	Winslow Upton	Providence, R. I.
Vassar College	12	Mary W. Whitney	Poughkeepsie, N. Y.
Wesleyan University	12	John M. Van Vleek	Middletown, Conn.
University of Cincinnati	11	J. G. Porter	Cincinnati, Ohio.
Daniel Scholl (Franklin and Marshall College)	11	J E. Kershner	Lancaster, Pa.
Smith (Hobart College) [See also Hobart College below.]	10	Wm. R. Brooks	Geneva, N. Y.
Lawrence University	10	F. E Millis	Appleton, Wis.
Bucknell University	10	W. C. Bartol	Lewisburg, Pa.
Haverford College	10	Wm. H Collins	Haverford, Pa.
Johns Hopkins University	9.5	Simon Newcomb	Baltimore, Md.
McKim (De Pauw University)	9.5	...	Greencastle, Ind.
Beloit College	9.5	Clement Rood	Beloit, Wis.
Shattuck (Dartmouth College)	9.4	Edwin B. Frost	Hanover, N. H.
Hartford Public High School	9.5	B. S. Annis	Hartford, Conn.
Catholic University	9	G. M. Searle	Washington, D. C.
Hobart College [See also Smith Observatory above]	8.75	H. L. Smith; Wm. R. Brooks	Geneva, N. Y.
Vanderbilt University	8.5	Wm. J. Vaughn	Nashville, Tenn.
Yale University	8	W. L. Elkin	New Haven, Conn.
Durfee High School	8	Iram N. Smith	Fall River, Mass.
Iowa College	8	S. J. Buck	Grinnell, Iowa.
Mount Holyoke College	8	Miss A. S. Young	South Hadley, Mass.
Alabama University	8	H. A. Sayre	Tuscaloosa, Ala.
Holden Memorial (Syracuse University)	8	Henry A. Peck	Syracuse, N. Y.
Annapolis (United States Naval Academy)	7.75	Lieut. Com'd. C. W. Bartlett	Annapolis, Md.
University of Missouri	7.5	J. N. Fellows	Columbia, Mo.
Amherst College	7.25	David P. Todd	Amherst, Mass.
Boston University	7.1	J. B. Colt	Boston, Mass.
University of Illinois	6	G. W. Myers	Urbana, Ill
Washington University	6.5	Wm. H. Roever	St. Louis, Mo.
Bates College	6.25	George C. Chase	Lewiston, Me.
Students' (University of California)	6	Armin O. Leuschner	Berkeley, Cal.
Swarthmore College	6	Miss S. J. Cunningham	Swarthmore, Pa.
Knox College	6	Chas. B. Thwing	Galesburg, Ill.
Central High School	6	Monroe B Snyder	Philadelphia, Pa.
Bowdoin College	6	C. C. Hutchins	Brunswick, Me.
Creighton University	5	Wm. F Rigge	Omaha, Nebr.
Iowa University	5	L. G. Weld	Iowa City, Iowa.
Georgetown University	4.8	John G. Hagen	Washington, D. C.
Williams College	4.8	Truman Henry Safford	Williamstown, Pa.

Following this table is found a very instructive statement regarding the equipment of these observatories, a part of which follows:

Yerkes Observatory of the University of Chicago, located at Williams Bay,

Wis., George E. Hale, Director.—The Yerkes Observatory has the form of a Latin cross, the longer axis of which lies due east and west. The 90-foot dome, which contains the 40-inch telescope, is at the western extremity of the building. At the eastern extremity is the meridian room, and the 26-foot and 30-foot domes terminate the north and south transepts. The motions of the great dome, the rising floor which gives access to the telescope in all its positions, and the telescope itself, are obtained by electric motors.

The large telescope is provided with all necessary accessories, including position micrometer, solar spectroscope, stellar spectrograph, spectroheliograph, and photoheliograph. In the 26-foot dome is mounted the 12-inch refractor, formerly at the Kenwood Observatory at Chicago, the entire instrumental equipment of this institution having been donated to the Yerkes Observatory. In the 30-foot dome a 24-inch reflecting telescope is mounted. The mirror of this instrument was made by Mr. W. G. Ritchey, optician of the Yerkes Observatory. Between the small domes is the heliostat room. Within the heliostat room are the mirrors and radiometer used by Professor Nichols for his measures of stellar heat radiations. In the meridian room, a small universal instrument, now at the students' observatory, was formerly used for latitude and time observations. A 3½-inch transit instrument is available for use. The body of the building, between the domes, is divided into laboratories for physical and chemical work and offices for members of the staff.

The principal work of the Observatory, under the director, George E. Hale, includes: 1. Observations of double stars with the 40-inch telescope, by Professor Burnham. 2. Micrometric observations of star clusters, nebulæ, planets, satellites, comets, etc., with the 40 inch telescope, by Professor Barnard. 3. Photographic studies of stellar spectra with the 40 inch telescope, by Professor Hale and Mr. Ellerman. 4. Determination of the motion of stars toward or from the Earth and of the motion of the solar system in space with the 40-inch telescope, by Professor Frost and Mr. Ellerman. 5. Spectroscopic observations of the Sun and photographic work with the spectroheliograph attached to the 40-inch telescope, by Professor Hale. 6 Stellar and nebular photography with a 6-inch portrait lens, by Professor Barnard, and with the 24-inch reflecting telescope, by Mr. Ritchey. 7. Miscellaneous spectroscopic and bolometric work. 8. Transit observations for the time service, by Mr. Adams.

Lick Observatory of the University of California, located at Mount Hamilton, California, J. E. Keeler, director.—The Observatory consists of a main building containing computing rooms, library and the domes of the 36-inch equatorial and the 12 inch equatorial, and detached buildings to shelter the Crossley reflector, the meridian circle, the transit, the horizontal photoheliograph, the portable equatorial, and the Crocker and Floyd photographic telescopes. On the ground are dwelling houses for the astronomers, students, and employees and shops for the workmen.

The Observatory is fully provided with instruments, some of which are the 36-inch equatorial objective, by Alvan Clark & Son, mounting by Warner & Swasey; this instrument has also a photographic corrector of 33 inches, figured by Alvan G. Clark; 3-foot reflecting telescope; 12-inch equatorial; 6-inch Bruce comet-seeker; 6½-equatorial mounting; 5-inch Floyd telescope; 6½ inch meridian circle; 4 inch transit; 4-inch comet seeker; 5-inch horizontal photoheliograph; Crocker photographic telescope; a spectroscope specially adapted for photography, given by Hon. D. O. Mills for use with the 36-inch refractor; a spectroscope specially adapted for photography with the Crossley reflector, and two photometers for use with the 36-inch and 12-inch telescopes have been provided from the proceeds of a gift from Miss C. W. Bruce, of New York City. There are, besides, many minor pieces of apparatus.

The scientific work of the Observatory is under the director, James E. Keeler. The students' observatory at Berkeley, Cal., described elsewhere, belongs to the University of California.

The general policy is to carry on investigations which cannot be pursued to so great advantage elsewhere. The observatory makes the most of its natural advantages, and extended theoretical researches, which can be made as well in a city as at a fine observing station, do not form a part of the general plan. The variety of instruments makes the field covered quite a wide one.

The principal work is devoted to spectroscopic determinations of the motions of stars in the line of sight, by Professor Campbell, assisted by Mr. Wright; and micrometric work and observations of the satellites of Neptune, Mars, and Uranus; measures of planetary nebulæ, for parallax; measures for determining a possible refractive effect on stars by the head of Swift's comet, by Professor Hussey and Messrs. Perrine and Aitkin; observations of comets, and, in the case of expected comets, for purposes of discovery; measurement and discovery of double stars, by Messrs. Hussey and Aitkin; astrophysical researches and photography of nebulæ, by Professor Keeler and Assistant Palmer; study of triple hydrogen lines, by Professor Campbell; investigation of stars in the great cluster in Hercules, by Mr. Palmer; telescopic photographs of the great nebulæ in Orion —an extension of the spectroscopic method to parts of the nebula which are too faint for visual observation; and a large variety of miscellaneous observations and computations.

United States Naval Observatory, located on Georgetown Heights, District of Columbia, Capt. C. H. Davis, U. S. N., director.—The instruments and accessories of the Naval Observatory consist of great equatorial and accessories (including elevating floor); east meridian circle (Pistor & Martens, 9-inch, remodeled); south transit instrument; prime-vertical instrument; 12-inch equatorial; 6-inch transit circle (Warner & Swasey); 5-inch alt-azimuth and building (Warner & Swasey); 1 comet seeker, 4-inch (Brashear), alt-azimuth: 1 comet seeker, 4-inch (old equatorial mounting); 13 astronomical clocks; 7 chronographs (with stands and scales); 3 personal-equation apparatuses; 2 level triers; meteorological apparatus; transit of Venus measuring engine; equipment of magnetic observatory; 1 kathetometer; instruments for testing sextants. Instruments unmounted: 9.6-inch equatorial, 7¾ equatorial, and Repsold transit of Venus, etc.

The instrumental equipment is for the most part new, few of the instruments of the old Observatory having been retained in their original form. An entirely new mounting has been provided for the 26-inch equatorial telescope, and the 9.6-inch telescope was replaced by a new refractor of 12 inches aperture. A large spectrograph, of modern design, was furnished for the 26-inch telescope. Two new instruments, constructed entirely of steel, were added to the equipment. One of these is a meridian circle of 6 inches aperture, and the other is a 5-inch alt-azimuth. The 8 5-inch Pistor & Martens meridian circle has been furnished with a new objective of 9.1 inches aperture and the mounting reconstructed. All the new instruments are of American make.

The Observatory work is divided into two classes, astronomical and nautical. The first includes the department of astronomical observations and the department of the Nautical Almanac. The second includes the department of nautical instruments, the department of chronometers and time service, and the department of magnetism and meteorology. A naval assistant is provided for the superintendent, and provision is made for a director of the Nautical Almanac and for heads of the various nautical departments.

On September 20, 1894, Prof. Wiiliam Harkness was appointed astronomical director. On June 30, 1897, he was also made director of the Nautical Almanac, after the resignation of Professor Hendrickson, who occupied the position for a short time after Professor Newcomb's retirement on March 12, 1897.

The work of the Observatory since its removal to the new site has included observations of the Sun, Moon and planets and certain ephemeris stars (suspended from 1891 to 1894), observations of stars in the zone —13° 50′ to —18° 10′ of the *Astronomische Gesellschaft*, observations of selected stars with the prime vertical transit and the alt-azimuth, micrometric observations with the 26-inch and 12-inch telescopes. Some photographs of stellar spectra have been made with the spectrograph attached to the 26-inch telescope. The meteorological observations have been continued, but magnetic work (first seriously undertaken in 1881) has been given up, owing to disturbances caused by electric cars. Professor Yarnall's catalogue, containing the positions of all miscellaneous stars, observed with the mural circle and transit instrument between 1845 and 1877, was published in 1878 (second edition). A third edition has since been brought out by Professor Frisby. Professor Eastman's catalogue of 5,151 stars, observed between 1866 and 1891, appeared in 1898. Of this catalogue the astronomical director remarks that it "has absorbed the labors of about two-thirds of the Observatory staff for more than thirty years."

Observing Stations for the Total Eclipse, May 28.—Professor Geo. E. Hale, Director of the Yerkes Observatory sends us the following note:

"The following list of stations to be occupied by eclipse parties is complete to date. I have not yet received replies from some of the most important institutions.

Norfolk, Va., National Geographic Society; Near Norfolk, Va. or Raleigh, N. C., Winslow Upton and party; Intersection of central line with Southern Railway, S. E. of Raleigh, N. C., C. W. Edwards and party; Wadesboro, N. C., parties of the Smithsonian Institution, Yerkes Observatory, Princeton University, and the British Astronomical Association; Newberry, S. C., U. S. Weather Bureau; At or near Macon, Ga., C. W, Crocket; Union Point, Ga., Charles Burckhalter; Thomaston, Ga., Lick Observatory; Brownsville, Ga., University of Virginia. (I have received this information at second hand): Washington, Ga., A. L. Rotch and party; Greenville, Ala., W. H. Pickering and party; Near Mexican Central Railway, Rose O'Halloran.

Professor Brown, Astronomical Director of the Naval Observatory, has not yet replied to the circular letter, but Professor See states that a number of parties will be sent out, one of which will go to Mexico. I have also learned that Professor Ames, of the Johns Hopkins University, Professor Crew, of the North-Western University, and Professor Lord, of the Ohio State University, will coöperate with the Naval Observatory. The Allegheny Observatory, Vassar College Observatory, and several other institutions will send out eclipse parties, but I do not now know what sites they will select." GEORGE E. HALE,

Secretary, Eclipse Committee.

Miss Rose O'Halloran will Observe the Total Eclipse in Mexico.—Miss Rose O'Halloran, of San Francisco, vice president of the Astronomical Society of the Pacific, will leave for Mexico about the middle of April to observe the total solar eclipse of May 28, 1900. After observing the southern variable stars for some weeks, as far south at least as the City of Mexico, Miss O'Halloran will travel northward about May 20, to the track of the lunar shadow, near the Mexican railway.

Her eclipse work will be carried on with unpretentious equipment. As the larger instruments of other observing parties from California and elsewhere will be used in positions further eastward in the United States, it has seemed to Miss O'Holloran wisely desirable to make photographic and visual observations near the western end of the path of totality.

The plan of Miss O'Holloran's work is to take a few photographs of the inner corona with a 4-inch Brashear refractor of six feet focal length, having a plate-holder and shutter in the focal plane of the telescope. The remaining time will be given to visual observations of the structure of the outer corona, and a drawing will be made when the total phase is ended.

As a mere experiment, a 2½-inch portrait lens will be tried for one second just before totality, and again, having reversed the plate-holder, will expose a plate for half a minute after totality. May favoring circumstances aid Miss O'Halloran's well-planned work.

The Lick Observatory Total Eclipse Expedition.—By the generosity of Mr. William H. Crocker, of San Francisco, the Lick Observatory will be able to send a party to Georgia, to observe the total solar eclipse of May 28. Only two observers, Messrs. W. W. Campbell and C. D. Perrine, will be sent out from the Observatory; but several European astronomers have expressed a desire to join the party, and similar requests have also been received from astronomers connected with American colleges which do not intend to send out expeditions of their own.

The instrumental equipment of the expedition will be quite complete. The principal instrument for photographing the corona will be the 5-inch telescope of 40 feet focal length, used by the Lick Observatory parties in South America and India. For photographing the corona on a smaller scale there will be several cameras of from five to six inches aperture, and others of smaller size. One slit spectrograph, and two objective spectrographs arranged to give a continuous record of the changing spectrum at the beginning and end of totality, are also included in the equipment. Observations of contacts will be made.

Any observers, having experience in astronomical or physical work, who wish to join the party at their own expense, like the gentlemen referred to farther above, are invited to communicate with the Director of the Lick Observatory before April 20, and after that date with Professor W. W. Campbell, Lick Observatory Eclipse Expedition, Atlanta, Georgia.

Queries and Short Answers.—8. What is the date and the path of totality of the next total solar eclipse visible in the United States. D. S.

Answer. The following letter by favor of H. D. Todd, Professor of Mathematics, U S. A., and Director of the Nautical Almanac, answers the query:

SIR:—I have the honor to state, in reply to your letter of the 2d instant, referred to this Office by the Naval Observatory, that the next total solar eclipse visible in the United States after that of May 28, 1900, will occur in 1918, June 8, G. M. T. This eclipse will commence in the Pacific Ocean, off the coast of China, and the central path will enter the United States at our extreme northwest corner, and follow approximately a path through the States of Washington, Idaho, Wyoming, Nebraska (the south-west corner), Kansas, Arkansas, Mississippi, Alabama and Florida, ending soon after it reaches the Atlantic Ocean.

I beg leave to add that there will also be a total eclipse of the Sun in 1905, August 30, not visible in the United States, but very near, commencing just north of the boundary line between Minnesota and North Dakota. The shadow path of this eclipse will pass nearly due east, turning slightly to the north, and will enter the Atlantic Ocean from the southern part of Labrador.

Very respectfully,

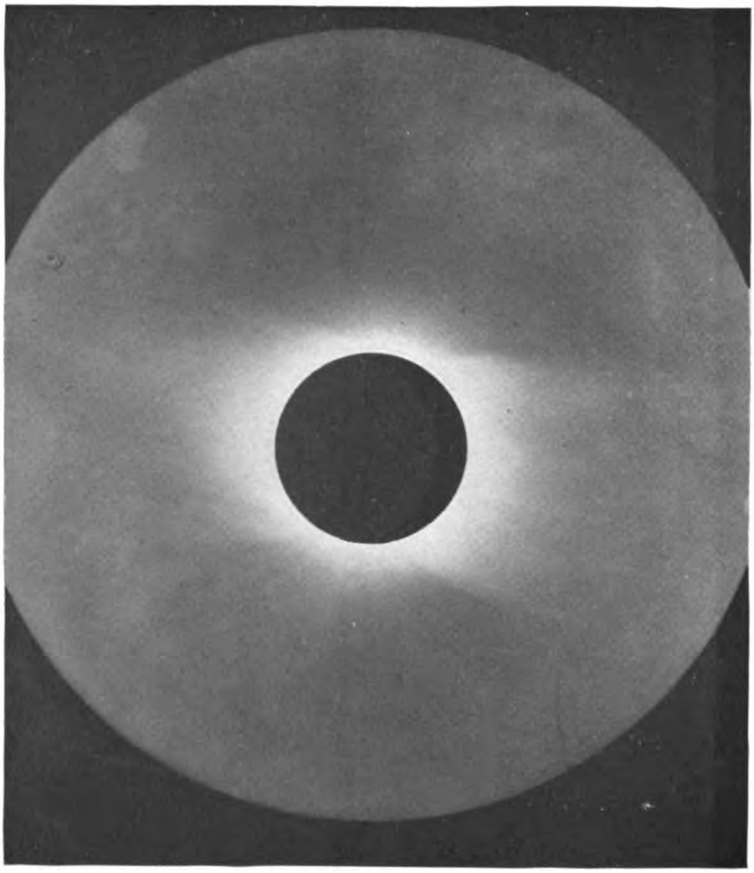
NAUTICAL ALMANAC OFFICE,
GEORGETOWN HEIGHTS, D. C.,
April 12, 1900.

H. D. TODD,
Professor of Mathematics, U. S. N.,
Director, Nautical Almanac.

9 I want an accurate up-to-date star map, one that shows Right Ascension and Declination correctly. Where can I get it? W J. L.

Answer. Professor Winslow Upton, has recently prepared a first rate Star Atlas with useful descriptive matter and a set of excellent star maps. The star places on these maps are reduced to 1900. Messrs. Ginn & Company, of Boston or Chicago are the publishers of this Star Atlas.

PLATE XI.



THE CORONA MAY 28, 1900.

Photographed with the 8-inch Clark Photographic Equatorial of Goodsell Observatory, near Southern Pines, N. C., by H. C. Wilson.

Popular Astronomy.

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THE TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.

H. C. WILSON.

Fair weather and splendid success seem to have been the lot of most of the astronomers who were scattered all along the path of totality across the United States. Probably no eclipse has ever been so extensively and successfully observed and much is to be expected from the photographic and spectrographic results which have been obtained.

It is too early to have obtained copies of the photographs taken at the various stations, so that we can present in this number of Popular Astronomy only some of those obtained by our own party, but we shall expect to present others in due time.

The frontispiece is a reproduction of one of the photographs of the corona taken near the end of totality with the 8-inch photographic refractor belonging to Goodsell Observatory. The exposure was 5 seconds, on a Seed nonhalation plate, backed with a paste of lampblack in 6 parts of essence of cloves to 1 part of turpentine. The plate was developed with weak pyro developer. It shows the two great streamers of the corona extending toward the west and one toward the east to the edge of the field of the telescope, besides many small streamers, some within and some alongside of the large ones. The polar streamers and rifts are well defined and their curvature is quite marked. At the lower right hand edge of the Moon's disk a row of brilliant prominences may be seen, one extending one-sixteenth of the Sun's diameter, or 54,000 miles from its edge. The photographic print shows these prominences much less plainly than the negative, and in the engraving they may be expected to be almost wholly lost.

The expedition from Carleton College to observe the eclipse was made possible by the generous enthusiasm of the junior class in the college, a large part of which has been studying Young's General Astronomy during the fall and winter terms, and Campbell's Practical Astronomy during the spring term. The class voted to defray the expenses of the expedition to the extent of one hundred and fifty dollars. We are greatly indebted also to the officials of the Chicago Great Western railway, through whose courtesy the party and instruments were conveyed to Chicago and back free of charge. Mention should also be made of the kind interest shown by the officials of the Chicago and Eastern Illinois and other roads, over which we passed, in their successful efforts to have our instruments handled carefully in transit.

The Faculty and trustees of Guilford College, near Greensboro, N. C., were much interested in the expedition and contributed largely to its success, in securing a favorable location, furnishing entertainment and rendering valuable assistance in the observations, a large party of the teachers and students being present at the observing station and taking assigned parts in the work.

The expedition was located near Southern Pines, N. C., on an eminence upon the large fruit farm of Mr. John Van Lindley, who very generously offered us the use of his commodious house and grounds, and bore the expense of our maintenance there. The Carleton party consisted of the writer as the astronomer in charge, with Professor and Mrs. A. H. Pearson, of Carleton College, as assistants. Mrs. Clements, of Faribault, also accompanied the party to North Carolina and assisted in sketching the corona. Our apparatus consisted of the 8-inch Clark photographic telescope of 9 ft. focus, the 6-inch Brashear stellar camera of 3 ft. focus and the 2½-inch Darlot lens of about 8 inches focus, all upon the same mounting and driven by clock work. With this apparatus, which was operated by the writer without assistance 8 photographs were taken: 4 of the corona during totality with the 8-inch telescope, the exposures being 1, 5, 30, and 5 seconds, the first two on Cramer crown plates and the last two on Seed nonhalation plates; 2 instantaneous exposures just a few seconds after totality upon nonhalation plates, both showing portions of the corona and chromosphere together with a reversed image of the sunlight crescent. With each of the cameras a single exposure was made, lasting 93 seconds, for the purpose of showing the outer extensions of the corona and any possible bright intra-mercurial planets. The last mentioned two photographs were both successful in showing the three long streamers of the corona extending out to at least two diameters from the edge of the Moon, but present only negative evidence of any bright planet other than Mercury near the Sun. Mercury is a conspicuous object upon both plates, but very few stars are noticeable.

The skylight was quite intense and comes out very black in the negatives. It may be that when I get time to go over the plates systematically with a microscope I shall find many more star images than I think now are there.

The plate exposed in the 6-inch camera was an 8x10 Seed non-halation backed with essence of cloves and lamp black. The field covered was 16° in diameter. The plate exposed in the 2½-inch camera was a 4x5 Cramer slow isochromatic, covering a field of 30° diameter, 20° of which is quite sharp in definition. Both plates were developed with quite strong hydrochinon developer in order to bring out strong contrasts. Both plates give practically the same extent of coronal streamers. With the 6-inch camera the chromosphere comes out very brilliant and partially reversed, while the prominences are entirely reversed.

Another piece of apparatus used was a prismatic camera consisting of two small 60° prisms, and a 3-inch visual lens of 30 inches focus, which were mounted in a box constructed at our station, after the photographic telescope had been got into adjustment. We had not fully decided to use these but took them along in case we should find time to mount them, yet doubtful whether the prisms, 1½ inches face, would give light enough for successful photographs of the "flash" spectrum. We were urged by Professors Hale and Frost, whom it was our great pleasure to accompany from Chicago to Wadesboro, to by all means make the attempt. The result shows that the combination of these small prisms and lens was quite sufficient to give at least the chromospheric spectrum. We had no collimator along and had to depend for the focus upon the sharpness, visually, of the edge of the continuous spectrum of the Sun. We adjusted it in this way as nearly as possible for the visual spectrum from *D* to *K* and used Cramer's instantaneous isochromatic plates 5x8.

With this camera, stationary during totality, Professor Pearson, assisted by Mr. Kelly of Haverhill, Mass., made four exposures, one beginning at the instant time was called by myself for the beginning of totality, as seen through the 5-inch guiding telescope, and ending at the count of 3 seconds; another from 15 to 75 seconds for the purpose of photographing the coronal ring; a third beginning at 87^s and ending at the call of time for the close of totality; and a fourth as short as possible, at 100^s, 6 seconds after the sunlight reappeared.

The photographs show a spectrum 5 inches long extending from D_3 to a little beyond *K*. Unfortunately, in planning for the long exposure without driving apparatus, I placed the edge of the prisms parallel to the direction of diurnal motion, not realizing that the curved cusp-lines of the Sun and chromosphere would be very nearly perpendicular to this direction. As a result the lines cross each other, all being nearly tangent at their brightest parts to a line lengthwise of the spectrum. They are therefore not suitable for reproduction and will be difficult of measurement. The first shows 12 very prominent chromospheric lines besides about 85 lesser ones. The plate is too much fogged to show the coronium line. The second is much blurred of course by the drift during the 60 seconds exposure, but is very interesting. It shows 15 prominences around the elliptic rings corresponding to the H and K lines, each prominence being drawn out into a line by the drift. The brighter of these prominences are shown in several other lines of the spectum, notably D_3, F, G' and h. The coronal spectrum is continuous from below D_3, running off the plate above K. The spectrum of the polar regions is faint forming a dark center to the band of the continuous spectrum. In the place of "coronium" line a ring is faintly shown. I was not able to see it until today, but when once pointed out it is easily seen. There is a faint suggestion of another similar ring near H and K, a little less refrangible than H, at about wavelength 3988. It is very vague but seems to me to be of the same form as its neighbor H, except as to the prominences.

The third plate, exposed just before the close of totality was jarred so badly during exposure that it is useless, but the coronium ring is plainly shown. An exceedingly faint suggestion of a ring is shown near H, but not sufficiently definite to be used as a verification of that in the second plate.

The fourth plate exposed 6 seconds after totality came out a surprise to me. It was intended to give the dark lines in the solar cusp spectrum, but it does not show a single dark line that I can find. The west edge of the spectrum is continuous, (this may be partly due to the overlapping of the lines) while beside it is a beautiful bright line spectrum of one of the cusps, the lines most of them running into the continuous spectrum, and some of them exceeding it in brightness. I have counted 170 lines between D_3 and K and there are fragments of perhaps as many more. They are distributed as follows:

Below D_3	2
From D_3 to F	37
From F to G'	58
From G' to h	56
From h to H	15
From H to K	3
Beyond K	2

I have been puzzled to account for the total absence of dark lines in this photograph, for several minutes before totality and again after totality they were visible to the eye upon the ground glass of the camera. It would seem possible that we may have caught that moment when the radiations of the reversing layer and those of the reappearing photosphere were of equal intensity so that no reversal would be produced.

The party from Guilford College, associated with us, consisted of Professor George W. White and Mrs. White, Professor Robert W. Wilson, Professor Hodgins, Miss Field and students Walter Hobbs, Thomas Hinton, Homer Ragan, Lacy L. Barbee and Emmit Shepard. Professor White photographed the corona with a 3-inch visual telescope, exposing four plates for 1 and 2 seconds each during totality. He obtained four very good photographs of the middle parts of the corona. Professor Wilson counted off the seconds of time during totality, so that those making the photographic exposures might follow their assigned programs without looking at timepieces. Messrs. Barbee and Shepard noted on a sidereal chronometer and an ordinary watch independently the times of the contacts as observed by the writer with the 5-inch telescope. Professor Hodgins, Mrs. White, Miss Field and Mrs. Couts, under the direction of Mrs. Pearson, sketched portions of the corona, using white crayon on blue paper. Their results agree well with the photographs in the main features of the corona. Four of the students watched for the shadow bands and noted their direction.

DESCRIPTION OF THE ECLIPSE.

For a popular description of the eclipse the following abstract from an article in the Haverhill (Mass.) Evening Gazette, by Mr. Austin P. Nichols, who was present with our party during the eclipse, is as good as any I have seen:

"As the Moon crept further and further over the face of the Sun the interest and excitement increased. Several times each member of the party took their assigned places and while the astronomer in charge of the chronometer counted off the 94 seconds of expected totality, rehearsed the part they were expected to perform an hour later. The light gradually diminished and the air became somewhat cooler, but the change was not especially marked. The writer took his place on the roof of a barn, with instructions to note the approach of the shadow from the westward. Another member of our party had been impressed into the service of Professor Pearson to assist him in photographing the spectrum. The martyr to science who was to count the seconds, and was therefore debarred from seeing the eclipse, took charge of the chronometer. A bewildered rooster gave a feeble, inquisitive crow, and all was in readiness for the great event.

"Five minutes, called the timekeeper, and everyone busied themselves to be sure that everything was all in order at the last moment—four minutes, three, two, one, and a great hush fell over the party like that which occurs between a lightning flash and the thunder clap. The sky rapidly darkened, except that around the horizon were tints of orange, and to the southwestward the country was wrapped in the gloom of the approaching shadow. Time! called the man at the telescope, and the eclipse was upon us.

"In an instant everything was transformed. The darkness was not intense, it was about that of late twilight, and the hands of a watch could easily be made out. Everyone was busy at their appointed task, not a sound was heard but the calling of the seconds by the timekeeper. Only 94 of them, and so much must be done in that brief time. One fairly begrudged every second as it was called off.

"Up in the heavens where an instant before had been the brilliant crescent of the Sun, hung the black disk of the Moon; around its edge was a narrow but brilliant ring of an indescribably beautiful pearly, silvery shimmering light—the inner corona. Extending out into space on either side of the Sun, like the wings of a gigantic bird, were the streamers of the outer corona less brilliant than the inner ring, but bright and equally beautiful. The light of this outer corona was not uniform but varied in intensity, giving the appearance of structure to it; the writer particularly noticed a leaf-like form in one of the wings, similar to those observed in previous eclipses. The outer corona wings were strikingly similar to the tail of a brilliant comet, in appearance, although nothing has yet been observed to indicate that they have the same composition. The length of these wings seemed to be from three to four times the diameter of the Sun, although to other observers they appeared much shorter. A few red prominences, due to masses of red hot hydrogen gas thousands of miles high, were also observed around the edge of the sun, but to the unaided eye they were not very conspicuous, and could only be seen to good advantage in a telescope. Close to the Sun the planet Mercury shone with an unaccustomed brilliancy, while lower down in the east Venus, the evening star, glowed even more brightly. No other stars were noticed.

"A more beautiful or more impressive scene is rarely witnessed, but the time was all too short. Probably no one who observed the eclipse but felt that he had left something undone that he ought to have done, but one cannot do everything in a minute and a half.

"The monotonous counting of seconds continued—ninety-one, two, three, four. A flash of sunlight like the sudden lifting of a thunder cloud, the corona vanished like a burnt-out firework, familiar features of the landscape shone out again, and, except for a certain pale, ghastly light, which lasted for nearly half an hour, everything took on its usual appearance. Everyone heaved a sigh of relief, and the great eclipse of 1900 was a thing of the past."

THE CORONA.

The general form of the corona, as it appeared to me in the 20 seconds I had in which to look, while the 30 second exposure was going on, struck me as being very similar to that which I had seen in 1889; the difference being that it was reversed east and west, the two equal parallel streamers extending toward the west instead of east and the long single streamer with smaller attendants extending toward the east. Thus the view is confirmed which has been tentatively held for some years that certain types of corona are associated with the phases of the sunspot period, and that the type which corresponds to the sunspot minimum is characterized by great streamers parallel to the Sun's equator and by very marked polar filaments and rifts.

The four photographs taken by the writer with the 8-inch telescope do not show any noticeable changes in the structure of the corona in the one minute and a half. They differ from each other because of differences of exposure and of development. Comparing any one of them with Barnard's print of the corona of Jan. 2, 1889, one would almost say it is the same corona rotated half way round on the polar axis.

THE SHADOW BANDS.

These were seen three minutes before totality and for an equal length of time after totality. A white sheet was stretched upon the ground for these observations, but it was unnecessary for the bands could be seen all around us upon the light colored sand. They came approximately from the direction from which the great shadow approached, but the direction of movement was not constant and at one time it seemed to be from the northwest. The lines of the shadows were not smooth curves, but were sinuous and continually wavering. I had asked the young men, if possible, to count the number of bands seen upon the sheet at once and how many passed in 10 seconds, but the movement was too swift for this and they could only catch the direction of the wave fronts by laying sticks down parallel to the bands. This they did four times, 3 minutes before totality; just as the great shadow came; just after it receded; and when they last saw the bands distinctly. The following angles with the meridian were measured by myself a few minutes after totality was over:

I S 42.°0 E. II S 37.7 E. III S 52.°4 E. IV S 37.7 E.

According to the map of the path of totality the direction of movement of the shadow was about N 60° E at Southern Pines.

Various estimates of the distance between the successive shadow bands placed it at from 6 to 8 inches.

OBSERVATIONS OF CONTACTS.

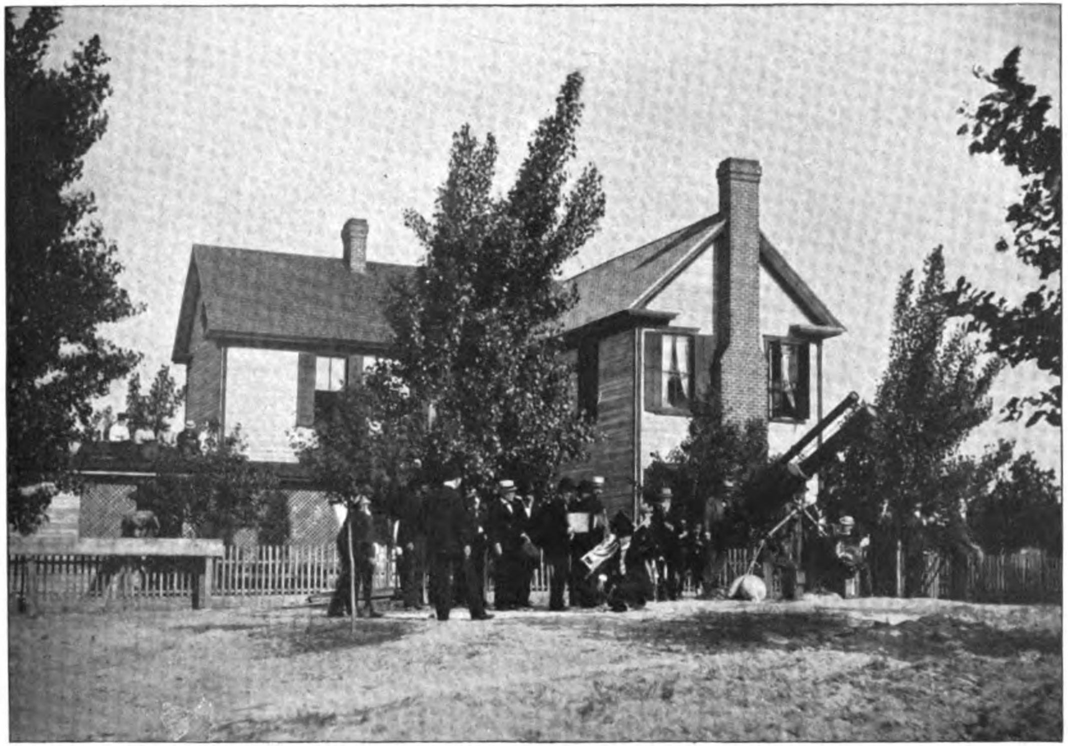
The four contacts were observed by the writer, the first three with the 5-inch guiding telescope of 9 feet focal length, the last with the 3-inch telescope belonging to Guilford College. The sidereal chronometer Bond 374 was compared by telephone with the signals transmitted from Washington to Pinehurst, N. C., on May 26 and 27 and with the mean time chronometer Negus 1749 at the U. S. Naval Observatory Station at Pinehurst on the afternoon of May 28, giving consistent rates between times. The watch used had a variable rate and the times noted on it are only rough checks of the chronometer times. The position of our station was determined by a rough triangulation from the station at Pinehurst and cannot be determined very exactly until certain data are obtained from that station, but the position was very nearly in. longitude 79° 24′ and latitude 35° 12′. The predicted times calculated with these data before the eclipse are here given for the sake of comparison, for the observed duration of totality agreed exactly with computed duration, which does not appear to have been the case at all the stations.

	Bond 374.	Corrections.	Reduced Greenwich Time.	Watch (corrected) Central Standard Time.	Computed Greenwich Time.
	h m s	m s	h m s	h m s	h m s
First contact....	22 57 19.5	+ 43 48.6	0 36 45.1	6 36 41	0 36 48.2
Second contact.	0 07 02.0	+ 43 48.8	1 46 16.4	7 46 14	1 46 26.5
Third contact...	0 08 36.0	+ 43 48.8	1 47 50.1	7 47 48	1 48 00.6
Fourth contact.	1 28 01.7	+ 43 48.9	3 07 02.9		3 07 08.3

AT OTHER STATIONS.

Pinehurst, N. C.—As the United States Naval Observatory station at Pinehurst was only 3 miles to the west of our loca-

PLATE XII.



THE CARLETON AND GUILFORD COLLEGE OBSERVING PARTIES

At their Station near Southern Pines, N. C., May 28, 1900.

POPULAR ASTRONOMY, No. 76.

tion, we had the opportunity of visiting with the astronomers and physicists there, seeing the apparatus, and becoming pretty well acquainted with the work which was to be done. The station was under the charge of Professor A. N. Skinner, who determined the latitude and longitude and had general oversight of all the work.

The most noticeable object as one approached the station was a large scaffold supporting the objective of the 40 foot telescope with which Mr. A. L. Colton was to secure large photographs of the corona, by the method which was so successfully used by Professor Campbell of the Lick Observatory in the Indian eclipse of 1898. The objective was of only 5 inches aperture but of 40 feet focal length. The tube was made of white canvas, supported by a skeleton framework of steel tubing. The plateholder was placed in a pit covered by a dark hut, and was moved by a clepsydra during the short interval of totality. Mr. Colton was to expose five 14 x 17 Seed nonhalation plates, the exposures being 2^s, 10^s, 45^s, 10^s and 2^s. He was assisted by Mr. M. G. Skinner.

A long shed with one-half of the roof covered with canvas, which could be rolled up out of the way, sheltered a row of equatorial telescopes, polariscopes and cameras which looked formidable to the spectator. The most important work, however, as it seemed to me was to be done with some instruments under a rougher looking shed partly covered only by loose boards. Here were three great slitless spectroscopes: one, operated by Dr. J. S. Ames of the Johns Hopkins University, having a 6-inch concave grating with 15,000 lines to the inch and giving a spectrum 2 feet long; another, also under Dr. Ames' charge, having a flat grating of the same dimensions as the concave grating; and a prismatic camera, with a 60° prism whose faces were 6 inches square and a lens of about 6 feet focal length. The last was under the charge of Dr. Chase of Yale University. Dr. Ames was assisted by Messrs. Hough, Rees and Gilbert of Johns Hopkins University. I understand that Dr. Ames made 15 exposures with the concave grating spectrograph and it is to be hoped that these have all turned out well.

The battery of cameras upon a long polar axis was managed by Professor W. S. Eichelberger and Assistant Astronomer T. I. King of the Naval Observatory assisted by Messrs. Beal, Kent and Gore. One of the cameras was provided with a color screen which would allow only the green rays to pass through it, the hope being to obtain an image of the corona largely from the light due to coronium.

Professor Edgar Frisby of the Naval Observatory and Mr. Everett I. Yowell of the Cincinnati Observatory observed the contacts and made visual observations of the corona with two 5-inch equatorials. Mr. N. E. Parsons and Dr. Dorsey of the Johns Hopkins University operated two polariscopes, the former a photographic and the latter a visual instrument.

Mr. R. W. Wood of the University of Wisconsin made interesting observations of the shadow bands with a peculiar instrument called the strobo-scope. His conclusion was that the shadow bands were not periodic. He also observed with a polariscope and made an excellent drawing of the corona.

From Professor Skinner we learned that the U. S. Naval Observatory had sent out three other parties, one at Barnesville, Ga., under Professor Brown, one at Winnsboro, S. C., under Professor Ormond Stone, Director of the Leander McCormick Observatory and one at Griffin, Ga., under Professor L. E. Jewell, of the Johns Hopkins University.

Barnesville, Ga.—The instruments used here were a 40 ft. telescope and polar axis with several cameras, similar to those at Pinehurst. Professors Updegraff and See of the Naval Observatory were assisted by a number of volunteer observers.

Winnsboro, S. C.—Professor Stone assisted by volunteers operated a third 40-foot telescope for the purpose of securing large photographs of the corona upon 14 x 17 plates.

Griffin, Ga.—This station was chosen near the edge of the path of totality for the purpose of obtaining long duration of the "flash" and chromospheric spectra, the whole expedition being spectroscopic. Professor Henry Crew, of the Northwestern University, worked with a flat grating. We are sorry to learn from a recent newspaper note, that his photographs all proved failures from insufficient exposure. Professor Humphrey, of the University of Virginia, operated with a concave grating of 21 feet focal length. Professor Mitchell, of the Columbia University, was also to be located at this station.

Wadesboro.—On our return journey Professors Hale and Frost gave us an interesting account of the work at this city, which seems to have been the favorite location for observing the eclipse, chosen no doubt on account of the low percentage of cloudy weather given in the special report of the Weather Bureau. Three important expeditions were located here, from the Smithsonian Institution, Princeton University, and the Yerkes Observatory. We can only speak definitely of the work done by the Yerkes party.

Professor E. E. Barnard assisted by Mr. Ritchey made 7 exposures with a 6-inch lens of 62 feet focus mounted horizontally. The light was thrown into the telescope by a coelostat with a 12-inch mirror made by Mr. Ritchey. The exposures made varied from one-half second to thirty seconds in duration, three upon 14 x 17 plates and four upon 25 x 30 plates, the largest that have ever been used for photographing the corona, with exception of those used at the same station by the Smithsonian Institution. A newspaper report, June 14, states that one of these plates, the last exposed, duration 1 second, had been developed and brought out many interesting details close to the edge of the moon. Mr. Barnard's hope is to bring out upon the longer exposed negatives the details of the outer corona as well as the inner upon that magnificent scale, which makes the diameter of moon's disk 7 inches; and we may be sure that Mr. Barnard will do it if any man can.

Several smaller cameras, from a 6-inch Voightlander down, were operated by volunteers. Some were mounted equatorially and driven by clockwork, others were simply fixed upon posts.

Professor E. B. Frost assisted by Dr. Isham of Chicago photographed the spectrum, using three slitless spectroscopes, one with a train of three prisms, one with a single prism and one with a concave grating. The signal for photographing the "flash" spectrum was given by Professor Frost observing with a flat grating. He said that he saw only dozens of lines reverse where he expected to see hundreds. Elsewhere also the "flash" appears to have been disappointing. At Pinehurst the whole party depended upon the observation of this phenomenon for the signal for the beginning of their program during totality. The one deputed to make this observation and give the signal failed to see the "flash" and as a result several seconds of totality had elapsed before the signal was given.

The coronium line too appears to have been weaker than usual, and Professor Young who made the determination of the position of this one line his special work failed to see it.

Professor Hale assisted by Mr. Ferdinand Ellerman undertook the very delicate operation of measuring the heat of the corona with bolometric apparatus, in connection with a large siderostat kindly loaned by the Smithsonian Institution. He had a very unfortunate experience. On arriving at Wadesboro ten days before the eclipse he found that a very delicate part of the apparatus had been broken. He had been warned by previous experience and had shipped a lathe and all necessary tools as a part of the equipment of the expedition. With characteristic energy he set about constructing a new bolometer and succeeding in making a better one than he had before and performed satisfactory preliminary experiments. All was in perfect adjustment and ready for use during totality, when just as the important moment arrived a small stick, which was used for some purpose in the dark bolometer room and had been leaned against the wall, fell and threw the galvanometer needle out of balance. The operation of balancing requires usually from two to three minutes. Professor Hale said that he never worked harder in his life than during the next minute and a half, and he succeeded in getting the instrument into balance, but only to see the sunlight reappear before any measures could be taken.

Mr. C. G. Abbott of the Smithsonian Institution by similar methods succeeded in detecting a slight amount of radiation from the corona as compared with that from the black disk of the moon. Professor Hale is confident from the results of his preliminary experiments that by these methods he can detect the change of heat at the edges of the great coronal streamers in full sunlight.

Professor A. S. Flint of the Washburn Observatory made the observations for time and position at Wadesboro, and noted the times of contact and counted the seconds of totality for Professor Frost.

The longest focus telescope ever used in observing an eclipse is probably that used by the Smithsonian Institution at Wadesboro, which had a focal length of 135 feet. This would give an image of the moon nearly 15 inches in diameter.

The telescope was mounted horizontally, the light being furnished by a coelostat. In the Chicago Journal of June 15, we find this statement concerning the photographs taken with this instrument:

"Mr. Smillie exposed six 30 x 30 plates during totality, with times ranging from one-half second to sixteen seconds. All these negatives have not yet been developed. Those of one-half second, two seconds and four seconds exposure have been hurriedly examined, however, and they give clear indications of the crossing and recrossing of filaments like the appearance of a field of grain bending in the wind. The prominences and polar streamers appear in imposing magnitude and detail."

GENERAL PERTURBATIONS AND THE PERTURBATIVE FUNCTION.

J. MORRISON, M. A., M. D., PH. D.

FOR POPULAR ASTRONOMY.

It was first proved by Sir Isaac Newton in his immortal work The Principia, that when a particle moves around a centre of force which varies directly as the mass and inversely as the square of the distance, the path or orbit described is a conic section with the centre of force in the focus, and the radius vector describes equal areas in equal times. In the case of a planet moving around the Sun, the orbit is an ellipse with the Sun in one of the foci. It is evident that the planet will move most rapidly in perihelion and most slowly in aphelion. The mean motion or that which it would have, if it described a circular orbit, is evidently equal to 360° or 2π divided by the periodic time T or $\frac{2\pi}{T}$. From perihelion to aphelion the true place of the planet will be in advance of the mean place; at aphelion the mean and true places will coincide, and from aphelion to perihelion the mean place will be in advance of the true until perihelion is reached when they again coincide and so on.

The angular distance between the true and mean places or to express it more technically, between the true and mean anomalies, is called the elliptic inequality or 'the equation of the centre,' and it is the only correction to be applied to the mean to obtain the true anomaly in the case we are now considering.

If however we suppose another planet to be added to the system, the circumstances of the motion of both planets, become much more complicated; each disturbs the motion of the other; the equable description of areas which obtained in the case of a single planet now no longer exists, and the computation of the true place of either planet is a work of prodigious difficulty. It is the famous "problem of three bodies" which has severely taxed the ingenuity and analytical skill of mathematicians since the discovery of the law of universal gravitation.

In this and subsequent papers we purpose to develop as clearly and as briefly as the difficulties of the problem will admit, the formulae for undisturbed and disturbed motion, so as to enable the reader to understand the more abstruse and elaborate developments of LaPlace, LeVerrier and others.

Let x, y, z be the coördinates of a planet referred to the centre of gravity of the Sun S, as the origin and r its radius vector, also let m denote the ratio of the mass of the planet (m) to that of the Sun or $m = \frac{\text{mass of planet}}{\text{mass of Sun}} = \frac{\text{mass of planet}}{k^2}$ where k^2 is the well known Gaussian constant of solar attraction whose value will be determined farther on, then the mass of the planet $= mk^2$.

Let x', y', z' be the coördinates, r' the radius vector and $m'k^2$ the mass of a second planet (m') and similarly for other bodies of the system and let ρ, ρ_1, ρ_2 be their mutual distance, or mm', mm'' etc., then we shall have

$$\begin{aligned} & r^2 = Sm^2 = x^2 + y^2 + z^2 \\ & r'^2 = Sm'^2 = x'^2 + y'^2 + z'^2 \\ & r''^2 = Sm'' = x''^2 + y''^2 + z''^2, \text{ etc.} \qquad (1) \\ \text{and } & \rho^2 = mm'^2 = (x' - x)^2 + (y' - y)^2 + (z' - z)^2 \\ & \rho_1^2 = mm''^2 = (x'' - x)^2 + (y'' - y)^2 + (z'' - z)^2, \text{ etc.} \end{aligned}$$

Considering only three bodies, the Sun S, the disturbed planet (m) and the disturbing planet (m') and putting for the sake of brevity $k^2 + k^2m$ or $k^2(1 + m) = \mu$, it is evident that in the relative motion of (m) around S, it will be acted on by the three forces $-\frac{\mu}{r^2}$, $\frac{k^2m'}{\rho^2}$ and $-\frac{k^2m'}{r'^2}$ respectively directed along the lines mS, mm' and $m'S$, and since the cosines of the angles which the directions of each of these forces make with the axis of x, are respectively

$$\frac{x}{r}, \quad \frac{x' - x}{\rho} \text{ and } \frac{x'}{r'} \quad .$$

We shall have for the components of these forces parellel to the same axis

$$-\frac{\mu x}{r^3}, \quad \frac{k^2m'(x' - x)}{\rho^3} \text{ and } -\frac{k^2m'x'}{r'^3} \text{ respectively,}$$

the first and third being negative because the force tends to diminish the coördinates x, y and z.

For the components of these same forces parallel to the axis of Y we shall have in a similar manner

$$-\frac{\mu y}{r^3}, \quad \frac{k^2m'(y' - y)}{\rho^3} \text{ and } -\frac{k^2m'y'}{r_1^2}$$

and for those parallel to the axis of Z

$$-\frac{\mu z}{r^3}, \quad \frac{k^2m'(z' - z)}{\rho^3} \text{ and } -\frac{k^2m'z'}{r^3}.$$

The sum of these three components for each direction is evidently the total force parallel to this direction, which acts on the planet (m) and it must be equal to the accelerations $\frac{d^2x}{dt^2}, \frac{d^2y}{dt^2}$ and $\frac{d^2z}{dt^2}$ respectively. If then we extend these results to a number of bodies m'', m''', etc., we shall have for the equations of the relative motion of (m) around S.

$$\begin{aligned} \frac{d^2x}{dt^2} + \frac{\mu x}{r^3} &= k^2 \sum m' \left(\frac{x' - x}{\rho^3} - \frac{x'}{r'^3}\right) \\ \frac{d^2y}{dt^2} + \frac{\mu y}{r^3} &= k^2 \sum m' \left(\frac{z' - z}{\rho^3} - \frac{z'}{r'^3}\right) \qquad (2) \\ \frac{d^2z}{dt^2} + \frac{\mu z}{r^3} &= k^2 \sum m' \left(\frac{z' - z}{\rho^3} - \frac{z'}{r'^3}\right) \end{aligned}$$

where the symbol $\sum$ indicates that each mass k^2m'', k^2m''', introduces a term similar to that which results from the action of m' on m — a term which we obtain by simply changing in the second members m', ρ, x' and r' into m'', ρ', x'' and r'' respectively, and so on.

To facilitate the solution of the problem, the second members of (2) are put into the following form.

From (1) we obtain

$$\frac{d}{dx} \cdot \frac{1}{\rho} = \frac{x' - x}{\rho^3}. \qquad \frac{d}{dy} \cdot \frac{1}{\rho} = \frac{y' - y}{\rho^3}, \qquad \frac{d}{dz} \cdot \frac{1}{\rho} = \frac{z' - z}{\rho^3}$$

and the terms $\frac{x'}{r'^3}, \frac{y'}{r'^3}, \frac{z'}{r'^3}$ are derivatives of $\frac{xx' + yy' + zz'}{r'^3}$ in regard to the variables x, y and z. If then we put

$$\Theta = \frac{m'}{1 + m}\left(\frac{1}{\rho} - \frac{xx' + yy' + zz'}{r'^3}\right) + \frac{m''}{1 + m}\left(\frac{xx'' + yy'' + zz''}{r''^3}\right) + \text{etc.} \qquad (3)$$

we shall have for the partial differential coefficients with respect to x, y and z

$$\begin{aligned} (1 + m)\left(\frac{d\Theta}{dx}\right) &= \sum m' \left(\frac{x' - x}{\rho^3} - \frac{x'}{r'^3}\right) \\ (1 + m)\left(\frac{d\Theta}{dy}\right) &= \sum m' \left(\frac{y' - y}{\rho^3} - \frac{y'}{r'^3}\right) \\ (1 + m)\left(\frac{d\Theta}{dz}\right) &= \sum m' \left(\frac{z' - z}{\rho^3} - \frac{z'}{r'^3}\right) \end{aligned}$$

Substituting in (2) we have

$$
\begin{aligned}
\frac{d^2x}{dt^2}+\frac{\mu x}{r^3} &= k^2\,(1+m)\left(\frac{d\Theta}{dx}\right)\\
\frac{d^2y}{dt^2}+\frac{\mu y}{r^3} &= k^2\,(1+m)\left(\frac{d\Theta}{dy}\right)\\
\frac{d^2z}{a\,t^2}+\frac{\mu z}{r^3} &= k^2\,(1+m)\left(\frac{d\Theta}{dz}\right)
\end{aligned}
\qquad (4)
$$

which are the differential equations of disturbed motion. The force whose components are expressed by the second members of (4) is the disturbing force. It expresses the difference between the action of the bodies m', m'', &c, on m and on the Sun, resolved parallel to the coördinate axes, and the quantity Θ from which the second members of (4) are derived is called the Perturbative Function, the development of which into an infinite series, constitutes the chief difficulty in the solution of this problem. The integration of the equations in group (4) has never been effected except by a series of approximations.

We must first consider the case of a single planet moving round the Sun, subject only to the reciprocal action of the two bodies.

This is the case of *undisturbed* motion; the disturbing force will then be zero and group (4) becomes

$$
\begin{aligned}
\frac{d^2x}{dt^2}+\frac{\mu x}{r^3} &= 0\\
\frac{d^2y}{dt^2}+\frac{\mu y}{r^3} &= 0\\
\frac{d^2z}{dt^2}+\frac{\mu z}{r^3} &= 0
\end{aligned}
\qquad (5)
$$

which are the differential equations of undisturbed motion and their integration will introduce six arbitrary constants which determine the circumstances of the orbit which the planet describes round the Sun under their mutual influence. The integration of (5) presents no great difficulty and is given in most works on Physical or Theoretical Astronomy, but as the student may not have any such works by him and in order to render these short papers as complete as practicable, we will give the integration here.

Multiply the first of (5) by y and the second by x and subtract the second product from the first, integrate the result and we have

$$x\frac{\cancel{z}dy}{dt} - \frac{ydx}{dt} = h \qquad \text{(a constant)}$$

similarly
$$\frac{zdx}{dt} - \frac{xdz}{dt} = h' \qquad \text{"} \qquad (6)$$

and
$$\frac{ydz}{dt} - \frac{zdy}{dt} = h'' \qquad \text{"}$$

If we multiply these by z, y and x respectively and add the products we obtain

$$hz + h'y + h''x \ = 0 \qquad (7)$$

which is the equation of a plane passing through the origin of coördinates, that is, through the center of the Sun.

Let dv be the angle described by the radius vector r in the time dt, then the area described by this radius on the plane of the orbit will be $\frac{1}{2}\, r^2dv$, and if i, i_1 and i_2 denote the angles which the orbit makes with the coördinate planes, xy, xz and yz respectively we shall have

$$\begin{aligned} r^2dv \cos i &= h\, dt \\ r^2dv \cos i_1 &= h'\, dt \\ r^2dv \cos i_2 &= h''\, dt \end{aligned} \qquad (8)$$

because the first members of (6) are the projections of double the area described by the radius vector during the instant dt, on the planes of xy, xz and zy.

Squaring, adding and reducing we have

$$\begin{aligned} r^2\, dv &= (h^2 + h'^2 + h''^2)\, dt \\ &= H\, dt \end{aligned}$$

or
$$r^2 \frac{dv}{dt} = H \qquad (9)$$

where for brevity we put $H = h^2 + h'^2 + h''^2$.

Let ☊ denote the angle which the common intersection of the plane of reference and the plane of the orbit, makes with the axis of x, or the longitude of the node, then by spherical trigonometry we shall have

$$\cos i_1 = -\sin i \cos ☊ \text{ and } \cos i_2 = \sin i \sin ☊$$

which combined with (8) and (9) give

$$\begin{aligned} h \ &= H \cos i \\ h' \ &= -H \sin i \cos ☊ \\ h'' &= \ \ H \sin i \sin ☊ \end{aligned} \qquad (10)$$

which determine i and ☊ when the arbitrary constants h, h' and h'' are known, thus they give

$$tan \ \Omega = -\frac{h''}{h'} \text{ and } tan \ i = \frac{\sqrt{(h'^2 + h''^2)}}{h}. \qquad (11)$$

If we multiply equations (5) by $2dx$, $2dy$ and $2dz$ respectively, add and integrate we shall find

$$\frac{dx^2 + dy^2 + dz^2}{dt^2} + 2\mu \int \frac{xdx + ydy + zdz}{r^3} = 0$$

and from the first of (1) we have

$$rdr = xdx + ydy + zdz$$

which substituted in the above and completing the integration, gives

$$\frac{dx^2 + dy^2 + dz^2}{dt^2} - \frac{2\mu}{r} - C = 0 \qquad (12)$$

where C is an arbitrary constant.

But $dx^2 + dy^2 + dz^2$ is the square of the space described by the body in the time dt, and therefore in polar coördinates.

$$\frac{dx^2 + dy^2 + dz^2}{dt^2} = \frac{dr^2 + r^2dv^2}{dt^2}$$

which substituted in (12) becomes

$$\frac{dr^2}{dt^2} + \frac{r^2dv^2}{dt^2} - \frac{2\mu}{r} - C = 0 \qquad (13)$$

Eliminating dt between (9) and (13) we obtain

$$\frac{dr}{dv} = \frac{r\sqrt{C\, r^2 + 2\, \mu r - H^2}}{H} \qquad (14)$$

But at the extremities of the major axis we must have $\frac{dr}{dv} = 0$, and therefore (14) enables us to determine the maximum and minimum values of r which we know to be $a(1+e)$ and $a(1-e)$ respectively. Equating the second member to zero and reducing we find

$$Cr^2 + 2\mu r - H^2 = 0$$

By the theory of quadratics, the sum of the two roots is equal to $-\frac{2\mu}{C}$ and their product to $-\frac{H^2}{C}$, we therefore have

$$2a = -\frac{2\mu}{C} \text{ and } a^2 (1 - e^2) = -\frac{H^2}{C}$$

whence $\quad C = -\frac{\mu}{a}$ and $H = \sqrt{a\mu\,(1 - e^2)}$

These values of C and H being substituted in (14) we have

$$dv = \frac{dr}{r} \frac{\sqrt{a\mu\,(1-e^2)}}{\sqrt{-\frac{\mu}{a}r^2 + 2\mu r - a\mu\,(1-e^2)}}$$

$$= \frac{dr}{r^2} \frac{\sqrt{a\mu\,(1-e^2)}}{\sqrt{-\frac{\mu}{a} + \frac{2\mu}{r} - \frac{a\mu\,(1-e^2)}{r^2}}}$$

and dividing numerator and denominator by $\sqrt{a\mu\,(1-e^2)}$ and writing $-d\frac{1}{r}$ for $\frac{dr}{r^2}$ we have

$$dv = \frac{-d\frac{1}{r}}{\sqrt{-\frac{1}{a^2(1-e^2)} + \frac{2}{ar\,(1-e^2)} - \frac{1}{r^2}}}$$

$$= \frac{-d\frac{1}{r}}{\sqrt{\frac{1}{a^2}\left\{\frac{1}{(1-e^2)^2} - \frac{1}{1-e^2}\right\} - \left\{\frac{1}{r} - \frac{1}{a\,(1-e^2)}\right\}^2}}$$

$$= \frac{d\left\{\frac{a\,(1-e^2)}{re}\right\}}{\sqrt{1 - \left\{\frac{\frac{a}{r}(1-e^2)-1}{e}\right\}^2}}$$

If we put $\frac{\frac{a}{r}(1-e^2)-1}{e} = x$ we have

$$dv = -\frac{dx}{\sqrt{1-x^2}}$$

and $v = \int \frac{-dx}{\sqrt{1-x^2}} = \omega + \cos^{-1} x$

$$= \omega + \cos^{-1}\left\{\frac{\frac{a}{r}(1-e^2)-1}{e}\right\}$$

ω being an arbitrary constant.

Whence we have

$$\frac{a}{r}(1-e^2) - 1 = e\cos(v-\omega)$$

or $$r = \frac{a\,(1-e^2)}{1+e\cos(v-\omega)} \qquad (15)$$

the polar equation of the ellipse.

The angles v and ω are the angles which the radius vector and line of apsides, make with a fixed axis situated in the plane of the orbit or the true longitude of the planet and the longitude of the perihelion respectively. The difference $v - \omega$ determines the angular distance of the planet from perihelion and is called the true anomaly.

If the angle $v - \omega$ is reckoned from the perihelion then $\omega = 0$ and the above equation becomes

$$r = \frac{a\,(1 - e^2)}{1 + e \cos v}. \tag{16}$$

If instead of eliminating dt between equations (9) and (13), we eliminate dv, we shall have

$$\frac{dr^2}{dt^2} + \frac{H^2}{r^2} = \frac{2\mu}{r} + C$$

whence $$dt = \frac{rdr}{\sqrt{C + \frac{2\mu}{r} - \frac{H^2}{r^2}}}.$$ and substituting the values of C and H, we find

$$dt = \sqrt{\frac{a}{\mu}}.\frac{rdr}{\sqrt{2ar - r^2 - a^2\,(1 - e^2)}}.$$

$$= \sqrt{\frac{a}{\mu}}.\frac{rdr}{\sqrt{a^2e^2 - (a - r)^2}}$$

which is easily integrated by introducing an auxiliary variable u connected with r by the relation

$$r = a\,(1 - e \cos u) \tag{17}$$

whence $$dr = ae \sin u du$$

and $$dt = \sqrt{\frac{a^3}{\mu}}\,(1 - e \cos u)\,du$$

an expression whose integral is

$$nt + c = u - e \sin u \tag{18}$$

where $n = \sqrt{\frac{\mu}{a^3}}$ and c is a constant.

The angle u is called *eccentric* anomaly, nt the *mean* anomaly of the planet (m) and n is the mean motion. When we take for the origin of time the instant the planet is in perihelion, $c = 0$ and we have

$$nt = u - e \sin u \tag{19}$$

If however we reckon the time to commence at any other instant after passing the perihelion nt must be increased by the constant $\varepsilon - \omega$, where ε denotes the mean longitude of the planet at the origin of the time or the longitude at the epoch, and then we shall have

$$nt + \varepsilon - \omega = u - e \sin u \tag{20}$$

Let T be the duration of the sidereal revolution of the planet (m) and a its mean distance from the Sun, then in putting $u = 2\pi$ in (19) we have $nT = 2\pi$

whence
$$T = \frac{2\pi}{n} = 2\pi \sqrt{\frac{a^3}{\mu}} \tag{21}$$

and also
$$\mu = 4\,\pi^2.\,\frac{a^3}{T^3}$$

Eliminating r between (15) and (17) we have

$$\cos u = \frac{e \cos (v - \omega)}{1 + e \cos (\ v - \omega)}$$

whence
$$\frac{1 - \cos (v - \omega)}{1 + \cos (v - \omega)} = \frac{1 + e}{1 - e} \cdot \frac{1 - \cos u}{1 + \cos u}$$

and
$$\tan \frac{1}{2}(v - \omega) = \sqrt{\frac{1 + e}{1 - e}}.\tan \frac{1}{2} u \tag{22}$$

If the angle v to be reckoned from the perihelion we have $\omega = 0$ and the above becomes

$$\tan \frac{1}{2} v = \sqrt{\frac{1 + e}{1 - e}}.\tan \frac{1}{2} u \tag{23}$$

a formula which enables us to determine the true anomaly in terms of u and also of nt the mean anomaly.

To determine the nature of the conic section described by the body (m) in its motion round the sun, let $V =$ the velocity in the orbit, then by (12) and (13) we have

$$V^2 = \frac{2\mu}{r} + C$$

$$= 2\left(\frac{\mu}{r} - \frac{1}{a}\right) \text{ since } C = -\frac{\mu}{a} \tag{24}$$

we also have
$$\frac{1}{a} = \frac{2}{r} - \frac{V^2}{\mu}$$

and as a is positive in the ellipse, infinite in the parabola and negative in the hyperbola we conclude that the orbit is an ellipse, a parabola or a hyperbola according as

$$V^2 < \frac{2\mu}{r}, = \frac{2\mu}{r} \text{ or } > \frac{2\mu}{r}$$

We have next to determine the value of k which is constant for the solar system.

From (21) we have $$T^2 = 4\pi^2 \frac{a^3}{\mu}$$

$$= 4\pi^2 \frac{a^3}{k^2(1+m)}$$

whence $$k^2 = \frac{2\pi}{T} \cdot \frac{a^{\frac{3}{2}}}{\sqrt{1+m}} \tag{25}$$

In the case of the Earth, $a = 1$, $T = 365.25638435$ days and the combined mass of the Earth and Moon is $\frac{1}{354710} = m$.

Therefore we easily find

$$\log k = 8.2355814$$

and in seconds of arc

$$\log k'' = 3.5500066$$

or $$k = 3548''.19 = 59' \; 8''.19$$

The quantity $\frac{2\pi}{T}$ is the mean angular motion in a mean solar day and since $\sqrt{1+m}$ differ very little from unity, k is very nearly equal to the mean daily motion of the Earth—a result which might have been anticipated, because the mass of the Sun is just such as will communicate to the Earth the mean daily motion which it actually has.

There is another method of arriving at the equation of the orbit described by the planet, which we will now give for the purpose of making the subject as clear and explicit as practicable. We have already shown (7) that the plane of the orbit passes through the centre of the Sun and if we take this as the plane of reference or the fundamental plane, then $z = 0$, and the general equations (5) of undisturbed motion are

$$\left.\begin{aligned} \frac{d^2x}{dt^2} + \frac{\mu x}{r^3} = 0 \\ \frac{d^2y}{dt^2} + \frac{\mu y}{r^3} = 0 \end{aligned}\right. \tag{26}$$

and (6) reduces to

$$x\frac{dy}{dt}-y\frac{dx}{dt}=h \tag{27}$$

which transformed into polar coördinates becomes

$$r^2\frac{dv}{dt}=h \tag{28}$$

where h is twice the area described in the time dt.

In polar coördinates we have

$$x=r\cos v \text{ and } y=\sin v$$

then we have

$$\frac{d}{dt}\left(\frac{x}{r}\right)=-\sin v\frac{dv}{dt}$$

$$=-\frac{r\sin v}{r^3}.\,r^2\frac{dv}{dt}$$

$$=-\frac{y}{r^3}\,h$$

whence $\quad \frac{y}{r^3}=-\frac{1}{h}.\frac{d}{dt}\left(\frac{x}{r}\right)$

Similarly $\quad \frac{x}{r^3}=\frac{1}{h}.\frac{d}{dt}\left(\frac{y}{r}\right) \qquad (29)$

which substituted in (26) give

$$\frac{d^2x}{dt^2}=-\frac{\mu}{h}.\frac{d}{dt}\left(\frac{y}{r}\right)$$

$$\frac{d^2y}{dt^2}=\frac{\mu}{h}.\frac{d}{dt}\left(\frac{x}{r}\right) \tag{30}$$

By the integration of these we obtain

$$\frac{dx}{dt}=-\frac{\mu}{h}\left(\frac{y}{r}+\beta\right)$$

$$\frac{dy}{dt}=\frac{\mu}{h}\left(\frac{x}{r}+\alpha\right)$$

where a and β are constants.

Substituting in (27) we have

$$\frac{\mu x}{h}\left(\frac{x}{r}+\alpha\right)+\frac{\mu y}{h}\left(\frac{y}{r}+\beta\right)=h$$

or $\quad \alpha x+\beta y+r=\frac{h^2}{\mu}=\gamma.\text{ (suppose)}] \quad (31)$

and eliminating r by the relation $r^2 = x^2 + y^2$ and reducing we get

$$(1 - \alpha^2)\, x^2 - 2\alpha\,\beta\, xy + (1 - \beta^2)\, y^2 \\ + 2\alpha\gamma x + 2\beta\gamma y - \gamma^2 = 0 \qquad (32)$$

which is the general equation of the conic sections, the origin of coördinates being evidently at the focus.

The significance of the constants α, β and γ are now to be determined, If we denote by ω the angle which the axis of the conic makes with the axis of x, and by p the distance from the focus to the directrix, the general equation of the conic is

$$(1 - e^2 \cos^2 \omega)\, x^2 - 2e^2 \sin \omega \cos \omega .\, xy + (1 - e^2 \sin^2 \omega)\, y^2 \\ + 2e^2 p \cos \omega .\, x + 2e^2 p \sin \omega .\, y - e^2 p^2 = 0, \qquad (33)$$

and comparing the coefficients of these two equations we easily find

$$e = \sqrt{\alpha^2 + \beta^2}$$

$$\tan \omega = \frac{\beta}{\alpha} \qquad (34)$$

If $\omega = 0$, the axis of x coincides with the axis of the curve, $\beta = 0$ and then (32) becomes

$$(1 - \alpha^2)\, x + y^2 + 2\alpha\gamma x - \gamma^2 = 0$$

and if $x = 0$, $\quad y = \gamma$

$= $ the semi-latus rectum

therefore $\quad \gamma = \dfrac{h^2}{\mu} \qquad (35)$

When $\beta = 0$, $\alpha = e$ and (31) becomes

$$ex + r = \frac{h^2}{\mu}$$

or in polor coördinates

$$r = \frac{\dfrac{h^2}{\mu}}{1 + e \cos v} \qquad (36)$$

the well known polar equation of the conic sections.

In the preceding formulae (16), (17) and (23) both r and v are connected with nt,—the mean anomaly which we shall henceforth denote by M — through the transcendental equation (19), and in the integration of the equations of disturbed motion it will be necessary to express r and v as functions of M.

Writing M for nt we have from (19)

$$u = M + e \sin u$$

from which we develop cos u, cos $2u$, etc., by Lagrange's theorem, thus

$$F(u) = F(M) + e \left\{ f(M) \frac{dF(M)}{dM} \right\} + \frac{e^2}{1.2} \frac{d}{dM} \,.$$

$$\left\{ (f(M))^2 \frac{dF(M)}{dM} \right\} + \frac{e^3}{1.2.3} \frac{d^2}{dM^2} \left\{ (f(M))^3 \frac{dF(M)}{dM} \right\} + \text{etc.}$$

Put $F(u) = \cos u$, $F(M) = \cos M$, $f(M) = \sin M$, then we shall have

$$f(M) \frac{dF(M)}{dM} = - \sin^2 M = \frac{\cos 2M - 1}{2}$$

$$\frac{d}{dM} \left\{ (f(M))^2 \frac{dF(M)}{dM} \right\} = \frac{d}{dM} \left\{ - \sin^3 M \right\} =$$

$$- 3 \cos M + 3 \cos^3 M$$

$$= \frac{3}{4} \cos 3\,M - \frac{3}{4} \cos M$$

$$\frac{d^2}{dM^2} \left\{ (f(M))^3 \frac{DF(M)}{dM} \right\} = \frac{d}{dM} \left\{ - \sin^4 M \right\}$$

$$= - 2 \cos 2M + 2 \cos 4\,M, \text{ etc.}$$

Substituting in the above we find

$$\cos u = \cos M + \frac{e}{1} . \frac{\cos 2M - 1}{2} + \frac{e^2}{1.2} \left(\frac{3}{4} \cos 3M - \frac{3}{4} \cos M \right)$$

$$+ \frac{e^3}{1.2.3} \; (- 2 \cos 2M + \cos 4M) + \text{etc.}$$

$$= \cos M + \frac{e}{2} \cos 2M - \frac{e}{2} + \frac{3e^2}{2^3} \cos 3M - \frac{3e^2}{2^8} \cos M$$

$$+ \frac{e^8}{3} \cos 4M - \frac{e^3}{3} \cos 2M$$

$$\begin{aligned} = -\frac{e}{2} &+ \left(1 - \frac{3e^2}{2^3} + \;.\;.\;.\;.\;.\;. \right) \cos M \\ &+ \left(\frac{e}{2} - \frac{e^3}{3} + \;.\;.\;.\;.\;.\;.\;. \right) \cos 2M \qquad\qquad (37) \\ &+ \left(\frac{3e^2}{2^3} - \;.\;.\;.\;.\;.\;.\;.\;.\;. \right) \cos 3M \\ &+ \left(\frac{e^3}{3} - \;.\;.\;.\;.\;.\;.\;.\;.\;. \right) \cos 4M \\ &+ \;\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;. \end{aligned}$$

In a similar manner we find

$$\begin{aligned}\cos 2u = & \left(\quad -e + \frac{e^3}{2^2.3} \ldots\ldots\ldots \right)\cos M \\ & + \left(1 - e_3 + \frac{5e^4}{2_3 3} \ldots\ldots\ldots \right)\cos 2\,M \\ & + \left(e - \frac{3^2 e^3}{2^3} + \ldots\ldots\ldots \right)\text{ccs } 3\,M \qquad (38) \\ & + \left(e^2 - \frac{2^2 e^4}{3} + \ldots\ldots\ldots \right)\cos 4\,M \\ & + (\ldots\ldots\ldots\ldots\ldots)\end{aligned}$$

and so on.

From (17) and (37) we easily find

$$\begin{aligned}\frac{r}{a} = & \left(1 \;\; + \frac{e^2}{2}\right) \\ & + \left(-e + \frac{3}{2^3}e^3 \;\ldots\ldots\ldots \right)\cos\; M \\ & + \left(-\frac{e^2}{2} + \frac{e^4}{3} - \;\ldots\ldots\ldots \right)\cos 2\,M \qquad (39) \\ & + \left(-\frac{3e^3}{2^3} + \ldots\ldots\ldots\ldots \right)\cos 3\,M \\ & + (\ldots\ldots\ldots\ldots\ldots\ldots)\end{aligned}$$

which expresses r in terms of M.

From (28) we have $\frac{dv}{dt} = \frac{h}{r^2}$

where h is twice the area described in a unit of time, therefore

$$\begin{aligned} Th &= 2 \times \text{area of the ellipse} \\ &= 2\pi a^2 \sqrt{1 - e^2} \\ &= \frac{dM}{dt} \cdot \frac{a^2}{r^2} \sqrt{1 - e^2)} \end{aligned}$$

and $$h = \frac{2\pi}{T} \cdot a^2 \sqrt{1 - e^2}$$

and $$\begin{aligned}\frac{dv}{dt} &= \frac{2\pi}{T} \cdot \frac{a^2}{r^2} \cdot \sqrt{1 - e^2} \\ &= \frac{dM}{dt} \cdot \frac{a^2}{r^2} \sqrt{1 - e^2}\end{aligned}$$

or $$\begin{aligned}\frac{dv}{dM} &= \frac{\sqrt{1 - e^2}}{(1 - e\cos u)^2} \quad \text{by (17)} \\ &= (1 - e^2)^{\frac{1}{2}}(1 - e\cos u)^{-2}\end{aligned}$$

Developing the second member by the binomial theorem and changing the powers of cos *u* to the cosines of multiples of *u* we have

$$
\begin{aligned}
\frac{dv}{dM} &= (1 - e^2)^{\frac{1}{2}} (1 - e \cos u)^{-2} \\
&= (1 + e^2 + e^4 + \ldots\ldots\ldots\ldots) \\
&+ 2\,(e + e^3 + e^5 + \ldots\ldots\ldots\ldots) \cos u \\
&+ \left(\frac{3}{2}\,e^2 + \frac{7}{2^2}\,e^4 + \ldots\ldots\ldots\ldots\right) \cos 2u \\
&+ \left(e^3 + \frac{11}{2^3}\,e^5 + \ldots\ldots\ldots\ldots\right) \cos 3u \\
&+ (\ldots\ldots\ldots\ldots\ldots\ldots\ldots) \ldots
\end{aligned}
$$

Substituting the values of cos *u*, from (37) (38), etc., multiplying by *dM* and integrating we obtain

$$
\begin{aligned}
v = M &+ \left(2e - \frac{e^3}{2^2} + \frac{5e^5}{3.2^5} + \ldots\ldots\ldots\right) \sin M \\
&+ \left(\frac{5e^2}{2^2} - \frac{11e^4}{3.2_3} + \ldots\ldots\ldots\right) \sin 2M \\
&+ \left(\frac{13e^3}{3.2^2} - \frac{43e^5}{2^6} + \ldots\ldots\ldots\right) \sin 3M \\
&+ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots
\end{aligned}
$$

No constant is added because $v = 0$ when $M = 0$.

The quantity $v - M$ is the equation of the centre.

For a more elaborate development of these formulæ extended to the 12th power of *e* and to the 12th multiple of *u* and *M*, see my paper in Monthly Notices of the Royal Astronomical Society, Vol. 43, No. 7..

The formulæ just derived enable us to arrive at an approximate integration of the formulæ (4) for disturbed motion.

REPRESENTATIVE STELLAR SPECTRA BY SIR WILLIAM HUGGINS AND LADY HUGGINS.

W. W. PAYNE.

As announced before in this magazine, we have received Vol. 1 of the publications of Sir William Huggins' Observatory at Tulse-hill, London, England. The full title of this noble volume is "An Atlas of Representative Stellar Spectra from λ 4870 to λ 3300. There is added a discussion of the evolutional order of the stars, and an interpretation of their spectra, preceded by a short history of the Observatory and its work. The book is a large quarto in form, printed on fine, heavy plate paper, with some titles and initial letters in red ink. It contains 165 pages with 13 full page plates of representative and most interesting stellar spectra. The plates are beautiful and perfect half-tones in almost every particular and the large scale in which they appear makes them most valuable for comparison or for general reference. The book as a whole is a superb specimen of printing, and is surely very creditably to the publishers, Messrs. Wm. Wesley & Son of London, one of the oldest and best known publishing houses in the world.

On account of its real scientific value, this book ought to find ready sale in America; for certainly scientists, Observatories, scientific libraries and the best general libraries will want a late, authoritative work on stellar spectroscopy by an author who is recognized everywhere as one of the first, if not the leading one in his chosen field of work.

Dr. Huggin's Observatory at Tulse-hill is widely known among astronomers as the pioneer institution in applying the spectroscope to astronomy. It was early in the sixties that Dr. Huggins began this work, and the rapid discoveries which he made have served as the foundation of the new astronomy which has since grown so rapidly and which still promises more and more by the aid of celestial photography. The broad outlook in science thus opened appears to be limitless in the way of better observation, permanent record and more refined and satisfactory measurement. These are the great factors of real progress to which the practical astronomer must ever look with increasing dependence as the limits of his field of labor and discovery are widened and removed farther and farther from the well beaten paths of knowledge.

When Dr. Huggins began to apply the spectroscope to the study of the stars, the difficulties which he met and was obliged to overcome were enormous. These are briefly set out in the first chapter of this volume which, in this regard, is especially good reading for young people who are anxious to do something in new, or comparatively new lines of work, and imagine the task will be an easy one when they once get at it. The experiences of such pioneers who have worked most industriously for nearly two scores of years must contain lessons of great value for those who would walk in like illustrious paths.

It was the announcement of Kirchoff in 1858, that he had discovered the true nature and the chemical conditions of the Sun, from his interpretation of the Fraunhofer lines that filled the mind of Dr. Huggins with thoughts of a new method for working out some of the hard problems pertaining to the heavenly bodies, which no one, thus far, had been able to solve by the methods of the old astronomy. With the fresh zeal of inventive thought, Dr. Huggins at once wanted to apply the Kirchoff method of the solar spectrum to the study of the stars. He consulted scholarly friends who would be most likely to give him helpful counsel in regard to the probability of success in such an undertaking; but they were uncertain, if not quite sure, of failure, in such an attempt, because they thought the light of the stars too faint for spectra, and because of the Earth's motion which no clock-work was deemed true enough to control for the length of time needed for the delicacy of spectroscopic work. If the Heideberg professor needed all the light of the Sun for the study of the solar spectrum, how could any one hope for success in trying to get the spectrum of the brightest of the stars, when it is remembered that the light of the Sun is 40,000,000,000 times as great as that of Vega, which is more than a first magnitude star. It was at once evident, also, that the prism by which the spectrum was to be secured, could not be placed in front of the object glass of the telescope, as Kirchoff had done, even if the spectrum of any star would be bright enough for observational uses, for it would not then be possible to get at the same time, a spectrum of some terrestrial substance which would serve as a comparison for the sake of identifying that which might appear in a star spectrum. Hence it was necessary to attach the prism to the eye-end of the telescope, and adapt it in such a way that these two spectra needed could be satisfactorily obtained and be definitely compared. This was not all. The telescopic image of a star, if we do not consider the spurious part of it, is only a point, and its spectrum would be ordinarily a narrow line of light without width enough to show the presence of dark lines across it, in a way suitable for study or measurement. To get this necessary breadth of spectrum band was a difficult task. It was finally accomplished by means of a special lens placed in front of the slit of the spectroscope and within the focus of the telescope, that would give just breadth enough to the point-like image of the star needed and no more, for the brightness of the band must diminish as its width increases, and the amount of light for use was too small to expend in that way except as it was absolutely necessary.

So much has been said to give some idea of the problem that our author had to solve in order to make the first stellar spectroscope. It is now so easy a task to obtain fine and complete instruments of this kind that probably astronomers themselves do not often realize the hard work that was done in those early days of pioneering in spectroscopy. It has been well said by another that such work demands a sacrifice of time that is very great when compared with the amount of information that the investigator will be able to obtain; and this is true in some things relating to the early progress of the new astronomy, but it is also true that the first ten years of the new science revealed more new and astonishing things in the way of important discoveries than have come to astronomy in any other like period of time since the invention of the visual telescope.

If we had now the time and space at command, it would well repay us, to set out, in detail, the wonderful history of those early years so admirably penned by Dr. Huggins in the volume before us. But we must be content only to give a passing notice of the more prominent parts of it which are already familiar to those acquainted with the elementary knowledge of spectroscopy.

In 1863 Dr. Huggins gave diagrams of the spectra of Sirius, Betelgeux and Aldebaran in a preliminary note to the Royal Society under the head, "On the Lines of Some of the Fixed Stars," with the statement that he had observed the spectra of some forty stars and also the spectra of Jupiter and Mars. It is an interesting fact to be noted in this connection, that our Mr. Rutherford of New York, independently began the same kind of work, about the same time, and a little later, Sicchi of Rome and Vogel in Germany.

In February of the same year attempts were made to photograph the star spectra, with some success, by the wet colodion process, but the method was so inconvenient that it was not continued, and the photography of stellar spectra was not resumed until 1875. The dry colodion plates were not used at this time because they were not rapid enough for the work desired.

The next thing needed in the new work was a convenient map of the spectra of the chemical elements. Such a map did not then exist. Kirchoff's maps contained only a few elements on an arbitrary scale, relatively to the solar spectrum, and as sunlight could not be used at night for comparison, such a scale was almost useless. To supply this want Dr. Huggins spent the greater part of the year 1863 in mapping the spectra of twenty-six chemical elements with a train of six prisims, the scale used being the spark spetrum of common air, at first carefully referred to that of purified oxygen and nitrogen. With such a map for reference, the work of the following year went on successfully and rapidly, as one after another the terrestial elements of iron, hydrogen, sodium, magnesium and calcium were easily and certainly found in the substance of the stars, revealing the stupendous fact, that these tiny twinkles of night are great Suns claiming kinship with our own orb of day in the real unity of one vast universe, so beautiful, and so sublime in the Creator's designing thought, that a finite mind stands in awe at the appalling concept.

On August 29, 1864, Dr. Huggins, for the first time, directed his telescope to the planetary nebula in Draco. He was curiously expectant to know if he could gain any knowledge about the nature of the mysterious nebulae which Herschel, Rosse and many others had studied long and profoundly, but without satisfactory results. His description of the first view of the spectrum of a nebulous body is graphic indeed, and is interesting reading, even now after a lapse of thirty six years.

When he looked into the spectroscope, no such view was seen as was anticipated. Only a single bright line at first. Looking a little more closely he saw two other bright lines on the side towards the blue with dark spaces between them. Such a sight from such a source probably never before had been seen by mortal eyes. Can we wonder that Dr. Huggins at first thought that something must be wrong with the spectroscope? But he knew his instrument too well to wait long for the wonderful meaning of this very wonderful discovery. The light from the nebula is truly monochromatic, therefore it is not an aggregation of stars, it is truly a mass of luminous gas.

The great question that had so long baffled the skill of the best scholars was at last solved, but like other important discoveries in science, its answer brought up a hundred others in its place, of less moment to be sure. but all pressing for answer like the first. What is the full meaning of these bright lines? Are the nebulae very hot, or only comparatively so? Are they very far away or only of the same order of distance as the stars. More observation, more thought and the opportunity for more work are the coveted things that await the enthusiastic zeal of those who will press their way into the new and vast fields of research now already so auspiciously opened.

At another time we must say more about Dr. Huggins' early work on comets, variable stars and double stars as well as call attention to the splendid services which the authors of this book have rendered to science in the later years of their lives.

