TELESCOPIC ASTRONOMY.

POPULAR TELESCOPIC ASTRONOMY

A. FOWLER, A.R.C.S.

A. J. Willson
1897.
£1-50
out of print.

METHOD OF OBSERVING THE SUN.

POPULAR TELESCOPIC ASTRONOMY

HOW TO MAKE A 2-INCH TELESCOPE AND WHAT TO SEE WITH IT.

BY

A. FOWLER, A.R.C.S., F.R.A.S.,

Demonstrator of Astronomy, Royal College of Science, London.

ILLUSTRATED.

LONDON:
GEORGE PHILIP & SON, 32 FLEET STREET, E.C.
LIVERPOOL: 45 TO 51 SOUTH CASTLE STREET.
1896.

PREFACE.

The aim of this little book is to show how an astronomical telescope may be brought within the reach of those who have not the means or inclination to provide themselves with a highly finished instrument, and to indicate briefly how the possessor of such a telescope, or of a telescope of equal power, can obtain the maximum amount of instruction and recreation by its use. A telescope of 2 inches aperture will be found quite capable of revealing many of the larger beauties of the celestial scenery, and the observer will soon realise that "an ounce of practice is worth a pound of theory."

The method of constructing the telescope which is followed is similar to that described in the book of *Demonstrations and Practical Work in Astronomical Physics*,* and adopted with great success by the students who attend Professor Norman Lockyer's courses in Astronomical Physics at South Kensington. The selection of objects for observation is based almost entirely on my own experience in teaching the use of both large and small instruments, but I am indebted

* Eyre & Spottiswoode, price 1s.

to Webb's *Celestial Objects for Common Telescopes* for much valuable information.

For the benefit of those making their first acquaintance with the outdoor study of astronomy, it has been thought advisable to include a chapter on the naming and identification of the stars, but the maps of the stars are not intended to be more complete than is necessary to sufficiently indicate the whereabouts of the objects to which attention is directed.

Finally, I may say that I have chiefly endeavoured to put the beginner in the right path for seeing as much as possible for himself, and making correct deductions from his observations.

I have to thank Mr. C. P. Butler for several valuable suggestions, and assistance in reading proof sheets.

A. FOWLER.

London,
October, 1895.

CONTENTS.

LIST OF ILLUSTRATIONS.

POPULAR TELESCOPIC ASTRONOMY.

CHAPTER I.

HOW TO MAKE A TELESCOPE.

Optical parts of a telescope.—The essential parts of a refracting telescope are—(1) a lens to form an image of a distant object, and (2) a lens, or combination of lenses, with which to magnify this image. Technically, the first lens is called the object-glass, objective, or O.G., while the second constitutes the eyepiece.

As the images formed by a simple lens are surrounded by coloured fringes, the object-glass employed in a telescope is a compound one, consisting of a double convex crown-glass lens and a concavo-convex, or plano-convex lens of flint glass. In this combination, the curvatures of the lenses and the optical properties of the two kinds of glass are such that the colouring effects of one are as nearly as possible neutralised by those of the other. Such a lens is said to be *achromatic.*

For a limited number of purposes, an ordinary double convex lens serves for the eyepiece of an astronomical telescope, but more perfect eyepieces are obtained by a combination of lenses. These are made nearly achromatic, and at the same time to give a large field of view by using lenses of the same kind of glass of a certain ratio of focal lengths,* and placed at the proper distance apart.

The following lenses, which are easily procured, are recommended for the construction of a small astronomical telescope :—

For the O.G.—A 2½-inch achromatic lens of 30 inches focal length. This is to be had in various qualities, but even the cheapest will serve the beginner's purpose ; although, of course, better results are obtained with the lenses of better quality.

For the eyepiece.—A lens 1 inch in diameter and 3 inches focal length. A lens 1 inch in diameter and 1 inch focal length.

For an additional eyepiece.—A lens about ½ inch diameter, ½ inch focal length. A lens 1 inch diameter and 1½ inches focal length.

These lenses are to be mounted in their proper positions with respect to each other, and provision made for varying the distance between the O.G. and eyepiece, in order to give the adjustment for focus. The possible methods of doing this are almost infinite, so that the method here indicated need not be followed absolutely.

Materials required.—Besides the lenses, the following will be required for making a telescope according to the instructions given :—

A tube of papier-mache or zinc, 27 inches long, 2¼ internal diameter.

A wooden cylinder (No. 1) 12 inches long, a very little larger in diameter than O.G. (say $\frac{1}{16}$ in.).

" " (No. 2) 6 " " a trifle larger in diameter than eye lenses.

" " (No. 3) 6 " " ⅛th of an inch larger in diameter than eye lens.

Several sheets of brown paper or cartridge paper.

Thick cardboard sufficient to make about half-a-dozen discs 3½ inches in diameter.

Paste or glue.

Indian ink or stencil ink.

Ready-made tubes, as well as the wooden cylinders and lenses, can be obtained at a very reasonable rate from the Publishers.†

* The focal length of a lens may be readily determined by measuring the distance of the lens from a piece of paper on which it produces a distinct image of the sun, or other distant object.

† Price list at end of book.

The telescope tube.—The main tube of the instrument must be very rigid, and it should be about 27 inches long for an O.G. of 30 inches focus. It is probably cheaper to purchase a tube ready made if only a single one be required ; but where several are wanted, they may be made by rolling brown paper with glue on a long cylinder of mahogany, or on a brass tube, whichever is most accessible. The internal diameter of the tube should be about an eighth of an inch greater than the diameter of the O.G., which may not be *exactly* 2½ inches. The thickness of the tube, if made of paper, should be nearly a quarter of an inch.

Tubes made of sheet zinc also answer the purpose very well.

The cell for the object-glass.—The object of this part of the instrument is to support the principal lens in its place at the end of the telescope tube. On the wooden cylinder No. 1, roll a paper tube to such a thickness that it fits nicely inside the main tube ; and if a deal cylinder be used, rub it with French chalk to facilitate the removal of the tube. In rolling the tube, give the paper a complete turn on the cylinder before applying the glue or paste, and press each layer as firmly as possible. It is a good plan to remove the tube from the cylinder before it is quite dry.

Trim the ends of the tube and cut it in two pieces, each of which will be about six inches long. Calling these A and B respectively, divide B into two halves, and cut out sufficient longitudinally to enable them to fit nicely inside A* when patched up again, and put the object-glass between them (*see* Fig. 2). A little extra time spent in making the O.G. as nearly as possible at right angles to the length of the tube will be well laid out.

* This method involves the least expense, but the same result may be arrived at by rolling the internal tubes on another wooden cylinder of smaller diameter.

As an adornment to this end of the instrument, a flange consisting of one or two thicknesses of stout card may be attached to the object-glass cell.

The eyepiece.—In the Huyghenian or negative eyepiece, the eye lens—that is, the lens which comes close to the eye—has a focal length one-third that of the "field" lens, while the distance between them is half the sum of the focal lengths: thus, for our first eyepiece the lenses should be two inches apart; for the extra eyepiece, with the lenses referred to, the distance should be one inch, and so on.

Roll a paper tube on cylinder No. 2 until the outside diameter is equal to that of cylinder No. 3; cut off a piece $2\frac{1}{2}$ inches long (*a*, Fig. 1), and, as in the case of the O.G. cell, slit the remainder, and cut out enough to make it slide inside the uncut piece. From this inner tube, cut two pieces about $\frac{15}{16}$ths of an inch long (*b* and *c*), and insert them in *a* with a diaphragm *d* between them, this being made of

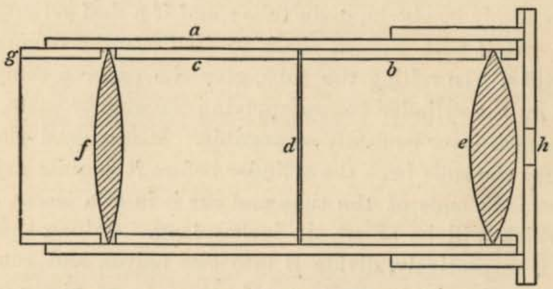


Fig. 1.—Details of the Eyepiece (full size).

thin card or sheet brass, and having a clean cut hole in the centre about half an inch diameter. Blacken the inside with indian ink or stencil ink, and when dry, fix the eye lens *e* in its place by means of a ring, about an eighth of an inch deep, cut from the remainder of the small tube; this may be glued. Similarly, support the field lens *f* in its place by a piece of tube *g* half an inch long, only in this case do not glue it; it should be long enough to slightly project beyond the end of the outer tube, to facilitate its removal.

It now remains to place an eyehole centrally over the eye lens, and close to it. This may either be a simple disc of cardboard with a central hole about $\frac{3}{16}$ths of an inch in diameter, or it may be made in the form of a cap, which may be removed at any time it is necessary to clean the lens. It is shown as a cap, *h*, in Fig. 1.

If the eyehole be not central, it will be at once detected by a darkening at one edge of the field on looking through the eyepiece.

The general construction of the extra eyepiece will be similar to that of the one described; it will only require a slight modification in consequence of the smaller diameter of the eye lens. As already stated, the lenses must be placed an inch apart, and the diaphragm should have an aperture of about a quarter of an inch.

The cost of the lenses for the eyepieces increases rapidly as the focal length diminishes.

Draw-tube and adapter.—The object of this part is to connect the eyepiece with the telescope tube, and to provide for adjusting its distance from the object-glass.

On the cylinder No. 1 roll another tube of such a thickness that it will slide nicely inside the principal tube (*D*, Fig. 2), and a tube (*A*) on cylinder No. 3 nearly $\frac{1}{8}$th inch thick and six inches long. Fix the latter very firmly to *D* by means of flanges F_2 and F_3, glued in position as shown in Fig. 2, taking care to make the axis of the smaller tube parallel to that of the larger. The draw tube should be about 10 inches long.

The completed instrument.—Finally, after being blackened internally, the various parts may be put together as in Fig. 2, showing a section of the instrument. It may

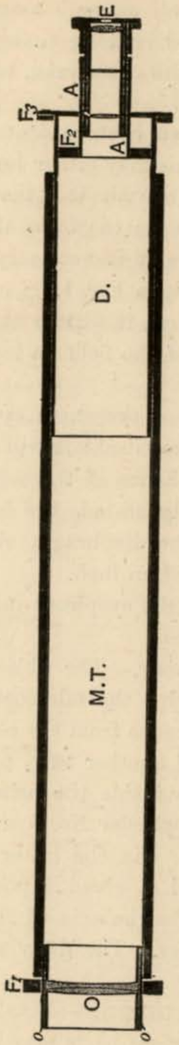


Fig. 2.—Section of Telescope.

O . . . Object glass.
E . . . Eyepiece.
o . . . Object-glass cell.
F1 . . . Flange for O.G. cell.

M.T. . . Main tube of telescope.
D. . . . Draw tube.
A . . . Adapter for eyepiece.
F_2, F_3 . . Flanges fixing adapter to draw tube.

possibly be found necessary to reduce the thickness of some of the tubes with sand-paper, or to increase the diameters of others by rolling thin pieces of paper over them, according as they are found to fit too stiffly or too easily.

All the inner parts of the tubes between the lenses should be dead-blacked with Indian ink or stencil ink, to prevent internal reflections. If readily obtainable, stencil ink is preferable for this purpose.

The outside appearance of the instrument may be improved by coating with shellac varnish, mixed with lamp black or vegetable black; or it may be painted with enamel, or embellished according to fancy.

The telescope stand.—A stand of some kind for supporting the instrument is almost indispensable, more especially when high powers are employed. Provision must be made for two movements of the telescope, a vertical and a horizontal one, so that it may be pointed in any desired direction. This result may be arrived at in various ways, two of which are here described.