The net price of this new volume is $5. Send to Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England.

MEASUREMENT OF PHOTOGRAPHIC INTENSITIES.

EDWARD C. PICKERING.

The comparison of various celestial and terrestrial sources of light has for many years been a subject for investigation by the officers of this Observatory. One of the first comparisons of the light of the Sun and Moon was made by Professor George P. Bond in 1861 (Mem. Amer. Acad. VIII, N. S , p. 298). Comparisons of the light of the solar corona, of the Moon, and of twilight, with a standard candle were made by the writer in 1870. A comparison of various artificial lights was made by Professor W. H. Pickering, as his graduating thesis in 1879 (Proc. Amer. Acad. XV, 236). Since 1887, all the photographs obtained with the principal instruments of this Observatory have had an image of a standard light photographed on them for purposes of comparison. In 1887, when Mr. W. H. Pickering was placed in charge of the Boyden Department, an important part of his work was a quantitative determination of photographic intensities. This investigation was completed in 1891, and the results are published in the Annals, Volume XXXII, Chapter I. The relative brightness of 10,498 stars, for the wave length 430, was determined by Mrs. Fleming and was published in 1890 in the Draper Catalogue (Annals, Volumes XXVI and XVII). An independent determination of the total photographic brightness of the stars was undertaken in 1896 by photographing stars out of focus. As none of these investigations served to determine certain constants, which seemed to the writer to be important, a more extensive investigation was assigned to Mr. Edward S. King, under whose direction the photographs are taken at Cambridge. This work has been modified and extended by Mr. King, so that it now includes the following researches, which he describes below:—

In 1896, a monthly test of plates was inaugurated, which was of routine character. A complete determination, not only of the sensitiveness of the emulsion, but of the constancy of the light and of the developer employed, is obtained by the expenditure of one 8x10 plate per month (photogram, VI, 261). The means of the results of these tests, extending over a long period of time and necessarily subject to all the accidental errors due to season or other factors, will probably show the effect of the age of the plate on its sensitiveness, whether the image is affected by the interval between the exposure and the development, and other facts of similar interest.

About the same time with the above, the director suggested that an extensive investigation be undertaken of the photographic measurements of various sources of light. The work was to be systematized into a routine, which should occupy the least time in making the observations. By extending the period over years and by performing each experiment under the most diverse circumstances, the final results should be of great accuracy. Preliminary to this work, an apparatus was constructed for making photographic wedges in which equal intervals of the scale corresponded to equal differences in stellar magnitude. The general design was the same as that described in the Annals, Volume XXVI, 6, except that the triangular aperture was replaced by an aperture bounded by a logarithmic curve. The part of the curve extending to minus infinity, but enclosing a finite area, is represented by admitting light through an additional aperture of equivalent area. This apparatus, having a range in aperture of five magnitudes, is useful for measuring the intensity of surfaces directly, or of bright objects, when the aperture is covered with porcelain. It is also of value in comparing the sensitiveness of plates, and for studying the relation of the darkening of the film to the exposure, and to the intensity of the light.

The object of this investigation is to determine the photographic intensity of various sources of light upon a uniform scale. This scale will be that of the Meridian Photometer, in which α Ursæ Minoris has the magnitude of 2.15. and one unit corresponds to the ratio of 2.518, whose logarithm is 0.400. Luminous points may be compared directly with stars. In the case of surfaces, the light emitted by a circle having a diameter of one minute of arc is employed. In general, different portions of the same photographic plate are exposed for a given time to the sources of light to be compared, and the darkening measured with a photographic wedge.

Observations of surfaces will include, intensity of the sky at different distances from the Sun; the sky in the zenith during twilight, on clear and cloudy days, on dark and moonlight nights; comparisons of blue sky with cumulus cloud; intensity of Milky Way, Aurora, and Zodiacal Light. For this purpose pinhole cameras are used with various apertures. For very faint lights, apertures subtending an angle of 60° or more are used. When possible, automatic devices are employed, both to make the exposure and to shift the plate.

For measuring luminous points, the light concentrated by a lens illuminates the plate placed at various distances from the focus. In this manner, bright stars, the planets, and the Moon at different phases and latitudes, may be compared with α Ursae Minoris or an artificial light placed at a distance. It is also necessary to determine the effect of any slight fogging before, after, or during the principal exposure. The total and local absorption of the lens will also be measured. The same objects are also compared directly by pinhole cameras. In using a pinhole camera to measure points differing greatly in brightness the duration of the exposure must be varied. This necessitates a study of the darkening of the plate with relation to time. The comparison is made, in all cases, with a light, producing an equal darkening in the same time. Another factor may be introduced by inclining the plate. An angel of 60° is equal to a diminution of one-half, or about three-quarters of a magnitude. The exact amount corresponding to the inclination used, must be determined by experiment.

The determination of the light of the Sun is a difficult problem. The light may be reduced by a distant lens of short focus, and compared with the standard light similarly reduced, but at less distance. Another way is by a combination of lenses like a telescope, which enlarges or reduces objects, as we look through one end or the other. The absorption of the instrument is thus eliminated. Two plates of glass, placed so as to give mutiple reflections, will also afford a wide range of exposure, as well as a means of comparing lights of great difference in intensity. Pinhole cameras having the aperture covered with a porcelain plate can be constructed so as to give a range of 15 to 20 magnitudes, which is sufficient for comparing the Sun and the Moon. A second pinhole camera placed in front will cut off the light of the sky from the aperture. The absorption and the diffusing power of the porcelain plate must be measured independently. In all the preceding plans the sensitiveness of the plates to different colors affects the results. By combining a slit spectroscope with the cameras just described, a comparison of the light of the Sun and the Moon may be made in different parts of the spectrum, corresponding to given wave lengths.

The comparison of the spectum of the various sources of light possesses many advantages. The work is placed on such a basis that the results are freed from the troublesome questions of absorption, sensitiveness of the plate, etc., and are rendered directly comparable with those that may be obtained at different times, by other observers, under widely differing circumstances. In fact, the results should be the same as those obtained by the eye, the bolometer, or in any other manner that may be devised. All these measures may be made either with a telescope and objective prism, or with a slit spectroscope combined with a pinhole camera or telescope. With the objective prism the spectra are made of the same width, either by interposing a cylindrical lens, by moying the plate at the same equable rate for each exposure,.or by throwing the image out of focus. In the latter case, a rectangular aperture should be placed over the prism, so as to give width with a minimum loss of definition. With the moving plate, a variation of light is obtained by covering one-half of the prisim at a time, along a line perpendicular to its edge.

The standard light used is an ordinary Argand gas burner shining through a small hole. The star α Ursae Minoris is made the ultimate standard to which all work is referred, since the standard light is compared with it before and after each monthly test of the plates. In addition to the wedges for measuring the density of photographic plates a polarizing photometer is used for comparing surfaces with each other.

Early in 1900, while this work was in progress, Mr. W. H. Pickering, in preparing to observe the Solar Eclipse of May 28, desired to select a suitable plate and developer for the work, and accordingly undertook the following investigation, which he describes below:—

A suitable standard of light has long been wanted in photography. Artificial sources usually give even more uncertain results photographically than they do visually, because a slight variation in temperature will effect the blue end of the spectrum even more than the red end. In 1893 it occurred to the writer to employ as a primary standard of actinic intensity the radiation of a star shining directly upon the photographic plate; without previously passing through or being reflected from any medium, except our atmosphere. Since this standard is too faint for general use, a secondary one to be standardized from it has been devised. The light from the star is condensed through a simple plano-convex lens of 8.2 cm. aperture and short focus, and is focused on a small circle of ground glass 0.5 cm. in diameter. This is placed 3 cm. in front of the sensitive plate, which is exposed to it through a small square aperture measuring 0.2 cm. on a side, cut in a blackened brass plate. The constant of this instrument was determined, and it was found to give about thirty times the light of the direct radiation of a star upon the photographic plate. With twenty minutes exposure α Ursae Minoris darkened the plate sufficiently to produce the "Sensitive

Tint," that is to say the tint where a small variation in the light is most noticeable. The secondary standard, however, is not sufficiently brilliant for ordinary purposes, and a tertiary one has therefore been devised. This consists of a box 50 cm. in length, one end of which contains an aperture 5 cm. in diameter, covered by a piece of ground glass, and the other end carries the sensitive plate and the blackened brass plate described above. Just inside the ground glass may be placed diaphragms ranging from 0.04 to 4.0 cm. in diameter. At a distance of about 200 cm. beyond the ground glass is placed an Argand gas burner. This apparatus gives ample light for all photographic purposes, and the plates exposed in it may always be standardized when necessary by an additional exposure to the secondary standard.

The three pieces of apparatus above described are adapted to various investigations. Thus the photographic brightness of the Moon, and of the brighter stars and planets, may be measured with accuracy by employing different apertures in front of the lens of the secondary standard, and measuring the brightness of the various images obtained by means of a photographic wedge, or a series of standard squares of varying density. It is very important to vary the aperture rather than the time of exposure, since the results obtained in the latter case would have to be corrected by the "time Correction" (Annals, Volume XXXII, 20). The secondary standard also enables us to express the sensitiveness of a plate, in terms of universal application throughout all time. Thus the Seed plate No. 27 is capable of being appreciably darkened when exposed for ten minutes to a source equal to 300 times the brightness of α Ursae Minoris. This amount of light is equal to about thirty times the brightness of a star whose photographic magnitude is 0.0. The logarithm of this number, 1.5, may be conveniently used to represent the sensitiveness of the Seed plate. By the use of the secondary and tertiary standard, together with an ordinary photographic telescope, we may make a study of the brightness of nebulae, comets and other luminous surfaces.

From these various investigations it is hoped that we shall obtain a scale of photographic intensities with which all sources of light may be compared and to which they may be referred.

HARVARD COLLEGE OBSERVATORY Circular No. 50.
May 9, 1900.

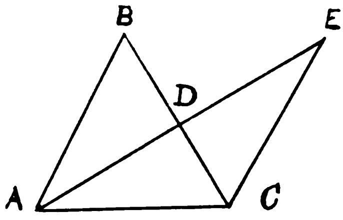
NON-EUCLIDEAN GEOMETRY.

W. H. S. MONCK.

FOR POPULAR ASTRONOMY.

The question of the universal validity of Euclid's axiom regarding parallel lines was one which exercised a good deal of my attention many years ago when I was a student. I came to the conclusion that strict proof was impossible, but that the axiom itself was true and that the objections to it arose either from not realizing its real import in the imagination, or from losing sight of the fact that we were dealing with the real properties of space and that, as always happens when we apply algebraic or symbolical reasonings to real objects, we might readily carry this symbolism too far. At this time I took no interest in astronomy. Indeed the book then used in Dublin University would hardly have led any one to think that astronomy was a physical science of a very progressive character.

But one thing it seemed to me that Legendre did establish without the aid of Euclid's famous axiom viz: that the three angles of a plane triangle could not *exceed* two right angles. The difficulty was to prove that they could not be *less*—perhaps even less than one right angle. The proof that they cannot be greater is substantially the following:



Let ABC be any triangle and let C be its greatest angle and B the next in magnitude. Draw AD bisecting BC and make DE equal to AD and join CE. Now the triangle EDC is evidently equal in all respects to the triangle ADB, and the sum of the three angles of the triangle AEC is evidently equal to that of the original triangle ABC. But the angle ACE is equal to the sum of the two greates tangles of the original triangle ABC viz: ACB and ABC. We can repeat this process as often as we like (bisecting AC instead of CE next time, if that course will increase the angle at C more rapidly), and by carrying this proces on sufficiently far we can obtain a triangle the sum of whose three angles is the same as that of the original triangle, but the two smaller angles in which taken together do not amount to one-millionth (or one hundredth millionth) part of the smallest of the three angles of ABC.

It seemed to me also that the failure to prove Euclid's axiom in the terms laid down arose from the difficulty of applying the principle of superposition to infinites. Let us suppose a number of right lines drawn from a centre and produced to infinity, the angles between each successive pair being equal. Then if the principle of superposition were applied each adjacent pair of lines would enclose an equal space, and if there were a million such lines each pair would enclose one millionth part of the whole plane extended to infinity. Now on the contrary take a pair of right lines crossing a third in such a manner that the two interior angles are together equal to two right angles.

Let *AB** be the intersected line and let the two intersecting lines be *CF* and *DG*. Take $DE = CD$ and draw *EH* making the angle $DEH =$ the angle *CDG*. Suppose all four lines produced to infinity towards the right. Then applying the principal of superposition the space enclosed between the *CF* and *DG* and that enclosed between the lines *DG* and *EH* (to the right of the intersecting line *AB*) will be equal. But if *AB* be produced to infinity we can mark off as many segments equal to *CD* upon it as we please and draw lines under similar conditions through the concluding point of each segment. Consequently the space included between the pair of lines *CF*, *DG* produced to infinity and the intersecting line *AB* does not bear any finite proportion to the whole plane extended to infinity.

Then draw *CI* such that the two angles *CDG*, *DCI* are together less than two right angles, reduce all the lines to infinity. The space included in the angle *FCI* is greater than that included in between the lines *CF* and *DG* since the former bears a finite ratio to the entire plane extended to infinity while the latter does not. But if the line *CI* does not intersect the line *DG* the former space is included in the latter space and we should have a part greater than the whole. Consequently if the principle of superposition is applicable to infinity Euclid's axiom holds good.

But it will be said that our experience can never extend to infinity and we are therefore not warranted in extending any principle of infinity. I do not desire to enter into the metaphysics of the question. I will only say that what holds good within the limits of our experience may be fairly assumed to hold good beyond these limits until we see some reason to the contrary. And

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* By mistake this cut was not engraved. The reader can easily supply it by reference to the figure on page 336 with the following suggestions: *AB* is the same in both figures, if *A* and *B* be placed respectively a little higher and lower than at the points of intersection of the lines. In the wanting cut *CF* is the same as *AC*, *CI* as *AE*, and *EH* as *BD*. Then draw a parallel line, *DG*, midway between *CF* and *EH* and the new figure is complete.—Ed.

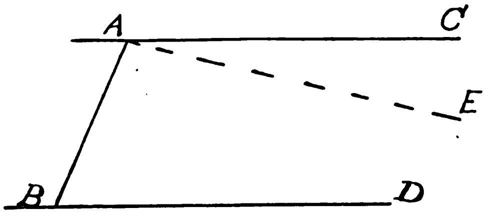
I think if Euclidean geometry did not hold good with respect to the most distant stars that we have tried, its failure ought to be brought to light by our researches on parallax. If the three angles of a triangle with very long sides fell short of 180° we should probably find a considerable parallax for any very remote star; while if it exceeded 180° we ought to discover many more negative parallaxes—perhaps of considerable amount—than we have done. Our researches are as far as I know grounded on the assumption that the three angles of the triangle (whose base consists of the line going two points on the earth's orbit and whose base angles are deduced from observation) are equal to 180°. Nor is this the only instance in which such an assumption is made; but it is not necessary to enter into details.

Although I am a firm believer in Euclidean geometery I am quite prepared to accept any evidence derived from observations on stars presumably very distant which seems to be irreconcilable with it. If Euclid be wrong the stars alone can prove him to be so and I think that our present knowledge of the stars has progressed far enough to throw considerable light on the subject. I should therefore be glad to hear from some non-Euclidean what are the observed facts of astronomy which are relied on as inconsistent with Euclidean geometry—a kind of geometry whose validity as regards terrestrial measurements seems to be established by ample experience.

Let me add however that in my opinion Euclid's geometry is not a mere logical deduction from his assumptions. He appeals at every step to our knowledge of space but this knowledge is so simple and universal that the reader is apt to overlook the fact that Euclid is always dealing with realities and not with mere argument. If you cannot draw the figure or draw it wrongly you cannot follow him. If when you were asked to bisect the base of a triangle by a right line from the vertex, you drew the line outside of the triangle and made the connection below the base, the conclusion will probably not follow. This, it may be said, would not be a right line. But can you prove this from Euclid's definition of a right line? If there were such a being as a man who had no idea of space he would find himself utterly unable to deduce any conclusion from Euclid's definitions and axioms. Euclid no doubt assumes that the properties of space are the same everywhere and at all times; but his constant appeal is, "Draw your figure. Test what I say by the space which you know and experience. You will not see the force of my reasonings until you do that."

I have treated Euclid's axiom as an assumption that the three angles of every plane triangle are equal to two right angles. If that fact could be proved otherwise the axiom might be dispensed with. Euclid puts it to no other use. Various forms of the axiom have been given with the view of making it more acceptable. Its acceptance I think does not depend on the terms but on the the realization of their import by the hearer.

Let the sum of the angles *BAC*, *ABD* be equal to two right angles (180°). It is susceptible of proof that the right lines *AC* and *BD* cannot meet. Draw the right line *AE*. Can you believe that however both lines may be produced *AE* will never meet *BD*? The difficulty of belief does not arise from the terms employed but from gazing at or contemplating the figure.



SPECTROSCOPIC NOTES.

The entire path of totality of the eclipse of May 28 has been favored with a perfect sky. European observers in Portugal, Spain, and Algiers report clear weather. In this country all along the central line weather conditions were magnificent; the good fortune of which is accentuated by the fact of partial cloudiness as near to the path as New York.

The instrumental equipment, which was elaborate, was installed chiefly at stations in North Carolina, Georgia and Alabama. Wadesboro, N. C., Pinehurst, N. C., Thomaston, Ga., Barnesville, Ga., Greenville, Ala., and Fort Deposit, Ala., might perhaps be mentioned as favorite points. Of the congregations of visiting sight-seers that at Norfolk, Va., was undoubtedly the most prominent.

The amount of apparatus was large, and its variety considerable, including instruments adapted to almost every possible line of research, visual, photographic, spectroscopic, bolometric. Of the spectroscopic results a few only have been reported through the medium of the daily press; the great mass being largely spectrographic, must await development of plates and subsequent publication in the scientific journals.

M. Paulsen (*Comptes Rendus*, March 5; *Nature*, April 26) during brilliant auroral displays in Iceland from Dec. 31 to Jan. 25 has succeeded in photographing a number of new bright lines in the violet and ultra-violet of the spectrum of the aurora.

The statement has been in general circulation that spectroscopic evidence of the rotation of Venus has at last been secured. The accuracy of measurement of rotation in the line of sight has for some time been adequate to the detection of the rotation of Venus if the period is as short as a day; in fact the persistent failure to find evidence of rotation has perhaps come to be regarded as evidence on the side of those who contend for a period of 225 days. If the planet rotates in a day the velocity would be about a third of a mile per second. The effective velocity at time of superior conjunction would be two-thirds of a mile per second, or, as near conjunction as observations could be taken, perhaps half a mile per second; a quantity at present measurable. For the present the announcement of Belopolsky's results goes no further than the bare statement that the period of the planet's rotation is found to be short.

In *Astronomische Nachrichten* No. 3633 Mr. Epsin publishes a further liberal list of stars with remarkable spectra. The stars are with one exception fainter than the seventh magnitude, and most of them are more or less striking examples of type III. A large majority of the stars of the present list are situated in the Milky Way near Cygnus.

At the meeting of the Royal Astronomical Society, March 9, Mr. Shackleton (*Monthly Notices*, March; *Observatory*, April) read a paper describing his apparatus for examining the distribution of matter in the sun's corona. A photograph was exhibited, taken near the middle of totality in the eclipse of 1896, showing the continuous spectrum to a distance of 15′ from the moon's limb, while the coronium line at λ 5303 reached a height of only 5′. Mr. Shackleton described a combination of color screens admitting a narrow band of green light in the neghborhood of λ 5303 and suppressing the rest of the spectrum. If coronium is confined to the inner corona, photographs taken through such a screen chiefly by the coronium radiation should be less extended and less irregular in form than ordinary photographs in which the entire continuous spectrum of the outer corona is active.

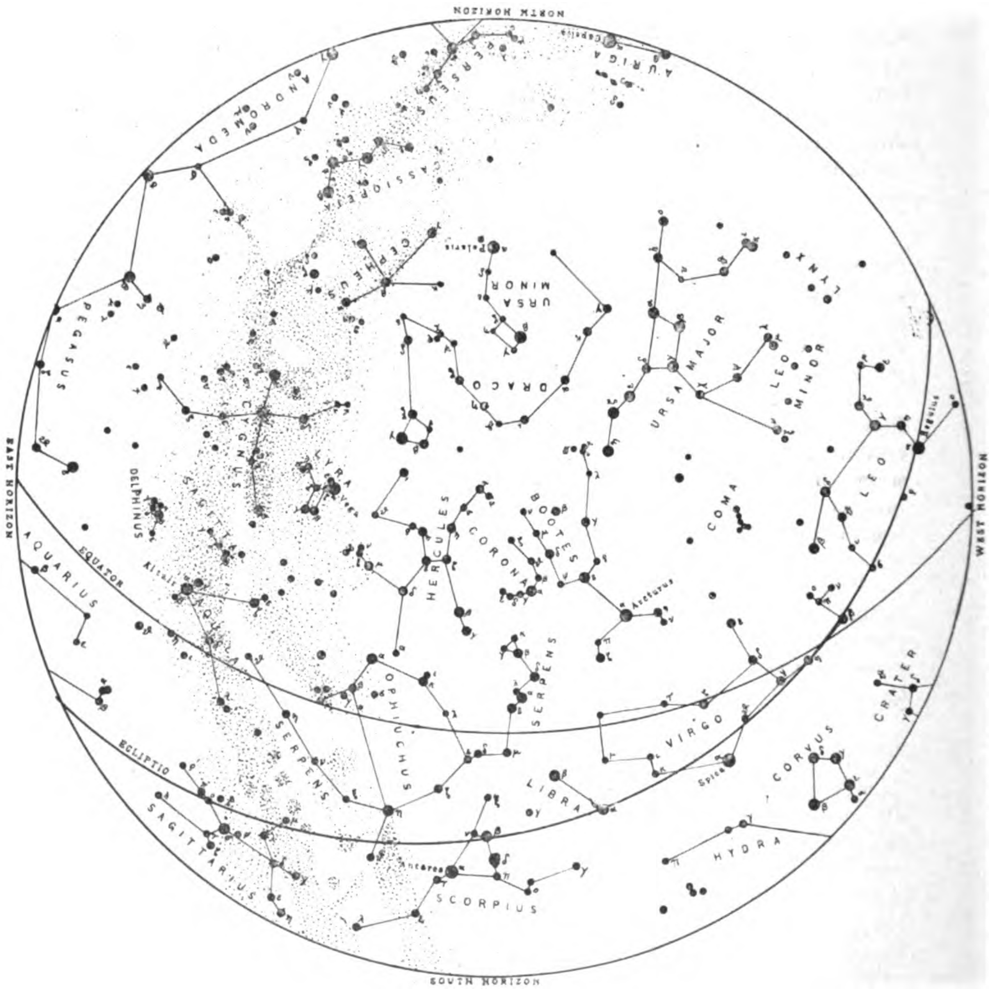
Prof. FitzGerald contributes to *Nature* of May 3 a short note in support of the idea that the sun's corona is of the nature of a solar aurora. He cites, to explain the absence of a dark line of coronium in the sun's spectrum, recent experiments by Herr Cantor which seems to show that when the radiation of a gas is due to electric discharge there is no corresponding absorption.

Mr. Newall contributes to the *Monthly Notices of the Royal Astronomical Society* for March some results of his study of the spectroscopic binary Capella. His former period of 104 days is confirmed. The observations show that the two components of different types of spectrum are nearly equal in mass, and are not very different in brightness. The radius of the relative orbit if it is seen edgewise is about 52,000,000 miles, or if seen inclined at an angle of 60° to the line of vision 104,000,000. Assuming as accurate Elkin's rather uncertain value of 0″.08 for the parallax, the actual brightness is about 500 times that of the Sun; for the orbit assumed to be seen edgewise the angular separation is 0″.04 and the mass 1.7 that of the Sun; for the orbit assumed to be seen under an angle of 60° the angular separation is 0″.08 and the mass 14 that of the Sun.

PLANET NOTES FOR JUNE AND JULY.

H. C. WILSON.

Mercury is evening star with Venus and will be visible to the naked eye at least during the first week in July. On June 22 in the morning Mercury will be in conjunction with Venus, Mercury being then 2°19′ north of Venus. Mercury and the new moon will be near each other on the night of June 28, and again on July 26. On the morning of July 4 Mercury will be at greatest elongation east from the Sun, 26° 1′. Toward the end of the month Mercury will approach the Sun, coming to inferior conjunction on the morning of August 1.



THE CONSTELLATIONS AT 9 P. M., JULY 1, 1900.

Venus will be visible as evening star only a few days more, since she will be at inferior conjunction on the morning of July 8. A few days after that one may look for the planet in the north-east in the morning.

Mars crosses the meridian between nine and half past nine and can only be studied now in the morning twilight. He is so nearly keeping pace with the earth in his orbit around the Sun that the relative positions change slowly.

Jupiter is at his best for this year, visible toward the south in Scorpio in the early evening. He will be stationary in right ascension July 28 and after that move eastward among the stars.

Saturn will be at opposition June 23 in the constellation Sagittarius. You see this planet every evening now, toward the southeast after nine o'clock, a golden star with steady light. It is a pity that, now that the rings are turned as open to us as they ever are, the altitude of the planet should be so low that observations are always unsatisfactory. Our loss, however, is gain to those in the southern hemisphere and they ought to have their turn at this splendid planet.

Uranus is in Scorpio and about 7° east and 2° south of Jupiter and may be seen at the same hours.

Neptune is behind the sun.

Phenomena of Jupiter's Satellites.

Central Standard Time.

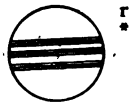
	h	m			
June 22	9	01	P. M.	II	Tr. In.
	10	14	"	II	Sh. In.
	11	27	"	II	Tr. Eg.
23	12	43	A. M.	II	Sh. Eg.
24	12	10	"	I	Sh. In.
	1	44	"	I	Tr. Eg.
	2	23	"	I	Sh. Eg.
	8	49	P. M.	I	Oc. Dis.
	11	39	"	I	Ec. Re.
25	8	11	"	I	Tr. Eg.
	8	52	"	I	Sh. Eg.
26	12	03	A. M.	III	Tr. In.
29	11	18	P. M.	II	Tr. In.
30	12	48	A. M.	II	Sh. In.
	1	44	"	II	Tr. Eg.
July 1	9	41	P. M.	II	Ec. Re.
	10	35	"	I	Oc. Dis.
2	1	33	A. M.	I	Ec. Re.
	7	45	P. M.	I	Tr. In.
	8	33	"	I	Sh. In.
	9	58	"	I	Tr. Eg.
	10	47	"	I	Sh. Eg.
3	8	02	"	I	Ec. Re.
6	7	18	"	III	Oc. Re.
	8	57	"	III	Ec. Dis.
	10	49	"	III	Ec. Re.
8	8	00	"	II	Oc. Dis.
9	12	18	A. M.	II	Ec. Re.
	12	22	"	I	Oc. Dis.
	9	33	"	I	Tr. In.
July 9	10	28	P. M.	I	Sh. In.
	11	46	"	I	Tr. Eg.
10	7	10	"	II	Sh. Eg.
	9	56	"	I	Ec. Re.
11	7	11	"	I	Sh. Eg.
13	8	54	"	III	Oc. Dis.
	10	51	"	III	Oc. Re.
15	10	24	"	II	Oc. Dis.
16	11	22	"	I	Tr. In.
17	7	14	"	II	Sh. In.
	7	35	"	II	Tr. Eg.
	8	37	"	I	Oc. Dis.
	9	44	"	II	Sh. Eg.
	11	51	"	I	Ec. Re.
18	8	02	"	I	Tr. Eg.
	9	06	"	I	Sh. Eg.
24	7	32	"	II	Tr. In.
	8	45	"	III	Sh. Eg.
	9	49	"	II	Sh. In.
	10	00	"	II	Tr. Eg.
	10	27	"	I	Oc. Dis.
25	12	19	A. M.	II	Sh. Eg.
	7	39	P. M.	I	Tr. In.
	8	48	"	I	Sh. In.
	9	53	"	I	Tr. Eg.
	11	01	"	I	Sh. Eg.
26	8	14	"	I	Ec. Re.
31	7	54	"	III	Tr. Eg.
	9	58	"	II	Tr. In.
	10	37	"	III	Sh. In.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., Eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

Jupiter's Satellites for July.

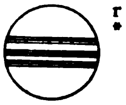
Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.



III.

II.



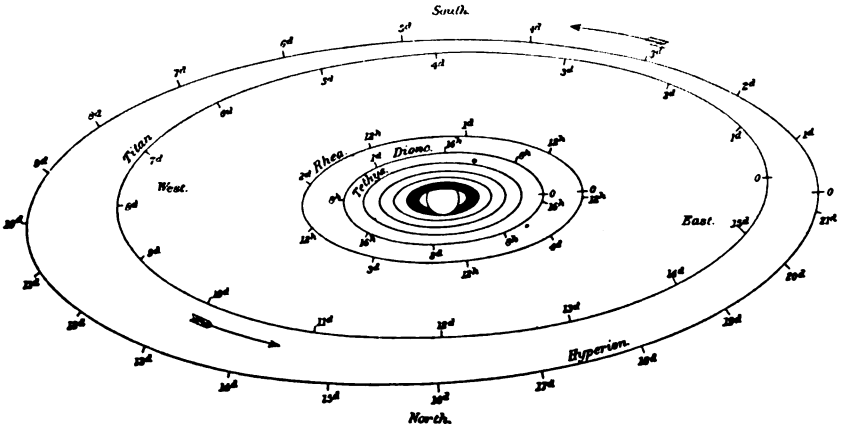
IV.

No Eclipse.

Configurations at 9h for an Inverting Telescope.

Day.	West.	East.
1	·4 ·1	○ .2 3·
2	○ 1· ·4	○ 3· 2·
3	3· 2·	○ ·1 ·4
4	3· ·2 1·	○ ·4
5	·3	○ ·1 ·2 ·4
6	·1	○ ·3 2· ·4
7	2·	○ 1· ·3 4·
8	1·	○ 3· 4· ·2●
9		○ 1· 3· 2· 4·
10	3· 2·	○ ·1 4·
11	3· ·2 1· 4·	○
12	4· ·3	○ ·1 ·2
13	4· 1·	○ 2· ·3●
14	4· 2·	○ 1· ·3
15	·4 ·1 ·2	○ 3·
16	·4	○ 1· 3· 2·
17	·4 3· 2·	○ .1●
18	3· ·4 ·2 1·	○
19	·3	○ ·1 ·2 ·4●
20	1· ·3	○ 2· ·4
21	2·	○ ·1 ·3 .4
22	·1 ·2	○ 3· ·4
23		○ 1· ·2 ·3 ·4
24	○ 2· 3· ·1	○ 4·
25	○ 1· 3· ·2	○ 4·
26	·3	○ ·1 ·2 4·
27	·3 1·	○ 4· 2·
28	2· 4·	○ ·1 ·3
29	4· ·2 ·1·	○ ·3
30	4·	○ 1. ·2 3·
31	4· ·1 3·	Ↄ2·

The Satellites of Saturn.



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, AT OPPOSITION IN 1900, AS SEEN IN AN INVERTING TELESCOPE.

I. MIMAS.

Period 0^d 22.6^h

	h		
June 23	2.3	A. M.	W
24	12.9	"	W
24	11.6	P. M.	W
25	10.2	"	W
26	8.8	"	W
27	7.4	"	W
July 1	2.5	A. M.	E
2	1.2	"	E
2	11.8	P. M.	E
3	10.4	"	E
4	9.0	"	E
5	7.6	"	E
6	6.3	"	E
10	1.4	A. M.	W
10	12.0	Midn	W
11	10.6	P. M.	W
12	9.2	"	W
13	7.9	"	W
14	6.5	"	W
18	1.6	A. M.	E
19	12.2	"	E
19	10.8	P. M.	E
20	9.5	"	E
21	8.1	"	E
22	6.7	"	E
27	12.5	A. M.	W
27	11.1	P. M,	W
28	9.7	"	W
29	8.3	"	W
30	6.9	"	W

II. ENCELADUS.

Period 1^d 08.9^h

	h		
June 21	5.9	A. M.	E
22	2.7	P. M.	E
23	11.6	"	E
25	8.5	A. M.	E
26	5.3	P. M.	E
28	2.2	A. M.	E
29	11.1	"	E
30	8.0	P. M.	E
July 2	4.9	A. M.	E
3	1.7	P. M.	E
4	10.6	"	E
6	7.5	A. M.	E
7	4.4	P. M.	E
9	1.2	A. M.	E
10	10.1	"	E
11	7.0	P. M.	E
13	3.9	A. M.	E
14	12.7	P. M.	E
15	9.6	"	E
17	6.5	A. M.	E
18	3.4	P. M.	E
20	12.2	A. M.	E
21	9.1	"	E
22	6.0	P. M.	E
24	2.9	A. M.	E
25	11.8	"	E
26	8.7	P. M.	E
28	5.5	A. M.	E
39	2.4	P. M.	E
30	11.3	"	E

III. TETHYS.

Period 1^d 21.3^h

	h		
June 21	2.4	A. M.	E
22	11.7	P. M.	E
24	9.0	"	E
25	6.3	"	E
28	3.6	"	E
30	12.9	"	E
July 2	10.1	A. M.	E
4	7.4	"	E
6	4.7	"	E
8	2.0	"	E
9	11.3	P. M.	E
11	8.6	"	E
13	5.9	"	E
15	3.2	"	E
17	12.5	"	E
19	9.7	A. M.	E
21	7.1	"	E
23	4.3	"	E
25	1.6	"	E
26	10.9	P. M.	E
28	8.2	"	E
30	5.5	"	E

IV. DIONE.

Period 2^d 17.7^h

	h		
June 20	6.9	A. M.	E
23	12.6	"	E
25	6.3	P. M.	E
28	11.9	A. M.	E
31	5.5	"	E

DIONE, Con't.

		h		
July	3	11.2	P. M.	E
	6	4.9	“	E
	9	10.5	A. M.	E
	12	4.1	“	E
	14	9.8	P. M.	E
	17	3.5	“	E
	20	9.1	A. M.	E
	23	2.8	“	E
	25	8.4	P. M.	E
	28	2.1	“	E
	31	7.7	A. M.	E

V. RHEA.

Period $4^d\ 12.5^h$

		h		
June	19	5.5	P. M.	E
	24	5.8	A. M.	E
	28	6.2	P. M.	E
July	3	6.5	A. M.	E
	7	6.8	P. M.	E

RHEA, Con't.

	h		
12	7.1	A. M.	E
16	7.4	P. M.	E
21	7.8	A. M.	E
25	8.1	P. M.	E
30	8.5	A. M.	E

VI. TITAN.

Period $15^d\ 23.3^h$

		h		
June	20	8.9	P. M.	W
	24	6.9	“	S
	28	3.9	“	E
July	2	4.2	“	I
	6	6.2	“	W
	10	4.2	“	S
	14	1.4	“	E
	18	2.2	“	I
	22	3.7	“	W
	26	1.7	“	S
	30	11.0	A. M.	E

VII. HYPERION

Period $21^d\ 7.6^h$

	d	
June	19.4	W
	25.2	S
	30.4	E
July	5.2	I
	10.6	W
	16.5	S
	21.7	E
	26.5	I
	31.9	W

VIII. JAPETUS.

Period $79^d\ 22.1^h$

	d	
June	12.7	I
July	2.9	W
	23.0	S
Aug.	10.9	E

VARIABLE STARS.

J. A. PARKHURST.

Maxima and Minima of Long Period Variables.

1900 August and September.

MAXIMA.

	Aug.
—Aurigae	4
V Orionis	4
V Virginis	4
R Tauri	5
SS Cygni	8?
RR Scorpii	8
U Draconis	11
S Orionis	14
R Ophiuchi	15
R Vulpeculae	16
RR Librae	18
RZ Scorpii	20
U Eridani	23
R Pyxidis	23
RT Librae	24
V Tauri	24
R Leonis minoris	25
R Aquilae	26
U Cygni	26
X Geminorum	26
RR Capricorni	28
R Bootis	29
R Corvi	29

MAXIMA, Con't.

	Sept.
S Herculis	1
T Arietis	2
X Puppis	3
T Herculis	4
R Serpentis	4
R Aurigae	5
T Centauri	6
V Canis min.	7
S Lyrae	7
RW Scorpii	7
—Aquilae	8
S Ursae Maj.	8
RU Librae	17
R Lyncis	19
Z Scorpii	19
T Serpentis	21
R Canis min.	22
W Hydrae	22
R Scorpii	22
RU Herculis	26
S Bootis	28
T Draconis	20
S Hydrae	30
W Scorpii	30

MINIMA.

	Aug.
W Persei	4
U Aurigae	5
U Piscium	7
T Ursae Majoris	8
RR Sagittarii	10
R Leporis	11
T Aquarii	14
Y Capricorni	17
R Microscopii	18
X Ophiuchi	19
Z Cygni	20
R Arietis	21
T Andromedae	22
R Cancri	28
	Sept.
R Trianguli	1
S Delphini	5
S Camelopard.	7
W Herculis	8
η Geminorum	10
S Leonis	12
R Canum Ven.	17
U Herculis	17
X Librae	20
U Bootis	26

NOTES TO LONG PERIOD EPHEMERIS.—The star "—Aurigae" is Ceraski's variable at $5^h\ 20^m\ 9^s$, +36° 49′, (1900.) For chart see this magazine, Vol. VII, page 43.

The star "—Aquilae" is Anderson's variable at $20^h\ 8^m\ 3^s$, +12° 41′.7, (1900.) See this magazine, Vol. VI, page 532 and VII, 265.

The star "W Persei" is V Persei in Chandler's Third Catalogue.

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900.

ALGOL.

	d	h
July	3	23
	6	20
	9	17
	12	13
	26	21
	29	18
Aug.	1	15
	4	12
	18	20
	21	17
	24	14
	27	10

λ TAURI.

	d	h
July	4	19
	8	18
	12	17
	16	16
	20	14
	24	13
	28	12

U CORONAE.

	d	h
July	10	15
	17	13
	24	10
	31	8
Aug.	10	16
	17	14
	24	12
	31	10

δ LIBRAE.

	d	h
July	1	8
	3	16
	8	18
	10	16
	15	8
	17	15
	22	7
	24	15
	31	15
Aug.	7	14
	14	14
	21	13
	28	13

Y CYGNI.

$2P = 2^d\ 23^h.9.$

Even min.

	d	h
July	2	14
Aug.	1	13

Odd min.

	d	h
June	30	17
July	30	16
Aug.	29	15

Z HERCULIS.

$2P = 3^d\ 23.8^h.$

Even min.

	d	h
July	1	13
Aug.	2	11

Odd min.

	d	h
July	3	13
Aug.	4	11

U CEPHEI.

	d	h
July	3	9
	5	20
	8	8
	10	20
	13	8
	15	20
	18	8
	20	19
	23	7
	25	19
	28	7
	30	19
Aug.	2	6
	4	18
	9	18
	14	18
	19	17
	24	17
	29	17

W. DELPHINI.

	d	h
July	2	13
	7	9
	21	19
	26	14
	31	9
Aug.	14	19
	19	15
	24	10

+ 45°3062.

	d	h
July	2	4
	6	18
	11	8
	15	21
	20	11
	25	1
	29	15
Aug.	3	4
	7	18
	12	8
	16	22
	21	11
	26	1
	30	15

U OPHIUCHI.

$P = 0^d\ 20^h.1.$

	d	h
June	30	6
July	31	7
Aug.	31	8

R CANIS MAJ.

$P\ 1^d\ 3^h.3.$

	d	h
June	30	8
Aug.	1	3
	31	19

SS CYGNI—After a normal period which had lasted 33 days SS Cygni began rising about 1900 April 25.0, passed 9.35 magnitude Apr. 25.7, passed maximum Apr. 27, and reached normal light again May 6.0. The maximum was as short as any on record, 11 days; the average of 8 short maxima being 12.2 days. As the order of maxima has been reversed, those of January and March 1900, both being long, it is a question of much interest what course the star will now follow. The past maximum was covered by 12 observations by Mr. Zaccheus Daniel and 3 by the writer.

AN UNUSUALLY FAINT VARIABLE has been discovered by Prof. Schwassmann and announced in No. 3636 of the *Nachrichten*. The following magnitudes were determined from photographs—

1892 April 17 not brighter than 14.
1893 April 14 about 10.2.
1894 March 29 not brighter than 14.
1896 April 16 about 11.2.
1900 April 2 not brighter than 14.

The place of the new variable is—

R.A. $13^h\ 2^m\ 39^s.5$, Dec. —12° 37′ 50″, (1900.)

COMET AND ASTEROID NOTES.

Ephemeris of Comet a 1900.

1900		α			δ		log r	log Δ
		h	m	s	°	′		
June	20	0	26	8	+ 36	29.9	0.1874	0.1886
	21		23	0	36	59.5		
	22		19	43	37	29.4	0.1916	0.1785
	23		16	16	37	59.5		
	24		12	38	38	29.7	0.1958	9.1683
	25		8	50	39	0.1		
	26	0	4	50	39	30.6	0.2000	0.1580
	27	23	0	40	40	1.1		
	28		56	17	40	31.5	0.2042	0.1478
	29		51	42	41	1.7		
	30		46	53	41	31.8	0.2085	0.1376
July	1		41	50	42	1.5		
	2		36	32	42	30.7	0.2128	0.1277
	3		30	59	42	59.4		
	4		25	11	43	27.4	0.2172	0.1181
	5		19	7	43	54.6		
	6		12	47	44	20.7	0.2216	0.1090
	7	23	6	10	44	45.6		
	8	22	59	17	45	9.2	0.2260	0.1003
	9		52	8	45	31.2		
	10		44	43	45	51.5	0.2304	0.0924
	11		37	2	46	9.8		
	12		29	5	46	25.9	0.2349	0.0850
	13		20	54	46	39.7		
	14		12	29	46	50.9	0.2393	0.0786
	15	22	3	52	46	59.4		
	16	21	55	5	47	5.1	0.2438	0.0733
	17		46	8	47	7.7		
	18		37	4	47	7.1	0.2483	0.0692
	19		27	55	47	3.2		
	20		18	42	46	55.9	0.2528	0.0662
	21		9	29	46	45.1		
	22	21	0	16	46	30.8	0.2573	0.0645
	23	20	51	6	46	13.0		
	24		42	2	45	51.8	0.2617	0.0644
	25		33	6	45	27.4		
	26		24	19	45	0.0	0.2662	0.0658
	27		15	43	44	29.6		
	28	20	7	20	43	56.4	0.2706	0.0686
	29	19	59	11	43	20.6		
	30		51	15	42	42.4	0.2750	0.0728
	31	19	43	37	+42	2.1		

Ephemeris of Eros.

[By James B. Westhaver from Elements by Henry Norris Russell; from *Astr. Journal* No. 479.]

Greenwich Midn.		R. A.			Decl.				log Δ	Mag.
		h	m	s		°	′	″		
May	27	23	46	17.5	+	2	39	4	0.26387	13.1
	29		49	53.3		3	13	22	0.25883	
	31		53	28.4		3	47	48	0.25370	13.0
June	2	23	57	2.6		4	22	22	0.24848	
	4	0	0	36.1		4	57	6	0.24317	12.9
	6		4	8.7		5	31	57	0.23778	
	8		7	40.7		6	6	57	0.23230	12.9
	10		11	11.9		6	42	6	0.22674	
	12		14	42.5		7	17	24	0.22108	12.8
	14		18	12.4		7	52	51	0.21533	
	16		21	41.7		8	28	27	0.20949	12.7
	18		25	10.3		9	4	12	0.20355	
	20		28	38.1		9	40	5	0.19752	12.7
	22		32	5.3		10	16	8	0.19140	
	24		35	31.8		10	52	19	0.18518	12.6
	26		38	57.5		11	28	39	0.17886	
	28		42	22.4		12	5	8	0.17244	12.5
	30		45	46.6		12	41	47	0.16593	
July	2	0	49	10.0	+	13	18	34	0.15932	12.5

The asteroid was picked up by Professor Howe, of Denver, on the night of May 27, the position being

May 27.9129 R. A. 23^h 48^m $3^s.9$ Decl. $+2^\circ$ $46'$ $33''$.

From this it may be seen that the planet is about 1^m in advance of its predicted place in right ascension and very close in declination.

GENERAL NOTES.

The next number of this publication, which will be for the months of August and September will be mailed about the 20th of August.

We have received so many articles about the total solar eclipse of May 28, 1900, that we could not publish all this time. Considerable more will appear in our next number.

The Spectrum of the "Flash."—We have had strong hope that some of the many parties who observed the total solar eclipse of May 28 last, in America, would obtain photographs of the spectrum of the "flash" so-called. We know this work was planned for by some parties, but up to this writing, we have not heard that any one succeeded. Along the entire path of totality in the United States, the oppertunity for all kinds of observation was excllent. It is not yet known why everyone was unsuccessful. For next number we hope to have the results of all important eclipse work done at home or abroad.

Observations of Eros—A letter received from the Arequipa Station of this Observatory gives details concerning four photographs of Eros taken there in April with the Bruce Telescope by Dr. Delisle Stewart.

An adjacent star was followed in an eyepiece, and by means of a micrometer screw the photographic plate was moved with regard to it by an amount and in a direction equal to the motion of Eros. The stars thus appeared as trails and Eros as a point. Approximate positions were determined from the plates at Arequipa with the results given below. Paper print of two of these plates were sent to Cambridge and measures of them are also given. The negatives are now on their way to Cambridge and as soon as received, accurate position will be derived from them.

Plate.	Date 1900.	G. M. T.		R. A. 1900.			Dec. 1900.	
		h	m	h	m	s	°	′
A 4333	April 26	21	20	22	49	21	—5	46 0
"	"	"			49	23	—5	46.4
A 4334	"	22	06		49	27	—5	45.8
A 4338	April 27	21	47		51	23	—5	29.6
A 4341	" 30	21	16		57	7	—4	42.1
"	" "	"			57	1	—4	42.3

These appear to be the first observations of Eros since its conjunction with the Sun. The second observations taken a month later are given in the accompanying bulletin. Efforts have been made here to observe Eros both visually and photographicaly, but have failed owing to twilight.

HARVARD COLLEGE OBSERVATORY, Cambridge, Mass.,
June 1, 1900.

Observations of the Eclipse of May 28, 1900.—The following observations of contacts were made at the Chamberlin Observatory, University Park, Colo., under favorable atmospheric conditions. The position of the Observatory is given in the American Ephemeris, under the name Denver.

FIRST CONTACT.

Greenwich M. T.			Instrument.	Observer.
0^h	44^m	$22^s.6$	Twenty-inch	Herbert A. Howe.
0	44	25 .5	Six-inch	Chas. J. Ling.

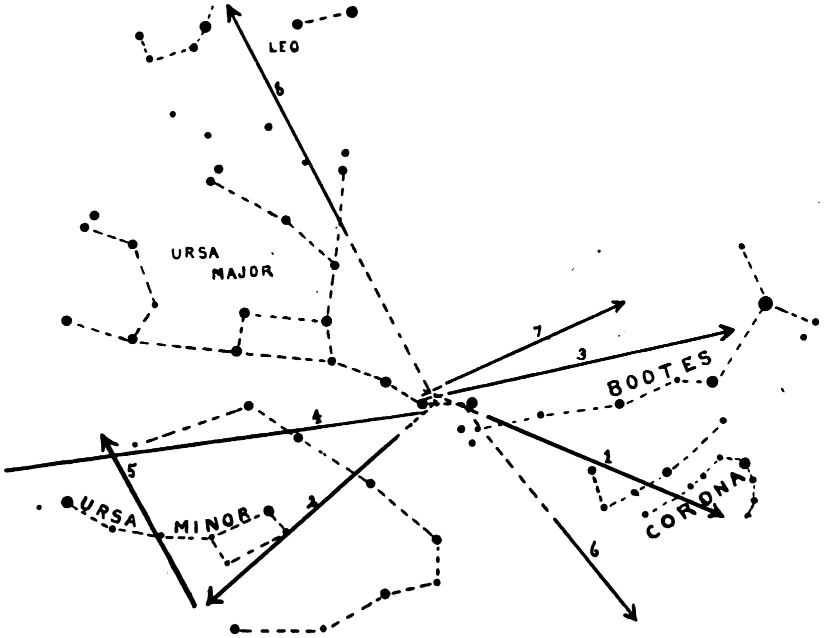
LAST CONTACT.

2^h	39^m	$34^s.9$	Twenty-inch	Herbert A. Howe.
2	39	32 .9	Six-inch	Chas. J. Ling.
2	39	33 .9	Five-inch	Julian O. Howe.

The times predicted from the data in the American Ephemeris were respectively 0^h 44^m $25^s.1$ and 2^h 39^m $38^s.0$. HERBERT A HOWE.

University Park, Colo.

The ζ Ursids—On the night of the 27th of April I saw a meteor appear between ζ and η Ursae Majoris. On the 28th, I was looking at the same place as the night before, and I saw a meteor of the first magnitude. It came from the same place as the one the night before. After a little I saw another faint one, and then another; they all shot from the same place. I then made a rough map, and watched for more. I saw after this four more, besides two Serpentids, and one Lyrid. 1 was on the 27th, it was red. On the 28th, 2 was bright, medium-speeded, white meteor, which shot into the clouds below; 3 was of fifth magnitude, slow, faint and shot parallel to ζ and η Ursae Majoris; 4 was of the 5th magnitude, green; 5 was a Lyrid, of second magnitude, red; 6 was short, of a blue color, fourth magnitude; 7 was a white meteor, of third magnitude; 8 was in Leo, white, of second magnitude; 9 was near Leo, off map, third white, and came from Serpens; 10 was a bright meteor. It started from Serpens, went under Corvus and disappeared below it. It was low in the south and had a curved track, left no trail, was of a pure white color and of 0 magnitude. It rivalled Venus in whiteness and brightness. The radiant is between ζ and η



METEORS FROM URSA MAJOR.

Radiant between ζ and η, April 27 and 28, 1900.

Time	Color.	Magn.	Class.	No.	Date and Remarks.
9.00	Red	2d	ζ. U M.	1	April 27 exactly at 9.00
8.27	White	1st	ζ. U. M.	2	" 28 quite bright.
8.30	White	5th	ζ. U. M.	3	" 28 faint, slow.
8.35	Green	5th	ζ. U. M.	4	" 28 "
8.42	Red	2d	Lyrid	5	" 28 came from Lyra.
8.48	Blue	4th	ζ. U. M.	6	" 28 a blue meteor.
9.03	White	3d	ζ. U. M.	7	" 28
9.06	White	2d	ζ. U. M.	8	" 28 In Leo.
9.07	White	3d	Serpentid	9	" 28 near Leo.
9.10	White	0	Serpentid	10	" 28 beautiful bright meteor.

ζ. U. M. = Zeta Ursæ Majoris. Average = one in every 7½ minutes.

ROBERT M. DOYLE.

A letter has been received at the Harvard College Observatory from Professor H. A. Howe at Denver stating that Eros was observed with the 20-inch refractor of the Chamberlin Observatory with the following results:

Gr. M. T.	Apparent R. A.	Apparent Decl.	Comp. Stars.
	h m s	° ′ ″	
May 27.90720	23 47 3.43	+2 46 27.3	Boss 8197
May 27.91859	23 47 4.37	+2 46 38.6	Boss 8198

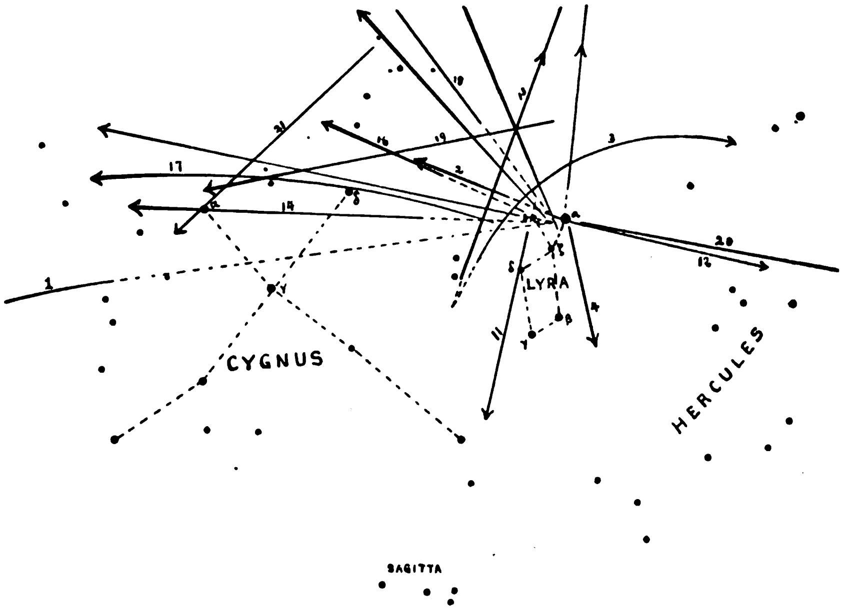
After taking parallax and aberration into account, a comparison of these observations with the ephemeris of J. B. Westhaver in A. J. No. 479 gave the following corrections to that ephemeris:

Gr. M. T.			
	s	″	
May 27.90729	+1.7	+28	Estimated Magn. 13.
May 27:91859	+1.5	+28	

So far as known this is the first visual observation of Eros since its conjunction with the Sun.

Harvard College Observatory, Cambridge, Mass.,
June 1, 1900.

The Lyrid Shower.—The nights of the 17th, 18th, 19th were cloudy, but the 20th was clear. The Moon was one day before last quarter. The radiant point was not very well defined but most of the meteors came from Vega, or between the region of α, ε, ζ Lyrae. Five of the meteors were outside of this triangle, numbers 13, 21, 3, 19 and 11. They were classed as Lyrids, because they were all very swift, excepting No. 3. At 12:30 my observations began, but one meteor was seen of third magnitude, medium speed, moving from Vega at 12:20. No. 2 was a short, swift and remarkably bright meteor, leaving a trail; 3 was an unusual meteor, it started slow and seemed to have several colors, it left a trail of red, white and blue colors. Another peculiarity of it was a very curved



The Lyrid Meteors, April, 20, 1900.

path; 4, 5 and 6 were minor meteors; 7 was blue, of the fourth magnitude, and quite swift, showing the characteristic of the Lyrid shower; 8, a repetition of No. 7; 9 was a most surprising meteor. It was so short, so bright and so swift, the eye couldn't quite make out whether it curved or not. It could not have lasted one-fifth of a second; 10 and 11 were faint; 12 was rather slow and very faint, of the sixth magnitude; 13 was a most beautiful sight. It started a little northeast of Lyra, and shot across the sky, disappearing in Virgo, passing Arcturus and Corona. It was of a red color, slow, left a persistent trail, lasting two seconds. After this the following meteors were so swift the eye just caught them. The shower was, I think, at its maximum on the 19th but, although the meteors on the 20th were few, yet they were swift, bright, interesting. They diminished in number as 4:00 o'clock approached, so I think the maximum must have been before the 20th. The shower might be called good, on account of the many interesting points about individual meteors.

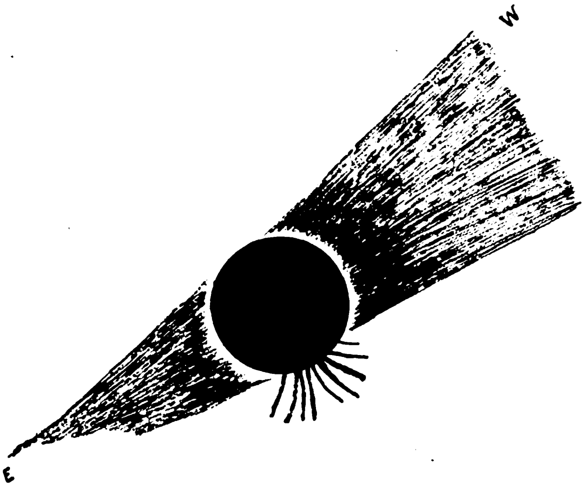
No	Color.	Magn.	Time.	Class.	Notes.	Trails.
1	W.	3	12.20	L	Mostly off map.	———
2	W.	0.5	12.43	L	Very bright, trail	4th magn. W.
3	R. (W. B)	0 5	1.01	L	of several colors.	Long R. 2d mag.
4	W.	3	1.10	L	Short one.	———
5	W.	2.5	1.28	L	Off map	———
6	W.	1	1.30	L	———	———
7	B.	4	1 35	L	Swift.	
8	B.	4	1 38	L	"	
9	W.	0	1 43	L	Very swift & bri't.	Bright.
10	B.	5	1.50	L	———	———
11	B.	4	2.01	L	———	———
12	——	6	2 07	L	Very faint.	Across sky.
13	R. W.	1	2.10	L	Beautiful.	2d magn. B.
14	R.	2	2 35	L	Swift.	———
15	R.	2	2 44	L	Very swift indeed.	
16	R.	2	2.48	L	" " "	
17	R.	4	2 55	L	" " "	
18	W.	1	2 56	L	A flash of white.	
19	W. (B.)	0.5	3.13	L	Medium speed.	Red.
20	R.	1.5	3.16	L	Swift.	3d magn.
21	W.	3	3.20	M	Short curved.	———
22	R.	2	3 45	L	Swift.	———
Apr. 5	B.	2.5	7 57	L	Medium speed, curved quite a little.	

1.5, 0.5, 2 5 mean, a little less than first magnitude, zero magnitude and second magnitude. Average one every nine minutes. Average magnitude 2 5 or a little less than second magnitude. ROBERT M. DOLE,

91 Glen Road, Jam. Plain, Mass.
April 21, 1900.

The Total Eclipse of the Sun at New Orleans.—The total eclipse was observed here in a remarkably clear area of a partly cloudy sky. The duration being scarcely more than a minute, the darkness was only that of early twilight. About ten seconds before totality the inner corona became visible.

The outer corona had two extensions one on the east tapering and not sharply outlined on the edges, the other somewhat longer, being about a degree at its outer edge from the Moon's limb. It was more conspicuous, was sharply outlined, and widened as it extended. Its upper edge pointed almost directly towards the planet Mercury. It left an impression of a more streaky structure than the eastern wing.



Corona of Total Solar Eclipse, May 28, 1900.
Seen at New Orleans, La., Drawn by Miss Rose O'Halloran.

The south polar rays were conspicuous pointed and curving.
The inner corona was shallow.
The tint of the entire appendage was that of feathering clouds after sunset.
May 28, 1900. ROSE O'HALLORAN.

Opposition of Eros in 1900.—The opposition of Eros during next autumn will afford opportunities for observations of especial interest. The near approach of the planet to the Earth will permit the solar parallax to be determined, while the great variations in phase and distance will give unusual value to photometric observations obtained at this time. The ephemeris of Dr. Millosevich, published in the Berlin Jahrbuch for 1902, provides the means for discussing the measures of position of Eros. The annexed table, which is based on this ephemeris, furnishes a part of the material required for the investigations mentioned above. The date is given in the first column. The right ascension and declination for 1855, for Berlin midnight, are given in the second and third columns. This epoch is selected for convenience in identifying Eros by comparison with the stars in the Durchmusterung. The daily motion in right ascension, expressed in seconds of time, and in minutes of arc when reduced to the equator, are given in the fourth and fifth columns. The daily motion in declination, and the total motion expressed in minutes of arc, are given in the sixth and seventh columns. These quantities are important in planning observations for parallax, especially those made photographically. The logarithm of the distance from the Sun has been kindly furnished by Dr. Millosevich and is given in the eighth column. The logarithm of the distance from the Earth is given in the ninth column. From this it appears that its distance when nearest the Earth is less than a third of that of the Sun from the Earth. This minimum occurs on December

26, nearly two months after opposition, which takes place on October 30. The phase angle between the Sun and Earth, as seen from Eros, is given in the tenth column. There are few asteroids for which this angle much exceeds 30°. In the table, beginning with the value 37°.5 it gradually diminishes to 28°.3 at about the time of opposition, and then gradually increases, until on January 31, it attains the extraordinary value of 56°.1, becoming even greater later. The photometric magnitude, neglecting the phase and assuming that the light is inversely proportional to the squares of the distances of the Earth and the Sun, is given in the eleventh column. It is based on the measures described in H. C. O. Circular No. 34, from which it appears that the magnitude would be 11.39 at a distance of unity from the Sun and Earth, and that the photographic magnitude is 0.6 fainter than the photometric. It will be noticed that these last values are nearly 0.8 fainter than those given by Dr. Millosevich, who based his magnitudes on visual observations. As the magnitude 9.5 in the Durehmusterung is about 10.5 on the photometric scale, this difference is readily explained. The difference becomes still greater if we apply a correction for phase. This correction, in the case of the asteroids, is about 0.03p, in which p is the phase angle. If we assume that this law can be applied to Eros for angles as great as 56° we obtain the corrected magnitudes given in the twelfth column. The phase angle in the observations described in Circular No. 34 is 21°.2. The magnitude at distance unity, therefore, becomes 11.39 — 0.64 = 10.75. The approximate mean time of meridian transit is given in the thirteenth column, and the aberration time in the fourteenth.

EPHEMERIS OF EROS.

Date.	R. A	Decl.	Daily Motion.										
1900-'01	1855.	1855.	R. A.	R. A.	Decl.	Tot.	log. r.	log. Δ.	Phase	Magn.	C. Magn.	M. Tr.	Aberr.
	h m	° ′	s	′	′	′			°			h m	s
Sept. 1	2 18.9	+ 33 27	+ 70	+ 15	+ 22	25	0.1830	9.9088	37 5	11.85	12.33	15 39	404
9	27.5	+ 36 25	+ 60	+ 12	+ 22	25	.1761	.8692	36.6	11 62	12.08	15 16	369
17	34.6	+ 39 26	+ 45	+ 9	+ 23	25	.1688	.8285	35.4	11.38	11.80	14 52	336
25	39 2	+ 42 29	+ 25	+ 5	+ 23	24	.1613	.7871	34 0	11 13	11.51	14 25	305
Oct. 3	40 8	+ 45 30	− 1	0	+ 22	22	.1535	.7456	32.5	10 89	11.23	13 55	278
11	38.7	+ 48 20	− 32	− 5	+ 20	21	.1455	.7048	31.0	10 64	10.93	13 21	253
19	32.0	+ 50 52	− 68	− 11	+ 17	20	.1374	.6654	29.6	10.40	10.65	12 43	231
27	20 6	+ 52 49	− 101	− 15	+ 12	19	.1291	.6286	28 6	10 18	10 40	12 0	212
Nov. 4	5.7	+ 53 55	− 121	− 18	+ 5	19	.1207	.5954	28.3	9 97	10.18	11 14	196
12	1 49.3	+ 54 0	− 120	− 18	− 3	18	.1124	.5066	29.1	9 79	10 02	10 26	184
20	35.0	+ 53 0	− 92	− 14	− 11	18	.1041	.5430	30 9	9.63	9.92	9 40	174
28	25.8	+ 51 2	− 45	− 7	− 18	19	.0961	.5248	33 6	9 49	9.86	8 59	167
Dec. 6	23.5	+ 48 22	+ 9	+ 2	− 22	22	0884	5117	36 8	9 39	9.85	8 25	162
14	28 2	+ 45 16	+ 60	+ 11	− 24	26	.0812	.5033	40.2	9.31	9 88	7 58	159
22	39 3	+ 41 56	+ 106	+ 20	− 26	33	.0746	.4994	43 7	9.26	9.93	7 38	157
30	56 0	+ 38 31	+ 143	+ 28	− 26	38	.0686	.4993	47 0	9.23	10 00	7 23	158
Jan. 7	2 17.1	+ 35 7	+ 172	+ 35	− 26	44	.0636	.5029	49.8	9 22	10.07	7 13	159
15	41 6	+ 31 43	+ 194	+ 41	− 25	48	.0595	.5101	52 2	9.24	10 17	7 6	161
23	3 8.6	+ 28 23	+ 210	+ 46	− 25	52	.0566	.5210	54 3	9 28	10 27	7 1	165
31	37 3	+ 25 7	+ 219	+ 50	− 24	55	.0548	.5353	56.1	9 34	10.38	6 58	171

As an example of the use of this table let us consider the most favorable conditions for determining the solar parallax. It soon appears that this problem is by no means a simple one. If we select the end of December, when Eros is nearest the Earth, we find that meridian transit occurs so early in the evening that Eros cannot be photographed far east of the meridian. Moreover, the motion both in right ascension and declination is so great that if the telescope is made to follow the stars, Eros will trail so rapidly over the plate that it may not leave any impression on it. If the total diurnal motion is 24′, the motion will be 1″ a minute. If, then, the diameter of the image is 2″, Eros cannot be photographed, unless an exposure of two minutes is sufficient. In such a case it may be necessary to make the telescope follow on Eros and not on a star. All the stars will then appear as short trails which are easily bisected. If the motion of Eros is large, its position with relation to the comparison stars will differ greatly when east and when west of the meridian. Moreover, it will be necessary to measure the total motion and after subtracting the large motion of Eros determine the small remaining parallax. During the latter part of January Eros culminates at nearly the same time on successive nights and will thus be favorably situated for observations west of the meridian for several weeks. The path of Eros has a loop extending over about 13° in right ascension and 20° in declination, and with a center at about R. A. $2^h\ 5^m$, Dec. +51°. The point of crossing is at R. A. $2^h\ 21^m.9$, Dec.+34°25′ (1855). It is, therefore, not far from the stars +34°447, magn. 9.3, and +34°448, magn. 8.0. Eros will pass through the point of crossing on September 3, 1900, and again on January 8, 1901. Photometric observations, if made on these dates, will have especial value, since the same comparison stars can be used for both.

A photograph of Eros was obtained on September 6, 1898, with the 11-inch Draper telescope, whose focal length is 153 inches. Stars of the ninth magnitude are readily photographed with this instrument in 5 seconds. The exposure was 10 minutes, the daily motion 18′, and the computed magnitude 12.1. Allowing for the difference in motion it would be equally difficult to photograph Eros on this date and on September 17, 1900.

EDWARD C. PICKERING

HARVARD COLLEGE OBSERVATORY Circular No. 49.
February 14, 1900.

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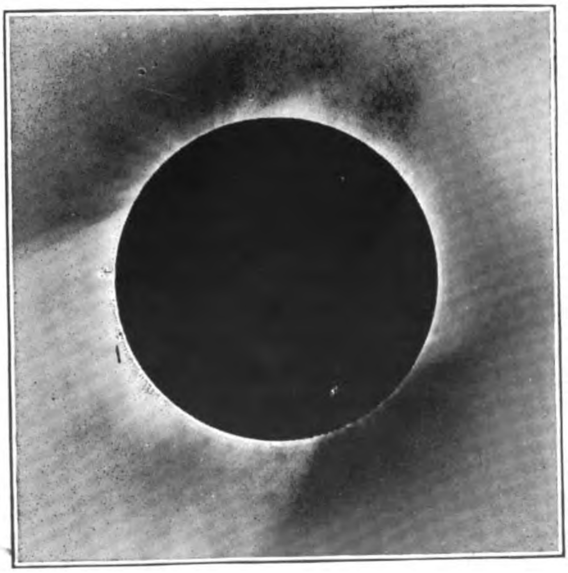
Northfield, Minn., U. S. A.

PLATE XIII.

No. 5. Uncontrolled; Exposure 8.^{s}00.

Exposure at	16′	20′	32′	50′	110′
No. 6	0.04^{s}	0.23^{s}	1.76^{s}	3.20^{s}	8.00^{s}



SOLAR CORONA, MAY 28, 1900.

Dolbeer Eclipse Expedition, Siloam, Ga. Photographed by C. Burckhalter, Chabot Observatory, Berkley, Cal.

Popular Astronomy.

Vol. VIII. No. 7. AUGUST and SEPTEMBER, 1900. Whole No. 77.

FEASIBILITY OF OBTAINING THE SOLAR PARALLAX FROM SIMULTANEOUS MICROMETER OBSERVATIONS OF EROS.

The unusual opportunity offered by the coming opposition of Eros for the determination of the solar parallax has been noticed in several journals, but the apparent facility with which simultaneous observations with filar micrometers at widely separated stations could be utilized has received little or no attention, the photographic method having been given the preference to the exclusion of the former. Although the parallactic factor, by suitable selection of stations may be made considerably larger, there are some inherent difficulties which do not occur in the method here proposed.

The high declination of the planet makes it possible to secure simultaneous observations at all the European observatories west of Pulkowa, and all the American observatories east of Denver, which are provided with sufficiently powerful telescopes. The following scheme in tabular form gives the Greenwich mean time at which the planet will be simultaneously visible, and at sufficient altitude to enable good observations to be made. At the most favorable time with reference to the parallactic factor, however, as well as at the beginning and end of the proposed series, daylight interferes with some of the observatories situated at the ends of the line, and it has been necessary to select two instants, one of which includes all except the extreme eastern, the other all except the extreme western.

The parallactic displacement varies from approximately 17″.0 to 30″.0 in the case of Pulkowa-Washington, to 14″.9 to 24″.5 in the case of Greenwich-Washington. The inclusion of Denver somewhat increases these quantities.

The principal difficulty in the proposed scheme is the selection with certainty of the same star or stars by the different observers.

NOTE.—This circular was prepared by S. J. Brown, Astronomical Director of the United States Naval Observatory, and it has been sent to the Astronomers of the United States who are willing to coöperate in the observations mentioned, and who are provided with suitable instruments for making them. Director Brown, also prepared a paper on the same subject which was presented before the International Astrophotographic Conference held in Paris, July, 1900. Ed.]

The planet will be situated in the Milky Way during the greater part of the time embraced in the series, which will afford many faint stars, but render their proper selection at the time of observation and future identification difficult. Experience shows that in the region of the Milky Way, the field of a telescope pointed at random will contain several stars from the 10th to 12th magnitude within a radius of 6′ of arc.

There would seem to be *a priori*, not much doubt that one or more stars as bright as the 11th magnitude would be found within a radius of 3′ of arc, from the true position of the planet as a center. The two or three brightest lying within this distance should be taken, limiting the choice if possible to magnitudes fainter than the 5th.

It will be necessary for the identification of the stars used that a careful sketch map of the field and the region immediately surrounding it, be made at the time of the observation, and that a photograph of the region be taken at about the same time. This would not only serve to identify the stars used, but, in cases where different observers should fail to select the same stars, it would furnish an accurate means of referring the observations to a common origin.

The coöperation of two or more photographic telescopes would obviate entirely the selection of the same reference stars by the different observers, as well as the necessity of adhering closely to the schedule time laid down for the observations, as the motion of the planet could be accurately computed for brief intervals of time thus arising, while the relative places of the stars used could be very accurately measured from the plates. At the same time the positions of the stars could be determined from the plate with sufficient accuracy to furnish the data for computing the coefficients in the equations of condition. The Naval Observatory has no suitable photographic telescope for this purpose, and with the exception of Harvard College Observatory there is none in this country. Except for this reason there would be no gain in resorting to micrometric observations. It will therefore be essensial to the complete success of the proposed scheme that one or more of the European observatories should take this portion of the work.

On account of the rapid motion of Eros, which makes observations of position angle and distance very troublesome, and also the ease and accuracy with which differences in its right ascension and declination can be interpolated, the measures should be made in rectangular coördinates, referred to the true equatorial position of the fixed wire of the micrometer. Also it is important to eliminate as far as possible any lack of parallelism of the micrometer wires by taking the measures of each coördinate in two positions of the micrometer differing 180° in position angle.

EROS.

Scheme for Simultaneous Observations.

Date.	G. M. T. of Transit. At Greenwich.	Decl.	Hor. Par.	G. M. T. of Obs'n.
	h m		"	h m
Oct. 1	14 02	45	15.4	14 30 16 40
11	13 21	49	17.4	14 20 16 00
21	13 33	52	19.4	14 00 15 00
31	11 37	54	21.5	13 20 14 20
Nov. 10	10 38	54	23.5	13 10 14 10
20	9 40	53	25.2	12 15 13 15
30	8 50	51	26.5	11 40 12 50
Dec. 10	8 11	47	27.4	11 20 13 00
20	7 43	43	27.5	11 20 13 00
30	7 20	39	27.9	11 20 13 00
1901 Jan. 9	7 12	34	27.5	11 20 12 20
19	6 53	30	26.9	11 10

INTERNATIONAL ASTROPHOTOGRAPHIC CONFERENCE OF JULY 1900.*

In conformity with the expressed objects of the conference, a special committee was appointed to prepare a general plan for systematic observations of Eros at the coming opposition, by which the widest co-operation of the observatories of the world would be secured.

The committee, besides the President, M. Loewy, comprised:
Messrs. André, Director of Lyons Observatory
Bakhuyzen, " " Leiden "
Christie, " " Greenwich "

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* Translated for Popular Astronomy from the French by S. J. Brown of the United States Naval Observatory, who also prepared the concluding paragraphs embodying some helpful explanations. Ed]

Elkin, Dirctor of New Haven Observatoy.
Gill, " " Cape "
Hartwig, " " Bamberg "
Henry (Prosper), Astronomer of Paris Observatory
Trépied, Director of Algiers Observatory
Weiss, " " Vienna "

The committee adopted the following resolutions:

I. It is desirable that the determination of the parallax of the planet Eros should be made by means of micrometric, photographic and heliometric measures:

(*a*) by means of observations of the planet in the east and in the west at the same observatory;

(*b*) by the coöperation of observatories of Europe and North America.

(*c*) by the coöperation of observatories of the northern and southern hemispheres.

II. During the period of the observation for parallax, the motion of the planet Eros should be determined as accurately as possible, by means of micrometric, heliometric and photographic measures.

III. The Commission recommends:—

(*a*) to those observers who will determine the parallax in right ascension by means of observations of any of the three methods of measurement, either at isolated observatories, or by the coöperation of the observatories of Europe and America, to make the observations each morning and each evening, and to take advantage of all favorable atmospheric conditions to extend the observations to the greatest practicable hour angles.

(*b*) to observers who will determine the parallax by differences of declination in the northern and southern hemispheres, to so arrange the time of observations, that the instant corresponding to the mean of the times will not differ widely from the time of meridian transit of the planet at the southern observatory.

IV. It is necessary to take special series of photographic plates in the regions traversed by the planet Eros in order to determine the position of the comparison stars.

The reference stars for the determination of the constants of the plates should be determined by meridian observations.

V. Mr. Hartwig is charged to arrange a program for the heliometric observations of the planet.

VI. Mr. André and Mr. Prosper Henry are charged with the investigation of the atmospheric dispersion. M. Loewy will communicate the results of these researches to the members of the commission and to the observatories participating.

VII. M. Loewy, Mr. Brown, Astronomical Director of the Observatory of Washington, and Mr. Bakhuyzen are charged with the duty of securing the execution of the different resolutions concerning micrometric and photographic observations.

The following reasons have led the special commission to propose the above resolutions to the General Conference:—

Resolutions I, II, III, and IV.—The committee is of the opinion that micrometric observations ought to be employed as well for parallax in right ascension as in declination, as it seems practicable to remove the difficulties involved in the determination of the parallax by micrometer observations in right ascension. These difficulties are of two kinds:

First—*The small field of view with the high magnifying powers employed with instruments of large size.*

The Commission finds the solution of this difficulty in the Resolution IV, prescribing series of photographic plates taken of the region traversed by the planet. The measurements will enable the relative positions of the comparison stars to be determined with extreme acuracy. If, on account of the rapid motion of the planet, the comparison star used in a morning observation is not found with the planet in the field of the telescope, another one can be selected, the position of which relative to the first, is known from the plates.

Second—*The difficulty of determination with exactness the motion of the planet.*

By means of Resolution II, the Committee hopes to obtain the motion of the planet, determined from day to day with such precision by means of a large number of observations, that the uncertainty of the daily motion of the planet between two successive observations in the evening and morning will have very small effect upon the resulting parallax.

It is for this reason that the Committee recommends in its Resolution III (*a*) the greatest possible continuity in the series of observations both morning and evening.

Resolution III (*b*) is necessary to give the observers of the southern hemisphere as great an altitude as possible for their observations.

Finally the Committee has considered the necessity of obtaining absolute positions of the planet, in view of the researches on the parallax which will be undertaken by the methods of celestial mechanics. The series of plates taken in conformity with Resolution IV, will naturally furnish all the comparison stars desirable for the determination of the absolute positions of the planet.

Resolutions I, IV, VI.—The committee thinks that the photographic method offers no insurmountable difficulty. One of the objections which has been raised against this method, rests upon the uncertainty resulting from the form of the trail of the star or planets, according as the former or latter has during the exposure been kept immovable upon the cross wires. The committee hopes that the uncertainties arising from this cause can be evaluated, if they exist, by means of experiments, easily carried out, which will consist in making three exposures under the following conditions:

(*a*) Keeping the image of the planet on the cross-wires;

(*b*) Keeping the image of a guiding star on the cross-wires;

(*c*) In giving to the telescope a motion in a contrary direction to that of the planet, but of nearly double its value. In comparing plates (*a*) and (*b*), it can be seen whether the mutual distances of the stars remain the same for all stellar magnitudes, or if it is necessary to apply a correction dependent upon the magnitude. At least analagous comparisons can be made by combining the three plates (*a*), (*b*), (*c*), in all possible ways. Several observatories have promised concurrence in these experiments, and it is important that they should be sufficiently large in number in order to ascertain the effect of the quality of the objective upon this phenomenon.

Another difficulty was considered, common to nearly all the methods of comparison, concerning systematic errors which may be introduced into the relative measures of the stars and the planet arising from atmospheric dispersion.

After the exchange of views of the members, and after having understood the methods proposed by Mr. Prosper Henry for evaluating the effect of influences of this kind, the committee appointed Messrs. Andrè and Prosper Henry to carry out the experiments for this object.

Such are the grounds of the resolutions concerning the parallax of the planet Eros. It may be asked if it is not necessary to draw up a complete programme for the combination of the observations of Europe and America. The committee has not thought it necessary to adopt such a program, for the reason that the daily motion of the planet ought to be determined directly, day by day, independent of all theory, and it is hoped with great precision, and that the absolute simultaneity of measures will not be indispensable.

Thus each observatory, which decides to share in this great common work, will find itself in a position to determine the part which it will undertake. It is simply asked of the observatories to clearly inform the president of the executive committee as soon as possible of their intentions, in order that the general plan of the necessary distribution of the work, if there is occasion, may be completed.

The observatories which have already promised their concurrence are as follows:

Algiers, Athens, Bamberg, Bordeaux, Cambridge (England), Cambridge (U. S.), Cape of Good Hope, Catania, Cordoba, Edinburgh, Yerkes, Greenwich, Heidelberg, Leyden, Leipzig, Lyon, Marseille, Minneapolis, Mount Hamilton, Nice, Paris, Potsdam, Rome (Collegio Romano), San Fernando, Strassburg, Tacubaya, Toulouse, Upsala, Vienna (Ottakring), Vienna (Wàhring), Washington.

In sending the translation of the resolution for publication, it may make the situation clearer to give a few words of explananation. The paper submitted to the conference, proposed to make in Europe and America nearly simultaneous observations of planet referred to contiguous stars, selecting preferably those of a magnitude not greatly different from the planet's, but in all, nearness was considered of more importance than magnitude. The same stars would generally be selected by limiting the distance to from 60″ to 120″, and leaving the magnitude arbitrary down to the 11th or 12th. The relative positions of the stars used were to be determined by daily photographs of the region traversed by the planet. In a programme based on the proposal, the motion of the planet would be practically eliminated, as the difference of time would always be small, as also the star positions; if the same stars should not have been selected, the relative positions on the same plate could be obtained with extreme accuracy.

The modification proposed by the Conference is to make 1st at all observatories in Europe and America daily morning and evening observations at hour angles as large as practicable, using stars adjacent to planet, and without reference to approximate simultaneity. In this case there would seldom be a difference as large as three or four hours between evening observations here and following morning observations in Europe.

The motion of the planet to be obtained, regardless of theory, from daily observations, morning and evening.

2d, Observations in northern hemisphere for parallax in declination are to be made at approximate time of meridian transit in a southern observatory.

This plan is applicable for all the three kinds of measurements, photographic, micrometric, and heliometric.

SUPPLEMENTARY INSTRUCTIONS ON RESOLUTION 3 OF THE CONFERENCE.*—

In this paragraph by the *largest hour angle practicable* is to be understood an hour angle large enough to obtain a great parallactic displacement without bringing the altitude of the star below a certain limit, 20° for example.

As explained in the preceding circular, the conference thought that the daily motion of the planet could be obtained each day, independently of the parallax and of all theory. Nevertheless, on account of interruptions of the measures caused by atmospheric conditions affecting all the stations at once, it might happen that this element could not be deduced directly from the daily observations. To avoid such a case, and in order to refer to the same instant of time the measures made in America and Europe, it will be necessary to carry out in each observatory a supplementary series beside the two already indicated, of which the first corresponded nearly always ta an eastern hour angle, and the second which should always be a western hour angle. The third series would be made under the following conditions:

(*a*) In the observatories of Europe the supplementary series should be made about two hours before the second series (western).

(*b*) In the observatories of North America the supplementary series should follow by about two hours, the first series of measures (generally in the east) made at the beginning of the evening. By this plan the means will be provided of referring the measures of the observatories of America and those of Europe to the same physical instant by an interpolation simple and sure. In a great number of cases it will suffice to adopt an interval of time less than two hours between the two successive series of measures.

This plan is in accordance with that proposed by Mr. Brown of Washington in a note submitted to the conference, in order to as-

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* Translation of the second circular of the International Conference, giving supplementary instructions concerning observations of Eros which ought to be begun at once, and also further details of the general plan of work.

sure simultaneity of observations in America and Europe.

WORK WHICH IT IS DESIRABLE TO BEGIN IMMEDIATELY.

1st. Micrometric observations of the planet with large equatorials by the ordinary method of comparison. These measures are designed to furnish precise position of the planet for the theory of its movement. It is much to be desired that some of these observations should be reduced and published immediately so that new corrections may be made to the ephemeris.

2nd. Special series of photographic plates in the region containing the apparent path of the planet, having for their object the determination of the relative positions of the comparison stars to which the planet will have been referred in the visual observations.

In order to gain time, to simplify the work and to carry out the project under the best conditions, it is not considered advisable to take the photographs of a given region at the same instant in which the planet is there. A reference to the ephemeris will show that there is great advantage in beginning this part of the work immediately.

The photographic experiments for the investigation of the effect of atmospheric dispersion and the trails of the stars referred to in the previous circular, should be carried on at the same time. But in this case, where the planet is not taken on the same plate, the photographic operation will be carried on as follows:

(*a*) Photograph of a portion of the apparent path under conditions equivalent to those laid down for short exposures in the photographic chart of the sky. For example, in making two successive exposures upon the same plate, one of six minutes, the other of two minutes, in such a way as to obtain for each star two images distant about 20″ from each other in declination. The plates of this series will be used for the determination of the relative positions of the comparison stars.

(*b*) Photograph of the same region, after giving to the instrument in reference to the diurnal motion an acceleration of one or two minutes of arc per hour.

It can be determined by examination, in accordance with the circular of August 3d, if the mutual distances of the stars on plate (*b*) have the same value as on plate (*a*), and from this comparison to deduce the systematic errors to be applied, if any. The plates of series (*a*) ought to lap over those of series (*b*), so that the same star will be on both plates.

The following rule is suggested for forming a table of equatorial co-ordinates of the center of the successive plates:

At the epoch of commencing the photographs adopt for the center of the first plate one of the positions given by the ephemeris and suitable for observation. Thus, for example, if it is desirable to mention the first of September the center of the plate should be taken at that point of the celestial sphere where the planet from its ephemeris will be on the 28th of November. To determine the center of the following plate calculate the right ascension and declination of the point situated about a degree distant from the preceding center and on the apparent path of the planet, and thus in succession for each plate.

In this way the area of the part common to two successive plates will never differ more than one-half of the total area; it will vary between .42 to .50.

The series for the determination of the parallax should commence about October 1st. A new circular containing various auxiliary tables and instructions for the observations will be distributed.

S. J. Brown,
Professor of Mathematics, U. S. N.,
Astronomical Director.

PTOLEMY'S THEOREM ON THE APPARENT ENLARGEMENT OF THE SUN AND MOON NEAR THE HORIZON.

T. J. J. SEE.

For Popular Astronomy.

The cause of the apparent enlargement of the Sun and the Moon near the horizon does not seem to be clearly understood, although the question was an old one even in the days of Ptolemy. An examination of the problem and of the theories given in the standard works on Astronomy can hardly fail to impress one with the desirability of a more satisfactory explanation of the phenomenon.

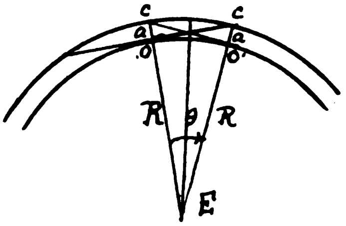
In the Almagest, Halma's Edition, page 9, Ptolemy says:

> *'Αλλὰ γὰρ καὶ τὸ πρὸς τοῖς ὁρίζουσι μείζονα τὰ μεγέθη*
> *φαίνεθαι οὐχ η ἀπόστασις ἐλλάττων ὀυσα ποιεῖ,*
> *ἀλλ' ἡ τοῦ ὑγροῦ τοῦ περιέχοντος τὴν γῆν ἀναϑυμίασις*
> *μεταξὺ τῆς τε ὄψεως ἡμῶν καὶ ἀυτῶν γιγνομένη*
> *καθάπερ καὶ τὰ ἐις ὕδωρ εμβληθέντα μείζονα φαίνεται,*
> *καὶ ὅσω ἂν κατωτέρω χωρῃ, τοσούτω μείζονα.*

"For if the Stars appear to us larger when on the horizon, this is not because they are less remote from us, but on account of the moist vapor which surrounds the earth between our eyes and the stars, and apparently enlarges them, just as things plunged into water appear to us the larger the deeper they are immersed."

Of course this explanation of Ptolemy is incorrect, yet it is quite as plausible as those given in text-books now in general use. In many such works we find the explanation that the Moon and Sun look larger on the horizon because of their proximity to neighboring terrestrial objects. Let us consider this question in a geometrical manner, such as the Greeks would employ if they had our knowledge of modern Physics.

Suppose o to be an observer on the surface of the Earth, $o\,o'$ an arc of the Earth's surface substending an angle θ at the center of the Globe, a the height of a layer of clouds in the terrestrial atmosphere (here somewhat exaggerated for the sake of illustration). And suppose an observer to ascend in a balloon to the upper surface of this stratum when the sky is clear; then he can see the station o' where the clouds disappear to the observer on the surface at o.



Now we have $\cos\theta = \frac{R}{R+a}$, and since $1 - \cos\theta = 2\sin^2\frac{\theta}{2}$,

we get $\sin\frac{\theta}{2} = \sqrt{\frac{a}{2\,(R+a)}}$.

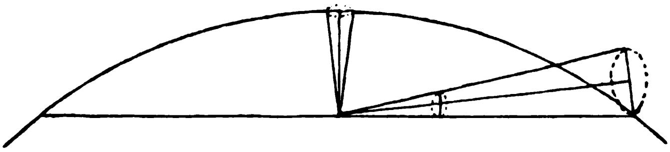
But $\sin\frac{\theta}{2} = \frac{\theta}{2} - \frac{\theta^3}{2^3}\cdot\frac{1}{1.2.3} + \frac{\theta^5}{2^5}\cdot\frac{1}{1.2.3.4.5} - \ldots\ldots.$

and when the angle is small, we may take the arc for the sine without sensible error, so that $\frac{\theta}{2} = \sqrt{\frac{a}{2\,(R+a)}}$.

If the height of the clouds be a little over a kilometer, say $\frac{1}{5000}$th of the Earth's radius, as frequently happens, the second term will reduce to $\sqrt{\frac{1}{10002}} = \frac{1}{100}$, nearly. Thus the station at o' removed from o by the angle θ is one-fiftieth of Earth's radius distant, or 127.6 kilometers, and the angle θ is $1.^\circ 15$.

Thus, neglecting refraction for the sake of simplicity, an observer at o could see clouds just on the horizon at o', 127.6 kilometers away, when they pass over his head at an elevation of 1.276 kilometers, which is probably a fair average of the height of most rain-bearing clouds. The observer sees these clouds going over daily, and becomes conscious of the fact that he can see much further near the horizon than overhead; and the result is that he conceives the sky unconsciously to be made up of strata such as the clouds float in — the vertical height being small compared to the horizontal distance to which he can penetrate.

If the clouds overhead are distant 1.3 kilometers, he ought theoretically to be able to see them at a distance of more than 120 kilometers. Practically he is accustomed to view them near the horizon, at a distance of some ten or twenty kilometers, as few persons make an effort to see clouds till they become conspicious objects near by. The concrete result is that almost all persons from the continued impressions of nature from childhood, come to view the dome of the heavens as having a horizontal extension ten or twenty times its vertical height. Those who have a more limited view, give the horizontal extension of the sky as only three or four times that of the vertical. Now the mind fixes the Sun and Moon on the visible surface of this flattened dome, whether they be near the horizon or high in the heavens. And as the angular aperture of the luminous disc is the same without regard to the distance of the vault into which it is projected, the mind involuntarily enlarges it strictly in proportion to the distance at which it is supposed to be. Thus near the remote horizon it may appear to have a diameter 3 or 5 or 10 or 20 times that which it has when floating in the sky overhead.



Enlargement of Objects near Horizon.

The enlargement is purely psychological, due to the deceptive shape of the celestial sphere continually produced upon our minds from childhood by the visible effects of clouds in the atmosphere. And as our habits of mind lead us to place the base of the dome of the heavens at a greater distance, while the arch overhead is quite near by, the eye is too accurate and faithful a guide to the mind, to fail to convey the impression of a rising luminary of immense extent, while overhead, the impression is that of a body of greatly diminished magnitude.

From these considerations it follows that while Ptolemy's explanation of the Moon's enlargement as being due to the envelope of vapors through which the body appears, is incorrect, it yet contains an element of truth in ascribing the illusory effect to the depths of vapor in which the disc is projected.

WASHINGTON, D. C., 1900, August 6.

REPRESENTATIVE STELLAR SPECTRA BY SIR WILLIAM HUGGINS AND LADY HUGGINS.

W. W. PAYNE.

In our last number we did not complete what we wished to say about Vol. 1, of the publications of the Sir William Huggins' Observatory at Tulsehill, London, England. But before continuing our brief account of this important work, we should make a correction in our statement of the price of the book which is given, in the second line from the bottom of page 327, as $5. The price, as announced in a circular just received from Messrs. William Wesley and Son is £1 5^s net, or $6.25, and not $5, as there printed.

It was in 1866, '67 and '68 that Dr. Huggins discovered, in three of the faint comets of those years, that part of the light emitted from them belonged to the comets themselves, and that the light of the comet of 1868 gave a spectrum consisting of three bright flutings. These new and intensely interesting facts awakened great expectations for the study of the much brighter comet which appeared in June 1868. As the telescope armed with a spectroscope was turned on this comet, the spectrum of three bright bands or flutings again appeared, each alike falling off in brightness toward the violet end of the spectrum. The positions of these bands were carefully measured from the bright and sharp edge on the red side, and to the surprise of Dr. Huggins they were found to agree, in position, with three similar flutings in the brightest parts of Carbon. For the first time, Dr. Huggins was privileged to see the fluted spectrum of this comet confronted with the spectrum of olefiant gas, and to find in this comparison a full and exact confirmation of the nature of the substance from which proceeds the greater part of the light of those comets which give spectra like these just described.

It will be remembered that the relation of comets and meteoric swarms, at this time, was attracting much attention by the discoveries of Newton of Yale, Adams of England and Schiaparelli of Italy, and so it became easy and natural to make a study of meteorites to find out what gases might be found in these sky-stones in an occluded state. As a result it was soon known that meteorites contain carbonic oxide, carbon dioxide and that many of them carry a large percentage of hydrocarbons. It has been later observed that some give spectra containing the three bands like those seen in the base of a candle flame, and it is now an accepted fact that the greater part of the light of comets is due to the fluted spectrum of carbon.

In this connection Dr. Huggins calls attention to some additional knowledge in respect to the light of comets which was gained by the aid of photography. In 1881, for the first time, suitable photographic plates were in the hands of astronomers, and the appearance of a bright comet that year, made it possible to examine its light in the invisible region of the spectrum toward the violet. Of this photograph Dr. Huggins says: "The plate contained an extension and confirmation of my earlier observations by eye. There were the combined spectra of two kinds of light—a faint continuous spectrum crossed by Fraunhofer lines which showed it to be reflected solar light. Upon this was seen a second spectrum of the original light emitted by the comet itself. This spectrum consisted mainly of two groups of bright lines, characteristic of the spectra of certain compounds of carbon. It will be remembered that my earlier observations revealed the three principal flutings of carbon as the main feature of a comet's spectrum in the visible region. The photograph brought a new fact to light. Liveing and Dewar had shown that one of these bands consisted of lines belonging to a nitrogen compound of carbon. We gained the new knowledge that nitrogen as well as carbon and hydrogen exists in comets. Now, nitrogen is present in the gas found occluded in some meteorites. At a later date Dr. Flight showed that nitrogen formed as much as 17 per cent of the occluded gas from the meteorites of Cranbourne, Australia."

So much has been said of the splendid work of Dr. Huggins in these earlier years of the so-called new astronomy to bring to the attention of our readers the large and important part due to his labors in its rise and rapid progress. Those who are acquainted with the history of practical astronomy between the years 1865 and 1885 especially, very well know that to Dr Huggins chiefly belongs the credit of outlining the large and grand foundation of the new astronomy as distinguished from the old, by all writers in science in later years. Those who are not familiar with the history of the new methods during, and since, the period named above, will find much information in the pages of this new book in regard to method and result in astronomical work which occupy the attention and the energies of foremost astronomers in all parts of the world, even at the present time.

Before closing this brief review, it may be profitable to the reader to have a short account of this new book as a whole, that he may gain thereby a more complete idea of its entire contents, including the work of the authors to the present time, as well as that referred to particularly in what precedes.

The contents of this volume is divided into eight chapters; the first treats of the history of the Observatory, and of the work done therein; the second is a list of the published papers on the work of the Observatory; third, description of the methods of taking the photographs of the stellar spectra; fourth, description of the spectroscopes in use in the Observatory; fifth, description of the automatic arrangement by which the necessary breadth was given to the stellar spectra on the photographic plate; sixth, discussion of the evolutional order of the stars, and the interpretation of their spectra, treated under the heads,

(1) Of the types of stellar spectra,
(2) Original differences of stellar constitution,
(3) Classification of stellar spectra,
(4) Physical and chemical interpretation of stellar spectra by means of terrestrial spectra observed in the laboratory.

Seven, description of the plate of historical spectra; and eight, preliminary discussion of the stellar spectra of the plates.

Following the contents are the twelve beautiful plates mentioned in the previous article. The first is spark spectra showing effect of density on the relative intensities of the lines of calcium. Second is historical spectra; third gives spectra of the Sun and the Great Nebula of Orion, of *A*, of *θ* Orionis, of the Sun and Nova Aurigæ. Four gives Spectra of *β* Lyræ and helium enlarged 4¾ times, of Bellatrix, oxygen and nitrogen, of Bellatrix and helium, of Rigel and helium. Five presents spectra of Rigel, sillicum and titanium enlarged 4¾ times, of *α* Cygni, sillicum and titanium, of *α* Leonis, of *γ* Lyræ, of *γ* Andromedæ, of *α* Lyræ. Six shows two spectra of Sirius, enlarged 4¾ times, of Castor (fainter star only), of *α* Aquilæ, of Procyon and of *γ* Cygni. Seven gives spectrum of *γ* Cygni, enlarged 4¾ times, of the Sun and Capella, of Arcturus, iron and calcium, of *γ* Andromedæ and of Betelgeuxe. Eight, enlarged 15 times, is the spectrum of *β* Lyræ, of Bellatrix, of Rigel and of *α* Cygni. Nine enlarged 15 times gives spectra of *α* Leonis, of *γ* Lyræ, of Serius, of Castor, and of *α* Aquilæ. Ten, enlarged 15 times, shows spectra of Procyon, of *γ* Cygni, of Capella and the Sun, of Arcturus and of Betelgeuxe. Eleven presents spectra of the component stars of Castor, of the component stars *γ* Andromedæ, and of the component stars of *β* Cygni.

Twelve gives the spectra of the component stars of Cor Caroli, of the component stars of α Herculis, and of the component stars of γ Leonis.

From such an outline the variety of work and the detailed extent of it at once appear. The stars chosen are typical ones, and the methods employed by these distinguished astronomers were among the best now known, and hence nothing less than quick and notable results would follow their pains-taking labors, even in laying the broad foundation of the new astronomy that the scientific world now so much enjoys in the end of the nineteenth century.

TOTAL SOLAR ECLIPSE OF MAY 28, 1900.

M. MOYE.

FOR POPULAR ASTRONOMY.

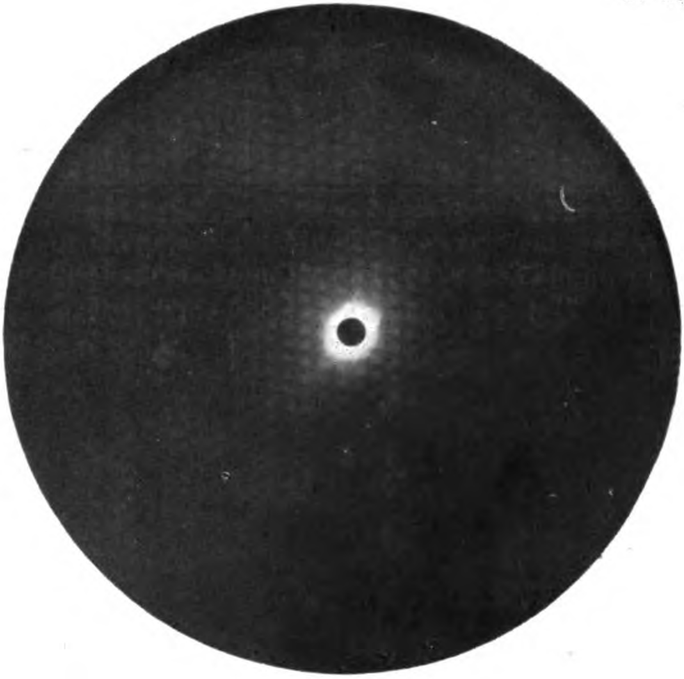
Being very desirous to observe this beautiful phenomenon, I went to Elche, near Aliconte, (Spain), a pretty town not distant from the central line of totality. At first I had some fears because of ominous clouds and rain, but on the 27th the sky became perfectly clear and the eclipse was observed without the slightest trace of a cloud.

Besides photographs of the corona made in connection with the Montpellier University Expedition (results of which will be separately published in *Comptes-Rendus de l'Académè des Sciences*), I have made the following scientific observations, especially on the Shadow-Bands and a tolerably exact sketch of the corona as seen to the naked eye. (See plate XIV.)

Shadow-Bands.—For the observations of these bands, I was seated on a corn-threshing floor, perfectly levelled and commanding a wide view of land. About three minutes before totality, I saw the shadow-bands. They were regular, with the appearance of sinusoidal curves, not clearly defined, but greyish and faint on the ground. However, their intensity was sufficient to get the attention of two Spanish policemen who were at my left. The width of the bands was two inches apart when it was about 1 or 1¼ foot. Their motion uniform, it seemed, was as rapid as a man walks.

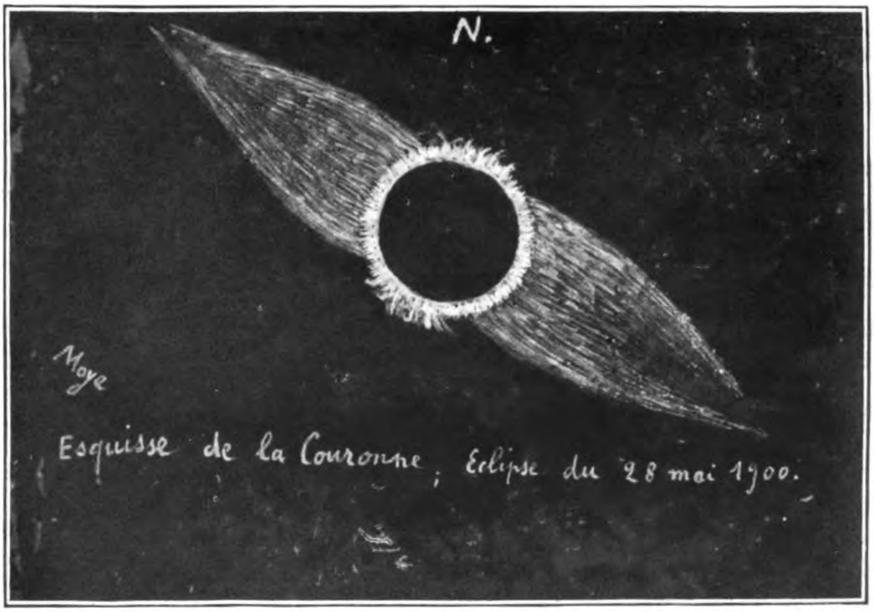
At first the motion was precisely the same direction of east and west. But one minute before totality, I saw a remarkable phenomenon (not observed before, I believe). Beides the first system already described, was seen suddenly a second system of

PLATE XIV.



THE SOLAR CORONA. MAY 28, 1900, WADESBORO, N. C.

Photographed by David E. Hadden, 2½ inch Portrait Lens, 18 inches focus. Exposure about 5 secs.

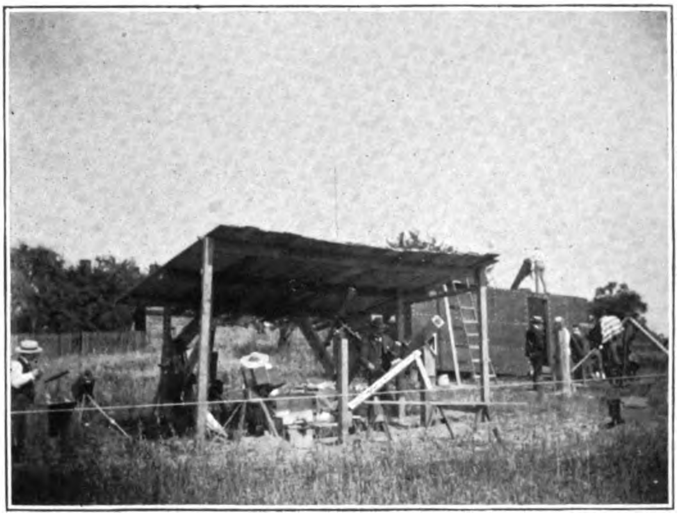


DRAWING OF CORONA MADE NEAR ALCANTE, SPAIN, BY M. MOYE, MONTPELLIER, FRANCE, MAY 28, 1900.

3 1

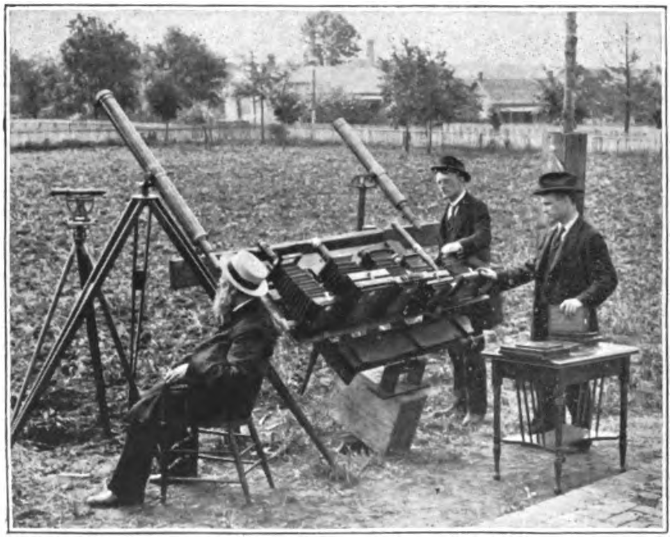
PLATE XV.

TOTAL SOLAR ECLIPSE, MAY 28, 1900.



BRITISH ASTRONOMICAL ASSOCIATION STATION, WADESBORO, N. C.

Photographed by H. E. Hadden.



ST. LOUIS UNIVERSITY STATION, WASHINGTON, GA.

Rev. C. M. Charroppin, at telescope.

bands, showing the same general appearance, but the motion was distinctly in the opposite direction, viz: from west to east.

I have satisfied myself of the reality of the thing, which was testified to after totality by several other persons near. I must say that the wind, moderate in force, was blowing during all the eclipse from the same direction, east south-east.

Appearance of the corona.—To the naked eye and in the opera glass, the Moon was perfectly black and it was surrounded by a circle of silvery white almost dazzingly bright, and resembling the classical drawings of an Annular Eclipse. This was the inner corona. At the right and left of the Sun, were two immense streamers, pearly of tinge, tolerably bright and fading away gradually on the edges. They were on the ecliptic or very near it, their length was two or three solar diameters, the western streamer was noticed almost near Mercury, at 2° from the Sun. The original form of the streamer was very conspicuous, each seemed like two curved rays with a central rift. At the Sun's poles were only short and faint plumes, a typical form of a minimum year.

No star, (except Sirius) was seen, but Mercury was bright, as Venus at the beginning of the twilight. It is needless to say that Venus was very bright over our heads.

General Notes. During totality the sky was dim, the blue become an ashy grey; round the horizon a large zone of a golden yellow hue, with rosy and lilac streamers, producing a very artistic and a beautiful view.

The landscape was as if draped in a dull leaden grey, the colors faded from objects and the appearance was grand and rather sorrowful.

The falling temperature as totality drew near, was very striking and the coolness was such as to become rather unpleasant. The thermometer (Centigrade) fell from 26° to 20° in the shadow.

The obscuration of the scene was not intense, all objects were distinctly seen, as the divisions of a watch; a newspaper could be read without artificial light; the general illumination was much greater than the light of the Full Moon.

UNIVERSITY AT MONTPELLIER, (FRANCE),
June 16, 1900.

TOTAL SOLAR ECLIPSE MAY 28, 1900.

W. W. PAYNE.

Something more can be said about the results of the observations of the last total, solar eclipse in addition to what was given, last month, by Dr. H. C. Wilson, of Goodsell Observatory, who was the astronomer of the party from Carleton College that observed the eclipse at Southern Pines, North Carolina.

In his account reference was made to the work of his party particularly, and the party from Guilford College. He gave a description of the eclipse, the corona, the observations of the contacts and some interesting and useful remarks about other stations near, such as Pinehurst, Barnsville, Winnsboro, Griffin and Wadesboro. At some of these stations were parties containing distinguished astronomers from home, and some from abroad. The names of most of them are given in the paper referred to, and something is said of the particular astronomical work that each had planned to do. Two illustrations accompany the paper; one is a picture of the observing station of the Carleton College party, and the other is a reproduction of one of the negatives taken with the eight-inch photographic telescope during totality. The cut does not give nearly all the detail which the original negative shows, either in the inner or in the outer corona. It is very much to be regretted that we have no means of reproduction which will faithfully bring out nearly all that the original negatives show. Hence, we have to be satisfied with that which can be secured, and try to make up what is lacking in verbal description.

The first thing that may come to the minds of thoughtful readers is, what have astronomers learned from the results of the total eclipse of May last? The day was almost a perfect one throughout the entire path in the United States, and the number of observing parties was large at different points along the line of totality all the way from the Gulf of Mexico to the Atlantic Ocean. Surely from such a favorable opportunity some satisfactory results must have been gained. If we notice Mr. Chas. Burckhalter's work which is presented in plate XIII the results of a new method of exposing plates to photograph the inner and outer corona at the same time will be seen. Mr. Burckhalter sent us six positives in the form of lantern slides. The reproductions are five and six in the series, and show very plainly the difference between an exposure which is controlled and one that is not controlled. No. 5 is the exposure of a plate for eight seconds of time, in the ordinary way, both for the inner and for the outer corona, and it is seen that the effect is about the same as that which is observed in any of the good photographs of the corona taken during the last eclipse. No. 6 shows the application of a piece of apparatus designed to control and adapt the time of exposure of a plate, so as to give less time to the bright, inner corona, and more time to the outer faint part, and thus to avoid over exposure of the former, and under exposure of the latter when it is desired to photograph both parts at the same time, on the same plate. Evidently the difference between the two pictures is marked, and largely in favor of the controlled method in securing details in all parts of the corona at the same time in a single exposure. These pictures were both taken at the same time, and the total exposure of each was eight seconds. The figures at the top of No. 6 show very closely the actual time of exposure of the plate at the respective distances in arc from the center, indicated by the figures of the upper line. In other words at a distance of 16′ from the center, the time of exposure was $0^s.04$; at 32′ it was $1^s.76$ and at 110′ it was $8^s.00$. The semi-diameter of the Sun on May 28, was nearly 15′ 47″, that of the Moon at the same time was 15′ 58″, nearly. From these figures it will be readily understood how the time of exposure was related to the corona and the limb of the black Moon in the short period of totality. It is also evident why the time of the total phase was so short which was a disadvantage, in view of the work, but also a small advantage in revealing the inner corona when the obscuration was greatest.

Mr. Burckhalter speaks confidently of the time of exposure in the different parts of the corona which was under control and says that they are not simply approximate, but they are very close to the values given, and certainly within one fortieth of the values named.

Astronomers who are practical photographers will certainly be interested in this new piece of apparatus, designed some time ago by Mr. Burckhalter but who has not before had opportunity to give it a trial in eclipse work.

Another feature of this eclipse of some interest was that of the shadow bands. As noticed in the article above referred to last month, care was taken at the station in Southern Pines, to observe this phenomenon and the results are given on page 303. In an article, elsewhere published in this number, by Professor M. Moye, of the University of Montpellier, France, interesting facts about the same phenomenon appear. They are so different from those noted by the observers of the Carleton College party and others at the same station, that it has seemed desirable to call attention to these observations. Both seem to be definite, and to have been carefully made in all respects, but the differences of velocity, width of shadow and direction of motion are considerable. It might be possible to bring these observations into harmony if we knew more of the nature of this phenomenon and the circumstances of observation at the two stations which may differ in some important particulars.

Another point of some interest, which may be spoken of more fully later, is the relation of the form, and some other features of the corona, to the 11-year cycle of the sun spots. Some astronomers have thought that such a relation exists, and they have been studying total eclipse of recent date to ascertain, if possible, the evidence on which such a supposition rests. It is claimed that in or near the maximum part of the period, solar eclipses show a correspondingly large and active corona, as indicated by the number and length of his streamers, its rifts and its varied and complex structure. In the inner corona and about the polar regions in the eclipse of 1889 a most beautiful display, probably of electrical and magnetic lines of force were seen by many observers. Those who gave special attention to a visual study of the corona of the eclipse in May last, say that the two have points of resemblance in the particulars just mentioned. On the whole, the supposition is a reasonable one. If the corona is due to the condition of the photographic regions, we ought to expect changes in its visible structure when the solar surface is most active. Since this is especially true of the equatorial regions of the Sun as compared with those of the polar, at all times, it ought also to be true of the equatorial regions when the greatest differences of activity exist there. More will be said later of the work of professional astronomers when the results of the same are more definitely known.

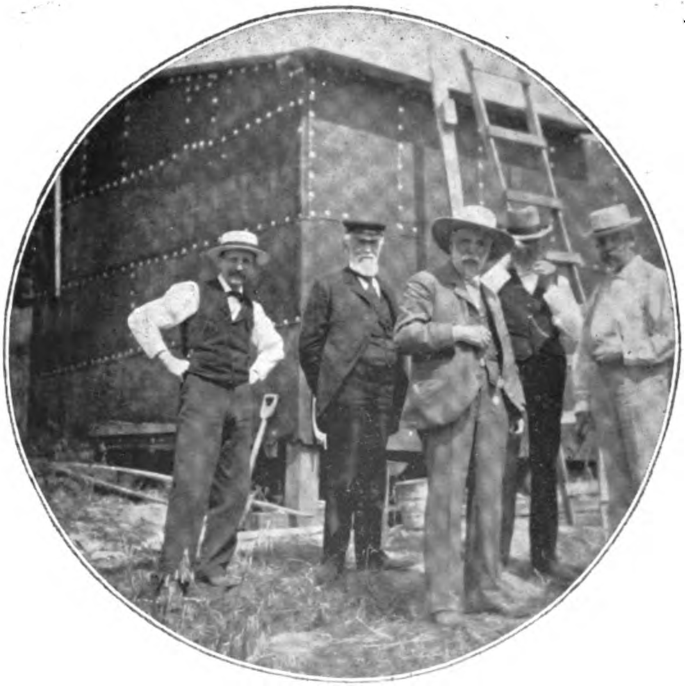
This brief account should not close, for the present, without reference to the work of some of the amateurs. It would be profitable to say much of what was done by this large and enthusiastic class of observers who occupied many stations in the line of totality, and who obtained useful results by the aid of small instruments. The articles for the papers, the many photographs of the corona and the illustrated pamphlets that have come to hand plainly show this. One of the neatest of these pamphlets was by David E. Hudden of Alta, Iowa, which is a

PLATE XVI.

TOTAL SOLAR ECLIPSE, MAY 28, 1900.

ECLIPSE STATION AT WADESBORO.

H. E. Hadden, with 4-inch telescope.



ECLIPSE STATION AT WADESBORO

1. THOS. LINDSAY, Toronto.
2. J. L. CAMPBELL, Wabash Coll., Ind
3. C. A. YOUNG, Princeton.
4. PROF. BRACKETT, Princeton.
5. PROF. LIBBEY, Princeton.

[Numbers read from left to right.]

fitting souvenir of his trip to Wadesboro, N. C. The illustrations of some of our plates were taken from this booklet; those showing Mr. Hadden at his 4-inch telescope, the location of the British Association Station and some observers with Professor Young in front of the temporary photographic house. The whole pamphlet consisting of a popular account of the eclipse is interesting reading, and the many photographs sent therewith are excellent.

Chas. P. Howard who observed in connection with the Trinity College party at Winston, N. C., has a good report of his observations and a drawing of the corona in the Trinity College Bulletin, No. 2, 1900. He says the conditions for work at Winston were favorable in a rare degree.

Professor C. M. Charroppin of St. Louis sent us very good photographs of the eclipse by small cameras. One in particular which showed streamers nearly three diameters of the Moon. In one of our plates his arrangement of a number of cameras is shown. Professor Charroppin is an excellent photographer. E. N. Fought, of the "Herald" Carlisle, Pa., who has written somewhat for this magazine, on popular themes, favored us with a full accout of the work of the Dickinson party which observed at Pungo, Virginia. A large Rowland concave grating was used in photographing the spectrum in the eclipse work of this party. We would speak of these and other parties from which notices have come, but space is wanting for it at this time. Later we will give the results of many amateur who have reported contact observations at stations in, and outside of, the path of totality.

ON THE PROPAGATION OF THE TIDAL WAVE UPON THE TERRESTRIAL SPHEROID REGARDED AS SOLID AND COVERED BY OCEANS OF UNIFORM DEPTH.*

T. J. J. SEE.

FOR POPULAR ASTRONOMY.

The aim of this short paper is merely to draw attention to certain simple phenomena connected with the tide-wave. The oscillations of the particles of the sea are very imperfectly set forth in every work with which I am acquainted, and as many elementary works treat the subject in an erroneous manner, I have been

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* Read before Section *A*, American Association for the Advancement of Science, New York, June 27, 1900.

led to think that a brief geometrical explanation of the chief phenomena would be welcomed by students of Physical Science.

It is shown in works on waves† that the motion of any particle may be defined by the relations

$$\left.\begin{aligned} x' &= x + \varphi\,(x,\, t) \\ y' &= y + \psi\,(y,\, t) \end{aligned}\right\} \qquad (1)$$

where x and y denote the coördinate of the particle when undisturbed by wave motion, and t the time reckoned from some arbitrary epoch. The functions φ (x, t) and ψ (y, t) represent periodic oscillations about a mean position, which may be best represented by cosines of angles.

$$\left.\begin{aligned} x' &= x + \xi\,(x) \cos\,(nt - vx) \\ y' &= y + \eta\,(y) \sin\,(nt - vx) \end{aligned}\right\} \qquad (2)$$

It is shown that these equations* may always be transformed into

$$\left.\begin{aligned} \Xi &= A\left(e^{\frac{2\pi\gamma}{\lambda}} + e^{-\frac{2\pi\gamma}{\lambda}}\right)\cos\,(nt - vx), \\ \Upsilon &= -A\left(e^{\frac{2\pi\gamma}{\lambda}} - e^{-\frac{2\pi\gamma}{\lambda}}\right)\sin\,(nt - vx) \end{aligned}\right\} \qquad (3)$$

where γ is the depth of the fluid, and λ is the wave length. When the waves are long compared to the depth of the sea, as in the case of the tide-wave.

$\frac{\gamma}{\lambda}$ is small, and we may put

$$\left.\begin{aligned} e^{\frac{2\pi\gamma}{\lambda}} + e^{-\frac{2\pi\gamma}{\lambda}} &= (2 + \delta) = a', \\ e^{\frac{2\pi\gamma}{\lambda}} - e^{-\frac{2\pi\gamma}{\lambda}} &= \left(\frac{4\pi\gamma}{\lambda} + \delta\right) = b' \end{aligned}\right\} \qquad (4)$$

where δ, a', b', are very small quantities. By means of equation (4) equation (3) thus gives $\frac{\Xi'^2}{a'^2} + \frac{\Upsilon'^2}{b'^2} = 1.$ which is the equation of an ellipse. As b' is very much smaller than a', the Ellipse is obviously very eccentric, or the horizontal motion is very much larger than the vertical motion, as is well known in the case of tides.

It is shown in works on the Mathematical Theory of Tides that the first and chief term of the tide-generating potential is

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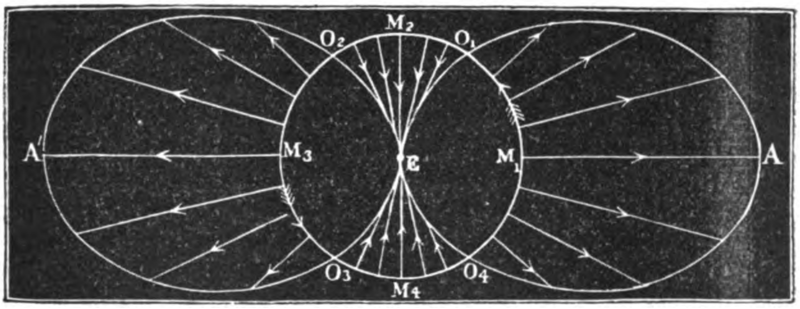
† "On the General Theory of Tides and on their Secular Effects upon the Figures and Motions of the Heavenly Bodies," by the author; or Airy's "Tides and Waves."

$$V=\frac{3}{2}\frac{m}{\rho^3}r^2\left(\cos^2\omega-\frac{1}{3}\right) \qquad (5)$$

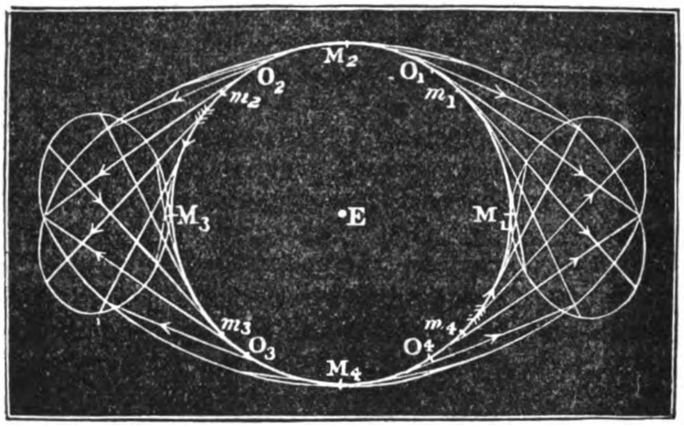
Where m is the Moon's mass, ρ its distance, r the radius of the Earth, ω the geocentric angular distance of the disturbed particle from the Moon.

If we differentiate this expression relative to any direction, we shall get the forces which disturb the particle relative to the center of the Earth. The whole theory of the tide is based upon the development and extension of this formula. If we differentiate V with respect to ω and put $\frac{\partial V}{\partial r}=0$, we shall have the condition that the force is entirely horizontal, and does not tend to elevate the water.

This gives $\cos^2\omega-\frac{1}{3}=0$, or $\omega=54.°75$. Thus in the Hemisphere under the Moon, from $\omega=0$, to $\omega=54.°75$, the forces tend to elevate the water; then in a zone from $\omega=54.°75$ to $\omega=121.°2$, the water is under a depressing influence; from $\omega=121.°2$ to $\omega=180°$ the forces again tend to raise the water. The following figures illustrate the radial and tangential forces which act upon the water.



The rise of the water is due principally to the action of the horizontal forces, as the vertical forces are of little effect against gravity. The ebb and flow of the tide is chiefly a horizontal oscillation of the water, the fluid either side of the point of highest elevation having run towards that point to raise the level, and having run away from both sides of the lowest depression to produce the drop. Let us now assume the Moon to move in the Celestial Equator and imagine an aqueous canal of uniform depth encircling the equator of the Earth, and let us then inquire in what manner the water is running in the different parts of the canal at any instant when tides are generated in the fluid by the disturbing action of the Moon. Since in case of the semi-diurnal tides there are two approximately equal tides each day, it is evident that the canal will be divided into four parts; first, an elevation extending over an arc of 109°.5; second, a depression extending over 70°.5; third, a second elevation extending over 109°.5; and fourth, a second depression extending over an arc of 70°.5.



Suppose we draw around the accompanying equatorial section of the earth a series of ellipses representing the oscillations performed by the particles, and indicate in each ellipse the approximate radius vector and phase of the particle at a given instant. To render these ellipses visible to the eye they are necessarily made much rounder than the paths actually described by the particles of our seas. In the figure let *h* and *h′* be the places of high water, where the flow is exactly horizontal and in the direction of the propagation of the tide-wave; let *f* and *f′** denote the two points where the water is falling most rapidly, and the motion of the particles is upward; and finally let *l* and *l′* be the two points where the water is lowest, and the motion directly contrary to the direction of the motion of the tide-wave. The arcs between these points are as follows:

$$hf = 54.7^\circ$$
$$fl = 35.3^\circ$$
$$lr = 35.3^\circ$$
$$rh' = 54.7^\circ$$

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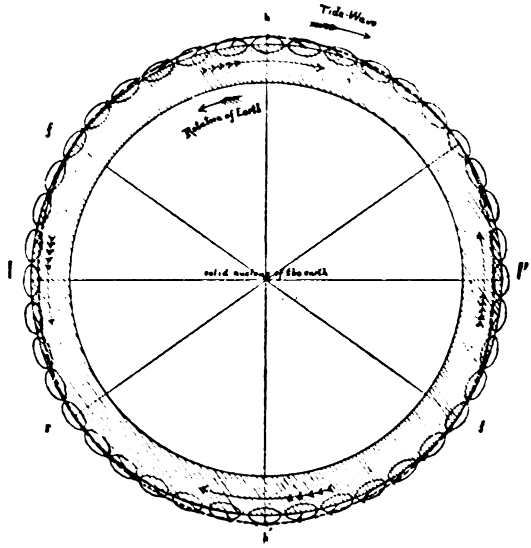
* The prime (′) is omitted in cut; should appear with f on lower right hand.

These arcs are deduced from the tide-generating potential, and represent the parts of the circumference over which the tide-generating forces tend to elevate or depress the water. Assuming that the fluid in the equatorial canal will respond to the forces acting upon it, we have inserted in the figure a series of ellipses with radii vectores showing the phase of the particles in the several regions, and also arrows showing the direction of the revolution of the ellipses, as the earth rotates and the tide-wave advances westward. A slight displacement of each particle in the direction of the advance of the tide-wave is seen to account for the motion of the shape, and in this way the major axis of the figure of the canal appears to revolve relative to the earth. The figure thus appears to explain the progress of the tide-wave in perfect accord with the preceding analytical theory. It will be seen that on each side of *r* the water is running toward that point over a total arc of 180°; 109.5° of the arc being on one side of *r* and 70.5° on the other; while on the other side of *f* the water is receding over similar arcs.



At *l* or *l'*, the center of the arc of 70.5°, the motion is exactly horizontal and backwards; at *h* or *h'*, the centre of the arc of 109.5°, the motion is exactly horizontal and forwards. It may be observed that the *tide-wave moves in the direction of the flow of the larger of the two arcs which contribute to raise or lower the water at r or r', f or f'.*

This consideration holds for the *propagation* of a *free wave,* such as the tide-wave becomes when once generated. *Forced waves* are of the same general character, but may be propagated at any velocity consistent with the action of the generating forces. Our actual tides are summations of a series of free and forced waves, superposed by the recurring periodic forces of the Sun and Moon; and as the ocean is of variable depth, the two series of waves are propagated at very unequal rates. If we consider the forced state of the sea following the Moon's transit, by a certain interval, it will correspond approximately to the foregoing figure of the tide wave.

NEW FORMS OF TELESCOPES AND OTHER OPTICAL INSTRUMENTS.

W. B. MUSSON.*

FOR POPULAR ASTRONOMY.

There have recently appeared in the newspaper and scientific press communications dealing with a new form of telescope, the fundamental principle of which consists in attaining the achromatism of a large object glass by the interposition of a small concavo-convex lens, silvered on the back. The curvatures of the small correcting negative lens, with its internal reflecting surface being so proportioned as to cause its negative chromatism to correct the positive chromatism of the object glass more completely than has yet been attained, at the same time at a much less cost and with a shorter tube.

It has recently been announced that Professor Schupmann of the Technische Hoch Schule at Aix-la-Chapelle in Prussia, on July 30, 1897, applied for, and obtained in the United States (under Letters Patent No. 620978, dated March 14th, 1899,) a patent on such an instrument as is aboved described under the name of "Medial-Fernohr." Among other things, it is claimed that one of the advantages of the telescope is that single crown glass lenses alone may be used. Prof. Schupmann, it is also announced, has published a book on the subject.

Under the circumstances, and in defence of the interests of two of its members, Messrs. Z. M. and J. R. Collins, the Astronomical Society of Toronto, thinks it proper to intervene for the purpose of laying before your readers certain facts not hitherto published, and which may tend to place the alleged new invention in a different light.

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*Secretary Toronto Astronomical Society.

In 1893 the Messrs. Collins constructed a Telemeter of their own design in which a modified form of dialyte objective was used for the purpose of shortening the tube and amplifying the focus. As a further result of their studies they came to the conclusion that certain principles employed in their Telemeter might be advantageously used in a telescope combining some of the properties of a refractor and a reflector. In the summer of 1896, they completed and exhibited to a few friends and a number of members of this Society an instrument of 4-inch aperture, 2 ft. in length and 4 ft. focus which they called the Monoplane achromatic Telescope. This instrument performed admirably, photographs being taken with it. On the suggestion of the Messrs. Collins, confidential communications were, in the spring of 189 7, addressed to Lord Kelvin, and to Professor J. A. Brashear, of Alleghany, Pa., and Dr. H. C. Vogel, Potsdam, Prussia. To these gentlemen were also submitted drawings as well as descriptions of the fundamentals of the Monoplane combination. On the data before him, Lord Kelvin declined, however, to express a conclusive opinion; Professor Brashear, while not committing himself to the principle involved, suggested that an eight-inch telescope of high quality should be constructed and tested. In his first communication, Dr. Vogel, who stated that he had shown the invention to his assistants, unsparingly condemned the telescope, but after a letter, explaining to him an error in the figures first supplied him, together with enlarged explanations, Dr. Vogel then said the combination appeared to him in an entirely new light, and with the figures then before him he found the correction for chromatism "to be more complete indeed than is the case with the ordinary achromatic objective."

As a result the construction of an instrument of 3 inches aperture was proceeded with—the late President, Mr. Arthur Harvey, F. R. S. C., and Mr. John M. Martin joining them with a view to furthering its completion. The development, however, of an important feature of the combination (not mentioned in the communications referred to and not included in Professor Schupmann's patent specifications) delayed the construction of the second instrument and it was not until this was nearly completed that Professor Schupmann's patent proceedings became known.

The point which the Society wishes to make is that, so long ago as the early part of 1896, a telescope embodying the essential features of that described by Professor Schupmann, was constructed and tested in Toronto. In each of two annual addresses to the Society, delivered in January in each of the years 1896 and 1897, Mr. John A. Paterson, M. A., President, referred to the instrument, and claimed for the Society the credit of having members sufficiently skilled in optics to produce a combination of lenses composed of one kind of glass, which could be used for telescopes, microscopes and cameras, greatly cheapening the cost and reducing the size of these instruments.

In the address of 1896 he says: "The Collins brothers have proved their ability in the figuring and polishing of parabolic mirrors for reflecting telescopes, and recently they have invented a telescope of an entirely new design, which will attain a maximum result at a minimum cost, measuring only half the length of the ordinary design, bearing at the same time the same magnifying power and possessing the virtue of achromatism by the use of two lenses, both of crown glass. By changing the relative position of the chief lenses the achromatism can be undercorrected or over-corrected. A short achromatic telescope with two lenses of the same material sounds like an impossibility.

In the address of 1897 he says: "Two of our most earnest members, the Collins Bros., are still developing their new Monoplane achromatic telescope. It is one of eight inches aperture, having a new form of objective of one kind of glass. Mounted equatorially it delivers an image of a celestial object in front of the eye-piece in dimensions equivalent to a focal length of forty feet, although the extreme length of the instrument complete is but four feet. It is able to correct for spherical aberration as well as chromatism and also for the "Schaeberle" aberration that must necessarily exist in the ordinary refractor of great angular aperture. Dr. H. C. Vogel, of the Astrophysical Observatory, Potsdam, after a mathematical analysis of the correction for achromatism, says: "A workable objective is now shown which, as the reasoning proves, unites in an excellent manner the rays from red to violet, better indeed than is the case with an objective of the usual construction" It may be added that the same principle may be applied to the microscope.

It may be added that upon this subject the Society is preparing a special report, which will include copies of the correspondence which passed between the Society and the authorities referred to.

In justice to the Messrs. Collins, I am to ask you to be so good as to find room in your valuable paper for this communication.

THE PLANET JUPITER.*

G. W. HOUGH.

1. The surface density of the planet Jupiter is presumably less than one-half that of water. The experiments made during the past twenty-five years in the liquefaction of air and gases enable us to imagine a plastic medium of the probable density of the planet.

If, then, the objects we observe are located at different levels in this medium, it would enable us to understand better why spots in the same latitude give different rotation periods.

2. The great Red Spot, 27,000 miles long, 8,000 miles wide, and possibly as deep as it is wide, drifts in both longitude and latitude.

It is the most stable of any marking seen on the disk. Its visibility may depend on its greater or less submergence beneath the surface, and its rate of drift (rotation period) may also be due to the same cause.

3. The rotation of the whole surface of the planet, on which spots or markings have been observed, is performed in 9^h 55^m to 56^m. The true rotation of the planet, however, may be slower than the longest rotation period hitherto observed, in which case all objects would drift in the same direction. My observations during the past twenty years extend from + 37° to — 38° of jovicentric latitude. Very few rotation periods have ever been determined outside these limits.

4. The rotation period is not constant for any latitude, but usually varies with the time.*

5. There is apparently no direct connection between latitude and rotation period, as is sometimes alleged.†

6. The rotation periods determined from spots or markings lying in the same latitude and at the same opposition may differ *inter se* 30 seconds or more. Hence the conclusions deduced by some observers for various permanent currents *on the surface of* the planet are based on insufficient data.

7. In the equatorial region from + 11° to — 8° of jovicentric

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* Vide Astronomische Nachrichten, 3354.

† Vide Popular Astronomy, February 1899, Table of Rotation Periods.

* This brief article contains the conclusions of a paper published in the May number of the Monthly Notes of the Royal Astronomeal Society by Professor G. W. Hough, Director of the Dearborn Observatory of the Northwestern University, Evanston, Ill.

latitude is found a rotation period $9^h\ 50^m \pm$, and this shorter period may possibly extend to 20° of latitude.

8. The periods $9^h\ 55^m +$ and $9^h\ 50^m \pm$ are found in the same latitude, and probably at the same time.

9. It seems to me that the complicated motions observed on the surface of the planet are best explained by assuming the existence of a number of layers, or strata, at different depths below the surface, in which are located the objects under observation.

Monthly Notices, May, 1900.

Revised List of Stars with Annual Motion of 1″ and Over.

J. G. PORTER.

NAME OF STAR.	MAG.	R. A. 1900.			DECL. 1900.		MOTION
		h	m	s	°	′	″
Cordoba Z. 5^h, 243	8	5	7	42	− 45	2.7	8.71
Groombridge 1830	7	11	47	13	+ 38	26.2	7.03
Lacaille 9352	7.5	22	59	25	− 36	25.8	6.88
Argentine G. C. 32416	8.5	23	59	31	− 37	51.0	6.22
61 Cygni, pr	5.5	21	2	25	+ 38	15.4	5.23
61 Cygni, fol	6.5	21	2	26	+ 38	15.2	5.16
Lalande 21185	7.5	10	57	52	+ 36	38.4	4.73
ε Indi	4	21	55	43	− 57	11.8	4.68
Lalande 21258	8.5	11	0	31	+ 44	2.4	4.47
40 Eridani	5	4	10	40	− 7	48.5	4.07
μ Cassiopeiae	5.5	1	1	37	+ 54	25.8	3.77
Weiss' Argel. 11702	9	15	4	44	− 15	59.1	3.72
α Centauri, mean	1	14	32	48	− 60	25.4	3.68
Weiss' Argel. 11703	9	15	4	45	− 15	54.1	3.66
Lacaille 8760	7.5	21	11	24	− 39	15.3	3.44
Lacaille 1060	4	3	15	56	− 43	27.1	3.11
Oeltzen's Argel. 11677	9	11	14	50	+ 66	23.3	3.04
α Groombridge 34	8	0	12	40	+ 43	27.3	2.85
Piazzi 2^h, 123	6.5	2	30	36	+ 6	24.6	2.33
Lalande 25372	8.5	13	40	40	+ 15	26.0	2.30
Struve P. M. 2164	8	18	41	40	+ 59	28.7	2.29
Lacaille 661	6.5	2	6	24	− 51	18.8	2.27
α Bootis	1	14	11	6	+ 19	42.2	2.27
Weisse I 5^h, 592	8.5	5	26	23	− 3	41.7	2.21
Lalande 7443	8.5	3	56	32	+ 35	1.9	2.20
β Hydri	3	0	20	30	− 77	49.0	2.19
Bradley 3077	6	23	8	28	+ 56	37.0	2.09
Piazzi 14^h, 212	5	14	51	37	− 20	57.9	2.06
ζ Toucani	4	0	14	52	− 65	27.8	2.03
Weisse I 9^1, 954	9	9	46	10	− 11	49.3	1.97
Lalande 15290	8.5	7	47	10	+ 30	54.8	1.95
τ Ceti	3.5	1	39	25	− 16	27.9	1.94
Auwers' A. G. C. 4999	9	13	40	13	+ 18	20.3	1.91
σ Draconis	5.5	19	32	33	+ 69	29.5	1.83
Lacaille 2957	6	7	41	51	− 33	58.6	1.72
Fedorenko 1457-8, mean	7.5	9	7	35	+ 53	7.0	1.70
δ Pavonis	3.5	19	58	55	− 66	26.2	1.64
Lalande 30694	7.5	16	47	56	+ 0	10.9	1.63

REVISED LIST OF STARS WITH ANNUAL MOTION OF 1″ AND OVER.

NAME OF STAR.	MAG.	R. A. 1900.			DECL. 1900.		MOTION
		h	m	s	°	′	″
Lacaille 8362	6	20	4	38	— 36	21.2	1.61
Lacaille 4887	6	11	41	45	— 39	57.4	1.58
61 Virginis	5	13	13	10	— 17	45.3	1.51
Lalande 31055	7.5	16	59	51	— 4	53.8	1.49
ζ′ Reticuli	5.5	3	15	36	— 62	57.5	1.47
Groombridge 1618	6.5	10	5	15	+ 49	57.6	1.45
Lalande 30044-5	7.5	16	25	33	+ 4	26.1	1.45
ν Indi	6	22	16	2	— 72	44.5	1.45
ζ^2 Reticuli.	5.5	3	16	2	— 62	53.3	1.43
Lalande 27744	7	15	8	50	— 0	57.8	1.39
Lalande 38383	7.5	19	59	41	+ 23	5.0	1.39
Lacaille 147	5.5	0	32	13	— 25	19.1	1.38
Becker A. G. C. 5072-3 m	9	14	21	7	+ 24	6.1	1.37
Lalande 6888-9	8	3	40	12	+ 41	9.0	1.36
Piazzi 0^h, 189	6	0	43	8	+ 4	46.0	1.35
Fedorenko 1384	8.5	8	45	59	+ 71	10.9	1.35
Lacaille 3386	6.5	8	28	57	— 31	10.9	1.34
Weisse I 17^h, 322	7.5	17	20	47	+ 2	14.0	1.34
Lalande 46650	8.5	23	43	59	+ 1	52.3	1.34
α Canis maj	1	6	40	45	— 16	34.7	1.32
γ Serpentis	3.5	15	51	50	+ 15	59.3	1.31
Oeltzen's Argel. 17315-6	9	17	37	0	+ 68	25.8	1.30
Weisse I 23^h,175	8	23	11	55	— 14	21.9	1.30
Weisse I 16^h, 906	9	16	50	8	— 8	9.1	1.29
85 Pegasi	6	23	56	57	+ 26	33.2	1.29
Lacaille 4955	7	11	52	58	— 27	8.7	1.28
36 A Ophiuchi	5	17	9	12	— 26	27.4	1.28
Lacaille 8381	5.5	20	9	3	— 27	19.9	1.28
ι Persei	4	3	1	51	+ 49	13.9	1.25
Weisse 4^h, 1189	6.5	4	55	51	— 5	52.3	1.25
α Canis min	1	7	34	4	+ 5	28.9	1.25
Bradley 2179	6	17	10	4	— 26	24.1	1.25
Munich 18180	9	18	53	7	+ 5	48.5	1.23
η Cassiopeiae	4	0	43	3	+ 57	17.2	1.21
43 Comae	4	13	7	12	+ 28	23.1	1.20
Lalande 28607	7	15	37	42	— 10	36.4	1.20
Weiss' Argel. 16089	8.5	20	17	42	— 21	39.7	1.20
δ Trianguli	5.5	2	10	57	+ 33	46.0	1.17
Lalande 15565	7.5	7	54	21	+ 29	31.1	1.16
Lacaille 7215	7	17	12	9	— 34	52.7	1.15
Fedorenko 2544	7.5	14	52	21	+ 54	4.3	1.13
70 Ophiuchi	4.5	18	0	24	+ 2	31.4	1.12
Lacaille 8620	6	20	51	3	— 44	29.2	1.11
θ Ursae Maj	3	9	26	10	+ 52	8.0	1.10
Bradley 1584	6	11	29	38	— 32	18.1	1.09
π Mensae	5.5	5	45	8	— 80	32.7	1.08
72 Herculis	5.5	17	16	55	+ 32	35.8	1.04
Lacaille 8267	6	19	55	32	— 67	34.9	1.04
Lalande 16304	6.5	8	13	39	— 12	17.6	1.02
Lalande 27026-7	8	14	46	0	— 23	52.8	1.02
Weisse I 21^h, 502	9	21	24	30	— 12	56.4	1.02
Lalande 5490-6	7	2	55	58	+ 61	19.9	1.00
ε Eridani	3	3	28	13	— 9	47.8	1.00

OBITUARY NOTICE.

RALPH COPELAND.

Charles Piazzi Smyth was born at Naples on 3 January 1819. His father was the well-known Admiral W. H. Smyth, whose numerous works on astronomy, written in a genial and popular style, has done so much to spread the love of astronomy in the British Islands. Doubtless the father's great personal regard for the venerable Italian astronomer Piazzi, then at Naples, led to the choice of the christian name by which his son was eventually so well known in the astronomical world. Educated at Bedford Grammar School, Piazzi Smyth was appointed assistant at the Cape Observatory in 1835 under Maclear. He assisted Maclear in the observation of Halley's comet and more particularly in making the typical drawings published in vol. X of the R. A. S. Memoirs. Seven years later he observed the Great Comet of 1843, of which he made a fine series of observations extending from March 5 to April 19, despite the imperfect character of the available instruments, the best of which seems to have been a portable equatorial of 3½ inches aperture. The general appearance of this great comet he preserved in a striking oil-painting which often called forth the admiration of astronomical friends in after years. Besides taking part in the regular work of the observatory he shared in the verification and extension of Lacaille's arc of meridian. The triangulation, in particular, involved much exposure notably in the winter of 1845 when he occupied the station of Sneeuw Kop at an elevation of 5070 feet above the sea. This was the last of his South African work, as he left the Cape shortly afterwards on his appointment to succeed Henderson as Astronomer Royal for Scotland and Professor of Practical Astronomy in the University of Edinburgh. He carried with him the best wishes of Maclear, who speaks of him as "experienced in the details of meridian work, and unflinching in hardships" and adds that "he had a happy talent, with the assistance of his pencil, in conciliating the inhabitants, . . . and his robust constitution fitted him for taking an active share in the triangulation."

On arriving in Edinburgh Piazzi Smyth loyally determined to complete the reduction of the meridian observations made by Henderson. This work was carried out in conjunction with Mr. Alexander Wallace, who most efficiently filled the post of assistant from the time of Henderson's appointment in 1834 until the end of 1880. In the course of his own work Piazzi Smyth greatly extended the investigations regarding the want of stability shown by the Transit Instrument, a defect which he eventually in great part remedied by discarding the movable Ys and their adjusting screws. This was done in 1848. The collected results of the Edinburgh meridional observations are published in vols. XIV and XV of the Edinb. Astr. Observations. In 1851 he went to Norway to observe the eclipse of the Sun in company with Dr. T. R. Robinson, the veteran Armagh astronomer. At their station on the Island of Bue near Bergen, the actual eclipse was obscured by clouds but the Professor, thanks to his skilful brush, brought home most successful sketches of the wonderful atmospheric coloring incidental to a solar eclipse. In 1856 he married Miss Jessie Duncan and in company with her sailed for Teneriffe in Mr. Robert Stephenson's yacht "Titania" on the expedition which gave so great an impetus to Mountain Astronomy. The scientific results of the mission are published in the Phil. Trans. for 1858, and more fully in Edinburgh Observations vol. XII, while their personal experiences in scaling the peak, and the circumstances of summer and autumn life at elevations of 9000 to 11000 feet above the sea are charmingly set forth in "Teneriffe, an Astronomer's Experiment", one of the few books illustrated with Photo-stereographs. Two further volumes entitled "Three Cities in Russia" are the outcome of another journey undertaken in 1859 to St. Petersburg, Moscow and Novgorod. The astronomical interest of this work centres in the account of Pulcova observatory and the circle of distinguished astronomers assembled there around the elder Struve.

In 1864 he published a volume entitled "Our inheritance in the Great Pyramid" in which he adopted and expanded certain eccentric ideas according to which this particular pyramid was the divinely revealed and universal standard of measure. The earlier part of the following year was spent in making an elaborate survey of the passages and chambers of the Great Pyramid together with determinations of their orientation. The details of this undertaking are given in Edinb. Observations vol. XII and also in the three volumes of "Life and Work at the Great Pyramid." Another volume, "On the Antiquity of Intellectual Man," Edinburgh, 1868, also bears on the hypotheses connected with the great pyramid. In recognition of the great pains and skill displayed in this work he was awarded the Keith Prize of the Royal Society of Edinburgh. The Professor's scientific friends would have been pleased had he contented himself with a strictly scientific treatment of the orientation of the pyramid and its passages, but the mystical hypotheses which he associated with the Great Pyramid led to discussions and controversies that culminated in Piazzi Smyth's withdrawal from the Royal Society of London in 1874.

At this period Spectroscopy attracted his attention and with his usual energy he devoted himself to the study of the Solar spectrum, the Spectra of luminous gasses, of the Aurora and of the Zodiacal light. He was the first to thoroughly map the absorption lines due to atmospheric vapour, and to advocate their observation as a meteorological phenomenon. He did much to advance the "end-on method" in dealing with faintly luminous media, and laboratory spectroscopy in general owes much to his numerous papers on the subject, which were invariably written in the attractive style so peculiarly his own. Of special importance was the discovery of the rythmical relation between the chief lines of Carbonic Oxide gas, a discovery in which he was associated with Prof. Alexander Herschel. In furtherance of his spectroscopic studies he paid long visits to Winchester, to Portugal and to Madeira, accompanied, as in all his journeys, by Mrs. Smyth who most devotedly assisted him in all his researches. The chief results of these studies are contained in the following papers: "End-on illumination in private spectroscopy;" "The Solar spectrum in 1877–1878," for which he received the Makdougall-Brisbane prize of the Edinburgh Royal Society; "Carbon and Carbo Hydrogen, spectroscoped and spectrometed in 1879," all three published in 1879; "Madeira Spectroscopic," 1882; "The Visual (Grating and Glass Lens) Solar Spectrum in 1884," 1886; and "Micrometrical Measures of Gaseous Spectra under High Dispersions," 1886.

With a view to facilitating telescopic observations at sea Prof. Smyth devoted much time and expense to the construction of a "Free Revolver Stand" on the principle of the gyroscope. This contrivance was tried on the voyage to Teneriffe with a considerable measure of success, though the smallness of the yacht tested to the utmost the steadying power of the apparatus. Unfortunately an accident to the mechanism put a stop to this promising experiment, which seems never to have been repeated at sea. Another of his inventions was a Distance-measurer of which the particulars will be found in the account of his journey to Russia. In 1852 Piazzi Smyth organised a system of exact time-signalling by means of a time-ball, followed in 1861 by the time-gun and sympathetic clocks in Edinburgh and afterwards in Dundee, which is still in operation. He gave much attention to the reduction of the temperatures shown by the deep-soil thermometers established on Calton Hill in 1837, and their comparison with the sunspot period and the mean temperature of Scotland. The results are depicted in the admirable graphic diagrams which form so conspicuous a feature of much of his work. Evidences of his artistic genius will be found in many of the vignettes on the title pages of the Edinb. Observations as well as in the illustrations of several of his popular books. He was also a skillful experimenter in all that concerned photographic methods from a relatively early date.

In 1888 he resigned the Directorship of the Observatory together with the Professorship in the University, which he had held for 43 years, and retired to Clova near Ripon in Yorkshire. With unflagging zeal he there continued his researches on the solar spectrum of which he made a large photographic chart with the aid of a Rowland grating. In 1895 he had the great misfortune to lose his wife, who for nearly forty years had been his faithful and untiring assistant in all his work. After Mrs. Smyth's death the Professor led even a more secluded life than before, though it is certain that he still busied himself with his favourite problems. He died on February 21, 1900 at Clova, where he as well as Mrs. Smyth are buried.

Though Piazzi Smyth is most widely known throughout the world by the mystical significance which he attributed to the Great Pyramid, his labours in sidereal astronomy, in mountain astronomy, in meteorology and especially in spectroscopy entitle him to a high place amongst the scientific worthies of the nineteenth century. To those who had the good fortune to know him personally he will ever be remembered as the most genial of hosts, ever ready to demonstrate the latest improvements of the always ingenious apparatus with which he chanced to be occupied at the time.

He was a corresponding member of the Academies of Munich and Palermo, and received the honorary degree of L L. D. from the University of Edinburgh. He was one of the oldest fellows of the Royal Astronomical Society having been elected as far back as 1846.

Astronomische Nachrichten, Royal Observatory, Edinburgh, April, 1900.

SPECTROSCOPIC NOTES.

In the *Astrophysical Journal* for June Prof. Vogel describes the large spectrograph built for use with the new 33-inch photographic refractor of the Potsdam Observatory. The collimator objective has a focal length of 48 centimeters (19 inches) and an aperture of 3 cm. (1.2 in.). The camera objective has a focal length of 56 cm. (22 in.) and an aperture of 4 cm. (1.6 in.); this may however be replaced for certain purposes by a cemented triple objective with a focal length of 41 cm. (16 in.) and the same aperture. The three simple prisms by Steinheil are of Jena glass which has a refractive index of 1.67 for the *Hγ* line in the violet, and which is very white. The refracting angle of the prisms is 63.°5, their height 4.0 cm. (1.6 in.), and the lengths of their refracting faces respectively 6.0 cm. (2.4 in.), 6.5 cm., and 7.0 cm. The whole is specially designed to prevent flexure in the parts. On trial the instrument has given gratifying results.

Prof. Vogel also contributes to the same number a very readable summary of the progress made in the last decade in the determination of stellar motions in the line of sight; a branch of spectroscopic science to which the aforesaid instrument will doubtless soon be making notable contributions.

In his Report to the Board of Visitors to the Greenwich Observatory the Astronomer Royal states (*Observatory*, July) that the 28-inch telescope has been used to examine Capella in accordance with Mr. Newall's suggestion that this spectroscopic binary might possibly be seen visually as a double star. An elongation was detected by several observers, and the position angle of this elongation varied consistently with the period of 104 days of the revolution of the spectroscopic components. This, it will be noticed, is about one fortieth of the period of the most rapid known visual binary.

The will of Prof. Piazzi Smyth makes provision for the publication of his spectroscopic manuscripts, and also for the assistance or promotion every ten or twenty years of an exceptional expedition for the study of some particular branch of astronomical spectroscopy at mountain elevations of not less than 6,000 feet.

An extended description of Prof. Smyth's spectroscopic work is contributed to *Nature* of June 14 by Prof. A. S. Herschel.

Among this year's Birthday honors is the promotion to K. C. B. of Dr. Gill, under whose very energetic directorship of the Observatory of the Cape of Good Hope important spectroscopic researches have recently been added to the other work of the Observatory.

The detailed spectroscopic measures have appeared from which Herr Belopolsky has been able to decide in favor of the short period of the rotation of Venus, (*Astronomische Nachrichten*, No. 3641; *Nature*, June 14). The photographs of the spectrum cover a period of time from the end of March to the middle of May, during which the planet was near greatest eastern elongation. The values obtained vary from 0.7 to 0.3 kilometers per second corresponding to values of the rotation period of 16 to 37 hours. The observations, while failing on account of the smallness of the quantity measured to fix the period of rotation closely, seem conclusive in showing that the real period of rotation is of the order of 24 hours.

If the report in *Science* is complete it would seem that the vice-president of section A of the American Association for the Advancement of Science at the New York meeting in his address on the subject of the teaching of astronomy in the United States did not so much as allude to the opportunities, difficulties, and progress of the teaching of spectroscopic astronomy.

Sir Norman Lockyer's study of the spectrum of α Aquilae (*Proceedings of the Royal Society*, No. 427) leads him to adopt the suggestion, originally offered by Prof. Pickering and later accepted by Prof. Vogel, that the haziness of the lines of the spectrum is the result of the star's rapid rotation. Using Prof. Scheiner's device of comparing with the spectrum of the sun or another star out of focus he finds that the spectrum of α Aquilae is much more like that of β Arietis and the Sirian stars than like that of α Cygni, with which Prof. Vogel originally classified it. He finds also that instead of Prof. Vogel's 17 miles per second the width of the lines is such as to require a velocity of more than 40 miles per second of rotation.

The new star in Aquila recently discovered by Mrs. Fleming from an examination of the Harvard plates follows the example of previous new stars in giving after its decline from maximum the spectrum of a planetary nebula.

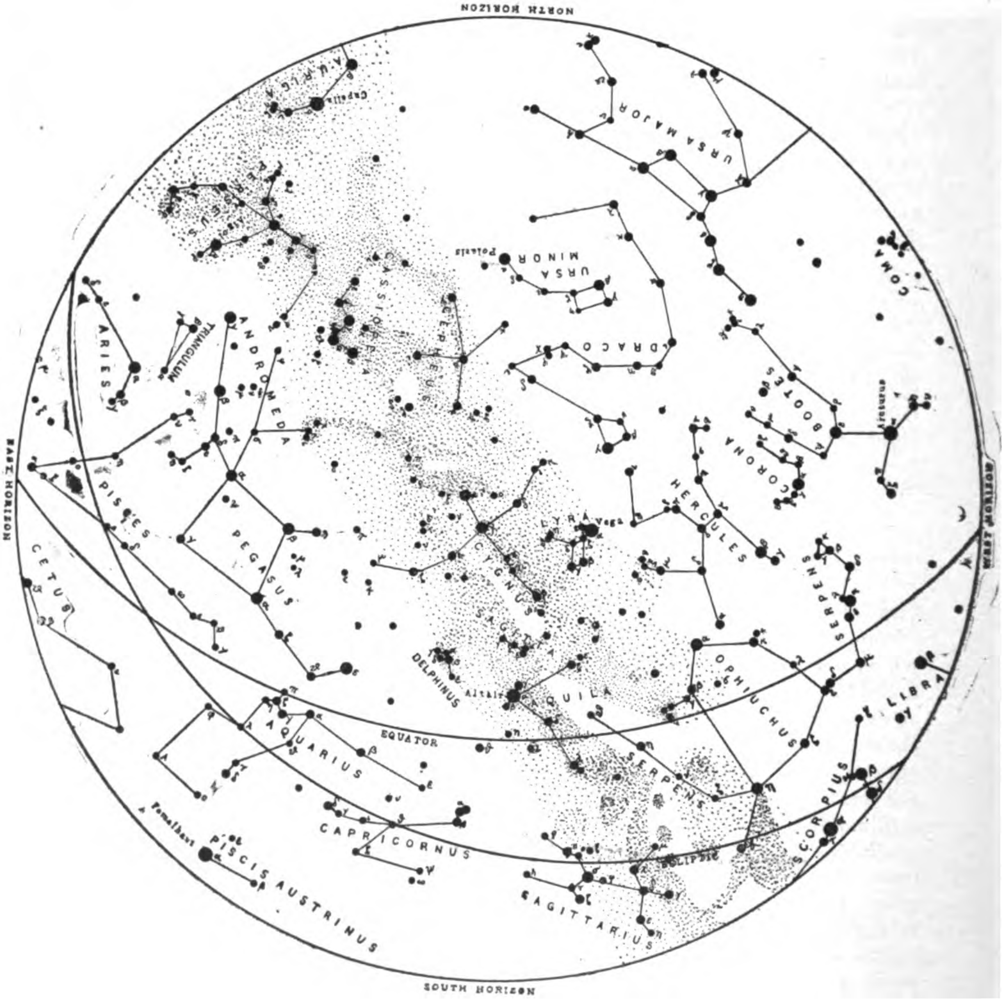
In the *Astrophysical Journal* for June Mr. Wright gives measures of photographs of the spectrum of ε Leonis taken with the Mills spectrograph of the Lick Observatory which do not confirm the variability of the velocity in the line of sight of that star announced by Mr. Adams from observations at the Yerkes Observatory.

The explanation of the continuous spectrum of the corona is the subject of an interesting communication of Prof. Scheiner to *Astronomische Nachrichten* No. 3647. In the continuous spectrum which the corona shows in addition to the bright line spectrum the dark lines are very weak. Consequently this part of the corona's light cannot be simply reflected sunlight, but must be largely light whose source is incandescent matter in the solid or liquid state. Such matter is found in the meteors which are undoubtedly present in great numbers near the sun's surface. If these, instead of simply reflecting the sun's light, are themselves the source of a luminous radiation which constitutes part of the light of the sun's corona, the necessary high temperature of the meteors must be explained. That the meteors are raised to a temperature of incandescence by friction in a rare medium, like the shooting stars of the earth's atmosphere, or by collisions, is improbable. Prof. Scheiner suggests, however, that direct radiation may be sufficient. The amount of heat received by a body so close to the sun would be very great; but on the contrary the radiation from a meteor, with no atmosphere to retain the heat, would be very free. Prof. Scheiner's conclusion is, from the rather meagre data available, that a meteor at a distance from the sun's surface equal to the sun's radius would reach a temperature of incandescence.

PLANET NOTES FOR AUGUST AND SEPTEMBER.

H. C. WILSON.

Mercury will be morning star during August, reaching greatest western elongation, 18° 32′ from the Sun, Aug. 19. The planet may then be seen a little north of east, about an hour before sunrise. On Sept. 13, Mercury will be at superior conjunction, so that during that month the planet will be invisible to the eye.



THE CONSTELLATIONS AT 9 P. M., SEPTEMBER 1, 1900.

Venus is the splendid morning star which one sees now, a little north of east, about three o'clock. She attains her greatest brilliancy on the morning of Aug. 14, and will continue to be the brightest "star in the east" for months to come. Venus and the Moon will be in conjunction on the mornings of Aug. 21 and Sept. 19. On Sept. 17 she reaches greatest elongation west from the Sun, 46° 3′.

Mars is now between the horns of Taurus and will move eastward through Gemini into Cancer during these two months. This planet can be observed only in the morning hours. Mars and the Moon will be in conjunction Aug. 20 and Sept. 18.

Jupiter is evening star, seen toward the southwest in Scorpio. In September Jupiter will be too far west for observation except in the early twilight. Jupiter and the Moon will be in conjunction Sept. 1 and 29. The planet will be at quadrature Aug. 25.

Saturn crosses the meridian now at about 9 o'clock and toward the end of September at a little after 5 o'clock P. M. It is the bright golden-colored star which you see in the Milky Way toward the south in the evening. Saturn will be at quadrature Sept. 21 and in conjunction with the Moon Sept. 3 and 30.

Uranus will be at quadrature Sept. 1, and in conjunction with the Moon Sept. 2 and 29. This planet, just below the limit of vision with the unaided eye in brightness, is among the stars in Scorpio southeast from Jupiter, and may be recognized when found by its dull greenish disc.

Neptune may be found in the morning, between 3° and 4° west from the star η Geminorum. It is not in convenient position for observation.

The Moon.

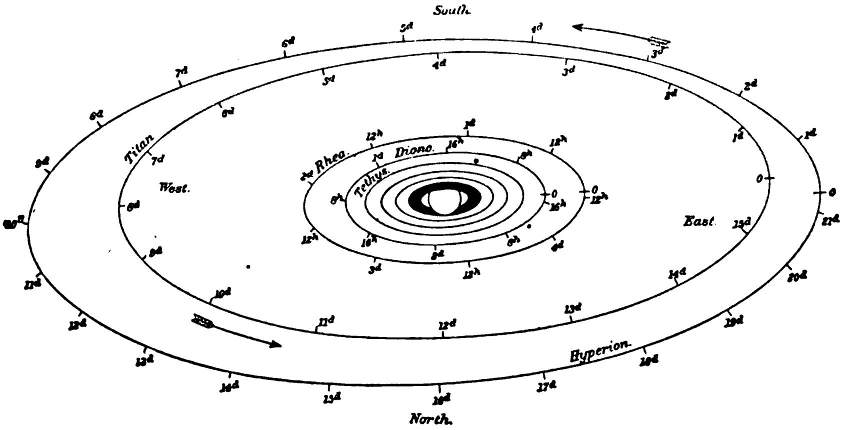
(Central Standard Time at Northfield; Local Time 13m less.)

		Phases.	Rises.		Sets.	
			h	m	h	m
Aug.	24	New Moon	5	01 A. M.	6	29 P. M.
Sept.	2	First Quarter	2	00 P. M.	11	09 "
	8	Full Moon	6	01 "	6	20 A. M.
	15	Last Quarter	10	48 "	2	23 P. M.
	23	New Moon	5	56 A. M.	5	44 "

Occultations Visible at Washington.

Date. 1900.		Star's Name.	Magnitude.	IMMERSION. Washington M. T.		IMMERSION. Angle f'm N pt.	EMERSION. Washington M. T.		EMERSION. Angle f'm N pt.	Duration.	
				h	m	°	h	m	°	h	m
Aug.	26	e Leonis	5.3	6	18	142	7	11	262	0	53
Sept.	12	η Arietis	5.7	7	10	43	7	49	286	0	39
	12	ρ^1 Arietis	7.0	9	08	64	10	01	260	0	53
	12	ρ^2 Arietis	6.0	9	57	26	10	37	296	0	40
	12	50 Arietis	6.8	12	13	132	12	44	186	0	31
	12	54 Arietis	6 3	16	00	75	17	21	256	1	21
	13	B.A.C. 1242	6.3	12	16	153	12	29	176	0	13
	14	ι Tauri	5 0	13	28	55	14	32	288	1	04
	27	ι^1 Librae	5.0	6	54	69	7	56	300	1	02

The Satellites of Saturn.



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, AT OPPOSITION IN 1900, AS SEEN IN AN INVERTING TELESCOPE.

I. MIMAS.

Period 0^d 22.6^h

	h		
Aug. 21	10.5	P. M.	E
22	9.1	"	E
23	7.7	"	E
24	6.3	"	E
29	10.7	"	W
30	9.3	"	W
31	8.0	"	W
Sept. 1	6.6	"	W
7	9.6	"	E
8	8.2	"	E
9	6 9	"	E
16	8.5	"	W
17	7.1	"	W
18	5.8	"	W
24	8.8	"	E
25	7.5	"	E
26	6.1	"	E

II. ENCELADUS.

Period 1^d 08.9^h

	h		
Aug. 21	9.4	P. M.	E
23	6 3	A. M.	E
24	3.2	P. M.	E
26	12.1	A. M.	E
.27	9.0	"	E
28	5.9	P. M.	E
30	2.7	A. M.	E
31	11.6	"	E
Sept. 1	8 5	P. M.	E
3	5.4	A. M.	E
4	2.3	P. M.	E
5	11.2	"	E
7	8.1	A. M.	E
8	5 0	P. M.	E
10	1.9	A. M.	E
11	10.7	"	E
12	7.6	P. M.	E
14	4.5	A. M.	E
14	1.4	P. M.	E
15	10.3	"	E
18	7.2	A. M.	E
19	4.1	P. M.	E
21	1.0	A. M.	E
22	9 9	"	E
23	6.8	P. M.	E
24	3.7	A. M.	E
26	12.6	P. M.	E
27	9.5	"	E
29	6.4	A. M.	E
30	3.3	P. M.	E

III. TETHYS.

Period 1^d 21.3^h

	h		
Aug. 22	9.2	A. M.	E
24	6.5	"	E
26	3.8	"	E
28	1.1	"	E
29	10.4	P. M.	E
31	7.7	"	E
Sept. 2	5.0	"	E
4	2 3	"	E
6	11.6	A. M.	E
8	8.9	"	E
10	6.3	"	E
12	3.6	"	E
14	12.9	"	E
15	10.2	P. M.	E
17	7 5	"	E
19	4 9	"	E
21	2.2	"	E
23	11.5	A. M.	E
25	8.8	"	E
27	6.1	"	E
29	3.5	"	E

IV. DIONE.

Period 2^d 17.7^h

		h		
Aug.	22	5.1	A. M.	E
	24	10.8	P. M.	E
	27	4.5	"	E
	30	10.2	A. M.	E
Sept.	2	3.9	"	E
	4	9.6	P. M.	E
	7	3.3	"	E
	10	9.0	A. M.	E
	13	2.7	A. M.	E
	15	8.4	P. M.	E
	18	2.1	"	E
	21	7.8	A. M.	E
	24	1.5	"	E
	26	7.2	P. M.	E
	29	1.0	"	E

VII. HYPERION

Period 21^d 7.6^h

	d	
Aug.	22.2	W
	28.2	S
Sept.	2.4	E
	7.1	I
	12.6	W
	18.5	S
	23.7	E
	28.5	I

V. RHEA.

Period 4^d 12.5^h

		h		
Aug.	21	10.4	P. M.	E
	26	10.8	A. M.	E
	30	11.2	P. M.	E
Sept.	4	11.6	A. M.	E
	9	12.1	"	E
	13	12.5	P. M.	E
	18	1.0	A. M.	E
	22	1.5	P. M.	E
	27	2.0	A. M.	E

VIII. JAPETUS.

Period 79^d 22.1^h

	d	
Aug.	10.9	E
	30.1	I
Sept.	19.7	W
Oct.	10.4	S

VI. TITAN.

Period 15^d 23.3^h

		h		
Aug.	23	11.7	A. M.	W
	27	9.7	"	S
	31	7.6	"	E
Sept.	4	8.8	"	I
	8	10.6	"	W
	12	8.7	"	S
	16	6.6	"	E
	20	7.9	"	I
	24	9.7	"	W
	28	8.0	"	S

Phenomena of Jupiter's Satellites.

Central Standard Time.

		h	m					h	m			
Aug.	25	6	46	P. M.	II	Tr. In.	10	6	55	P. M.	II	Oc. Dis.
		6	53	"	I	Oc. Dis.	12	6	24	"	II	Sh. Eg.
		7	29	"	III	Oc. Dis.		7	49	"	III	Tr. Eg.
	26	6	23	"	I	Tr. Eg.	17	7	11	"	I	Oc. Dis.
		7	41	"	I	Sh. Eg.	18	6	44	"	I	Tr. Eg.
	27	6	43	"	II	Ec. Re.		7	56	"	I	Sh. Eg.
Sept.	1	8	49	"	I	Oc. Dis.	19	6	26	"	II	Sh. In.
	2	6	05	"	I	Tr. In.		6	33	"	II	Tr. Eg.
		7	22	"	I	Sh. In.	23	6	50	"	III	Ec. Re.
		8	19	"	I	Tr. Eg.	25	6	28	"	I	Tr. In.
	3	6	45	"	I	Ec. Re.		7	37	"	I	Sh. In.
		6	46	"	II	Oc. Re.	26	6	43	"	II	Tr. In.
		6	52	"	II	Ec. Dis.		6	59	"	I	Ec. Re.
	5	6	34	"	III	Sh. Eg.	28	6	34	"	II	Ec. Re.
	9	8	02	"	I	Tr. In.	30	6	29	"	III	Oc. Re.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., Eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

VARIABLE STARS.

J. A. PARKHURST.

Maxima and Minima of Long Period Variables.

1900 October and November.

MAXIMA.	
	Oct.
ST Cygni	1
WR Hydrae	1
RR Virginis	2
S Librae	4
SS Cygni	5?
U Andromedae	6
T Capricorni	6
RT Cygni	6
V Capricorni	8
T Sagittarii	11
RR Aquilae	12
R Piscium	12
R Piscis Aust.	13
R Sculptoris	13
V Bootis	14
V Coronae	15
T Ophiuchi	15
S Scorpii	17
R Persei	18
R Draconis	19
R Microscopii	21
V Cassiopeae	22
U Librae	23
W Aquarii	24
— Aquarii	26
R Camelopardalis	26
X Scorpii	26
U Piscium	29
S Sagittarii	29
R Delphini	30
— Pegasi	30
RV Sagittarii	30

MAXIMA, Con't.	
	Nov.
S Pyxidis	2
Z Aquilae	3
S Cygni	3
R Andromedae	5
RS Herculis	8
T Aquarii	10
S Columbae	10
T Hydrae	10
V Lyrae	15
R Pegasi	15
W Monocerotis	19
S Sculptoris	19
R Arietis	20
W Aquilae	22
U Cancri	23
T Ursae Maj.	24
W Ceti	26
V Cygni	26
V Ophiuchi	26
Y Capricorni	28
T Sagittae	28
U Capricorni	30

MINIMA.	
	Oct.
U Ceti	2
T Sagittae	9
R Virginis	9
RR Cygni	11
R Sagittarii	12
R Leonis	21
R Ceti	23
U Virginis	24
T Canum Ven.	27
R Vulpeculae	29
S Coronae	31
	Nov.
T Librae	6
S Canis min.	16
V Cancri	18
S Piscium	19
V Aurigae	20
V Tauri	20
V Geminorum	26
S Geminorum	29
T Herculis	29
S Cassiopeae	30

NOTES TO THE EPHEMERIS.

LONG PERIODS.

ST CYGNI—The maximum calculated for Oct. 1, needs considerable correction. The star was fading towards minimum the latter part of July, and will pass the minimum probably in November. The discrepancy seems to have arisen from the assumption of 4 instead of 5 periods as having elapsed between the maxima of 1893 and 1898.

—*AQUARII*—Maximum. Oct. 26. The place of this star for 1885 is, R. A. $21^h\ 7^m\ 28^s$, Dec. 3° 29.′6, according to Dr. Hartwig.

—*PEGASI*—Maximum Oct. 30. The place of this star for 1855 is R. A. 21^h $14^m\ 8^s$, Dec. $+13° 50'.3$.

FAINT MINIMA—Three of the stars in the above list have been found very faint at minima. T Librae was $<$16th magnitude in April, V Lyrae $<$15th magnitude in May, and S Cygni $<$16th magnitude in July.

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900.

U CEPHEI.

	d	h
Sept.	3	16
	8	16
	13	16
	18	15
	23	15
	28	14
Oct.	3	14
	8	14
	13	13
	18	13
	23	13
	28	12

ALGOL.

	d	h
Sept.	7	22
	10	19
	13	15
	16	12
	19	9
	30	20
Oct.	6	14
	9	11
	12	7
	23	19
	26	16
	29	12

λ TAURI.

	d	h
Sept.	9	24
	13	23
	17	21
	21	20
	25	19
	29	18
Oct.	3	17
	7	16
	11	15
	15	14
	19	12
	23	11
	27	10
	31	9

U OPHIUCHI.

$P = 0^d\ 20.1^h$.

Sept.	0	8
	30	13
Oct.	31	13

R CANIS MAJ.

$P = 1^d\ 3.3^h$.

	d	h
Sept.	0	19
	30	8
Oct.	31	0

S CANCRI.

	d	h
Sept.	2	11
	11	22
	21	10
	30	22
Oct.	10	9
	19	21
	29	9

U CORONAE.

	d	h
Sept.	7	7
	17	16
Oct.	4	22
	8	9
	15	7
	18	17

Y CYGNI.

$2P = 2^d\ 23.9^h$.

Odd min.