A simple arrangement may be made for attaching to a window sash, the top of a fence, or any other object which comes to hand. If the services of a wood-turner be not obtainable, the support may be made in the way indicated in Fig. 3, provided some fairly hard wood be used. *A* is about 5 in. × 4 in., *B* 4 × 1½, *C* 6 × 1½, *D* 4½ × 1½ × 1½; *E* consists of two pieces, each 8 × 2, screwed together at right angles; the wood throughout, except for *D*, should be about half an inch thick. *C* is fixed upright on *B*; *D*, when cut out so as to admit the upper part of *C*, is fixed firmly to *E*. *C* and *D* are connected by a thumb-screw passing through them, and allowing *D* to turn on it when not screwed tight; the screw should be about 1⅝ ins. in length, working in a nut at its extreme end. *B* and *A* are similarly connected with a shorter thumb-screw and nut which will admit of adjustment right and left. *A* may be attached by screws or by a bracket to any convenient object, and the telescope may be held in its place on E by two small straps.

Fig. 4 shows this arrangement attached to a fence post, and if well made, it is certainly satisfactory. When the screws are freed the instrument can readily be moved about, and when pointed to the desired object they can be screwed up, so that the telescope will not slip out of its position; but they must not be screwed up so much as to prevent the small continuous movements required for keeping the object in view. Of course, a single fence will be insufficient if the observer has not right-of-way on both sides of it; but this difficulty can readily be overcome by fixing a post in the most suitable place, or a tripod stand may replace it if firm enough.

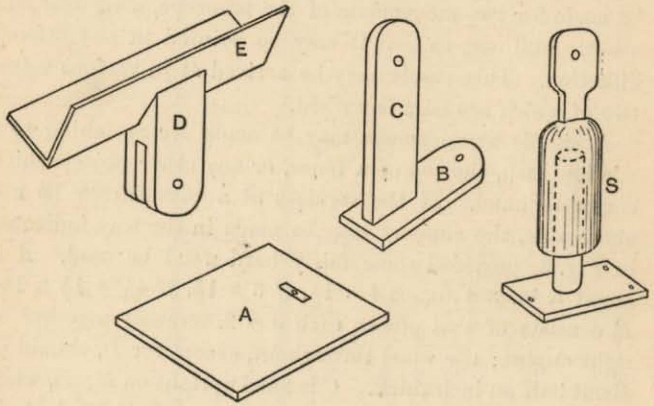


Fig. 3.—Parts of a Simple Telescope Support.

For a turned wood support, D and E remain as before; but the lower part of C is turned and hollowed out to fit nicely on a vertical cylindrical support, which may be attached as desired either to a tripod stand or post; this is

shown at S in Fig. 3, and again on a tripod stand in the frontispiece.

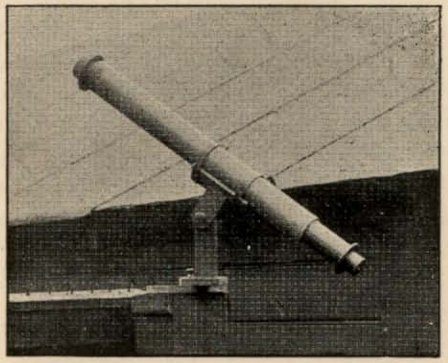


Fig. 4.—A Simple Telescope Support.

The inversion of the image.—On looking through the completed instrument at any terrestrial object, it will at once be seen that the image appears upside down. In ordinary day telescopes this inversion is corrected by inserting additional lenses between the object-glass and the eye-piece; but since this involves a loss of light by absorption, and by reflection from the surfaces of the extra lenses, it would be a disadvantage in an astronomical telescope, one of the chief functions of which is to collect as much light as possible. Hence, astronomers are content to see things upside down, and indeed, there is no objection to it, so long as it is borne in mind.

Although this is not a text-book on optics, a few words as to the action of the lenses may not be out of place, as the cause of the inversion of the image seems not a little puzzling to those not versed in optical matters.

First, then, let it be understood that if we have a lens, L (Fig. 5a), a beam of parallel rays impinging upon it in the same direction as the axis of the lens will converge to the point *F*, which is called the principal focus; and, similarly, rays diverging from a point *F* will emerge from the lens as a parallel beam. Whether *F* be on one side or other of the lens is immaterial; but if the rays be not parallel, the point *F* will be nearer to or farther from the lens, according as the rays are converging or diverging. The distance of *F* from the lens for parallel rays, that is, rays from very distant objects, is called the focal length of the lens, and this distance depends upon the curvatures of the two surfaces and the optical properties of the glass of which the lens is made.

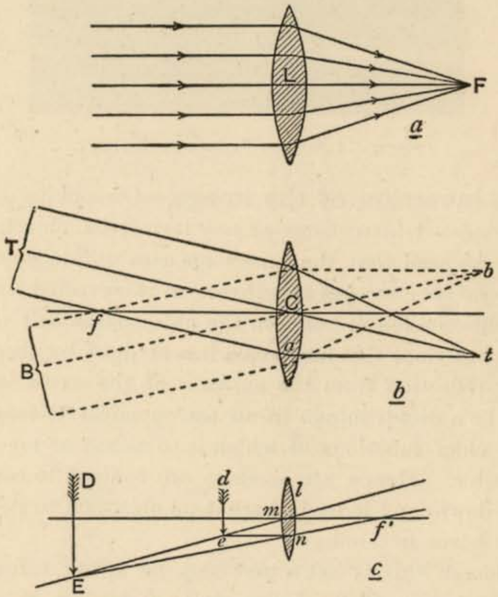


Fig. 5.—Showing the action of Telescope Lenses.

Next, if we have a parallel beam, *T* (Fig. 5*b*), not in the same direction as the axis of the lens, they will still converge to a point, but this point will not be in the axis of

the lens. If we neglect the thickness of the glass, as is usual in elementary optics, the ray *TC*, passing through the centre, will not be deviated; a ray *Tf*, passing through the focus *f* of the lens, will emerge parallel to the axis along *a t*, for the reason stated in the previous case; and all the parallel rays of the system will converge to this point *t*. A similar construction will at once show that another parallel system of rays, *B*, will be brought to a focus at *b*. If, then, we imagine the rays *T* to be coming from the top of the moon, and *B* from the bottom, it is evident that the image *b t* must be inverted. The whole image is, of course, built up by an infinite number of such parallel beams, proceeding from the various points on the object observed.

If we now for a moment regard the eyepiece as a simple lens, *l* (Fig. 5*c*), with its principal focus at f^1, its action on an object, or on the image formed by the O.G., can be determined by similar constructions. Thus, if we take an object or image represented by *d e*, the ray *e m* passing through the centre will emerge undeviated, and the eye will see it in the direction *m e;* a ray *e n* parallel to the axis will, as before, pass through the point f^1 after emergence, and the eye will see it in the direction of f^1 *n*. In this way it can be shewn that the whole system of rays reaching the eye from *e*, after passing through the lens, will appear to converge to the point *E*, *on the same side of the axis* as *e*. Similarly, the magnified image of *d* will appear at *D*.

In this way, then, it is shown that the image formed by the object-glass is inverted, and that the eyepiece does not re-invert it.

The field lens, in the case of the compound eyepiece which has been described, falls inside the focus of the object-glass, and its effect is to bring the rays to a focus at a point within the principal focus, but it will be seen at once that it is incapable of reinverting the image.

CHAPTER II.

A FEW HINTS.

Squaring the object-glass.—Before proceeding to examine the various objects of interest, the telescope should first be tested, in order to determine if the best possible results will be obtained from the lenses employed. The definition is most seriously affected if the object-glass be not properly "squared on"; that is, if it is not at right-angles to the axis of the telescope. To see if this be correctly placed, direct the telescope to a bright star, and observe it out of focus. If the O.G. be square, an evenly illuminated circle of light will be observed, and if it show any signs of ellipticity it should be corrected before proceeding further. The observer may convince himself of the importance of this by purposely putting the object-glass considerably out of square.

If the object-glass be too tightly fitted in its place, the images of the stars will appear spiky, and care must be taken to guard against this defect.

Magnifying power.—If the focal length of the object-glass be divided by the focal length of the eyepiece, or the equivalent focus of a compound eyepiece, the quotient gives the magnifying power of the telescope. For the form of eyepiece which has been described, the equivalent focal length is twice the product of the focal lengths of the eye lens and field lens divided by their sum. Thus, for the first eyepiece, the equivalent focal length will be—

$$\frac{2 \times 3 \times 1}{3 + 1} = 1\tfrac{1}{2} \text{ inches.}$$

and for the second—

$$= \frac{2 \times 1\frac{1}{2} \times \frac{1}{2}}{1\frac{1}{2} + \frac{1}{2}} = \tfrac{3}{4} \text{ inch.}$$

Then, if the focal length of the objective be 30 inches, the magnifying power with the first eyepiece will be 20, and with the second 40. In general, increase of focal length of O.G., or reduction of focal length of eyepiece, increases the magnifying power.

For many purposes, especially in the examination of double stars or a planet, a simple lens answers very well as an eyepiece, so long as the object is kept pretty near the centre of the field. Thus, if in the first eyepiece the field lens be removed, the remaining lens will give a magnifying power of 30, its focal length being an inch, while with the eye lens of the second eyepiece the magnifying power will be 60 times. By this simple plan, the observer has at hand a range of powers from 20 to 60 if he has provided himself with both the eyepieces described. In the sequel, these powers will be simply referred to as 20, 30, 40, and 60, the second and fourth meaning that the field lens alone is employed.

The cheap achromatic object-glasses perform satisfactorily on sun spots, lunar craters, the planets, and double stars, with powers up to 60, but powers as high as 100 or 120 may be occasionally employed if the object-glass be a very good one. For many observations, however, the power of 20 is most effective. The lowest power which gives satisfactory results will be indicated for each of the objects to be observed.

The beginner is apt to under-estimate the magnification when observing such an object as the moon or a planet, but if, while observing with one eye, he keeps the other open, he will see the image apparently projected on the sky, and the true amplification will then be evident. A power of 60 for instance, will show Jupiter in this way to be about equal to the apparent diameter of the moon as seen with the unaided eye.

Some 2-inch objectives have a focal length of 40 inches, and for these, with the same eyepieces, the magnifying powers will be each increased by one-third. This gain, however, is accompanied by a reduction of the field of view, and, on the whole, the 30-inch lenses are perhaps to be preferred.

The field of view.—The angular diameter of the field of view may be roughly estimated by observing the moon, which is about half a degree in diameter. Or, the time required by a star nearly due south, and about 40° above the horizon (in England), to pass across the field may be noted, and the number of seconds divided by four will give the number of minutes of arc corresponding to the diameter, since a star so situated traverses 360° on a great circle of the celestial sphere in 24 hours.

When any particular object is under examination, as in the case of a lunar crater, it is important that it should be brought to the centre of the field of view, where the definition is best.

Focussing.—No object will be seen at its best unless sufficient care be taken with regard to the focus, especially when the higher magnifying powers are employed. It is best to move the eyepiece by means of the draw tube both inside and outside of the true focus, as it is only in this way that the proper place for it can be found. If only moved on one side of the focus, the eye is apt to strain itself, and consequently does not perform its functions under the best conditions. The great variation in the focus for different observers is surprising.

Observing weather.—Experience is the best guide as to the kind of sky adapted for observations. Fogs or haze, if not too thick, are by no means detrimental for observations of the sun, moon, and planets, though obviously unfavourable for such things as comets and nebulæ. Excellent views of the objects named are frequently obtained through a slight fog or haze.

It is commonly imagined that clear frosty nights, when the stars are sparkling, are especially good for astronomical purposes, but this is by no means the case for observations of stars, as the images are often very unsteady. This, however, has far less effect on small than large telescopes, and such nights are the best for observing nebulæ.

Estimation of angular distances.—In defining the positions of planets or other heavenly bodies, it is sometimes convenient to state that they are so many degrees or minutes from well-known stars which are recognised without difficulty. It is therefore worth while bearing in mind that the sun and moon are each slightly over half a degree in diameter.