Aug.	29	17
Sept.	28	16
Oct.	28	15

W. DELPHINI.

	d	h
Sept.	7	20
	12	16
	17	11
Oct.	6	16
	11	12
	16	7
	30	17

DM + 45°3062.

	d	h
Sept.	4	5
	8	18
	13	8
	17	22
	22	12
	27	1
Oct.	1	15
	6	5
	10	19
	15	8
	19	22
	24	12
	29	2

ALGOL-TYPE STARS.

The ephemeris for Y Cygni is taken from Dunér's latest elements in No. 3633 of the *Nachrichten*. The rest of the ephemeris, both for long-periods and Algol stars, is taken from Dr. Hartwig's paper in the *Vierteljahrsschrift*, Vol. 34, part 4.

NEW VARIABLE OF THE SS CYGNI TYPE.—Dr. Hartwig has a note in No. 3652 of the *Nachrichten* stating that Stanley Williams' new variable in Cygnus, BD. + 46° 2966, resembles U Geminorum and SS Cygni in the rapidity of its rise to maximum. The position is

R. A.	20^h	28^m	9.7^s	Dec. + 43°	6.′1,	(1855)
		29	38.0		15. 2,	(1900)

The range of variation is stated by Dr. Hartwig to one and one-quarter magnitudes, but it was estimated as 7.0 magnitude by Prof. Krueger 1857 June 19, and has lately been seen not much, if any, brighter than the 10th magnitude. Its period is stated as 15.2 days, and it passed a maximum about 1900 July 1. It is so near α Cygni that it can be easily located without circles. See also Nos. 3629, 3632 and 3637, of the *Nachrichten*.

COMET NOTES.

New Comet Borrelly-Brooks, 1900 b (July 23)—A new comet was discovered by Prof. W. R. Brooks of Rochester, N. Y., an hour after midnight July 23 in R. A. $2^h\ 43^m\ 40^s$ and Dec. + 12° 30′. It has been moving quite rapidly northward and on Aug. 3 was in the constellation Perseus in R. A. $2^h\ 58^m$ and Dec. + 45° 30′. The comet is quite bright but not visible to the naked eye. It has a stellar nucleus of about the 10th magnitude and a tail about 1° in length.

A telegram received Aug. 10 gives the following provisional elements and ephemeris computed by C. D. Perrine of the Lick Observatory from observations on July 25, July 30, and Aug. 4.

Elements by Perrine.

$T =$ Aug. 3.21
$\omega =$ 12° 27′
$\Omega =$ 328 0
$i =$ 62 3
$q =$ 1.0148

Ephemeris for Greenwich Midnight.

		R. A.			Dec.		Light.
	h	m	s	°	′		
Aug.	10	3	15	16	+ 63	41	0.83
	14	3	34	44	+ 72	17	
	18	4	12	28	+ 79	11	
	22	5	46	24	+ 84	11	0.43

From *Astronomische Nachrichten* No. 3653 we learn that the comet was discovered by Borrelly at Marseilles, at $12^h\ 50^m$ Marseilles time, July 23, so that Borrelly precedes Brooks by about 5½ hours in the discovery of the comet.

Finding Ephemeris for Comet 1894 IV. (E. Swift)—In a supplement to *Astr. Nach.* No. 3653 is given a short finding ephemeris for the faint periodic comet discovered by Edward Swift in 1894 and which is probably identical with the lost comet of De Vico, 1844 I. The ephemeris was computed by Mr. Frederick H. Seares, now in Berlin. The calculated light of the comet renders the search for it this year almost hopeless, since it was seen with the greatest difficulty in 1894 and the computed light this year is only one ninth as great as then.

Ephemeris for Berlin Midnight.

1900		R. A.			Dec.		log. Δ	Aberration.	
		h	m	s	°	′		m	s
July	23	15	53	28	—24	32 8	0.2496	14	46
	27		53	42	24	30.7	.2552	14	58
	31		54	26	24	30.2	.2608	15	10
Aug.	4		55	39	24	30.8	.2666	15	22
	8		57	20	24	32.8	.2724	15	34
	12	15	59	31	24	36.0	.2784	15	47
	16	16	02	10	24	40.2	.2845	16	00
	20		05	17	24	45.4	.2906	16	13
	24		08	50	24	51.4	.2967	16	27
	28	16	12	50	—24	58.1	0.3026	16	40

The light ratios compared with the light at the time of discovery in 1894 are

1900		$1:r^2\Delta^2$	$1:r^2$
July	23	0.12	0.35
Aug.	28	0.11	0.42

GENERAL NOTES.

We have held this number back several days longer than previously announced, in order to get the latest plans and instructions for observations of the planet Eros, to determine its parallax. Work has already begun, and this opposition of Eros offers a favorable opportunity for the observations desired.

The Late James E. Keeler.—The news of the death of Professor James E. Keeler, Director of the Lick Observatory, Mt. Hamilton, California, will be sad news to scientific circles the world over. It occurred Sunday, Aug. 19, in San Francisco, after a brief illness, the particulars of which have not come to hand. A full account of the life work of Mr. Keeler will be given in our next, by persons well qualified to speak of it.

A Few Astronomical Instruments is the title of a fine quarto volume in board and cloth covers giving excellent, full-page plate illustrations of some of the astronomical instruments made by the well-known firm of Warner & Swasey, Cleveland, Ohio. It is only a few years since this firm began work on astronomical instruments. We well remember with what hesitation and self-distrust the first steps in this new line of telescope-making for them was undertaken. It is now very remarkable that in so few years it should be possible for any instrument makers to have achieved such a reputation, for high grade work, on the largest scale, as that enjoyed today by Messrs. Warner and Swasey. One has only to open this neat, new book to find illustrations of telescopes having object glasses varying from 6 to 40 inches in diameter, bearing the impress of their handy and skillful work, in mounting or other contrivance to put the working astronomer at his nightly task with ease and comfort hitherto unknown. In this new volume we not only find refracting telescopes of various sizes of the most modern and approved pattern, but also meridian circles and photograhic instruments with all the appliances which the ingenuity of the electrical and mechanical engineer can devise to transform the drudgery of the taxing routine work of the observer into the delight and exhiliration of pure observational research. Of late we have wondered what Herschel would do and say if he were privileged now to use one of America's great refracting telescopes. If his enthusiasm was kindled inordinately with the help of such telescopes as he could make for the study of the heavens, his wonderful genius aided by the celestial views of the modern telescope would have given him insight and an impression of mind that would have filled his longing and devout soul, not with fancy and theory, however probable, but with fact and sublime reality which he so loved and bravely sought with all his great mental power.

The reason for the rapid growth of the reputation of the firm of Warner & Swasey in the new line of telescope making is not hard to understand. They went at it deliberately. They had the means and the ability to experiment exhaustively on new and difficult methods of mounting telescopes. They had skill enough to make a dome for an observatory that has proved to be a perfect success. We have used two of their steel domes, large and small, for fifteen years, and we now say we could reasonably ask for nothing better. They have made position micrometers that work very well and keep a good record for steadiness in time under certain astronomical tests. They do well and faithfully many other kinds of work in scientific lines that we have not the space now to speak of. But the one very difficult piece of machinery, which has occupied the attention of these makers for some time, is the structure of a dividing engine for ruling the fine measuring circles which are a necessity to all instruments of precision. To make such an engine, whose errors of division are less than values easily seen by good visual apparatus, is a problem that has baffled the ingenuity and the skill of the best mechanical engineers down to the present time. We notice a cut of a dividing machine in this book, and we have heard something of the fine work that can be done by it. We sincerely hope that the problem of producing highly accurate dividing apparatus has been solved by Warner & Swasey for it will certainly mean much for Warner & Swasey and for science generally. Later we hope to print a cut and an explanation of this new ruling engine.

Military Rank of Professors of Mathematics in the United States Navy.—The Navy Register for 1900 gives the *real*, not *relative* or *assimilated*, rank of all Professors of Mathematics in the Navy up to January 1, 1900. On the active list we find: "With rank of Captain:" Profs. Hendrickson, Todd and Oliver. "With rank of Commander:" Profs. Brown, Rawson, Alger and Dodge. "With rank of Lieutenant:" Profs. Paul, Skinner, See and Updegraff.

On the retired list we find: "Rank of Rear Admiral:" William Harkness. "Rank of Captain:" Profs. Newcomb, Hall and Eastman. "Rank of Commander:" Profs. Frisby, Prudhomme and Rice.

The equivalent ranks in the army are as follows:

Rear Admiral	with	Maj. General.
Captain	"	Colonel.
Commander	"	Lt. Colonel.
Lt.Commander	"	Major.
Lieutenant	"	Captain.

Total Solar Eclipse May 28, 1900. Observed by Party from Leander McCormick Observatory.—The party from the Leander McCormick Observatory of the University of Virginia was stationed at Winnsboro, S. C. The day of the eclipse was beautifully clear and the programme was carried out successfully.

The equipment included a camera having a lens of five inches aperture and 39 ft. focal length. Seed's triple-coated plates having 27x as the upper emulsion were employed. Ten plates were secured during totality. The exposures were made by Mr. J. W. Mayo of the Engineering Department of the University of Virginia, assisted by Mr. J. W. Hanehon of Winnsboro. Several smaller cameras were also mounted on a polar axis, the plates being exposed by Messrs. J. A. Lyon and E. O. Eastwood of the Observatory. One of these cameras having a focal length of four feet was provided with a color screen. The negative obtained shows no detail owing to failure of the clepsydra to work properly, but the intensity of the coronal image is such as to indicate that good results might easily be obtained with a long focus camera. Visual observations were made by Mr. H. R. Morgan of the Observatory and Prof. H. L. Smith of Davidson College with four inch refractors and myself with a six inch refractor. Preceding the eclipse, observations were made for the determination of latitude and longitude.

The polar coronal filaments greatly resembled those of the eclipse of 1878, but seemed at the time longer than those seen at Denver. On the other hand the equatorial filaments were not so well defined nor did they interlace to the same extent as in 1878, being more nearly radial and consequently not intersecting except at some distance from the sun's limb. Vastly more of detail was seen in the telescopes than is shown on the negatives. No relation was noticed in the former between the filaments and the protuberances, although carefully looked for. Such relation is however apparent on the negatives, at least in the case of one of the principal prominences seen. On the negatives made also, the forms of some of the filaments were interesting. In the region between the two principal prominences, for instance, there are filaments which near their base are directed away from the sun's equator, while at a distance higher above the sun's limb they curve back again toward the equator. In this case, at least, the filaments do not form elliptic curves having their foci at the centre of the sun.

To the United States Naval Observatory and to Mr. Geo. N. Saegmuller the expedition was indebted for the use of instruments, to Prof. W. W. Campbell for valuable advice and for developing the plates obtained with the forty foot camera, to the Southern Railway and the Western Union Telegraph Company for railway and telegraphic facilities, and to the authorities and people of Winnsboro for their untiring and helpful courtesies.

Occultation of Saturn.—The following observations of the occultation of Saturn on July 10, 1900, were made at the Chamberlin Observatory, University Park, Col. The twenty inch refractor was equipped with a power of 200. The six inch refractor was used by Prof. Chas. J. Ling, and the five inch by Julian O. Howe. The atmospheric conditions were unfavorable. Local mean times are given; the position of the observatory is given in the American Ephemeris under the title "Denver."

Immersion.

	20-inch.			6-inch.			5-inch.		
	h	m	s	h	m	s	h	m	s
Outer edge of ring				7	59	3.6			
Encke's division	7	59	5.5						
Inner edge of ring			14.6			14.6			
First edge of ball			23.2			24.7			
Center of ball			43.6						
Second edge of ball	8	0	5.2	8	0	3.8			
Inner edge of ring			16.7			13.4			
Outer edge of ring			34.5			30.5	8	0	32.0

Emersion.

	h	m	s	h	m	s	h	m	s
Inner edge of ring	9	16	4.5						
1st contact with ball			20.2						
Center of ball			38.0						
2d contact with ball			58.2	9	17	1.0	9	17	1.0
Inner edge of ring		17	13.5			15.9			
Outer edge of ring			25.4			27.5			

HERBERT A. HOWE.

University Park, Colo., August 1900.

On July 21st *o Ceti* was observed and seemed equal to *Gamma Ceti* of third magnatude. On July 27th it seemed slightly less bright than that star, but was brighter than *Delta Ceti*.

The nights were clear and moonless. The maximum was predicted for July 31st.

R. O. H.

San Francisco, August 10th.

Death of David Flanery.—Mr. David Flanery, well known to all readers of Popular Astronomy, died at his home in Memphis, Tenn., on August 6. Mr. Flanery was much interested in the variable stars, and has for many years been an observer of them. During the last six years he has followed up, among other stars, Mira Ceti and R Leonis with great persistency, and has furnished a number af maxima of these stars which are of considerable value. He has also kept watch of SS Cygni, and the new short-period star, SV Cygni, furnishing observations of them which the writer has been glad to use to supplement the gaps in his own.

Though knowing him only by letter, I have found him a genial and faithful correspondent, and an honest, open-minded and careful observer, always making the most and the best of such material and information as was accessible to him. He was very modest as to the value of his own astronomical work, and deserved to be more generally and favorably known to the regular astronomers than has been the case. P. S. YENDELL.

Dorchester, Aug. 10, 1900.

Discovery of Comet Brooks.—It was my pleasure on the early morning of July 23 to discover a new bright comet in the eastern heavens; right ascension 2^h 43^m 40^s; declination north 12° 30′. The motion of the comet was rapid, about three degrees daily, and in a northerly direction. The comet has a bright stellar nucleus, large coma and rather broad tail. In the 10¼ equatorial of this observatory, it is a very beautiful telescopic object, resembling a great naked eye comet in miniature. Discovered in the southern part of Aries it is at this writing in the head of Medusa and yesterday morning, was in the same low power field with Algol.

The approximate position of the comet this morning was as follows: Aug. 2nd 14^h 19^m E. ST. T. R. A. 2^h 55^m 35^s ; + 42° 34′. This position compared with the observation of yesterday morning, shows a daily motion of 1^m 25^s east, and 3° 3′ north. The nucleus has always appeared considerably elongated, until this morning it was nearly round.

WILLIAM R. BROOKS.

LINETTE OBSERVATORY, Geneva, N. Y.
August 3rd, 1900.

The Total Eclipse at Barnesville and Griffin, Ga.—Mr. Geo. A. Hill sends the following notes correcting and supplementing the very brief mention of the work at these stations in our paper in the last number of Popular Astronomy:

"The latitude and longitude of the station at Griffin, Ga., was determined by myself assisted by Mr. Littell. The site was selected, piers built, dark room constructed under my personal direction and in my judgment it was one of the finest that could have been found.

At Barnesville I made an accurate determination of the latitude and longitude, exchanging longitude signals with the Observatory here in Washington.

In addition we had with us Professor Lord, of the Ohio State University, equipped with his fine spectroscopic outfit. On the day of the eclipse Mr. Littell and I observed the first contact, each using one of the five inch equatorials. At the time of totality I had charge of the guiding telescope mounted on the polar axis, which held five cameras. Mr. Littell gave the proper time of exposure on each set. We secured four sets or twenty in all for the polar axis.

Mr. Peters, the photographer of the Observatory had immediate charge of the

40 foot lens. His devotion to his duty should not go unmentioned, for the end of the long focus lens was in a dark room, and he did not see the totality at all. Mr. Peters secured four plates with that lens. He was in charge of placing all the lenses in focus and his plates when published will indicate how well he did his work.

The two inner contacts were observed by Professors Eastman and Updegraff. Dr. See did not arrive at the station until two days before the eclipse and had nothing to do with preparing for the affair.

Professor Brown was in general charge of the station up to the day of the eclipse, but he observed from Griffin."

Occultation of Saturn by the Moon June 13, 1900.—This occultation was seen in a perfectly clear sky and good images. The instrument was a 4¼ inch refractor with a magnifying power of 160.

Ingress.—The planet was very pale, much less bright than the lunar disk and even the floor of Grinaldi or Plato. I saw no abnormal appearance on the rings or on the ball of Saturn. No dark band on the lunar limb.

Egress.—Same appearance. The egress was regular. Saturn always very little bright, but no trace of a lunar atmosphere. After 10 or 12 minutes the planet was seen to the naked eye.

M. MOYE.

MONTPELLIER, (FRANCE)
June 12, 1900.

Corona Seen After Totality.—As the visibility of the corona after totality appears to have been a peculiar feature of the recent eclipse, the following notes may be of interest to readers of POPULAR ASTRONOMY.

The eclipse of May 28 was witnessed by the writer in Norfolk, Va., from a hotel roof secured for our party by the Hartford Scientific Association, and commanding a fine view of the surrounding country. Totality was due at about seven minutes before nine A. M. At 8:45 the Moon was far advanced upon the Sun, the daylight was distinctly dimmed and the air had grown cold. (The fall of temperature during the eclipse was found by one of the party to be more than fifteen degrees.*) At about eight minutes before nine totality was immanent, the crowd on the house-top was silent and minds were tense with expectation. I glanced at the Sun. The dwindling cresent formed now no more than a slight border upon the central zone of the Moon. Turning quickly toward the southwest where a moment ago the sky had been clear, or but slightly smoky along, the horizon, I saw, as it were, a black thunder cloud beyond the harbor and islands. I was unable to see the outline of the shadow advancing through the air, though to some of the party it was indistinctly visible. Indefinite darkness filled in two or three seconds the whole southwest sky. Meanwhile the shadow fell upon us in sudden successive waves. The daylight was, as it were, snatched away, and in a second or two again snatched away. I noticed at least three times this weird sinking of the daylight. Every beholder felt himself alone and overawed as the shadow fell. We were now enveloped in an unearthly twilight. When it was evident that the shadow was fully upon us, I turned to the east to look at the Sun. It hung black as ink in the sky with the corona springing from its equatorial zone in two wings or shafts of light like auroral streamers, seen beautifully aslant the sky. The western wing which was the longer could be

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*This amount is so large there may be some mistake about it.—Ed.

traced nearly two solar diameters. Both wings were irregular at the boundary, and one, the eastern(?) flared more than the other, appearing in fanlike form. There were evidently structures just eluding vision (of the naked eye), but in the northern angle of the eastern wing my attention was fixed by a ray which curved back strongly from the polar regions, leaving almost a black shadow between itself and the bright polar filaments. From drawings made by members of the party I judge this may have formed the edge of a cone superposed upon the equatorial fan. The polar rays were beautiful silvery filaments springing singly from the sun's black poles. They were widely separated and quite long, the one in the northwestern angle, next the equatorial shaft seemed nearly equal to the Sun's diameter. All curved beautifully away from the poles, suggesting the lines of force about a disk magnet. I saw several bright dots on the Sun's edge which must have been prominences, but did not catch the delicate pink color of these and the rosy border on a portion of the Sun's edge seen by others of the party. Near by to the northwest of the Sun, Mercury shone out in fine flame color. The inky black globe of the Moon, the silvery wings of coronal light and the planet burning like a live coal through the sky formed a spectacle of weird beauty never to be forgotten. Barely had we looked at it however when a beaded mass of light broke out upon the western border of the Moon and unwelcome daylight dispelled the wondrous apparition. As partial compensation in this unhappy moment came an interesting and most unexpected phenomenon. At the instant of reappearance of the crescent, the equatorial wings of the corona vanished. But in their stead was seen a silver ring around the Sun, fringed with a flame pattern not previously visible. It called at once to mind a drawing of the inner corona in Young's Astronomy. For perhaps a second it was very bright, then I was aware of the return of daylight (which seemed to come perceptibly later than the reappearance of sunlight on the Moon's limb). To my still greater surprise the fringed ring did not vanish, but remained visible for what seemed a long time. This may have been ten seconds or so but I didn't count. One seemed to see this corona through a veil of glare like, for example, the beams from a search light in dusty air. At last it faded from sight and the eclipse was to all intents and purposes over. The inner corona has been reported as telescopically visible after totality at stations farther south. A possible connection is suggested between the prolonged display of the corona and the gradual falling of the shadow in this eclipse. Or the corona may have been unusually brilliant and so have outshone the returning daylight.

ANTONIA C. DE P. P. MAURY.

The Theory and Practice of Interpolation.—We have been much interested in a book recently published on The Theory and Practice of Interpolation by Herbert L. Rice, assistant in the office of the American Ephemeris, and Professor of Astronomy in the Corcoran Scientific School, Washington, D. C. It is in quarto form, consists of 234 pages, and is neatly printed by the Nichols Press of Lynn, Mass. In his office work the author has "felt the need of a book that would give, exclusive of other matter, a simple, practical and yet comprehensive discussion of all that is useful concerning *differences, interpolation, tabular differentiation and mechanical quadrature*," and, that should also include all tables auxiliary to the text needed by the practical computer.

In a brief review of this book, it seems to us that the author has carried out well, his design of bringing together these kindred themes and of treating them in very plain and practical way. The first chapter which treats of differences speaks of the nature of a function in mathematical sense, then illustrates the notation of differences in tabular form, and immediately calls attention to a method of checking work for numerical accuracy. The theoretical part is stated in the form of theorems to be proved which, as far as we have noticed, are done in clear, concise and accurate way. The numerical examples which illustrate every important step in the development are an admirable feature which will at once attract the attention of the mathematical student.

This book contains, in our judgment, the clearest, fullest and best presentation of these topics that we know of either for study or for practical use in the hands of the computer. We think enough of it to adopt it in the post graduate course of study in Mathematics and Astronomy at Carleton College. It will be used at Goodsell Observatory as as reference book in respect to the themes of which it treats so fully and well.

Elements and Ephemeris of Comet *b* 1900 (Borrelly-Brooks.)—From Mr. Crawford's observation made on July 25th and my own of July 30th and August 4th, I find the following parabolic elements:

$$T = 1900 \text{ August 3d, 20726 Gr. M. T.}$$

$$\left.\begin{array}{rrrr} \omega = & 12^\circ & 26' & 13.2'' \\ \Omega = & 328 & 0 & 30.1 \\ i = & 62 & 30 & 46.3 \end{array}\right\} 1900.0$$

$$\log q = 0.006390$$

Residuals $(O - C)$: $\Delta\gamma' \cos\beta' + 4.4''$; $\Delta\beta' - 0.9$.

CONSTANTS FOR THE EQUATOR OF 1900.0

$$\begin{array}{l} x = r\,[9.945799] \sin(\ 86^\circ\ 21'\ 14.2'' + v) \\ y = r\,[9.686698] \sin(283\ \ 9\ \ 4.5 + v) \\ z = r\,[9.996636] \sin(\ 0\ \ 10\ \ 7.0 + v) \end{array}$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1900.		Time α			Time δ		Log Δ	Br.
		h	m	s	°	′		
Aug.	10.5	3	15	15	+63	41.0	9.699	0.83
	14.5	3	34	46	72	17.2	9.746	0.65
	18.5	4	12	27	79	10.8	9.781	0.54
	22.5	5	46	25	84	11.3	9.823	0.43
	26.5	9	29	40	85	46.3	9.864	0.34
	30.5	12	5	24	83	37.7	9.902	0.27
Sept.	3.5	13	3	6	80	49.1	9.936	0.22
	7.5	13	30	37	78	13.1	9.968	0.18
	11.5	13	47	22	75	57.6	9.998	0.15
	15.5	13	59	9	74	0.1	0.025	0.12
	19.5	14	8	25	72	19.1	0.049	0.10
	23.5	14	16	17	70	52.6	0.072	0.09
	27.5	14	23	17	69	39.2	0.092	0.08
Oct.	1.5	14	29	46	68	37.4	0.111	0.07
	5.5	14	35	54	67	46.0	0.128	0.06
	9.5	14	41	53	67	4.4	0.144	0.05
	13.5	14	47	44	66	31.6	0.158	0.04
	17.5	14	53	33	66	7.2	0.171	0.04
	21.5	14	59	21	65	50.6	0.183	0.03
	25.5	15	5	12	+65	41.9	0.195	0.03

This comet seems to have been quite bright when discovered but to have faded rapidly since. On August 4th it was just visible to the naked eye, with a nucleus estimated at 10th magnitude. On July 28 the nucleus was elongated as seen with the 36-inch refractor.

C. D. PERRINE.

Mount Hamilton, California, Aug. 14, 1900.

Occultation of Saturn at St. Paul, Minn., July 10, 1900.—Mr. S. J. Corrigan of our city sent me some computations for the occultation of the planet Saturn, which took place Tuesday evening, July 10. I observed the times of immersion of both the ring and ball of the planet and sent my results to him. He advised sending them to Popular Astronomy for publication.

Mr. Corrigan's computations for the times of all the phases for ball and ring were as follows:

Immersion (Central Time).

	h	m	s
First contact with ring	9	24	47.2
" " " ball	9	25	11.6
Center of ball	9	25	28.8
Last contact with ball	9	25	46.0
" " " ring	9	26	10.4

Latitude +44° 53′
Longitude 93° 05′ W. of Greenwich.

Times of Observations were:				Difference.
	h	m	s	s
First contact with ring	9	24	45.0	+2.2
Center of Saturn	9	25	26.	+2 8
Last contact with ring	9	26	07.	+3.4

"The observed times are thus about three seconds earlier than the computed, which may be due to errors in the tabular places of the Moon and of Saturn. Washington observations of the late eclipse of the Sun indicate that the Moon was several seconds ahead of the computed time, and my observations would indicate that it was three seconds ahead in the times of this occultation."

I secured the time from Goodsell Observatory of Carleton College, at 6 o'clock P. M. I used a good watch for time-piece, and made these observations three-fourths of a mile northwest of the city hall of St. Paul. The occultation of the ring from first to last required just one minute and twenty-two seconds, and it was a beautiful sight. The last contact with the ring, I think, was observed to the fraction of a second, it was so distinctly seen.

T. D. Simonton.

We take the privilege of copying some of the private letter accompanying the above useful observations made by Dr. Simonton, to show amateurs what good work may be done sometimes with very simple means. Ed.]

Professor H. T. Todd, Director of Nautical Almanac, Retired.—Professor H. T. Todd, Director of the Nautical Almanac, Washington, D. C., retired from office, Aug. 25, having reached the age limit for this branch of the Government service. The directorship of the Nautical Almanac will be assumed by Professor S. J. Brown, Astronomical Director of the Naval Observatory.

We learn from the *Washington Star* (Aug. 25) facts of unusual interest in the service of Professor Todd. He was graduated from the Naval Academy in 1857, was two years under Capt. Dupont, in Chinese waters, was present at the attack on the Taku forts in 1858 and at Tien Tsin when the treaty was signed. He was next on duty on the coast of Africa and took part in capturing the slaver, Erie, with 897 slaves on board. He was one of the officers of the prize crew ordered to take the slaves to Monrovia, and to bring the ship, her captain and mates into a United States port. This capture was an important one, as the ship was condemned, and the captain of the Erie was hanged, being the only officer of a slaver ever executed for participation in the slave trade.

Professor Todd was appointed Professor of Mathematics in the Navy in 1877, and served eight years as head of the department of Physics and Chemistry at the Naval Academy. In 1886 he was placed on duty in the Nautical Almanac office, and continued there until he became Director, which position he held at the time of his retirement.

A New Star in Aquila.—From an examination of the Draper Memorial photographs, Mrs. Fleming has discovered a new star in the constellation Aquila. Its position for 1900 is R. A. $= 19^h\ 15^m\ 16^s$, Decl. $= -0°\ 19'.2$. It was too faint to be photographed on 96 plates taken between August 21, 1886, and November 1, 1898, although stars as faint as the thirteenth magnitude are visible on some of them. It appears on 18 photographs taken between April 21, 1899, and October 27, 1899. On April 21 it was of the seventh magnitude, and on October 27, 1899, of the tenth magnitude. Two photographs taken on July 7, and July 9, 1900, show that the star is still visible, and that its photographic magnitude is about 11.5. A photograph taken on July 3, 1899, shows that its spectrum resembled those of other new stars, while a photograph taken on October 27, 1899, shows that the spectrum resembled those of gaseous nebulæ.

On July 9, 1900, the object was discovered with the 15-inch Equatorial by Professor Wendell, who estimated its magnitude as 11.5 to 12.0, and confirmed the mono-chromatic character of its spectrum. E. C. PICKERING.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., July 11, 1900.

POSITIONS OF EROS (433) IN 1893, 1894 AND 1896.

Approximate positions of Eros (433) during the oppositions of 1894 and 1896 will be found in Circulars No. 36 and 37. Since then, the photographs from which these positions were derived have been measured by the method described in the Harvard Annals, Vol. XXVI, p. 237, and reduced by the method of Turner. The measurements have been made by Miss E. F. Leland, and the reductions by Miss A. Winlock aided by Miss I. E. Woods. These photographs were taken with the Bruce, Bache and Draper photographic doublets, whose apertures are 60, 20 and 20 cm., and the focal lengths such that 1 mm. equals 60″, 179″, and 163″, respectively. Photographs taken with these instruments are designated by the letters A, B, and I, respectively. The smaller instruments photograph a field 10° square, and as some of the images fall near the corners of the plates it was not supposed that positions could be determined from them with a high degree of accuracy. In some cases, the images are more than 5° from center of plates and are consequently much distorted, the greatest diameter exceeding a minute of arc; yet, as will be seen below, the accuracy of the places does not greatly differ from that ordinarily obtained with the meridian circles. The most remarkable conclusion to be derived from these observations is that if, in the future, any other object like Eros should be discovered, we have at this Observatory the means of tracing its path since 1890, during the time in which it was moderately bright, with nearly as great accuracy as if a series of observations had been taken of it with a meridian circle.

In the following table the designation of the original negative is given in the

first column. The date, the Greenwich Mean Time of the middle of the exposure, and the duration of the exposure, are given in the next three columns. Two enlargements, on a scale of 0.1 cm. = 10″, were made from each of these negatives, and their designations are given in the fifth column. The number of catalogue stars on these enlargements used to determine the constants of the plates, such as errors of scale, orientation, etc., is given in the sixth column. The standard coördinates of Erosare given in the seventh and eighth columns, and the resulting right ascension and declination for 1875, in the ninth and tenth columns. The two measures of each plate are independent, except for errors in the original negatives and in the method of reduction. The differences in the two results for the right ascension, and for the declination, are given in the last two columns.

POSITIONS OF EROS.

Plate.		Date.			G. M. T.		Exp.	Enl.	St	X	Y	R. A. 1875.			Dec. 1875.			ΔR.A	ΔD.
		y	*m*	*d*	*h*	*m*	*m*			″	″	*h*	*m*	*s*	°	′	″	*s*	″
I	9801	1893	10	28	21	55	14	6441	9	− 9627.2	−15941 0	5	58	48.11	+53	39	46.8	+0.03	−0.1
								6442	9	− 9626 9	−15941.2	5	58	48.14	+53	39	46.7		
I	9832	1893	10	30	20	18	10	6377	9	+ 9760 3	−14440.0	6	4	33.13	+54	6	25.8	+0.03	−1.3
								6378	9	+ 9760.7	−14441.3	6	4	33.16	+54	6	24.5		
I	9862	1893	10	31	21	21	15	6391	7	−10903.8	+ 3653.4	6	7	37.42	+54	20	11.2	+0.40	+2.2
								6392	7	−10900 1	+ 3655.3	6	7	37.82	+54	20	13 4		
I	10095	1893	11	26	20	26	17	6390	7	−15368.2	+ 4066.2	7	17	31.35	+57	49	34.0	−0.29	−1.0
								6389	7	−15370.6	+ 4065.5	7	17	31 06	+57	49	33.0		
I	10215	1893	12	19	18	21	14	6375	4	+10544.4	+ 5340.3	7	45	56.41	+54	38	39.2	+0.28	+0.1
								6376	4	+10546 8	+ 5340 5	7	45	56.69	+54	38	39.3		
I	10280	1893	12	23	19	49	13	6416	4	−10591.8	− 642.9	7	45	57.59	+52	58	16.4	−0.19	−1.7
								6417	4	−10593 7	− 644.5	7	45	57.40	+52	58	14.7		
I	10321	1893	12	27	17	32	10	6383	7	+10580 3	+10362.3	7	44	43.17	+50	55	0 2	+0 03	−0.6
								6382	7	+10580 7	+10361.7	7	44	43.20	+50	54	59.6		
I	10469	1894	1	19	16	57	10	6408	7	− 654 1	−15761.6	7	26	28.40	+28	45	48.4	−0.20	+0 9
								6409	7	− 656.7	−15760.7	7	26	28.20	+28	45	49.3		
I	10559	1894	1	25	16	16	13	6393	9	− 3564 4	+11541.9	7	23	33.46	+21	14	58.0	−0 01	−1.0
								6394	9	− 3564.6	+11541.0	7	23	33.45	+21	14	57.0		
A	222	1894	2	5	15	26	60	6410	7	− 4630 1	+ 5011.8	7	23	17.83	+ 8	45	22 8	−0.05	+1.9
								6411	7	− 4630.8	+ 5013.7	7	23	17.78	+ 8	45	24.7		
A	246	1894	2	16	14	49	12	6414	8	+ 1059 4	− 9589 6	7	29	58 55	− 0	21	42.7	−0 08	+0.6
								6415	8	+ 1058.2	− 9589 0	7	29	58 47	− 0	21	42.1		
I	10685	1894	2	16	14	59	13	6436	11	+10997.4	−13093.8	7	29	59.01	− 0	21	54.4	−0.32	−3.6
								6437	11	+10992 6	−13097.4	7	29	58.69	− 0	21	58.0		
B	10909	1894	4	16	14	13	10	6371	7	+ 2201 3	+13823.8	9	17	0.62	−13	33	54.0	−0 03	+1.8
								6374	7	+ 2200.9	+13825.6	9	17	0.59	−13	33	52.2		
B	10951	1894	4	18	14	29	10	6365	9	+ 8489 9	+12761.3	9	21	47 01	−13	38	52.7	−0.10	+1.3
								6370	9	+ 8488.5	+12762 6	9	21	46 91	−13	38	51.4		
B	11174	1894	5	19	14	16	10	6344	7	+ 7170.1	−10985.5	10	38	1.88	−14	57	21 9	+0.10	+3.6
								6346	7	+ 7171.6	−10981 9	10	38	1.98	−14	57	18.3		
B	15531	1896	4	6	20	52	60	6360	7	− 7958.9	− 3771.5	18	36	59.92	−38	32	48.8	+0 03	+1.0
								6361	7	− 7958.6	− 3770.5	18	36	59.95	−38	32	47.8		
B	16108	1896	6	4	16	40	70	6350	5	−10686.4	− 9103.3	18	30	6.81	−40	2	45.2	+0.75	+0.2
								6351	5	−10677 8	− 9102.7	18	30	7 56	−40	2	45.0		
B	16157	1896	6	5	19	54	10	6355	5	+15242.6	+ 8861.3	18	27	51.27	−39	58	33 0	+0.24	+0.7
								6357	5	+15245 4	+ 8861 9	18	27	51.51	−39	58	32.3		
B	16165	1896	6	5	22	4	11	6353	4	+ 1306 6	− 8891.1	18	27	39 55	−39	58	2 1	+0.07	+3.4
								6354	4	+ 1307.4	− 8887.7	18	27	39.62	−39	57	58 7		
B	16518	1896	6	29	19	17	15	6348	9	− 9732 7	+ 4124.9	17	37	43 91	−36	21	26 7	−0.09	+1.4
								6349	9	− 9733.9	+ 4120.3	17	37	43.82	−36	21	25.3		
A	1876	1896	6	30	13	46	60	6413	6	− 5864 8	+ 4719.0	17	36	22.23	−36	11	20.9	0.00	+0.5
								6412	6	− 5864.8	+ 4719.4	17	36	22.23	−36	11	20.4		

On I 9832, the image is irregular. The position of the brightest part is given. The center precedes it $0^s.66$, and is $8''.6$ south. On A 222 and A 1876, the images are much elongated, owing to the motion of Eros. The means of the measures of the ends are given. The discordance in the positions derived from I 10685 and B 16108 is probably due to the poor quality of the images.

A complete discussion of these measures, including the original settings and the results for each comparison star, is in course of preparation for the Annals.

The positions of the stars have been taken from the Catalogues of the Astronomisches Gesellschaft, except in the case of the plates taken in 1896 for which the Cordoba Catalogues have been used. The average value of the 296 residuals for the catalogue stars is, for *x*, ± 1″.03, for *y*, ± 1″.06. The average difference of the standard coördinates of the two positions of Eros is, for *x*, ± 1″.8, for *y*, ± 1″.4. For the three Bruce plates these values become ± 0″.6, and ± 1″.0, respectively.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY, Circular No. 51,
June 7, 1900.

Occultation of Saturn at Providence, R. I., July 10, 1900.—The occultation of Saturn by the Moon, July 10, was observed at Seagrave Observatory, this place, with the following results:

		h	m	s
Immersion.	First contract	11	17	8
	Second contact	11	17	24
Emersion.	Third contact	12	35	59
	Fourth contact	12	36	17

These results are given in Providence local mean time.

Our party was located at Southern Pines, North Carolina, for observations of the total solar eclipse of May 28. Our position was longitude + 79° 20′ and latitude + 35° 15′. We secured six good photographs during totality which lasted just 96 seconds. The photographs were taken with a Clark 4-inch objective, five feet focal length. The plates have been examined very carefully, but no trace of Intra-Mercurial planet is found. The Corona was seen by the writer with a three-inch telescope two minutes before and after totality.

F. E. SEAGRAVE.

PROVIDENCE, R. I., July 13, 1900.

The Eclipse of Last May.—Professor Charles A. Young, of Princeton, gives, in the *Independent* of Aug. 30, some results of the observations of the total solar eclipse of May 28, 1900. In that article he says "no really brilliant discovery was made, since anything of that sort would have been announced; nor can it be expected that any very remarkable extension of our knowledge will prove to have been gained, because in every respect except the weather, the circumstances of the eclipse were rather unfavorable." The unfavorable conditions referred to were the short time of totality (less than 100 seconds), and the fact that the sunspot period was near the time of its minimum. The short period of totality was unfavorable for visual or photographic purposes and the time of minimum of the spot period is unfavorable because of the quiescent state of the solar surface. The time of contacts at stations where latitude and longitude were accurately known agree in showing that the eclipse was four or five seconds ahead of time, and some of the observers were of the opinion that the length of totality was notably shorter than the computed time. This last statement is a surprise to us, and we wonder what the real cause of such an opinion is. We can guess two things that might contribute somewhat to such a result: one is the fact that some observers were at fault in beginning their observations; another may be that some stations were not as near the center line of totality as was supposed when they were chosen. If the error of position in this regard was small the difference in time of the length of totality would not be noticeable; but if it was considerable it would shorten the obscuration somewhat.

Professor Young says that the Princeton party at Wadesboro photographed the last contact with an exposure of about one-half second, purposely instead of making it instantaneously. The result was to get *positives* of the Sun's disk instead of *negatives*, but they were as sharp as the negatives of the first contact.

The conclusion of the article gives some results that are best expressed in Professor Young's own words, as follows:—

"My own special observational objective, for instance, was to determine by accurate measurement the true position of the bright green line in the spectrum of the corona, which line I had identified in 1869 (probably erroneously, as now appears) with the so-called "1474" line of the chromosphere spectrum. In 1869, 1870 and 1878 I had not the least difficulty in seeing it all through the eclipse, and did not dream of any embarrassment on that score at this time. But in my instrument, an "integrating spectroscope" which showed clearly the dark 1474 line in the spectrum of a cloudy sky, I failed to see the corona line at all; and my assistant, with essentially the same instrument that I used in 1878, caught only a glimpse of it, too faint and momentary to permit any measurement. The failure to photograph it was less surprising, as the available time of exposure was very short.

"The flash-spectrum observations and photographs were also many of them failures, but there were some successes, and when we get the full reports of the Johns Hopkins photographs, and of those obtained with Sir Norman Lockyer's twenty-foot prismatic camera, and of several other parties on both sides of the Atlantic, we may find that considerable advance has been made in our knowledge of the constitution and characteristics of this most interesting and significant spectrum, especially as to its ultra-violet regions. For these reports we shall, however, have to wait till November at least, and perhaps much longer. The study and measurement under the microscope of such complicated photographs is a time-consuming process.

"There can be no doubt that the experience gained on this occasion will be of the greatest value to the fortunate observers of the eclipse of next May, when the totality will last more than six minutes, and when it is expected that the solar energies will have begun to resume their usual activity.

"The "intra-Mercurial planet" photographic campaign, instituted by Professor W. H. Pickering, seems to have been a failure. The shortness of totality was such as to make success more than doubtful from the outset on account of necessary limitation of exposure, and the brightness of the sky. Next year these difficulties will vanish.

"Professor Turner, of Oxford, was quite successful in his photograbic study of the polarization of the light of the corona. He pursued a method substantially like that used by Professor Wright in 1878, but with improvements. The amount of reflected light in the corona is shown to be very considerable; in fact, it seems likely that on this occasion the principal portion of the light was of this character, the gaseous true radiation (which produces the bright lines in the corona-spectrum) having been relatively very feeble.

"The "shadow-bands," which appear for about a minute and a halfjust before and after totality, were well observed at several stations. It seems to be conclusively shown that they are of atmospheric origin—a phenomenon closely analgous in cause and nature to the twinkling of the stars, and due to the passage of the light through moving masses of air of unequal density. For their formation it is necessary that the light should come from a line of star-like points, such as the narrow crescent of the Sun when almots covered by the Moon."

PLATE XVII.

JAMES EDWARD KEELER.

1857–1900.

Popular Astronomy.

Vol. VIII. No. 8. OCTOBER 1900. Whole No. 78.

JAMES EDWARD KEELER.

C. D. PERRINE.

FOR POPULAR ASTRONOMY.

That "death loves a shining mark" is once more exemplified in the case of Professor Keeler. His life exhibited not only a long array of worthy accomplishments but a brilliant promise for the future. In the very prime of life and vigor of faculty, with all the benefits of a ripe experience, who will say what secrets he might not have wrested from the universe in the allotted span of human life?

What a loss to astronomy and the scientific world! To the Observatory over which he presided! But above all, what a cruel, crushing loss to a devoted family!

Professor Keeler was descended from New England stock on both sides. His first American ancestor was Ralph Keeler, who settled in Hartford, Conn., in 1635. His father was Wm. F. Keeler, Paymaster in the United States Navy, and an officer of the original "Monitor."

His mother, Anna E. Keeler, is still living. She is a daughter of Henry Dutton, former Judge of the Supreme Court, Governor of Connecticut and Dean of the Yale Law School.

James Edward Keeler was born in La Salle, Ill., September 10, 1857. He was one of four children, of whom only one sister survives. His early education was received in the public schools of his native town. In November 1869 the family removed to Mayport, Florida, where his studies were pursued at home.

He seems to have evinced early in life a decided mechanical turn, and a fondness for the natural sciences. It is not evident just what turned his attention to astronomy, but in all probability it was almost a natural selection to one of his nature and tastes. The first reference to astronomical matters in his diary is under date of September 22, 1875, as follows:—

"After supper went up in the lookout and took the altitude of the North Star, 31° 05′, liable to inaccuracy on account of indistinct vision through the sights of my quadrant."

About a month later he writes—"Concluded to get a two inch achromatic and Huyghenian ocular for my telescope." Later these optical parts were ordered and his telescope constructed: the mounting being of the alt-azimuth form, complete with tripod and finder. The lenses were tested, and the powers of his eyepieces were determined.

After the completion of his telescope, here is the very matter of fact way in which he describes what must have been to him an exciting moment—his first opportunity to test his instrument on the stars, after a long and trying cloudy period, during which he had to be content with observing terrestrial objects:

"Directed my telescope to the stars and saw the rings of Saturn for the first time. Could not see any satellites. Observed the gibbous phase of Venus with difficulty." The following nights were spent in observing a long list of objects.

He was not afraid of the discomforts incident to astronomical work, for we find him rising at 4:30 A. M. on January 26th following to observe Jupiter, and continuing until stopped by the sun.

His attention was apparently fastened, for in 1877 his astronomical equipment was increased by the addition of a meridian-circle. This instrument was of his own construction, the axis being neatly turned from cedar wood, into which the telescope was screwed. Spider threads were used, and illuminated in the usual way by means of a hollow axis and a diagonal reflector. The wooden circle was made up of sections, the graduations being on paper. With this instrument and an ordinary clock he determined the places of some of the brighter stars and planets, and the latitude of his observatory. He named his observatory the "Mayport Astronomical Observatory." His observing book contains many excellent sketches of lunar craters, the planets and double stars: where the components of the latter are colored, the colors have been reproduced.

His telescope and tripod complete as well as the axis and tube of his meridian circle, have been preserved.

A very pronounced feature in all his work was the painstaking care exercised in everything which he undertook, even to his notes, a characteristic which is strongly marked in his work as an amateur. His very first observations show the true scientific spirit which he possessed, recognizing what was important and recording it no matter how seemingly trivial, omitting the superfluous, and going straight to the core of a subject.

In the winter of 1877 he entered Johns Hopkins University, graduating in 1881 with the degree of Bachelor of Arts. In 1882 he received the appointment as Graduate Scholar of the University for one year.

While a student he helped defray his expenses by assisting at the lectures and in the laboratory, and by making computations for some of the almanacs.

During his attendance at the University he made lasting friendships with some of the foremost men in science, and through them entered seriously into astronomical work.

While a student at Johns Hopkins University and not yet twenty-one years old he was selected as a member of the party sent out by the United States Naval Observatory to Central City, Col., in charge of Professor Holden, to observe the total solar eclipse of July 29, 1878. The report of his observations and his drawing of the corona are published in the U. S. Naval Observatory Report of that eclipse.

Immediately after his graduation he was engaged by Prof. Langley as assistant at the Allegheny observatory. He took part at once in the preparations which Professor Langley was making for the expedition to Mt. Whitney, Cal., to determine anew the value of the solar constant. The expedition left Allegheny on July 7, 1881, returning on September 28. The conditions for this work were found to be much better at Mt. Whitney than at any of the stations at which a previous determination had been made, and the resulting value of the constant is therefore reliable in proportion. The observations at Mt. Whitney showed that the absorption of heat by the earth's atmosphere was much greater than appeared from observations made at lower levels. A full account of this expedition and of the results obtained is published as No. XV of the *Professional Papers of the Signal Service.*

His work at Allegheny consisted largely in work with the Bolometer which Professor Langley was then perfecting and which was being used for the detection and measurement of heat radiations from the celestial bodies. He found time for the observation of other phenomena, notably the planets and the transit of Venus of December 5, 1882. He independently observed the bright spot which appeared on the exterior limb of Venus during this transit.

In 1883 Mr. Keeler went to Germany for a year to continue his studies, sailing from Baltimore on May 10, on the S. S. "Braunschweig." He arrived in Bremen on the 24th and from there went to Heidelberg where he matriculated at the University on June 9. His principle work was in the Physical Laboratory under Professor Quincke whose lectures on the Undulatory Theory of Light he attended. He also attended lectures on Chemistry by Professor Bunsen and on Integral Calculus by Professor Fuchs.

In the Fall he spent a month's vacation traveling in Italy, visiting the principal cities and points of interest. Upon his return from Italy he went to Berlin, entered the University on October 16. Here as in Heidelberg, much of his work was in the laboratory. He attended lectures by von Helmholtz, Kayser, Runge and Glan. On June 4, 1884 he sailed from Bremen for New York, where he arrived on the 14th.

Returning to Allegheny in August he resumed his work at the observatory with Professor Langley, where he remained until 1886.

In the latter year he came to California as Assistant to the Lick Trustees, and took up his residence at the observatory, which was then nearing completion. Arriving at Mt. Hamilton on April 25th, he immediately began the installation of the time service. The observatory equipment was soon in order, but owing to delays in the construction of the telegraph line and in furnishing the necessary instruments, the regular transmission of signals to San Jose did not commence until January 1, 1887. Besides the work connected with the time service, he made observations with such other of the instruments as were then in readiness.

Upon the formal transfer of the Observatory to the Regents of the University in June 1888, Professor Keeler was appointed Astronomer.

His ingenuity devised many valuable devices and improvements about the observatory. One of these in the time-service consisted of a new break-circuit attachment for the Hohwü clocks and is in use yet. Upon the completion of the 36-inch refractor he devised a magnetic control for its driving clock, for use especially in photography where accurate following was necessary. By means of this attachment the driving clock was controlled by one of the standard clocks and almost perfect coincidence was obtained without any jarring.

The first spectroscope for the great equatorial was designed by him. At that time photography had not established itself in this department of astronomical research, and the instrument was therefore planned for visual observations only. With it all the spectroscopic work up to 1894 was done, when new conditions and new requirements entered the problem.

The Lick Observatory undertook to establish a standard meridian line for Santa Clara county. This work was successfully accomplished by Professor Keeler in August 1889.

On January 1, 1889, a total eclipse of the Sun occurred which was visible in California. The belt of totality passed across the state about 150 miles north of Mt. Hamilton. An expedition was sent out from the Lick Observatory in charge of Professor Keeler. The eclipse station was established at Bartlett Springs in Lake county and a successful program carried through, Professor Keeler's portion consisting in repeating the spectroscopic observations made by Professor Hastings in 1883 in the Caroline Islands. The full report of this eclipse is published as No. 1 of the *Contributions from the Lick Observatory.*

In February of the same year Professor Keeler determined the position of the eclipse station at Norman, Colusa county, occupied by Professor Pritchett's party from Washington University.

Professor Keeler's work has been largely of a physical nature probably the result of early associations and training.

As soon as the 36-inch refractor was completed and before a suitable spectroscope could be provided much of his time was given to visual and micrometrical observation of the planets. Being a skilled artist he undertook the delineation of planetary details, securing excellent series of Mars, Jupiter and Saturn. Besides these many observations were made of the other planets and especially of the form of and the markings on the satellites of Jupiter.

He was in charge of the spectroscopic work, and as soon as possible began systematic researches in this line. In his observations of the spectra of the nebulae he early suspected that the discordances between the positions obtained for the chief nebular line in different nebulae could not be explained by supposing them to be due to instrumental causes, or to uncertainties in the observations. By a careful investigation he proved conclusively that these apparent discrepancies were due to motions of the nebulæ in the line of sight, and hence that the same conditions of motion that existed among the stars also existed among the nebulæ. Previous to this the observations of this character had not been of sufficient accuracy to disclose this fact.

On June 1, 1891 he resigned his post as Astronomer in the Lick

Observatory to accept the position of Professor of Astrophysics in the Western University of Pennsylvania and Director of the Allegheny Observatory, succeeding Professor Langley.

His services at the Lick Observatory were so highly prized as to call forth the following resolution from the Regents of the University:—

Resolved, that in accepting the resignation of Mr. Keeler, the Regents desire to express their high appreciation of his astronomical work at the Lick Observatory and that they wish him every success in his new position."

During his directorship at Allegheny his time was largely devoted to spectroscopic observations of the stars by means of photography, using a spectrograph of his own designing.

His adaptation of the spectroscope to the problem of determining the character of Saturn's Ring was most ingenious. Clerk Maxwell had shown a third of a century before, from mathematical considerations, that this appendage of the planet must consist of a multitude of small bodies, each revolving in its own orbit. The instrumental proof was lacking, however, until April 1895 when Professor Keeler with his new spectrograph attached to the 13-inch equator al of the Allegheny Observatory, succeeded in obtaining photographs of the planet's spectrum of such excellence that the relative motions of different portions of the Ring were disclosed at once. The observed motions accorded perfectly with the theory. An accurate measurement and reduction of the displacements of the lines showed wonderful agreement with those computed from the known dimensions of the system.

In March 1898, Professor Keeler was elected Director of the Lick Observatory to fill the vacancy caused by the resignation of Professor Holden. He assumed the duties of his office on June 1.

Early in the present summer he contracted a heavy cold which obliged him to give up observing for a time and to place himself under the care of a physician. His condition was not considered at all serious, however. The last of July he went to San José for treatment, and then to Lake county with his family for a short vacation. Not feeling so well there, he returned to San Francisco, accompanied by Mrs. Keeler. On August 10th, while en route, he suffered a light stroke of appoplexy and on August 12th came the fatal stroke. He had apparently been subject to heart disease for many years.

Prof. Keeler was married at Oakley Plantation, Louisiana, June 16, 1891, to Miss Cora Slocomb Matthews, daughter of William Wilson and Isabel Matthews, and niece of the wife of

Captain R. S. Floyd, President of the Lick trustees. Mrs. Keeler and two children, Henry Bowman and Cora Floyd, survive him.

The crowning work of his life was undoubtedly his skillful administration of the Lick Observatory and his monumental work with the Crossley Reflector. Upon taking charge of the Lick Observatory, he made this instrument his especial care, determined to see what its possibilities were. He went about his task with that care and deliberateness which characterized all his investigations. After making a careful examination and trial of the instrument, its defects were one by one eliminated until the results were of the highest possible excellence.*

The first photograph was taken on September 15, 1898 and was for experimental purposes only. By November 4 the instrument was in condition and regular work was begun. The first object photographed was Brooks' Comet, of which a considerable series was secured. On November 16, 1898 a photograph of the Orion Nebula was secured which Professor Keeler pronounced "superb." During this time improvements were still being made: subsequently the changes and additions were slight, although continuing as long as the instrument was used.

He became very much attached to the Reflector and often spoke affectionately of it, believing thoroughly in its power as a photographic instrument. His first thought was that it would be most efficient in the spectroscopic field. The first trials were made, however, with the instrument as an ordinary photographic telescope, and during these its great efficiency in showing the structure of the nebulae determined him to explore this field more thoroughly. This work was in progress at the time of his death. The work already done in this direction has led to some very far-reaching conclusions, e. g., the immense number of faint nebulae yet undiscovered; and of more importance, the prevalence of the spiral structure among these bodies. Notwithstanding the magnitude of the work in hand he did not lose sight of the spectroscopic problems. The ease with which a photographic impression was secured of the central star in the Annular Nebula in Lyra suggested to him the possibility of photographing the spectra of such faint objects on a small scale. To this end he designed a slitless spectrograph to be used with the Crossley Reflector for this especial purpose. An instrument after these de-

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* The June number of the *Astrophysical Journal* contains a very complete account of the work with the Crossley Reflector by Professor Keeler. This article will also be reprinted in the *Publications* of the Astronomical Society of the Pacific.

signs was constructed at the observatory but not completed in time for him to use. An early trial of it will be made.

Arrangements have been made to continue the work which Professor Keeler began with the Crossley Reflector, and the first efforts will be devoted to completing the program which he had under way — that of photographing all the brighter nebulae within reach of the telescope. In the prosecution of this work two new asteroids were found on the negatives by Professor Keeler. One at least of these was so faint that it could not be seen with certainty in the large refractor.

Professor Keeler was affiliated with many of the most prominent scientific societies. He was a member of the National Academy of Sciences; Fellow of the American Association for the Advancement of Science; Associate of the American Academy of Arts and Sciences; Fellow of the American Philosophical Society; Honorary Member of the Astronomical and Physical Society of Toronto; Fellow and Foreign Associate of the Royal Astronomical Society; Member and Councilor of the Astronomical and Astrophysical Society of America; Member and President of the Astronomical Society of the Pacific, and others. He was President of the Academy of Science and Art of Pittsburgh, 1897–98.

Professor Keeler was associate editor of *Astronomy and Astro-Physics* 1892-94 and editor (with Professor George E. Hale) of the *Astrophysical Journal* since its establishment in 1895.

As the "expert agent" required by the contract with Alvan Clark & Sons, Professor Keeler was invited by Professor Hale to test the objective for the 40-inch Yerkes telescope in 1895.

At the dedication of the Yerkes Observatory Professor Keeler delivered one of the addresses.

In 1893 the University of California conferred upon him the degree of Sc. D. in recognition of his scientific work.

In 1898 he was awarded the Rumford medals by the American Academy of Arts and Sciences "for his application of the spectroscope to astronomical problems, and especially for his investigations of the proper motions (line of sight motions) of the nebulae, and the physical constitution of the rings of the planet Saturn, by the use of that instrument." At the annual meeting of the National Academy of Sciences held in Washington, April 18-20, 1899, the Henry Draper gold medal was awarded to Professor Keeler.

Professor Keeler was a broad and liberal minded man, and made an ideal director. Tactful and judicious in dealing with men he harmonized all interests and had the fullest confidence of everyone. He took the greatest interest in each man's work, giving encouragement, furnishing every assistance, and allowing the freest possible hand. In illustration of his modesty it is said of him that when discussing the work of the Observatory, he would speak enthusiastically of the successes of his associates without even referring to his own.

One of his greatest ambitions was to secure some time an endowment for the Lick Observatory, sufficient for all its needs.

Though quiet and studious in his tastes he was genial and kindly and had also many close friends outside of scientific circles. Especial mention should be made of Mr. William Thaw's kind interest and helpfulness in advancing Professor Keeler's career when he knew him as a young man—an interest which Mrs. Thaw and her family continued to show in subsequent years.

We mourn not only for an able executive and a man of the highest motives, but for a staunch personal friend and adviser, and a cheery companion.

MT. HAMILTON, CALIFORNIA,
1900 September 12.

ASTRONOMY*

DR. A. A. COMMON.

It has been decided to form a Department of Astronomy under Section A, and I have been requested to give an address on the occasion. In looking up the records of the British Association to see what position Astronomy has occupied, I was delighted to find in the very first volume, "A Report on the Progress of Astronomy during the Present Century," made by the late Sir George Airy, so many years our Astronomer Royal, and at that time Plumian Professor of Astronomy at Cambridge. This report, made at the second meeting of the Association, describes in a most interesting manner, the progress that was made during the first third of the century, and we can gather from it the state of astronomical matters at that time. The thought naturally occurred to me to give a report, on the same lines to the end of this century, but a little consideration showed that it was im-

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* Opening Address by Dr. A. A. Common, F. R. S., F. R. A. S., Chairman of the Department of Astronomy, at the Bradford meeting of the British Association for the Advancement of Science.

possible in the limited time at my disposal to give more than a bare outline of the progress made.

At the time this report was written we may say, in a general way, that the astronomy of that day concerned itself with the position of the heavenly bodies only, and, except for the greater precision of observation resulting from better instruments and the larger number of observatories at work, this, the gravitational side of astronomy, remains much as it was in Airy's time.

What has been aptly called the New or Physical Astronomy did not then exist. I propose to briefly compare the state of things then existing with the present state of the science, without dealing very particularly with the various causes operating to produce the change; to allude briefly to the new astronomy; and to speak rather fully about astronomical instruments generally, and of the lines on which it is most probable that future developments will be made.

In this report (*Brit. Assoc. Report*, 1831-32, p. 125) we find that at the beginning of the century the Greenwich Observatory was the only one in which observations were made upon a regular system. The thirty-six stars selected by Dr. Maskelyne, and the Sun and the Moon, were observed on the meridian with great regularity, the planets very rarely and only at particular parts of their orbits; small stars, or stars not included in the thirty-six, were seldom observed.

This state of affairs was no doubt greatly improved at the epoch of the report, but it contrasts strongly with the present work at Greenwich, where 5,000 stars were observed in 1899, in addition to the astrographic, spectroscopic, magnetic, meteorological and other work.

Many observatories, of great importance since, were about that time founded, those at Cambridge, Cape of Good Hope and Paramatta having just been started. A list is given of the public observatories then existing, with the remark that the author is "unaware that there is any public Observatory in America, though there are," he says, "some able observers."

The progress made since then is truly remarkable. The first public Observatory in America was founded about the middle of the century, and now public and private observatories number about 150, while the instrumental equipment is in many cases superior to that of any other country. The prophetic opinion of Airy about American observers has been fully borne out. The discovery of two satellites to Mars by Hall in 1877, of a fifth satellite to Jupiter by Barnard in 1892, and the discovery of Hyperion by Bond, simultaneous with Lassell, in 1848, are notable achievements.

The enormous amount of work turned out by the Harvard Observatory and its branches in South America, all the photographic and spectroscopic work carried out by many different astronomers, and the new lines of research initiated show an amount of enthusiasm not excelled by any other country. A greater portion of the astronomical work in America has been on the lines of the new astronomy, but the old astronomy has not been at all neglected. In this branch pace has been kept with other countries.

From this report we gather that the mural quadrant at most of the observatories was about to be replaced by the divided circle. Troughton had perfected a method of dividing circles, which, as the author says, "may be considered as the greatest improvement ever made in the art of instrument making."

Two refractors of 11 and 12-inches aperture had just been imported into this country; clockwork for driving had been applied to the Dorpat and Paris equatorials, but the author had not seen either in a state of action.

The method of mounting instruments adopted by the Germans was rather severely criticised by the author, the general principle of their mounting being "telescopes are always supported at the middle, not at the ends."

"Every part is, if possible, supported by counterpoises."

"To these principles everything is sacrificed. For instance, in an equatorial the polar axis to be supported in the middle by a counterpoise. This not only makes the instrument weak (as the axis must be single), but also introduces some inconvenience into the use of it. The telescope is on one side of the axis; on the other side is a counterpoise. Each end of the telescope has a counterpoise. A telescope thus mounted must, I should think, be very liable to tremor. If a person who is no mechanic and who has not used one of these intruments may presume to give an opinion, I should say that the Germans have made no improvement in instruments except in the excellence of the workmanship."

I have no doubt that this question had often occupied Airy's mind, for in the Northumberland Equatorial telescope which he designed shortly after for Cambridge he adopted what has been called the English form of mounting, where the telescope is supported by a pivot at each side, and a long polar axis is supported at each end. This telescope is in working order at the present time at Cambridge.

When he became Astronomer Royal he used the same design for what was for many years the great equatorial at Greenwich, though the wooden uprights forming the polar axis were in the Greenwich telescope replaced by iron. It says much for the excellence of the design and workmanship of this mounting, designed as it was for an object-glass of about 13 inches diameter, when we find the present Astronomer Royal, Mr. Christie, has used it to carry a telescope of 28 inches aperture, and that it does this perfectly.

Notwithstanding the greater steadiness of the English form of mounting, the German form has been adopted generally for the mounting of the large refractors recently made.

There is much interesting matter in this report of an historical character.

As I have already said, the New Astronomy, as we know it, did not exist; but in a report (*Brit. Assoc. Report*, 1831-32, p. 308) on optics, in the same volume, by Sir David Brewster, we find that spectrum analysis was then occupying attention, and the last paragraph of this report is well worth quoting: "But whatever hypothesis be destined to embrace and explain this class of phenomena, the fact which I have mentioned opens an extensive field of inquiry. By the aid of gaseous absorbent we may study with the minutest accuracy the action of the elements of material bodies in all their variety of combinations, upon definite and easily recognized rays of light, and we may discover curious analogies between their affinities and those which produce the fixed lines in the spectra of the stars. The apparatus, however, which is requisite to carry on such inquiries with success cannot be procured by individuals, and cannot even be used in ordinary apartments. Lenses of large diameter, accurate heliostats, and telescopes of large aperture are absolutely necessary for this purpose; but with such auxiliaries it would be easy to construct optical combinations, by which the defective rays in the spectra of all the fixed stars down to the tenth magnitude might be observed, and by which we might study the effects of the very combustion which lights up the suns of other systems."

Brewster's words are almost prophetic, and it would almost appear as if he unknowingly held the key to the elucidation of the spectrum lines, for it was not until 1859 that Kirchhoff's discovery of the true origin of the dark lines was made.

Fraunhofer was the first to observe the spectra of the planets and the stars, and to notice the different types of stellar spectra. In 1817 he recorded the spectrum of Venus and Sirius, and later, in 1823, he described the spectrum of Mars; also Castor, Pollux, Capella, Betelgeux and Procyon.

Fraunhofer, Lamont, Donati, Brewster, Stokes, Gladstone and others carried on their researches at a time when the principles of spectrum analysis were unknown, but immediately upon Kirchoff's discovery great interest was awakened.

With spectrum analysis thus established, aided as it was later by the greater development of photography, the New Astronomy was firmly established.

The memorable results arrived at by Kirchhoff were no sooner published than they were accepted without dissent. The works of Stokes, Foucault and Angström at that period were all suggestive of the truth, but do not mark an epoch of discovery.

Astronomical spectroscopy divided itself naturally into two main branches, the one of the Sun, the other of the stars, each having its many offshoots. I shall mention a few points relating to each. The dark lines in the solar spectrum had already been mapped by Fraunhofer, and now it only needed better instruments and the application of laboratory spectra with Kirchhoff's principle to advance this work still further.

Fraunhofer had already pointed out the way in using gratings and these were further improved by Nobert and Rutherfurd.

Kirchhoff's Map of the Solar Spectrum, published in 1861-62, was the most complete up to that time; but the scale of reference adopted by him was an arbitrary one so that it was not long before this was improved upon. Angström published in 1868 his map of the "Normal Solar Spectrum," adopting the natural scale of wave-lengths for reference, and this remained in use until quite recent times.

The increased accuracy in the ruling of gratings by Rutherfurd materially improved the efficiency of the solar spectroscope, but it was not until Prof. Rowland's invention of the concave grating that this work gained any decisive impetus. The maps (first published in 1885) and tables (published in the years 1896-98) of the lines of the solar spectrum are now almost universally accepted and adopted as a standard of reference. These tables alone record about 10,000 lines in the spectrum of the sun, which is in marked contrast to the number 7 recorded by Wolliston at the beginning of the century (1802). Good work in the production of maps has also been done in this country by Higgs.

Michelson has also recently invented a new form of spectroscope called the "Echelon" (*Ast. Phys. Journal*, vol. viii, 1898, p. 37), in which a grating with a relatively small number of lines is employed, the dispersion necessary for modern work being obtained by using a high order (say the hundredth) into which most of the light has been concentrated.

Besides lines recorded in the visual and ultra-violet portions of the solar spectrum, maps have been made of the lines in the infra-red, the most important being that of Langley's published in 1894, prepared by the use of his "bolometer." Good work had, however, been done in this direction previously by Becquerel, Lamansky, and Abney;.the last, indeed, succeeded even in photographing a part of it.

The recording of the Fraunhofer lines in the solar spectrum is not all, however. The application of the spectroscope to the sun has several epoch marking events attached to it, notably those of proving the solar character of the prominences and corona, the rendering visible the prominences without the aid of an eclipse by the discovery of Lockyer and Jansen in 1868, the photography of the prominences both round the limb and those projected on the solar disc by the invention of the spectra-heliograph by Hale and Deslandres in 1890.

Success has not yet favored the many attempts to photograph the corona without an eclipse by spectroscopic means; but even now this problem is being attacked by Deslandres with the employment of calorific rays.

Spectroscopic work on the sun has led to the discovery of many hundreds of dark lines, the counterparts of which it has not yet been possible to produce on the earth.

But besides those unknown substances which reveal their presence by dark lines, there were two others discovered, which showed themselves only by bright lines, the one in the chromosphere, to which the name of Helium was given, and the other in the corona, to which the name of Coronium was applied.

The former was, however, identified terrestrially by Ramsay in 1895, though the latter is still undetermined. The revision of its wave-length, brought about by the observations of the eclipse of 1898, may, however, result in this element being transferred from the unknown to the known in the near future.

The study of stellar spectra was taken up by Huggins, Rutherford and Secchi. Rutherford (*Am. Journal*, vol. xxxv. 1862, p.

77) published in 1862 his results upon a number of stars, and suggested a rough classification of the white and yellow stars: but Secchi deserves the high credit of introducing the first systematic differentiation of the stars according to their spectra, he having begun a spectroscopic survey of the heavens for the purposes of classification (*Comptes rendus*, t. lvii. 1853), whilst Huggins devoted himself to the thorough analysis of the spectra of a few stars.

The introduction of photography marks another epoch in the study of stellar spectra. Sir William Huggins applied photography as early as 1863 (*Phil. Trans.* 1864, p. 428), 'and secured an impression of the spectrum of Sirius, but nearly another decade elapsed before Prof. H. Draper (*Am. Journal of Sci. and Arts*, vol. xviii, 1879, p. 421) took a photograph of the spectrum of Vega in 1872, which was the first to record any lines. With the introduction of dry plates this branch of the New Astronomy received another impetus, and catalogues of stellar spectra have now become numerous. Among them may be mentioned those of Harvard College, Potsdam, Lockyer, McClean and Huggins. The Draper Catalogue (*Annals Harvard Coll.*, vol. xxvii. 1890) of the Harvard College, which is a spectroscopic Durchmusterung, alone contains the spectra of 10351 stars down to the 7-8 magnitudes, and this has further been extended by work at Arequipa, whilst Vogel and Muller of Potsdam *Astro-Phys. Obs. zu Potsdam*, vol. iii 1882-83) made a spectroscopic survey of the stars down to the 7·5 magnitude between -1° and +20° declination. This has again been supplemented by Scheiner (*ibid.*, vol vii. 1895; "Untersuchungen uber die Spectra des hellerem Sterne"), and by Vogel and Wilsing (*ibid.*, vol. xii. 1899; "Untersuchungen uber die Spectra von 528 Sternen"). Lockyer (*Phil. Trans.*, vol. clxxxiv. A, 1893) in 1892 published a series of large scale photographs of the brighter stars, and more recently McClean (*Phil. Trans.*, vol. cxci. A, 1898) has conpleted a spectroscopic survey of the stars of both hemispheres down to the 3½ magnitude. For the study and investigation of special types of stars, the researches of Dunèr on the red stars, made at Upsala, and those of Keeler and Campbell on the bright-line stars, made at the Lick Observatory, deserve mention. For the study of stellar spectra the use of prisms in slit or objective-prism spectroscopes has predominated, though more recently the use of specially ruled gratings has been attended by some degree of success at the Yerkes Observatory.

Several new stars have also been discovered by their spectra by Pickering in his routine work of charting the spectra of the stars in different portions of the sky. The photographic plate containing their peculiar spectra was, however, not examined in many cases until the star had died down again.

Spectrum analysis also opened up another field of inquiry, viz., that of the motion of the stars in the line of sight, based on the process of reasoning due to Doppler, and accordingly named Doppler's Principle ("Ueber das farbige Licht der Doppelsterne," . . . *Abhandl. der K. Böhmischen Ges. d. Wiss.* V. Folge, 2 Bd. 1843).

The Observatories of Greenwich and Potsdam were among the first to apply this to the stars, and more recently Campbell at Lick, Newall at Cambridge, and Belopolsky at Pulkowa have made use of the same principle with enormous success.

It was also discovered that there are certain classes of stars having a large component velocity in the line of sight, which changes its direction from time to time, and in many such cases orbital motion has been proven, as in the case of Algol.

Another class of binary stars has also been discovered spectroscopically and explained by Doppler's principle. I refer to the stars known as spectroscopic binaries, in which the spectrum lines of one luminous source reciprocate over those from the other source of light, according as one is moving towards or away from the Earth. This displacement of the spectrum lines led to the discovery of the duplicity of β Aurigæ, and ζ Ursæ Majoris by Pickering (*Am. Jour.* [3], 39, p. 46, 1890).

Several other such stars have now been detected, notably β Lyræ, and lastly Capella, discovered independently by Campbell (*Astro-Phys. Jour.*, vol. x. p. 177) at Lick, and Newall (*Monthly Notice*, vol. lx. p. 2, 1899) at Cambridge.

(To be continued.)

ON THE ADJUSTMENT OF THE EQUATORIAL TELESCOPE.

FIRST PART.

KURT LAVES.

FOR POPULAR ASTRONOMY.

A relatively large number of amateur astronomers in the United States possess equatorials, which are mounted on piers and supplied with graduated circles. It is quite an easy task to put the equatorial approximately into the meridian, and to place the polar axis at the proper elevation. It is more difficult to apply the final corrections, since they have to be derived from observations of stars, to be chosen advantageously from the list of Standard stars, published in the American Ephemeris and Nautical Almanac*. Still any one familiar with plane trigonometry and the use of logarithmic tables should be able to do this work satisfactorily. It is the purpose of this paper to furnish the proper directions in such an elementary fashion, as to keep within the prerequisites mentioned above, namely plane trigonometry and logarithms. In the first part of the paper the mathematical formulas will be derived; in the second part, to be published in a later issue, actual observations will be given and the methods will be explained in detail, of obtaining from them the values of the errors of the equatorial. It is advantageous to have a chronometer that keeps sidereal time, but if the observer has none, he may use instead a mean time chronometer, or a well regulated watch. In this case the additional work of transforming mean time into sidereal time will be necessary. A filar micrometer with position circle is not absolutely required for the work; a positive eyepiece with a pair of wires set perpendicular to each other and an incandescent lamp placed sidewise in front of the objective, will be all we need to point it to a star. He then selects an equatorial star in culmination and turns the eyepiece in the adapter so as to have one wire fall into the direction of the parallel; the other will then indicate the direction of the declination circle. The wires will appear as black lines on a white background, and care should be taken, that both the star and the wires appear clear and sharp to the observer; this is done by first focusing on the star and then shifting the eyepiece till the lines appear sharp. To avoid altering the position of the parallel a mark on the metal of the eyepiece and another on the adapter should be made when the parallel is determined.

We have now to develop the mathematical formulas, which will form the basis of our observatory work. The first three paragraphs are devoted to the development of the three fundamental formulas of spherical trigonometry.

§ 1. *Formulae of transformation for rectangular co-ordinates in the plane with the same origin.*

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* The American Ephemeris is sold for one dollar. Application is to be made to "The Superintendent of the Nautical Almanac, Navy Department, Washington, D.C." To all places in the U. S. it is sent post free. Applicants from Canada have to add 30 cents to the price.

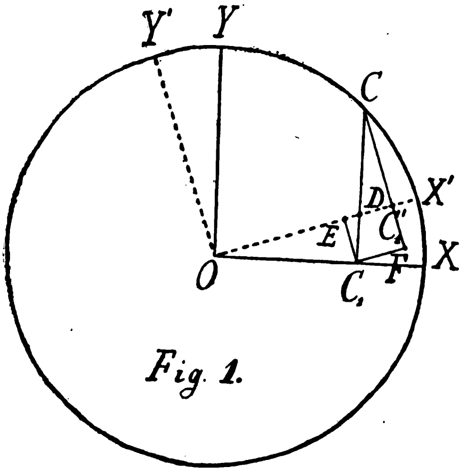


Fig. 1.

On a circle with radius r and center O we draw two radii perpendicular to each other OX and OY. Select a point C on the circumference between X and Y and let fall the perpendicular CC_1 on the line OX. We shall call OX and OY the X-axis and Y-axis respectively. The position of the axis being fixed, we see that OC_1 and $C_1 C$ will define the position of C in a definite manner so far as the quadrant XY is concerned. Let $OC_1 = x$ and $CC_1 = y$, and call x and y the rectangular coördinates of C. Now give to the axes OX and OY a common rotation through the angle φ so that they take the new positions OX' and OY' respectively. The rectangular coördinates of C in this system are x' and y', $x' = OC'_1$ and $y' = CC_1'$. We shall now establish the following relations among the coördinates x', y' and x, y:

$$x' = x \cos \varphi + y \sin \varphi,$$
$$y' = - x \sin \varphi + y \cos \varphi.$$

Analytical Proof. Let us call the angle $COX = \psi$; then we have

$$x' = r \cos (\psi - \varphi) \text{ and } y' = r \sin (\psi - \varphi).$$

Expand $\cos (\psi - \varphi)$ and $\sin (\psi - \varphi)$ and we obtain:

$$x' = r \cos \varphi \cos \psi + r \sin \varphi \sin \psi;$$
$$y' = r \cos \varphi \sin \psi - r \sin \varphi \cos \psi;$$

since $r \cos \varphi = x$ and $r \sin \varphi = y$, we have our desired formulas at once.

Geometric Proof.—Draw C_1E perpendicular OX' then is $x' = OE + ED + DC_1'$ since angle $EOC_1 = \varphi$ and angle $EDC_1 =$ angle $CDC'_1 = 90 - \varphi$ we have $x' = OC_1 \cos \varphi + C_1 D \sin \varphi + DC \sin \varphi = OC_1 \cos \varphi + (C_1D + DC) \sin \varphi$ or $x' = x \cos \varphi + y \sin \varphi$.

Similarly we have $y' = CF - C_1'F = CC_1 \cos \varphi - OC_1 \sin \varphi$, $y' = y \cos \varphi - x \sin \varphi$. Q. E. D.

§ 2. *Rectangular and Polar co-ordinates of a point in space.*

Let us now go over from the realm of two dimensions to that of three.

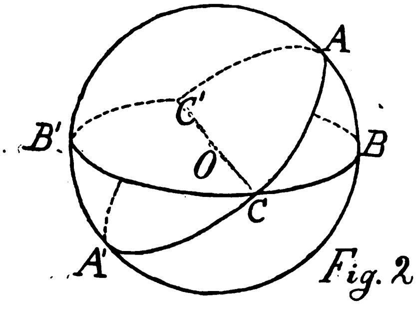


Fig. 2.

In figure 2, O is the center of a sphere, the radius of which we put equal to 1. Select three points A, B and C on its surface and pass three planes through O, the first containing A and B; the second B and C; and the third, C and A. The intersections of these planes with the surface of the sphere are great circles and by their mutual intersection in six points A, B, C and A', B', C' eight *spherical* triangles are formed on the surface. We shall limit our attention to the triangle ABC and we shall develop the three fundamental formulas in which the sin- and cosine-functions of the angles and sides will appear. Before doing this, we must acquaint ourselves with the meaning of the rectangular and polar coördinates of a point in space. To simplify matters let us use a square paper box as a model. Removing the cover we mark with ink the three inside edges which intersect each other under right angles in one corner. Call this corner O and select three points X, Y, Z on the three edges as indicated by figure 3; OX, OY, OZ will be referred to as the X-, Y- and Z-axes passing through the origin O. Stick a pin from above into the bottom of the box, so that it is parallel to the OZ-axis. Call the head of the pin C, and the foot point C_1. It is our purpose to describe in mathematical language the position of C so uniquely, that we may be able to find the point even when the pin is removed. To do this, we define first the position of C_1 by dropping the perpendiculars $C_1 C_2$ and. $C_1 C_3$, the former one $C_1 C_2$, is the y coördinate of C_1 the latter, the x coördinate in the X Y-plane. Having defined C_1 we at once can find C, provided we know the distance $C_1 C = z$ measured from C_1 upward along a line perpendicular to the XY-plane. $C_1 C = z$, $C_1 C_2 = y$, $C_1 C_3 = x$ are called the *rectangular coordinates* of C.

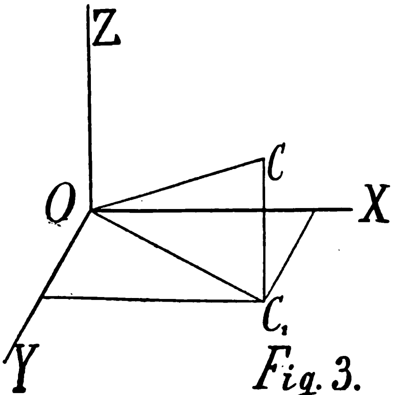


Fig. 3.

They suffice to define uniquely the position of C with respect to O, when we restrict our attention to that part of space which is limited by the lines X-, Y- and Z-axis in the directions from O to X, from O to Y, and from O to Z. The same result can be obtained by defining C by means of two angles φ and u and the distance of $OC = r$. The angles φ and u are defined as follows: pass a plane through C, O and Z, it will be perpendicular to the XY-plane. OC_1 is the projection of OC and we define φ as the angle which OC forms with its projection on the XY-plane. The angle is measured in the direction toward the OZ axis starting from the line OC_1. It is evident that φ lies between 0° and 90°. The angle u is the angle which the OX axis forms with the projection OC_1 measured in the direction from the X-axis to the Y-axis. With our restrictions we have u lying between 0° and 90°. r, φ, u are called the *polar coördinates* of C; it is obvious that by them C is uniquely defined. Since $z = CC_1 = OC \sin \varphi = r \sin \varphi$, and $OC_1 = r \cos \varphi$ we see at once that the relations among the rectangular and polar coördinates are as follows:

$$\begin{aligned} x &= r \cos \varphi \cos u, \\ y &= r \cos \varphi \sin u, \qquad \text{(a)} \\ z &= r \sin \varphi. \end{aligned}$$

It should be remarked, although we shall not make use of it, that these formulas hold generally for points located anywhere in space and not alone for points in that octant of space which we have considered. In this general case we have to distinguish between a positive and a negative direction of each axis and give to the rectangular coördinates the + or — sign according as they are measured on the positive or negative side of each axis. Similarly we have to extend the limit of φ and u; in the general case φ will vary between — 90° and + 90° and u can take any value from 0° to 360°.

§ 3. *The fundamental formulae of spherical trigonometry.*

In figure (4) AB is an arc of a great circle on the surface of a sphere with radius $OA=1$. Select the radius OB as the $+Z$-axis of a system of three rectangular axes, passing through O. Let OX be the $+X$-axis; erect a perpendicular at O to the XZ-plane intersecting the hemisphere upon which C is located in Y; OY is the $+Y$-axis. The plane OXY intersects the surface of the sphere along the great circle XY. The plane OBC intersects the XY-plane in the line OC_1; OC_1 is the projection of OC on the XY-plane. Using our former symbols we have $r = 1$, $\varphi =$ angle C_1OC, $u = XOC_1$, the rectangular coördinates of C are x, y, z, and we have

$$x = 1.\cos\varphi.\cos u$$
$$y = 1.\cos\varphi.\sin u$$
$$z = 1.\sin\varphi$$

We now turn the X- and Z-axis around the $+\ Y$-axis from the right to the left through the angle BOA which we call c. Then will the $+Z$-axis fall upon OA the $+\ X$-axis will be directed to a point 90° distant from A. Let us distinguish the new positions from the old by calling the new axis OZ' and OX' respectively. The Y'-axis coincides with the Y-axis as remarked before. We have dotted the lines and circles in the new system in our figure. To find the coördinates x', y', z' of C in the new system we proceed as we did before. Plane OAC and plane $OY'X'$ intersect each other in the line OC_1', OC_1' being the projection of OC on the $X'Y'$-plane, angle $C_1'OC = \varphi'$, angle $X'OC_1' = u'$ therefore we have

$$x' = 1.\cos\varphi'.\cos u',$$
$$y' = 1.\cos\varphi'.\sin u',$$
$$z' = 1.\sin\varphi'.$$

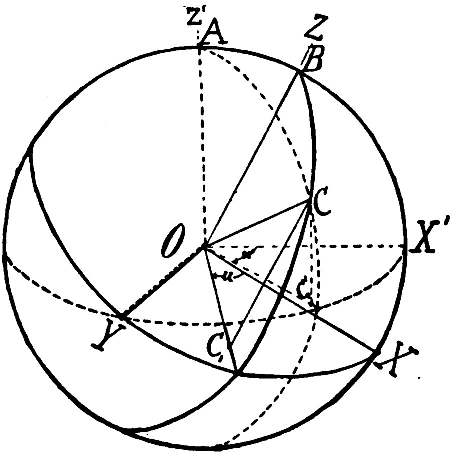


Fig. 4.

But we know from figure (4) that $y' = y$ since both are the projection of OC on the same axis, it is therefore but necessary to see how x', z' and x, z are related to each other. To establish these relations we need but make use of the theorem in § 1. Indeed in the OAB-plane we have two systems each of two rectangular axes, which are inclined to each other by the angle c. Therefore we have

$$x' = x\cos c + z\sin c,$$
$$z' = -x\sin c + z\cos c.$$

Introducing the polar coördinates we have the following system of equations

$$\cos\varphi'\sin u' = \cos\varphi\sin u,$$
$$\cos\varphi'\cos u' = \sin\varphi\sin c + \cos\varphi\cos c\cos u,$$
$$\sin\varphi' = \sin\varphi\cos c - \cos\varphi\sin c\cos u.$$

It is but necessary to identify u, φ, u', φ', c with the angles and sides of triangle ABC to obtain the desired result.

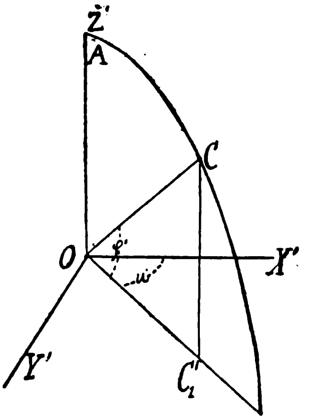


Fig. 5.

Let A, B, C designate the angles and a, b, c the sides of the triangle ABC. Since $BOC_1 = 90°$, and $C_1OC = \varphi$, therefore $90° - \varphi = a$. Since $AOC'_1 = 90°$ and $C_1'OC = \varphi'$, therefore $90° - \varphi' = b$. The plane angle $u = XOC_1$ is measured on the surface of the sphere by the arc of great circle contained between OX and OC_1, but this same arc measures as well as the angle CBX on the sphere which is $180 - B$, therefore we have $u = 180 - B$. In the same manner we obtain $u' = A$. Introducing the values of φ, u; φ', u' and c into our last equations and remembering that $\sin(180 - B) = \sin B \cos(180 - B) = -\cos B$, $\sin(90 - a) = \cos a$, $\cos(90 - a) = \sin a$, we get:

$$\left.\begin{aligned} \sin b \sin A &= \sin a \sin B, \\ \sin b \cos A &= \cos a \sin c - \sin a \cos c \cos B, \\ \cos b &= \cos a \cos c + \sin a \sin b \cos B. \end{aligned}\right\}\text{(b)}$$

These are the three fundamental equations of spherical trigonometry.

§ 4. *The errors of the Equatorial Telescope.*

The characteristic features of an equatorial are:

(1) A system of two axes perpendicular to each other, one of which—the polar axis—is fixed, the other—the declination axis—can revolve about the first in a plane which is the instrumental equator. By means of a graduated circle, the hour angle circle, which lies in the plane of the instrumental equator the actual position of the declination axis in this plane can be ascertained.

(2) The telescope itself, fastened to one side of the declination axis and revolving about this axis. By means of a graduated circle, called the declination circle, fastened to the opposite side of the declination axis the actual position of the telescope, or more exactly that of the optical axis of the telescope, can be determined in the declination plane.

The zero point in the hour circle is very nearly the point where the projection of the south point upon the equator meets the equator. The angles measured by means of this circle are therefore hour angles and it is evident, that the hour angle of the declination axis will differ by very nearly 90° from that of the object to which the telescope is directed. In the declination circle the angles are measured from the equator either upward to the North Pole or downward to the South Pole. The readings on both circles are effected by an index and the amount by which this is placed erroneously in position is the index error of the hour circle and declination circle respectivly. The first we shall designate later by $\triangle T$, the second by $\triangle D$. Let us suppose that the polar axis and the declination axis are both hollow tubes, which we may imagine to be transformed into small telescopes.

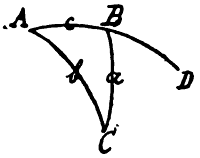


Fig. 6.

The objective of the polar axis will be on that end which is turned toward the North Pole, the objective of the declination axis telescope on that end where the circle is situated. Let π be the point in which the celestial sphere is pierced by the optical axis of the polar axis telescope, K the corresponding point for the declination axis telescope, and finally S the point to which the optical axis of the telescope itself is pointing. The spherical triangle πKS will then be the fundamental triangle for our later consideration. We shall call π the pole of the equatorial; it is obvious that under ideal conditions π would coincide with the celestial pole P. Designating the instrumental declination of the object S with d, we have $\pi S = 90 - d$, the instrumental declination of the point K will be called n, therefore $\pi K = 90 - n$. The angle measured by the arc KS is very nearly 90°; it is the angle which the optical axis of the telescope forms with that of the declination telescope. Let us put $KS = 90 + c$ and call the small quantity c the *error of collimation* of the telescope. πK and KS differing both from 90°, we cannot assume that the angle $K\pi S$ will be exactly $= 90°$. Let Q be the amount by which this angle differs from 90° and call $K\pi S = 90 + Q$. Evidently Q will depend upon c, n and d and we can easily determine Q in terms of these quantities. Applying the last equation of system (b) to our triangle πKS we obtain

$$\cos KS = \cos \pi K \cos \pi S + \sin \pi K \sin \pi S \cos K\pi S, \text{ or}$$
$$-\sin c = \sin n \sin d - \cos n \cos d \sin Q.$$

When an angle x is smaller than 15′ ($= 900''$) and we compute its log sin and log cos by means of a five place logarithm table, we may put $\sin x = x \sin 1''$ and $\cos x = 1$ without committing an error of one unit in the last place of each logarithm. The two quantities c and n will always be very much smaller than 15′ and we may therefore write $\sin Q = n \sin 1'' \operatorname{tg} d + c \sin 1'' \operatorname{tg} d$.

Except for a star, the polar distance of which is less than 1°, we may also put $\sin Q = Q \sin 1''$, so that we obtain
(*1*) $Q = n \operatorname{tg} d + c \sec d$. Of all the Nautical Almanac stars none has at present a polar distance less than 1°, so that we may safely employ this last simple equation for determining Q in terms of c, n and d.

The errors of the equatorial which we have so far discovered are the index errors $\triangle T$ of the hour circle and $\triangle D$ that of the declination circle, the collimation error c and the declination of the point K. We have mentioned that under ideal conditions π would coincide with P, but this will never be fufilled in reality. Referring the reader to figure 9 on Page 435 we observe that PZ is the ideal meridian, πZ the instrumental meridian. Calling πP (the arc between P and π) χ, it is obvious that the position of π with reference to P and the ideal meridian, will be defined by χ and the angle πPZ. If we drop a perpendicular from π upon the ideal meridian and call its foot point π°, we may as well define π by the two quantities $\pi\,\pi^\circ$ and $P\pi^\circ$; we shall call $\pi\,\pi^\circ$, η and $P\pi^\circ$, ξ. Then ξ and η are the rectangular coördinates of π with reference to a system of axis with origin at P, the $+ X$-axis of which is in the direction PZ, the $+ Y$-axis is in the 6^h circle and directed toward the west. The smaller χ, the nearer will ξ and η be represented by straight lines. The four quadrants around P will be numbered 1, 2, 3, 4 in the direction from PZ to the West, North, East and back to the South. Iu figure 9, π is therefore located in the fourth quadrant, ξ is a positive, and η a negative quantity. We are now going to show how the errors of the instrument and the quantities ξ and η are going to affect the declination and hour angle of a star. In order to have a complete enumeration of all the errors of the equatorial, the flexures of the telescope tube and of the polar and declination axes should be mentioned here. At present we disregard them, at the end of the next paragraph their effects upon the observations will be studied.

§ 5. *How to obtain the ideal hour angle τ and declination δ from the instrumental hour angle t and declination d.*

"Ideal hour angle" and "ideal declination" will be defined as the hour angle and declination as referred to the celestial pole P and meridian PZ, freed from the effect of refraction. The instrumental hour angle t and declination d are referred to the pole π and instrumental meridian πZ.

When we observe a star in the meridian, we can either place the tube of the telescope on the East or on the West side of the pier. For stars in upper culmination the first position — telescope East — will mean that the declination axis is in the West, the second — telescope West — that the declination axis is in the East. Considering the apparent revolution of the sky the point *K* will in the first position precede the object, i. e., it will set before the object *S* does, in the second position *K* will follow *S* in the direction of daily rotation. For lower culmination the conditions are reversed. Indeed *K* being in the West as before, and the star in the North, it is obvious that *K* follows *S*, whereas when *K* is in the East *K* has attained a position to which *S* will come after about six hours. From these examples we see that without stating the particular position of the star, the remarks "circle preceding" or "circle following" will give us a unique definition of the relative position of *K* to *S*. In this way the observer, when discussing his observations, will at once be able to trace the fundamental triangle $K\pi S$ on the celestial sphere.

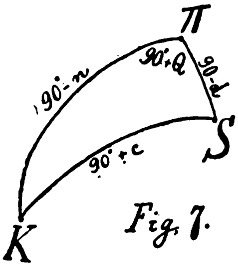


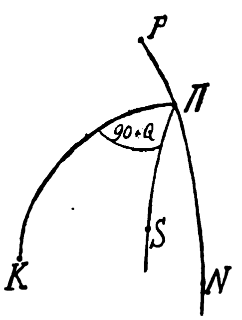
Fig. 7.

We shall designate the readings of the declination circle by *D*, and those of the hour angle circle by *T*. To distinguish the position "circle preceding" (*C. P.*) from that of "circle following" (*C. F.*) we shall use D' and T' for the readings in the first position, and D'' and T'' for those in to second position. The declination circle is generally divided in the four quadrants and the graduation runs from 0° to 90° in each quadrant, in the hour angle circle the graduation goes from 0^h to 24^h in the direction from the South to the West.

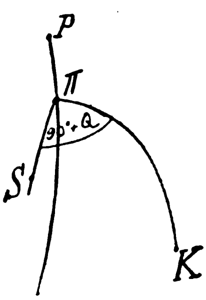
Assuming a positive index error, the instrumental declination in the position *C. P.* will be $d = D' + \varDelta D$. Turning the telescope about the polar axis without loosening the declination clamp at first we reach the position *C. F.*, but to bring the telescope to the star again we have to turn it through the angle $2(90 - D)$, so that with a graduation from 0° to 180° we would directly read $180 - D$ in this position. This angle is too small by the amount $\varDelta D$ as before and we obtain therefore $180 - d = 180 - D'' + \varDelta D$ or since the graduation is supposed to run from 0 to 90

$$(2) \qquad \begin{array}{ll} d = D'' - \varDelta D & C.\ F. \\ d = D' + \varDelta D & C.\ P. \end{array}$$

from these two equations we obtain $d = \dfrac{D'' + D'}{2}$ and $\varDelta D = \dfrac{D'' - D'}{2}$



Circle preceding. Fig. 8^a



Circle following Fig. 8^b

Let us consider the corresponding equations in hour circle. In figures 8^a and 8^b we pass a great circle through P and π and to shorten our expressions we assume a point N on the prolongation of $P\pi$. Let the star S be on the west side of the instrumental meridian πZ. By means of the hour angle circle we can measure the hour angle $S\pi Z$ and derive from it and the errors of the instrument (including ξ and η among them) the ideal hour angle SPZ. In figure 8^a we have

$$S\pi N = K\pi N - K\pi S = K\pi N - (90 + Q)$$

Let us imagine that the numbers of the hour angle circle be projected on the celestial sphere by radii drawn from the centre of the circles and prolongated till they meet the celestial sphere. Then the arc of great circle πK will intersect this great circle in a point the lettering of which may be designated by T' and the point where πN intersects it will show a reading which we shall call T°. The angle $K\pi N$ is measured on the great circle and since the number increases from the meridian towards the west, we shall have $K\pi N = T' - T^\circ$. We have therefore

$$S\pi N = T' - T^\circ - (90 + Q). \qquad C.\,P.$$

In figure 8^b we obtain

$$S\pi N = S\pi K - N\pi K = 90 + Q - (T^\circ - T'').$$

The hour circle being graduated from 0^h to 24^h in the direction to the west starting from the instrumental meridian it is evident from what was said before, that the angle $N\pi K$ will be measured by $T^\circ - T''$, (T° will be very nearly 360° and T'' in our figure about 250°, so that $T'' -- T^\circ = 110^\circ$ when we assume $S\pi N = 20^\circ$).

For Q we have had [see formula (1)], $n \operatorname{tg} d + c \sec d$. Putting this into our equation we have

$$S\pi N = T' - T^\circ - 90 - c \sec d - n \operatorname{tg} d \qquad C.\,P.$$
$$S\pi N = 90 - (T'' - T^\circ) + c \sec d + n \operatorname{tg} d \qquad C.\,F.$$

But we do not want to refer S to the circle πN but to the instrumental meridian πZ. Call the angle $Z\pi N$, r measured around π

through the West, North, East to the line πN and subtract $360° - r$ from $S\pi N$ in both cases. We thus obtain $S\pi Z$, which is the instrumental hour angle, we shall designate it by t' and t'', the first one for *C. P.*, the second one for *C. F.* We obtain

$$(3)\quad \begin{array}{ll} t' = (T' - T^{\circ} - 90 + r) - c\sec d - n\,\mathrm{tg}\,d & C.\,P. \\ t'' = (90 - (T'' - T^{\circ}) + r) + c\sec d + n\,\mathrm{tg}\,d & C.\,F. \end{array}$$

We have distinguished here between t' and t'' since the hour angle will change its value in the time required to reverse the telescope. In the equations (2) we have evidently $d = d' = d''$.

Having indicated how d and t can be obtained from the direct readings of the circles and the quantities c, n, r and $\varDelta D$ we shall now show how from d, t, r and ξ and η the ideal coördinate and τ are determined.

In triangle $S\pi P$ we have $SP = 90 - \delta$, $S\pi = 90 - d$,
$P\pi = \chi$; S angle $PZ = \tau$,

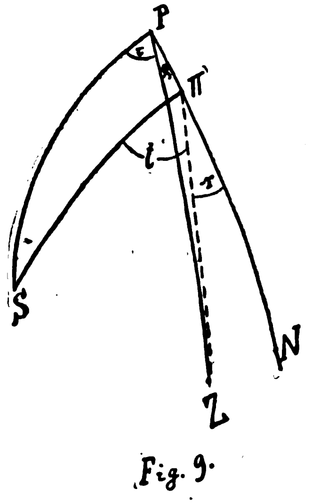


Fig. 9.

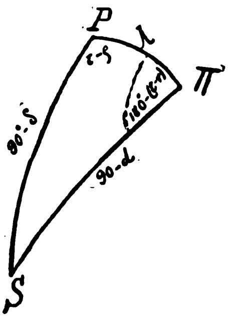


Fig. 10.

putting the angle $ZP\pi = \rho$ when measured around P in the direction West, North, East, we have $SP\pi = \tau - \rho$. The angle $S\pi P = r - 180 - t = 180 - (t - r)$. Applying formulas ($b$) to this triangle we get:

$$(4)\quad \begin{array}{l} \sin\delta = \cos\chi\sin d - \sin\chi\cos d\cos(t - r), \\ \cos\delta\sin(\tau - \rho) = \cos d\sin(t - r), \\ \cos\delta\cos(\tau - \rho) = \sin d\sin\chi + \cos d\cos\chi\cos(t - r) \end{array}$$

Putting $\cos\chi = 1$, and $\sin\chi = \chi\sin 1''$, we have in the first equation $\sin\delta = \sin d - \chi\sin 1''\cos d\cos(t - r)$.

Since $$\delta = \frac{\delta + d}{2} + \frac{\delta - d,}{2}$$

$$d = \frac{\delta + d}{2} - \frac{\delta - d,}{2}$$

we have $\sin \delta - \sin d = 2 \sin\left(\frac{\delta - d}{2}\right) \cos\left(\frac{\delta + d}{2}\right) =$

$$- \chi \sin 1'' \cos d \cos (t - r).$$

But $\cos \frac{\delta + d}{2} = \cos d \ldots\ldots$

$2 \sin\left(\frac{\delta - d}{2}\right) = (\delta - d) \sin 1''$ and we obtain

(5.) $$\delta = d - \chi \cos (t - r).$$

To obtain an expression for $\tau - t$ from the last two equations of system (4) we must first find an expression for $\rho - r$. In the triangle $ZP\pi$ we have $ZP = 90 - \varphi$, where φ is the altitude o P, $Z\pi = 90 - f$, where f is the altitude of π, angle $P\pi Z = r - 180$ and angle $ZP\pi = 360° - \rho$.

The application of the first two equations of system (b) gives

$$\cos f \sin r = \cos \varphi \sin \rho,$$
$$- \cos f \cos r = \sin \varphi \sin \chi - \cos \varphi \cos \chi \cos \rho.$$

Forming the quotient of the two equations we get

$$- \frac{\cos r}{\sin r} = \operatorname{tg} \varphi. \frac{\sin \chi}{\sin \rho} - \cos \chi \frac{\cos \rho}{\sin \rho}, \text{ or}$$

$$- \cos r \sin \rho = \sin \chi \operatorname{tg} \varphi \sin r - \cos \chi \cos \rho . \sin r$$

or putting $\cos \chi = 1$ and $\sin \chi = \chi \sin 1''$ we obtain

$$\sin (\rho - r) = - \chi \sin 1'' \operatorname{tg} \varphi . \sin r \qquad \text{or}$$

(6.) $$\rho - r = - \chi \operatorname{tg} \varphi . \sin r. \ \ldots\ldots$$

The last two equations under (4) can be transformed by elementary operations in such a manner that we finally get an equation for $\tau - t$; this will be

(7.) $$\tau - t = - \chi \operatorname{tg} \varphi . \sin r - \chi \operatorname{tg} d \sin (t - r) \ldots\ldots$$

It will now depend which value of t we employ, that one for circle preceding or that for circle following, in the first case we get

$$\tau' = T' - T^{\circ} - 90 + r - \chi \operatorname{tg} \varphi \sin r - c \sec d - n \operatorname{tg} d$$
$$- \chi \operatorname{tg} d \sin (t - r) \quad C. P. \text{ in the second case:}$$
$$\tau'' = 90° - (T'' - T^{\circ}) + r - \chi \operatorname{tg} \varphi \sin r + c \sec d + n \operatorname{tg} d$$
$$- \chi \operatorname{tg} d \sin (t - r) \quad C. F.$$

(8.) Call $T' - T^{\circ} - 90 + r - \chi \operatorname{tg} \varphi \sin r = \mathrm{T}' + \Delta \mathrm{T}$,
and $90 - (T' - T^{\circ}) + r - \chi \operatorname{tg} \varphi \sin r = \mathrm{T}'' + \Delta \mathrm{T}$.

ΔT is the under error of the hour angle circle.

With these simplifications we write:

$$\tau' = T' + \Delta T - c \sec d - n \operatorname{tg} d - \chi \operatorname{tg} d \sin (t' - r) \qquad C.\ P.$$
$$\tau'' = T'' + \Delta T + c \sec d + n \operatorname{tg} d - \chi \operatorname{tg} d \sin (t'' - r) \qquad C.\ F.$$

$\chi \sin (t - r)$ we may replace by $\chi \sin (\tau - \rho) = \chi \sin \tau \cos \rho - \chi \cos \tau \sin \rho$. But $\chi \cos \rho = \xi$, and $\chi \sin \rho = \eta$; we have therefore $\chi \sin (\tau - \rho) = \xi \sin \tau - \eta \cos \tau$. Putting this into the last equations with the proper index in each case we have the equations in this final form:

$$\tau' = T' + \Delta T - c \sec d - n \operatorname{tg} d - \xi \sin \tau' \operatorname{tg} d + \eta \cos \tau \operatorname{tg} d$$
(9.) C. P.
$$\tau'' = T'' + c \sec d + n \operatorname{tg} d - \xi \sin \tau' \operatorname{tg} d + \eta \cos \tau \operatorname{tg} d$$
C. F.

To obtain the equations for δ we put the values of d as given in system (2) into equation (5) and expand $\chi \cos (t - r)$ as before.

$$(10) \qquad \begin{array}{ll} \delta = D' + \Delta D - \xi \cos \tau - \eta \sin \tau & C.\ P. \\ \delta = D'' - \Delta D - \xi \cos \tau - \eta \sin \tau & C.\ F. \end{array}$$

We have so far neglected the effects of the flexures of the declination axis, the polar axis and the tube of the telescope upon the observations of a star. We shall call the maximum of flexure of the declination axis (when it is in horizontal position) *E*, the maximum of flexure of the tube of the telescope *e* and shall neglect the flexure of the short polar axis entirely. By elementary considerations like those given before, we can show that the equations for δ will have to be completed on the right side by a term $-e\,(\sin f \cos d - \cos f \sin d \cos \tau)$. The equations for τ will contain two additional terms namely:

$$\pm E\,(\sin f \operatorname{tg} d + \cos f \cos \tau) + e.\ \cos f.\ \sec d.\ \sin \tau$$

the upper sign of the first term to be used for *C. P.*, the lower sign for *C. F.*

THE UNIVERSITY OF CHICAGO.
1900 Sept. 15th.

TABLES FOR THE OBSERVATIONS OF EROS.

Bulletins No. 3 and 4 of the "Conference astrophotographique internationale" of July 1900, contain tables which are of great use to those who are taking part in the observation of Eros, for the purpose of determining the solar parallax. We take the liberty of printing these tables in full.

1. The first is an ephemeris of Eros, calculated by M. Millosevich and interpolated for each day, to which has been applied the correction resulting from observations made at Paris on Aug. 4 and 7, 1900.

2. A table containing, for the region of the apparent path of Eros and for a width of about 2° 20′, the stars of reference whose pôsitions it will be necessary to have determined by means of meridian instruments, in the largest possible number of observations. In accordance with the desire expressed by the conference, this table has been constructed in such a manner that one may select about twelve stars of reference for computing the constants of each plate, in the new series of photographs to be obtained by means of the instruments designed for the photographic chart of the heavens.

3. A table giving approximately the local time at the two moments when Eros is 20° above the horizon.

4. A table giving the equatorial coördinates of points 1° apart, within a half minute of arc, upon the apparent trajectory of Eros. These coördinates may be adopted as the centers of photogrąphic plates designed for furnishing the relative positions of the comparison stars.

For the purpose of obtaining the greatest homogeneity in the construction of the photographic catalogue of the heavens, the conference decided that stars of reference should be referred to Newcomb's Catalogue of Fundamental Stars. The president of the conference, Mr. Loewy, suggests that it would be well to adopt the same rule with reference to the comparison stars for Eros.

EPHEMERIS OF EROS FOR 12h BERLIN MEAN TIME.

Dates.	R. A. (true)	Dec. (true)	log *r*.	log Δ.	Par.
	h m s	° ′			″
1900. Sept. 19............	2.39. 3	+40.24,2	0,1669	9,8182	13,4
20............	39.43	40.47,1			
21............	40.20	41. 9,9			
22............	40.55	41.32,8			
23............	41.27	41.55,7			
24............	41.56	42.18,6			
25............	42.23	42.41,4			
26............	42.46	43. 4,2			
27............	43. 7	43.27,0			
28............	43.25	43.49,7			
29............	43.40	44.12,3	0,1574	9,7663	15,1
30............	43.51	44.34,8			
Oct. 1............	44. 0	44.57,2			
2............	44. 6	45.19,6			
3............	44. 7	45.41,8			
2.4............	2.44. 4	+46. 3,8			

EPHEMERIS OF EROS FOR 12^h BERLIN MEAN TIME.

Dates.	R. A. (true)	Dec. (true)	log r.	log Δ.	Par.
	h m s	° ′			
1900, Oct. 5	2.43.58	+46.25,7			
6	43.50	46.47,5			
7	43.37	47. 9.0			
8	43.20	47.30,3			
9	42.58	47.51,4	0,1475	9,7149	17,0
10	42.33	48.12,3			
11	42. 4	48.32,9			
12	41.31	48.53,2			
13	40.53	49.13,2			
14	40.11	49.32,8			
15	39.24	49.52,0			
16	38.32	50.10,8			
17	37.36	50.29,2			
18	36.36	50.47,2			
19	35.31	51. 4,6	0,1373	9,6654	19,0
20	34.21	51.21,5			
21	33. 7	51.37,8			
22	31.48	51.53,6			
23	30.25	52. 8,7			
24	28.58	52.23,1			
25	27.27	52.36,8			
26	25.52	52.49,8			
27	24.13	53. 2,1			
28	22.30	53.13,6			″
29	20.44	53.24,2	0,1269	9,6199	21,1
30	18.55	53.34,0			
31	17. 2	53.43,0			
Nov. 1	15. 8	53.51,1			
2	13.11	53.58,3			
3	11.12	54. 4,5			
4	9.11	54. 9,8			
5	7. 9	54.14,1			
6	5. 7	54.17,5			
7	3. 4	54.19.8			
8	2. 1. 0	54.21,1	0,1165	9,5804	23,1
9	1.58.56	54.21,4			
10	56.53	54.20.7			
11	54.51	54.18,9			
12	52.50	54.16,1			
13	50.51	54.12,3			
14	48.54	54. 7,4			
15	47. 0	54. 1,4			
16	45. 9	53.54,5			
17	43.22	53.46,6			
18	41.38	53.37,7	0,1061	9,5484	24,9
19	39.59	53.27,8			
20	38.24	53.17,0			
21	36.54	53. 5,2			
22	35.30	52.52,6			
23	34.11	52.39,1			
24	32.57	52.24,7			
25	31.50	52. 9,6			
26	30.48	51.53.7			
27	29.53	51.37.0			
28	29. 5	51.19,7	0,0961	9,5248	26,3
29	28.23	51. 1,7			
30	27.48	50.43,0			
Dec. 1	1.27.20	+50.23,8			

EPHEMERIS OF EROS FOR 12^h BERLIN MEAN TIME.

Dates.		R. A. (true)	Dec. (true)	log *r*.	log Δ.	Par.
		h m s	° ′			″
1900. Dec.	2	1.26.59	+50. 4,0			
	3	26.43	49.43 7			
	4	26.35	49.22 9			
	5	26.33	49. 1,7			
	6	26.39	48.40,0			
	7	26.50	48.17,9			
	8	27. 9	47.55.4	0,0865	9,5092	27,3
	9	27.34	47.32 5			
	10	28. 5	47. 9,3			
	11	28.44	46.45 7			
	12	29.28	46.21,9			
	13	30.18	45.57,8			
	14	31.15	45.33,5			
	15	32.18	45. 9,0			
	16	33.26	44.44 3			
	17	34.41	44.19 4			
	18	36. 1	43.54.3	0,0778	9,5008	27,8
	19	37.28	43.29,1			
	20	38.59	43. 3,8			
	21	40.36	42.38 3			
	22	42.19	42.12 8			
	23	44. 7	41.47,2			
	24	46. 1	41.21,5			
	25	47.59	40.55.8			
	26	50. 1	40.30 0			
	27	52. 9	40. 4 2			
	28	54.21	39.38.4	0,0700	9,4990	27,9
	29	56.38	39.12,6			
	30	1.58.58	38.46,8			
	31	2. 1.23	38.21,0			
1901. Jan.	1	3.53	37.55 2			
	2	6.26	37.29 4			
	3	9. 3	37. 3.6			
	4	11.43	36.37 8			
	5	14.27	36.12,1			
	6	17.14	35.46.3			
	7	2.20. 5	+35.20,6	0,0636	9,5029	27,6

Comparison Stars for Observations of Eros.

No.		Mag.	R. A. 1900,0.	Dec. 1900,0.	No.		Mag.	R. A. 1900,0.	Dec. 1900,0.
	°		h m s	° ′		°		h m s	° ′
399 BD	+49	8,6	1.24. 0	+49.25,5	442BD	+47	9,3	1.26.17	+47.54,2
370	+46	6,0	24. 6	46.29,5	299	+50	8,8	26.23	50.18,6
317	+51	8,9	24.26	51.34,7	300	+50	9,5	26.48	50.57,9
400	+49	9,5	24.33	50. 5,6	301	+50	9,3	26.59	50.22,4
429	+47	8,5	24.33	47.22,9	463	+48	8,7	27.16	48.30,3
401	+49	8.5	24.38	50. 9,2	412	+49	9,3	27.49	49.37,0
373	+46	8,1	24.48	47. 3,1	331	+51	8,6	27.59	51.19,3
403	+49	9,1	24.51	49.54,9	376	+45	8,9	28. 0	45.27,8
434	+47	9,5	24.51	47.54,1	450	+47	8,9	28. 5	47.54,5
453	+48	7,1	24.54	48.49,8	414	+49	9,3	28.19	50. 1,1
454	+48	9,0	25.26	48.31 5	470	+48	7,6	28.20	49. 3,1
455	+48	9,1	25.26	48.16,3	334	+51	9,0	28.33	51.38,5
297	+50	9,5	25.42	50.56,5	379	+45	9,0	28.33	46. 0,8
323	+51	7,8	25.46	51.57,3	326	+44	8,8	28.38	45. 5,0
298	+50	9,5	1.26.10	+50.38,6	383	+45	9,0	1.29.16	+45.19,0

COMPARISON STARS FOR OBSERVATIONS OF EROS.

No.		Mag.	R. A. 1900,0.	Dec. 1900,0.	No.		Mag.	R. A. 1900,0.	Dec. 1900,0.
	°		h m s	° ′		°		h m s	° ′
338 BD	+51	7,4	1.29.22	+51.39,2	386 BD	+53	7,6	1.41.15	+53.30,3
329	+44	8,5	29.20	44.24,9	373	+42	7,9	41.25	42.34,9
389	+46	8,3	29.30	46.22,9	388	+53	8,3	41.35	53.23,4
393	+46	7,4	29.59	46.36,2	347	+41	8,7	41.45	41.55,4
416	+49	9,1	30. 3	50.11,7	441	+52	8,3	41.53	52.45,0
477	+48	8,7	30. 3	48.41,6	375	+42	8,9	41.56	42.42,8
397	+46	7,0	30.19	46.48,9	383	+54	8,6	42.39	54.38,6
460	+47	6,6	30.20	48.12,7	352	+41	9,1	42.55	42.12,6
339	+51	7,6	30.24	51.14,3	373	+43	8,6	43.11	43.14,3
462	+47	7,3	30.33	47.33,8	395	+53	8,6	43.11	53.25,0
387	+52	8,5	30.39	52.35,8	353	+41	8,5	43.14	41.29,5
463	+47	7,5	30.40	47.48,3	388	+54	7,9	43.57	54.43,3
314	+50	8,7	30.44	50.45,0	398	+53	8,4	44. 0	53.14,8
418	+49	9,5	30.55	49.26,4	392	+54	8,0	44.42	54.54,6
344	+51	9,2	31. 9	52. 7,3	393	+54	7,3	44.53	54.25,8
404	+46	7,8	31.13	46.26,3	388	+42	8,0	45. 3	43. 1,8
392	+45	7,8	31.14	45.57,0	402	+53	8,7	45.11	53.22,3
394	+45	8,7	31.25	45.26,9	390	+42	8,5	45.22	42.16,1
422	+49	8.8	31.42	50. 5,8	396	+54	6,1	45.25	54.39,2
335	+44	8,7	32. 5	44.18,5	384	+40	9,2	45.37	40.57,6
337	+44	8,1	32.21	45. 9,3	421	+39	8,8	46.25	40. 3,2
398	+45	8,4	32.22	45.55,2	362	+41	8,2	46.43	41.20,9
341	+44	7,4	32.30	44.53,5	390	+40	8,2	46.49	40.59,5
393	+52	8,6	32.31	52.43,9	364	+41	9,0	47.10	42. 2,3
337	+43	8,1	32.40	43.38,2	408	+54	6,8	47.11	55. 6,3
355	+53	8,4	33. 4	53.37,6	394	+40	6,2	47.17	40.14,2
341	+43	8,8	33.10	43.31,6	416	+53	8,4	48. 7	53.24,0
399	+52	8,1	33.13	52.24,5	413	+54	9,0	48.13	54.14,2
357	+51	7,7	33.13	51.45.6	419	+53	7,4	48.25	53.41,8
343	+43	5,5	33.21	43.52,7	400	+40	8,5	48.27	40.23,9
360	+51	7,6	33.34	52. 8,4	431	+39	7,4	48.37	40. 9,9
321	+41	8,7	33.41	42.13,9	401	+40	8,9	48.39	41. 9,0
363	+53	6,8	33.50	53.21,7	434	+39	6.9	48.53	40.12,8
363	+51	8,1	34. 2	51.21,5	415	+54	8.0	49. 8	55. 5,2
364	+51	8,6	34.10	52. 1,4	440	+55	8,0	4 9.14	55.20,2
346	+44	9,0	34.45	44.16,5	417	+54	8,4	49.31	55.10,0
347	+44	8,4	34.48	44.30,8	374	+41	7,4	50.28	41.24,2
416	+45	9,0	35.22	45.54,4	377	+41	8,2	51.10	41.16,7
406	+52	8,7	35.23	52.52,3	424	+54	9,1	51.13	54.52,9
352	+44	8,0	35.51	45. 4,3	406	+40	8,9	51.14	40.16,3
351	+42	9,1	35.58	42.21,5	428	+53	8,8	51.36	54. 7,2
352	+42	7,0	36. 4	43. 8,1	429	+54	7,8	52.10	55. 5,7
354	+42	8,6	36.16	42.31,0	412	+40	8,3	52.20	40.25,6
329	+41	8,5	36.17	41.25 5	447	+39	8,5	52.22	40. 3,1
422	+45	9,0	36.24	45.32,2	464	+55	8,2	52.51	55.18,0
424	+45	8,8	37. 4	45.26,2	431	+54	8,7	52.56	54.20,2
354	+44	7,0	37.11	44.49,1	448	+39	8,2	53.36	40. 4,7
356	+42	8,8	37.17	43.12,0	415	+40	7,5	53.39	40.51,9
420	+52	7,0	37.17	52.22,9	452	+37	7.4	54.18	38. 6,8
375	+53	8,8	37.25	53.26,7	450	+39	7,9	54.29	39.29,0
368	+54	7,0	37.47	54.23,0	421	+40	7,1	54.41	40.52,6
424	+52	8,3	37.58	52.41,2	392	+38	7,8	54.48	39. 7,4
360	+42	7,6	38. 5	42.44,3	423	+40	7,3	55. 9	40.43,7
361	+42	8,2	38.13	43. 8,7	437	+53	8,9	55.22	53.32,0
433	+52	8,6	39.43	53. 6,4	439	+53	5,4	55.38	54. 0,3
364	+43	8,5	40.15	44. 8,8	454	+39	8,6	55.45	40.11,1
370	+42	8,6	40.17	43.12,3	444	+54	8,0	56.26	54.45,0
364	+40	7,8	40.37	41. 3,1	465	+37	8,1	56.38	38. 3,7
342	+41	8,8	1.41.11	+41.41,7	440	+53	7,6	1.56.45	+54.12,8

COMPARISON STARS FOR OBSERVATIONS OF EROS.

No.		Mag.	R. A. 1900,0	Dec. 1900,0.	No.		Mag.	R. A. 1900,0.	Dec. 1900,0.
	°		h m s	° ′		°		h m s	° ′
484 BD	+55	8,6	1.57. 4	+55.17,2	597 BD	+52	8.8	2.27.23	+52.57.9
468	+37	8,7	57. 5	38. 9,9	594	+51	8,8	27.40	51.32,0
448	+54	9,0	57. 6	54.38,4	587	+50	9,1	28.24	50.45,1
457	+39	9,1	57.45	39.34,5	546	+53	8,8	28.31	53.15,0
452	+54	8,0	57.58	54.16,6	547	+53	8,4	28.34	53.52,7
453	+54	6,6	58.17	55. 8,6	598	+51	8,0	29.15	52. 3.0
402	+38	8,0	58.43	38.57,3	599	+51	7,1	29.56	51.31,5
457	+54	9,0	59. 8	54.27,0	602	+52	8,7	30.52	52.22,7
464	+39	7,8	1.59.43	39.16,9	589	+50	8,6	31.23	50.26,1
451	+53	8,2	2. 0. 2	53.49,8	604	+51	9,0	31.37	51.38.7
408	+38	8,2	0.22	38.25.3	595	+50	8,5	32.25	50.21,1
468	+39	8,5	0.30	40. 7,3	733	+49	8,9	32.49	50. 5.3
453	+53	8,5	1.36	54. 7,7	609	+52	7,6	33.23	52.22,4
486	+37	5,0	2.26	37.23,1	601	+50	8,4	33.42	51.11,6
527	+55	9,1	2.48	55.22,8	567	+40	8,7	34.12	40.53.2
416	+38	7,3	2.49	38.52,4	741	+49	9,3	34.18	49.35.0
488	+37	8,6	2.54	38. 3,4	743	+49	9,1	34.25	49.41,4
469	+54	8,8	3. 9	55. 0,8	616	+51	8,8	35.21	52. 0,4
459	+53	8,2	3.21	53.51,5	609	+39	9,0	35.38	40. 4.7
460	+53	6,2	3.24	53.22,3	570	+40	7,5	35.38	40.58,0
470	+54	8,9	3.28	54.49,2	618	+51	9,1	35.39	51.28.5
470	+53	8,5	4.59	54. 4,8	517	+41	8,2	35.47	41.44.9
483	+54	8,7	6.11	54.38,5	616	+52	6,2	35.56	53. 6,0
474	+53	8,2	6.26	53.45,0	617	+52	9,2	36.20	52.19,8
494	+54	7,5	7.42	54.51,0	610	+42	8,4	36.34	42.35,1
485	+53	9,0	7.57	53.34,5	620	+51	9,6	36.38	51.59,3
486	+53	7,8	8. 5	54. 3,9	613	+50	8,4	36.40	51. 6,5
551	+55	8,1	8. 6	55.16,8	752	+49	8,6	36.46	49.57.6
497	+54	7,1	8.17	54.37,3	753	+49	9,3	36.48	50.10,3
549	+52	8,4	8.28	53. 6,7	613	+42	8,6	37. 5	42.46.9
500	+54	7,9	8.34	55. 7,7	614	+42	7,3	37. 6	43. 6,8
494	+53	8,6	11. 6	54. 0,1	615	+42	8,8	37. 6	42.11,8
511	+54	8,6	11.35	55. 4.7	577	+40	7,5	37.21	41. 4,4
497	+53	7,8	11.34	53.49,0	746	+48	4,0	37.21	48.48,4
501	+53	8,7	12. 6	53.38,0	617	+50	8,9	37.24	50.48,0
563	+52	8,5	12. 6	53. 6,9	566	+43	6,5	37.34	43.52,3
525	+54	6,5	14. 4	54.56,9	581	+40	9,0	37.53	40.21,6
507	+53	6,0	14.20	54. 3,1	622	+46	7.9	37.53	46.25.3
513	+53	8,8	14.54	53.47,5	582	+40	8,6	37.56	40.41,0
530	+54	9,2	15.44	54.37,4	620	+50	8,4	38. 5	50.18,3
535	+54	6,2	16.54	54.54,6	569	+44	8.1	38.12	45.10,6
519	+53	8,4	17.20	53.44,2	623	+50	8 8	38.33	51. 9,8
521	+53	8.4	17.29	53.19,2	750	+48	8.3	38.56	48.32,2
576	+52	8.8	17.35	52.59,6	692	+47	8,3	38.58	47.43.3
539	+54	7.6	18.14	54.48,1	530	+41	8,6	39.12	42. 6 3
580	+52	8,7	19. 3	52.55,0	628	+46	9,0	39.23	46.48,7
525	+53	8.4	19.30	53.40,5	627	+50	8,4	39.29	50.11,8
581	+52	8,7	20.30	53. 3,0	589	+40	8,0	39.29	40.29.4
554	+54	8,4	21.46	54.31,6	752	+48	9,0	39.35	48.56,4
585	+52	9,2	21.54	53. 5,6	628	+39	7,9	39.38	40.11,5
587	+52	8,5	22.52	52.36,9	573	+44	8,5	39.44	45. 1,8
532	+53	8,2	23. 5	53.24,4	590	+40	8,8	39.47	41. 2,4
565	+54	8,5	24.33	54.27.1	626	+51	9,0	39.53	51.47,1
587	+51	9,2	24.57	51.51,8	574	+43	7,9	40. 1	43.20,7
592	+52	8,3	25. 3	52.23,5	628	+51	8,9	40. 7	51.43,7
539	+53	8,8	25.30	53.52,0	660	+45	7,2	40.34	45.29,8
540	+53	9,3	25.49	53.32,1	538	+41	8,0	40.42	41.45,3
541	+53	7,2	25.55	54. 6,2	628	+42	7,6	40.53	42.59,0
595	+52	8,6	2.27.16	+52.23,5	576	+43	7,0	2.40.59	+43.51,2

COMPARISON STARS FOR OBSERVATIONS OF EROS.

No.		Mag.	R. A. 1900,0.	Dec. 1900,0.	No.		Mag.	R A. 1900,0.	Dec. 1900,0.
	°		h m s	° ′		°		h m s	° ′
577 BD	+44	8,8	2.41. 1	+44.50,8	610 BD	+40	8,5	2.43.51	+40.24,3
773	+49	9,1	41. 5	49.39,6	711	+47	7,9	43.53	47.52,6
630	+50	7,9	41. 6	51. 8,0	665	+45	8,8	44. 0	45.25,4
698	+47	8,4	41.20	47.46,7	612	+40	9,3	44. 6	40.53,0
760	+48	8,9	41.25	48.48,1	638	+42	7,6	44. 6	42.54,0
541	+41	9,0	41.26	41.27,0	550	+41	8,7	44. 7	41.31,8
636	+50	7,6	41.36	50.28,8	586	+43	8,7	44. 7	43.56,7
700	+47	8,3	41.43	48. 2,2	667	+45	8,2	44. 9	45.39,5
579	+43	7,5	41.43	43.12,3	770	+48	8,7	44.20	48.56,2
638	+46	8,7	41.50	46.32,8	714	+47	8,3	44.40	48. 5,6
762	+48	8.0	42. 1	48.46.0	669	+45	8,4	44.54	45.34,6
602	+40	8,8	42. 4	40.33,7	648	+46	6,4	45. 0	46.25,8
543	+41	8,8	42.12	41.59,9	591	+44	7,8	45. 7	44.38,8
633	+42	8,9	42.13	42.18,9	593	+44	7,0	45.17	44.28,9
702	+47	8,0	42.19	47.12,6	777	+48	8,3	45.20	48.28,3
763	+48	8,4	42.27	48.53,1	720	+47	9,1	45.37	47.30,1
641	+46	7,5	42.28	46.48,1	782	+48	8,9	45.39	49. 5,4
633	+51	8,6	42.28	51.13,6	721	+47	8,5	45.51	48. 0,5
580	+43	9,0	42.35	43.53,9	593	+43	8,8	45.53	43.21,7
764	+48	8,6	42.43	48.27,8	556	+41	7,2	45.54	41.36,6
662	+45	8,2	42.55	45.59,2	643	+42	9,1	46. 6	42.21,5
782	+49	9,0	42.59	49.35,9	652	+46	7,4	47.16	46.45,2
582	+44	8,6	43. 5	44.59,3	650	+42	8,9	48.26	42.48,4
709	+47	7,7	43.21	47.43,9	656	+46	7,3	48.48	46.53,9
583	+43	8,9	43.26	43.23,9	679	+45	8,7	49.15	45.26,1
637	+42	9,1	43.27	42.23,1	598	+44	8,9	2.49.29	+44.34,7
644	+46	9,2	2.43.34	+46.59,9					

Table giving, in mean time, the approximate limits between which the altitude of Eros above the horizon is greater than 20° for the dates and latitudes indicated.

	Oct. 9.			Oct. 19.			Oct. 29.		
°	h m		h m	h m		h m	h m		h m
36…………	6.51	to	20. 9	5.52	to	19.34	4.47	to	18.51
37…………	6.46		20.14	5.46		19.40	4.41		18.57
38…………	6.41		20.19	5.40		19.46	4.34		19. 4
39…………	6.36		20.24	5.34		19.52	4.27		19.11
40…………	6.30		20.30	5.28		19.58	4.20		19.18
41…………	6.25		20.35	5.21		20. 5	4.13		19.25
42…………	6.19		20.41	5.14		20.12	4. 5		19.33
43…………	6.13		20.47	5. 7		20.19	3.57		19.41
44…………	6. 7		20.53	4.59		20.27	3.49		19.49
45…………	6. 1		20.59	4.51		20.35	3.40		19.58
46…………	5.54		21. 6	4.43		20.43	3.31		20. 7
47…………	5.47		21.13	4.35		20.51	3.21		20.17
48…………	5.40		21.20	4.27		20.59	3.11		20.27
49…………	5.32		21.28	4.18		21. 8	2.59		20.39
50…………	5.24		21.36	4. 8		21.18	2.47		20.51
51…………	5.16		21.44	3.57		21.29	2.34		21. 4
52…………	5. 7		21.53	3.46		21.40	2.21		21.17
53…………	4.57		22. 3	3.34		21.52	2. 2		21.36
54…………	4.47		22.13	3.19		22. 7	1.39		21.59
55…………	4.36		22.24	3. 3		22.23	1.14		22.24
56…………	4.26		22.34	2.46		22.40	0.47		22.51
57…………	4.12		22.48	2.23		23. 3	—		—
58…………	3.56		23. 4	1.55		23.31	—		—
59…………	3.39		23.21	—		—	—		—
60…………	3.19		23.41	—		—	—		—
Meridian Passage at Paris	13^h30^m			12^h43^m			11^h49^m		

Table giving, in mean time, the approximate limits between which the altitude of Eros above the horizon is greater than 20° for the dates and latitudes indicated.

	Nov. 8.		Nov. 18.		Nov. 28.		Dec. 8.		Dec. 18.		Dec. 28.	
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
36...	3.44	17.56	2.49	16.53	2. 7	15.53	1.40	14.58	1.23	14.13	1.16	13.38
37...	3.37	18. 3	2.42	17. 0	2. 1	15.59	1.35	15. 3	1.19	14.17	1.13	13.41
38...	3.30	18.10	2.35	17. 7	1.55	16. 5	1.30	15. 8	1.15	14.21	1. 9	13.45
39...	3.23	18.17	2.28	17.14	1.49	16.11	1.25	15.13	1.11	14.25	1. 5	13.49
40...	3.16	18.24	2.21	17.21	1.43	16.17	1.19	15.19	1. 6	14.30	1. 1	13.53
41..	3. 8	18.32	2.14	17.28	1.36	16.24	1.13	15.25	1. 1	14.35	0.57	13.57
42...	3. 0	18.40	2. 6	17.36	1.29	16.31	1. 7	15.31	0.56	14.40	0.54	14. 0
43...	2.52	18.48	1.58	17.44	1.22	16.38	1. 1	15.37	0.51	14.45	0.50	14. 4
44...	2.43	18.57	1.50	17.52	1.14	16.46	0.55	15.43	0.46	14.50	0.46	14. 8
45...	2.34	19. 6	1.41	18. 1	1. 6	16.54	0.49	15.49	0.41	14.55	0.42	14.12
46...	2.24	19.16	1.32	18.10	0.58	17. 2	0.42	15.56	0.36	15. 0	0.38	14.16
47...	2.14	19.26	1.22	18.20	0.50	17.10	0.36	16. 2	0.30	15. 6	0.34	14.20
48...	2. 3	19.37	1.11	18.31	0.42	17.18	0.29	16. 9	0.24	15.12	0.29	14.25
49...	1.51	19.49	0.59	18.43	0.32	17.28	0.21	16.17	0.18	15.18	0.24	14.30
50...	1.37	20. 3	0.48	18.54	0.22	17.38	0.13	16.25	0.12	15.24	0.19	14.35
51...	1.22	20.18	0.35	19. 7	0.11	17.49	0. 5	16.33	0. 6	15.30	0.14	14.40
52...	1. 7	20.33	0.20	19.22	0. 1	17.59	−0. 4	16.42	−0. 1	15.37	0. 8	14.46
53...	0.45	20.55	−0. 1	19.43	−0.13	18.13	−0.14	16.52	−0. 8	15.44	0. 3	14.51
54...	0.20	21.20	−0.25	20. 7	−0.28	18.28	−0.24	17. 2	−0.16	15.52	−0. 3	14.57
55...	−0. 9	21.49	−0.52	20.34	−0.44	18.44	−0.35	17.13	−0.24	16. 0	−0. 9	15. 3
56...	—	—	−1.21	21. 3	−1. 2	19. 2	−0.46	17.24	−0.33	16. 9	−0.15	15. 9
57...	—	—	—	—	−1.27	19.27	−1. 1	17.39	−0.43	16.19	−0.22	15.16
58...	—	—	—	—	−1.57	19.57	−1.17	17.55	−0.53	16.29	−0.29	15.23
59...	—	—	—	—	—	—	−1.35	18.13	−1. 4	16.40	−0.37	15.31
60...	—	—	—	—	—	—	−1.55	18.33	−1.14	16.50	−0.45	15.39
Meridian Passage at Paris	10h.50m		9h.51m		9h.0m		8h.19m		7h.48m		7h.27m	

SUCCESSIVE POINTS ON THE APPARENT PATH OF EROS, ONE DEGREE OF ARC APART.

Dates.	R. A.	Decl.	Dates.	R. A.	Decl.
	h m s	° ′		h m s	° ′
Sept. 19.50	2.39. 3	+40.24.2	Nov. 24.00	1.33.33	+52.32.0
22.00	2.40.38	+41.21.4	27.26	1.30. 6	+51.41.0
24.54	2.41.57	+42.19.5	30.40	1.27.51	+50.44.9
27.12	2.42.59	+43.18.3	Dec. 3.39	1.26.45	+49.45.9
29.75	2.43.43	+44.17.9	6.23	1.26.37	+48.45.9
Oct. 2.42	2.44. 6	+45.17.8	8.90	1.27.19	+47.46.2
5.14	2.44. 0	+46.17.8	11.41	1.28.40	+46.47.7
7.90	2.43.31	+47.17.5	13.78	1.30.34	+45.51.0
10.71	2.42.27	+48.16.6	16.02	1.32.53	+44.56.2
13.56	2.40.51	+49.14.4	18.14	1.35.32	+44. 3.3
16.46	2.38.34	+50.10.0	20.16	1.38.28	+43.12.4
19.41	2.35.37	+51. 3.0	22.10	1.41.39	+42.23.0
22.40	2.31.56	+51.52.0	23.95	1.44.57	+41.35.6
25.44	2.27.33	+52.36.0	25.72	1.48.26	+40.50.1
28.54	2.22.26	+53.14.0	27.44	1.52. 1	+40. 5.7
31.70	2.16.39	+53.44.7	29.10	1.55.43	+39.22.9
Nov. 3.91	2.10.22	+54. 6.8	30.70	1.59.27	+38.41.6
7.18	2. 3.44	+54.19.2	Jan. 1.25	2. 3.15	+38. 1.6
10.51	1.56.54	+54.20.7	2.76	2. 7. 7	+37.22.7
13.88	1.50. 7	+54.10.4	4.24	2.11. 1	+36.44.5
17.27	1.43.46	+53.48.5	5.68	2.14.57	+36. 7.5
20.66	1.38.10	+53.15.1	7.09	2.18.55	+35.31.1

THE PLANET EROS.

W. W. PAYNE.

The planetoid Eros (433) is now occupying the attention of working astronomers more than any other one celestial object. On this account it will be of interest to many of our readers to have a re-statement of the principal facts about this new planet:

It was discovered by Witt of Berlin on August 13, 1898, when it appeared as a star of only the 11th magnitude. Its discovery, however, was not announced by telegraph until Sept. 5, which gave some information of its remarkable orbit which was then known to be in part, at least, within the orbit of planet Mars. An announcement of this discovery promptly appeared in the foreign scientific journals, especially in the *Astronomische Nachrichten*, No. 3512, in which attention was called to the rapid motion of the planet, which, on the average, was about 2000 seconds of arc daily.

During the same month and under date of Sept. 30, Professor E. C. Pickering of the Harvard College Observatory published a circular, which was numbered 34 in the regular series, setting forth much important information about the new, little planet. From the data then known relating to its path, it was found that its minimum distance from the Earth, where the orbit lies near the path of the Earth, was only 15,000,000 of miles. The importance of this interesting fact will at once appear, when it is remembered that the nearest approach of the planet Mars to the orbit of the earth is about 35,000,000 of miles, and that the Earth and Mars are so related in nearness of position, only once in 15 or 17 years. Since the planet Eros is distant from the Earth, at times of favorable opposition only 15,000,000 it is evident that this planet furnishes a most favorable means for the study of parallax, and astronomers are using the present opposition of the planet as an opportunity for prosecuting work of this kind most vigorously. For those who do not know how the parallax of the planets is determined approximately, it may be said that the parallax of Venus or Mars when nearest is only about 40 seconds of arc, a very small angle to measure accurately. The parallax of Eros is nearly 60 seconds of arc which, of course, is a more favorable angle for measurement on account of its increased size.

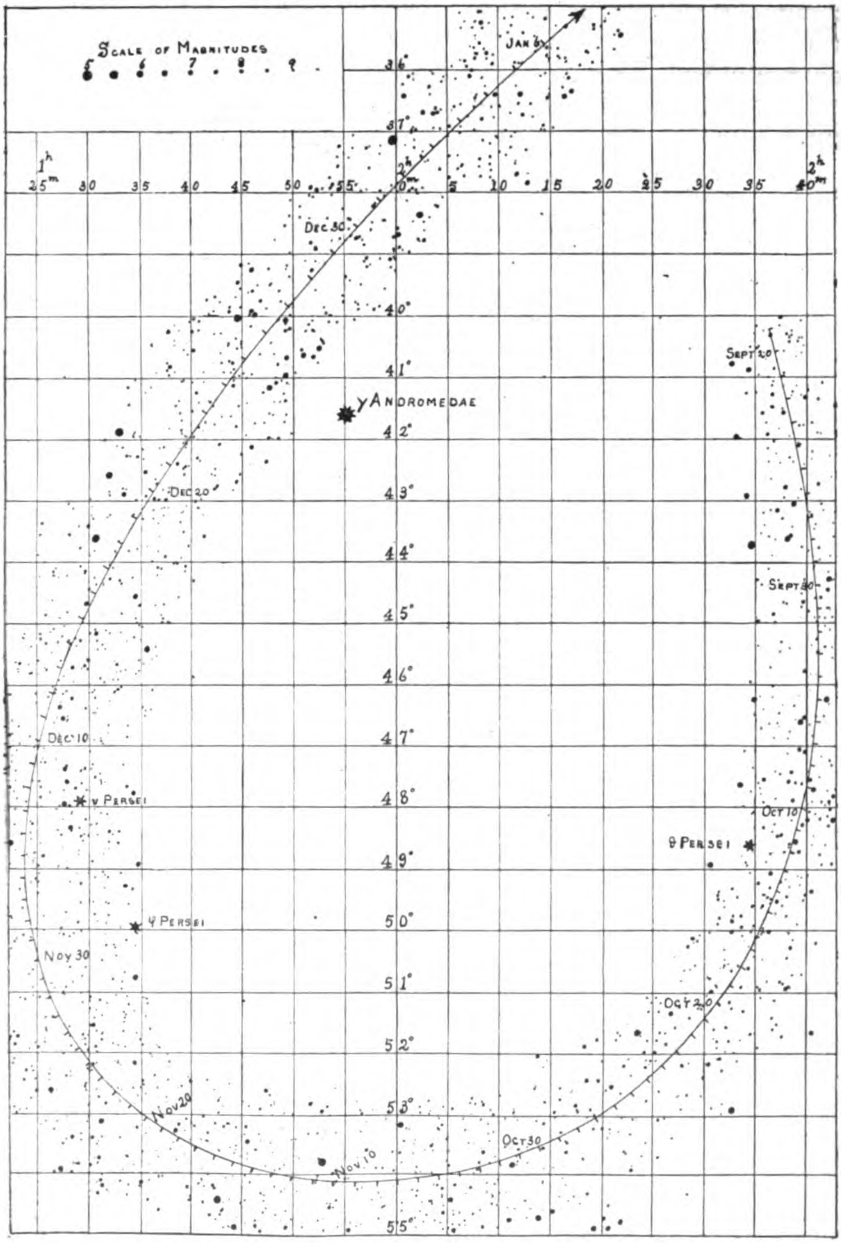
Astronomers know very accurately the ratio distances of all the planets in the solar system in units of the Sun's distance.

Now, if the parallax of any one planet can be obtained very accurately then the distance of all will be known, including that of the Sun in miles or other terrestrial units. This is the same old problem that has been before the minds of the students of the heavens since the dawn of the science of Astronomy.

The methods of the New Astronomy offer some advantages in the study of the problem. Photography is being used at a number of the larger observatories. But some difficulties are met in the work on this new planet which act as somewhat of a drawback, in the use of this favorite way of determining the places of the planet at specific times so as to map its path among the stars during the next few months to come. In the Harvard College Circular just referred to it was said that short exposures of Eros could not be used to determine the photographic brightness of the planet because it was so faint and its motion so rapid. Long exposure could not be used because the planet's trail could not be compared with the circular images of the stars near by to determine the planet's brightness relatively. The point of interest to observers now is can these planet trails on the photographic plates be used to determine the exact places of Eros in reference to adjacent stars, so that measures on the photographic plates may be employed to get the parallax of the planet. If so it will certainly give aid in the prosecution of this work in connection with the measures by the micrometer with visual objectives of a large aperture.

The photographic plan being tried at Goodsell Observatory with the 8¼-inch Clark refractor is to make exposures of plates for different lengths of time. The longer exposures to be broken for brief intervals at certain times which will be recorded on the chronograph. From such attempts already made, it seems clear that measures from the beginnings and ends of these trails, as points, may be taken to near stars that may be identified, on the plates, and in this way an accurate place of the planet may be known at the particular time of the observation. How well this plan will work out photographically we are not yet able to say, but we hope for results in a few days, if the nights are favorable.

The work of determining the places of Eros on every clear night by the aid of the micrometer and the 16 inch equatorial is carried forward with much interest and ease. It is not at all difficult to "pick up" the planet in the large instrument because of its rapid motion. By looking at such a chart of the path of Eros as ac-



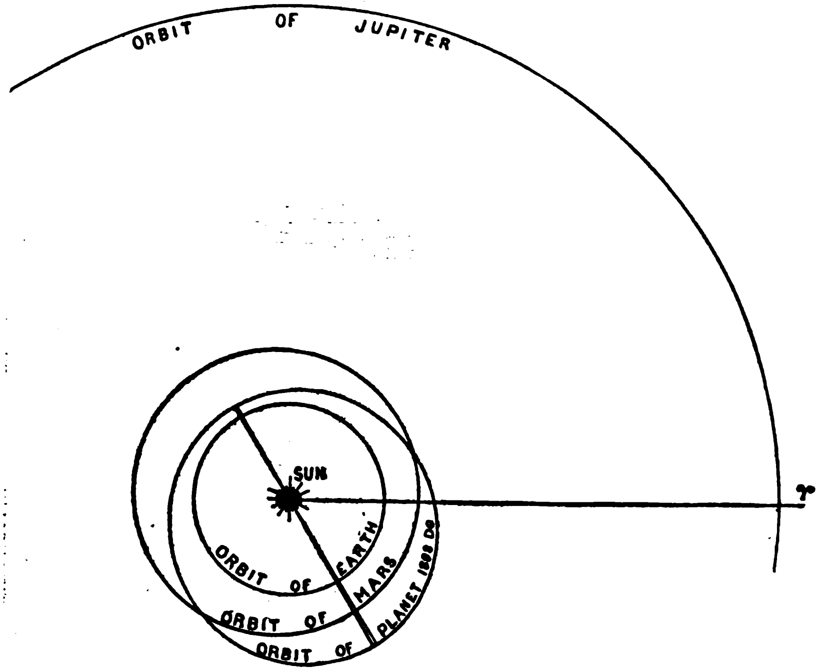
THE APPARENT PATH OF EROS AMONG THE STARS,

From Sept. 20, 1900, to Jan. 6, 1901.

The positions platted are for the epoch 1855. The precession to 1900 is approximately + 3^m in R.A. and + 12′ to 14′ in Dec.

companies this article one can pretty certainly locate the moving star, which is easily and certainly determined in a few minutes by the aid of the micrometer wires and known adjacent stars.

For the aid of those who may not have seen a chart containing the orbits of the Earth, Mars, Eros and Jupiter we re-print one herewith that was used in October 1898, when the planet was called DQ, and before it was named Eros.



THE ORBIT OF EROS.

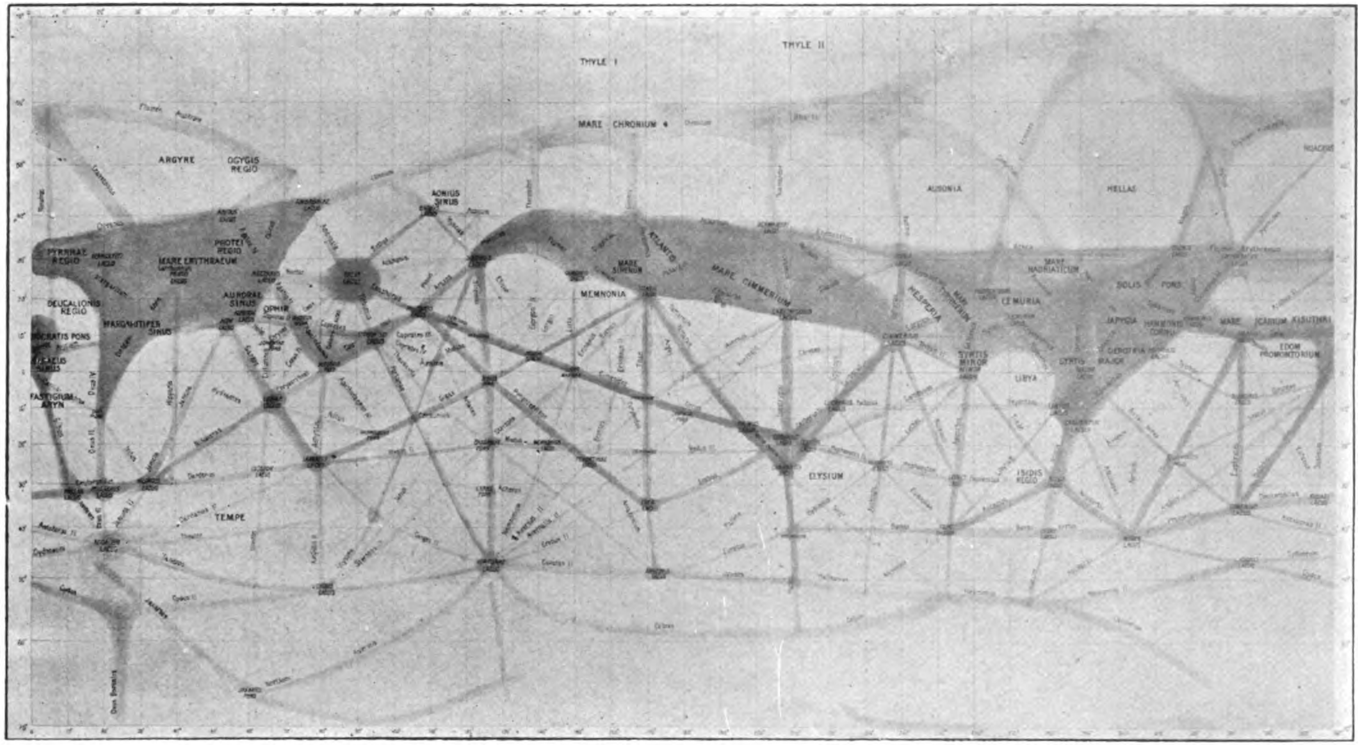
At another time more will be said of the details of both the photographic and the micrometric methods of determining the parallax of Eros.

RECENT WORK AT THE LOWELL OBSERVATORY.

W. W. PAYNE.

We have received Volume II of the Annals of the Lowell Observatory, the observations of which were made at Flagstaff, Arizona, and Tacubaya, Mexico, on Jupiter and his satellites in 1894 and 1895 and on Mars in 1896 and 1897. In July 1896, Mr. Lowell, the director of the Observatory received from Alvan Clark and Sons the new 24-inch telescope with which the astro-

PLATE XVIII.



Map of Mars, 1896–7.

Popular Astronomy No. 78.

Annals of Lowell Observatory, Vol. II.

nomical work of the Observatory was continued as mentioned above. In the completion of this telescope, utting it in place in the Observatory, and in adjusting it, Mr. Alvan G. Clark was much interested, as those who were present at the time very well know, and they speak of it really as his last work in the line of telescope-making. Those who have used this noble instrument are unsparing in praise of its fine—even its superb qualities.

In November of this year the entire Observatory was removed to Tacubaya, a suburb of the city of Mexico, where it remained until the end of March 1897, at which time it was removed again to Flagstaff where it has since remained.

In the Annals so far published, Volume I gives the complete work on Mars in the years 1894 and 1895. The volume before us "completes the strictly astronomical work of that year by giving that done on Jupiter and its satellites." The volume also commences the publication of subsequent work with the 24-inch instrument by presenting that on Mars in the second observational year, and the third year of the Observatory. This volume is therefore occupied with work relating to two objects: Mars and Jupiter and its satellites.

The observations on Jupiter in 1894 were made by William H. Pickering and those in 1895 by A. E. Douglass. Together they make the first long series of physical observations of the planet Jupiter and its satellites known to us. In this statement we do not forget the long, skillful and painstaking work of Professor G. W. Hough, of Dearborn Observatory, now of Evanston, Ill., who for more than twenty years, has been giving more or less attention to the surface markings of Jupiter, and who is estemeed a high authority, by astronomers generally, in relation to the physical characteristics of the planets.

The larger part of the work on the Jovian system in this was done by William H. Pickering, whose methods of research in 1895, were especially well adapted to gain the information desired. Later it fell to Mr. A. E. Douglass to carry through the mathematical part of this work by his own methods, yet with the consent of Professor Pickering. One peculiarity is noticeable in these observations and that is, that they are given complete in the original form in which they were made. The reasons assigned are two: one, because they are the first extensive, systematic study of the kind ever made, and second, because in most of the work the observer and the reducer were two different persons, and the equations of each enter into the results.

The observations of Mars were made by Mr. Lowell, the

Director, assisted by Mr. D. A. Drew, Miss W. L. Leonard and Mr. A. E. Douglass. Dr. T. J. J. See and Mr. W. A. Cogshall were also members of the Observatory, and made occasional observations. Mr. Douglass did, or had charge of, the reductions and the analytic study, save the tables of diameters by Mr. Lowell and such short preliminary articles as have been previously published by other persons belonging to the Observatory.

This quarto volume consists of 523 pages and, in general appearance is like the Harvard College Observatory Annals.

One distinguishing feature in addition to those already mentioned is the number and character of the plates and drawings. The first is a full page plate showing nine figures of Mars in color, representing the planet as seen between Jan. 9, and March 27, 1897. The drawings were made by Mr. Lowell and the reproductions are facsimiles that give a very close representation of the telescopic view in a large instrument, as we remember the appearance of the planet at that opposition. The heliotype printing of the plate is well done.

The observations and drawings of the Satellites of Jupiter by William H. Pickering together make a noble piece of astronomical work, for completeness and thoroughness in detail. On looking over this part of the volume we are reminded of the criticisms that were made upon some parts of it while it was in progress and the preliminary results only had been given to the scientific Journals. From the full representations given and the detailed observations that accompany them, it does not seem possible that Professor Pickering could have been mistaken in what he saw, or, even wrong in the general interpretations and conclusions which he drew from those observations.

If the observations had been irregular, less systematic and less extended, as must be said of other observers fairly when put in comparison with this series, then some of the objections offered might have more probability.

The lithographic work representing the markings of the four satellites of Jupiter is presented in many full-page plates, on which are given from a few to fifty drawings of each satellite by itself with the hour in Greenwich time and the position of the central meridian. The ellipticity of these satellites as well as their surface markings are objects of very great interest. It is especially surprising that the ellipticity of the different satellites should vary so much, and we do not see how the figures of the satellites could be differently drawn from the numerical results of observation which are given so fully in detail.

The planet Jupiter is not figured, but the measures of the equatorial and polar diameters are given and the mean of these is $\frac{1}{16.11,}$ somewhat greater than the value that has been generally accepted, that being about $\frac{1}{17.}$

The results of work on the satellites of Jupiter may be briefly stated as follows:

Satellite I appears to be a prolate spheroid revolving, end over end, about one of its minor diameters in a period of $13^h\ 00^m\ 38^s$ according to observations in 1894. In 1895 the period was within one minute of time of the same quantity. The axis of rotation is very nearly perpendicular to the plane of the orbit of the satellite, and the greater diameter seems to be inclined about 4° to the plane of the orbit, or 86° to the axis of rotation. The statement made by the author concerning these details is that they were seen without difficulty, and consisted of north and south lines, or belts, frequently bent at the center, and an occasionally bright equatorial belt.

Satellite II is the most difficult of the four, and very little in detail was learned about it by observation. An elliptical form is suspected and a north and south belt is thought to exist extending in a direction parallel to the supposed elongation.

Satellite III apparently has but slight ellipticity in a direction perpendicular to its orbit. Fifteen drawings of this satellite were made and the more conspicuous markings were a northern belt, rarely a central, forked belt, and once a southern belt. The white cap at the north pole of the satellite in 1894 and 1895 was a conspicuous object, and carefully observed at Mt. Hamilton as well as at the Lowell Observatory. In the 24 inch instrument this white north polar cap appeared to be associated with the northern belt, and the author of this description suggests that it is probable that one may be a contrast effect of the other. The time of rotation of this satellite is given as $2^d\ 9^h$ as determined by observations of this northern belt.

Satellite IV has a period of rotation of about five days, a time probably identical with its period of revolution about its primary. The markings on this satellite are an equatorial belt, sometimes forked, and on one date a well-marked southern belt, with a bright south polar cap. The drawings of 1894 and 1895 are in good agreement. The form of the fourth satellite is thought to be like that of the third, a prolate spheroid, keeping the same face, constantly toward its primary, and turning on an axis inclined only 15° to its greatest diameter.

These satellites have different colors. "If the first is taken as a standard yellow, the second satellite has a trifle of red with it, the third a little green, and the fourth has red and green with only a little of the yellow."

The work on the planet Mars was done in the years 1896 and 1897 with the 24-inch Clark refractor. The range of positive eye-pieces used was of powers 186 to 1580. The least and the greatest negative eye-pieces were of powers 129 and 4138. The subjects of study were the polar caps of the planet, the diameters of the planet and the positions of the markings on the surface, the drawings and notes, the map of the surface for 1896-7, the double canals and the canals in the dark regions, the seasonal changes, limb and terminator observations and a summary of notes upon the meteorology and surface condition of Mars. Over one-half of this large volume is devoted to this planet. The deductions made from this large amount of observational matter may be briefly presented under a few heads as follows:

1. Concerning the existence of an atmosphere on the planet, the Flagstaff observers say: "Evidence is given of the existence of simple meteorological phenomena, occurring on Mars, the migration of the heat equator, the winds toward it and from it causing an interchange between the poles and the equator, cyclonic storms and diurnal effects. This, so far as it goes, sustains the idea that the meteorology of Mars is similar to our own, save in the changes caused by the limited water supply." As the polar caps sometimes disappear the heat equator must sometimes practically reach to the pole. This has never happened on the Earth in historic time, although geology and astronomy point to such possibilities at some remote time in the past.

2. In regard to moisture it is said that the quantity is very small, and appears chiefly at the heat equator, at certain seasons and near the polar regions. The increase in the polar indicates an increase of moisture in the late Martian autumn and winter, rising to maximum in the late winter, lessening in the spring and disappearing in the summer. It is an interesting sight to see one polar cap decreasing and vanishing when the cap at the opposite pole is forming and increasing. "This indicates an interchange of moisture between the summer and winter hemispheres. Radiation and polar clouds are the more common forms on Mars; cyclonic

and convectional clouds are very rare." It seems as if the larger transportation of moisture is aerial, while that on the surface of the planet is more limited.

3. The question of temperature has always been one of the most interesting ones in the study of the physical conditions of the planet. A knowlege of the temperature ought to aid in the explanation of the dark areas which are variable and therefore difficult to measure. It is noticed that the color of the dark markings in high latitudes changes from green, at the melting of the polar caps, successively to brown and yellow as the cap disappears. These changes are so much like those of the Earth, in regions near the equator, that there is reason to suppose that the dark markings on the planet mean vegetation. From all that can be gathered, it would seem that the mean temperature of the poles of the planet is likely not far below freezing point, and that the contrast between night and day is considerable.

The beautiful plate which is numbered XLI in the volume is reproduced to bring to the eye of the reader, a view of all the dark markings on entire surface of the planet to 70° of latitude north and south of the equator, as an aid to the description that precedes.

We ought to say in this connection that we have just received an interesting publication from V. Cerulli of the private Observatory at Collurania, which gives quite fully the observations of Mars for the years 1898 and 1899, and which contains all of the surface markings of the planet as seen two years later, which are presented also in a chart on about one-half the scale of the one prepared at Flagstaff. It will be profitable later to make a careful comparison of these two volumes giving study to the planet Mars, to so late a date.

SPECTROSCOPIC NOTES.

Spectroscopic science has suffered a severe loss in the sudden death Aug. 12 at San Francisco of Prof. James Edward Keeler, Director of the Lick Observatory.

Prof. Keeler's early experience in spectroscopic work was as a graduate student at Johns Hopkins University and as assistant in the spectroscopic and bolometric work of the Allegheny Observatory.

Leaving Allegheny for the Lick Observatory in the early history of that institution he there made his classical research on the motion of nebulæ in the line of sight, (*Publications of the Lick Observatory, Vol. III*). In this work he used a grating spectroscope attached to the 36-inch equatorial, using chiefly the third and fourth order spectra in order to secure the necessary dispersion. The uncertainty with regard to the absolute position in the spectrum of the chief nebula line he sought at first to remove by assuming that the average velocity of the nebulæ measured was zero; an assumption admittedly dangerous on account of their small number and their unsymetrical distribution in the sky. Later the motions of the nebula of Orion and of the nebula G. C. 4390 were measured by a fine series of comparisons of the position of the *F* line of hydrogen as shown by these nebulæ with the position of the same line given by terrestrial hydrogen; the position of the chief nebula line as determined by comparison with a neighboring lead line was in each corrected for nebular motion and so was fixed definitively λ 5007.05 ± 0.03. The motions of the nebulæ were shown to be of the same order as those of the stars, ranging from 40.2 miles per second of approach to 30.1 miles per second of recession; with an average motion of perhaps 15 miles per second. The measures further showed indubitably a motion of the solar system in the direction previously indicated by proper motions of the stars.

Leaving the Lick Observatory after the completion of his work on the motion of the nebulæ Prof. Keeler was appointed Director of the Allegheny Observatory. Here his spectroscopic work was photographic. The plates used were usually isochromatic, which admitted of valuable work on the yellow and orange of the star spectra. Prof. Keeler's most conspicuous contribution to spectroscopic science during his residence at Allegheny was his spectroscopic confirmation of the meteoric constitution of Saturn's rings. In photograping the spectrum of Saturn for this purpose the isochromatic plates were sufficiently sensitive to allow the use of the yellow of the spectrum, while the granulation of the plates was sufficiently fine to permit the detection of inclination of excessively short spectral lines obtained from the small image of the planet given by the Allegheny telescope. The slit of the spectroscope was placed along Saturn's equatorial diameter, cutting the ball of the planet, and, beyond the vacant interval at each side, the rings. The lines in the spectrum due to the ball of the planet were inclined so as to indicate a rotation of the planet, though not to determine this rotation so accurately as it had been otherwise derived. The lines due to the rings were also inclined, but in the opposite direction, demonstrating that the inner edge of the ring moves faster than the outer; which is clearly impossible if the rings are solid.

The character and promise of Prof. Keeler's work was such as very properly to inspire a desire on the part of the citizens of Pittsburg and Allegheny that a large telescope should be available for its prosecution. Accordingly a movement was inaugurated for the erection of a 30-inch telescope and the removal of the Observatory to a new and more suitable site. Measures were being energetically taken to this end when the project was interrupted by circumstance arising from the outbreak of the Spanish war.

On the delay then ensuing Prof. Keeler accepted the offer of the position of Director of the Lick Observatory, which he held at the time of his death. Here, with what seems certainly rare generosity, he resigned not only the spectroscopic work of the Observatory, but the use of the great refractor as well, into other hands, and, discontinuing his spectroscopic work, has been engaged in securing his remarkable series of photographs with the Crossley refractor.

In the *Astrophysical Journal* for July, Exner and Haschek give measures of silicon lines, completely confirming Mr. Lunt in attributing certain lines in the spectra of several stars to silicon.

In the *Philosophical Magazine* for September Prof. Trowbridge describes his experiments on the spectra of hydrogen. The four line spectrum he found very readily produced in the presence of water vapor. The presence of the four line spectrum of hydrogen in the sun he regards as substantial evidence in favor of the presence in the sun of water vapor, and consequently of oxygen.

The *Astrophysical Journal* for July devotes fifty pages to American eclipse reports from the various parties along the path of totality. Spectroscopic work constitutes a considerable part of the total work of the larger parties.

The Naval Observatory was represented by three parties, two near the central line, at Pinehurst, N. C., and at Barnesville, Ga., and one just inside the northern limit of totality, at Griffin, Ga. The equipment included a prismatic camera, a slitless spectrograph, two grating objectives, and three concave gratings. The observations with the concave gratings for various reasons all failed. Dr. Huff with a grating objective (plane grating with quartz lens) at Pinehurst obtained three successful plates, one giving four corona lines in the ultra-violet. With the prismatic camera, using erythro plates, a good photograph of the spectrum of the flash was obtained, showinga large number of bright lines, including six or eight in the red and orange between C and D_3. Prof. Lord's observations with objective prism train seem to indicate a very short duration of flash. Mr. Jewell at the station near the limit of totality was able to observe the gradual appearance of the reversal of the metallic lines; and infers that the chromosphere is dense at its base, probably merging into the upper photosphere.

With the Smithsonian party at Wadesboro, N. C., the objective prisim with the 135 ft. lens, which was responsible for the striking bifurcated appearance of that apparatus, for some unknown reason failed to give any results.

In the Princeton party at Wadesboro, N. C., Prof. Miller observed in the flash fewer lines than had been expected, and at mid totality saw eight bright rings. Prof. Young, contrary to his experience at three previous eclipses, was entirely unable to see the green corona line, and Mr. Russell was equally unsuccessful. The plate exposed in the large spectrograph especially with a view of determining the position of the corona line in the spectrum failed to show any trace of the line.

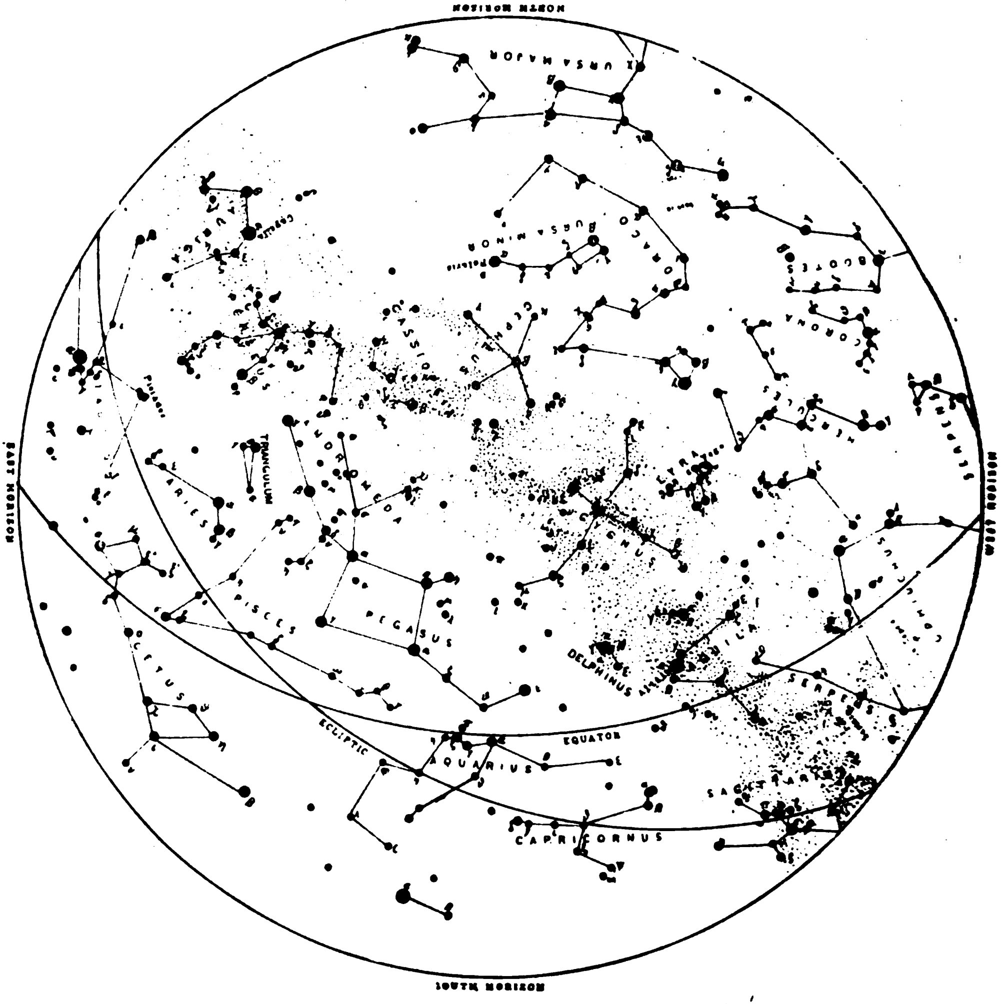
In the Yerkes Observatory, also at Wadesboro, Prof. Frost, assisted by Dr. Isham, obtained photographs of the flash spectrum at second and third contacts and of the spectrum of the cusps some seconds after totality. One plate of the violet part of the corona spectrum was secured, showing several chromosphere lines and one or possibly two corona lines. No results were secured from the attempt to obtain a photograph of the red end of the spectrum with a plane grating.

In the party from Brown University, stationed at Centerville, Va., Mr. Slocum used successfully a prismatic camera, securing plates which show a considerable number of bright lines, including prominently the chief chromosphere lines.

PLANET NOTES FOR OCTOBER.

H. C. WILSON.

Mercury will be evening star during this month, coming to greatest eastern elongation, 23°44′ from the Sun, on Oct. 29. The planet may then be seen near southwestern horizon soon after sunset, but only for a short time.



THE CONSTELLATIONS AT 9 P. M., OCTOBER 1, 1900.

Venus is the bright star in the east, rising a little before three o'clock and reaching the meridian about nine o'clock in the morning. Her course is south-eastward through Leo. On the morning of Oct. 7 Venus will be in conjunction with the first magnitude star Regulus, the former being about one degree north of the latter. The waning moon will be in conjunction with Venus on the 19th.

Mars rises toward the northeast about midnight, and moves eastward through Cancer during this month. The planet is conspicuous for its ruddy color to the naked eve, being a little redder and brighter than the star Aldebaran. The Moon will be in conjunction with Mars on the night of October 16. The distance of Mars from the Earth is about 158,000,000 miles and the apparent diameter of the disk of the planet is only six seconds, so that observations of its surface-markings are yet very difficult.

Jupiter, Saturn and *Uranus* are evening stars but too low in the southwest for observation except during the twilight.

Neptune rises between nine and ten o'clock in the evening and may be observed under favorable conditions during the latter half of the night. The position of the planet October 1 is R.A. 5^h 56^m 38^s, Dec. 22° 13′ 16″, North.

Eros—The *Astronomische Nachrichten* No. 3662 contains an extension of the ephemeris of Eros, by Millosevich, from Jan. 1 to April 1, 1901.

The Moon.

(Central Standard Time at Northfield; Local Time 13m less.)

		Phases.	Rises.		Sets.	
			h	m	h	m
Oct.	1	First Quarter...............	1	32 P. M.	10	59 P. M.
	8	Full Moon.....................	5	31 "	7	48 A. M.
	15	Third Quarter................	11	45 "	2	10 P. M.
	23	New Moon.....................	6	50 A. M.	5	06 "
	31	First Quarter...............	1	32 P. M.	12	15 A. M.

Occultations Visible at Washington.

				IMMERSION.			EMERSION.				
Date. 1900.		Star's Name.	Magnitude.	Washington M. T.		Angle f'm N pt.	Washington M. T.		Angle f'm N pt.	Duration.	
				h	m	°	h	m	°	h	m
Oct.	1	29 Sagittarii	5.5	8	32	17	9	15	308	0	43
	5	Lalande 44337	6.3	12	44	121	13	17	184	0	33
	6	9 Piscium	6 6	6	56	7	7	33	299	0	37
	6	16 Piscium	5.8	12	01	79	13	08	223	1	07
	6	19 Piscium	4.9	17	17	27	17	52	295	0	35
	10	13 Tauri	5.7	15	16	142	15	54	200	0	38
	12	ζ Tauri	3.3	11	27	75	12	33	275	1	06
	15	29 Cancri	6.0	16	07	76	17	18	324	1	11
	26	Uranus	.....	5	26	95	6	39	256	1	13
	27	52 Ophiuchi	6.5	5	32	50	6	39	290	1	07
	27	B.A.C. 5954	6.8	7	28	56	8	27	283	0	59
	29	B.A.C. 6658	7.3	7	56	11	8	33	307	0	37

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900.

U CEPHEI.

	d	h
Nov.	2	12
	5	0
	7	12
	10	0
	12	11
	14	23
	17	11
	19	23
	22	11
	24	22
	27	10
	29	22

λ TAURI.

	d	h
Nov.	4	8
	8	7
	12	6

ALGOL.

	d	h
Nov.	1	9
	10	0
	12	20
	15	17
	18	14
	21	11
	24	8

S CANCRI.

	d	h
Nov.	7	20
	17	8
	26	19

U CORONAE.

	d	h
Nov.	1	13
	5	0
	15	8
	22	6
	25	17

R CANIS MAJ.

$P = 1^d\ 3.3^h$.

Oct.	31	0
Nov.	30	16

Y CYGNI.

$2P = 2^d\ 23.9^h$.

Odd min.

Oct.	28	15
Nov.	27	15

W. DELPHINI.

	d	h
Nov.	4	12
	9	8
	14	3
	18	23
	23	18
	28	13

BD + 45°3062.

	d	h
Nov.	2	15
	7	5
	11	19
	16	9
	20	22
	25	12
	30	2

Maxima and Minima of Long Period Variables.

1900 December.

MAXIMA.

	Day.
SS Cygni	2?
T Eridani	4
RU Cygni	5
V Aquarii	6
T Centauri	6
RV Herculis	7
T Leporis	7
X Cassiopeae	8
U Arietis	9
RT Herculis	9
X Librae	9
T Camelopardalis	10
R Aquarii	11
Y Librae	11
V Cephei	12
W Persei	13
T Andromedae	15
Z Librae	15

MAXIMA, Con't.

	Day.
W Capricorni	16
X Delphini	17
R Virginis	17
W Librae	18
Z Ophiuchi	20
X Ceti	23
Z Cygni	23
RX Sagittarii	24
T Delphini	25
V Leonis	27
RR Sagittarii	28
R Trianguli	29
U Bootis	30
T Geminorum	30
R Cancri	31
Z Sagittarii	31
R Vulpeculae	31
R Ceti	32

MAXIMA Con't.