The three stars which form the belt of Orion (*see* Map 2), which are sometimes known as the Yardstick, may be also employed for the same purpose, and thus be made to justify the popular designation. The angular distance between the two extreme stars is about three degrees. Perhaps the two stars in the Plough, which point nearly to the Pole star (Fig. 6), are even better adapted for this purpose, as they can be seen all the year round ; the distance between these is about 5 degrees.

Works of reference.—Anyone possessing a telescope, and wishing to use it, will find an almanac almost indispensable. There is none better for general purposes than the edition of *Whitaker's* almanac which is published at a shilling. For a beginner this is handier than the *Nautical Almanac*, as it tells him exactly what he wants to know, without burdening him with data which are chiefly of use to the professional astronomer. The star maps included in this little book are intended to be little more than an introduction to the constellations, though it is hoped that they are sufficiently detailed to indicate the places of most of the objects to which reference will be made. If it be desired to go beyond these, many excellent atlases are available. Among the smaller ones, the "New Star Atlas," by the late R. A. Proctor,* is one of the most useful. "An Atlas of Astronomy,"† by Sir Robert Ball, will furnish the student with excellent maps of the moon and stars, and much valuable information as to the heavenly bodies.

Working lists.—The systematic astronomer goes to his observatory on a clear evening, and a reference to his "working list" removes any doubt as to what he shall do with his instrument. A list carefully prepared beforehand indicates the objects to be examined in order to advance in any particular line of investigation, and it is only by such preparation that so much valuable work can be accomplished in the few fine hours that we get for observation in this country.

Even a beginner, with his modest 2-inch telescope, will find it an excellent plan, and a great saving of time, to imitate the more advanced astronomer, and prepare for himself a working list. The objects included on such a list would, of course, vary according to the magnifying powers of the instrument, and more especially according to the time of the year. Sufficient data are given in the chapters which follow, as to the times of visibility of the various objects visible in a 2-inch telescope, to enable the observer to make such lists. As an example, such a list as the following might be prepared for observations in February, with an instrument having only an eyepiece magnifying 20 times, or 30 times when the field lens is removed :—

* Longmans & Co., price 5s. † G. Philip & Son, price 15s.

WORKING LIST FOR FEBRUARY.

Double Stars—	γ Arietis.	ζ Geminorum.
	λ „	11 Monocerotis.
	ι Cancri.	δ Orionis.
	δ Cephei.	ζ Ursæ Majoris.
Star Clusters—	Pleiades.	Double Cluster in Perseus.
	Præsepe.	M 34 Persei.
	M 14 Canis Majoris.	M 35 Geminorum.
Nebulæ—	Great Nebula in Orion.	
	„ „ Andromeda.	
Planets (1895)—	Venus.	
	Mars, in Aries.	
	Jupiter, in Gemini.	
Occasional Objects (1895)—	Maximum of the variable star Mira.	

CHAPTER III.

HOW TO LEARN THE NAMES OF THE STARS.

Star names.—When looking at the sky on a clear moonless evening, one might easily imagine the number of stars visible to the naked eye alone to be countless; but, as a matter of fact, the number visible in one hemisphere probably never amounts to as much as 3,000. But even if one had no more stars than these to deal with, it is evident that some system of naming and identifying them must be devised.

Since the stars preserve very nearly the same relative positions for very long periods, they have from very remote times been divided into groups called *constellations.* The names of these groups have been chiefly derived from mythological sources, and these names are still conveniently retained, although the custom of representing the various figures on the star maps is fast dying out. For a clear understanding of the use of constellations, it is only necessary to regard them as divisions of the celestial sphere corresponding to the division of the earth's surface into countries, and to look upon the name given to any particular star as the name of a town or city.

The names usually given to the constellations are in Latin, as Gemini, the Twins; Taurus, the Bull; and so on.

For the identification of the separate stars — for the brighter ones at least—the letters of the Greek alphabet are employed, usually, though not always, in the order of

brightness in each constellation. Thus, α Tauri is the brightest star in Taurus, and β is the next in order of brightness. The Greek alphabet is as follows, in so far as it concerns stellar nomenclature:—

α Alpha.	ι Iota.	ρ Rho.
β Beta.	κ Kappa.	σ Sigma.
γ Gamma.	λ Lambda.	τ Tau.
δ Delta.	μ Mu.	υ Upsilon.
ϵ Epsilon.	ν Nu.	ϕ Phi.
ζ Zeta.	ξ Xi.	χ Chi.
η Eta.	o Omicron.	ψ Psi.
θ, ϑ Theta.	π Pi.	ω Omega.

From the examples quoted below, it will be seen that the name of a star is formed from the genitive case of the constellation name.

Many of the brighter stars have proper names in addition to those derived from the constellation in which they fall; of these, the ones most commonly employed are as follows:—

α Aquilæ—Altair.	α Lyræ—Vega.
α Aurigæ—Capella.	α Orionis—Betelgeux.
α Boötis—Arcturus.	β " —Rigel.
α Canum Venaticorum—Cor Caroli.	γ " —Bellatrix.
α Canis Majoris—Sirius.	β Persei—Algol.
α " Minoris—Procyon.	α Piscis Australis—Fomalhaut.
o Ceti—Mira.	α Scorpionis—Antares.
α Geminorum—Castor.	α Tauri—Aldebaran.
β " —Pollux.	ζ Ursæ Majoris—Mizar.
α Hydræ—Cor Hydræ.	α Ursæ Minoris—Polaris.
α Leonis—Regulus.	α Virginis—Spica.

For the designation of many less conspicuous stars, the numbers assigned to them by Flamsteed are generally adopted; *e.g.* 70 Ophiuchi, 11 Monocerotis.

The thousands of stars not included in these nomenclatures are identified by a number in some general catalogue, such as the great catalogue of Argelander; these, however, will scarcely concern individually the possessor of a telescope of only two inches aperture.

In all cases, a star is sufficiently defined by its Right Ascension and Declination—measurements which are to the stars what longitude and latitude are to terrestrial places. Right Ascension, or R.A., is reckoned in hours, minutes, and seconds of time, while the Declinations are reckoned in degrees north or south of the celestial equator.

Star seasons.—The observer will soon find that the apparent positions of the constellations in the heavens depend upon the time of observation. Thus at one time, in this country, a constellation may appear low down near the northern horizon; six hours later it will appear in the north-east, in another six hours it will be nearly overhead. Some of the constellations—those not more than 50 degrees from the Pole—never set in the latitude of London, and so may be seen all the year round. They must, however, be looked for in a different part of the sky at different times of the year, if one looks for them at about the same time at night. During this apparent change of position, their distances from the Pole remain the same. Some stars will be seen to rise towards the east, and set towards the west, exactly as the sun and moon do, so that at any one time of night only certain groups of stars will be visible.

Again, in consequence of the fact that the earth travels round the sun once a year, the part of the celestial sphere which we see in the evening—being that part we see looking away from the sun—will vary throughout the year. As the earth travels round the sun in about 365 days, that is, nearly a degree a day, the stars will be seen to rise nearly 4 minutes earlier on each succeeding day, as reckoned by mean time clocks, which, of course, are regulated by the apparent movements of the sun (the earth turns 360° in 24

hours, *i.e.*, one degree in 4 minutes). In a month the accumulations of these intervals of 4 minutes amount to about 2 hours, so that the stars which are due south at 10 o'clock at the beginning of a month will be due south about 8 o'clock at the end of the month. The dates and times on the maps at the end of this chapter, showing the constellations which appear on the meridian at 8, 10, and 12 P.M. at the beginning of each month, are arrived at in this way, and it is hoped that they will be of assistance in identifying the stars visible any particular evening. The celestial globe also furnishes a ready means of determining the situation of any object in the sky at any hour of any day in the year, and the Planisphere* does this almost equally well at a very much smaller cost. Such tables as those given in "Lockyer's Elementary Lessons in Astronomy," Art. 352, serve a similar purpose.

Star maps.—The positions of the stars with respect to each other can only be precisely represented on a spherical surface, as on a celestial globe. Nevertheless, they may be represented with sufficient accuracy on maps by adopting some sort of projection, similar to those commonly employed in the construction of maps of the world, and so long as the area covered by each map is not too great, there is but little distortion. If, however, one attempts to show all the stars in one hemisphere on a single chart, the forms of the constellations towards the edges will be scarcely recognisable, and this must be remembered when using such maps. The Planisphere, for example, though admirably adapted for its special purpose, is for this reason not the best guide for learning the individual stars.

In Maps 2, 3, 4, at the end of this chapter, the defect of the projection employed is to increase the distances between the stars at the top of the maps as compared with those nearer the middle. In Map 1, the constellations near the

* Published by G. Philip & Son, price 2s.

edges are somewhat compressed, but these defects will not be found of much consequence. For the sake of simplicity, the lines indicating the Right Ascensions and Declinations have been omitted in these maps.

Since the planets change their positions with respect to the stars, it is obvious that they cannot be represented on star maps. Hence, if a bright body not on the map should be noticed, steps should be taken to identify it as a planet. The positions of the planets up to the end of 1897 will be found in Chapter VI.

How to use the maps.—Acquaintance should first be made with that portion of the constellation of Ursa Major which is variously known as the Plough, the Dipper, or Charles's Wain. This will be found in the northern sky, and consists of seven conspicuous stars, never to be forgotten when once recognised. Next, observe that a line drawn through two of these stars—the "Pointers"—to about 4 times the distance between them, nearly passes through the north Pole Star, as indicated in Fig. 6. Almost balancing the Plough, on the opposite side of the Pole Star, will be found Cassiopeiæ, the principal stars of which form a sort of W (Map 1). Proceeding in this way, by imaginary lines and estimates of distance, the other constellations will be found without much difficulty, if they happen to be above the horizon at the time of observation.

One naturally falls into the habit of connecting the stars of a constellation by imaginary lines, and those joining the stars of Maps 1—4 are only to be regarded as examples of these aids to memory.

Map 1 shows some of the stars surrounding the Pole, while 2, 3, and 4 show stars down to and below the celestial equator. Vega, Capella, and Perseus will sufficiently serve to connect Maps 2, 3, 4, respectively with Map 1, and the repetition of stars at the edges of the maps will indicate their connection with each other. It may be worth while

Fig. 6.—The Plough and the Pole Star.

to mention also that Arcturus (Map 2) lies very nearly in a continuation of the curve of stars which forms the handle of the Plough; the Great Square of Pegasus (Map 4) lies nearly on a line drawn from the Pole Star through the eastern side of Cassiopeiæ; and Leo (Map 3) lies nearly on a line from α through β Ursæ Majoris (Map 1).

In using Maps 2, 3, and 4, look for the date of observation along the bottom of the map on the first, second, or third lines according as the time may be 8, 10, or 12 P.M.; the stars on the lower part of the map will then be due south, while those towards the top will be almost overhead.