	Day.
S Delphini	32
RR Cygni	32
R Orionis	32

MINIMA.

R Columbae	1
U Orionis	3
Y Virginis	5
X Geminorum	8
R Camelopardalis	19
R Cassiopeae	20
U Canis minoris	21
R Ursae Majoris	23
S Ursae "	26
R Sculptoris	29
R Bootis	31

NOTES TO THE EPHEMERIS.

The dates are taken as before from Dr. Hartwig's paper in the *Vierteljahrsschrift*, except for Y Cygni for which I have used Duner's data given in No. 3633 of the *Nachrichten.* These times are two and three hours later than those in Hartwig's ephemeris.

W Persei is called V Persei in Chandler's Third Catalogue.

SS CYGNI.—The maxima are now about a month behind the ephemeris, which is founded on the changes observed previous to the reversal of the order of maxima which occurred in the early part of 1900. The rise which was set for Aug. 8 by this ephemeris, did not take place till Sept. 7.

OBSERVATIONS OF VARIABLE STARS AT THE GERMAN OBSERVATORIES.

The following items of news are extracted from Part 2 of Vol. 35 of the *Vierteljahrsschrift*, which has just appeared.

BAMBERG—For the year ending May 1, 1900, Dr. Hartwig reports 733 observations of variables by Argelander's method. Of this number 77 referred to SS Cygni. Of this star the intervals between the times of rise since Oct. 25, 1899, were 32, 35, 69 and 48 days. U Geminorum was found bright from April 1 to 3. Minima of Algol and λ Tauri were observed on three nights, and light estimates were made of β Lyrae, η Aquilae and δ Cephei on 18 nights. The variability of one of the Pleiades stars, B.D. + 24°531, was discovered by photography. Its magnitude in the B.D. is 9.5, but it was fainter than 12th magnitude in November 1899 and certainly fainter than 11th magnitude in April 1900.

HEIDELBERG.—Dr. Valentiner announces the early publication of Schönfield's original observations of variable stars. Most of them were made at Mannheim from 1865 to 1875. There are 35963 complete observatons of 117 variables, comprising over 80000 single estimates, besides 4000 or 5000 comparisons of the comparison stars among themselves. It is needless to say that the quality of these observations is fully equal to the quantity, and the publication will be simply invaluable.

MUNICH.—Observations of Nŏva Aurigae were continued and a decline of 0.2 magnitude was recorded in 1899. On the 22d of December it was estimated as 12.7 or 12.8 magnitude.

VIENNA.—(*The Von Kuffner Observatory.*) Dr. Wirtz has continued the investigation begun by Dr. Schwartzchild of the determination of the photographic light curves of variables. Preliminary reductions lead to the conclusion that the curve for δ Cephei resembles that for η Aquilae, that is the photographic amplitude is nearly double the optical, thus showing a decided increase of redness at minimum.

OBSERVATIONS OF FAINT VARIABLES AT THE YERKES OBSERVATORY.

The greater part of the work hitherto done on variable stars consists in determinations of their maxima and periods, comparatively few of them being followed through the complete cycle of their change. As a result our knowledge of the variation of most stars is fragmentary. For this reason the opportunity to observe faint minima with the Yerkes 12 and 40-inch telescopes was welcomed by the writer, and the following items from the work done between January and August, 1900, may be of interest. They are extracted from Bulletin No. 13 of the Yerkes Observatory:

This preliminary report will be followed by more definite results when the magnitudes of the comparison stars have been determined with the stellar photometer, now in use in this work. The magnitudes given in the present paper are only approximate, based on the assumption that the limit of the 12-inch is 14.0 magnitude, and that of the 40-inch 17.0 magnitude.

Of the 22 stars in this report, 16 are contained in Chandler's *Third Catalogue of Variable Stars* and supplements. For these stars Table I gives from this catalogue the minimum magnitude and number of minima on record, to show what was previously known on the subject; also the results of the work at the Yerkes Observatory from January to June 1900, giving the date and magnitude of the observed minima.

TABLE I.

	From III. Cat.		Yerkes observations	
	Min. mag.	No.	1900	Min. mag.
267 V Andromedae	——	—	January	14
2530 V Canis minoris	<13.7	—	April	15
2625 V Geminorum	12.0–14.0	3		
2815 U Geminorum	13.1	—		
2976 V Cancri	<12	3	February	12
4315 R Comae	<13.5	—	March	<14
5070 Z Virginis	<14	—	May	15
5430 T Librae	<14.7	3	Feb. or Mar.	<16
5593 W Librae	<14	—		
5830 R Scorpii	<13	—	May	16
5831 S Scorpii	<13	—		
6100 RV Herculis	——	—	February	<15
6871 V Lyrae	<12	—		
6894 S Lyrae	12 0	—	May	16
7458 V Delphini	12?	—		

Six of the stars in Table I did not pass minimum during the time covered by this report; the following notes show the observed magnitudes, the stars being referred to by their numbers only:

2625 14.5 magnitude by the end of January, brighter by middle of February.

2815 Carefully followed throughout its period. About 14 magnitude at normal light, but with considerable fluctuations.

2976 Has a 13 magnitude companion, 10″.8 preceding, on the parallel.

5593 15 magnitude and rising early in February.

5831 Apparently stationary at 15 magnitude in February.

6871 About 15.5 magnitude early in June and still fading.

7458 Maximum 1899 October 1, at 7.5 magnitude; invisible in 40-inch (low power) 1900 July 20, therefore <17 magnitude: a range of nearly or quite 10 magnitudes.

Particular attention has been paid to new variables, not in the Third Catalogue, whose light-curves suggest very faint minima. Table II gives six stars selected from these, showing the number (in parenthesis, provisionally assigned by the writer), the place for 1900, found by micrometer measures with the 40-inch, except for the 2d and 5th, the discoverer, and a reference to the announcement of discovery in the *Astronomische Nachrichten*.

TABLE II.

STARS NOT IN CHANDLER'S THIRD CATALOGUE.

	1900.						Discoverer	*Ast. Nach.*	
	R. A.			Dec.				Vol.	Page.
	h	m	s	°	′	″			
(1922)............................	5	20	8.6	+36	48	53	Ceraski	148	15
(4696)..	13	2	39.5	−12	37	50	Schwassmann	152	183
(6458)............................	17	56	17.2	+54	52	45	Anderson	151	307
(7258)............................	20	11	32 9	+30	46	3	Anderson	150	325
(7579)............................	21	3	38.5	+82	39	50	Ceraski	147	142
(8517)............................	23	39	41.1	+56	1	35	Anderson	148	79

The preliminery results of the observations of these new variables are given in the following notes:

(1922) Minimum early in March, about 15 magnitude.

(4696) Not visible in the 12-inch June 20, limit about 13 magnitude. Between 13 and 14 magnitude July 5, with 40 inch.

(6458) Not visible in 12 inch in March, limit 14 magnitude, had risen to 10 magnitude by June 23.

(7258) Minimum in May, about 14.5 magnitude.

(7579) Had passed below the limit of the 40-inch in June, and therefore not brighter than 17 magnitude.

(8517) Stationary at about 15 magnitude in January, rising in February.

COMET NOTES.

EPHEMERIS OF COMET *b* 1900.

1900.		α app.			δ app.		Log r	Log $\varDelta$	B.
		h	m	s	°	′			
Oct.	1	14	29	45	+68	38.1	0.1492	0.1105	0.07
	3		32	53	68	11.0	1559	1193	06
	5		35	55	67	46.6	1625	1277	06
	7		38	55	67	24.5	1691	1357	06
	9		41	53	67	4.8	1757	1434	05
	11		44	50	66	47.3	1822	1508	05
	13		47	44	66	32.0	1887	1579	05
	15		50	38	66	18.7	1951	1646	04
	17		53	33	66	7.6	2015	1711	04
	19		56	27	65	58.3	2078	1773	04
	21	14	59	22	65	50.9	2141	1833	04
	23	15	2	16	65	45.6	2202	1890	03
	25		5	12	65	42.1	2264	1946	03
	27		8	8	65	40.4	2324	1998	03
	29		11	4	65	40.5	2384	2049	03
	31	15	14	2	+65	42.4	0.2444	0.2098	0.03

Search Ephemeris for Comet 1884 II, (Barnard).—This comet was not found at its return to perihelion in 1894 and 1895 because of its unfavorable situation. This year again its position is quite unfavorable. It will be at perihelion, according to the ephemerides on October 28, 1900, and will then be only from three to four hours east of the Sun, and about thirteen degrees farther to the south than that body. In the southern hemisphere the situation is somewhat more favorable and it may be possible that the comet may be found. In the *Astronomische Nachrichten* No. 3660, Dr. Berberich gives a search ephemeris of the comet, a portion of which we give here.

Date Berlin Midnight.		R. A,		Dec.		Log r	Log Δ	Light
		h	m	°	′			
Oct.	3	16	13.8	−25	45			
	7	16	28.5	26	13	0.1170	0.2001	0.23
	11	16	43.6	26	37			
	15	16	59.0	26	55	0.1123	0.2016	0.24
	19	17	14.8	27	07			
	23	17	30.9	27	12	0.1097	0.2042	0.24
	27	17	47.2	27	11			
	31	18	3.7	27	04	0.1095	0.2080	0.23
Nov.	4	18	20.3	26	50			
	8	18	36.9	26	29	0.1114	0.2135	0.22
	12	18	53.4	26	01			
	16	19	09.9	25	26	0.1155	0.2207	0.21
	20	19	26.2	24	45			
	24	19	42.4	23	57	0.1216	0.2298	0.20
	28	19	58.3	23	03			
Dec.	2	20	13.9	−22	05	0.1295	0.2405	0.18

As the time of perihelion is uncertain by two or three weeks the observer will need to extend his search to a considerable distance on each side of the predicted place of the comet, possibly as far as a half hour in R. A. and a degree or more in Dec.

GENERAL NOTES.

We have greatly tried the patience of our subscribers for the last three issues, sometimes for good and sufficient reasons, and sometimes for reasons, though beyond our control at the time, were not good reasons. We believe that we will have no more trouble of this kind, and that hereafter each number will be mailed on time.

We have given considerable space in this number to useful tables for the observations of the planet Eros, because there are so many observers who are supplied with telescopes who may wish to do some work of this kind during the weeks to come, that such aid may be quite widely useful.

Observations of the Partial Eclipse of the Sun, May 28, 1900, at Orono, Maine.—

Longitude $4^h\ 34^m\ 40^s.5$ W.
Latitude 44° 54′ 3″ N.

Observer	A. R. Crathorne	F. C. Mitchell	L. H. Homer
Instrument	4-in. Clark telescope	Repsold Vertical Circle	3 in. telescope
First Contact	$8^h\ 1^m\ 1^s$	$8^h\ 0^m\ 33^s$	$8^h\ 0^m\ 27^s$
Last Contact	10 37 12	10 37 11	10 37 15

Times are reduced to Eastern Standard Time.

The Recent Solar Eclipse.—The report of the expeditions organized by the British Astronomical Association to observe the total solar eclipse of May 28, 1900, will be contained in a volume shortly to be issued from the office of *Knowledge*. The work will be edited by Mr. E. Walter Maunder, F. R. A. S., and will contain many fine photographs of the various stages of the eclipse.

Observation of Contacts by the Creighton University Party at Washington, Ga.—The internal contacts were observed with the naked eye. The external contacts were observed by projecting the Sun's image upon a white screen secured by two light wooden rods beyond the eye-piece of a 3-inch telescope. I prefer this way of observing the Sun to the more usual direct-vision method by means of a sunshade or helioscope, because the projection method does away with the heat and glare of the Sun, admits of the use of both eyes and of any desirable magnifying power, is equal, if not superior, in accuracy of observation, and especially because it enables the observer to mark the point of first contact upon the screen and thus obtain the advantages of a position micrometer from a telescope of the most ordinary construction and mounting.

The comparison of observed and computed time is as follows:

Central Time.	I	II	III	IV
	h m s	h m s	h m s	h m s
Computed	6 33 17.0	7 40 57.1	7 42 23.0	8 59 29.8
Observed	6 33 18.3	7 40 50.0	7 42 16.0	8 59 18.6
Computed — Observed	$-1.^{s}3$	$+7.^{s}1$	$+7.^{s}0$	$+11.^{s}2$

	Mid Totality	Duration of Totality	Duration of Whole Eclipse
	h m s	m s	h m s
Computed	7 41 40.0	1 25.9	2 26 12.8
Observed	7 41 33.0	1 26 0	2 26 0.3
Computed — Observed	$+7.^{s}0$	$-0.^{s}1$	$+12.^{s}5$

The correction and rate of the chronometer were obtained from the Naval Observatory noon signals at the railroad depot.

The geographical coördinates of my position were, latitude 33° 44′ 13″ N., longitude $5^{h} 30^{m} 58^{s}.9$ W. WM. F. RIGGE, S. J.

CREIGHTON UNIVERSITY OBSERVATORY.

Comet *b*, 1900.—The independent discovery of this comet by Borrelly and myself was made on the same morning, July 23, and at nearly the same date of local time, the instant of my discovery preceding Borrelly's by a few minutes. Although the difference in longitude between the two stations favors my esteemed fellow-worker by about five hours, it is an interesting fact, that the Harvard cablegram announcing my discovery of the comet, reached Kiel two hours before Borrelly's announcement was received. The comet has been an exceedingly fine telescopic object in the 10-inch refractor. For some time after discovery it bordered closely on naked eye visibility. The nucleus and coma were easily visible with the telescope in the presence of a full Moon. Although it is now rapidly fading, the comet will from its favorable position in the northern heavens, remain visible in large apertures for some time to come. Soon after discovery two faint branches or auxillary tails were detected, one upon each side of the main tail. Although the principal tail has become much fainter, as the comet receded from the Sun, it has very singularly maintained its original length of about one degree.

In the first note on page 396 of September number Dr. Wilson inadvertently places my Observatory at Rochester. It is where it has been for thirteen years past, at Geneva, N. Y. On the other hand, the name of their Observatory is Smith Observatory, and not the peculiar name given to it by the compositor at the foot of my note on page 400. WILLIAM R. BROOKS.

SMITH OBSERVATORY, Geneva, N. Y.
Sept. 10, 1900.

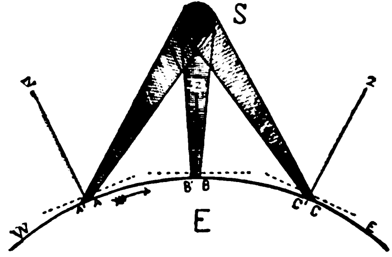
New Form of Telescope.—Referring to telescope decribed in *Popular Astronomy*. No. 77 page 379, allow me to say that the principle of such a telescope is by no means new. About the year 1872-3 I sent to the English Mechanic drawings of a somewhat similar instrument with concave-convex lens, and in 1870-1 I made a 5-inch aperture telescope on that principle a plano-convex lens having its aberrations corrected by a smaller concave lens and mounted as a Newtonian Telescope for a gentleman then going to India, uncle to Stanley E. Lane Poole, Esq., now I believe of the British Museum Library, who informed me that it was a success, but I heard nothing from the owner and concluded that he did not consider it worth pursuing. In any instrument of considerable aperture there certainly must be trouble and not a little of it with the oblique rays: and this very important point seems to have been entirely overlooked by the ingenious projectors. Nor is this at all an unusual phenomenon. Any one reading over the accounts published by Dr. Smith, of Geneva, N. Y., some twenty years ago, of Mr. Ingalls, of Liverpool, England, Dr. Wilson, of Edinburg, and Professor Barlow of their various dialytic instruments and of Dr. Blair, of Edinburg of his third lens, would think from what they say of them there was nothing to be desired. All the said lenses are reported to be even when used under high power, perfectly free from aberrations, either chromatic or spherical, etc. and if so what became of them, for although they were, some of them, of eight or nine-inch aperture; we never hear of them again.

Mr. Wray, a celebrated English maker pursued the matter most perseveringly, he constructed one of nearly 20 inches aperture, but was obliged to confess, as indeed any one may see who will go to work and trace the rays through geometrically, that nothing could be done with the oblique rays, although he went to great trouble in making special eyepieces for it. So that he at length gave it up. Many others have tried with no better success. Then the difficulty of proper adjustment would be very great and of keeping the various surfaces, in proper ajustment, still greater, to say nothing of the trouble and expense of figuring and testing at least 5 surfaces. So that one may well ask where would the saving come in? It would be, not a simplified achromatic, but rather a highly complicated reflector and that is really all there is to it.

CAMDEN, N. J. E. M. TYDEMAN.
Sept. 8, 1900.

An Interesting Phase of the Recent Solar Eclipse.—One of the most noticeable features of the recent solar eclipse was the rapidity with which the light returned after totality. At one minute after totality the landscape was quite as bright as it was at 10 minutes before totality. It would naturally be supposed that the gradation from sunlight to darkness and from darkness to sunlight would be the same before and after totality. But this did not seem to be the case. The difference was so marked as to preclude any theory of "illusion" or of "effect of contrast," there was no doubt in the writers mind that it was a real appearance. Other observers, when questioned, testified to the same effect. Miss Bacon, of the British Astronomical Asso., observing in this country, noticed the same appearance, and made particular mention of it in her report, remarking that "there is at present no theory that will account for this phenomenon, which is not at all what might be expected. This point alone will afford food for speculation and research." The text-books do not mention the phenomenon, nor is there any explanation of it in the recent astronomical journals.

With a view of bringing this question up for solution or discussion the writer wishes to advance the following theory of the phenomenon and believes that it is due to the inclination of the Moon's shadow to the Earth's surface. The accompanying diagram will illustrate the theory.



In the diagram *S* is the eclipsed Sun, *A*, *B* and *C* the observer's position at forenoon, noon and afternoon respectively, the lines drawn from *S* to *A*, *B* and *C* are the Moon's shadow, the dotted lines indicate the horizontal view and *Z* the zenith at the various positions, the arrow indicates the direction of the Moon's shadow over the earth's surface.

When the observer is at *A*, where the totality occurs at about 9 o'clock in the morning, the Sun will be in the east about half way to the zenith and the Moon's shadow will stretch across the zenith to the west, thus covering about three-fourths of the observers sky, leaving only one-fourth of the sky in the sunlight. As the shadow approaches, the light will fade rapidly before totality. When the shadow has passed the observer's position, and he is in a position corresponding to *A′*, and the Sun begins to be uncovered, it will be seen that three-fourths of the sky will be in the sunlight, and only one-fourth in the shadow. This will cause the light to increase rapidly, which corresponds to the observations above stated.

When the observer is at B the Moon's shadow will be in the zenith and the illuminated sky will be the same at a given time before and after totality. Therefore the light should fade and return in about the same way before and after totality.

When the observer is at C, when the totality is at 3 o'clock in the afternoon, the effect should be opposite to that of the observer at A, and the light be greater before than after totality. The Sun will then be in the west about half way to the zenith; but the moon's shadow will cover only about one-fourth of the observer's sky, leaving three-fourths in the sunlight. This will cause the light to fade slowly before totality. After the shadow has passed, and the osberver is in a position corresponding to C′, three-fourths of the sky will be covered by the shadow leaving only one fourth of the sky in the sunlight. This will cause the light to return slowly.

At all stations between A and B, the effect should be the same as at A, but in a less marked degree, and in the same way at all stations between B and C, the effect should be the same as at C, though in a less marked degree. The nearer the observer is to noon at totality the less will be the gradation of light and shadow before and after. The farther the observer is from noon at totality the greater will be the contrast before and after totality.

It may be remarked, in conclusion, that in the case of the recent eclipse no observations were made at the noon period—that occurring in the Atlantic Ocean but there were numerous observers in the afternoon, though not many in the late afternoon, where the contrast would be great enough to attract attention. It would be well for future observers of total eclipses to pay some attention to this feature, so that more light may be thrown upon this interesting question.

BROOKLYN, N. Y.
September 10, 1900. A. J. B.

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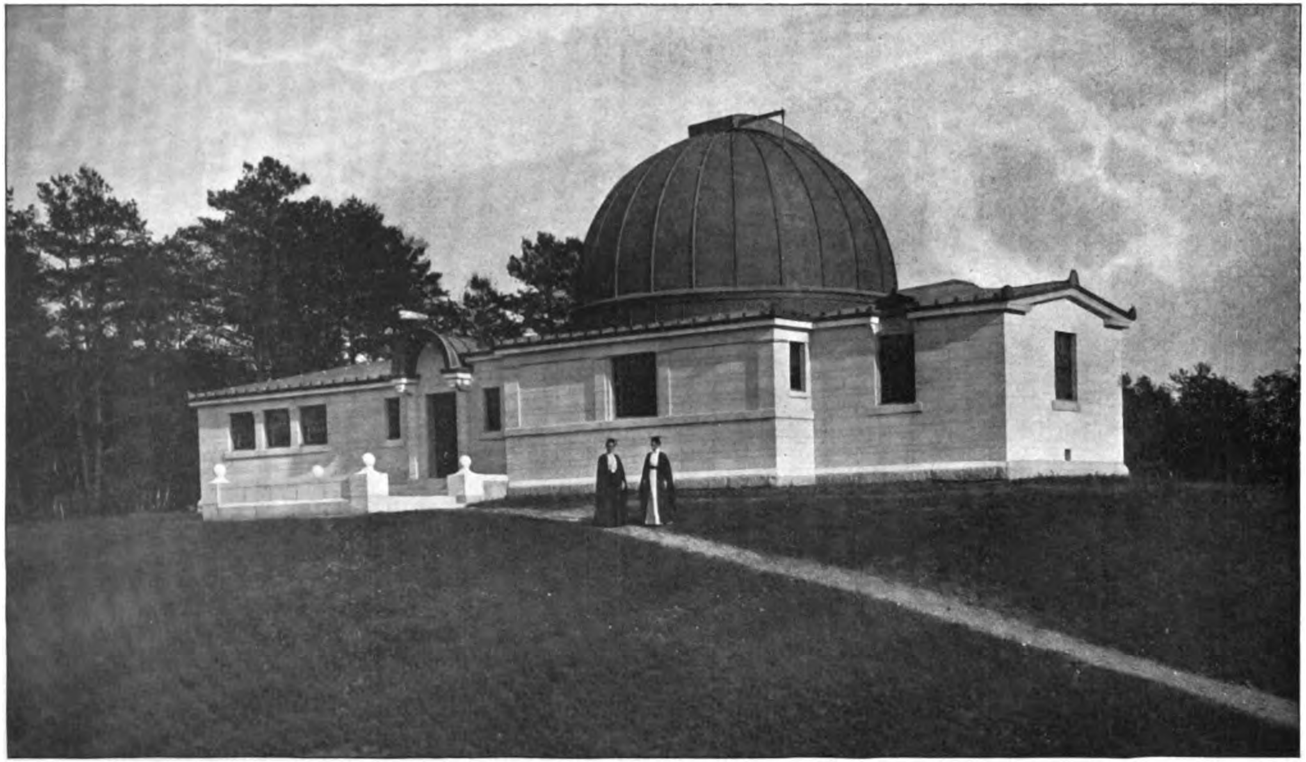

THE WHITIN OBSERVATORY OF WELLESLY COLLEGE.

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Popular Astronomy.

Vol. VIII. No. 9. NOVEMBER 1900. Whole No. 79.

ON LABORATORY METHODS IN TEACHING ASTRONOMY.*

I remember reading once a strangely attractive monograph on "The Hindu Zodiac, or the Discovery of the Lost Key," by N. Chidambarum Iyer, F. T. S., in which he quotes Bhagavan Garga as authority for the statement that "as the night is without a lamp, and the sky without the Sun, so is a prince without an astronomer, and he gropes his way in the dark. That service which an astronomer can render to a prince can not be effected by a thousand elephants and by five thousand horses!"

I strongly suspect that President Hazard, in her historic researches, must already have met this same quaint estimate of an astronomer's worth; for something like a twelvemonth ago she gave utterance, from this platform, to a significant sentiment,—"There have always been women, from the days of the Queen of Sheba, who sought out wisdom and endured arduous toil to come to a fountain head of knowledge." And surely, if the knowledge possessed by astronomers can be worth so much to Hindu princes, *a fortiori* how can the president of an American woman's college afford to do without one? Furthermore, a fine Observatory is no less a fitting corollary of, than a sturdy necessity for, an able astronomer.

But my purpose is other in turning your thoughts thus backward to the very beginnings of astronomy, even to the days of its parentage in astrology, which taught—and in some not very distant cities still affects to teach—the divination of the future by configurations of the heavenly bodies. So deeply rooted was this belief among the early peoples, that kings and potentates were themselves the Astronomers Royal of those days, each devoting himself keenly to the quest of new knowledge concerning the motions of the planets, in the vain hope of truthful prediction of events that might betoken the elevation of his sword or the downfall of his realm.

Virtually everybody believed in astrology; but mankind long

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* An address at the inauguration of the Whitin Observatory of Wellesley College, Massachusetts, by Professor David P. Todd, Director of the Observatory of Amhurst College.

since discovered that nothing of the sort obtains. Still, the old beliefs die hard: humanity hesitates to admit that it has been duped. But in this fact, that the astronomy of our own era cannot live up to the pretensions of the past, I see the chief cause for that prevailing lack of interest in the bodies of the sky, which is responsible for an ignorance of astronomy at the present day, dense and well-nigh universal, so far as the masses of humanity are concerned.

I do not say that no one takes an interest in quizzing the telescope man on the Common, and peering eagerly through his "optick tube," if haply he may discover the "man in the moon;" as Piazzi Smyth tells us the inhabitants of Teneriffe, on looking through his telescope, thought they could see their favorite goats grazing on the craggy surface of our satellite.

Nowadays the question most often asked the astronomer in ordinary life—"Are there any inhabitants in the heavenly bodies?" is one that seemingly attracts him least, and is in fact remote from the range of his usual enquiry. And this single question betrays the main trend of unthinking interest of the people in astronomy to-day.

If the astrology of an ancient era fooled the human race, and the astronomy of the present has no answer for this oft reiterated questioning, how can we hope to create that wide and healthful popular interest in the science on which its future development so largely depends?

Clearly, as it seems to me, by a different method of teaching it.

I will not stop to criticise the earlier book-methods: the main criticism is apparent, if I but state the fact that no instructor now teaches geology or chemistry or physics or biology as formerly by books alone: the laboratory is an indispensable prerequisite for instruction in all these sciences.

Why not teach astronomy in like fashion?

Says Professor Huxley in his *Outlines of Physiography*, "The attempt to convey scientific conceptions without the appeal to observation, which can alone give such conceptions firmness and reality, appears to me to be in direct antagonism to the fundamental principles of scientific education." Singularly enough, these self-evident principles have long been neglected in the elementary teaching of astronomy, which is pre-eminently a science of observation, and should be taught as such. Charts of the sky and planispheres have been used in tracing constellations and studying the geography of the heavens, and in a few colleges expensive instruments have been employed by a small body of students in that training requisite for the professional astronomer.

But we must do much more than this: it is necessary to direct the attention of elementary students to observation of the heavens in that fundamental and practical way which imparts a complete mastery of first principles.

In adopting laboratory methods of teaching astronomy, the degree of attention to manual training now given in the schools is a vast assistance; for instructors and pupils of moderate mechanical deftness can themselves make and use nearly all the apparatus requisite for illustrating these principles, and making observations similar to those that led to their discovery. Only the things commonly found in every house are needed: apparatus is constructed with a little ingenuity, not exact in result, to be sure, but accurate in principle—which imparts the main lesson. And rightness of principle ought everywhere to take precedence of display of mere precision in result, this latter being chiefly the concern of the professional astronomer in perfecting his science.

Will it not enlist the student's interest if we can show him how, with a plumb-line, a paste-board box and a paper quadrant, he can determine for himself the obliquity of the ecliptic within a fraction of a degree?

And abundantly equipped with yardstick, pin-hole and "rule of three," the young pupil may measure for himself the Sun's diameter, arriving nearer the truth than was known in Herschel's time. Youthful students must be taught to connect the principles of astronomy with tangible material objects, somewhat as in physics and chemistry. And although we cannot journey to the heavenly bodies nor touch them, it is clear that a laboratory course in astronomy is practicable, for their light comes to us in decipherable messages, and geometric truth provides the interpretation.

So is it possible to impart a competent knowledge of astronomical principles, and keen interest in their significance, with all that zest characteristic of the geologist, who sometimes affects to know the whole earth—in much the same way, however, as an insect that has bored half way through the shell may be said to know the whole nut. Or of the physicist and chemist who, with all the narrow restrictions of a terrestrial laboratory, are still far from able to tell us all we should like to know about the behavior of matter on an asteroid, or on the Sun, where enforced conditions of temperature and pressure are widely remote from those of our experience here. Or again of the biologist, who has hardly yet begun to ponder a primal question of the cosmic biology of the future: granted the presence of protoplasm and the chemical elements on Mars, as on the earth, would the process of evolution necessarily develop the same types of animal life on that planet as here?

The truly great astronomer of a coming century must be able to reach a satisfactory solution of such riddles; but to do so he must be equally trained in biology, in physics and in chemistry—quite the opposite direction from that in which present schools are faced. Only thus can we realize that ultimate ideal of our science which was implied by the most eminent of poet-mathematicians, Sir William Rowan Hamilton, who speaks of astronomy as enabling us to "learn the language and interpret the oracles of the universe."

Then, too, we must unceasingly combat the widespread notion that of all the sciences astronomy is the most useless. In reality it is among the most useful; and has always, even in the earliest days of the history of the race, been cultivated mainly for its utility. Consider the question of chronology: many are the disputes over the dates of ancient events that have been settled forever by an appeal to astronomy. Also the important matter of accurate time: the work of the astronomers at Washington affords direct and immediate assistance to hundreds of thousands every day throughout the country, who have engagements to meet and trains to dispatch. One standard clock, when coupled with the telegraph, can effect all this service; but an astronomer must regulate the clock by frequently comparing it with the Sun and stars. Costly instruments are, of course, needed for this work; but the cardinal principles underlying them are quite within easy understanding of young pupils, who should be taught first of all how to find true north from the stars, and then how to construct and use a home-made transit which will give the time, accurate to a few seconds at noon throughout the year. By such methods of teaching astronomy, the Sun by day and the stars by night become part of the apparatus of a grand laboratory, the use of and familiarity with which enhance the pupil's interest with each fresh observation of his own.

In the presence of an audience like this, I do not of course need to emphasize the eminent utility of astronomy in ascertaning the exact boundaries of estates and countries: without an astronomer's help, no nation can make accurate maps of its domain, or trustworthy charts of coast-lines. Nor need I speak of the vast benefits to all navigation interests, which obtain from the application of astronomical principles in very simple fashion, for conducting ships safely from port to port. Without their astronomical instruments and tables, the good captains who brought us the letters of greeting from Lady Margaret Huggins and Mademoiselle Klumpke, would not have thought of undertaking their Atlantic voyages. And in such measure as the master of a vessel employs the methods of astronomy in guiding his ship across the ocean, by precisely that measure is he an astronomer; because he is an observer of the heavenly bodies, and calculates the observations to find his precise location just as an astronomer would on land, though he usually does this without thinking how many generations of past astronomers have by their observations and mathematical discussions contributed to the perfection of the tables he has used by simple "rule of thumb."

What better training for the keen eye and the steady hand than this same astronomy of navigation? Simple and inexpensive, too, the instruments; and large classes are within easy direction of a single instructor. And as the pupil advances, he may gradually be inducted to practical work with actual astronomical instruments, though of small size; with real telescopes mounted and manipulated in exactly the same manner as the large ones in a fixed observatory.

But I must not pursue these details farther: I have sought only to suggest the lines along which a revolution in astronomical teaching may be brought about. And in so far as the genuine interest of able teachers can be enlisted, the adoption of laboratory methods may be relied upon to create in their pupils a new interest in the things of the sky, both real and abiding.

As America was the first to introduce laboratory methods of instruction in natural philosophy, so too she is the first to set forth the possibilities of teaching astronomy by continual reference to and immediate connection with the laboratory of the heavens. But whether this much desired change in astronomical instruction can be effected in a quarter century, is, I think, very doubtful; for the body of astronomical teachers is, in the main, a very conservative one; and a conservative, as you know, was best depicted by Douglas Jerrold, as "one who would never look at the new moon—and all out of respect and veneration for that ancient institution the old one."

On an occasion like this I cannot, of course, omit remarking the golden opportunity that lies within easy grasp of the well-trained woman, as a teacher of the elements of astronomy by this new method; and I venture to predict for her that full measure of success in the restoration of astronomy to its ancient seat in human interest, which attended the diligent labors of Caroline Herschel as chief assistant and companion of her brother in his nocturnal watchings, and of Mary Somerville in her essay to popularize the equations of the *Mecanique Celeste.*

In particular must the very young pupil be sought out and instructed to look heavenward. Such teaching cannot, indeed, begin too early; for close upon our childhood's

"Twinkle, twinkle little star,"

follows an alertness of investigation that enables us soon to say,

"Now I know just what you are;
When I see you in the sky,
I the spectroscope apply."

And upon this early interest in astronomy, all the keener and more lasting if connected as in a laboratory with the natural concerns of every-day life, must rest our chief dependence for the future of the science; not only for replenishing that small band of investigators who tread a steady advance beyond the borderland of the known, but for that patronage of the highly intellectual who must provide support for researches in fields, financially non-remunerative, not to say also the costly instruments with which new investigations must be prosecuted.

An American who has made one of the largest gifts to astronomy once told me why he had made that donation: the immediate occasion seemed to be that the president of a youthful and strenuous university had made a powerful appeal. But the prime reason was that this munificent patron had in early life, when studying astronomy at school, become so engrossed therein that he had resolved to build some day the most powerful telescope in the world, if ever he had money enough to do so. The president well knew that he had money enough; but who will say that his appeal would have been successful, except for that unforgotten resolve of an enthusiastic boy?

And from the singularly appropriate edifice that we dedicate to-day, most useful as a complement, and most graceful as an ornament, shall go forth the apostles of this new learning—neither neglecting the old astronomy, nor placing undue stress upon the new; and as they nightly pass beneath its sculptured lintel, ever remembering one whose munificence has inseparably knit her name with that aristocrat of all the sciences, which "contemplated as one grand whole is the most beautiful monument of the human mind, the noblest record of its intelligence."

AN HYPOTHESIS REGARDING THE SURFACE MARKINGS OF JUPITER.

A. E. DOUGLASS.

No planet presents such rapid changes in its surface markings as the largest of them all, Jupiter. The great red belts which are visible in the smallest telescope are constantly changing in minute detail. This is apparently because the belts are on the dividing line between the temperate zone currents and a swifter moving equatorial stream of perhaps twenty thousand miles in width and a velocity of two hundred and fifty miles an hour greater than the regions on each side of it. The markings where these two currents adjoin are literally torn to shreds as Mr. Stanley Williams describes them (Pub. A. S. P., Vol. XI, No. 70). Seemingly the only immovable object is the great red spot and that is not absolutely stationary, for its period of rotation has changed since its first discovery. What then produces this swift equatorial current that rends apart and joins in new forms the red and gray patches along its border?

The polar compression of Jupiter is in the neighborhood of one-sixteenth; that is the polar regions are about six per cent nearer the center of internal heat than the equator. Now owing to the very great reflecting power of Jupiter's atmosphere (albedo 0.62) and its distance from the Sun (mean distance 5.2 or 483,000,000 miles), it is the internal heat that governs the circulation of the atmosphere rather than solar energy and we have an atmospheric circulation the reverse of ours.

Permit the digression in saying that that appears to be the meteorological distinction between a cloudy and a non-cloudy planet. The former controls its own atmospheric movements, producing a convectional current over its hottest parts; the latter has its atmospheric movements controlled by the Sun, with upward currents near the equator. This has a bearing on the rate of cooling of planets.

Upon Jupiter, therefore, the ascent of air occurs at the poles. The masses of warmed air or gases then spread toward the equator. But as their linear velocity about the axis of rotation is not so great as that of the regions nearer the equator, they act as a retarding surface current. On this hypothesis therefore it is the equatorial current that represents nearly the true rotation of the planet, and the temperate zone currents that show us the retarding action of this planetary circulation, namely two hundred and fifty miles an hour.

Let us in imagination follow the course taken by a mass of air or gas or cloud in this retarding current. In mid northern latitudes the low-level winds far below the visible surface move toward the north pole. Somewhere beyond latitude 60° or 70°, perhaps, a mass gets sufficiently warmed to rise. It does so. Then it commences to move southward toward the equator, but immediately it turns toward the right as its velocity in its new latitudes is not great enough for it to keep pace with the planetary surface beneath it, therefore almost at once begins to retard the velocity at the apparent surface. Its maximum turning force occurs at the start. The latitude of its maximum retardation depends upon the actual rate at which it turns in direction. Now, on the earth, the trade winds are supposed to be composed of masses of air that have actually turned about and are on their way back to the equator. This suggests that on Jupiter the return currents to the pole are down too deep in the atmosphere for us to see them and that the masses that do not turn back are the ones that finally get near the equator. So just as we have on the earth a polar whirl blowing in advance of the actual rotational velocity, so on Jupiter we find an equatorial, or as it happens, a sub-tropical retarding current, opposing the rotational motion.

If these north and south retarding currents actually met at the equator, we would practically be unaware of their existence, for we would have nothing to compare them with and they would hardly show sensible change in rate for many degrees on each side of the equator. But we find an equatorial zone largely unaffected by this retardation, although subject to rapid changes in configuration of detail. There may be at least two causes for the existance of this equatorial zone unaffected by retardation. First, the equatorial retarding currents may be simply not strong enough to reach the equator, for they have turned to an east-and-west direction and have little force left to push on north or south. Second, the effect of heat received from the Sun, even though very weak, would be to expand the air over the equator and cause it to spread north and south, thus interfering with the approach of the retarding currents to the equator, and also causing the slight seasonal change that has been suspected.

Above the actual visible surface that reflects solar light there must be considerable atmosphere for the limb of Jupiter is very dark all around. But as the polar and equatorial zones are also much darker than the temperate regions, except in small spots, we infer that the gases freshly brought to the surface in the regions of convection have less reflecting power than those in other parts of the planet. The red marks of all kinds act like some kind of cloud condensation, light because they float high in the atmosphere, yet differing from the other visible materials, and showing a strong tendency to accumulate and last longest in the region that upon the hypothesis given above, must be the coldest part of the planet's visible surface.

Perhaps it is presumption to suggest more definitely the nature of the red spot. But the spot can be attributed to some special uprush of the same gas that forms the red belts, but to an uprush which occurred within the colder borders of the retarding current. A strong condensation ensued in the upper levels of the retarding current, followed by a gradual dissolving or falling downward of the red material. As the under side of the red mass is nearer the warm surface of the planet than the upper side, the most rapid breaking up of the mass would, we can infer, occur on the under side. We can therefore conclude that with the breaking up of the red spot and its becoming more and more confined to the upper levels only, of the retarding current, we are getting more and more accurate measures of the surface velocity of the retarding current. As the rotational velocity of the red spot has been decreasing since 1878, we conclude that the surface of the retarding current is moving more rapidly than the lower levels; and that is precisely the effect that friction produces.

At the present time, therefore, the red spot appears to be floating quietly in the retarding current, possibly held in place by an eddy, very slowly breaking up, perhaps already partly covered by other cloudy material and yet still dense and strong enough to preserve its form and size.

LOWELL OBSERVATORY, Flagstaff, Arizona, Oct. 16, 1900.

NOTE—At the Geodetic Congress which met at Paris at the end of last month, Sir David Gill, director of the Cape Town Observatory, reported the progress made in measuring an arc of meridian of 104 degrees from the Cape to Alexandria. They were passing by permission through German East Africa. Five degrees had been already measured in Rhodesia and three and a half in Natal. The measurement by international co-operation of an arc from French Congo to German East Africa was considerrd. A report was also made to the effect that the measurement of the geodetic line between Malta and Sicily had been successfully carried out under the superintendence of Dr. Guarducci, the chief of the geodetic division of the Italian Geographical Institute. The Malta station was at Gozo, and the chief Sicilian stations were on the mountains of Etna and Cammarata. The distance between Malta and Sicily is about 125 miles, and signals were exchanged at this distance by means of the oxyacetylene search-light.—*Science, October 19, 1900.*

JAMES EDWARD KEELER.

BY J. A. BRASHEAR.

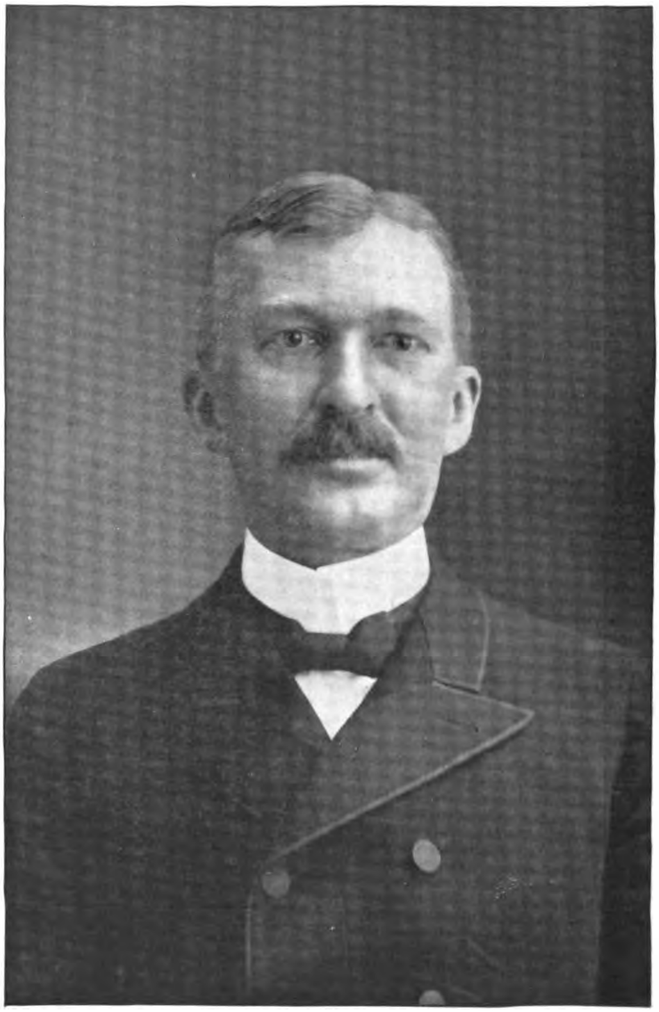
"God did anoint thee with odorous oil,
To wrestle, not to reign, and He assigns
All thy tears over like pure crystallines
For younger fellow-workers of the soil
To wear for amulets. So others shall
Take patience, labor, to their heart and hand
From thy hand, thy heart and thy brave cheer."
—ELIZABETH BARRETT BROWNING.

A great soul has gone from us, "our" dear Keeler has finished his work among the stars. There is universal sorrow at his taking away; his colleagues on the mountain, his friends everywhere, say, how can it be that so great and promising a life has been blotted out and we left to mourn his loss. A colleague upon the mountain writes: "We are inexpressibly sad, are inconsolable, every one of the fifty people regarded Mr. Keeler as his personal friend! You most assuredly can say that he was liked by all his associates. There was never any unpleasantness in those two years. He made a great success of his own work, and saw that every body else had all the opportunities in the world to do the same. He never questioned or interfered with our plans, with the result that we all kept him posted as to the state of our work. Socially, he and his family were simply delightful. You may say that he established ideal conditions in this ideal place."

One who knew him only to love him writes: "My heart is heavy for Keeler, our dear friend Keeler, the bright, lovable, genial Keeler, who died last night. All day I have been like one in a dream; Keeler, our Keeler, gone." A colleague at the University writes: "All the professors at the University have words of kindness for him, and the deepest sympathy for Mrs. Keeler and the dear children." Another life-long friend writes: "Yes, our Keeler has passed away, well may you and I and Professor Brown call him our Keeler, and all who knew him could call him the same for all his energies and all his marvellous fund of information was ever at the disposal of his friends. I have never met a man in all my life who was more willing and anxious to assist others in every way than he, and how my heart goes out for his dear companion and the children."

Were I to write only of the kindly words that I have received in letters from friends who have known this great man, it would

PLATE XX.



JAMES EDWARD KEELER.

1857–1900.

POPULAR ASTRONOMY No. 79.

fill many pages of this journal. Never have I known such spontaneous expressions of sorrow over the death of a humble student of science, for he was without the least taint of egotism to mar his splendid record.

I have known Professor Keeler for more than twenty years, our first acquaintance dating from the time he came to the Allegheny Observatory to assist Professor Langley in his Mount Whitney expedition. Professor Langley at once recognized his ability, not only with reference to his scientific attainments, but for his knowledge of experimental methods and his mechanical skill. I can remember as it were only yesterday, how I admired his beautiful tool box, made by his own hands, and the fine tools he brought with him from college. Professor Langley at once placed unlimited confidence in him, and many of the more important arrangements of the expedition were placed in his hands. It was during the preparation for the Mount Whitney expedition that he visited our workshop so frequently, and here was formed a friendship that has never been sullied by an unkind word or caustic criticism; a fellowship that has been prolific with pleasureable memories—memories that make life worth living.

I can well remember a remark made by Professor Langley after the Mount Whitney expedition. I was always a welcome guest at the Observatory and it was meat and drink to me to hear of the work done by the Director and his corps ot assistants. Speaking of Keeler he said: "I have never known a young man so thoroughly competent as an assistant in scientific research, some day he will make himself known."

William Thaw, that great and good friend of science, who did so much to enable Professor Langley to carry on his researches, saw in Mr. Keeler a "world of promise," and he, with Professor Langley advised him to study a year or so abroad. In 1883 while studying with Helmholtz, he made a thorough study of the selective absorption of radiant heat by carbon dioxide, which was published in the *American Journal* for September 1884. This research at once showed his ability as an original investigator. Although he had been working in the same scientific lines with Professor Langley, as well as in other fields of research, as an assistant, this paper was recognized at once as having an important bearing upon a subject at that time of great interest to the scientific world.

Returning to Allegheny Mr. Keeler assisted Professor Langley in his now historic studies of the infra red end ot the solar spectrum and the selective absorption of solar energy.

In one of his papers upon this subject Professor Langley says: "I have received constant and valuable aid from Mr. Keeler, not only in the graphical constructions but in the experiments and in the computations, through all the details of which his aid has been more that of a coadjutor than an assistant." The astronomical world knows the results of the splendid work done by Professor Langley with the assistance of Mr. Keeler and Mr. Very in the early eighties, a work that brought rays of bright sunlight to shine upon the New Astronomy. During these years of hard work at the Observatory, Mr. Keeler made many friends for he was socially a man who was always welcome at the fireside of any household. He could draw from his storehouse of scientific knowledge, weave the facts into fairy stories we all loved to listen to. It was a sad day when he left us for Mount Hamilton.

Professor Holden had asked Mr. Keeler to accept a position upon the Lick Observatory staff, which he accepted. He commenced his work in April, 1886 as assistant to the Lick Trustees, which position he held for about two years. His first task was to establish the time service, which he did most successfully, and and on the first of January 1887 the first time signals were sent out from Mount Hamilton. During the latter part of this period he devoted much of his time to installing the instruments of the Observatory. A very dear friend who spent many months with him on the mountain erecting the great refractor, has often repeated the story of his stay there, in which a friendship of the most endearing nature was formed for the man whose genius and whose kindly nature were such potent factors in the completion of the great Mountain Observatory.

From June 1st, 1888 to June 1st, 1891 he held the position of astronomer in the Observatory. During this time he made his splendid drawings of the major planets, by the aid of the great refractor, and successfully carried out the eclipse expedition of January 1st, 1889, of which he was placed in charge. It was during this peroiod that a life long friendship was formed between those splendid men: Captain Floyd, Burnham, Barnard, Keeler, Schaeberle and Hill. The world knows of their successes in the field of astronomical research. The ranks are broken now for the second time. Among his earlier friends whom he esteemed most highly were Mr. Chas. Rockwell and Dr. Chas. Hastings.

"Great souls by instinct to each other turn
Demand alliance and in friendship burn."

The plans were now made for the first great spectroscope to be constructed for a study of the motion of nebulæ in the line of sight, and which was completed about a year later.

His first measures of the nebulæ with this instrument (as kindly given me by Professor Campbell) are:

Orion Nebulæ, February 13th, 1890.
G. C., June 13th, 1890.

This work alone was of a character that at once stamped Mr. Keeler as an investigator of the highest type, and his subsequent researches in this prolific field have borne out the most sanguine anticipations engendered by his early studies of the motion of the nebulæ.

In 1890 Professor Langley was called to the Smithsonian Institution and the following spring Professor Keeler was unanimously elected to the Directorship of the Allegheny Observatory. Shortly after accepting the position he was married to Miss Cora Matthews, a niece of Captain Floyd, President of the Lick Trustees. Professor and Mrs. Keeler received a most hearty welcome from the friends of the Allegheny Observatory, and he at once commenced his work at the Observatory, which at that time was unfortunately quite poorly equipped for the continuation of the research he had been carrying on at Lick Observatory. William Thaw, the friend and patron of the Observatory had gone from among us, but Mrs. Thaw at once proposed to furnish the means for the construction of a spectroscope and spectrograph of his own design, which, when completed placed Mr. Keeler in the possession of an instrument particularly adapted to his wants, and which proved to be a type thoroughly satisfactory in every way. Mr. William Thaw, Jr., contributed a fund to rejuvenate the mounting of the old 13-inch equatorial and furnish a new driving clock, and the Junta Club of Pittsburg furnished the money to replace the old shutter of the dome, and with these improvements and additions Mr. Keeler commenced a series of investigations, which have been almost epoch making in the history of astrophysics.

Perhaps his spectroscopic study of the rings of Saturn will always be considered his greatest achievement at the Allegheny Observatory, but he was an indefatigable worker, and during his directorate many researches were successfully carried out and during the seven years he was with us, he published forty-eight papers on his scientific investigations, many of them of great value. Besides these his series of articles on the spectroscope have proven to be of inestimable value to young men taking up this field as their chosen persuit, as well, indeed, to many of the older observers in astronomical spectroscopy.

The limitations of this article prevent my giving even a synopsis of his more important papers, but readers of astronomical and astrophysical literature during the past ten years well know how this literature has been enriched by articles from his master mind.

It has been thought that our dear friend may have been broken down by over work. This I cannot think is true for although he was a most earnest and enthusiastic investigator, I have never seen a man who went about his task with so much ease, so much confidence, so much freedom from nervous haste. Aye, it was a pleasure to see him preparing his spectroscope for a night's work. Always cheerful, happy if results were commensurate with his anticipations, optimistic if otherwise. I cannot but think that this characteristic of the man was a prime factor in his splendid successes. Besides this he was ever ready to help his fellow workers to solve problems that troubled them, and ever willing to give them all the credit of the solution.

In the early part of 1898 an effort was made to raise funds for a new Observatory, and although a large part of the money needed was subscribed by the friends of the institution, the breaking out of the Spanish-American war and other unfortunate circumstances prevented, for the time, a successful issue of this undertaking. About this time Mr. Keeler was offered a position on the staff of the Yerkes Observatory, and he was also elected Director of the Lick Observatory. After careful consideration he concluded to accept the call to the Lick Observatory, and while we were all proud that his genuine worth had been recognized by the Trustees of the University of California, we knew we were to suffer an almost irreparable loss in our own Observatory, but we could not say, stay with us, for here was the opportunity of a lifetime, and it would have been almost sacrilege to urge him to stay under the circumstances.

The words of one of his associates quoted in the beginning of this article tells us the story of the last two years of the life of Professor Keeler. With his kindly spirit he poured oil upon the troubled waters; made every man, woman and child upon the mountain his friend; organized the work and as Professor Hale has said, gave himself the most difficult task of all. After a year of unremitting labor with the Crossly Reflector, he has given to the world the most magnificent photographs of the nebulæ ever produced. Here is the way he modestly gives the results of his labors. In a letter to the writer dated October 16, 1899, he says: "After spending no end of time on the old mounting of the Reflector I have it working very well indeed and the results of our photographic work are really surprising. I have just sent an article to the *Nachrichten* which describes what is, I think, the best discovery I have made yet, namely, that the majority of the nebulæ are spirals, and that the spiral form is that which is usually or normally assumed by nebulæ in the process of condensation. I have estimated that there are not less than 120,000 nebulæ in the sky within the range of the Crossley Reflector."

Since that letter was written his monographs on the subject have been published in the *Astrophysical Journal*, clearly and cleanly written as is characteristic of all his papers, for Keeler wielded a facile pen; his logic always clean cut and his descriptions wonderfully clear and charming. His lecture courses in the Carnegie Institute in Pittsburg were listened to with profound interest and his generous proposal to open the Allegheny Observatory one night a week, between May and December,—which he faithfully carried out until he left the Observatory—served to create an interest in astronomy among our people which made itself manifest in a most potent way when the proposal to erect a new Observatory was carried out.

But I have, perhaps, already exceeded the limits given me in this sketch of the life work of our departed friend, yet the half has not been told of him who

"Surveyed God's beauteous firmament unrolled
Like to a book new writ in golden words
And turned the azure scroll with reverent hand
And read to man the wonders God hath wrought."

Professor Keeler's father passed away many years ago, but his good mother, a most noble woman, is still living in Washington, making her home with Dr. David T. Day, Chief of the Department of Mineralogy, U. S. Geological Survey, who married her daughter, the only sister of Professor Keeler. To Professor and Mrs. Keeler were given two bright and lovable children,—Cora and Henry. How great our loss; how inconceivably greater theirs. Our sympathy, aye, that of many kindred hearts goes out to them in their great sorrow.

The scientific world honored our departed friend in many ways, but honors lay lightly upon his great soul, and those who knew him best, knew he would rather see his colleagues gain the coveted prize than to win it himself.

"Death makes no conquest of this conqueror;
For now he lives in Fame, though not in life."

THE WHITIN OBSERVATORY OF WELLESLEY COLLEGE.

S. F. WHITING.

The opening of a new Observatory, whether it be primarily for research or primarily for teaching, or primarily to obtain the data for the practical work of the navigator or geodetic engineer is always a matter of importance in the astronomical world. In astronomy, as in every other science, the three classes of workshops and workers are always needed; the investigator and his research Observatory, the teacher and his students' Observatory, the government staff and their naval and geodetic stations. All contribute to the advancement of science, and notably, the teaching Observatory must do something of the work of each to accomplish the best results.

An Observatory, primarily for students' laboratory work in astronomy, has just been opened at Wellesley College, built and equipped by the enlightened liberality of one of the Trustees, Mrs. John C. Whitin.

In the building, the problem of harmonizing beauty of proportion and ornament with adaptation to special functions, has been happily worked out by the architect and director together, and equipment has not been sacrificed to costly material. The plan is that of a dome twenty-three feet in diameter, flanked by wings to the east and west. The smaller one, west, is the transit room, the larger one, east, contains spectroscope and photographic rooms, library and vestibule. A well finished basement affords place for a workshop.

The material is white marble from Georgia quaries with granite base course, and ribbed copper roof, adorned with acroteria with honeysuckle ornament. A brick paved terrace with marble walls leads up to the hooded entrance, above which is carved the seal of the college enclosed in a wreath, bearing the dates 1875, the founding of the college, and 1900, the completion of the Observatory.

The initial equipment consists of a 12-inch Clark equatorial refractor, a three-inch transit, a sidereal clock and chronograph, and a six-foot focus Rowland concave grating spectroscope, with heliostat. The telescope is furnished with spectroscope for solar work, polarizing photometer, micrometer, and small star spectroscope, all with electric illumination. Other minor instruments are already purchased, and it is intended to provide less costly apparatus in duplicate for the elementary practice of laboratory divisions.

The opening exercises were in the beautiful new Houghton Chapel. After the entrance of the academic procession led by the vested choir of the college, and an organ voluntary by the professor of music, Professor Hazard introduced Professor E. C. Pickering, who gave the address. He chose for his subject, "The New Planet Eros," and treated it most happily. He spoke of the discovery of the Asteroids, of the early patient work done upon them, of their late embarrassing number, so that Asteroid hunting seemed a doubtful reward, until this little object was found coming periodically into our near neighborhood, so that observations for its exact position might throw light upon vexed astronomical questions. He related the story of the computation of its orbit by Professor Chandler, based upon positions obtained from photographic plates by the patient scrutiny of Mrs. Fleming, and he told of the plans for observation at the coming approach. The usual note of inspiration for genuine work for which the speaker is well known, pervaded the address, and may wisely set the standard for the new Observatory.

Professor David P. Todd of Amherst spoke by request on "Laboratory Work in Astronomy," a work which he has already done much to promote. He claims that it is the method by which that healthful interest in the science so essential to its future development, may be created. He criticised the method of teaching astronomy which has up to this time prevailed, as in direct antagonism to the fundamental principles of scientific education. He expressed the belief that students should be given apparatus by means of which they could test great principles, since rightness of principle in this work at first should take precedence of display of mere precision of result. This suggestive address held the close attention of the audience.

Letters of greeting were read from foreign women of eminence in astronomy: from Lady Huggins, Miss Agnes Clerke and Miss Dorothea Klumpke. The singing by the choir and audience of Addison's great hymn of nature, "The glorious firmament on high," concluded the academic exercises.

The guests followed by the students, crossed the meadow to the new building. The whole company gathered about the front entrance, where the key was presented by the donor to the president of the college with the words: "It gives me great pleasure to present this building to Wellesley College and the keys to you, her president. I do it in the hope that the telescope and other instruments may inspire a love of astronomy and the Observatory become a factor in the higher education of the young women who come to Wellesley College." As Mrs. Whitin threw open the door the musical notes of the Wellesley cheer rose from the students crowding the hillside, and her name rang out at the end.

The guests next assembled in the library where the fire was lighted upon the hearth by a symbolic torch handed to the donor by President Hazard. In the torch, as was explained, were the simples of the field which stood for health of body, the fern for grace and beauty, the leaf of the oak and elm for peace and civic virtues, the laurel for the breath of fame, the pine for hope of immortality. To these were added rosemary for remembrance and pansies for thoughts. "With these holy associations we light this fire, that from this place where Sun and stars are to be observed, true life may ever aspire with the flame to the Author of this light." As the torch, lighted from a silver lamp fed with aqua vitæ, kindled the fire, the chorus burst into song, rendering verses written for the occasion to the tune Hendon:

Stars above that shine and glow
Have their image here below,
Flames that from the earth arise,
Still aspiring, seek the skies.

Upward with the flame we soar;
Learning ever more and more;
Light and love descend till we,
Heaven reflected here shall see.

The visiting astronomers then inscribed their names in the Observatory book, and all proceeded to an inspection of the building. Refreshments were served in the dome.

In the circle south of the building, upon a granite shaft, is a sundial, the gift of an English friend of one of the professors. It bears the inscription which is upon the sundial in the garden of Sir William and Lady Huggins, "Nil nisi caelesti radio." The motto on the stone course beneath the dome is "Night unto night showeth knowledge."

Classes in physical astronomy and mathematical astronomy are already proving the priceless value of these new facilities.

A FAITHFUL WORKER.

P. S. YENDELL.

Mr. David Flanery, a notice of whose death appears on page 400 of the POPULAR ASTRONOMY for September, was born in

Limerick, Ireland, February 16, 1828. He came to this country in 1847, remaining but a short time, and returning to Ireland. Several years later he returned to the United States. He had become an expert telegraph operator, and was employed in that capacity at several points in the state of Mississippi.

At the breaking out of the Civil War in 1861, Mr. Flanery was residing in Jackson, Mississippi, where he was superintendent of the Southwestern Telegraph Company. He volunteered at the first call of the Confederacy for soldiers, but was induced to retain his position, and when the Confederacy took control of the lines was appointed censor at Jackson. He remained in the telegraph service through the whole war, being frequently under fire in the course of his duty.

In 1865, after the war ended, Mr. Flanery came to Memphis. He at once became permanently identified with the telegraph service, and in 1870 was appointed manager of the New Orleans offices of the Western Union. He was afterward manager at Richmond, Virginia. He returned to Memphis in 1870, and remained there until his death in August last.

Besides being an expert operator, Mr. Flanery was a scientific electrician, well known to the electrical world by his contributions to technical literature, and by several important inventions. His life was a busy and active one up to the last few weeks of his illness. It was only when he was too frail for active duty that he consented to leave his desk at the Western Union office.

Aside from his mastery of electrical science, he was to the end a student of astronomy, and was for many years a contributor to the popular astronomical periodicals.

It was in this connection that I first heard from him, early in the nineties, in a letter inquiring for information regarding certain variable stars. The exchange of letters grew into a sustained correspondence, which continued from the year 1895 till within four weeks of his death. He was a constant and regular correspondent, and I have many postal cards sent to keep me informed as to his latest observations of stars in which we were both interested.

He was a very persevering observer, disposed rather to attempt too much than too little, as is attested by the number of stars which he attempted to observe during his first year of this work, many of which were beyond the reach of his field-glass, which, however, he had not at that time the means of knowing.

In a letter, the last but one received from him, dated 1900, June 30, he says: "I write chiefly to say I am alive after being as near death's door as a man gets without being drawn in. So I have little to communicate, but I have notwithstanding kept up my observations of SU Cygni, not missing one on any favorable night." In a postal card of June 17 he says, "I am confined to my room, but slipped down stairs three steps to an eastern window last night, and had a view of SU Cygni." I had considered myself a rather persistent observer, but this puts me to shame.

Through the courtesy of his son, Mr. Charles M. Flanery, I have by me all his note-books for the years 1895 to 1900 inclusive. They contain in all some four thousand observations, on about eighty stars. In the first year many of these are mere identifications, but about a dozen stars were carefully and persistently followed as long as he lived.

Early in 1897 he purchased a small telescope, with a view to extending downward the range of his observations of variables, and also of making a course of observations of sun spots. This latter series was continued, as his son informs me that up to the day before his death, his daughter made the observations for him. The last entry of astronomical character is August 2, "Nothing on Sun."

An examination of these notes shows that the observations were made with very great care, and the notes are carefully and minutely kept. He was very solicitous in securing the best information accessible to him as to positions and magnitudes, and in taking every possible precaution against avoidable errors of observation.

Mr. Flanery received little attention or encouragement from the regular astronomers; what he did receive he repaid with a great gratitude and appreciation. He was exceedingly modest as to the value of his astronomical work, and never seemed to think it good enough for publication. In spite of all discouragements and difficulties, and the occupations of a busy life, he secured valuable lines of observations of a number of variable stars, the results of which I hope to make public at a later day.

DORCHESTER, Mass., 1900, Oct. 1.

THE DISCOVERY AND PERIOD OF A SMALL VARIABLE STAR IN THE CLUSTER M 13 HERCULIS.

BY E. E. BARNARD.

While engaged in micrometrical work on the stars in the great globular clusters, I have become deeply interested in the variable stars found by Professor Bailey on his photographs taken at

Arequipa, and a large number of observations of some of these stars has been secured and will be printed with the micrometrical work when it is issued.

The great cluster of *Hercules*, *M 13*, at first seemed to differ from the other globular clusters in having no variable stars within its boundaries. This seemed to be the case as late as 1898. About that time, however, Professor Bailey found two stars slightly variable among the outliers on the Harvard photographs. I have simply heard that such were found, but have seen nothing stated as to their position in the cluster so that they might be identified and observed. I therefore do not know of the location of any such variables, and have made no special search for such stars. During the micrometer measures, however, I have found a variable star just within the edge of the brightest part of the cluster.

This star was found from visual observations alone, and not from an examination of photographs. Indeed, the only photograph that I had seen up to the time of finding it that showed the star at all was the Potsdam photograph. Its region is burned out in the other photographs by over-exposure. I have identified the star as No. 216 of Scheiner's catalogue, measured on a photograph of *M 13*. Its position has been micrometrically measured with reference to other stars of the cluster.

Scheiner Nos. 205 and 216,
14°.12 (2)   21″.49 (2).
Scheiner Nos. 183 and 216,
129°.53 (4)   17″.50 (4).
Scheiner Nos. 373 and 216,
288°.45 (2)   55″.16 (2).

The variation is about one entire magnitude, from the 13th to the 14th, or rather from the 14th to the 13th, because its normal condition is faint.

From observations covering an interval of 70 periods, from 1899, August 14, to 1900, August 7, I deduce a period of 5 days, 2 hours and 24 minutes (5^{d}.10). From approximate elements its light curve seems to be much like the ones found by Professor Bailey for the variables in *M 5 Libræ*. The rise in brightness is rapid and the decline relatively slow. The star takes about 1 day to rise to its maximum, and its decline occupies about 2½ or 3 days. The rise is therefore about 0.2 and the decline about 0.5, or 0.6 of the entire period.

The photographic magnitude given this star by Professor Scheiner is 12.4.

I have compared the light of the variable with No. 200 near and preceding it.

Following are the observations:

COMPARISON OF THE LIGHT OF THE VARIABLE (NO. 216) WITH NO. 200.

TIME: 6 hours slow of Greenwich.

1900, July	9	$0^m.2$ brighter than No. 200 at	11^h	35^m
	10	0 .1	11	10
	10	0 .4	14	0
	11	1 .0	9	40
	12	0 .7	10	10
	24	0 .1	10	0
	24	0 .1	12	25
	25	0 .1	9	15
	25	0 .0	10	20
	26	0 .7	12	0
	28	0 .3	9	15
	29	0 .1	9	10
	29	0 .1	10	55
	30	0 .0	9	45
	30	0 .1	12	0
	31	0 .7	8	50
	31	0 .7	10	10
Aug.	1	1 .0	10	10
	4	0 .1	8	15
	5	0 .7	12	0
	6	1 .0	8	35
	7	0 .5	8	15
	12	0 .5	8	35
	13	0 .1	8	50
	14	0 .0	8	5
	18	0 .1	8	25
	20	0 .1	8	00
	21	1 .0	8	40
	27	0 .6	7	35
	28	0 .3	9	00
Sept.	3	0 .1	7	20
	3	0 .2	7	50
	4	0 .1	7	15
	4	0 .2	8	0
	19	0 .2	10	10

This star was also at its maximum on August 14, 1899.

YERKES OBSERVATORY, August, 1900.

THE OBSERVATIONS OF EROS.[*]

It seems to us wise to communicate to you the opinion of the special commission appointed by the International Conference in the matter of two questions concerning the carrying out of the micrometric observations of the planet Eros.

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[*] Circular No. 5 of the International Astrographic Conference, July, 1900, prepared by the President, M. Loewy, Paris, Oct. 10, 1900. Translated from the French by Miss I. Watson, Professor of French and German, Carleton College.

The members were unanimously of the opinions:

I. That it was preferable to every other mode of operation to determine the relative positions of the asteroid with regard to the neighboring stars by the aid of measures of rectilinear coordinates.

II. That it seemed best to adopt the 11th magnitude as the lowest limit of brightness for the stars of comparison, so as to avoid too great accidental errors and slight systematic errors.

Since the object of this research is to reach the greatest possible precision, we beg our co-laborers to use exceptional care in the determination of instrumental constants, and especially in the frequent verification of the thread of the screw which, in the observatories of the northern hemisphere could easily be done by the aid of observations on the group of *h* Persei (Krueger).

On account of the numerous gaps which are certain to occur during the winter months, it is important that each Observatory try to take the greatest possible advantage of every favorable evening. We therefore advise the astronomers who undertake observations at great hour-angles east and west, (Circular No. 2, ¶¶ *a* and *b*) not to be content with a single supplementary series, but to make several of them. They will thus increase the possibility of making the results, which are obtained on different parts of the globe correspond to the same physical instant; and besides, they will obtain a series of observations made under the best conditions of altitude and which, in a general way, will always be valuable from divers points of view. But the interval between the successive series could then be reduced to one hour.

As to the execution of photographic work, it is fitting to make the following remarks:

I. For the special series of plates of which the sole object is to furnish the positions of stars of comparison, and which should contain all the stars to the eleventh (11th) magnitude at least, we would advise making on the same plate two exposures of different duration, in such a way that each star shall be represented by two images, distant by about twenty seconds of arc in declination. The second exposure would have for its object on the one hand to render the the true images of the stars more recognizable; and on the other hand, to permit two series of measures to be made on images of different intensity.

With the instruments which are employed in the construction of the photographic chart of the heavens (aperture $0^{m}.33$) a duration of three minutes might be considered sufficient for obtaining the greater part of the stars of the 11th magnitude.

But since it will be interesting to go beyond this limit in order to meet all possible contingencies, such as the very considerable differences between photographic and visual magnitudes, or a diminution in the transparency of the air, or even, in certain cases, the difficulty of finding stars of comparison of the eleventh magnitude in the immediate vicinity of the planet, it seems to us more reasonable and prudent to adopt a duration of 6 minutes for the first exposure, and of 3 minutes for the second; as is the case in the construction of the photographic catalogue of the heavens.

II. With regard to the series of plates intended for the measures of the positions of the planet, it would be equally useful to make two successive exposures on the same plate, first by following a guide star, *i. e.* by holding the image of this star at the crossing of the threads of the guiding telescope; second by following the image of the planet; but since the faintness of the asteroid would render this operation too difficult, one could obtain the same result by giving to the image of the guide star a movement equal to that of the planet and in the opposite direction. One would thus have for the planet in the first case a slightly elongated image and in the second a circular image.

As a matter of information we can announce that the planet has been photographed at the observatories of Paris and Algiers, Oct. 4 and 6, by following a guide star for 3 minutes and that perfectly sharp and quite intense images have been thus obtained. It is then beyond question that the photographic observation of the asteroid can be accomplished under good conditions. At the two dates indicated the planet was judged at Paris to be of a brilliancy at least equal to that of a star of magnitude 10.5.

M. Joly also has informed us that he obtained images of the planet on the 24th of last September at the Observatory at Dublin with a 15-inch reflector and with exposures of six and of two minutes. Mr. Turner, of Oxford, tells us that he reached the same result with an exposure of one minute, and that the rapid motion of Eros gives no equation for difficulty.

For the purpose of assuring so far as possible the success of this important work in which about fifty observatories are taking part, it is essential to know the exact state of advancement of each of these contemplated operations. The executive committee would thus be in a position to meet the difficulties which might arise and to secure the measures necessary for filling up the accidental gaps in the realization of the plan of work followed.

Accordingly we beg the astronomers who participate in this enterprise to kindly send us reports of the successive degrees of progress which they shall have accomplished in the different kinds of observation.

Here is a more complete list of the observatories which, after the publication of the preceding circulars have given their adherence: Berlin, Besancon, Brussels, Charlottesville, Christiania, Denver, Dublin, Evanston, Florence, Helsingfors, Konigsberg, Lisbon, Madison, Northfield, Oxford (Eng.), Padua, Palerma, Pulkova, Tachkent, Teramo, Yerkes.

Below will be found the continuation of the auxiliary tables intended to facilitate the observations and calculations for the months of January and February, 1901. We have added to it a little recapitulative schedule containing the principal data which permit the astronomer to inform himself on the general conditions of the observations. Especially there will be found the visual brilliancy of the planet Eros, calculated for various epochs. According to the estimates made by Messrs. Bigourdan, Henry, Luther and Millosevich the value 10.5 has been adopted for the apparent magnitude of the star Sept. 29, 1900. The other numbers have been deduced taking into account the angle of the phase by means of the empiric formula of Mr. E. C. Pickering, (Circular No. 49, Harvard College Observatory).

In order to facilitate the reduction of the meridian observations of the reference stars, we will furnish, for a certain number of fundamentals situated in the region traversed by Eros, the positions calculated at intervals of ten days, from September 15 to December 31, 1900, and based on Newcomb's catalogue of fundamental stars.

SUMMARY OF THE CONDITIONS OF OBSERVATION OF THE PLANET EROS.

Date.	Magnitude.	R. A.	Decl.	Meridian Passage.	Parallax.
1900, Sept. 29	10.50	2^h 44^m	+ 44° 12′	14^h 10^m	15″.1
9	10.30	2 43	+ 47 51	13 30	17 .0
19	10.06	2 36	+ 51 5	12 43	19 .0
29	9.81	2 21	+ 53 24	11 49	21 .1
Nov. 8	9.56	2 1	+ 54 21	10 50	23 .1
18	9.34	1 42	+ 53 38	9 51	24 .9
28	9.15	1 29	+ 51 20	9 0	26 .3
Dec. 8	9.05	1 27	+ 47 55	8 19	27 .3
18	9.02	1 36	+ 43 54	7 48	27 .8
28	9.04	1 54	+ 39 38	7 27	27 .9
Jan. 7	9.12	2 20	+ 35 20	7 14	27 .6
17	9.26	2 51	+ 31 5	7 5	27 .1
27	9.47	3 26	+ 26 55	7 0	26 .1
Feb. 6	9.71	4 2	+ 22 52	6 57	24 .9
16	9.97	4 40	+ 19 1	6 56	23 .4
26	10.24	5 17	+ 15 24	6 54	21 .9
Mar. 8	10.48	5 54	+ 12 3	6 51	20 .3

AN ANCIENT ASTRONOMICAL INSTRUMENT.

KURT LAVES.

Some years ago I happened to see in the Ethnological Museum at Berlin among a collection of East Indian curiosities a small rectangular board about three inches by four, to the middle point of which a chord of about ten inches was fastened. A number of knots were tied into the string and on the one side of the board some words in foreign characters were visible. The explanation given by the label, attached to this item of curiosity, was, that the board was used by the tribes of the west shore of East India, accustomed to sea-faring life, for the purpose of determining their latitudes at sea.

It is evident how the little device can be used for this purpose. Holding with the one hand the board in a vertical position, so that the longer edges are horizontal, the observer with his face to the North Star can bring the upper edge to pass through the star whilst the lower edge is touching the horizontal line all the time, keeping the middle point of the board level with his eye. Stretching the cord to the tip of his nose and marking this point, the observer will have approximately determined the length of one of the equal sides of the isosceles triangle, which has its vertex in the eye of the observer; its base is formed by the vertical line passing through the middle point of the board. I have said, that the string measures one of the sides and not the height of the triangle, since it is stretched to a point nearly half the length of the base below the vertex of the triangle. The facial differences of the different observers must have established such a strong personal equation, as to limit each observer to his own apparatus. If we assume for a moment, that the North Star actually coincides with the North Pole, we can imagine, that the ancient observers needed only to find on land the lengths of the string for a number of conspicuous land marks of the shore, to have a ready means of finding between the latitudes of which two standard places their boat was located. Indeed we know the base b and the side l of the isosceles triangle, we have, therefore, when we call the angle at the vertex L

$$\sin L/2 = \frac{b}{2l}$$

L will be the altitude of the North Star or the latitude of the observer in our hypothesis. The rudeness of the method is apparent with its many and conspicuous defects, still there is a certain ingenuity in this proceeding cognate to that displayed in the invention of the gnomon. But there seems to be a serious difficulty when we give up our hypothesis, that the daily apparent orbit of the North Star is reduced to a point. It is obvious, that, when we determine the reference points in the string from observations of the North Star in upper culmination, we would arrive at absolutely erroneous results. The same is true when the star is in lower culmination. We can hardly assume, that the ancient observers had provided for that purpose a table of correction. A much simpler explanation appears to me to be the following: The great monsoon winds always occur at the same seasons of the year once in a southward, and once in a northward direction. Upon them communications between distant tribes of the East Indian shore have been dependent from times immemorial. Their two seasons are half a year apart and begin with January and July respectively. In the early evening hours of January, the Pole Star is near its upper culmination, in July near its lower culmination. If the ancient navigators were provided therefore, for the southward trip in January, with a set of reference points based upon observations in upper culmination, and for their northward journey in July with one derived from lower culmination, it seems that the difficulty would be easily remedied. It would seem therefore not improbable, that the little instrument in the Berliner Museum was invented for the very purpose of making possible these great and periodical journeys to distant shores. Since the East Indian peninsula lies between $+ 25°$ aud $+ 70°$ it is obvious that in these low latitudes the instrument is at its best, in as much as a small change in latitude will produce an appreciable change in the length of the string. Indeed

$$\frac{1}{\sin\frac{L}{2}}$$

varies between 5 and 11 in this interval of latitudes from 25° to 7° so the string at Cap Camorin will be about 16 inches with $b = 3$ inches and at the mouth of the Indus about 7 inches.

THE UNIVERSITY OF CHICAGO,
1900 Oct. 30th.

BURCKHALTER'S APPARATUS FOR PHOTOGRAPHING THE SOLAR CORONA.*

Charles Burckhalter's successful invention which enabled him to secure such excellent photographs at the Georgia eclipse last

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* Extracts from an article that recently appeared in the *Oakland Inquirer.*

May is bringing much favorable notice both to himself and the Chabot Observatory of Oakland, with which he is connected. The leading astronomers of the world unite in declaring that Professor Burckhalter's invention is an important addition to the science and that it will probably lead to discoveries in the study of the Sun's corona.

As has been noted before, Professor Burckhalter's invention consists of a device whereby both the brighter and darker portions of the Sun's corona may be photographed at the same time. Professor Burckhalter was able to give his invention a thorough test at the Georgia eclipse last May, thanks to the generosity of John Dolbeer, a San Francisco business man who takes much interest in astronomy and who provided the necessary funds for the expedition. William M. Pierson of San Francisco had previously presented a photographic telescope to Chabot Observatory and Dr. George C. Purdee of Oakland had provided a duplicate lens and both of these instruments were taken to Georgia for use in the eclipse, most successful results being obtained, as can be judged from the extracts of letters from the astronomers given below.

Professor C. A. Young of Princeton Observatory, writes as follows:

"I congratulate you most heartily on your practically perfect success. All six of your revolver plates are admirable and the way in which different exposures and developments of positives made from a single negative bring out quite different details is very interesting, as exemplified in the two pairs of pictures made from your negatives 7 and 8."

Professor George E. Hale, director of the Yerkes Observatory, has the following to say:

"Many thanks for your kindness in sending the lantern slides of your photographs of the corona. They certainly show very clearly the advantage of your method of exposing and I only wish it were not too late to publish them with the other eclipse photographs in the *Astronomical Journal.*"

Professor E. C. Pickering of Harvard College Observatory says:

"Your letter and the lantern slides arrived safely. The latter are very interesting and ought to give us many new facts regarding the corona."

Professor J. E. Keeler, the late director of Lick Observatory, wrote shortly before his death as follows concerning the results of Professor Burckhalter's work at the Georgia eclipse:

"I congratulate you heartily on the success of your method and the final results you have obtained with it. While the the corona is less interesting than that of the India eclipse, your negatives are technically more perfect than those secured on that occasion."

Professor A. O. Leuschner, who is in charge of the students' Observatory of the University of California, had this to say:

"Please accept my sincere thanks for the fine slides from your photographs of the recent solar eclipse. There is no doubt in my mind that your method of obtaining composite photographs of the solar corona is an immense success and I extend to you my sincere congratulations on your fine work."

Captain William Noble, a prominent member of the Royal Astronomical Society of England, expressed himself as follows:

"I am delighted with them—there is no other word for it—and thank you most sincerely for so really beautiful and valuable a gift. It seems invidious to pick out one when all are so excellent, but I gravely doubt if 'No. 1' has ever been surpassed as a picture of the region immediately surrounding the Sun's limb, or 'No. 6' as a view of the entire solar surroundings. You ought to feel most uncommonly proud of yourself and of your really brilliant and original invention."

In writing concerning the sending of copies of Professor Burckhalter's photographs of the eclipse to Flammarion, the great French astronomer, M. J. Costa, the Consul of Uruguay at San Francisco, says:

"It is a pleasure to me to notify you that the great astronomer, Camille Flammarion, has received, through J. C. Cebrian, your photographs of the Sun's corona and he has pronounced them the best he has seen and he is going to print them in his paper, (*Astronomie Popularie*). He will write you about some details of said photographs."

Dr. L. Weinek, director of the Royal Observatory of Prague, Austria, says:

"I must confess that I have never seen such clear eclipse photographs with protuberances and a perfectly sharp rim of the Moon * * * * and I congratulate you upon the wonderful, astonishingly beautiful results."

In writing to John Dolbeer, who furnished the funds for the Chabot expedition Dr. Weinek said:

"At your kind suggestion, Mr. Charles Burckhalter, director of Chabot Observatory, Oakland, has sent me five splendid positives of this year's total eclipse of May 28th, taken at Siloam, Georgia; they arrived here on September 29th in perfect condition. I am exceedingly gratified to possess these pictures which show the corona in an incomparably beautiful and clear manner. I congratulate you upon your great-heartedness in sending this expedition as well as Mr. Burckhalter upon the wonderful results obtained by his method of control. I have never seen even on the best eclipse photographs taken in any country and by any astronomers, the corona as a whole with the protuberances as they are shown in numbers 6 and 8. The protuberances on number 10 also show a surprising sharpness and distinctness."

Professor Edward S. Holden, formerly director of Lick Observatory, who is now in New York, expressed himself in the following enthusiastic manner:

"I've just received your splendid box of slides and given some little time to examining them. They are most instructive and do you the greatest credit. It is all your own plan, invented throughout and carried out unaided and these slides are a positive addition to science. I mean to study them in connection with other slides I have in New York and expect to learn much. The detail is wonderful and they are a success. I thank you sincerely for the chance of seeing them and congratulate you heartily."

W. H. Wesley, secretary of the Royal Astronomical Society, England, wrote, "the detail near the Moon's limb is marvelous and shows the immense superiority of the method."

Highly commendatory articles have also appeared in various astronomical journals, testifying to the importance and value of Professor Burckhalter's invention.

ASTRONOMY.*

DR. A. A. COMMON.

The progress of the new astronomy is so closely bound up with that of photography that I shall briefly call to mind some of the many achievements in which photography has aided the astronomer.

Daguerre's invention in 1839 was almost immediately tried with the Sun and Moon, J. W. Draper and the two Bonds in America, Warren de la Rue in this country, and Foucault and

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* Opening Address by Dr. A, A. Common, F. R. S., F. R. A. S., Chairman of the Department of Astronomy, at the Bradford meeting of the British Association for the Advancement of Science. Continued from page 424.

Fizeau in France, being among the pioneers of celestial photography; but no real progress seems to have been made until after the introduction of the collodion process. Sir John Herschel in 1847 suggested the daily self-registration of the sun-spots to supercede drawings; and in 1857 the De la Rue photo-heliograph was installed at Kew. From 1858-72 a daily record was maintained by the Kew photo-heliograph, when the work was discontinued. Since 1873 the Kew series has been continued at Greenwich, and is supplemented by pictures from Dehra Dun in India and from Mauritius. The standard size of the Sun's disc on these photographs has now been for many years 8 inches, though for some time a 12-inch series was kept up.

The first recorded endeavor to employ photography for eclipse work dates back to 1851, when Berowsky obtained a daguerreotype of the solar prominences during the total eclipse. From that date nearly every total eclipse of the Sun has been studied by the aid of photography.

In 1860 the first regularly planned attack on the problem by means of photography was made, when De la Rue and Secchi successfully photographed the prominences and traces of the corona, but it was not until 1869 that Professor Stephen Alexander obtained the first good photograph of the corona.

In recent years, from 1893 until the total eclipse which occurred last May, photography has been employed to secure large-scale pictures of the corona. These were inaugurated in 1893 by Professor Schaeberle, who secured a 4-inch picture of the eclipsed Sun in Chilli; these have been exceeded by Professor Langley, who obtained a 15-inch picture of the corona in North Carolina during the eclipse of May 1900.

Photography also supplied the key to the question of the prominences and corona being solar appendages, for pictures of the eclipse Sun taken in Spain in 1860 terminated this dispute with regard to the prominences, and finally to the corona in 1871.

In 1875, in addition to photographing the corona, attempts were made to photograph its spectrum, and at every eclipse since then the sensitised plate has been used to record both the spectrum of the chromosphere and the corona. The spectrum of the lower layers of the chromosphere were first successfully photographed during the total eclipse of 1896 in Nova Zembla by Mr. Shackleton, though seen by Young as early as 1870 and a new value was given to the wave-length of the coronal line (wrongly mapped by Young in 1869) from photographs taken by Mr.

Fowler during the eclipse of 1898 (India).

Lunar photography has occupied the attention of various physicists from time to time, and when Daguerre's process was first enunciated, Arago proposed that the lunar surface should be studied by means of the photographically produced images. In 1840 Dr. Draper succeeded in impressing a daguerreotype plate with a lunar image by the aid of a 5-inch refractor. The earliest lunar photographs, however, shown in England, were due to Professor Bond, of the United States. These he exhibited at the Great Exhibition in 1851. Dancer, the optician, of Manchester, was, perhaps, the first Englishman who secured lunar images, but they were of small size (Abney, "Photography.)"

Another skillful observer was Crookes, who obtained images of 2 inches diameter, with an 8-inch refractor of the Liverpool Observatory. In 1852 De la Rue began experimenting in lunar photography. He employed a reflector of some 10 feet focal length and about 13 inches diameter. A very complete account of his methods is given in a paper read before the British Association. Mr. Rutherfurd at a later date having tried an 11½-inch refractor, and also a 13-inch reflector, finally constructed a photographic refracting telescope, and produced some of the finest pictures of the Moon that were ever taken until recent years. Also Henry Draper's picture of the Moon taken Sept. 3, 1863, remained unsurpassed for a quarter of a century.

Admirable photographs of the lunar surtace have been published in recent years by the Lick Observatory and others. I myself devoted considerable attention to this subject at one time; but only those surpassing anything before attempted have been published in 1896-99 by MM. Loewy and Puiseux, taken with the Equatorial Coude of the Paris Observatory.

Star prints were first secured at Harvard College, under the direction of W. C. Bond, in 1850; and his son, G. P. Bond, made in 1857 a most promising start with double-star measurements on sensitive plates, his subject being the well-known pair in the tail of the Great Bear. The competence of the photographic method to meet the stringent requirements of exact astronomy was still more decisively shown in 1866 by Dr. Gould's determination from his plates of nearly fifty stars in the Pleiades. Their comparison with Bessel's places for the same objects proved that the lapse of a score of years had made no difference in the configuration of that immemorial cluster; and Professor Jacoby's recent measures of Rutherfurd's photographs taken in 1872 and 1874 enforce the same conclusion.

The above facts are so forcible that no wonder that at the Astrophotographic Congress held in Paris in 1887 it was decided to make a photographic survey of the heavens, and now eighteen photographic telescopes of 13 inches aperture are in operation in various parts of the world, for the purpose of preparing the international astrographic chart, and it was hoped that the catalogue plates would be completed by 1900.

Photography has been applied so assiduously to the discovery of minor planets that something like 450 are now known, the most noteworthy, perhaps, as regards utility being the discovery of Eros (433) in 1898 by Herr Witt at the Observatory Urania, near Berlin.

With regard to the application of photography to recording the forms of various nebulæ, it is interesting to quote a passage from Dick's "Practical Astronomer," published in 1845, as opposed to Herschel's opinion that the photography of a nebula would never be possible.

"It might, perhaps, be considered as beyond the bounds of probability to expect that even the distant nebulæ might thus be fixed, and a delineation of their objects produced, which shall be capable of being magnified by microscopes. But we ought to consider that the art is only in its infancy, and that plates of a more delicate nature than those hitherto used may yet be prepared, and that other properties of light may yet be discovered, which shall facilitate such designs. For we ought now to set no boundaries to the discoveries of science, and to the practical applications of scientific discovery, which genius and art may accomplish."

It was not, however, until 1880 that Draper first photographed the Orion Nebula, and later by three years I succeeded in doing the same thing with an exposure of only thirty-seven minutes. In December 1885 the brothers Henry by the aid of photography found that the Pleiades were involved in a nebula, part of which, however, had been seen by myself (*Monthly Notices*, vol. xl. p. 376) with my 3-foot reflector in February 1880, and later, February 1886; it was also partly discerned at Pulkowa with the 30-inch refractor then newly erected.

Still more nebulosity was shown by Dr. Roberts's photographs (*ibid.*, vol. xlvii, p. 24), taken with his 20-inch reflector in October and December 1886, when the whole western side of the group was shown to be involved in a vast nebula, whilst a later photograph taken by MM. Henry early in 1888 showed that practically the whole of the group was a shoal of nebulous matter.

In 1881 Draper and Janssen recorded the comet of that year by photography.

Huggins (*Proc. Roy. Soc.*, vol. xxxii. No. 213) succeeded in photographing a part of the spectrum of the same object (Tebbutt's Comet 1881, II.) on June 24, and the Fraunhofer lines were amongst the photographic impressions, thus demonstrating that at least a part of the continuous spectrum is due to reflected sunlight. He also secured a similar result from Comet Wells (*Brit. Assoc. Report*, 1882, p. 442).

I propose to consider the question of the telescope on the following lines: (1) The refractor and reflector from their inception to their present state. (2) The various modifications and improvements that have been made in mounting these instruments, and (3) the instrument that has lately been introduced by a combination of the two, refractor and reflector, a striking example of which exists now at the Paris Exhibition.

At a meeting of the British Association held nearly half a century ago (1852) (Belfast) Sir David Brewster showed a plate of rock crystal worked in the form of a lens which had been recently found in Nineveh. Sir David Brewster asserted that this lens had been destined for optical purposes, and that it never was a dress ornament.

That the ancients were acquainted with the powers of a magnifying lens may be inferred from the delicacy and minuteness of the incised work on their seals and intaglios, which could only have been done by an eye aided by a lens of some sort.

There is, however, no direct evidence that the ancients were really acquainted with the refracting telescope, though Aristotle speaks of the tubes through which the ancients observed distant objects, and compares their effect to that of a well from the bottom of which the stars may be seen in daylight ("De Gen. Animalium," lib. v). As an historical fact without any equivocations, however, there is no serious doubt that the telescope was invented in Holland.

The honor of being the originator has been claimed for three men, each of whom has had his partisans. Their names are Metius, Lippershey and Janssen.

Galileo himself says that it was through hearing that some one in France or Holland had made an instrument which magnified distant objects that he was led to inquire how such a result could be obtained.

The first publisher of a result or discovery, supposing such discovery to be honestly his own, ranks as the first inventor, and there is little doubt that Galileo was the first to show the world how to make a telescope (Newcomb's "Astronomy," p. 108). His first telescope was made whilst on a visit to Venice, and he there exhibited a telescope *magnifying three times*: this was in May, 1609. Later telescopes which emanated from the hands of Galileo magnified successively four, seven and thirty times. This latter number he never exceeded.

Greater magnifying power was not attained until Kepler explained the theory and some of the advantages of a telescope made of two convex lenses in his "Catoptrics" (1611). The first person to actually apply this to the telescope was Father Scheiner, who describes it in his "Rosa Ursina" (1630) and Wm. Gascoigne was the first to appreciate practically the chief advantages by his invention of the micrometer and application of telescopic sights to instruments of precision.

It was, however, not until about the middle of the seventeenth century that Kepler's telescope came to be nearly universal, and then chiefly because its field of view exceeded that of the Galilean.

The first powerful telescopes were made by Huyghens, and with one of these he discovered Titan (Saturn's brightest satellite): his telescopes magnified from forty-eight to ninety-two times, were about 2⅓ inches aperture, with focal lengths ranging from 12 to 23 feet. By the aid of these he gave the first explanation of Saturn's ring, which he published in 1659.

Huyghens also states that he made object-glasses of 170 feet and 210 feet focal length; also one 300 feet long, but which magnified only 600 times; he also presented one of 123 feet to the Royal Society of London.

Auzout states that the best telescopes of Campani at Rome magnified 150 times, and were of 17 feet focal length. He himself is said to have made telescopes of from 300 to 600 feet focus, but it is improbable that they were ever put to practical use. Cassini discovered Saturn's fifth satellite (Rhea) in 1672, with a telescope made by Campani, magnifying about 150 times, whilst later, in 1684, he added the third and fourth satellites of the same planet to the list of his discoveries.

Although these telescopes were unwieldy, Bradley, with his usual persistency, actually determined the diameter of Venus in 1722 with a telescope of 212 feet focal length.

With such cumbersome instruments many devices were invented of pointing these *aerial telescopes*, as they were termed, to various parts of the sky. Huyghens contrived some ingenious arrangements for this purpose, and also for adjusting and centre-ing the eye-piece, the object-glass and eye-piece being connected by a long braced rod.

It was not, however, until Dolland's invention of the achromatic object-glass in 1757-58 that the refracting telescope was materially improved, and even then the difficulty of obtaining large blocks of glass free from striæ limited the telescope as regards aperture, for even at the date of Airy's report we have seen that 12 inches was about the maximum aperture for an object-glass.

The work of improving glass dates back to 1784, when Guinand began experimenting with the manufacture of optical flint glass.

He conveyed his secrets to the firm of Fraunhofer and Utzschneider, whom he joined in 1805, and during the period he was there they made the 9.6-inches object-glass for the Dorpat telescope.

Merz and Mædler, the successors of Fraunhofer, carried out successfully the methods handed down to them by Guinand and Fraunhofer.

Guinand communicated his secrets to his family before his death in 1823, and they entered into partnership with Bontemps. The latter afterwards joined the firm of Chance Bros., of Birmingham, and so some of Guinand's work came to England.

At the present day MM. Feil, of Paris, who are direct descendants of Guinand and Messrs. Chance Bros., of Birmingham, are the best known manufacturers of large discs of optical glass.

It is related in history that Ptolemy Euergetes had caused to be erected on a lighthouse at Alexandria a piece of apparatus for discovering vessels a long way off; it has also been maintained that the instrument cited was a concave reflecting mirror, and it is possible to observe with the naked eye images formed by a concave mirror, and that such images are very bright.

Also the Romans were well acquainted with the concentrating power of concave mirrors, using them as burning mirrors, as they were called. The first application of an eye lens to the image formed by reflection from a concave mirror appears to have been made by Father Zucchi, an Italian Jesuit. His work was published in 1652, though it appears he employed such an instrument as early as 1616. The priority, however, of describing, if not making, a practical reflecting telescope belongs to Gregory, who, in his "Optica Promota," 1663, discusses the forms of images of objects produced by mirrors. He was well aware of the failure of all attempts to perfect telescopes by using lenses of various curvature, and proposed the form of reflecting telescope which bears his name.

Newton, however, was the first to construct a reflecting telescope, and with it he could see Jupiter's satellites, etc. Encouraged by this, he made another of 6½-inches focal length, which magnified thirty-eight times, and this he presented to the Royal Society on the day of his election to the Society in 1671.

To Newton we owe also the idea of employing pitch, used in the working of the surfaces.

A third form of telescope was invented by Cassegrain in 1672. He substituted a small convex mirror for the concave mirror in Gregory's form, and thus rendered the telescope a little shorter.

Short, also from 1730-68, displayed uncommon ability in the manufacture of reflecting telescopes, and succeeded in giving true parabolic and elliptic figures to his specula, besides obtaining a high degree of polish upon them. In Short's first telescopes the specula were of glass, as suggested by Gregory; but it was not until after Liebig's discovery of the process of depositing a a film of metallic silver upon a glass surface from a salt in solution that glass specula became almost universal, and thus replaced the metallic ones of earlier times.

Shortly after the announcement of Liebig's discovery Steinheil (*Gaz. Univ. d'Augsburg*, March 24, 1856)—and later, independently, Foucault, (*Comptes rend.*, Vol. XLIV, February 1857)—proposed to employ glass for the specula of telescopes, and as is well known, this is done in all the large reflectors of to-day.

I now propose to deal with the various steps in the development of the telescope, which have resulted in the three forms that I take as examples of the highest development at the present time. These are the Yerkes telescope at Chicago, my own 5-foot reflector, and the telescope recently erected at the Paris Exhibition, dealing not only with the mountings, but with the principles of construction of each. When the telescope was first used all could be seen by holding it in the hand. As the magnifying power increased, some kind of support would become absolutely necessary, and this would take the form of the altitude and azimuth stand, and the motion of the heavenly bodies would doubtless suggest the parallactic or equatorial movement, by which the telescope followed the object by one movement, of an axis placed parallel to the pole. This did not come, however, immediately. The long focus telescopes of which I have spoken were sometimes used with a tube, but more often the object-glass was mounted in a long cell and suspended from the top of a pole at the right height to be in a line between the observer and the object to be looked at; and it was so arranged that by means of a cord it could be brought into a fairly correct position. Notwithstanding the extreme awkwardness of this arrangement, most excellent observations were made in the seventeenth century by the users of these telescopes. Then the achromatic telescope was invented and mechanical mountings were used, with circles for finding positions, much as we have them now. I have already mentioned the rivalry between the English and German forms of mountings, and Airy's preference for the English form. The general feeling amongst astronomers has, however, been largely in favor of the German mounting for refractors, due, no doubt, to a great extent, to the enormous advance in engineering skill. We have many examples of this form of mounting. * * *

The small reflector made by Sir Isaac Newton, probably the first ever made, and now at the Royal Society, is mounted on a ball, gripped by two curved pieces, attached to the body of the telescope, which allows the telescope to be pointed in any direction. We have not much information as to the mounting of early reflectors. Sir William Herschel mounted his 4-foot telescope on a rough but admirably planned open-work mounting, capable of being turned round, and with means to tilt the telescope to any required angle. This form was not very suitable for picking up objects or determining their position, except indirectly; but for the way it was used by Sir William Herschel it was most admirably adapted: the telescope being elevated to the required angle, it was left in that position, and became practically a transit instrument. All the objects passing through the field of view (which was of considerable extent, as the eye-piece could not be moved in declination) were observed, and their places in time and declination noted, so that the positions of all these objects in the zone observed were obtained with a considerable degree of accuracy. It was on this plan that Sir John Herschel made his general catalogue of nebulæ, embracing all the nebulæ he could see in both hemispheres; a complete work by one man that is almost unique in the history of astronomy.

Sir William Herschel's mounting of his 4-foot reflector differs in almost every particular from the mountings of the long focus telescopes we have just spoken of. The object-glass was at a height, the reflector was close to the ground. There was a tube to one telescope, but not to the other. The observer in one case stood on the ground, in the other he was on a stage at a considerable elevation. One pole sufficed with a cord for one; a whole mass of poles, wheels, pulleys and ropes surrounded the other. In one respect only were they alike—they both did fine work.

Lassell seems to have been the first to mount a reflector equatorially. He, like Herschel, made a 4-foot telescope, and this he mounted in this way. Lord Rosse mounted his telescopes somewhat after the manner of Sir William Herschel. The present Earl has mounted a 3-foot equatorially.

A 4-foot telescope was made by Thomas Grubb for Melbourne, and this he mounted on the German plan. The telescope being a Cassegrain, the observer is practically on the ground level. A somewhat similar instrument exists at the Paris Observatory. Lassell's 4-foot was mounted in what is called a fork mounting, as is also my own 5-foot reflector, and this in some ways seems well adapted for reflectors of the Newtonian kind.

We now come to the Paris telescope. This is really the result of the combination of a reflector and a refractor. I cannot say when a plane mirror was first used to direct the light into a telescope for astronomical purposes. It seems first to have been suggested by Hooke, who, at a meeting of the Royal Society, when the difficulty of mounting the long focus lenses of Huyghens was under discussion, pointed out that all difficulties would be done away with if, instead of giving movement to the huge telescope itself, a plane mirror were made to move in front of it (Lockyer, "Star-gazing," p. 453).

The Earl of Crawford, then Lord Lindsay, used a heliostat to direct the rays from the Sun, on the occasion of the transit of Venus, through a lens of 40 feet focal length, in order to obtain photographs, and it was also largely used by the American observers on the same occasion.

Monsieur Loëwy at Paris proposed in 1871 a most ingenious telescope made by a combination of two plane mirrors and an achromatic object-glass, which he calls a Coudé telescope, which has some most important advantages. Chief amongst these are that the observer sits in perfect comfort at the upper end of the polar axis, whence he need not move, and by suitable arrangements he can direct the telescope to any part of the visible heavens. Several have been made in France, including a large one of 24 inches aperture, erected at the Paris Observatory, and which has already made its mark by the production of perhaps the best photographs of the Moon yet obtained. I have already spoken of Lord Lindsay and his 40-foot telescope, fed, as it were with light from a heliostat. This is exactly the plan that has been f o lowed in the design of the large telescope in the Paris Exhibition. But in place of a lens of 4 inches aperture and a heliostat a few inches larger, the Paris telescope has a plane mirror of 6 feet and a lens exceeding 4 feet in diameter, with a focal length of 186 feet. The cost of a mounting on the German plan and of a dome to shelter such an instrument would have been enormous. The form chosen is at once the best and cheapest. One of the great disadvantages is that from the nature of things it cannot take in the whole of the heavens. The heliostat form of mounting of the plane mirror causes a rotation of the image in the field of view which in many lines of research is a strong objection. There is much to be said on the other side. The dome is dispensed with, the tube, the equatorial mounting and the rising floor are not wanted. The mechanical arrangements of importance are confined to the mounting of the necessary machinery to carry the large plane mirror and move it round at the proper rate. The telescope need not have any tube (that to the Paris telescope is, of course, only placed there for effect) as the flimsiest covering is enough if it excludes false light falling on the eye-end; and, more important than all, the observer sits at his ease in the dark chamber. This question of the observer, and the conditions under which he observes, is a most important one as regards both the quality and quantity of the work done.

We have watched the astronomer, first observing from the floor level, then mounted on a high scaffold like Sir William Herschel, Lassell and Lord Rosse; then, starting again from the floor level and using the early achromatic telescope; then, as these grew in size, climbing up on observing chairs to suit the various positions of the eye-end of the telescope, as we see in Mr. Newall's great telescope; then brought to the floor again by that excellent device of Sir Howard Grubb, the rising floor. This is in use with the Lick and the Yerkes telescopes, where the observer is practically always on the floor level, though constant attention is needed, and the circular motion has to be provided for by constant movement, to say nothing of the danger of the floor going wrong. Then we have the ideal condition, as in the Equatorial Coudé at the Paris Observatory, where the observer sits comfortably sheltered and looks down the telescope, and from this position can survey the whole of the visible heavens. The comfort of the observer is a most important matter, especially in the long exposures that are given to photographic plates, as well as for continued visual work. In such a form of telescope as that at Paris, the heliostat form of mounting the plane mirror is most suitable, notwithstanding the rotation of the image. But there is another way in which a plane mirror can be mounted, and that is on the plan first proposed by Auguste many years ago and lately brought forward again by Mons. Lippman, of Paris, and that is by simply mounting the plane mirror on a polar axis and parallel therewith, and causing his mirror to rotate at half the speed of the Earth's rotation. Any part of the heavens seen by any person reflected from his mirror will appear to be fixed in space, and not partake of the apparent movement of the Earth, so long as the mirror is kept moving at this rate. A telescope, therefore, directed to such a mirror can observe any heavenly body as if it were in an absolutely fixed position so long as the angle of the mirror shall not be such as to make the reflected beam less than will fill the object-glass. There is one disadvantage in the cœlostat, as this instrument is called, and that is its suitability only for regions near the equator. The range above and below, however, is large enough to include the greater portion of the heavens, and that portion in which the solar system is included. Here the telescope must be moved in azimuth for different portions of the sky, as is fully explained by Professor Turner in Vol. LVI of the *Monthly Notices*, and it therefore becomes necessary to provide for moving the telescope in azimuth from time to time as different zones above or below the equator are observed. No instrument yet devised is suitable for all kinds of work, but this form, notwithstanding its defects, has so many and such important advantages that I think it will obviate the necessity of building any larger refractors on the usual models. The cost of producing a telescope much larger than the Yerkes on that model, in comparison with what could be done on the plan I now advocate, renders it most improbable that further money will be spent in that way. It may be asked, What are the lines of research which could be taken up by a telescope of this construction, and on what lines should the telescope be built? I will endeavor to answer this. All the work that is usually done by an astronomical telescope, excepting very long continued observations, can be equally well done by the fixed telescope. But there are some special lines for which this form of research is admirably suited, such as photographs of the Moon, which would be possible with a reflecting mirror, of say, 200 feet focal length, giving an image of some 2 feet diameter in a primary focus, or a larger image might be obtained either by a longer focus miror or by a combination. It might even be worth while to build a special cœlostat for lunar photography, provided with an adjustment to the polar axis and a method of regulating the rate of clock to correct the irregular motion of the Moon, and thus obtain absolutely fixed images on the photographic plate.

The advantage of large primary images in photography is now fully recognized. For all other kinds of astronomical photography a fixed telescope is admirably adapted; and so with all spectroscopic investigations, a little consideration will show that the conditions under which these investigations can be pursued are almost ideal. As to the actual form such a construction would take, we can easily imagine it. The large mirror mounted as a cœlostat in the center; circular tracks round this center, on which a fan-shaped house can be travelled round to any azimuth, containing all the necessary apparatus for utilising the light from the large plane mirror, so as to be easily moved round to the required position in azimuth for observation. In place of a fan-shaped house movable round the plane mirror, a permanent house might encircle the greater portion round the mirror, and in this house the telescope or whatever optical combination is used might be arranged on an open framework, supported on similar rails, so as to run round to any azimuth required. The simplicity of the arrangement and the enormous saving in cost would allow in any well-equipped Observatory the use of a special instrument for special work. The French telescope has a mirror about 6 feet in diameter and a lens of about 4 feet. This is a great step in advance over the Yerkes telescope, and it may be some time before the glass for a lens greater than 50 inches diameter will be made, as the difficulty in making optical glass is undoubtedly very great. But with the plane mirror there will be no such difficulty, as 6 feet has already been made; and so with a concave mirror there would be little difficulty in beginning with 6 feet or 7 feet. The way in which the mirror would be used, always hanging in a band, is the most favorable condition for good work, and the absence of motion during an observation, except of course that of the plane mirror (which could be given by floating the polar axis and suitable mechanical arrangements, a motion of almost perfect regularity).

One extremely important thing in using silver or glass mirrors is the matter of resilvering from time to time. Up to quite recently the silvering of my 5-foot mirror was a long, uncertain and expensive process. Now we have a method of silvering mirrors that is certain, quick and cheap. This takes away the one great disability from the silver or glass reflecting telescope, as the surface of silver can now be renewed with greater ease and in less time than the lenses of a large refracting telescope could be taken out and cleaned. It may be that we shall revert to speculum metal for our mirrors, or use some other deposited metal on glass; but even as it is we have the silvered glass reflector, which at once allows an enormous advance in power. To do justice to any large telescope it should be erected in a position, as regards climate, where the conditions are as favorable as possible.

The invention of the telescope is to me the most beautiful ever made. Familiarity both in making and in using has only increased my admiration. With the exception of the microphone of the late Professor Hughes, which enabled one to hear otherwise inaudible sounds, sight is the only sense that we have been able to enormously increase in range. The telescope enables one to see distant objects as if they were at, say, one-five-thousandth part of their distance, while the microscope renders visible objects so small as to be almost incredible. In order to appreciate better what optical aid does for the sense of sight, we can imagine the size of an eye, and therefore of a man, capable of seeing in a natural way what the ordinary eye sees by the aid of a large telescope, and, on the other hand, the size of a man and his eye that could see plainly small objects as we see them under a powerful microscope. The man in the first case would be several miles in height, and in the latter he would not exceed a very small fraction of an inch in height.

Photography also comes in as a further aid to the telescope, as it may possibly be to the microscope. For a certain amount of light is necessary to produce sensation in the eye. If this light is insufficient nothing is seen; but owing to the accumulative effect of light on the photographic plate, photographs can be taken of objects otherwise invisible, as I pointed out years ago, for in photographs I took in 1883 stars were shown on photographic plates that I could not see in the telescope. All photographs, when closely examined, are made up of a certain number of little dots, as it were, in the nature of stippling, and it is a very interesting point to consider the relation of the size and separation of these dots that form the image, and the rods and cones of the retina which determines the power of the eye.

Many years ago I tried to determine this question. I first took a photograph of the Moon with a telescope of very short focus (as near as I could get it to the focus of the eye itself, which is about half an inch). The resulting photograph measured one two-hundredth of an inch in diameter, and when examined again with a microscope showed a fair amount of detail, in fact, very much as we see the Moon with the naked eye; making a picture of the Moon by hand on such a scale that each separate dot of which it was made corresponded with each separate sensitive point of the retina employed when viewing the Moon without optical aid, I found, on looking at this picture at the proper distance, that it looked exactly like a real Moon. In this case the distance of the dots was constant, making them larger or smaller forming the light or shade of the picture.

I did not complete these experiments, but as far as I went I thought that there was good reason to believe that we could in this way increase the defining power of the eye. It is a subject well worthy of further consideration.

I know that in this imperfect and necessarily brief address I have been obliged to omit the names of many workers, but I cannot conclude without alluding to the part that this Association has played in fostering and aiding Astronomy. A glance through the list of money grants shows that the help has been most liberal. In my youth I recollect the great value that was put on the British Association Catalogue of Stars; we know the help that was given in its early days to the Kew Observatory; and the Reports of the Association show the great interest that has always been taken in our work. The formation of a separate Department of Astronomy is, I hope, a pledge that this interest will be continued, to the advantage of our science.—*Nature.*

THE REFLECTOR IN AMERICA.

W. W. PAYNE.

Not long ago we received a reprint of an article prepared by the late Professor James E. Keeler, entitled "The Crossley Reflector of the Lick Observatory, with which were given several plates, explanatory of the instrument, and one illustrating its work as a photographic telescope. The object photographed was the Trifid nebula. The negative was taken July 6, 1899, with an exposure of three hours. In the article above referred to, Professor Keeler said that the negative "was not selected as a specimen of the work of the instrument, for it was made in the early stages of experiments, and the star images were not good, but rather on account of the interest of the subject."

The reproduction of the negative was by the photogravure process, and reported to be fairly successful. It was enlarged, as compared with the original negative, 2.9 diameters (1 mm = 13 minutes of arc), the scale being somewhat greater than that used by Dr. Isaac Roberts of England, who photographed the same object, July 13, 1899, with a 20-inch reflector, giving his plate an exposure of ninety minutes. The scale used in the last named negative was 1 mm to twenty seconds of arc. The reproduction of the Lick negative appears to be better than that secured for the other. In the former the shading of the bright and faint parts of the nebula and the rifts in it are shown beautifully. The star-like points scattered all through the nebula come out in this cut with surprising distinctness. If these images were good, they are bright enough and sharp enough for measures for relative position, a most important point for the study of the drift of the nebula, if they are stars independent of the nebula; and also important in another way if they are only nebulous knots in the vast, rifted masses of nebulæ surrounding them.

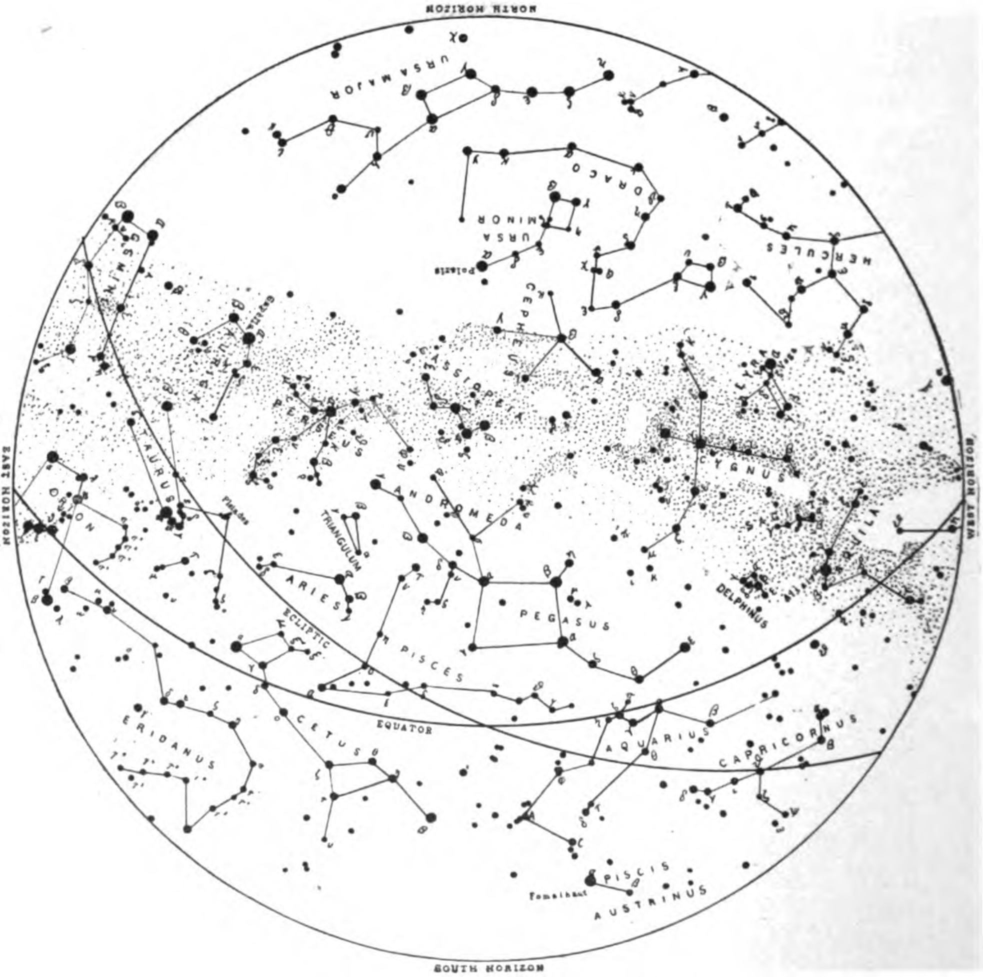
Some years ago, when a prominent astronomer was giving some attention to this nebula, he suggested that the position of one bright star in the edge of one of the three great rifts might be chosen as a reference star, for the purpose of determining whether or not this particular nebula is in motion with reference to the stars. Either of the negatives above referred to must give ample opportunity for such work in a much wider range than could have been expected by any astronomer a few years ago. This is due to the progress of photography as an aid in mapping faint objects and to the reflecting telescope as an instrument especially adapted to photograph such celestial objects in a way to secure a variety of details hitherto unknown.

The Crossley reflector of the Lick Observatory in the hands of so skillful an astronomer, as was the late Professor Keeler, has drawn general attention of American astronomers again to this kind of a telescope for photographic work. For common astronomical work Americans have generally preferred the refracting telescope, and the success of the American refractor for most kinds of observation has probably warranted the preference of astronomers on this side of the sea for the refractor. But the unexpected success that came from the limited use of the Crossley reflector in photographing difficult celestial objects, will certainly give the reflector a new and important place in the attention of astronomers in the west who are to devote themselves largely to photographic work.

PLANET NOTES FOR NOVEMBER.

H. C. WILSON.

Mercury will be at inferior conjunction on the morning of Nov. 20 and will be invisible in the rays of the Sun except for the first few days of the month.



THE CONSTELLATIONS AT 9 P. M., NOVEMBER 1, 1900.

Venus rises at about three o'clock in the morning and passes the meridian on Nov. 1 at 9^h 11^m A. M. local time. The planet is bright enough to be seen with the naked eye at any time during the forenoon, if one knows just where to look. Venus and the star η Virginis will be in conjunction Nov. 6 at noon, the star being

13′ south of the planet. The Moon and Venus will be in conjunction Nov. 18 at 7 P. M. Central Standard time, Venus then being nearly 6° north of the Moon.

Mars will be near the meridian from 6^h to 7^h in the morning and may be identified by early risers without difficulty, from its position in the constellation Leo and its ruddy color, contrasting strongly with the white blue light of Regulus. The planet will move southeast passing Regulus Nov. 17. Mars will be at quadrature, 90° west from the Sun, on the morning of Nov. 22.

Jupiter, Saturn and *Uranus* may still be seen toward the southwest very early in the evening, but at too low an altitude for satisfactory observation.

Neptune is like a star of the 8th magnitude in that part of the sky where the three constellations Taurus, Gemini and Orion meet. Its position Nov. 15 is R. A. $5^h\ 54^m\ 33^s$; Decl. + 22° 12′, and changes very little during the month.

The Moon.

(Central Standard Time at Northfield; Local Time 13m less).

	Phases.	Rises. h	m	Sets. h	m
Nov. 6	Full Moon	4	41 P. M.	7	51 A. M.
13	Last Quarter	11	39 "	1	05 P. M.
22	New Moon	7	41 A. M.	4	59 "
29	First Quarter	12	26 P. M.	12	27 A. M.

Occultations Visible at Washington.

Date. 1900.	Star's Name.	IMMERSION. Magnitude.	Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
Nov. 6	ρ^1 Arietis	7.0	6	17	24	6	54	299	0	37
6	50 Arietis	6.8	9	00	86	10	09	234	1	09
6	54 Arietis	6.3	13	10	27	13	59	308	0	49
7	B.A.C. 1242	6.3	7	45	49	8	37	289	0	52
7	ω^2 Tauri	5.7	16	06	118	17	06	242	1	00
11	1 Cancri	6.3	8	41	126	9	31	249	0	50
12	60 Cancri	6.0	13	24	181	13	44	213	0	20
12	α^2 Cancri	4.0	14	43	66	15	21	337	0	58
25	*d* Sagittarii	5.0	8	43	94	9	34	233	0	51
30	16 Piscium	5.8	4	30	47	5	43	253	1	13
30	19 Piscium	4.9	11	01	53	12	02	260	1	01

Annular Eclipse of the Sun.—On Nov. 21 at $19^h\ 22^m\ 49^s.0$, Greenwich Mean time, or on the morning of Nov. 22, Central Standard time, the Sun and Moon will be in conjunction and there will be an annular eclipse of the Sun. It will be visible only in South Africa and Australia and the islands in the vicinity of these countries. The following chart shows the path of the annulus and the region of partial eclipse. As there is no hope of the corona being visible, but little interest attaches to this eclipse.

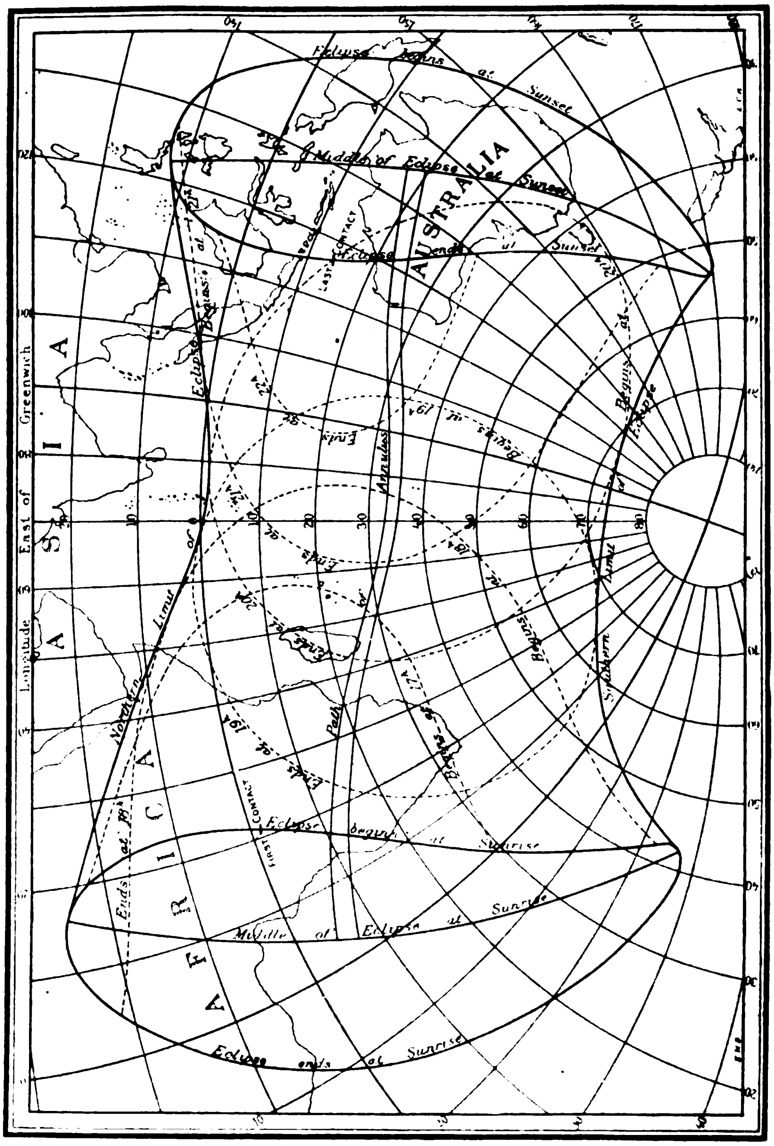


CHART OF THE ANNULAR ECLIPSE OF THE SUN, NOV. 21, 1900.

New Planetoid 1900 FL.—This was discovered by Dr. Wolf of Heidelberg, Germany, upon a plate exposed Sept. 26 for the purpose of finding the planet (406) [1895 *CB*]. It is of the 14th magnitude and its position was: Sept. 26.53 R. A. $22^h\ 46^m.8$; Decl. — 2° 36′. Its daily motion is — $0^s.6$ and —6′.

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time).

1900.

U CEPHEI.

	d	h
Dec.	2	10
	4	22
	7	10
	9	21
	12	9
	14	21
	17	9
	19	21
	22	9
	24	20
	27	8
	29	20
	32	8

S. CANCRI.

	d	h
Dec.	6	7
	15	19
	25	6

ALGOL.

	d	h
Dec.	2	22
	5	19
	8	16
	11	13
	14	9
	17	6
	23	0
	25	21
	28	17
	31	14

B. D. $+45^{\circ}3062$

	d	h
Dec.	4	16
	9	5
	13	9
	18	23
	22	19
	27	12
	32	2

δ LIBRÆ.

	d	h
Dec.	1	23
	8	23
	15	22
	22	22
	29	21

U CORONÆ.

	d	h
Dec.	2	15
	12	23
	19	21
	26	18

Y CYGNI.

$2P = 2^d\, 23^h.9$

Odd min.

Nov.	27	15
Dec.	27	14

R. CANIS MAJ.

$P = 1^d\, 3^h.3$

	d	h
Dec.	0	16

W DELPHINI.

	d	h
Dec.	3	9
	17	19
	22	14
	27	9

λ TAURI.

	d	h
Dec.	2	0
	5	23
	9	22
	13	21
	17	19
	21	18
	25	17
	29	16

NOTES TO THE EPHEMERIS.

The times for Y Cygni are taken from Duner's paper in No. 3633 of the *Nachrichten*; for the rest of the list from Hartwig's ephemeris in the *Vierteljahrsschrift*.

No ephemeris of Long Period Variables for 1901 is yet at hand.

MISCELLANEOUS NOTES.

PERIODS OF TWO VARIABLES DISCOVERED AT MOSCOW.—M. Blajko, of the Moscow Observatory, has published two papers in No. 3665 of the *Nachrichten* on two variable stars discovered by Madam Ceraski on Blajko's photographs. The conclusions ars as follows:

Variable in Auriga, $5^h\, 20^m.1$, $+\, 36^{\circ}\, 49'$ (1900).

From photographs from 1895 to 1899 and visual observations in 1898, 1899 and 1900, M. Blajko deduces a period of 0.75 of a year, with observed maxima as follows:

(1). March or April......................1895
(2). December..............................1895
(3). December 24.......................1898
(4). September............................1899

The star seemed to be at maximum at the time of writing, June 21, 1900, therefore the following maximum is due in March, 1901. See Nos. 3529, 3553 of the *Nachrichten;* No. 457 of the *Astronomical Journal;* the *Astrophysical Journal* for July, 1900, page 54 (here called (1922)); POPULAR ASTRONOMY for January, 1899, page 43, Feb. 1899, page 94, October, 1900, page 461.

Variable in Cepheus, $21^{h}\ 3^{m}.6$ +82° 40′ (1900).

From photographs taken in 1896, 1897, 1898 and 1899, and visual observations in 1898 and 1899, M. Blajko deduces a period of about 1.4 years, with a maximum in 1899 September or early in October. See No. 3512 of the *Nachrichten*, Nos. 457, 475 and 482 of the *Astronomical Journal;* POPULAR ASTRONOMY VI, 532, VII, 493 and VIII, 461; *Astrophysical Journal* XII, 54 [here called (7579)].

It may be remarked in addition to M. Blajko's results that this variable perhaps enjoys the distinction of being the faintest ever observed, at the minimum of last summer the photographic magnitude was not brighter than the 18th.

ASTEROID NOTES.

Ephemeris of Planetoid (212) Medea.—This planet was observed in 1880, 1882, 1883, 1885, 1886 and 1888 and was photographed in 1894, but the data of the photographs are too inexact to permit of their use in determining the orbit. No later observations are known. Mr. B. Kudrjavzeff gives in *Astr. Nach.* No. 3643, the following approximate ephemeris for the opposition which occurs during this month:

1900	R. A.			Decl.		log Δ	Aberration.	
	h	m	s	°	′		m	s
Nov. 13	3	53	39	+ 26	54.91	0.2487	14	43
14		52	45		52.40	82		42
15		51	50		49.81	78		41
16		50	56		47.14	74		40
17		50	02		44.39	71		39
18		49	08		41.56	69		39
19		48	14		38.64	67		39
20		47	20		35.64	66		39
21		46	26		32.55	65		39
22		45	32		29.38	66		39
23		44	39		26.12	67		39
24		43	45		22.78	69		39
25		42	51		19.36	71		40
26		41	58		15.86	74		40
27		41	05		12.27	78		41
28		40	11		08.60	83		42
29	3	39	18	+ 26	04.84	0.2488	14	43

Elements and Ephemeris of Planetoid (295) Theresia.—Dr. Berberich in *Astr. Nach.* No. 3668 gives new elements of this asteroid, based upon observations made at five oppositions since 1890. These elements represent the observations very closely indeed.

$$
\begin{array}{rrrr}
\text{Epoch} & \multicolumn{3}{l}{\text{Decl. 10.0, 1900}} \\
 & {}^{\circ} & {}' & {}'' \\
M = & 8 & 35 & 38.2 \\
\end{array}
$$

$$
\left.\begin{array}{rrrr}
\omega = & 143 & 50 & 29.2 \\
\Omega = & 277 & 24 & 13.4 \\
i = & 2 & 40 & 22.2
\end{array}\right\}1900.0
$$

$$
\begin{array}{rrrr}
\phi = & 9 & 41 & 31.5
\end{array}
$$

$$\mu = 758''.6107$$

$$\log a = 0.4466584$$

Berlin Midnight.	R. A.			Decl.		log r	log Δ
1900	h	m	s	°	′		
Nov. 10	4	59	38	+25	05.9	0.3655	0.1469
12		58	18	25	03.6		
14		56	52	25	00.7	0.3656	0.1403
16		55	21	24	57.2		
18		53	44		53.4	0.3657	0.1350
20		52	03		49.2		
22		50	18		44.4	0.3659	0.1310
24		48	29		39.3		
26		46	38		33.9	0.3661	0.1284
28		44	45		28.2		
30		42	50		22.3	0.3663	0.1271
Dec. 2		40	54		16.1		
4		38	58		09.8	0.3665	0.1273
6		37	03	24	03.3		
8		35	09	23	56.6	0.3667	0.1288
10		33	17		49.9		
12		31	28		43.1	0.3670	0.1317
14		29	42		36.3		
16		28	01		29.5	0.3673	0.1359
18		26	24		22.7		
20	4	24	51	23	15.9	0.3677	0.1414

Elements of the Planetoid (457) Pariana.—In *Astr. Nach.* No. 3667 Professor G. Boccardi gives the following elements of this asteroid, based upon the observations made in 1892, 1894, 1898 and 1899:

Epoch and Osculation, Oct. 31.51900, Berlin M. T.

$$\begin{aligned} M &= 226^\circ\ 16'\ 42''.77 \\ \left.\begin{aligned} \omega &= \ \ 83\ \ 25\ \ 28\ .53 \\ \Omega &= \ \ 85\ \ 56\ \ 17\ .34 \\ i &= \ \ 11\ \ 42\ \ 01\ .37 \end{aligned}\right\} & 1900.0 \\ \phi &= \ \ \ 9\ \ 34\ \ 30\ .57 \\ \mu &= 840''.53887 \\ \log a &= 0.4169658 \end{aligned}$$

The opposition for this year occurred Oct. 19. The following portion of the ephemeris by Professor Boccardi, though late, may yet be of some use:

Berlin Midnight.	R. A.			Decl.			log Δ.	Aberration.	
	h	m	s	°	′	″		m	s
Nov. 16	1	15	03.39	−7	10	12.6	0.32515	17	34
17		14	29.58	7	08	10.3			
18		13	57.03	7	05	57.0			
19		13	25.77	7	03	33.0			
20		12	55.83	7	00	57.3	0.33186	17	51
21		12	27.22	6	58	11.1			
22		11	59.96	6	55	14.3			
23		11	34.07	6	52	06.8			
24	1	11	09.57	−6	48	49.0	0.33908	18	09

GENERAL NOTES.

Change of printing offices and the procuring of an entirely new typographical dress for this publication are the main reasons for being late this month. Some of the supplies which were ordered from distant type founders have not yet reached us. We hope the December number will be ready for mailing nearly on time.

The Bulletin of Astronomy (French) for September has two full page plates, showing results in attempts to photograph Jupiter, Saturn, planetary nebulæ in Andromeda and Draco, and the nebula of Orion.

Full Sets of the Monthly Notices and the Memoirs of the Royal Astronomical Society. We learn with interest, that Ambrose Swasey, of the firm of Warner & Swasey, Cleveland, Ohio, has recently secured full sets of the *Monthly Notices* and the *Memoirs of the Royal Astronomical Society* which he found last year while in London. They are ot course valuable, because complete sets are now scarce, and because they contain not only a history ot astronomy, but also much about astronomical instruments that have been devised and used since 1820, (the year when the Royal Astronomical Society was founded); they are therefore largely useful to astronomers and instrument-makers as well.

New Allegheny Observatory. October 20 was the time set for the ceremonies attending the laying of the corner stone of the new Allegheny Observatory at Riverside Park, Allegheny, Pa. It was planned that the ceremonies should be brief and of the simplest character. Later some account of them will be given in this publication.

The November Leonid Meteors.—Although observers were generally disappointed last November on account of the small shower witnessed at the usual time of the Leonid display, they are preparing for a careful watch for this year. The mornings of the 14th, 15th and 16th of this month are the times thought of as most probable for seeing the best display. Astronomers are not well enough acquainted with this meteor stream or streams to predict very positively about the return of its densest parts in the long period of 33 years. It was confidently expected in November 1899, because brilliant showers of the Leonids had been seen in 1833 and in 1866. It is possible that this month will give a rich shower from this stream. Certainly no observer of meteors will let the opportunity pass without a faithful watch on the mornings above mentioned. Probably the morning of the 15th is as promising as any. The same drawback will hinder this year as last, viz.: the light of the Moon near the radiant in Leo.

Publication No. 1 Vassar College Observatory.—The first of the publications of Vassar College Observatory has been received. It is a catalogue of stars within one degree of the North Pole, and a study of the optical distortion of the Helsingfors astro-photographic telescope deduced from photographic measures. This work was done by Caroline E. Furness, assistant in the Observatory of which Mary W. Whitney is director.

This interesting paper was submitted by Miss Furness in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of Pure Science at Columbia College, New York City.

The Vassar College Observatory was established when the college was first opened in 1865, its purpose being for instruction rather than for scientific work for publication. Its first director, Maria Mitchell, became widely known, as a discoverer of comets, and she was honored by being the recipient of a medal from the king of Denmark for the discovery of a comet in 1847. "Professor Mitchell published a series of observations on the surface features of Jupiter and Saturn in *Silliman's Journal* and the *American Journal of Science.*" Since 1890 more observational work outside of instruction has been attempted, attention being given mainly to comets and the minor planets.

The position of this Observatory is:

Latitude........................41° 41′ 18″
Longitude..................... 4^h 55^m $53^s.6$

west of Greenwich, which was determined by Professor Mitchell in 1872. The longitude was determined by aid of telegraphic signals in connection with Harvard College Observatory in 1877.

The Observatory is provided with a 12-inch equatorial the object-glass of which was made by Fitz of New York, but recently recut by Alvan Clark of Cambridgeport, Mass. The re-mounting of the telescope was done by Warner & Swasey, of Cleveland, Ohio, in 1888.

The Repsold measuring machine by which the work of the paper above referred to was done, was the joint gift to the Observatory, of Miss Catherine Bruce and Mr. Frederick Thompson.

We hope soon to have an illustrated paper setting out fully the method of work used by Miss Furness in obtaining the results to which reference has been made.

Eros at Yerkes Observatory with 40-Inch Equatorial.

Oct.	2	Evening, Midnight and Morning.
	3	... Midnight ... ...
	4	... Midnight ... ...
	8	Evening, Midnight and Morning.
	9	Evening, ... Morning.
	10	... Midnight ... ...
	11	Evening, Midnight and Morning.
	14	Evening, ... Morning.
	15	Evening, ...
	16	Evening, Midnight and Morning.
	17	Evening, Midnight and Morning.
	18	... ... Morning.
	25	Evening, Midnight and Morning.
	26	Evening, Midnight and Morning.
	27	Evening, ...
	30	... ... Morning.
Nov.	1	Evening, ... Morning.
	2	Evening, Midnight and Morning.
	3	Evening, Midnight and Morning.
	4	Evening, Meridian and Morning.
	5	Evening, Meridian ... ...

In a few of these measures it has been necessary to use stars as small as $12\frac{1}{2}^{m}$ or 13^{m}. This could not be avoided if measures were made at all at such times.

Since Eros has become bright, it is seen to be of a slightly yellowish color.

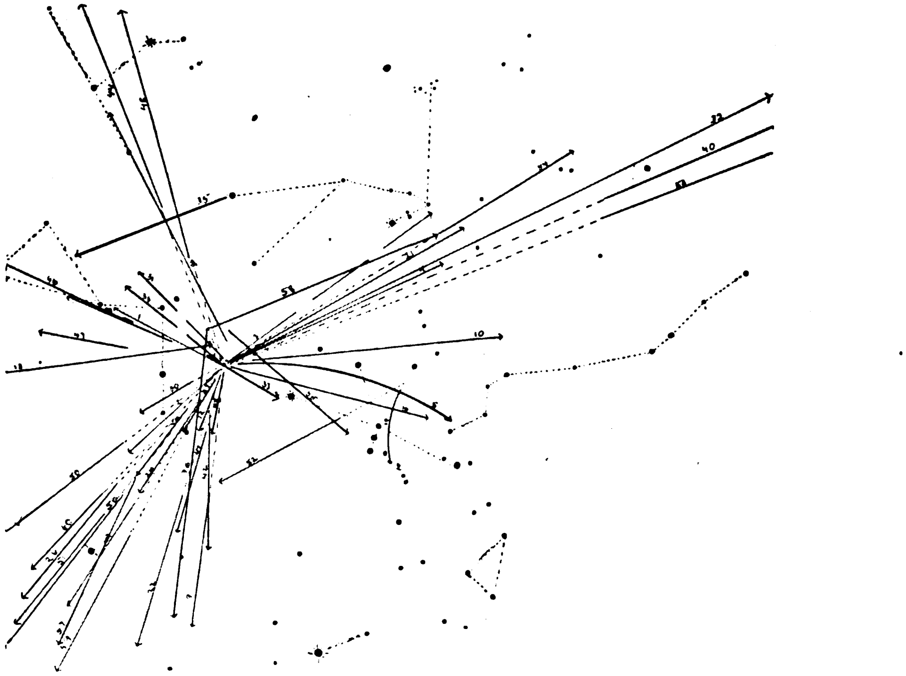
A power of 700 diameters is used when possible, failing this, 460.

Every available opportunity has been used to secure measures of Eros since October 1.

On every night that measures are made, the difference of declination of Atlas and Pleione if the Pleiades are measured, and frequent measures of the difference of declination of Electra and Celæno are also made, as a check on the changes taking place in the great telescope. Of Atlas and Pleione about 180 nights' measures have been made since the erection of the 40-inch. This will give a thorough check on any changes taking place in the great object-glass or tube and micrometer.

E. E. B.

The ν Urionids of 1900, Oct. 18, 1900 (12.50-4.50).—The night of Oct. 18, 1900 at 9:00 was cloudy, with rain. At 12:30, however, it was clear, except for slight cloud patches. At 12:45 the sky was clear. There was no Moon until after 2:00. Together with the ν Orionids there were some shooting stars, a large part of which radiated from β Tauri, and a region between δ and η Orionis. Some meteors, Nos. 36, 42, 48, 68 (and 55) seemed to be from a separate radiant. No. 33 instead of shooting exactly from ν Orionis, started a little north of it. There were two Leonids, a good sign so far ahead of the time of the shower (Nov. 13). Any (ν Orionis) of this shower brighter than 2d magnitude had slight trails. No. 4 was a little brighter than 1st magnitude, blue and left a trail. No. 5 started as 2nd magnitude and suddenly burst into a (—3)rd magnitude, green meteor of striking brightness. No sound came. It also left a trail. No. 9 left a white trail. At 2:14-16 there were four faint shooting stars in Orion. One curved very much. Two came at the same time. Nos. 24, 26 left trails. No. 35 started from β Tauri and was very broad, of 0 magnitude. It was a broad streak. A large part of the meteors now were swift. Nos. 40, 48 and 49 left trails. Nos. 50 and 51 were very swift. At 4:50 observations stopped. The meteors were of medium speed, having trails brighter than 2nd magnitude. There were 17 shooting stars recorded not on map, 5 unrecorded, 2 Leonids, 37 ν Orionids and 6 uncertain; which amount to 68 in all.



THE ν ORIONID SHOWER OF METEORS.

The ν Orionids were of medium speed, usually leaving trails or streaks of a white or red color. They came one in every 5½ minutes. The shower was not a brilliant one, nor were there many meteors. They seemed to come in shoals, at one time there was an interval of 23 minutes without one, and another interval of 15 minutes. When most were seen was between 2:50 and 3:35 when there were 15. There were a very large number of shooting stars. All that were recorded (not on map) were within the region of Orion, Gemini and Taurus.

ROBERT M. DOLE.

91 Glen Road, Jamaica Plain, Mass.

Observing Eros at Washburn Observatory.—Replying to your request of recent date: Observations of Eros in accordance with the plan proposed by the Paris Conference have been made by the undersigned with the 40cm. equatorial of the Washburn Observatory on every clear night since Sept. 29. On twenty-one nights the planet has been compared with two or more stars and on two nights, owing to unfavorable conditions, with one star only. In every case rectangular co-ordinates have been measured and especial care has been given to the determination of instrumental constants which can affect the observations.

UNIVERSITY OF WISCONSIN, Madison, Wis., GEO. C. COMSTOCK.
Nov. 6, 1900.

Perturbations of the Major Axis of Eros by the Action of Mars.—From an instructive article by H. N. Russell in the *Astronomical Journal* (No. 484) the following summary is taken:

(1). It has been shown by actual computation that Le Verrier's method of interpolation, which is theoretically capable of solving any case of general perturbations, will solve the case of Mars and Eros practically, that is, without a prohibitive amount of labor.

(2). It has been found that the "great inequality," of period about 1000 years, will not affect the place of Eros sensibly during the next dozen years, after which time it may be approximately determined.

(3). The perturbations of moderately long period are much the largest produced by Mars on any planet. They may displace Eros by 90″ in mean longitude; and since at a perihelion-opposition any change in the mean longitude of Eros produces one ten times as great in its geocentric longitude, the measurement of this displacement will eventually lead to a valuable determination of the mass of Mars.

Knowledge Diary and Scientific Handbook is intended to form an aid to the labors of scientific workers in all branches, notably in astronomy, and is issued in conjunction with *Knowledge*. It is designed to meet a well-marked want, now that the circles of students in every branch of scientific work are so extensive, and the need of an authoritative record so much felt.

Although the scope of the work is mainly astronomical, it is not intended to confine its usefulness entirely to that science, and the diary portion of the book is of course available for every description of record and observation work.

The new handbook will make its appearance with the beginning of the new century, and will contain a retrospect of the remarkable advances which Science has made in the course of the Nineteenth Century.

Other points of the contents will be twelve star maps showing the night sky for evey month of the year, with appropriate descriptive matter; a calendar of notable events; the hundred brightest stars and a monthly astronomical ephemeris. Under these and other important subdivisions of the work, will appear original essays to make the work generally useful.

Meeting of Astronomers at Buffalo.—A correspondent suggests the possibility of a convention of astronomers to be held in connection with the Pan-American Exposition which is to be in the city of Buffalo, N. Y., May 1 to Nov. 1, 1900. It is possible that such a meeting could be secured, if the matter were planned for soon. We would gladly receive suggestions from our readers who are interested in such a convention.

Professor W. H. Wilson at Wooster, Ohio.—Our readers will be interested to learn that Professor W. H. Wilson, who has been connected for some time with Geneva College, at Beaver Falls, Pa., has accepted the position of Professor of Mathematics in the University at Wooster, Ohio, and has already begun his work in the new position.

His duties include, for the present, Dr. S. J. Kirkwood's astronomical work as well as the mathematics during Dr. Kirkwood's illness.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

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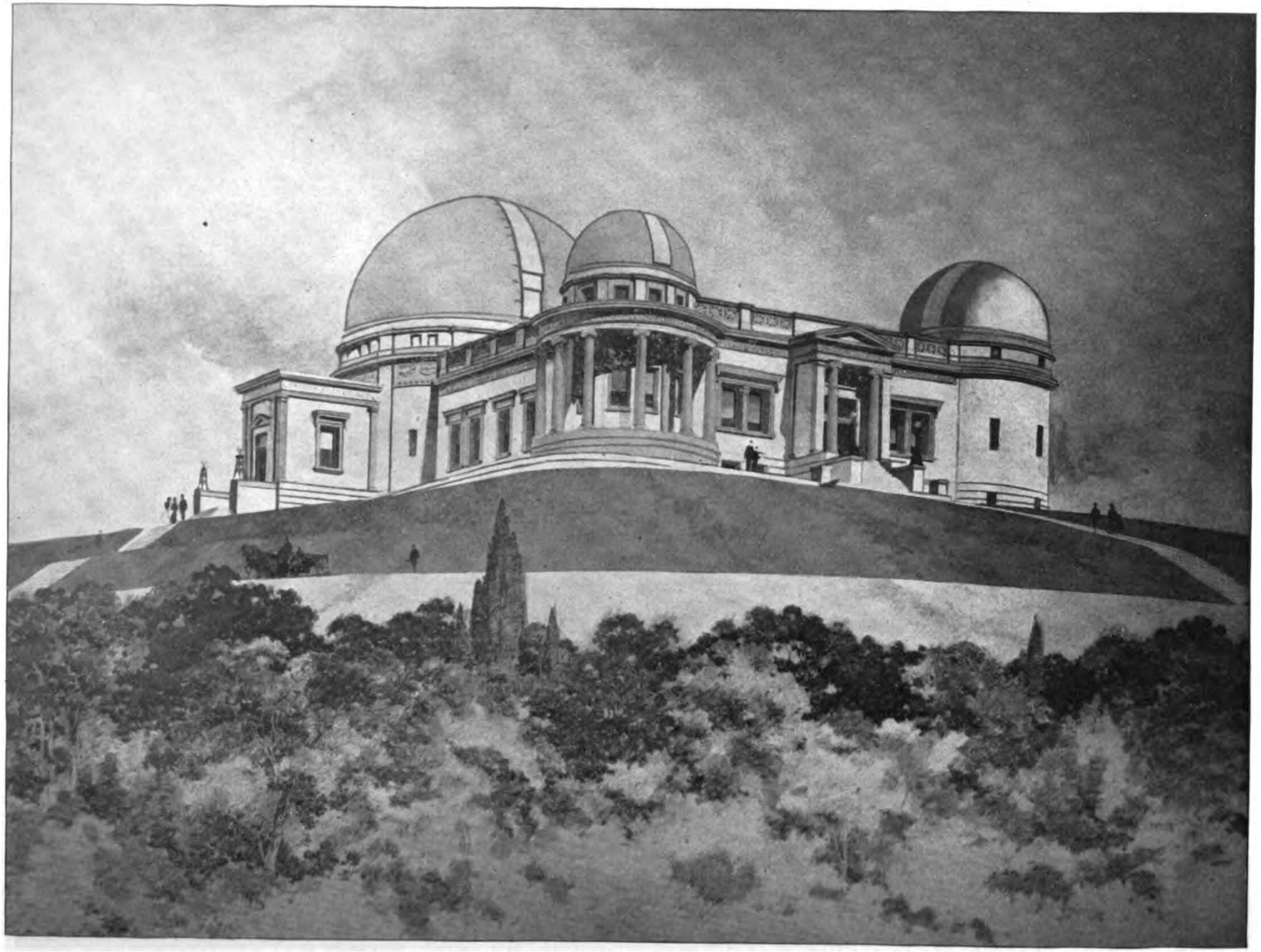
PLATE XXI.



NEW ALLEGHENY OBSERVATORY.

(Photographed from Architect's Plans.)

Popular Astronomy.

Vol. VIII. No. 10. DECEMBER 1900. Whole No. 80.

THE ORBIT OF THE LEONID METEORS.

W. W. PAYNE.

During the last year and a half, some astronomers have expressed opinions, with more or less assurance, that the path of the Leonid stream of meteors has been so changed, that we may no longer hope for such grand showers as were seen in 1866 and notably in 1833. Particular attention was called to this possibility and even probability, by a paper presented before the Royal Astronomical Society, March 2, 1899, by G. Johnstone Stoney and A. M. W. Downing, an abstract of which was printed in *The Observatory*, for May, 1899. In that paper it was said that Professor J. C. Adams' object in investigating the Leonid orbit was to determine the shift of the nodes of the orbit due to the disturbances by the planets and to compare the calculated amount with that obtained by Professor H. A. Newton, of Yale College, from a study, which he had made, of observations at intervals during the last thousand years. Professor Adams, of England, gave attention to this interesting piece of mathematical work about 30 years ago, using what is known as the method by Gauss for computing perturbations. Mathematicians esteem it a method of great elegance, because it "furnishes the average amount of each perturbation on the supposition that the periodic times of the disturbed body and the disturbing planet are incommensurable, so that in the course of time, the two bodies present themselves in every possible position in relation to one another." It will readily be seen that these conditions could be only imperfectly fulfilled in the short period of 1000 years from which time all available observations were secured, and so results obtained from the most excellent of methods would be incomplete for obvious reasons.

The three planets which influenced the path of the Leonids most during the last period of revolution of the stream were Jupiter, Saturn and Uranus. If we remember that 14 revolutions of Jupiter equal 5 revolutions of the Leonids within about one-fifth of a year; that 2 revolutions of Uranus equal the same time within two years, and that 9 revolutions of Saturn equal 8 of the Leonids within a fraction of a year, it will be easy for any reader to understand how the attraction of these great planets when near the thickest part of the stream will certainly change its course.

Now, since these cycles of planetary attraction have been several times repeated during the 1,000 years already referred to, it is known that the points of intersection of the Earth's orbit with that of the Leonids has oscillated about a mean value of the advance of the node, so that predictions of showers dependent on this mean motion have usually varied several hours from the times of their actual occurrence. In the article referred to, one instance is mentioned in which the computed time was twenty-six hours later than the appearance of the shower. This occurred in the year A. D. 1533. Some computations for the present century have furnished results showing as great a difference between the forecast and the actual shower, as in this instance, but, in the opposite direction.

From these and other facts like them it must be evident that the problem of determining the exact position of the orbit of the Leonids for any date is a very difficult one. Astronomers are fully aware of this, and they have given earnest attention to its study for some years past, and they are still at work on the details of the problem which seem almost endless in kind and variety.

It may be instructive to the ordinary reader to have a few more points in outline to get a fuller view of the nature and extent of the problem. In order to predict the coming of a great Leonid shower satisfactorily, it will be necessary to know the actual amount of the perturbations in each revolution of the swarm of meteors, and also for meteors occupying various stations along the path of the stream, so as to determine its course in space as definitely as possible. The dense part of the stream is called the ortho-stream, which means the great body of the Leonids travelling around the Sun, in nearly a compact swarm of such length that it requires about three years for the whole train to pass the point of intersection which the Leonid orbit makes with that of the Earth; but on account of the inclination of the two orbits the time that is required for the Earth to pass through the ortho-stream each year is only five or six hours. There are also other Leonid meteors that have fallen behind, or are in advance of the parent stream, so that all parts of the great orbit are probably more or less occupied by astray members of the group. This stream which is wider and less dense than the other is called the clino-stream. The clino-Leonids are comparatively few and are seen at the usual time in November every year. The ortho-orbit is the mean path of the ortho-stream, and the clino-orbit which is obtained by the study of clino-Leonids every year is the mean path of this diffuse clino-stream. The clino-Leonids are so scattered that they produce only feeble Leonid showers every year, but they last for several days, instead of a few hours as is true of the great ortho-showers. In consequence of irregularities in the stream of the ortho-Leonids the ortho-orbit does not generally cross the Earth's orbit at points in successive periods which show a regular progressive change of node, but irregular ones as before indicated. Add to this the uncertainty and lack of agreement of the mean of the clino-paths of the clino-Leonids, and the wonder is that astronomers can do scarcely anything at all in securing what may be called a definitive orbit of the Leonids, much less determine well the dates of great showers that last 6 hours at intervals of 33 years.

But these and other great difficulties which appear in calculating the perturbations of the planets do not discourage the patient astronomer. His work goes on, though he does not expect the end of it for centuries; he will still earnestly seek the best knowledge he can get from time to time as the years go on, waiting for better and fuller knowledge when it can be secured by the aid of more exact and more comprehensive data.

The work in hand at the present time toward getting a better knowledge of the path of the Leonids is largely concerned in a study of perturbations. This has been undertaken by cómputing the actual perturbations of a definite part of the ortho-stream over the whole of one revolution in the orbit as computed by Professor Adams, of Cambridge, England, in November, 1866, until January, 1900, when the same part of the stream would again reach the Earth's orbit. Two things aid us now, probably, which were not taken into the account when Adams computed the orbit a third of a century ago. One is the aid of photography in determining the radiant, and the other is the influence of the Earth in deflecting the meteors that are observed.

The aid that photography can give under favorable circumstances must be considerable, although it must be confessed that very little assistance was gained from this source in 1899, because of moonlight chiefly; and so far as we have heard, the same is true this year. Not a single meteor trail was caught in the region of the radiant on the plates exposed at Goodsell Observatory on the morning of November 15 between the hours of 3 and 5.

From these facts it will be seen readily, that the Adams orbit can only be considered as an approximate one, and hence present and future work on this problem must so use it.

The authors, whose names are mentioned at the beginning of this article, have published a brief paper in *Nature*, Nov. 1, 1900, indicating some interesting results in regard to the probability of a Leonid display in November, 1900. It will interest our readers to compare the probable conclusions reached by G. Johnstone Stoney and A. M. W. Downing with the observations of the Leonids made last month. The article is titled "The Leonids—a Forecast" and is as follows:

"In the *Proceedings* of the Royal Society for March 2, 1899 (vol. lxiv. p. 403), will be found an account of the perturbations suffered since 1866, November 13, by the Leonids which in that month intersected or passed close to the Earth's orbit. This position in the meteor stream may be called station *A* (Fig. 1).

We have since investigated the principal perturbations affecting two other points in the stream, viz., the station *z*, which intersected the Earth's orbit 360 days earlier, *i. e.* in November, 1865, and the station *B*, which intersected the Earth's orbit 360 days later, *i. e.* in November, 1867.

We therefore now know the principal perturbations which during the last revolution of the meteors have affected three points, *z*, *A* and *B*, situated along an orbit (Adams's orbit) which, at the commencement of the revolution, lay within the stream.

The full results of the investigation will not be ready for publication till after the time when the Leonid shower of this year is due, and on this account it has been thought expedient to publish beforehand such of the results as have special reference to it.

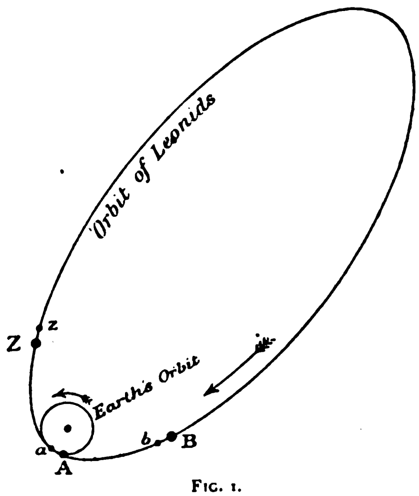


Fig. 1.

A point in the stream which in 1867 lay along Adams's orbit between *A* and *B*, but nearer *B*, and which we may call the point *b*, will this year reach its descending node simultaneously with the Earth. This will happen approximately on 1900, November, 15^d 3^h Greenwich mean astronomical time.

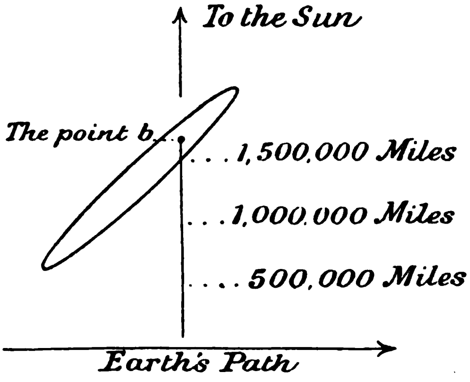


FIG. 2.

Unfortunately, the orbit of a meteor situated near point *b* in the stream, instead of intersecting the Earth's orbit as it did in 1867, will now pierce the plane of the ecliptic in a point which lies about 0.018 nearer the Sun. Now, 0.018 of the Earth's mean distance from the Sun is 1,674,000 miles; so that, of the meteors which in 1867 intersected the Earth's orbit, those which will come nearest to the Earth in the present year will not approach it nearer than a million and six hundred thousand miles.

It is known from the duration of the great showers that the width of the ortho-stream, if measured in the direction which is parallel to the Earth's path, is only about 300,000 miles; but there is reason to believe that the Leonids entered the solar system under conditions which have made the section of the stream much longer than it is broad, so that its trace upon the plane of the ecliptic is something like what is represented in Fig. 2. The longer axis of this cross section lay originally along the radius vector from the Sun, but perturbations have acted on the Leonids for nearly 1,800 years of such a kind as have probably caused the section of the stream to incline in the direction represented in the figure.

If the section is long enough to reach the Earth's orbit, we shall have a great meteoric shower this year. It is, besides, just possible that a sinuosity in the stream may so displace a part of the section as to bring it sufficiently far out. But neither of these seem likely to have happened; so that the present investigation does not raise any hope of a great shower this year.

If, contrary to our expectation, the axis major of the section proves to be long enough to reach the Earth's orbit, the consequent shower of ortho-Leonids is likely to occur several hours—possibly more than a whole day—earlier than

1900, November, 15^d 3^h

The number of hours by which it will precede that epoch depends upon the angle which the axis major of the section makes with the radius vector from the Sun—an angle which is at present unknown. If there is this year a shower of ortho-Leonids, the time at which it occurs will enable us to determine this important datum.

Station *a* in the stream (see Fig. 1) intersected the Earth's orbit in 1866, but after completing a revolution it passed the Earth in November of last year at a distance of some 1,300,000 miles; and *z*, the corresponding point for the preceding year, which also intersected the Earth's orbit in 1865, was on its return distant from the Earth in November 1898 by about 960,000 miles. It thus appears that the displacements of the meteoric orbits which have been brought about by the perturbations of the last thirty-three years suffice to have prevented the meteoric orbit from now intersecting the Earth's orbit. This accounts for our not having had any great shower in either of the last two years, and unfortunately the conditions seem still more unfavorable in the present year.

Nevertheless, as there is always a possibility that one or the other of the contingencies mentioned above may carry a part of the ortho-stream out as far as the Earth, and as we have no means of ascertaining whether those contingencies have arisen, it is desirable that preparation shall be made for adequately observing the shower, if it should unexpectedly come.

The perturbations during the last revolution which have for the present carried the ortho-stream of Leonids so far from the Earth's orbit, belong to the class of perturbations which act at different times with equal effect in opposite directions; so that there is reasonable ground for expecting that further perturbations must at some future time bring this remarkable stream back to the Earth's orbit. It would be possible to ascertain when this will happen, by an investigation carried over a sufficient time forward upon the same lines as those which we have pursued."

NOTE ON THE DOUBLE STAR, β 107.

S. W. BURNHAM.

FOR POPULAR ASTRONOMY.

In POPULAR ASTRONOMY for January, 1899, I called attention to the decided discrepancy in the positions of this and other stars in the field as compared with the positions given in the *D. M.*, and gave diagrams from recent micrometer measures, and from the meridian places in Argelander showing the relative positions of the several stars according to these authorities. From this it appeared to be impossible to identify with absolute certainty the stars in the one with those of the other. In *A. N.* 3652 Kreutz has a note upon this subject, and has given the positions in right ascension and declination from my measure in 1898, and compared them with the corresponding positions of the *D. M.* At first glance it would appear that the two sets of places of four of these stars were after all practically identical, with one star wanting altogether. The fact is, however, that these places give exactly what was much better shown for the purpose of comparison in the diagrams referred to, and the apparent change in some of these stars still remains unaccounted for, and particularly the stars designated in my measures as *D* and *F*.

I have suggested in view of the general accuracy of the *D. M.* positions that this change might be due to a considerable proper motion of some one or more of these stars, and therefore connected them by a series of measures with the double star *A*. At my request Barnard repeated these measures in 1899, and I have re-observed them this year.

These results are as follows:

		A and *C*		
1898.73	336°.2	46″.95	2*n*	β
1899.82	336 .7	46 .83	2*n*	Bar
1900.71	336 .7	46 .78	2*n*	β
		A and *D*		
1898.73	146°.6	50″.27	2*n*	β
1899.82	146 .6	50 .30	2*n*	Bar
1900.71	146 .6	50 .32	2*n*	β
		A and *E*		
1898.76	171°.2	113″.78	1*n*	β
1899.82	171 .0	113 .48	2*n*	Bar
1900.71	170 .9	113 .55	2*n*	β
		A and *F*		
1898.76	113°.9	150″.44	1*n*	β
1899.82	113 .8	150 .32	2*n*	Bar
1900.71	113 .9	150 .49	2*n*	β

Although the interval is too short for the detection of a small movement in space, the close agreement of all the measures makes it extremely probable, if not certain, that the discrepancy in question cannot be explained by the proper motion of any one of these stars, and that the apparent change of the star *D*, which appears to be No. 96 of the *D. M.*, is due to errors in the meridian observations. All of these stars are wanting in the *A. G.* Catalogue, and are not included in any other star catalogue so far as I have been able to find.

It is very probable, as suggested by Kreutz, that the double star *A* is identical with No. 94 of the *D. M.*, and this is confirmed by the comparison I have made of *A* with a south-preceding star, No. 85 of the *D. M.* The catalogue difference of declination agrees with that shown by recent measures, and the same is true of *E* and No. 97. It is therefore safe to say that the stars, *A*, *C*, *D* and *E* are respectively Nos. 94, 93, 96 and 95 of Argelander. Further measures are necessary to show the character of the change in *AB*.

The 40-inch shows that the star *E* has a 16^m. companion 8″.61 distant in the position-angle of 139°.1.

THE PROPER MOTION OF β 182.

S. W. BURNHAM.

To this close pair has been assigned a somewhat remarkable proper motion for a star which is fainter than eighth magnitude. The several determinations of this movement are:

Romberg	1″.297 in 200°.4
Radcliffe	1 .331 in 202 .4
Porter	1 .302 in 201 .2

The last named value is probably the most accurate since the interval is considerably longer. It is catalogued as Wesse XXIII 175 and S. D. (14°) 6437. In the latter it is rated 8.2^m.

In order to test the correctness of this movement by a method independent of meridian observations, I measured in 1898 a 12.5 star from the close pair with the Yerkes refractor. This was the nearest star which could be readily measured with that aperture. I have recently re-measured this star, and these observations, with an intermediate set of measures by Barnard, are as follows:

1898.66	79°.9	68″.04	2*n*
1899.75	78 .5	68 .66	3*n*
1900.72	77 .5	69 .55	3*n*

It will be seen that the change in the position of the small star corresponds to the proper motion of the close pair. With the proper motion given in the Cincinnati Catalogue and the first set of measures in 1898, the computed position of small star for 1900.72 is 78°.0: 69″.47, which is practically identical with the observed place from the micrometrical observations.

The principal star is a close pair of nearly equal components, the present distance being about 0″.7. The observations indicate very slow retrograde motion in angle, with some diminution in the distance. Of the physical relation of the components there is no question, but the period is probably long. The facts cited suggest the comparative nearness of the system, and indicate that it may be a good subject for parallax observations.

AMONG THE STARS.

EDWARD S. HOLDEN.

The achievements of astronomy during the nineteenth century have been little short of marvelous. Not only have the classic methods of research been expanded and developed, but in the latter half of the century new instruments of unexpected power have been perfected and results obtained by their use in fields utterly closed to the astronomers of a hundred years ago.

Mathematical analysis reached a high state of perfection in the researches of Laplace and Lagrange at the century's beginning; the labors of profound analyists like Gauss, Adams, Le Verrier, Gylden, Hill, Newcomb and many others have placed mathematical astronomy on an entirely new footing.

It is impossible in a popular paper to give any account of the triumphs of mathematicians. It must suffice to say that the advances in the theory of the motions of the heavenly bodies are as important and far reaching as the results obtained by the spectroscope, the photometer and the photographic plate. One signal result stands out as a brilliant type of the power of analysis.

The planet Neptune was discovered with the telescope in 1846 in consequence of laborious calculations by Le Verrier, (and Adams) upon the materials of the planet Uranus. Uranus had been discovered by chance by Sir William Herschel in 1781. A body of unusual appearance was seen in his telescope. Examination showed that it was a major planet revolving about the Sun in eighty-four years. Careful observations gave the shape and size of its orbit. Calculations of the perturbing forces exerted by the other known major planets—Mercury, Venus, the Earth, Mars, Jupiter, Saturn—showed that its course in space would be along a certain line if these planets, and only these, affected its motion.

Renewed observations showed very slight, yet obvious, deviations from the predicted course. It occurred to several astronomers—to Arago, Bessel, Struve, Le Verrier, Adams—that these deviations were produced by the attraction of a major planet as yet unknown. Sir John Herschel wrote of the new planet a few weeks before its discovery in memorable words: "We see it as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far-reaching line of our analysis with a certainty hardly inferior to ocular demonstration." The extraordinarily complex problem of inverse perturbations was worked out by Le Verrier and by Adams and the place where the new planet would be found was foretold. When the telescope was directed to the predicted place the unknown planet was there; the mathematician, in his study, had directed the observer's telescope. Other achievements of the same order of merit, though far less striking, have distinguished the present century.

In the mathematical processes relating to spherical and to practical astronomy, also, this century has made its mark in history. Bessel, Struve and their successors in Europe and in America have reconstructed these branches of the science from the foundations. Every pupil in our colleges is now familiar with the highest refinements of observation and calculation; and the principles of instrument-making have been carried well nigh to perfection.

In some departments the instruments furnished are so perfect that the outstanding errors of observation are due chiefly to the human being who uses the apparatus, not to the apparatus itself. The distances of the Sun and many of the stars have been fixed with exactness. Telescopes are now made of great size and power. In 1824 Sir John Herschel became possessed of a very good refractor of five inches aperture, then the largest of its kind in the world. An instrument of equal power is now attached alongside the thirty-six inch telescope of the Lick Observatory to serve as a mere finder—like the sights of a rifle—to direct the giant tube of the main instrument.

Reflecting telescopes too, have been much improved, though not greatly increased in size, since the days of the elder Herschel. Well-equipped observatories are now scattered all over the earth.

The heavens are assiduously watched by professionals and by amateurs in all the length and breadth of the globe, and no change of importance can take place without being detected—perhaps by photography—and reported by the electric telegraph to every interested watcher in all the continents.

The advent of photography as the handmaid of astronomy marks a distinct advance in the processes of observation. The sensitive plate partially records all rays of light that fall upon its surface. Such a plate directed at the heavens shows thousands upon thousands of stars, each registered in its proper position and of its proper brightness. A second plate taken upon a succeeding night records all changes, either of position or of brilliancy. It is in this way that new minor planets are discovered (by their change of position), new variable stars detected (by their change of brilliancy). Maps of the whole sky are now made by photography and they record millions upon millions of stars. The inventory of the stellar universe will soon be completed, a magnificent gift of this century to the next.

Photography has proved to be of immense importance in the study of the Moon. A satisfactory picture of the full Moon can be made in less than a second of time which will show more than is contained in the best lunar maps that required a lifetime to construct by the old methods. The study of the solar corona would have been impossible without the photographic plate.

The mysterious world of the nebulæ, too, is depicted by means of photography with extraordinary faithfulness, the work of years of observation being compressed into hours. Up to this time little success has been attained, however, in the study of planetary features by photography, and the old methods of telescopic examination and pictorial representation by drawing are still employed. It is partly for this reason that so much remained doubtful in the accounts of the surface details of Mars, Jupiter, etc.

In the study of the physical characteristics of comets also photography has proved to be of the very first importance. Features quite impossible to see with the eye are distinctly shown on the negative plate, and in this field we are on the very verge of great discoveries. The connection of comets with meteor swarms is a fact of capital importance.

The electric telegraph has revolutionized certain parts of astronomy and geodesy. All longitudes are now fixed by "the American method" with unheard-of accuracy and rapidity, and the figure of our globe will soon be well determined. One of the striking discoveries of the century is Dr. Chandler's detection of a minute regular change of the axis of rotation of the Earth whose effect is shown in a regular, though small, variation of the latitudes of places. This discovery is an excellent example of the thoroughness with which all astronomical work, both observation and calculation, is now performed.

At the beginning of the century Sir William Herschel was in midcareer. He discovered the planet Uranus in 1781; its two brighter satellites were discovered by him in 1787; the two innermost satellites of Saturn in 1789. The satellite of Neptune was discovered by Lassell in 1846; two more satellites to Uranus, again by Lassell, in 1851; a satellite to Saturn by Bond in 1848; two satellites to Mars by Hall in 1877; a satellite to Jupiter by Barnard in 1892; a ninth satellite to Saturn by Pickering in 1899.

Newton's discovery of universal gravitation reached no further than the outermost planet known to him, Saturn. The discovery of Uranus and Neptune extended the scope, but Herschel's detection of systems of binary stars revolving about each other according to this law made gravitation truly universal; the law was effective to the boundaries of the universe. Our knowledge of double stars has been vastly extended by the discoveries of this century. Thousands of such systems have been discovered and many orbital motions are already calculated.

To Herschel a star was a shining body like the Sun, both being of unknown constitution. The spectroscope (invented by Bunsen and Kirchhoff in 1859) brought a new engine to bear on problems until then utterly unsolvable. The spectrum of the Sun, or of a star, compared with the spectra of terrestrial substances, proves the existence in the fiery envelopes of these bodies of incandescent clouds of metallic vapors. Lead, iron, gold, copper and other metals are there present.

The nebular hypothesis of Laplace (published in 1706) had declared that the Sun and all the planets were but condensations from a single vast nebula that once filled all space. The spectroscope proves that the stars, the Sun and the Earth are made up of the same elements. If the Earth were to be raised to the temperature of the Sun it would be like it—a miniature sun. The Sun is, in fact, a star. The stars are, in general, composed of terrestrial elements. This great generalization strengthens the nebular hypothesis in its larger acceptation, but the century has brought forward many doubts as to its minor details. With the discovery of the spectroscope the science of astronomical physics was born. The most amazing single results of spectroscopic observation is the determination of the velocity with which stars are approaching to or receding from the Earth. All stars are in motion with respect to the Earth. As they move away from or toward us the pitch of their spectral lines is altered by their velocity, precisely as the pitch of the bell of a passing locomotive engine is altered by its motion toward us or from us. We are approaching some stars; we are receding from others. The line of the motion of our whole solar system can thus be drawn in the universe, and this problem is now being worked out in all its details at several places, notably at the Lick Observatory.

In the foregoing paragraphs it has not been possible to note more than a few of the greater achievements of the astronomy of the century. Only a few of the greater men are named. A full account of the astronomical progress would require a volume, and it would include a host of honored names. In each and every department we should find Americans in the highest places. Nowhere has astronomy flourished better than upon our soil, and we may look forward to the next century with confidence.—"*Evening Star*" (*Wash.*), *Nov. 3, 1900.*

ON THE ADJUSTMENT OF THE EQUATORIAL TELESCOPE.

SECOND PART.

KURT LAVES.

FOR POPULAR ASTRONOMY.

Having derived in the first part of this paper the mathematical formulæ, upon which the final adjustment of the equatorial depends, it is left to show how the quantities $\xi, \eta, \Delta D, \Delta T, c, n, E, e$, can be determined from actual observations of the stars. Before doing this it will be necessary to indicate how an equatorial is to be put *approximately* into position without the use of the elaborate system of equations (9) and (10).

§ *6. The approximate adjustment of the equatorial.*

This problem resolves itself into two parts:

(1) To bring the polar axis of the instrument into the plane of the meridian.

(2) To point the polar axis to the pole of the heavens, *i. e.* to give to the polar axis an elevation above the horizon, which is equal to the latitude of the place of observation.

For the first part it is necessary to show how we determine the sidereal time for any given standard time. From an accurate map we take the longitude of the place of observation from Greenwich. The sidereal time at Greenwich mean noon for every day in the year is given in the *Nautical Almanac* on page II of the monthly calendar (pages 2 to 217; the eighteen pages devoted to each month numbered by Roman numbers). This quantity changes by $3^m\ 56^s.55$ in 24^h which gives an hourly change of nearly 10^s. We compute the sidereal time for local mean noon by adding to the sidereal time for Greenwich mean noon 10^s multiplied by the longitude expressed in hours. Thus we know the sidereal time for local mean noon for every day. To transform a given standard time into local mean time we must know the difference between the standard meridian and the local meridian; if the standard meridian is east of the local, we subtract the difference in longitude from the given standard time; if it is west, we add it to the standard time. We next transform a given local mean time into sidereal time by changing the mean time interval since noon, into a sidereal time interval using for this purpose table III (pp 548-550). This value we add to the sidereal time at mean noon and obtain the sidereal time corresponding to the mean time moment [we have assumed that we had to do with a P. M. time]. But we need for our purposes also the knowledge of the mean time when the sidereal time is given. It is evident that we have then to subtract from the given sidereal time the sidereal time at mean noon. This difference, which is expressed in sidereal time, we transform into mean time by table II (pp. 545-547).