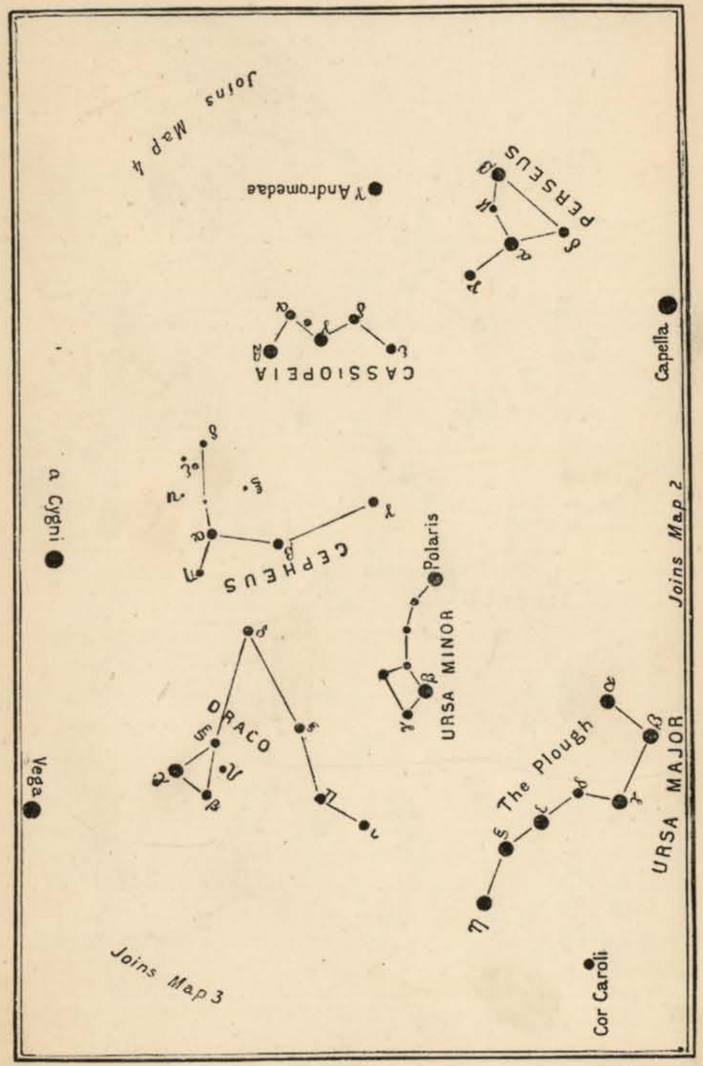
For the other hours of the evening the positions will readily be found by interpolation, one hour being equivalent to a shift of half a month, as already explained (p. 21).

In the case of the map of the north polar stars, it must be borne in mind that the Pole Star remains in very nearly the same place at all times, while those $38\frac{1}{2}°$ from it in the latitude of London (the latitude subtracted from 90°) will in turn pass through the point overhead.

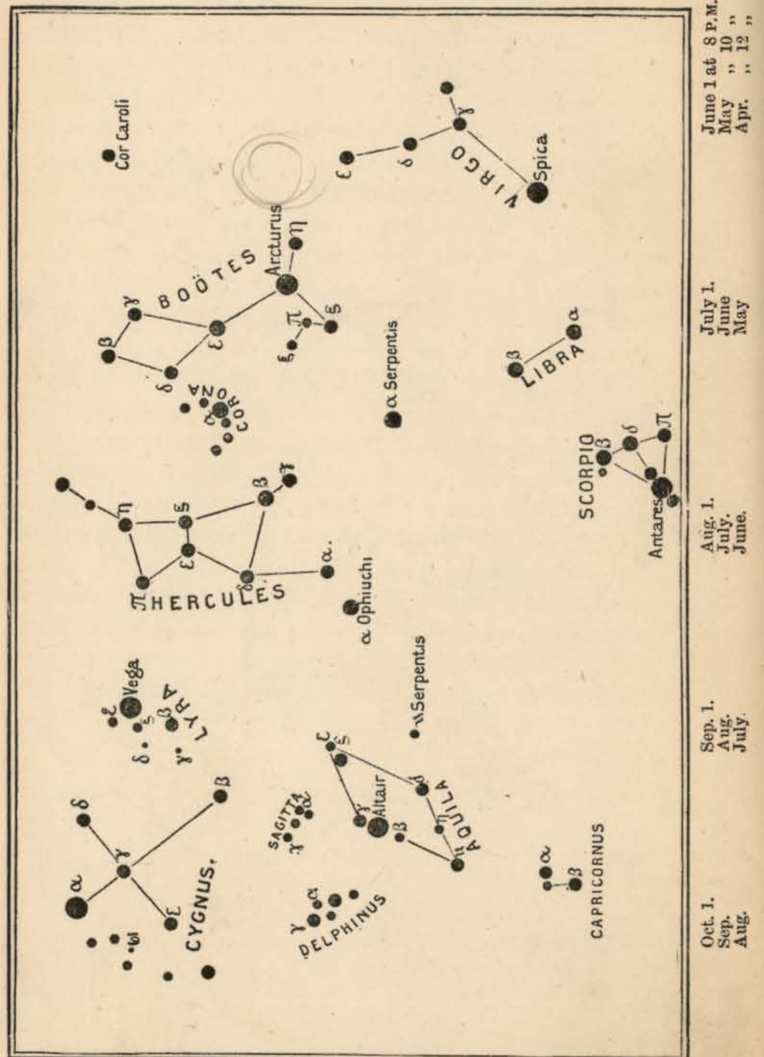
With a knowledge of the principal stars, no difficulty should be experienced in directing the telescope to any desired object. If, for example, a certain star cluster is said to be 4° S. of Sirius, this distance will be mentally estimated with the aid already referred to (p. 15), and the telescope pointed accordingly, the lowest magnifying power being first employed in order to give a large field of view.

If some object not mentioned here is to be observed, as for instance, a small comet, a more complete map will probably be found necessary, unless the source of information as to position refers it to the brighter stars in its neighbourhood. If the position of such object, whatever its nature, be indicated only by its R.A. and declination, the numbers at the sides of star maps must be used in exactly the same way that those on an ordinary map would be used to find the situation of a place of given latitude and longitude.

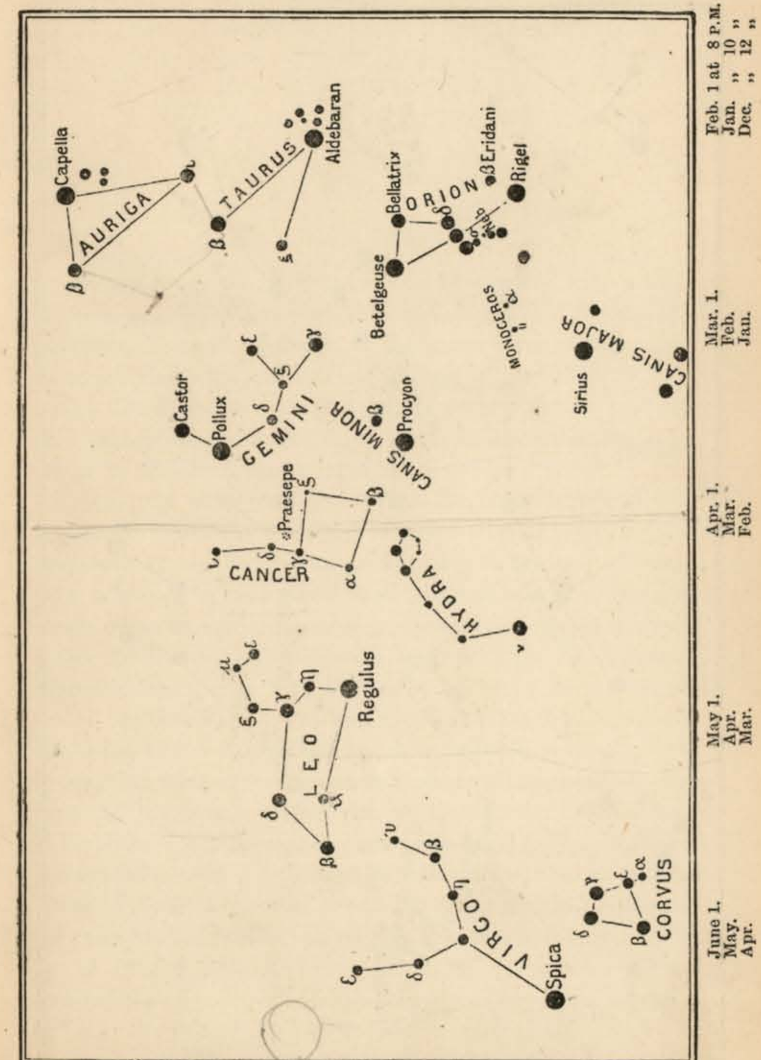
MAP 1.



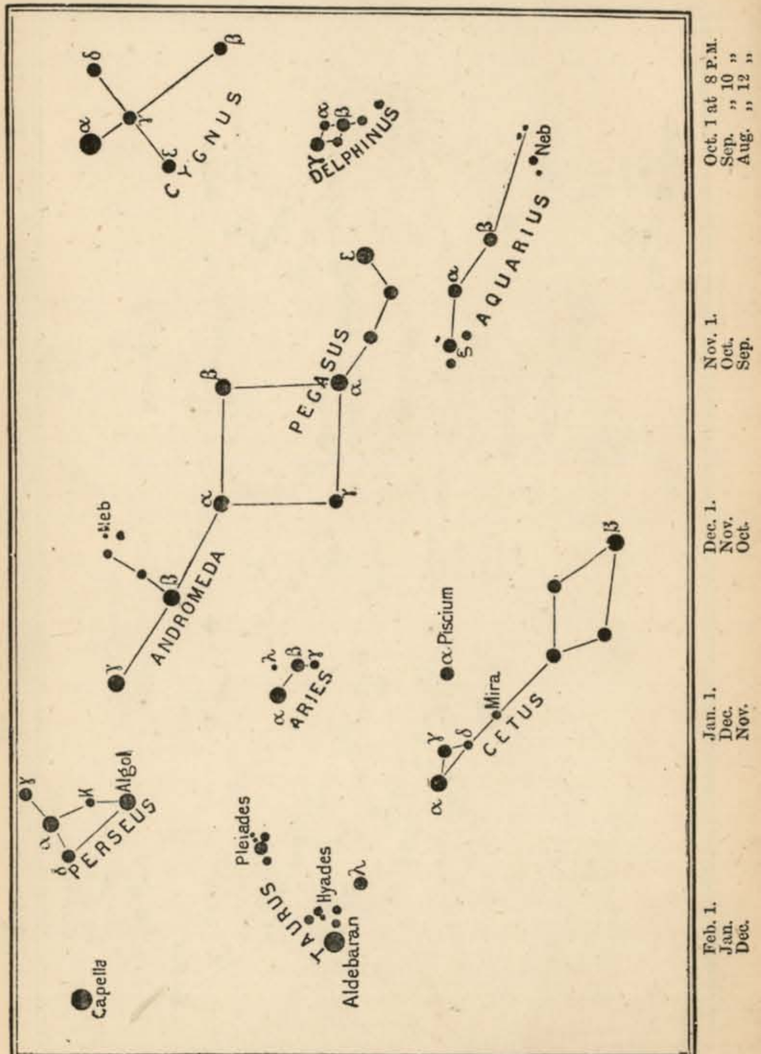
Map 2.


Cor Caroli
VIRGO
Spica
BOÖTES
Arcturus
CORONA
α Serpentis
LIBRA
SCORPIO
Antares
HERCULES
α Ophiuchi
ν Serpentis
LYRA
Vega
CYGNUS.
SAGITTA
AQUILA
Altair
DELPHINUS
CAPRICORNUS
June 1 at 8 P.M.
May „ 10 „
Apr. „ 12 „
July 1.
June
May
Aug. 1.
July.
June.
Sep. 1.
Aug.
July.
Oct. 1.
Sep.
Aug.

Map 3.


Capella
AURIGA
TAURUS
Aldebaran
ORION
Bellatrix
β Eridani
Rigel
Betelgeuse
MONOCEROS
CANIS MAJOR
Sirius
Castor
Pollux
GEMINI
CANIS MINOR
Procyon
Praesepe
CANCER
HYDRA
Regulus
LEO
VIRGO
CORVUS
Spica
Feb. 1 at 8 P.M.
Jan. „ 10 „
Dec. „ 12 „
Mar. 1.
Feb.
Jan.
Apr. 1.
Mar.
Feb.
May 1.
Apr.
Mar.
June 1.
May.
Apr.

Map 4.



CHAPTER IV.

THE SUN.

At certain times the observation of the sun with a telescope is of the greatest possible interest, and though no great additions to our knowledge of the great giver of light and heat are likely to follow from the use of our little instrument, the observer will find much satisfaction in proving for himself some of the facts which have been brought to light by the labours of others.

How to observe the sun.—It is necessary, at the outset, to warn the would-be observer that he must always take precautions to guard against injury to the eyes. When the telescope is not more than 2 inches aperture, there is little or no danger in observing the sun directly, if the eyepiece be merely covered with a dark glass of sufficient density; in winter this method is perfectly safe with so small an instrument. A small piece of plane glass should be fitted inside a little cap which is made to cover the eyepiece, and smoked with a candle flame to a blackness suitable for the brightness of the sun at the time of observation. If a piece of neutral tint or dark green glass can be obtained, so much the better; this can also be smoked to the required density, according to the conditions of observation. Special devices are adopted when larger telescopes are employed.

In general, however, observations of the sun should be made by projecting the image. The telescope being directed to the sun, a magnified image will be formed on a sheet of paper or card held some distance behind. The size of the image will depend upon the distance of the card from the eyepiece, and the position of the eyepiece necessary to focus the image must be found by trial. If the power 20 be employed, an image about 3 inches in diameter will be obtained at a distance of about 14 inches from the eyepiece.

A convenient arrangement for projecting the image is to attach a screen to the telescope by means of a light framework. The screen may be made of a thin board, to which the paper for the sketch can be attached by drawing pins; the frame should fit fairly stiffly on the *body* of the telescope, but not so that it cannot be rotated, or made to travel a short way up and down the tube. A piece of card about 12 inches square, fitted at the object-glass end of the tube, will help to screen the drawing paper from direct sunlight. Such a frame is shown in the frontispiece, but it may be made in any way which suggests itself; it is only necessary to provide for slightly changing the distance of the screen from the eyepiece, to admit of adjustment of the size of the image, and a movement of rotation for setting the paper at the proper angle. A piece of cloth or velvet should be thrown over the frame.

Sun-spots.—It is very often the case that the sun exhibits certain dark spots when examined with the telescope, and occasionally they are even large enough to be visible to the naked eye. These are the sun-spots, and if of any considerable size, it will readily be seen that the central part is much darker than the outer part, and, as a rule, distinctly outlined. The inner and darker part of the spot is the *umbra*, and the outer part is the *penumbra*. Sometimes there is a still darker part in the umbra, which is called the *nucleus* of the spot. Some of the spots are of very regular forms, appearing almost as two concentric circles; at other times they exhibit the most varied and irregular outlines, and frequently are to be seen in groups. The umbra is sometimes crossed by bright *bridges*, which are often seen to change in the course of a few hours. For examining the details of a spot, the power 60 will be found very effective on a common 2-inch telescope, when the image is viewed directly.

Some of the spots produced on the screen may be due to dirt on the lenses of the eyepiece, but the fact that these do not partake of the apparent movement of the sun will enable them to be distinguished at once. If any such should be suspected when viewing the sun directly, see if they move when the eyepiece is turned round.

When observing sun-spots, the tremendous scale of the phenomena should be borne in mind. A sun-spot appears all the more impressive to the observer if he reflects that it could swallow up the whole earth, and perhaps all the other planets in addition. The smallest spot that can be telescopically observed is some hundreds of miles across, and spots no less than 100,000 miles across have been recorded. Remembering that the sun's diameter is about 860,000 miles, a rough estimate will readily be made of the dimensions of any spot which may be observed; if near the edge, foreshortening will reduce the apparent size.

The Faculæ.—In addition to the spots, it will frequently be noticed that near the *limb*, or boundary of the sun, there are irregular patches, which are much brighter than the rest of the disc. These are called *faculæ*, and are especially brilliant in the neighbourhood of spots seen near the limb. It may be added that the limb of the sun is somewhat darker than the centre, in consequence of the absorption taking place in the sun's atmosphere.

To demonstrate the sun's rotation.—That the massive globe which forms the centre of our system is in rotation, can easily be demonstrated by means of our small instrument, and many facts regarding this rotation can be noted. A series of drawings of the sun, indicating the positions of the spots from day to day, will show that the spots change their apparent places on the disc, and if the drawings be continued long enough, the time of their passage across can be determined.

The observer will not have proceeded very far, however, before he perceives the necessity of some means of marking a "top" and "bottom" of the sun. What might be called the top at mid-day will have got away towards the right in the afternoon, so that the drawings require "orientation." The north and south points of the sun's limb are respectively the upper and lower points of the disc cut by a meridian passing through the sun's centre, that is to say, by a great circle which passes through the celestial poles; the eastern limb is that towards the east, or on the left hand as we look at the sun with the naked eye, while the western limb is on the right hand.

After finding by trial what size of disc is most convenient (say 3 inches), draw circles of this diameter on sheets of paper, and rule two diameters at right angles. Placing one of these on the screen, adjust the eyepiece and distance of the screen so that the image just fills the circle; this adjustment will be slightly different at different times of the year, in consequence of the variation in the sun's apparent diameter. As the sun is apparently in motion relatively to the telescope, its image will be in motion across the screen, and the fact that this movement is along an east and west line furnishes the means of orienting the drawings. Turn the screen round until the apparent movement, as shown by a spot, or by the sun's edge, is in the direction of one of the diameters; then the advancing edge of the image will be the western limb, and the edge which comes to the centre as the telescope is slightly raised will be the northern one.

When the sun is viewed directly through the eyepiece, the image is inverted, so that the four points will appear as in

Fig. 7*b*; when projected on a screen they will be as in Fig. 7*c*.

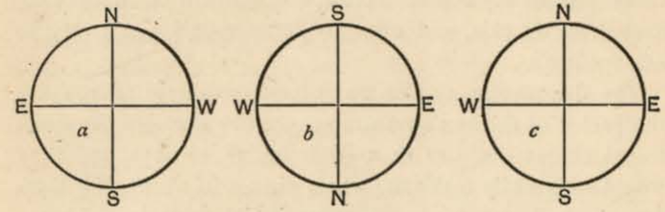


Fig. 7.—ORIENTATION OF SUN'S IMAGE.
a Direct view with naked Eye. *b* As seen in an Astronomical Telescope. *c* As projected on a Screen.

Having taken the precaution to orient the sun's image in the way indicated, mark the positions of the various spots, and afterwards sketch in the details of each, numbering or lettering them for reference.

On comparing such sketches made on successive days, it will be seen that the spots have an apparent movement across the disc from E. to W. Two sketches made on Feb. 11 and 15, 1892, are shown in Fig. 8. It will be seen that the large spot *a* was visible on both days, *b* was carried off the visible disc by the sun's rotation between the dates of the sketches, while a new group *c* was brought to our view.

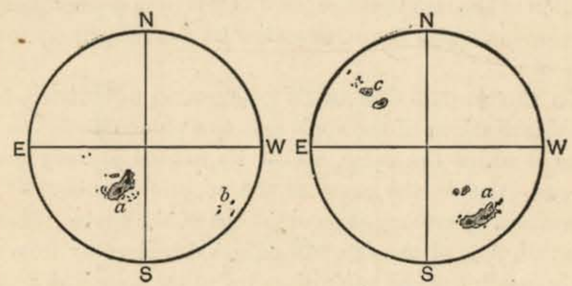


Fig. 8.—SUN-SPOTS OF FEBRUARY, 1892, ILLUSTRATING SUN'S ROTATION.

As sun-spots are evanescent formations, it must not be expected that the same spots will of necessity be seen to travel completely across the disc, but many of them last long enough to do this, and even to come round again on the eastern limb.

The drawings may also be utilised to determine roughly the period of the sun's rotation. On the average the spots travel across the disc in a little under 14 days, and they would apparently make the whole circuit in about 27¼ days. The earth, however, is travelling in its orbit in the same direction, so that the true time of the sun's rotation is less than the apparent time. Allowance being made for the earth's movement at the rate of nearly 1 degree a day, the mean rotation period is a little over 25 days; but extended observations have shown that it increases from the equator to the poles.

The inclination of the sun's axis.—Nor is this all. The spots will be found to travel in different paths across the disc, according to the time of the year in which the observations are made. In June and December they appear to traverse the disc in straight lines; in September they have curved paths, with the convex side towards the south; while in March they again have curved paths, but with the convexity towards the north. This is an obvious demonstration of the fact that the sun's axis is not perpendicular to the plane in which the earth makes its annual journey round the sun.

To mark out the sun's poles and equator.—The actual inclination of the sun's axis to a perpendicular to the plane in which the earth makes its annual journey round the sun—that is, the plane of the ecliptic—is about 6°, as determined by prolonged observations of the spots. Hence, the north pole of the sun will depart considerably from the northern point of the sun's disc during the course of a year, since the latter is referred to the perpendicular to the plane

of the equator, which is inclined 23½° to the plane of the ecliptic. Tables have been constructed which show at once the position of the N. pole with reference to the north point, and also showing the point on the north and south diameter which is crossed by the equator. The former is indicated by "position angle," and is positive when to be reckoned from N. to E., negative when reckoned towards W.; the latter is defined by the heliographic latitude of the centre of the sun's disc, *i.e.*, the latitude as reckoned from the centre of the sun itself; thus, if the latitude of the centre is northerly, the equator is a corresponding amount below the centre. There is nothing permanent enough on the sun to define a meridian from which spot-longitudes can be reckoned, so that the plan adopted is to take a certain mean period of rotation, and starting at a definite epoch, the position occupied by the imaginary "Greenwich" of the sun can be computed at any time.

The following table shows to the nearest degree the angles in question at the beginning, middle, and end of each month. For other days they may be estimated with sufficient accuracy.

Date.	Position Angle.	Heliographic Lat. of Centre.	Date.	Position Angle.	Heliographic Lat. of Centre.
Jan. 1	+ 2°	− 3°	July 1	− 3°	+ 3°
„ 16	− 6	5	„ 15	+ 4	5
Feb. 1	13	6	Aug. 1	11	6
„ 15	18	7	„ 16	17	7
Mar. 1	22	7	Sept. 1	21	7
„ 15	25	7	„ 15	24	7
Apr. 1	26	6	Oct. 1	26	7
„ 15	26	5	„ 15	26	6
May 1	24	4	Nov. 1	24	4
„ 16	21	− 2	„ 15	22	3
June 1	15	0	Dec. 1	16	+ 1
„ 15	− 10°	+ 1°	„ 15	+ 10°	− 1°

A more complete table, from which the above figures have been derived, will be found in the annual *Companion to the Observatory*.

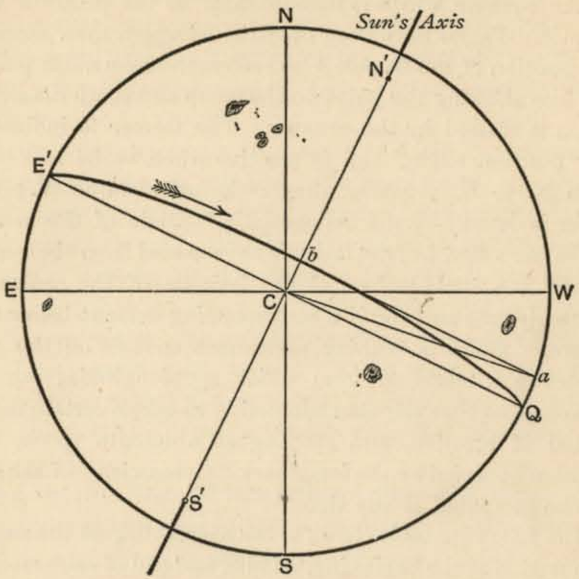


Fig. 9.—THE SUN'S AXIS AND EQUATOR IN MARCH.

Fig. 9 illustrates the use of this table in the case of a drawing made on March 25, 1892. The position angle of the axis for this date is $25\frac{1}{2}°$ W., and the heliographic latitude of the centre is $6\frac{1}{2}°$ S. The angle NCN′ is made to equal $25\frac{1}{2}°$, and E′Q is drawn at right angles to this line. *ca* is drawn at an angle of $6\frac{1}{2}°$ to the north of CQ, and *ab* is made parallel to E′Q. Then *b* is the point where the equator crosses the axis, and E′*b*Q is a semi-ellipse with *cb* as the semi-minor axis. By this construction it is evident that the centre of the disc has a latitude of $6\frac{1}{2}°$ S., as required by the table, and the sun's south pole is presented towards us as indicated in the diagram.