The right ascension of the star α Ursæ Minoris (North Star) is now $1^h\ 23^m$; when it is in upper culmination the sidereal time is equal to $1^h\ 23^m$. We find for a given day the corresponding mean time and turn our equatorial instrument to the star a few minutes before the culmination occurs. We keep the declination axis in a horizontal position; an assistant shifts the basis of the instrument till the star appears in the field and keeps turning it till the star is, at the computed time of culmination, well in the middle of the field. In the late fall the upper culmination of the North Star takes place conveniently in the early evening hours; in the spring the lower culmination will have to be used instead.

To give to the polar axis the proper elevation we should observe the declination of a star in both positions of the telescope, east and west of the pier. We shall then have two equations of the character of those under (9) in the preceding article, which could be solved for ξ and ΔD. To find the value of ΔT it is necessary to have the declination axis in a horizontal position and to observe the instrumental hour angle of an equatorial star in both positions. We would then form the arithmetical mean of the two equations corresponding to those under (10) and find the index error of the hour angle circle. To effect the horizontality of the declination circle, a level attached to the declination axis seems to be necessary. But very few instruments are provided with such a level and it seems therefore impossible to obtain ΔT independent of the error of the chronometer, if this one is not known from observations with the meridian instrument. A simple but very ingenious method has been devised by Professor Schaeberle to overcome this difficulty, and since from it at the same time the value for ξ and ΔD can be conveniently determined in day time it will be best to reprint here the clear exposition of the method as given by Professor Campbell in his *Practical Astronomy* (2d ed. pp. 215-216):

"Across the object end of the telescope firmly tie a piece of "wood which projects several inches from the telescope tube on "the side opposite the pier. Pass a fine thread through a very "small hole in the projecting end and fasten it. Direct the tele-"scope to the zenith. Near the eye-end and on the same side as "the projecting arm, fasten a block of wood. To this screw a "metal plate so that it will be perpendicular to the axis of the "tube, and in which is a very small circular hole as nearly as pos-"sible (by estimation) under the hole above. Pass the thread "through it, tie a plumb-bob to the end of the thread near the "floor, and let it swing in a vessel of water. Move the telescope "by the slow-motion screws until the plumb-line passes through "the center of the lower hole. Read both verniers of the hour "and declination circles. Unclamp, hold the plumb-bob in the "hand to avoid displacing the metal plate, remove the telescope "to the other side of the pier and set it so that the plumb-line "again passes centrally through the hole. Read both circles as "before.

It is obvious that the two readings of the declination circle give rise to the following two equations (see equation 9):

$$\phi = D' + \Delta D - \xi \qquad \text{C. P.}$$
$$\phi = D'' - \Delta D - \xi \qquad \text{C. F.}$$

Indeed the declination of the zenith is the latitude of the observer, the term in e will be zero. From these observations we obtain $\Delta D = \frac{D''-D'}{2}$ and $\xi = \frac{D''+D'}{2} - \phi$. (The value of ϕ can be obtained from a map with sufficient accuracy for this preliminary work). Placing the index of the declination circle on $\frac{D''+D'}{2}$ by means of the slow-motion screw, we shift the index arm bodily by the amount $\frac{D''-D'}{2}$ in the proper direction. We next place the index on the declination $= \phi$ and move the polar axis by means of the proper screw till the plumbline will take its position in the middle of the circular hole. The adjustment of the polar axis being accomplished, we take the arithmetical mean of the hour circle readings. This taken with the negative sign is the value of ΔT; placing the index on the hour circle equal to the arithmetical mean, we shift the index arm till it reads $0^h\ 0^m\ 0^s$.

With the adjustment so far effected it is possible to obtain a closer determination of the error of the chronometer. It will be readily granted that the error with which the longitude can be taken from a map is large and that standard clocks which are daily regulated by means of a time signal from the Washington Observatory are not always easily reached. It will therefore be preferable to do away with this round-about method of finding the sidereal time from the mean time. The stars will furnish us the correct time. For this purpose we turn to equation (10) (Part I). The hour angle of a star is the difference between the sidereal time and the right ascension of the star. Let, at two moments of time, θ' and θ'' be the sidereal times as obtained from the chronometer, and let $\Delta\theta'$ and $\Delta\theta''$ be the corrections to be applied to θ' and θ'' respectively, to give the correct sidereal times. Assume $\theta'' - \theta'$ smaller than 10^m, then we may assume that $\Delta\theta'$ will be equal to $\Delta\theta'' = \Delta\theta$ for a fairly good watch. Select a star which culminates near to the equator and observe its transit over the vertical wire in both positions; *C. P.* when the instrumental hour angle is about 3^m east, and *C. F.* when it is about 3^m west. From the foregoing definition we have

$$\tau' = \theta' + \Delta\theta - \alpha \text{ and } \tau'' = \theta'' + \Delta\theta - \alpha.$$

With these values we find,

$$\theta' + \Delta\theta - \alpha = T' + \Delta T - c \sec\delta - n \operatorname{tg}\delta + \eta \operatorname{tg}\delta \qquad \text{C. P.}$$

$$\theta'' + \Delta\theta - \alpha = T'' + \Delta T + c \sec\delta + n \operatorname{tg}\delta + \eta \operatorname{tg}\delta \qquad \text{C. F.}$$

We have neglected in both equations the flexures and have put $\sin\tau' = \sin\tau'' = 0$ and $\cos\tau' = \cos\tau'' = 0$ since the observations are made so close to the meridian.

By addition of the two equations we obtain

$$\varDelta\theta - \varDelta T = \alpha - \frac{\theta' + \theta''}{2} + \frac{T' + T''}{2} + \eta \operatorname{tg} \delta$$

α is known from the *Nautical Almanac*, $\frac{\theta' + \theta''}{2}$ and $\frac{T' + T''}{2}$ are known from observation; we obtain therefore a value for $\varDelta\theta - \varDelta T - \eta \operatorname{tg} \delta$, and since we may safely assume that by the foregoing method $\varDelta T$ is reduced to one unit of the graduation of the hour circle we shall obtain $\Delta\theta$ with an accuracy equal to that of $\varDelta T$ provided we have taken a star so close to the equator that $\eta \operatorname{tg} \delta$ can be neglected.

§ 7. *The determination of ΔD, ΔT, ξ, η, c, n, E, e as derived from observations of stars.*

Since the equations (9) and (10) contain on the right sides terms which have either sin τ or cos τ as a factor, it will be advantageous to divide our work into two distinct parts. The first part will deal with the observations which are made close to the meridian, the other close to the $6^h - 18^h$ circle. Our equations (9) and (10) will be reduced in these two cases to the following:

(*a*). *Near the meridian.*

$$\theta' - \alpha = T' + \Delta T - \Delta\theta - c \sec \delta - n \operatorname{tg} \delta \pm \eta \operatorname{tg} \delta$$
$$\pm E \cos \frac{(\phi \mp \delta)}{\cos \delta} \qquad \text{C. P.}$$
$$\theta'' - \alpha = T'' + \Delta T - \Delta\theta + c \sec \delta + n \operatorname{tg} \delta \pm \eta \operatorname{tg} \delta$$
$$\mp E \cos \frac{(\phi \mp \delta)}{\cos \delta} \qquad \text{C. F.}$$
$$\delta = D' + \Delta D - \xi - e \sin (\phi - \delta) \qquad \text{C. P.}$$
$$\delta = D'' - \Delta D - \xi - e \sin (\phi - \delta) \qquad \text{C. F.}$$

The upper signs in the terms in E and η pertain to stars in upper culmination, the lower signs to stars in lower culmination.

(*b*). *Near the $6^h - 18^b$ circle.*

$$\theta' - \alpha = T' + \Delta T - \Delta\theta - c \sec \delta - n \operatorname{tg} \delta$$
$$\mp \xi \operatorname{tg} \delta + E \sec \phi \operatorname{tg} \delta \pm e \cos \phi \sec \delta \qquad \text{C. P.}$$
$$\theta'' - \alpha = T'' + \Delta T - \Delta\theta + c \sec \delta + n \operatorname{tg} \delta$$
$$\mp \xi \operatorname{tg} \delta - E \sec \phi \operatorname{tg} \delta \pm e \cos \phi \sec \delta \qquad \text{C. F.}$$
$$\delta = D' + \Delta D - \eta - e \sin \phi \cos \delta \qquad \text{C. P.}$$
$$\delta = D'' - \Delta D - \eta - e \sin \phi \cos \delta \qquad \text{C. F.}$$

The upper signs in the ξ and e terms belong to stars in the 6^h circle, the lower ones to those in the 18^h circle. It should be remarked that we have replaced in the trignometrical functions on the right side d by δ and f by ϕ. This is permitted, since each of these terms is multiplied by a small factor, so that the quantities thus neglected will be inappreciable. Only for the stars in the neighborhood of the pole, will it be necessary to use the rigorous formulas since for instance the term ξ tg δ can even for small values of τ become appreciable on account of the factor tg δ, which becomes 56 in the case of the star λ Ursae Minoris. To avoid unnecessary calculations it will therefore be wise to observe as close to the meridian, or $6^h — 18^h$ circle as possible. We cannot observe the same star in both positions near the $6^h — 18^h$ circle, since the pier will interfere, but we can easily apply the rule just stated even in this case. For the meridian observations in τ we should by all means observe each star in both positions, since we get a very valuable change of signs in this way for our equations. It will require therefore some skill to keep close to the meridian with both observations. But since we read but the hour circle for hour circle observations and pay no attention to the declination circle, the work is considerably reduced. The same holds true with respect to observations in declination, where the hour circle readings are omitted, but on account of the absence of magnifying factors in the equations for the declination, we may observe even at a considerable hour angle without danger.

(To be continued.)

NOTE ON THE COMPANION TO β CASSIOPEIÆ.

S. W. BURNHAM.

FOR POPULAR ASTRONOMY.

The first measures of the small attendant to β Cassiopeiæ, discovered by Alvan G. Clark, were made by me at the Lick Observatory in 1889, and so far as I know it has not been measured by any other observer. I have re-observed it with the 40-inch of the Yerkes Observatory during the present year.

The two sets of measures are:

1889.59	189°.2	22″,63	3*n*
1900.70	204 .2	22 .66	2*n*

The large motion in position-angle corresponds with practical accuracy to the recognized proper motion of the bright star. This annual movement according to Auwers is 0″.550 in the direction of 110°.2. Taking this value and the position of *B* from the first set of measures as given above, the companion if fixed in space should be at the date of the last measures, 204°.8; 22″.28. This is practically identical with the observed place, and therefore the companion is not connected with the principal star. The minimum distance of 22″.4 occurred in 1897.

THE ALLEGHENY OBSERVATORY.*

The story of the old Allegheny Observatory is replete with interest not only to the astronomer, but to the good people of Pittsburg and Allegheny, for are we not proud of its history, proud of its achievement in the domain of science, proud of the men who have done so much to advance our knowledge of the beautiful science of astronomy, for discoveries of momentous interest in solar, stellar and planetary physics have been made within the walls of the dear old building on Observatory Hill, and today the discoveries made there give us a standing in the scientific world second to none.

Have we not also a pardonable pride in that noble corps of men who a little more than forty years since planned and builded the old Observatory; builded better than they knew for forty years ago little was known of the new astronomy in the field of which so much has been sown and reaped in the old institution.

On the evening of February 15, 1859, three citizens of this city and Pittsburg met at the office of Professor Bradley to consider the purchase of a telescope, "the magnifying power of which would bring the heavenly bodies near enough to be viewed with greater interest and satisfaction." These three citizens were Professor Lewis Bradley, Josiah King and Harvey Childs. After some conversation upon the subject it was decided to request other gentlemen to meet with them. The next meeting was held on the evening of Washington's birthday, February 22, 1859. At this meeting, "after further conversation, in which it was proposed to place the telescope upon a house-top in the central part

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* Address of J. A. Brashear at the laying of the corner stone of the new Allegheny Observatory which took place at Riverview Park, Allegheny, Pa., October 20, 1900. The address was was printed in the *Pittsburg Press*, October 21.

of Allegheny." So far as can be learned the house selected was on the southeast corner of Parkway (then called Water Street, as it was nearest the canal) and Federal street. However, at a subsequent meeting it was decided to abandon the idea of placing it upon a house-top in the center of a city and a committee was appointed to select a more suitable site. Three sites were proposed by this committee—one on Seminary Hill, one on Quarry Hill, and a site on the west end of Seminary Hill, owned by Judge Irwin. At this time and for long afterward the association was known as the "Allegheny Telescope Association," and it is a matter of great interest to us to know of the men who were the prime movers in this pioneer astronomical association, for at that time in our history there were very few astronomical observatories of any note in the United States. I find on this roll of honor the names of Hon. Thomas M. Howe, Professor Lewis Bradley, R. S. Hays, Henry Irwin, William J. Bissel, Felix R. Brunot, John A. Wilson, James Park, Jr., Josiah King, C. G. Hussey, Edward Rahm, James Marshall, John Dean, David Campbell, William Bagaley, G. W. Cass, H. Hepburn, Henry Bollman, William Thaw, John S. Shoenberger, David McCandless, General Robinson, Christian Yeager, Mr. O'Hara, Washington McClintock, James M. Cooper, Robert Dalzell, William Morrison, Thomas Bakewell, Samuel Gormley and R. B. Sterling.

So far as I can learn all of these grand men, except C. Yeager, have passed away from Earth, but they have left an honored name, names to grace the roll of honor of any community. Many other citizens joined the association shortly after these names were recorded in the minute book, which names will be recorded at the end of this paper.

The committee on site had some negotiations with the city with reference to a location on Seminary Hill, a lease of which was offered to the association for an annual rental of sixty dollars per year, but about this time Mr. Ferguson and Mr. McClintock offered free of cost a large part of the plot of ground on which the Observatory now stands, and an additional piece was purchased from Mr. Ashworth, making in all a tract of over ten acres, on what was then perhaps as fine a location for an Observatory as could be found near the city, as the prevailing winds carried the smoke away from it, thus insuring good observations in its earlier history.

So successful was the association in raising funds for the proposed Observatory that it was decided to purchase a 13-inch telescope instead of an 8-inch, as originally proposed, and on motion of Mr. William Thaw it was decided to instruct a committee to make arrangements for the purchase of an instrument from Mr. Fitz, of New York, who had only a short time before completed a similar instrument for the Dudley Observatory at Albany, New York.

This committee, consisting of Mr. Josiah King, Hon. Thos. M. Howe and Dr. C. G. Hussey, requested Prof. Bradley to go to New York and make arrangements for the telescope of 13 inches aperture to be mounted equatorially and placed in the Observatory when completed. Professor Bradley's report was of such a satisfactory character that the proposal of Mr. Fitz, made on the 17th of January, 1860, was accepted at the meeting of the board held January 31.

The complete organization of the association did not take place until May 15, 1860, when the constitution and by-laws were reported and adopted and a board of directors elected. The members constituting the board were: Hon. Thomas M. Howe, Dr. C. G. Hussey, Mr. William Thaw, Mr. Josiah King and Mr. John H. Shoenberger.

Dr. C. G. Hussey was elected president of the board and Mr. James Park, Jr., secretary.

The act of incorporation by the legislature of Pennsylvania was approved by Governor Packer on the 22d of March, 1860.

At this epoch in the history of the Observatory there is some discrepancy in the dates, as the architect's plans were accepted and approved about the 8th of May, just a week before the election of the board of directors. Messrs. Barr & Moser were the architects.

The contract for the building was awarded to several parties, Mr. J. S. Knox building the stone work and Messrs. Smith & Bungy the carpenter work.

Mr. Fitz' work on the great telescope, its completion and the reports of the tests by Dr. Lewis Rutherford and Dr. Brunnow make up a most interesting part of the history during this period of the development of the Observatory and its equipment, all of which is recorded in the minute book of the association. Suffice it to say that the Observatory was completed and the telescope erected between the first of November, 1860, and the end of January, 1861.

Professor Bradley delivered an address before the board of trustees and their friends when they took possession of the building and instruments, but for some unknown reason this address has disappeared from the book of records of the Observatory.

On Tuesday evening, November 17, 1863, Professor Philotus Dean was elected Director of the Observatory for one year. The records do not show any important observations or discoveries made up to this time, indeed it is presumed that the telescope was used almost entirely for observations of the Moon and planets by the members of the association.

The first director of the Observatory served without any salary, save that he was furnished with a dwelling house free of rent.

On the 10th of May, 1867, a meeting was held of the stockholders of the Allegheny Astronomical association, as it is now called, to consider its transfer to the trustees of the Western University of Pennsylvania. The association had incurred an indebtedness of about $12,000 and they recognized that to carry it on in the interests of education and the advancement of science a fund must be raised to pay the debt, and also raise a fund to endow a chair of astronomy in the university. It was therefore proposed to raise the sum of $30,000 by which this desirable end should be attained. The future usefulness of the Observatory seemed to be fully recognized by the board at that time, as the minutes of this date are filled with expressions of hope and prophecy regarding both the University and the Observatory.

A large majority of stock holders and contributors voted to convey their interests in the Observatory to the University, with the proviso that they were to be credited with the amount they had subscribed, and provided further that they should have the privileges formerly accorded them of making occasional use of the instruments, and provided still further that an endowment fund be raised and the property forever be held for Observatory purposes. The Astronomical Association through its officers conveyed the Observatory to the Western University on the first day of July, 1867. The records of this transfer cover many pages of the minute books of the Western University, and bear testimony to the care with which the transfer was made.

On the 8th of August, 1867, the names of Professor S. P. Langley and Professor James Thompson were placed before the board of trustees soliciting an appointment to the chair of Astronomy and Physics. Professor Langley was unanimously elected to the chair.

At this meeting it was resolved to equip the Observatory with a transit instrument, chronograph, clocks, etc. The duties of the Professor of Astronomy were also decided upon, in which it was to teach the classes in astronomy and physics in the university, duties from which he was afterwards entirely released.

At a meeting held June 8, 1869, it was decided to change the name of the Allegheny Observatory to the "Observatory of the Western University of Pennsylvania," but at the meeting of the board on the 4th of October of the same year the motion to change the name was rescinded, and the old name retained.

Subscriptions to the endowment fund and paying off the debt amounted at this period to the sum of $15,000, subscribed by Dr. Hussey, Hon. Thomas M. Howe, Mr. William Thaw, Thomas A. Clark, Thomas Fawcett, Christopher Zug, Chas. Knap, James B. Lyon, Dr. Hostetter, Mr. Smith and General Cass. As this fund covered the indebtedness of the Astronomical Association, leaving a balance of $3,000 toward the endowment fund, thus requiring $17,000 to complete the endowment of $20,000. This amount, so far as I have been able to find out, was contributed by Mr. Thaw, who a few years afterwards also contributed $100,000 to the University fund.

It was stipulated by Mr. Thaw that the director of the Observatory should be free from teaching in the University, except to deliver lectures at his convenience and thus be free to carry on original research.

From this time onward the institution took its place among the working observatories of the world. It would be impossible within the limits of this paper to tell you more than a moiety of the splendid observations and discoveries made by Professor Langley and his able assistants. The long series of solar observations, for which this region is so well suited, gave to the world new views of the Sun and its surroundings, and the series of magnificent drawings of sun spots made by Professors Langley, Frost, Keeler and Mr. Very are now considered classic and invaluable in our studies of solar phenomena.

In his studies of solar physics Professor Langley was impressed with the idea that much of the radiant energy coming from the Sun was not recognized with the instruments then in use, and after a long series of experiments he discovered that marvelously delicate thermometer which he called the bolometer.

With the instrument a series of studies were commenced upon the Sun, Moon and stars, which brought to light some of the most important facts in the whole realm of astronomical physics. Rigorous experiments and many critical researches were made in what may be called the hitherto unknown region of solar radiation. This work covered years of earnest, patient labor and tens of thousands of observations, and now we know, through the long continued study of these devoted men that we have in the dark rays that come from our great luminary that which is the source of all life upon our planet. I cannot dwell upon this topic, charming as it is to the student of astronomical physics. Suffice it to say that so valuable have been these discoveries that they have formed an epoch in astronomical science. Professor Langley made many more important studies and discoveries, and he became so well known in the scientific world that he was honored as few men were in his day.

Not the least important work he did at the Observatory was the introduction and development of the time service, which has been kept up without a break since it was started.

In all Professor Langley's investigations he was always assisted by that noble friend of the Observatory, through whose liberality alone he was able to carry out many of his most valuable studies. The expedition to Mount Whitney was paid for entirely by funds furnished by Mr. Thaw, and all his studies in the selective absorption of the Earth's atmosphere were carried on by means furnished from the same source. Professor Langley became greatly interested in aerodomics, or the science of aerial navigation. Upon this he made many valuable experiments from the purely scientific side. Mr. Thaw paid all the expenses of this research up to the time Professor Langley left the Observatory. The experiments are still in progress at the Smithsonian institution.

In 1890 Professor Langley was called to the highest position of any scientific institution in the land, namely the Smithsonian institution in Washington, D. C., to fill a chair that had been occupied by Henry and Baird, where, amidst his many duties, he still finds the time to carry on his bolometric and aerodrómic researches. Professor Langley contributed 54 papers to scientific journals during his directorate of the Observatory.

Professors Frost, Hall, Very and Keeler had been associated with Professor Langley during his stay at the Observatory, all of whom have made for themselves an honored record. Professor Frost now occupies the position of professor of physics in the Western University and Professor Very accepted a position at Ladd Observatory of Brown University.

Professor Keeler, after spending a year studying with Helmholtz and Quinke in Germany, returned to the Observatory, where he further assisted Professor Langley in his researches of the selective absorption of solar energy and other problems of scientific value.

In 1886 Professor Keeler was called to the Lick Observatory, where he had charge of the erection of the instruments and installed all the apparatus for the time service, and was the only astronomer on the mountain for many months. After Professor Holden took charge of the Lick Observatory Professor Keeler was appointed astronomer. Here he soon developed the astronomical spectroscope to a high degree of perfection and made a series of observations on the motion of the nebulæ in the line of sight, which at once brought his work the highest recognition throughout the scientific world. His magnificent drawings of the planets Jupiter, Saturn and Mars, made by the aid of the great 36-inch telescope, have never been equalled. Many other studies of importance were conducted at the Observatory, which at once placed Professor Keeler as one of the most earnest and successful observers in the realm of the new astronomy.

In May, 1891, Professor Keeler was unanimously elected to the directorship of the Allegheny Observatory, a position he at once accepted. When Professor Keeler came to Allegheny he found the Observatory poorly equipped for the line of investigation he desired to pursue as a continuation of his work at Lick Observatory, but friends of the institution and of Professor Keeler soon furnished the means. Mrs. William Thaw contributed the money to construct a spectroscope of the highest type, which was designed by Professor Keeler. Mr. William Thaw, Jr., supplied the means for a new driving clock and the remounting of the 13-inch equatorial, while the Junta club of Pittsburg generously donated a sum sufficient to place a modern shutter on the dome. Thus equipped, Professor Keeler commenced a series of researches by which, in the years he was with us, some of the most brilliant discoveries ever made in astronomical science were added to those he had already given to the world.

Of the sixty-two papers he contributed to various scientific journals during his directorate perhaps the most important ones are those which we have numbered 120 and 121 in the transactions of the Observatory. No. 120 refers to his spectroscopic study of the constitution of Saturn's rings; No. 121 a paper on a spectroscopic proof of the meteoric constitution of Saturn's ring. Had he made no other discovery than this solution of the character of Saturn's rings, his name would forever be remembered in the annals of scientific discovery, for the mathematicians, physicists and astronomers of centuries had labored in vain to solve the problem, which, with his keen intellect, his methods of precision, his marvellous ability to make his instrumental epuipment do his bidding enabling him to solve the mystery and establish the splendid theory of Doppler on a still more secure foundation.

It would be impossible, in the limits of this paper, to tell you of the splendid achievements in the domain of astrophysics of our departed friend, for since this new temple of the skies began to rise from its foundation his spirit has taken its flight to dwell among the stars he loved so fondly. Socially, Mr. Keeler was a most charming man, and as a scientific investigator he was of the highest type, ever ready, ever willing to help the earnest student over the rough ways that here and there lay before him. Thousands of our people have enjoyed his Thursday night receptions at the Observatory, and he was one of the first to suggest that if we should have a new Observatory, one department should be erected that should be forever free to the people, so that they too might enjoy the beauties of the skies.

Professor Keeler was elected director of the Lick Observatory in the spring of 1898. He did not wish to leave us: social and scientific associations, ties of friendship bound him to us closely and had we succeeded in raising a fund large enough to build a new Observatory on this beautiful spot, which had been secured long before he left us, I do not think that even the great attractions of that ideal Observatory on the summit of Mount Hamilton would have been sufficient to take him from us, but the breaking out of the Spanish-American war and the excitement associated with it prevented for the time being the successful issue of the important enterprise. Notwithstanding all this, Professor Keeler hesitated as long as he could, with courtesy to the Lick trustees, and only accepted the position when the time limit was reached. The two years since his acceptance of the directorate of the great mountain Observatory were replete with success, and we lovingly place under this corner stone a record of the last and one of the most important discoveries he had yet made, indeed in a recent letter to me he modestly mentioned it as the greatest discovery of his life, namely that the normal condition of the greater number of nebulæ are spirals.

But he has gone from among us leaving a loving companion and two bright children to honor his memory.

Professor Frank Very remained at the Observatory until his work undertaken for the United States weather bureau on atmospheric radiation was practically completed. This work has just been issued from the government press, and in Professor Moore's transmittal of the work to the secretary of agriculture, he acknowledged it to be a research of great importance in the absorption and radiation of heat in the Earth's atmosphere.

Professor Henry Harrar was a faithful assistant to Professor Keeler, having charge of the time service and other duties in connection with Professor Keeler's research work.

After an interim of about eighteen months our present director, Professor F. L. Wadsworth, was unanimously elected to fill the place made vacant by the resignation of Professor Keeler.

Before Professor Keeler left us he had made a carefully prepared plan for a new Observatory. Professor Wadsworth at once took a deep interest in working out the details of the proposed new building and after spending the best part of a year on the plans, he has given to us to the most minute detail a building in which the science of astrophysics can be studied as never before, a building large as it is, has every nook and corner suited to carrying out some problem in the new astronomy of which there are vast fields yet unexplored, and in which our new director, let us hope, may reap a harvest of discovery yet undreamed of. Professor Wadsworth comes to us as Professor Keeler's first choice. He has already made many important researches in the realms of astrophysics. He has labored day and night for the success of the new Observatory, and we only trust that with his indomitable will and energy he will not pass the elastic limit and break down ere his work is finished.

Our architect, Mr. T. E. Billquist, has put many hours of faithful work into the development of the exterior beauty and completeness of the building throughout, and we trust when it is finished it will be an honor to him and his craft, and, may I add, that if the remainder of the Observatory is constructed by the contractors with the same fidelity and good workmanship that has characterized the work already done, we shall have a building that will stand the storms for centuries.

The Observatory committee of the board of trustees of the university wish also to speak of the generous manner in which the officers of the city government have treated us. Mr. McAfee, Mr. Fulton and Mr. Brown have done everything in their power to facilitate our work. A six-inch water-main has been laid to the very door of the Observatory, and Mr. Fulton has been untiring in his efforts to help us on to ultimate success.

Our site, so kindly given us by those of our citizens who purchased the park for the city and deeded it to us forever for the Observatory, is one almost unsurpassed for the beauty of its scenery, and as the prevailing winds bring us but little smoke, we think we have reason to be hopeful for a continuance of the splendid work of the old institution. Our work will proceed as rapidly as material can be secured, and by this time a year hence we hope to see the completion of the building, although we can scarcely expect to have the instrumental equipment finished by that time, but this instrumental equipment has been thoroughly worked out by our director with especial reference to a continuance of studies of yet unsolved problems in the domain of astronomy and astronomical physics.

One department of the Observatory we propose shall be open day and night to the students in the high schools and higher grades of the common schools in both cities, and to every citizen who wishes to enjoy the fragrance of the "flowers of the sky." When all is complete,

> "Then will holy science, putting off
> Earth's dusty sandals from her radiant feet,
> Survey God's beauteous firmament unrolled
> Like a book new writ in golden words,
> And turn the azure scroll with reverent hand
> And read to man the wonders God hath wrought."

TOTAL ECLIPSE OF THE SUN MAY 28, 1900.*

CHARLES P. HOWARD.

Four days before the eclipse, I joined the Trinity College party at Winton and set up my instruments beside theirs, on the edge of a bluff 40 feet high, on the southwest bank of the Chowan river, here 750 feet wide. This location was a fine one for observing every aspect of the eclipse, for it gave a perfectly clear view of the eastern sky, across a wide expanse of water.

My instruments consisted of a 4-inch photographic telescope, to the upper end of which was attached a 2-inch visual telescope. The photographic object-glass had a focal length of 58 inches, and gave an image of the Moon 0.52 inches in diameter on a 4 by 5-inch plate. The tube was of wood 6 inches square and was, of course, nearly 5 feet long.

The visual telescope had an object-glass of 1.97 inches clear aperture and 22 inches focal length, and the Miller solid achro-

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* A short account with rough illustration was published in the Hartford Courant of June 2d, and also in the Trinity College Bulletin No. 2, for July, 1900. Observations were made at Winton, North Carolina.

matic eyepiece used, gave a field of view 2° 10′ in diameter, and a magnifying power of 18. The field of view was therefore equal to four diameters of the Moon.

Both telescopes were made to follow the motion of the Sun, by a simple contrivance. The upper end of the wooden tube rested on a polar axis, while its lower end heavily weighted, rested on a 4-inch piston traversing a cylinder filled with oil. The cylinder was thickly jacketed to prevent external changes of temperature from affecting the viscosity of the oil. The speed with which the piston descended through the oil, was regulated by a small valve. This method of supporting the tube at both ends was very satisfactory, giving great steadiness and freedom from vibration, but its rate of motion was not quite perfect.

All was mounted on a heavy tripod 7 feet high, bolted to stakes driven firmly into the ground and having a plumb-bob swinging seconds suspended from its apex.

Previous to the eclipse the following program for the 99 seconds of totality was planned aud rehearsed, until its performance became automatic:

1st. 8 seconds for a general naked-eye view of the spectacular aspects of the eclipse.

2nd. 74 seconds for taking six photographs of the corona, with exposures varying from ¼ second on slow plates to 20 seconds on rapid plates, and during the 20 seconds exposure, to have another and longer naked-eye view of the eclipse.

3d. 18 seconds for a view of the corona through the 2-inch telescope.

Unfortunately this program was exactly carried out, for although five of the photographs proved perfect, it was a great mistake to give so much time to photography, and so little to the view through the wide field telescope.

During totality, the atmospheric conditions were phenomenally perfect.

1st. There was a dead calm accompanied by an impressive stillness, that many remarked could actually be felt.

2nd. The air was remarkably clear and transparent. There was not a single cloud, nor a trace of haze, smoke or whitish film in the sky.

3d. Best of all, the telescopic seeing was perfect. Through the telescope not a single tremor of the atmosphere was noticed.

During the partial phase, I had carefully avoided looking at the Sun or at any bright object, in order that during totality my retina should be as sensitive as possible to faint objects. Near second contact I kept my eyes fixed upon the ground and saw the feeble sunlight die rapidly away, with a sort of trembling motion, until it disappeared entirely and it was evident that totality had commenced. I then looked up at the eclipse and saw the corona different from what was expected: There was no very bright inner corona, but only a pale greenish-yellow glow uniformly surrounding the Moon. This halo was brightest at at the limb, and faded rapidly away until lost to sight at a distance of about one-quarter of the Moon's diameter.

The outer corona though much paler, was very distinct, and instead of being hazy and of indefinite outline, had as hard and definite boundaries, and appeared of almost as uniform a tint as if cut from cardboard. It gave the effect of two wings, extending east and west from behind the Moon, each to a distance of about two and one-half diameters, and had a lively or active look that gave to the Sun the appearance of flying.

The naked-eye view of the eclipse was very impressive, particularly the unnatural blue-black color of the sky, and the much blacker disk of the Moon, with the coronal wings extending from behind it. The general darkness was much greater than that at full Moon, for it was difficult to see the swinging plumb-bob, but the general illumination of the sky was much greater, for only one fixed star could be seen by any of our party. The light on the landscape came from the widely diffused light in the sky from beyond the Moon and from a faint brownish illumination of the sky near the horizon, and but little came from the corona itself.

The view through the telescope, however, was far grander than the naked-eye view and most awe-inspiring. Around the Sun was an appearance that almost made one exclaim, "the Sun is an enormous magnet, alive and hard at work."

I made an attempt to represent the general effect of this first view, and although doing so with some degree of accuracy, it but faintly indicates the beauty, grandeur and solemnity of the great action going on all around the Sun.

At the first look it was perfectly obvious that the bright ball of the Sun was wholly hidden behind the black disk of the Moon. Emanating from it in all directions, but not all radially, were an almost infinite number of pink and greenish-yellow forms of various degrees of luminosity, that as a whole formed an oblate spheroid, enveloping the Sun.

The apparent elliptical outline of the spheroid extended 2° in the direction of the Sun's equator, and ⅞° in the direction of the

Sun's poles. Its whole volume was full of these strange forms, most of them seen in perspective, that made it seem to round up toward the eye, in a very striking manner.

With the exception of eight self-luminous "stalks" rising from each polar region, these forms appeared to consist of three distinct kinds:

1st. Long quiescent pink streamers rising from both polar regions and arching away to right and left, in curves that at the moment gave the impression of being magnetic.

2nd. Short quiescent pink stems with enlarged tops, standing out radially from the southwest limb of the Sun like a fungus growth.

3d. Projected greenish-yellow wings, rays, fountains and wisps, thrown out of the Sun in every direction, and at all sorts of angles so as often to cross each other, all showing decided perspective and making as a whole an intricate and involved mass. Some of them were brighter and some were darker, than the mass of similar forms composing the background against which they were seen. Some and perhaps all of the dark ones were not rifts between the bright ones, but were actually composed of darker material as proved by the appearance and arrangement of the minute filaments of which they were composed. Although the color of most of them, when examined separately appeared greenish-yellow, some near the plane of the equator seemed pink, and the general effect of them all was pinkish.

Of course it was impossible to tell whether the filaments of these jets were really in rapid motion or were so in appearance only, for not the slightest motion was noticed; nor could have been detected during the almost instantaneous glimpse of them obtained, had their velocity been even at housand times greater than that of a common ball.

All three kinds of forms had the remarkable characteristics:

1st. They had a peculiar crispness of appearance unlike any other object with which I am acquainted.

2nd. They consisted of an excessively attenuated kind of matter; as was proved both by their reflecting so little light, and by their being apparently entirely uninfluenced by the attraction of gravitation.

3rd. They were all practically perfectly transparent, so that any number of them could be seen through each other.

4th. When looked at attentively, only one set of forms could be seen at once; all the others, even those situated in the same line of sight, becoming invisible. This phenomenon was particularly noticed at the south pole, where three or four sets of forms appeared superposed—viz., the white stalks, long pink streamers, dark jet and explosive rays. When either of them, it did not matter which, was looked at attentively, that one could be seen with perfect distinctness, but the others, for the time being, were invisible.

In the first general view of the corona, the most conspicuous of the projected forms were four broad wings, that rose from the Sun at about latitude 65° and arched away to right and left in beautiful curves; as if the matter composing them, was acted on by an intense force that repelled it from the poles and compressed it toward the plane of the equator. Their appearance was not that of a thin sheet, but they seemed to round up towards the eye as if having considerable volume.

Only two other of these projected forms, happen to catch my attention, although they probably were not more conspicuous than many others. The first was a broad smooth bright wing, decidedly pinkish in color, extending from the south equatorial region towards the east, but cut off from the Sun by a darker wing that seemed to pass diagonally across it. The second was a decidedly dark, fountain shaped jet, of a clear greenish-brown or gold color, projected somewhat diagonally from a little west of the south pole. It had a rather broad base and ran up to a sharp point, and appeared somewhat more than one-third of the Sun's diameter high. It was full of a sort of ruffled up detail, made up of minute short filaments seen with the most perfect distinctness. It curved slightly away from the pole and showed strong indications of perspective as if inclined towards the eye.

While examining this dark jet I saw many other nearly straight bright greenish-yellow rays composed of the same kind of short filaments, apparently thrown off by the Sun radially to beyond the limits of the spheroid.

This filamentous structure was seen with wonderful distinctness, although it was so fine as to be about at the limit of vision. The filaments all seemed to be of about the same size, 600 miles in diameter by 800 miles long. They ranged about longitudinally along the jets, not smoothly as if combed, but bunched together more in some places than in others. They were not straight and geometrical but were bent slightly in groups.

The only surface I have seen since the eclipse giving a somewhat similar effect, is that of a field of coarse grass gone to seed, with each high stem ending in a cylindrical tuft. When these tufts stand so high and numerous that no blades of grass show among them, the field has a certain resemblance to this filamentous structure.

(To be continued.)

SPECTROSCOPIC NOTES.

The complete account of Dr. Wilsing's important work on the spectrum of Nova Aurigæ constitutes No. 40 of the Potsdam Observatory Publications. The characteristic double lines of the Novae, each having a bright and a dark component, are described; and against the prevailing explanation, that this appearance results from two unlike stellar components moving with great relative velocity, strong objections are urged. Dr. Wilsing's experiments are described in which he has succeeded in producing artificially lines practically identical in structure with those of the Novae.

Professor W. H. Pickering, in his study of Swift's comet, 1892 I, (Harvard Annals, Vol. 33 Pt. 2; *Nature*, Sept. 20) finds that the spectrum photographs show an intense and very narrow line about λ 3890, with no indication of hydrogen lines.

Professor Campbell contributes to the *Bulletin of the Astronomical Society of the Pacific*, No. 75, an account of his expedition to Georgia to observe the eclipse of May 28. His spectroscopic observations indicate that the matter radiating the green light is conspicuously heaped up in the sunspot zones; that the position of the green corona line is at λ 5303; and that the spectrum of the inner corona is free from dark lines.

The report of Her Majesty's Astronomer at the Cape of Good Hope for the year 1899 states that Mr. Lunt has charge of the McClean telescope and the work of the Astrophysical department, and that Mr. Bergh has assisted at the McClean telescope. The report refers briefly to the return of the photographic objective for correction of faults of color-correction, and to the papers communicated to the Royal Society on the occurrence of lines of oxygen and silicon in certain star spectra.

Mr. Aitken (*Bulletin of the Astronomical Society of the Pacific*, No. 75), examining Capella with the great Lick refractor on occasions of greatest separation of the spectroscopic components and under favorable circumstances, has been unable to detect the least evidence of visual duplicity.

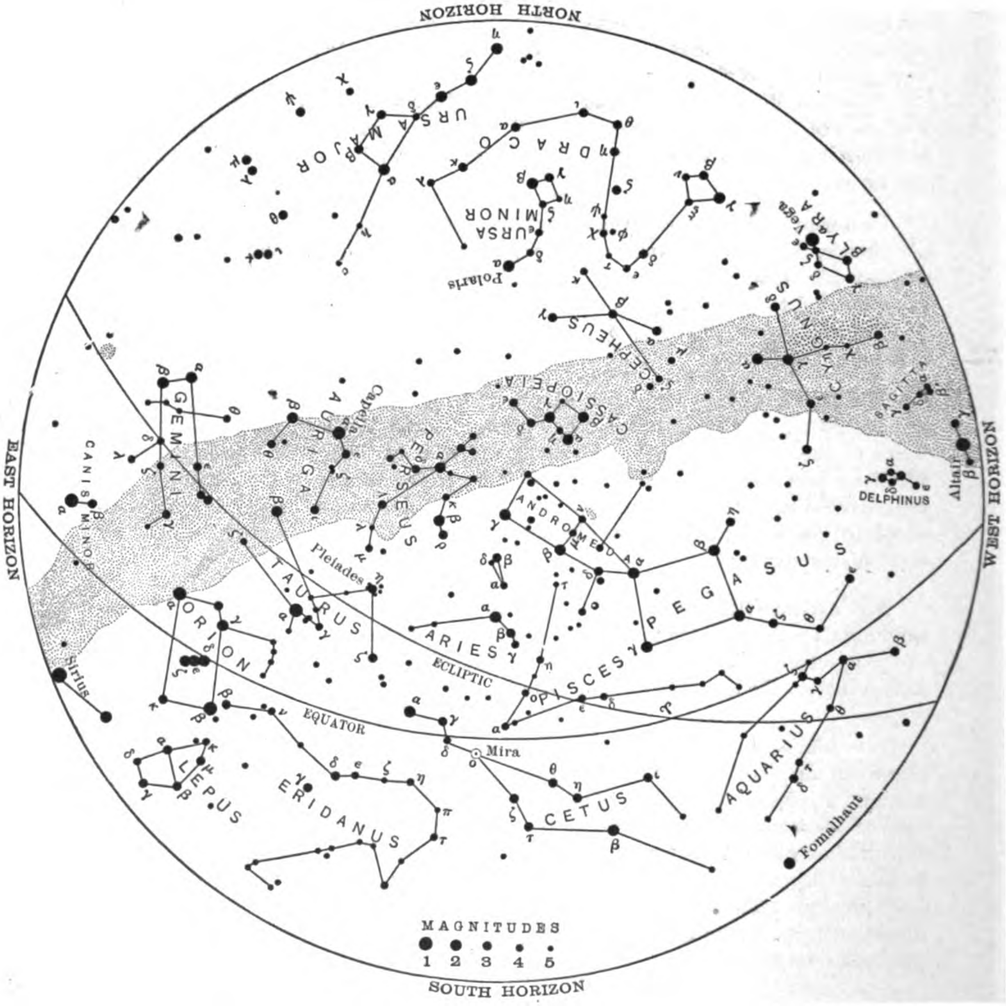
It would seem, then, that κ Pegasi, after this second and very surprising attempt to displace it, is to remain for the present the shortest known visual binary. Professor Campbell (*Bulletin Astron. Soc. Pacific*, No. 75) finds that one of its components is a spectroscopic binary. The components are so close that he has not been able to determine definitely which of them is the spectroscopic binary, though it is probably the one which is stronger in the blue end of the spectrum. The period of the bright star about its invisible companion is about 6 days. There are certain changes in the character of the spectrum not yet determined.

PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be at greatest elongation west from the Sun 20° 50′, Dec. 7, and so will be visible as morning star during the first two weeks of the month. One must look for it toward the southeast, near the horizon, from an hour to a half hour before sunrise. Mercury will be in conjunction with the Moon Dec. 20 at 6 A. M., with Uranus Dec. 22 at 9 A. M. and with Jupiter Dec. 30 at 10 A. M.

Venus rises about 4 A. M. and is near the meridian between 9 and 10 o'clock in the forenoon, when the planet may be seen without the aid of a telescope although her brightness is only about one-third of that in August last. Venus and the Moon will be in conjunction Dec. 19 at 1 A. M.



THE CONSTELLATIONS AT 9 P. M., DECEMBER 1, 1900.

Mars must have been recognized by all who watched for the Leonid meteors, as the bright ruddy star which deformed the handle of the "Sickle" in Leo. The planet is a little brighter than Regulus and therefore of the first magnitude or brighter. The diameter of its disk is a little over 8″ and will increase during

December to nearly 11″. Mars will be in conjunction with the Moon Dec. 12 and with the star *l* Leonis Dec. 16 at 8 A. M., at which latter time the star will be only 6′ north of the planet.

Jupiter, *Saturn* and *Uranus* are behind the Sun, superior conjunction occurring for Uranus on Dec. 5, for Jupiter Dec. 14 and for Saturn Dec. 29.

Neptune comes to opposition Dec. 19 and so is in best position for observation. Its place Dec. 15 is R. A. $5^h\ 51^m\ 12^s$; Decl. $+\ 22°\ 11'$. Its motion during the month is westward, amounting to a little less than one degree.

The Moon.

	Phases.	Rises.		Sets.	
		(Central Standard Time at Northfield; Local Time 13m less).			
		h	m	h	m
Dec. 6	Full Moon......................	5	02 P. M.	8	40 A. M.
13	Last Quarter.................	11	28 "	11	55 "
21	New Moon......................	7	21 A. M.	4	37 P. M.
28	First Quarter...............	11	27 "	12	43 A. M.

Occultations Visible at Washington.

			IMMERSION.			EMERSION.				
Date. 1900.	Star's Name.	Magnitude.	Washington M. T.		Angle f'm N pt.	Washington M. T.		Angle f'm N pt.	Duration.	
			h	m	°	h	m	°	h	m
Dec. 3	π Arietis	5.7	16	36	88	17	25	259	0	49
4	13 Tauri	5.7	13	01	122	13	58	227	0	57
4	14 Tauri	6.3	13	54	141	14	33	211	0	39
6	ζ Tauri	3.3	8	05	51	9	00	299	0	55
9	A^1 Cancri	6.0	17	56	87	18	59	325	1	30
10	ω Leonis	5.9	14	42	123	16	10	296	1	28
12	55 Leonis	6.2	11	37	175	12	04	228	0	27
12	p^2 Leonis	5.4	16	33	110	18	00	316	1	27
17	10 Libræ	6.5	14	30	78	15	20	319	0	49
27	κ Piscium	4.7	7	04	74	8	14	229	1	10
27	9 Piscium	6.6	7	19	115	8	01	189	0	42

COMET AND ASTEROID NOTES.

Comet 1894 IV (E. Swift).—The perihelion passage of this comet does not occur until Feb. 13 next but it will then be involved in the rays of the Sun. A finding ephemeris was computed by Mr. F. H. Seares beginning with July 23 and ending with Dec. 30. The comet has not yet been found and there is but little hope that it may be picked up during this month, the circumstances are so unfavorable. The finding ephemeris for December is as follows:

Berlin Midnight.	R. A.			Decl.		log Δ	Aber.		Light.
	h	m	s	°	′		m	s	
Dec. 2	19	26	54	− 24	30.5	0.3900	20	25	0.11
6		37	43	24	04.1	3916		29	
10		48	38	23	34.4	3932		34	
14	19	59	39	23	01.7	3948		38	0.12
18	20	10	44	22	25.9	3965		42	
22		21	54	21	46.9	3981		47	
26		33	07	21	04.5	3996		52	
30	20	44	24	− 20	19.1	0.4011	20	57	0.12

Ephemeris of Brorsen's Comet.

1900.	R. A.		Decl.		log r	log Δ	$1:r^2Δ^2$
	h	m	°	′			
Nov. 23	22	17.8	−53	54	0.0691	9.9500	0.9
25		16.6	53	17			
27		15.5	52	39	0.0487	9.9373	
29		14.6	51	59			
Dec. 1		13.8	51	18	0.0271	9.9227	1.3
3		13.1	50	35			
5		12.5	49	50	0.0044	9.9059	
7		11.9	49	3			
9		11.3	48	14	9.9806	9.8866	1.8
11		10.6	47	23			
13		9.8	46	29	9.9557	9.8645	
15		8.8	45	32			
17		7.7	44	32	9.9298	9.8392	2.9
19		6.3	43	28			
21		4.4	42	20	9.9031	9.8104	
23	22	2.1	41	6			
25	21	59.2	39	46	9.8761	9.7779	4.9
27		55.6	38	19			
29		51.2	36	45	9.8494	9.7419	
31		45.8	35	0			
Jan. 2		39.4	33	4	9.8241	9.7037	8.8
4		31.7	30	54			
6		22.7	28	30	9.8016	9.6659	
8		12.4	25	49			
10	21	8.9	22	54	9.7835	9.6338	14.6
12	20	48.3	19	44			
14		35.0	16	24	9.7717	9.6146	
16		21.3	12	59			
18	20	7.6	9	37	9.7676	9.6146	17.2
20	19	54.4	6	26			
22	19	42.1	− 3	28	9.7717	9.6340	

Ephemeris of Comet 1900 *b*.

1900.	R. A.			Decl.			log r	log Δ
	h	m	s	°	′	″		
Dec. 1	16	3	9.47	+ 69	38	51.6	0.32810	0.26920
2		4	53.44	69	52	27.4	33055	27087
3		6	38.19	70	6	23.5	33299	27240
4		8	13.71	70	20	39.5	33541	27400
5		10	10.09	70	35	14.8	33783	27560
6		11	57.38	70	50	9.5	34023	27719
7		13	45.61	71	5	23.1	34261	27877
8		15	34.85	71	20	55.7	34498	28036
9		17	25.14	71	36	46.6	34733	28194
19		19	16.52	71	52	55.8	34967	28352
11		21	9.02	72	9	23.0	35200	28510
12		23	2.89	72	26	8.1	35431	28669
13		24	57.97	72	43	10.5	35661	28828
14		26	54.43	73	0	30.1	35890	28987
15		28	52.31	73	18	6.5	36117	29147
16		30	51.71	73	35	59.5	36343	29307
17		32	52.71	73	54	8.7	36568	29468
18		34	55.40	74	12	33.7	36792	29630
19		36	59.91	74	31	14.3	37014	29792
20		39	6.34	74	50	9.9	37235	29956
21		41	14.81	75	9	20.3	37455	30120
22		43	25.44	75	28	45.0	37673	30285
23		45	38.42	75	48	23.5	37890	30452
24		47	53.88	76	8	15.4	38106	30620
25	16	50	12.02	+ 76	28	20.5	0.38321	0.30788

1900.	R. A.			Decl.			log *r*.	log. Δ
	h	m	s	°	′	″		
26	16	52	33.03	+ 76	48	38.2	0.38535	0.30958
27		54	57.19	77	9	7.8	38747	31130
28		57	24.73	77	29	48.9	38958	31303
29	16	59	56.03	77	50	40.9	39168	31477
30	17	2	31.39	78	11	43.4	39377	31653
31		5	11.21	78	32	55.7	39585	31831
Jan. 1		7	55.94	78	54	17.4	39791	32011
2		10	46.11	79	15	47.9	39997	32191
3		13	42.31	79	37	26.6	40201	32374
4		16	45.23	79	59	12.9	40405	32558
5		19	55.66	80	21	6.2	40607	32744
6	17	23	14.51	+ 80	43	6.0	0.40808	0.32933

Ephemeris of Planetoid (306) Unitas.

1900	R. A.			Decl.			log. *r*	log Δ	Aber.
	h	m	s	°	′	″			s
Nov. 29	5	14	17.67	+ 12	8	57.2	0.403889	0.196175	783
30		13	14.96	12	8	3.7			
Dec. 1		12	11.71	12	7	15.7			
2		11	8.01	12	6	33.2			
3		10	3.93	12	5	56.1	0.404817	0.195574	782
4		8	59.54	12	5	24.5			
5		7	54.93	12	4	58.9			
6		6	50.18	12	4	39.2			
7		5	45.35	12	4	25.6	0.405731	0.196230	783
8		4	40.54	12	4	18.0			
9		3	35.80	12	4	16.4			
10		2	31.20	12	4	20.9			
11		1	26.83	12	4	31.6	0.406631	0.198144	787
12	5	0	22.74	12	4	48.2			
13	4	59	19.06	12	5	11.0			
14		58	15.84	12	5	40.3			
15		57	13.14	12	6	15.9	0.407517	0.201301	793
16		56	11.02	12	6	57.7			
17		55	9.62	12	7	45.9			
18		54	8.99	12	8	40.4			
19		53	9.17	12	9	41.2	0.408390	0.205664	801
20		52	10.22	12	10	48.3			
21		51	12.26	12	12	1.7			
22		50	15.34	12	13	21.5			
23		49	19.51	12	14	47.6	0.409248	0.211168	811
24		48	24.79	12	16	19.9			
25		47	31.30	12	17	58.3			
26		46	39.09	12	19	43.1			
27		45	48.18	12	21	33.9	0.410093	0.217725	823
28		44	58.61	12	23	30.7			
29		44	10.44	12	25	33.3			
30		43	23.73	12	27	41.8			
31	4	42	38.54	12	29	56.2	0.410923	0.225227	838

New Asteroids.—Five new asteroids were discovered by Professor Wolf on a photograph taken at Königstuhl Oct. 22 and a sixth on a photograph taken Oct. 23. The last is perhaps identical with Irma (117). The following were the positions at the time of discovery:

	Königstuhl M. T.			R. A.			Decl.		Daily Motion.		Mag.
		h	m	h	m	s	°	′	s	′	
1900 FM	Oct. 22	11	12.8	1	49	0	+ 11	02	— 48	+ 2	12.2
FN	"	"	"	1	36	16	+ 9	50	— 48	— 7	12.8
FO	"	"	"	1	30	24	+ 9	38	— 60	— 8	12.3
FP	"	"	"	1	37	40	+ 8	26	— 36	— 4	13.5
FQ	"	"	"	1	50	08	+ 6	03	— 48	— 6	13.2
FR	Oct. 23	10	17.2	1	47	16	+ 12	53	— 56	— 5	......

Ephemeris of Eros, for Berlin Midnight.

Dates			R. A.			Decl.		log *r*.	log Δ	Par.
			h	m	s	°	′			
1901	Jan.	7	2	20	5	+ 35	20.6	0.0636	9.5023	27.6
		8		22	59	34	54.9			
		9		25	55	34	29.2			
		10		28	55	34	3.6			
		11		31	57	33	38.0			
		12		35	2	33	12.4			
		13		38	10	32	46.8			
		14		41	20	32	21.3			
		15		44	33	31	55.8			
		16		47	48	31	30.4			
		17		51	6	31	5.0	0.0587	9.5118	27.1
		18		54	25	30	39.7			
		19	2	57	47	30	14.4			
		20	3	1	10	29	49.2			
		21		4	36	29	24.1			
		22		8	3	28	59.0			
		23		11	32	28	34.0			
		24		15	2	28	9.0			
		25		18	34	27	44.2			
		26		22	8	27	19.4			
		27		25	43	26	54.6	0.0555	9.5271	26.1
		28		29	19	26	30.0			
		29		32	56	26	5.4			
		30		36	34	25	41.0			
		31		40	12	25	16.6			
	Feb.	1		43	52	24	52.3			
		2		47	33	24	28.1			
		3		51	14	24	4.0			
		4		54	56	23	39.9			
		5	3	58	38	23	16.0			
		6	4	2	21	22	52.2	0.0543	9.5476	24.9
		7		6	4	22	28.5			
		8		9	47	22	4.9			
		9		13	31	21	41.4			
		10		17	15	21	18.0			
		11		21	0	20	54.8			
		12		24	44	20	31.7			
		13		28	29	20	8.7			
		14		32	13	19	45.9			
		15		35	58	19	23.2			
		16		39	42	19	0.6	0.0550	9.5733	23.4
		17		43	27	18	38.2			
		18		47	12	18	16.0			
		19		50	56	17	53.9			
		20		54	41	17	32.9			
		21	4	58	25	17	10.2			
		22	5	2	9	16	48.5			
		23		5	53	16	27.1			
		24		9	36	16	5.7			
		25		13	19	15	44.6			
		26		17	2	15	23.6	0.0577	9.6035	21.9
		27		20	45	15	2.8			
		28		24	27	14	42.2			
	Mar.	1		28	8	14	21.7			
		2		31	49	14	1.4			
		3		35	29	13	41.3			
		4		39	9	13	21.3			
		5		42	49	13	1.5			
		6		46	28	12	41.9			
		7		50	6	12	22.4			
		8	5	53	44	+ 12	3. 2	0.0621	9.6370	20.3

Elements of Asteroid (444) Gyptis.—In *Bulletin Astronomique* for September, 1900, M. L. Fabry gives the following elements of this planet, based upon 71 observations made during April, May, June and July, 1899:

Epoch, May 30.5, 1899, Paris mean time.

$$
\begin{array}{rl}
 & \quad {}^{\circ}\qquad {}'\qquad {}'' \\
M & = 228\ \ 23\ \ 14.3 \\
\begin{array}{r}\omega\\ \Omega\\ i\end{array} & \left.\begin{array}{l}= 151\ \ 48\ \ 57.8\\ = 196\ \ 12\ \ 20.8\\ = \ \ 10\ \ 13\ \ 43.5\end{array}\right\}1899.0 \\
\phi & = \ \ \ 9\ \ 59\ \ 24.0 \\
\mu & = 769''.234 \\
\log a & = 0.442632
\end{array}
$$

Magnitude of planet: $7.7 + 5\,(\log \Delta + \log r)$.

GENERAL NOTES.

It is our expectation now to have the January number of this publication ready for mailing about December 20. All articles intended for that issue should be sent on or before the 10th of December.

The Adjustment of the Equatorial.—We are very sorry that our supply of type for our new printing office did not reach us in time to enable us to print in this number all of the second part of Dr. Laves interesting article on the adjustment of the equatorial. The remainder will appear in the next issue. The article as a whole is just what some of our readers have been seeking, for some time in the past.

Military Rank of Professors of the U. S. Naval Observatory.—In our article in the August and September numbers of POPULAR ASTRONOMY we gave the military rank of Professors of Mathematics in the U. S. Navy, and we intended also to give the pay of the same; but the manuscript was mislaid and is appended here. It is from the *Navy Register*, January, 1899. The Navy Personel Bill of 1900 may have changed a very little if at all.

First five years after date of commission, at sea, $2,400; on shore duty, $2,400; on leave, $1,500.

Second five years after date of commission, at sea, $2,700; on shore duty, $2,700; on leave, $1,800.

Third five years after date of commission, at sea $3,000; on shore duty, $3,000; on leave, $2,100.

After fifteen years from date of commission, at sea, $3,500; on shore duty, $3,500; on leave, $2,600.

It will be seen that these salaries compare favorably with those paid to professors of mathematics in many of our wealthy colleges, and have the advantage of being *life* positions. The above table gives the pay of those only on the *active* list.

The Use of the Reseau.—In *Bulletin Astronomique* for September, 1900, M. K. Bohlin gives an account of some interesting researches upon the errors of the réseau, used for measuring stellar photographs, and incidentally brings out the fact that the distortions of the photographic film, which the réseau was originally intended to detect, were almost insensible.

He says: "The réseaux recently constructed by M. Gautier have received a very high degree of perfection, leaving it almost superfluous to determine the errors of the individual lines. In the introduction to the first volume of the *Photographische Himmelskarte, Zone* + *31° bis* + *40° Deklination,* M. J. Scheiner has given the results of researches on the réseau Gautier No. 47, belonging to the Observatory of Potsdam. The high precision of the réseau is confirmed very strongly by these measures. So M. Scheiner has come to the conclusion that, for the measures of the chart of the sky, the errors of the réseau are quite insensible.

At the Observatory of Upsala they have also made a determination of the errors of the réseau which belongs to that Observatory, and it is reported that this réseau is as perfect as that at Potsdam. For this reason they have referred the measures to two central lines and to four other lines forming, so to speak, the frontier of the réseau. The total number of lines being 50, this reduction of the work necessary to the determination of the réseau is very notable.

"Having begun at our Observatory a determination of the corrections to the measuring apparatus and the réseau by Gautier, we have likewise established the great precision of the réseau employed. We have, however, thought that we should determine the corrections not only to the different lines of the original réseau but also of copies made on photographic plates. So we have measured thus far six plates on which the réseau was photographed in the usual manner, placing the réseau holder at the focus of the photographic objective of the refractor. At the same time with this determination measures have been made on the same lines on the original réseau. The comparison of these two series of observations brings to light a circumstance which does not appear to have been sufficiently considered before."

Here M. Bohlin gives four tables showing the individual measures along two lines of the original réseau and the six copies, in which the mean of the six measures of the original réseau shows an error greater than 0″.05 in only one case, the majority of the errors being only 0.″02 or 0″.03. The means of measures of the six copies on the same lines give slightly larger corrections, the largest being 0″.17. The differences between the individual measures of the six copies are no greater than those of the six measures of the original, but for certain points on the lines there are errors which appear to be systematically common to all the copies. These cannot be due to distortion of the photographic film, which would be likely to affect the same points on different copies with errors of different signs and so be eliminated from the mean of six. They are rather to be traced to some inequality of density or other imperfection in the plate of glass upon which the réseau is ruled and through which the light must pass in making the copy. The largest error of this sort given in the measures is 0″.17, all six copies agreeing in giving an error with the same sign, where the error of the same point in the original réseau is only 0″.01. It would seem better, therefore, to determine the errors of a number of copies of the réseau for practical use than those of the original itself.

M. Bohlin draws the following conclusions from his measures:

1. "The probable errors are very satisfactory and small enough to guarantee the reality of the means.

2. "The corrections to the original réseau are almost insensible.

3. "The corrections to the copies are greater than those to the original and are very irregular.

4. "The probable errors being essentially of the same magnitude in both cases, one may conclude that the real *deformations* of gelatinobromide film on glass (plates of Lumière and Son) *are almost insensible.*"

The last conclusion will be very encouraging to those who are working in the line of celestial photography without the use of a réseau. H. C. W.

Reproductions of Star Charts.—In the supplementary number for 1900 of *Monthly Notices* of the Royal Astronomical Society, Professor Turner gives a valuable note on the "Accuracy of the Star Charts Published by the French Observatories as Reproductions of their Plates for the Astrographic Chart." These charts are large paper sheets, reproducing by heliogravure the long exposure plates on a scale of 2^{mm} to 1′ (twice that of the original negatives). Professor Turner says that these reproductions are very beautiful but apparently somewhat expensive, and estimates that it would cost each of the observatories taking part in this great work about $50,000 to reproduce their plates in this manner. He questioned, therefore, whether the charts will be of sufficient accuracy to warrant the outlay, and has had a portion of one of the Paris reproductions measured roughly and compared with an Oxford original plate of the same region. The results were unexpectedly gratifying, seeming "to indicate that *we can get star places from paper charts at least as good as those obtained with meridian instruments.*"

In view of the probable accuracy of the charts Professor Turner suggests that no hand work should be allowed in their reproduction, such as the retouching of weak images and the insertion of omitted stars, for this cannot be done with anything like the accuracy of the purely photographic process. H. C. W.

The Collins' Monoplane Telescope.—The writer of the letter appearing in the last issue of POPULAR ASTRONOMY, criticising the Collins' Monoplane Telescope, is evidently under some misapprehension as to the optical arrangement of this new form of telescope.

There are no "oblique rays" to be dealt with, neither are special eyepieces required. The glass employed by the Messrs. Collins, throughout their instrument, is of one kind only—crown of uniform density. A crown and flint combination is not used.

A diagram and further particulars of the optical arrangement of one particular form of the instrument that has been made with aperture of 4 inches, equivalent focus of 10 feet, and but 28 inches total length, including dew cap, is shown in the November number of *Knowledge* (English) page 252.

W. B. MUSSON,
Sec'y of the Toronto Astronomical Society.

The Present Opposition of Eros (433).—P. Stroobant, adjunct astronomer with the Royal Observatory of Belgium at Brussels, has recently prepared a very useful pamphlet of about fifty pages, printed in *French* pertaining to the present opposition of the little planet Eros. In a few introductory pages facts about the discovery and special features of the orbit of the planet are given, with a neat graphical illustration. Then follow a set of useful tables and six large plates. The tables are essentially those being published from month to month in this journal. The plates give the path of the planet from Oct. 16, 1900 to Jan. 31, 1901, on a scale of about ¾ of an inch to one degree in declination, and about 11/16 of an inch to 4^m in right ascension. This pamphlet will save observers much time in platting the path of Eros.

Eros Observations at Leander McCormick Observatory.—Professor Ormond Stone, director of the Leander McCormick Observatory University of Virginia, Charlottesville, Va., had obtained up to the first of November, 43 sets of positions of the planet Eros, by the aid of the micrometer with the 26-inch refractor, of which about half will be available for parallax determinations.

Eros Observations at Ladd Observatory.—Professor Winslow Upton, director of Ladd Observatory of Brown University, Providence, R. I., reports that micrometer observations have been made with the 12-inch equatorial each clear evening for position, and that special determinations of the position of the little planet, in right ascension, by comparison with neighboring stars, are made each evening and morning. The latter are made by a transit reticle of 11 lines, ruled on glass, and the times recorded on a chronograph. The observations are made in duplicate by Professor Slocum and Professor Upton.

Observations of Eros at Northfield.—At Goodsell Observatory of Carleton College the planet has been observed at each opportunity since Sept. 26. The general plan has been to obtain a photograph with the 8-inch photographic refractor, as early as possible in the evening, then a series of micrometric measures with the 16-inch refractor and finally a second photograph when the planet was near the meridian. Our teaching duties prevent us from working during the whole night, so that it has been thought best for the most part to omit the morning observations. A few morning photographs, however, have been obtained. Early evening photographs were taken Sept. 26, 29, Oct. 9, 10, 11, 12, 16, 18, 19, 23, 24, 25, 26, Nov. 1, 2, 7, 8, 10, 13, 15, 22 and 24; meridian photographs Sept. 26, Oct. 5, 10, 11, 12, 16, 18, 19, 23, 24, Nov. 13; morning photographs, Nov. 13, 14, 22. Micrometric measures were taken from the nearest star of at least the 11th magnitude, Sept. 26, Oct. 10, 11, 12, 16, 17, 18, 19, 23, 24, 25, 26, Nov. 13, 22.

The planet has been bright enough since Oct. 15 to give a measurable image upon the photograph in one minute. We have generally made five exposures on each plate, setting the guiding star in succession upon the four corners of a small rectangle formed by four threads intersecting near the center of the eyepiece. The fifth exposure is a duplicate of the first, but the asteroid having moved in the mean time impresses a second image beside the first, thus making one corner of its rectangle double, while those of the stars are single. It is easy thus to identify the asteroid. On two occasions we have used the asteroid as the guiding star, once by accident, the second time by design, the result being that the stars were all doubled at the corner of the rectangle corresponding to the duplicate exposure, while the images of the asteroid were all round. The elongation of the asteroid image in five minutes is only slight and, being symmetrical, can be measured with the same accuracy as if it were round. We have, however, made our exposures in the following order: at north corner of rectangle 5^m, at east corner 1^m, at south corner 2^m, at west corner 1^m, and duplicate at north corner 5^m; so that the measures of the individual images can be easily compared with the mean of all and thus any systematic errors noticed. H. C. W.

Eros Observations at Chamberlin Observatory, University Park, Col.—Professor H. A. Howe, director of Chamberlin Observatory of the Denver University, reports that forty micrometrical measures of $\Delta\alpha$ and the same number of $\Delta\delta$ are made each clear week night, between Eros and one or more faint companion stars; the observations are divided into two sets, separated by an interval of about one hour, during which Professor Chas. J. Ling connects Eros with two catalogued stars. One of the companion stars is also related certainly to a companion star. Occasionally companion stars are as faint as the 12th magnitude, because no brighter stars are available. Twenty-three nights have been so utilized at Chamberlin Observatory, an excellent start in the parallax work on Eros.

Laying the Corner Stone of the New Allegheny Observatory.—The corner stone of the new Allegheny Observatory was laid October 20, 1900, with appropriate ceremonies. A large audience gathered at Riverside Park, in Allegheny on that occasion which, for some time previously had been in anticipation, in view of its novel and interesting character. During the exercises of this occasion some facts came out that are especially worthy of notice, in relation to the new Observatory and the astronomical work to be pursued by it in the future.

The new building is to cost about $110,000. The material is to be of chiseled granite. The edifice will be over 200 feet long by about 100 feet wide, which will be surmounted at the ends by domes in which the telescopes will be placed.

J. A. Brashear, the head of the well-known firm of makers of optical instruments at Allegheny presided on this occasion and Dr. W. J. Holland, ex-chancellor of the University of Western Pennsylvania made a brief address. Among other apt things he said: "A few weeks ago I was in Italy and met there a British officer. I told him I came from Allegheny. He thought a moment, scratched his head, and said, 'Oh, yes! I know Allegheny; it has a fine Observatory—and by the way isn't there a town called Pittsburg near it?' So you see, the fame of the Allegheny Observatory has spread, and now that we are to have a finer and better one, the world will be brought closer in contact with the little city of Allegheny."

Next followed the chief part of the programme, the historical address by Mr. J. A. Brashear. It is elsewhere printed in full in this number. It was a masterful, apt, fitting and eloquent setting forth of the merits of the theme most dear to his heart. The right man was chosen for this task, and he performed it right royally.

At the close of this address Mr. Brashear deposited the copper box in the niche prepared for it and the great corner stone was lowered to its place. As Mr. Brashear stood upon it he fittingly announced the names of a long list of donors who have made the existence of the new Allegheny Observatory possible. All lovers of astronomy will want to see these names. They follow:

C. G. Hussey, Thomas M. Howe, William Thaw, Mary Thaw, Elizabeth Thaw, J. H. Cooper, H. Childs, W. McClintock, Robert Robb, J. M. Pennock, Felix R. Brunot, W. S. Howe, G. W. Cass, James Park, Jr., B. L. Fahnestock, C. Yeager, D. McCandless, John Dean, W. Bagaley, H. Harper, J. B. Legget, James Patton, Matthew Ferguson, James McCandless, Josiah King, Charles H. Pantser, Alex. Speer, William McKnight, Thompson Bell, J. H. Shoenberger, James Dalzell, O. P. Scaife, W. Dilworth, Isaac Jones, A. Garrison, Laird Campbell, George A. Berry, John A. Wilson, William Wilkins, R. B. Sterling, Joseph Smith, C. W. Ricketson, R. Ashworth, B. Bakewell, R. S. Hays, William Morrison, Henry

Irwin, Louis Jones, W. S. Bissell, B. F. Bakewell, Samuel Gromerly, William Walker, Hay Walker, James A. Wright, N. Holmes, William McCully & Co., A. L. Bollman, J. B. Jackson, Mrs. A. Cosgrove, J. S. Cosgrove, C. Rahm, L. O. Livingstone, James Marshall, J. McD. Crossan and W. F. Johnston.

At the conclusion the spectators were taken all over the basement of the new building and everything was explained to them by Mr. Brashear.

The New Allegheny Observatory.—By kindness of Mr. Brashear and Professor F. L. O. Wadsworth, director of the Allegheny Observatory, we have the privilege of presenting to our readers a view of the new Allegheny Observatory, as photographed from the perspective made by the architect. It is the frontispiece to this number.

The corner stone referred to above was really the cap-stone of the first story, and $22,000 has already been expended in this first story which is to contain the laboratories. The work is now going on for the second story of the building. The outside will be finished in light cream-colored brick and terra-cotta. The dome over the columns will have the 13-inch telescope of the old Observatory mounted in it, and this is to be forever free to students of all educational institutions and to the public under suitable regulations. The great dome will contain the 30-inch equatorial and siderostat telescope, and there will probably be placed in the other dome a special form of reflecting telescope, devised by Professor Wadsworth as a monument to Professor James E. Keeler.

Director Wadsworth is greatly interested in astrophysical research, and he is sparing no pains to secure an Observatory adapted in the very best of modern ways for research in both the old and the new astronomies.

Leonids at Vassar College, Poughkeepsie, N. Y.—The students in the astronomical department at Vassar College, watched for the Leonid meteors on Wednesday and Thursday nights, Nov. 14 and 15. Tuesday night preceding was cloudy. A fairly continuous watch was kept up by different groups of students from 1 to 5 o'clock on the mornings named. Forty-two Leonids were counted on Wednesday and fifty on Thursday. Many other meteors, Geminids and Orionids were also noted; these were not recorded.

The Leonids at Jamaica Plain, Mass.—I observed on the 12th from 2:30 to 5:30 A. M. I saw during this period 5 Leonids and 7 other meteors. The 13th was cloudy until about 6 o'clock. The 14th was cloudy from 12 to 1:30 A. M. My observations were from 12 to 5:20 A. M. During that time I saw 47 Leonids and 31 other meteors. The 15th I did not observe. On the 16th, 4 Leonids and 9 others, making a total of 103 meteors in all, 56 Leonids and 47 others. All these shooting stars with perhaps three exceptions were from radiants in Gemini and Auriga, Leo Minor, δ Ursæ Majoris and one or two from Taurus. The larger number came from Gemini, and the next largest from ι (Iota) Aurigæ. These meteors with five exceptions (one 0.5 magnitude, three of 1st magnitude and an especially brilliant one of (— 2) from δ Ursæ Majoris) were of third magnitude. They were very frequent. So that the number of Geminids, etc., were more numerous than the Leonids. I only recorded meteors that shot into region somewhere near Leo.*

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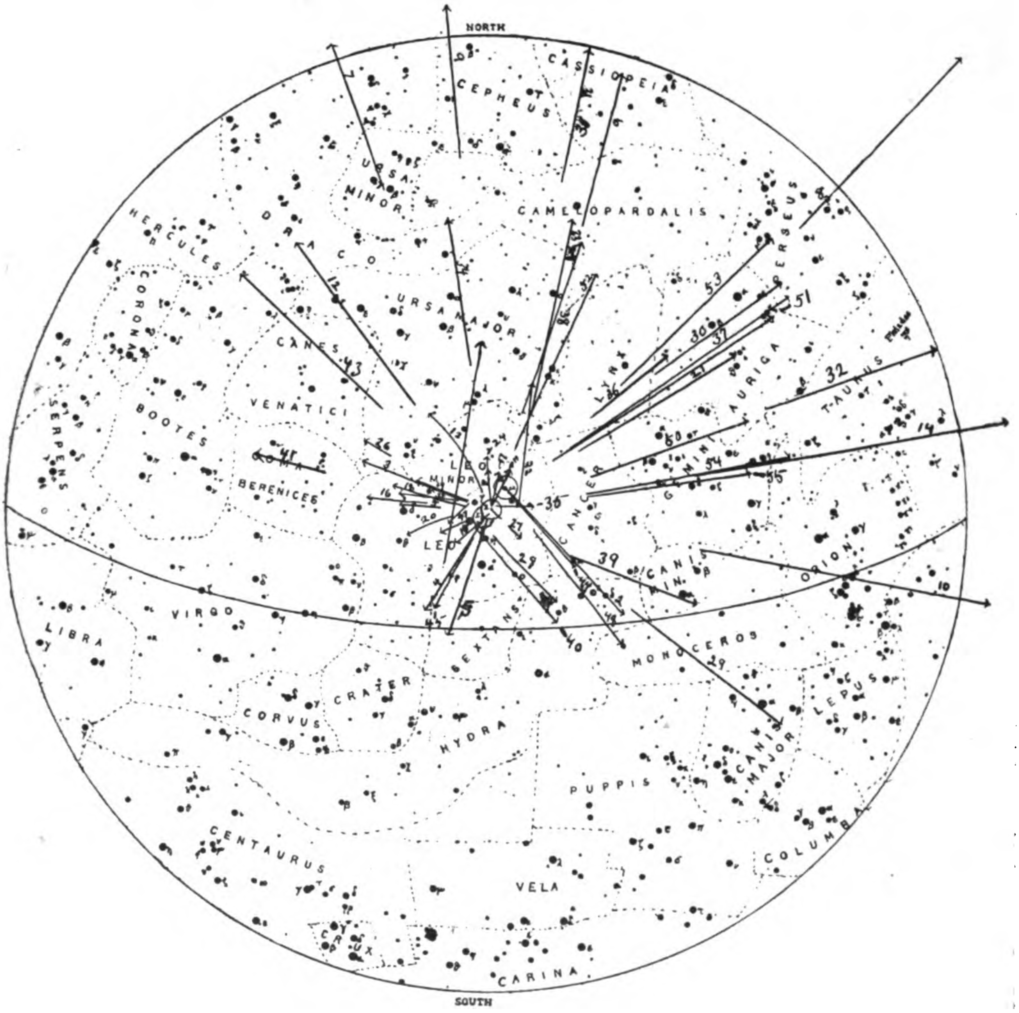
* For want of space the detailed observations in tabular form are omitted. The observations appear to be carefully made.

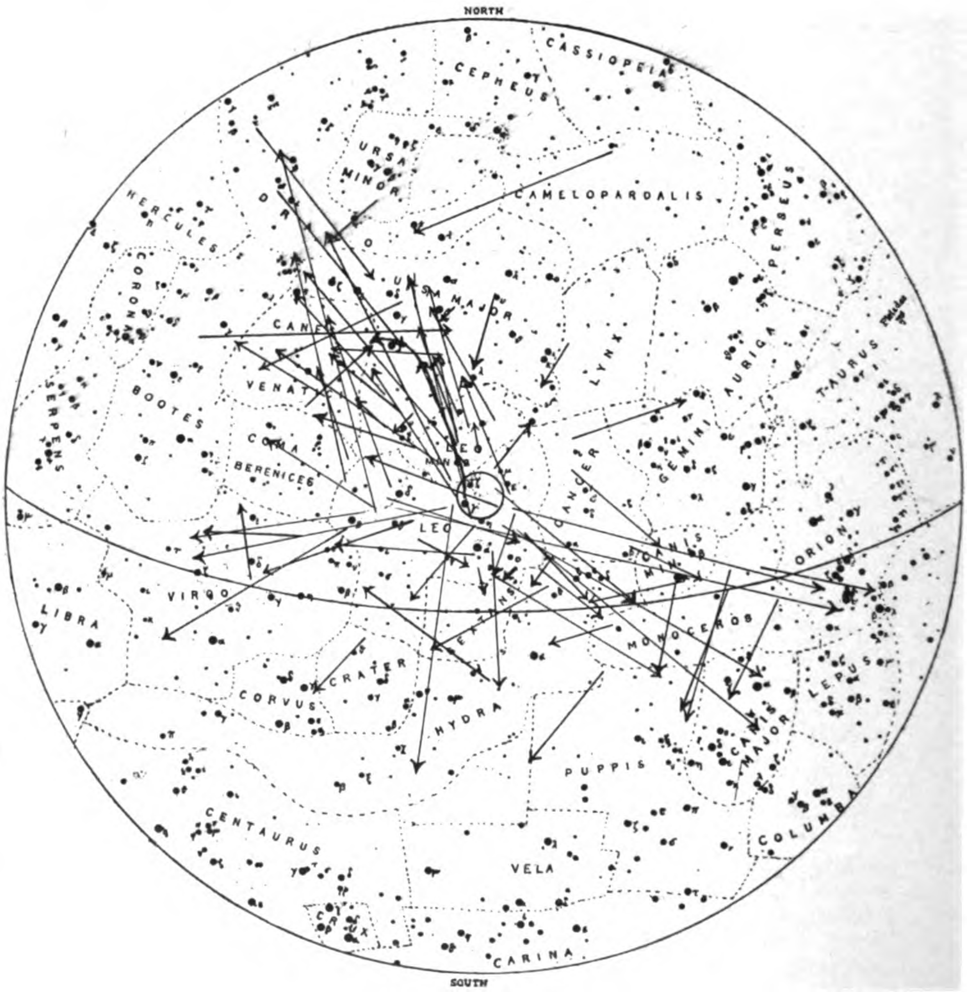
There seemed to be three radiants. The regular radiant and one at γ Leonis and μ Leonis. Nos. 17, 39, 44, 27, 43, 34, 35 and 28 were observed to come from different radiants than the regular one. There was one that started outside of the Sickle, which was marked shooting star, although it may have been a Leonid.



METEORS CHARTED NOV. 12, 14, 16, 1900, AT JAMAICA PLAIN, MASS.

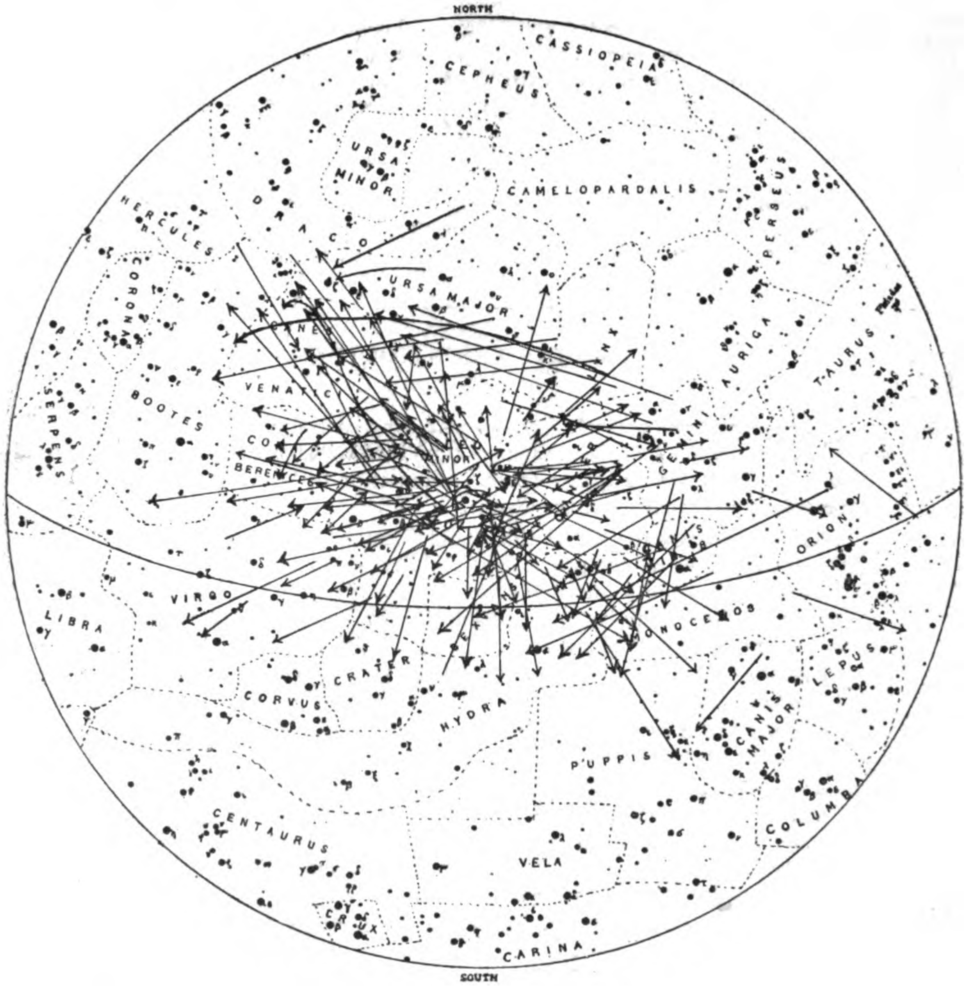
Nos. 2, 8, 10, 12, 13, 18, 19, 37, 44 were brighter than 1st magnitude; Nos. 12, 13 and 44 were especially bright. On Nov. 14, 1900 a very brilliant meteor of — 3 magnitude, green, of 3rd magnitude trail shot from δ Ursæ Majoris. On the 16th observations stopped at 4 o'clock A. M. This shower is not as hopeful as those of 1898 and 1899.

The Leonid Meteors.—Although no remarkable shower has been reported as seen anywhere this year, it is evident that the swarm of Leonids has not all been diverted from its former course far enough to miss the Earth. Watch was kept for the meteors by the astronomy class at Carleton College, Northfield, Minn., on the nights of Nov. 13, 14 and 15 from midnight to morning, with the result that about 30 Leonids were seen on the 13th and on the 14th. The night of the 15th was cloudy except from 12:30 to 13:30 when the portion of the sky near Leo was partly clear. In that interval only one meteor was seen that being a fine Leonid close to the radiant.



METEORS CHARTED NOV. 13, 1900, 12^h TO 18^h CENTRAL STANDARD TIME AT GOODSELL OSBERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.

The observers being most of them without experience, the radiant indicated is spread over a pretty wide area, but the center is about two degrees southwest from ζ Leonis. As many meteors were seen from other radiants, as from Leo, there being quite a large number from the region of Gemini.



METEORS CHARTED NOV. 14, 1900, 12^h^ TO 18^h^ CENTRAL STANDARD TIME AT GOODSELL OBSERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.

The accompanying charts show the trails platted by about half of the members of the class, duplicates being excluded where it was possible to identify them.

Leonids Observed at Park College, Parkville, Mo.—Professor A. M. Mattoon, director of Scott Observatory, reports observations of the Leonids made on the mornings of the Nov. 14 and 15. On the morning of Nov. 16 it was cloudy at Parkville from midnight till morning. The morning of the 15th was not satisfactory, on account of passing clouds which continued until 5 o'clock C. S. T. at which time it became perfectly clear.

But few meteors were seen until about 10 minutes after 4 o'clock A. M. From that time until 5:45, 42 meteors were seen and recorded; all but 7 were Leonids.

On Thursday morning (16th) only 8 meteors (due to prevalence of clouds possibly) were seen before 5 o'clock; 22 were counted in the next fifty minutes, all but 3 being Leonids. Observations as compared with those of last year were very unsatisfactory.

Omissions.—Credit should be given for the tables on pages 558 and 559 to *Astronomische Nachrichten* Nos. 3669 and 3670, and for the ephemeris of Eros on page 560 to Bulletin No. 5 of the *Conference Astrophotographic International.*

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All correspondence and all remittances should be sent to

Wm. W. Payne,
Northfield, Minn., U. S. A.

GENERAL INDEX TO VOLUME VIII.