If it be desired to determine with some precision the latitudes and longitudes of the spots, use may be made of

Thomson's discs (see *Ball's Atlas of Astronomy*, or Journal of the *British Astronomical Association*, Vol. I., p. 75).

The sun-spot zones.—Continued observations of the sun's surface have revealed the fact that spots occur in two zones or belts, one north and one south of the equator. These extend from about 5° to 35° on each side of the sun's equator, and it is very rarely that spots occur outside these limits. This becomes quite apparent when the equator and axis are drawn in as in Fig. 9; spots which might otherwise appear to have a high latitude are seen to be comparatively near to the equator.

Periodicity of sun-spots. — Sun-spots are by no means equally numerous at all times. From observations extending over more than two centuries, it has been ascertained that the number and magnitude of the spots wax and wane in a period of about 11 years. Near a time of minimum, the disc may be quite free from spots for weeks together; while at maximum they are generally to be seen every day, large and numerous, sometimes being easily visible to the naked eye, if protected by smoked glass or a convenient London fog.

The last maximum occurred about the end of 1893, and it is probable that the number of spots will steadily diminish until a minimum is reached about the end of the present century, when they will again increase and reach another maximum about 1904.

Hence a telescope is not to be condemned if it fails to show sun-spots on every occasion that it is applied to the sun.

Eclipses of the sun.—These phenomena, when total, present us with one of the most magnificent though fleeting spectacles that can be conceived. Unfortunately, they are of extremely rare occurrence at any given place, and as it is not to be expected that our modest instrument will be taken to the ends of the earth to observe total eclipses, a passing reference suffices. It may be of interest to state, however, that there will be a total eclipse on Aug. 9, 1896, visible in Norway, Nova Zembla, Siberia, and Japan. It will not be until June 29th, 1927, that a total eclipse will be seen in this country, and then it will only last for a few seconds.

Partial eclipses of the sun, however, are of comparatively common occurrence, and on such occasions our little telescope will materially add to the interest of the phenomenon. The usual precautions being taken, the intensely black body of the moon may be watched gradually sliding across the sun's disc, perhaps eclipsing one by one the spots which lie along its path. The ruggedness of the moon's edge will be very forcibly impressed upon the observer on such occasions.

Any almanac or diary will furnish particulars of the eclipses to be seen during the year.

Thus, with a simple telescope, it is easy to demonstrate that the sun is not the immaculate body that it was once supposed to be, that it turns on an inclined axis, that the spots are not indiscriminately scattered over his disc, and that there is a grand cyclical change in the disturbances going on, as indicated by the varying amount of spotted surface. Surely our instrument would be justified if it could teach us nothing more !

CHAPTER V.

THE MOON.

An interesting study.—To the naked eye alone our satellite is a beautiful object, showing various dark patches which have given rise to the popular belief in the "man in the moon." Telescopically, these larger patches lose their prominence, but the moon remains one of the most fascinating objects in the heavens, and it is worth while to make a small telescope if only for the sake of the beautiful views of the moon which may be obtained by its aid. Notwithstanding that it is so often called a "dead world," the return of the moon to first quarter is always awaited with interest by anyone possessing a telescope.

Even a magnifying power of 20 or 30 reveals a vast amount of detail, and with powers of from 40 to 100, the construction of a great many of the lunar formations can be investigated.

The diameter of the moon is about 2,000 miles, while its distance from us is nearly 240,000 miles. Hence a magnifying power of 60 will appear to diminish the moon's distance to 4,000 miles.

The varying appearances.—As the moon is a dark body, revolving round the earth once a month, only the hemisphere which is turned towards the sun is illuminated at any one time, and according to how this hemisphere is presented to us, we see full moon, half moon, or other phases. It so happens that the moon turns on its axis in the same time that it goes round the earth, so that we always see very nearly the same face. In consequence of the "librations," however, the poles of the moon are sometimes presented to us at slightly different angles, never varying more than 7°, and there is also a displacement of about 8° E. and W. The effects of these small changes are most apparent near the edge of the disc, and indeed could hardly be detected in the middle without measurements. The uneven and rugged surface naturally appears to us very differently under the different conditions of illumination, so that the true nature of the various markings can only be ascertained by continuous observations. Though the best general views of the moon are to be obtained when it is near half, some of the features can only be observed when it is near full.

The terminator.—This is the name given to the boundary of light and darkness when the moon is not at full. Along this line the sun is rising if before full moon, and setting if after full moon ; so that the sunbeams are falling almost horizontally on the points of the moon which it cuts. Consequently, the terminator presents a very irregular appearance when viewed with the telescope ; some of the higher peaks are illuminated for some time before the valleys beneath, and thus appear as very conspicuous bright points or rings of light standing out in darkness. The relief of most of the lunar features is best observed when the terminator is not far from them.

Earth-shine.—Everyone must have noticed that soon after new moon the whole of the disc is feebly visible, giving rise to the appearance of the old moon in the new moon's arms. This is especially noticeable when a telescope is employed, and it is scarcely necessary to add, that this illumination of the "dark" part of the moon is due to the sunlight reflected by the earth on to the moon, and back again to us. At these times, owing to the fact that bright objects appear larger than dark ones of exactly the same

size, the bright crescent of the moon appears to belong to a circle of larger diameter than the darker part.

The "Seas."—The great dusky patches which are visible to the naked eye were formerly imagined to represent tracts of water, and though this is now known to be erroneous, the name "sea" (maria) is still conveniently retained. Thus we have the Mare Crisium, Mare Imbrium, &c., while along the "coast-lines" of these a certain number of bays are separately named. Among the latter, the Sinus Iridum, or Bay of Colours, is most likely to attract the attention of the beginner (*see* Fig. 10).

Craters, Ring Mountains, and Walled Plains.—The first glance at the moon with a telescope, if it be not near full, will reveal the presence of an immense number of circular or elliptical cavities, closely resembling the craters of terrestrial volcanoes as they would appear from a balloon. They vary greatly in size, and three classes are recognised. The smaller ones are classed as *Craters*, and similar but larger ones are distinguished as *Ring Mountains*. The so-called *Walled Plains*, though similar in shape to the ring mountains, are much shallower, and resemble in their interiors the floors of the "seas."

Several of the craters are as much as 50 miles in diameter, while some are more than 100, so that the scale of these remarkable features is much greater than that of their terrestrial analogues.

The larger of these formations have been named after noted astronomers and philosophers of past times, such as Archimedes, Copernicus, Kepler, &c., while many of the smaller ones take their names from more modern men of science, such as Schiaparelli, Lockyer, and Foucault.

Nearly forty of the most striking craters are represented and named in the Sketch Map of the Moon (Fig. 10), and the process of learning to recognise these on the moon itself will occupy many a pleasant half-hour. If further identifications

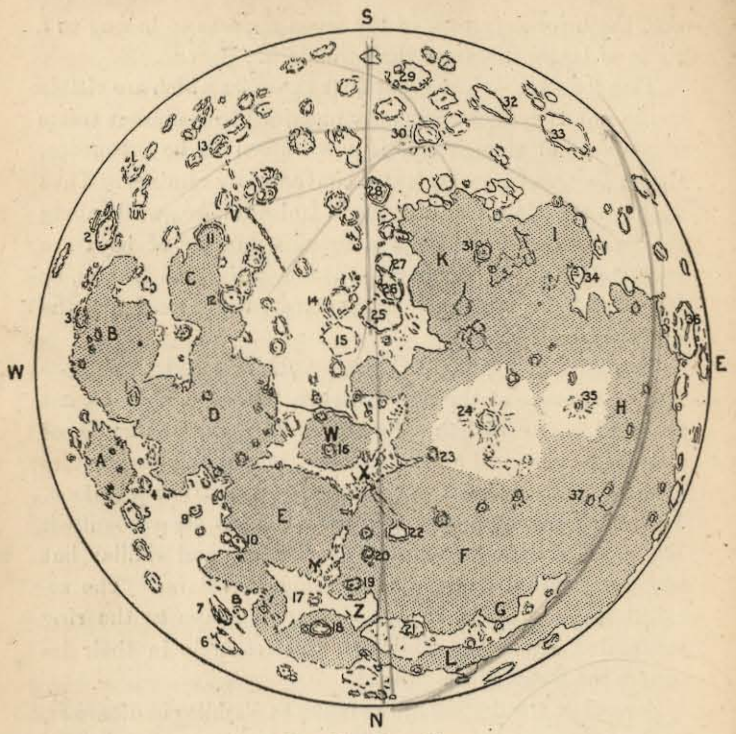


FIG. 10.—THE MOON.

1. Furnerius.	14 Albategnius.	27. Arzachel.
2. Petavius.	15. Hipparchus.	28. Walter.
3. Langrenus.	16. Manilius.	29. Clavius.
4. Macrobius.	17. Eudoxus.	30. Tycho.
5. Cleomedes.	18. Aristotle.	31. Bullialdus.
6. Endymion.	19. Cassini.	32. Schiller.
7. Altas.	20. Aristillus.	33. Schickard.
8. Hercules.	21. Plato.	34. Gassendi.
9. Römer.	22. Archimedes.	35. Kepler.
10. Posidonius.	23. Eratosthenes.	36. Grimaldi.
11. Fracastorius.	24. Copernicus.	37. Aristarchus.
12. Theophilus.	25. Ptolemy.	
13. Piccolomini.	26. Alphonsus.	

A Mare Crisium.	F Mare Imbrium.	V Altai Mountains.
B ,, Fecunditatis.	G Sinus Iridum.	W Mare Vaporum.
C ,, Nectaris.	H Oceanus Procellarum.	X Apennine Mountains.
D ,, Tranquilitatis.	I Mare Humorum.	Y Caucasus ,,
E ,, Serenitatis.	K ,, Nubium.	Z Alps ,,

are desired, reference can be made to a more complete map. Mr. Mellor's "Handy Map of the Moon,"* or Mr. Elger's new and admirable map,† will be found very serviceable. The latter has the great advantage of a larger scale. It is quite impossible to represent on so small a scale as that of our sketch map more than a fraction of the craters which can be seen with a 2-inch telescope.

Any of the larger craters will well repay minute observation with the highest power that can be brought to bear upon them, and many features of the greatest beauty and interest cannot fail to be noted. The dense black shadows cast by the higher elevations near the terminator frequently show the irregular edges which indicate the rugged character of the walls of the craters. In some craters, a point of great interest is the central peak; in others it will be the connection with smaller craters that will be specially remarked. The floors of some of the craters will be seen to be filled with shadow; in others the shadows will only extend partly across the cavity. These appearances are constantly changing, but are not less interesting on that account. A sectional drawing of a crater mountain (Fig. 11) illustrates the origin of the shadows, and the effect of changing the direction of the sun's rays upon the shadows, as seen in a plan view, will be more readily understood by varying the direction of the incident light. The perfect sharpness of the shadows is due to the absence of any appreciable lunar atmosphere.

It will be found instructive to compare the telescopic views of the craters with the drawings which are given in many of the ordinary text-books. The observer will be both delighted and surprised to find that his little telescope will reveal so many of the beauties of the lunar scenery.

The fact that the moon is a spherical body is responsible for the ellipticity of the craters seen near the edge of the

* Published by Messrs. Horne & Thornthwaite, Strand, price 2s.

† Published by G. Philip & Son, price 2s. 6d.

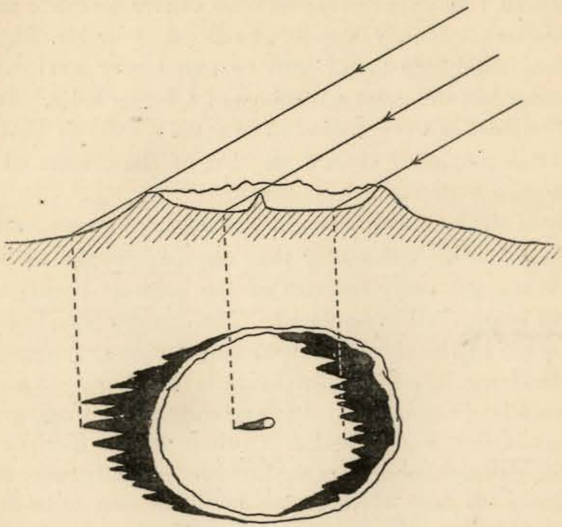


FIG. 11.—LUNAR SHADOWS.

moon, and the consequent apparent reduction in size. To give an idea of the scale of the craters, it may be added that Atlas is 55 miles across, Plato 60 miles, and Ptolemy 115 miles.

It is by no means generally agreed that the lunar craters really represent the results of volcanic action, but this is at all events a convenient working hypothesis.

Mountain Ranges.—A few mountain-ranges, resembling somewhat those with which we are familiar on the earth, are to be found on the moon. These mostly take their names from their terrestrial analogues, so that on our lunar map we find the Alps, the Apennines, Mont Blanc, and so on. Four of the more conspicuous ranges are indicated in our sketch map, and the observer will have no difficulty in identifying them when near the terminator. By far the most imposing is the Apennines, which, with the craters in

the immediate neighbourhood, form a magnificent picture when seen about a day after half moon; in some parts they reach a height of 20,000 feet above the level of the neighbouring Mare Imbrium. The curved ridge bordering the Sinus Iridum is also very beautiful, and may be seen a little later. The projection of this magnificent curve into the darkness when on the terminator is very striking.

Rills or clefts.—These lunar features have the appearance of excavations, which are sometimes straight, and sometimes bent. More than 1,000 of these are known, and the most conspicuous of them—the Cleft of Hyginus—may be seen with a 2-inch telescope. It lies in the southern part of the Mare Vaporum.

Rays or streaks.—Near the time of full moon, even an opera-glass reveals certain bright rays or streaks, one system, apparently radiating from the crater Tycho, being particularly noticeable. These are so conspicuous that they almost give one the impression of meridians radiating from Tycho as a pole. Another important centre is the crater Kepler. The long rays pass over immense tracts, through mountains or valleys, without apparent interruption. So far they remain without satisfactory explanation.

Eclipses of the Moon.—Like other dark bodies in the neighbourhood of the sun, the earth casts a shadow, and when the moon passes through this, there is an eclipse of the moon.

Although it is very interesting to watch the progress of a lunar eclipse, such phenomena are not of very great scientific importance. The moon mostly remains very feebly visible, even during totality, shining with a dull, coppery-red light, due to the rays of light which have been bent out of their courses after traversing the earth's atmosphere. During the comparative darkness, the opportunity may be taken of observing the occultations of stars which are too faint to be seen close to the moon on ordinary occasions.

Any almanac will give the dates on which eclipses of the moon may be expected.

Occultations of Stars.—In its monthly journey round the earth, the moon is constantly "occulting" or eclipsing some or other of the myriads of stars which people space. When it passes in front of a bright star or planet, the occultation may be observed even with the naked eye. In consequence of the moon's eastward motion relatively to the stars, the disappearances will take place on the eastern or left-hand limb, while the reappearances will occur on the western or right-hand limb. Whitaker's Almanac gives reliable particulars of the occultations of the brighter stars, and may be conveniently consulted by those desiring to look out for these phenonema. The scientific value of such observations depends upon the exactness of the records of the times at which they occur. The instantaneous disappearance of the stars at the moon's limb is one of the demonstrations that the moon is without atmosphere.

It must be understood that the objects on the moon to which attention has been drawn are a mere fraction of what can be observed even with a 2-inch telescope, especially if the object-glass be good enough to bear a power of 80 or 100. There would be no difficulty in filling a whole volume of the size of this with descriptions of the lunar scenery as made visible by a telescope of this aperture. The charm of the subject, however, will inevitably lead the observer to search for details other than those to which reference has been made. Reference has already been made to Mr. Elger's new map, and it may now be added that the book which accompanies the map is sufficiently comprehensive to meet the requirements of beginners as well as those who already have some experience.

Tabulate some of chief occultations

CHAPTER VI.

THE PLANETS.

How to recognise the planets.—Circling in their respective orbits round the sun, there are other bodies besides the earth on which we dwell; some of them are larger than our own planet, others are smaller. Mercury, Venus, Mars, Jupiter, and Saturn, have been known since pre-historic times; the first-named being nearest to the sun, and the last farthest removed. The dim and distant worlds of Uranus and Neptune, and the 400 or so of small but relatively near "asteroids," or "minor planets," are modern discoveries.

Beginners in the out-door study of astronomy are apt to imagine that there is some considerable knowledge required for the mere identification of the planets, but this is not so. In the first place, if we consider only the principal ones, they are distinguished as a body from the stars by the steadiness of their light, and if watched closely for some nights they will be seen to change their positions with respect to the stars. Venus and Jupiter, again, are distinguished from all other bodies in the evening sky by their great brilliancy; and they are distinguished from each other, leaving out telescopic considerations, by the fact that Venus is never very far from the sun, while Jupiter may even be rising when the sun is setting. Mars, again, is distinguished by its ruddy appearance, and Saturn by his steady yellow radiance. When one has become accustomed to the use of a star map, there can no longer be any difficulty in recognising the planets, if the map be used in conjunction with an almanac. Reference to this will at once indicate whether a planet is to be seen in the evening, or in the morning only, and particulars will be found as to the stars near which it lies. The table giving the right ascension and declination of the planets (see page 20) will enable the student to plot its exact place on the star map, and to at once recognise it in the corresponding place in the heavens. *Philips'* Patent Orrery is also very useful in this connection, and may be used to determine the times of the rising and setting of the planets or other heavenly bodies.

The observer must bear in mind that, in their movements, the planets will sometimes approach within such distances of stars that the stars will look like satellites; and if, for example, such should be the case with Jupiter, it must not be imagined that one is seeing the newly-discovered fifth satellite.

Mercury.—It is usually only after careful searching that this planet can be seen at all in this country, except by those provided with equatorially mounted telescopes. This is not on account of lack of brilliancy, as it is at least equal to a first-magnitude star, but because it can only be observed in the twilight or dawn. At its maximum departure from the sun it is only 28 degrees removed, so that it is never visible for more than 2 hours after sunset or before sunrise, according as it follows or precedes the sun in its apparent movement across the sky. When furthest from the sun on the eastern side, it is said to be in eastern elongation, and when furthest on the other side it is said to be at western elongation.

The revolution of the planet round the sun is so rapid, that during a year it is three times an "evening star" and three times a "morning star." On account of the eccentricity of its orbit, however, it does not always reach the

same angular distance from the sun at the elongations, so that it cannot be equally well observed at all the elongations.

In small telescopes this planet presents no features of interest, but there is certainly great satisfaction to be derived from merely catching a glimpse of the swift "Messenger of the Gods," for it is said that Copernicus, to whom astronomy owes so much, never saw it at all.

At times the planet occupies a part of the sky near to the planet Venus, or, perhaps, Jupiter. On these occasions it may be found pretty readily by means of an opera or field-glass. An opera-glass is indeed almost indispensable in searching for Mercury.

The real diameter of the planet is about 3,000 miles, and its apparent diameter varies from 5 seconds of arc, when it is farthest from us, to 13 seconds, when it is nearest to us. To appreciate these values, one should remember that the sun and moon are each about half a degree in diameter, that is, 30 minutes, or 1,800 seconds.

Being a dark body illuminated by sunlight, Mercury will put on phases like the moon.

During a transit of Mercury, when the planet is seen to pass in front of the sun, the planet appears as a dark circular spot, which, though not visible to the naked eye, can easily be seen with a telescope of as low a power as 2½.

The planet will be favourably situated for observation on or about the *evenings* of the following days :—

1895.	June 5.	Nearly 24° from Sun, in Gemini.
	8.	0° 47' N. of Jupiter.
	Oct. 1.	25° from Sun, but rather low.
1896.	May 16.	22° from Sun.
	Sep. 12.	Nearly 27° from Sun.
1897.	Apr. 28.	Nearly 21° from Sun.
	Aug. 26.	27° from the Sun.

There are other eastern "elongations" besides those

40 shows half phase clearly

stated, but these have been omitted in consequence of the low altitude of the planet.

Venus.—Like Mercury, Venus is an interior planet revolving between the earth and the sun, so that we see it as a morning or evening star, and can never by any possibility see it at midnight.

Telescopically it is a very unsatisfactory object on account of its great brilliancy, but there should be little difficulty in noting the great changes in its apparent size as well as its varying phases. When nearest to us, in the same line of sight as the sun, the dark side of Venus is turned towards us, and we do not see it, unless it happens to pass across the sun's disc, a phenomenon known as the Transit of Venus; this will not occur again until June 8, 2004. For some weeks before and after this "inferior conjunction," the planet appears as a crescent, and it is then that our small telescope will be most effective. At the greatest apparent angular distances from the sun, the appearance of a half moon is presented, while the full moon phase will obviously occur when the planet is farthest removed from us, and when, consequently, its apparent size is smallest. There are certain delicate markings on Venus which are quite beyond the range of a 2-inch telescope. Occasionally the planet is bright enough to be visible to the naked eye in daylight, and may easily be seen in full sunlight with a small telescope, if there are any means of pointing the instrument in the proper direction.

The diameter of Venus is very nearly the same as that of the earth, but in consequence of its varying distance from us, its angular or apparent diameter ranges from 11 to 57 seconds of arc. A magnifying power of 20 suffices to show the phase when crescent; but when gibbous, like the moon a few days from full, a power of about 60 is required to show it distinctly.

The time of revolution round the sun is longer than that

of Mercury, so that instead of appearing as an evening star about every three months, Venus only recovers similar positions with respect to the sun and earth at intervals of about a year and seven months. It will be seen as an *evening star* for three or four months before, and for about a month after the following dates, when the planet will be at eastern elongation :—

1895.	July 11.	45° 31′	E. of Sun.
1897.	Feb. 15.	46° 38′	„ „

Mars.—Passing outwards from the earth in our survey of the planets, we come to Mars, which has been an object of interest in all times, but more especially since the discovery of the markings which suggest some resemblance of its surface to that of the earth. It is only when at very favourable oppositions (see *Lockyer's Elementary Lessons, art.* 393), as it was in 1892, and will be again in 1907, that the various markings are well seen even in large telescopes, so that it is almost entirely beyond the reach of a 2-inch. It is possible, however, to at once observe a disc of sensible size, thus distinguishing it from stars, and to see also that, when not too near opposition, it exhibits a phase like the moon 3 or 4 days from full. The crescent phase can never be put on by planets which revolve outside the earth's orbit. The redness of the planet is very noticeable in the telescope. At favourable oppositions, the most conspicuous dark marking—the Hour Glass, or Kaiser Sea—has been seen with telescopes of even less than 2 inches aperture.

Although the orbit of Mars is not very far from circular with reference to the sun, the apparent movements of the planet as seen from the earth are very remarkable, and it will be found very interesting to keep a record of its position relatively to the stars near which it passes. This may conveniently be done by recording the places on a star map, or on a tracing showing the principal stars.

It may be added that the diameter of Mars is little more than half that of the earth.

Mars will not again be in "opposition," that is, in the opposite part of the heavens to the sun, until December 10, 1896, and then it will be at too great a distance from us to be well observed. The planet will be recognised in Taurus (Map 4) from September, 1895, onwards, and it will be seen to move, first to the east, then towards the west, and again towards the east, relatively to the stars, if watched for four or five months.

Jupiter.—In consequence of its great size and brightness, and the conspicuous character of some of his markings, Jupiter readily lends itself to observation with a small telescope. In addition, his four principal satellites are a never-failing source of interest.

With a 2-inch object-glass a magnifying power of 80 or 100 may be employed on Jupiter without sacrifice of definition, but even with the power of 40 or 60 on our home-made instrument, no difficulty is experienced in seeing the four satellites, the two principal cloud belts, and the large ellipticity of the disc. When observed with large telescopes, the finer structure of the cloud belts is seen to be subject to frequent changes. It seems highly probable that we never see the real surface of Jupiter, on account of the dense clouds in his atmosphere.

As they revolve round the planet in different periods, the satellites present an ever-varying aspect, but they are never far removed from the plane of the planet's equator, which is parallel to the belts. Sometimes all the satellites will be seen on one side of the planet, at other times there may be two on each side, and so on. Frequently one may be invisible, for the reason that it is passing behind the planet, and is therefore occulted, or because it is passing through the shadow of the planet, when it is said to be eclipsed. Sometimes they pass in front of the planet, and with good instruments may be seen to transit across the disc, especially if their tracks lie along one of the dark belts; at such times a dark spot representing the shadow is occasionally observed.

A fifth, and very small satellite, nearer to Jupiter than any of the others, was discovered by Prof. Barnard with the Lick telescope in 1892, but this is invisible in all but the largest telescopes.

The four satellites of Jupiter discovered by Galileo are usually known by their numbers, which proceed in order of distance from the planet, but they are also known by the names Io, Europa, Ganymede, and Callisto, respectively.

Our good friend *Whitaker* includes particulars of the phenomena of the satellites for all the dates on which they can be observed in this country, and the observer will find it interesting to compare what he actually sees with the predictions made and printed years before.

In this case, again, it is important to remember the scale of the object observed. The diameter of Jupiter is about 80,000 miles, so that the smallest marking one can observe is really of very considerable size.

The planet will be best observed near the following times of opposition:—

1896.	Jan. 24.	In the constellation Cancer (Map 3).
1897.	Feb. 23.	,, ,, Leo (Map 3).

Saturn.—This planet is one of the finest objects in the heavens when seen with adequate instruments. Even with our modest telescope, the observer can at least satisfy himself that "Saturn's ring" is not a myth, and with a little care he may succeed in recognising the principal features of the planet.

A power of 30 appears to be about the minimum on a 2-inch telescope that will give clear indications of the ring. With a power of 40 it is clearly visible, and 60-100, with a good object-glass, will even render visible the dark line which divides the ring into two parts—the so-called Cassini's division. When the definition is very good, a keen-sighted observer may also be able to distinguish the belts on the surface of the planet itself, resembling the belts of Jupiter; and one observer states that he has succeeded in seeing, with a 2-inch telescope, the shadow cast by the ball on the ring.

A drawing of Saturn—familiar to most text-books of astronomy—should be compared with the telescopic view, but it must be remembered that the aspect of the ring changes in consequence of the inclination of the axis of the planet.

Of the eight satellites attending this wonderful planet, the brightest—Titan by name—is the only one which comes within range of a 2-inch. This is nearly as large as the planet Mars in reality, but, owing to its greater distance from us, it appears only as a star-like companion to Saturn.

Like Mars and Jupiter, Saturn can be best observed when it is near opposition, and the following notes of these dates may be useful to the beginner.

In 1896, May 5. In Libra, Map 2.
In 1897, May 17. " "

The remaining planets present no features of interest in our small instrument, so that no further reference to them need be made.

CHAPTER VII.

COMETS.

Orbits of Comets.—No opportunity should be lost of examining with the telescope any of these remarkable objects. Sometimes they are bright enough to attract universal attention, as in 1858 and 1882, while many of them are only perceived with difficulty in the most powerful instruments which can be brought to bear upon them. Observations of their apparent movements have shown that they revolve in regular orbits round the sun, but whereas some of them travel in ellipses, and thus make their appearances regularly, others move in orbits having the forms of parabolas or hyperbolas. These come upon us suddenly, pay their respects to the sun, so to speak, and afterwards pass off into the depths of space, far beyond the sway of our luminary. Hence some of the comets now belong to our system as much as the planets do; and it is believed that these have been diverted by the attraction of one of the great planets out of their parabolic paths into elliptic ones. The orbits are mostly very eccentric—that is, the ellipses are much elongated; so that at "perihelion"—the point of the orbit nearest to the sun—they are very much closer to the sun than at "aphelion," as the most distant point of the orbit is called. For this reason, the periodic comets, unlike planets, are only seen when they are near perihelion, for it is then that their brightness is greatest. Few of the comets which revolve round the sun in short periods attain any considerable degree of brightness.

Where to look for Comets.—It is evidently only in the case of the fainter comets that any directions for seeing them can be needed, and in such cases a star map of some sort is essential. When a comet has been observed on three or four nights, it becomes possible to compute its path, and its place on future dates can then be predicted. Accordingly, one obtains an "ephemeris" of a comet from some source such as *The Observatory*, *Nature*, *The English Mechanic*, &c., or even occasionally some of the daily papers; this will furnish particulars of the Right Ascension and Declination of the comet for the time of observation, and by finding the corresponding place on a star map, its position in relation to surrounding stars will be at once determined. In this way, if bright enough, the comet will be readily found. The Planisphere, if used in place of the star map, will further indicate in what part of the sky the comet and surrounding stars may happen to be at any particular hour.

The parts of a Comet.—The popular impression of a comet is that it is like a star with a tail. This is to some extent true of large comets, but many of the comets have no tail at all. When present, the tail is, undoubtedly, a most striking feature, though presenting nothing of interest when seen with the telescope. Sometimes, comets have two or even as many as 6 tails, some of which are small, and only seen with the aid of a telescope.

The brightest part of a comet—*the coma*, or head—sometimes shows a considerable amount of interesting detail. There is a star-like point in the centre called the *nucleus*, and sometimes this is half surrounded by a series of *envelopes* somewhat resembling the layers of an onion; at other times, *jets* or fan-like structures of luminous matter proceed from the nucleus and project into the coma. All such phenomena will no doubt prove of great interest when the opportunity of observing them occurs.

The more numerous class of small comets do not exhibit such great variety of telescopic details, and at some stages of their careers they simply appear as faint patches of luminosity. Continued watching may reveal the gradual formation of a short tail, and the intensification of the nucleus during the approach to the sun.

Not the least remarkable thing about a comet is the transparency of its various parts; stars situated behind it continue to shine with undiminished lustre.

Movement.—The movement of comets is frequently so rapid that even an hour's observation with a telescope will suffice to show it. The position of the comet with regard to the more conspicuous stars which may happen to be in the field at the same time should be noted at intervals for this purpose. When this relative position is determined by micrometric measurements, the Right Ascension and Declination of the comet can be determined with great accuracy, from the known positions of the comparison stars. This is, in fact, often the only possible way of finding the position of a comet with the requisite degree of accuracy, as it is sometimes impossible to observe it on the meridian with the transit instrument.

The movement of a comet in relation to the stars furnishes a ready means of distinguishing it from the nebulæ and star-clusters; and if the observer should be fortunate enough to discover a comet, he can make himself quite certain of its character by this feature.

Returns of Periodic Comets.—Among the more interesting periodic comets which may be expected to reappear are the following:—

1896.	Faye's Comet.	Period	7½ years.
	Brooks's "	"	7 "
1897.	D'Arrest's "	"	6½ "
	Swift's "	"	5½ "

1898.	Winnecke's Comet.	Period	5½ years.
	Wolf's "	"	7 "
1899.	Tuttle's "	"	13¾ "
1911.	Halley's "	"	76 "

A complete history of these and other comets will be found in *Remarkable Comets*, a little book by Mr. W. T. Lynn.*

* Stanford, price 6d.

CHAPTER VIII.

THE STARS.

Telescopic appearance of a star.—The stars are so immensely distant that, even with the most powerful telescopes that can be applied, they do not show sensible discs like those of the planets. There is, indeed, what is called a "spurious disc," seen especially in the brighter stars with high powers; but, as a matter of fact, this diminishes in size as the aperture of the telescope is increased. The formation of this disc, and the bright and dark rings by which it is surrounded, is due to diffraction phenomena, the explanation of which is beyond the scope of the present work. With a high power on a good night, the discs and rings should be readily seen if the object-glass be good.

In the case of the brighter stars, a certain amount of colour will also be seen surrounding the images, but this is a defect of nearly all existing refracting telescopes, owing to the imperfect achromatism of the object-glass. There is some satisfaction in knowing that the colour is very much less than would appear if the lens were a single one.

Magnitudes of Stars.—As "one star differeth from another in glory," it is necessary for astronomical purposes to adopt some means of denoting their brightnesses. The ancient astronomers, who were naturally concerned only with stars visible to the naked eye, recognised six grades of stars. The brightest were called stars of the first magnitude, while the faintest visible to the naked eye were said to be of the sixth magnitude. So far as it goes, this notation is still retained; but now that we have telescopes, it is necessary to carry it further. It has been found that the average star of the first magnitude may fairly be reckoned 100 times brighter than one of the sixth magnitude; so that a star of any particular magnitude is really about $2\frac{1}{2}$ times as bright as a star one magnitude fainter. This will be understood if it be considered that 2·5 multiplied by itself 5 times amounts to 100 in round numbers.

Instruments of precision are now employed in the measurement of stellar magnitudes, so that if a star be found $2\frac{1}{2}$ times less bright than a 6th mag. star, it is rated 7th mag.; if 6·25 (*i.e.*, $2{\cdot}5 \times 2{\cdot}5$) times less bright, it is reckoned 8th mag., and so on. Fractions of a magnitude are also taken count of, so that we may have, for example, the magnitude of a star stated as 7·5.

Magnitudes and Number of Stars seen with a 2-inch.—If telescopes had never been invented, we should have remained in total ignorance of the existence of the great majority of the heavenly bodies, and our ideas of the universe would have been greatly out of proportion.

Millions of stars not visible at all to the naked eye become apparent in telescopes. This is because the object-glass collects a larger amount of light than the pupil of the eye, and the light-grasping power of the instrument is nearly equal to the area of the object-glass divided by the area of the pupil. If we take the diameter of the pupil to be one-fifth of an inch, its area will only be one-hundredth that of a 2-inch object-glass. Hence, 100 times more light from a star falls on the 2-inch O.G. than on the pupil, so that if all this light were really utilised, a telescope of this size would show stars as faint as 11th mag.—*i.e.*, 5 mags. lower than the naked eye limit. Owing to the loss of light by absorption and reflection in the lenses, however, the minimum

magnitude visible with a 2-inch is about 10·5 on very clear nights. With a 6-inch it is 12·9, and with a 10-inch 14.

In the northern celestial hemisphere alone there are over 300,000 stars of or above magnitude 9·5, and all these, as well as many still fainter ones, should come within the range of a 2-inch glass under favourable atmospheric conditions.

Star fields.—Although individually the stars may be of little interest telescopically, they are frequently to be met with in beautiful streams or groupings well worthy of scrutiny. In "sweeping" through some parts of the sky on a good night with the telescope, such groups are almost numberless, and the great variety in brightnesses and colour adds to the charm of observing them. It may be pointed out that the neighbourhood of the Milky Way is specially interesting in this respect, and the constellations Cygnus, Auriga, Sagitta, Aquila, and the neighbourhood of α Persei may be cited as particularly rich regions.

When stars are very closely grouped together in the field of view, they are distinguished as star clusters (Chap. X.)

Coloured stars.—Many stars are remarkable for their deep colours, chiefly red or yellow. Among the brighter stars of a reddish tint are Betelgeux, Antares, Aldebaran, β Pegasi, and Cor. Hydræ. Reference to the maps will at once enable these to be recognised. The deep red stars are mostly of feeble radiance, so that if it be desired to observe these, a little more patience will be required in pointing the telescope. Among the more remarkable which can be easily identified are :—

μ Cephei (Map 1).
Mira Ceti („ 4).
δ Virginis („ 3).
α Herculis („ 2).

Variable stars.—Some of the stars are subject to periodic fluctuations in brilliancy; in some cases the variation is not very great, and occurs in periods measured by days and hours; in others the range of variation is greater, and the period is measured by months.

The observation of this class of phenomena, which must necessarily extend over a considerable period, is full of interest. In the case of many of the short period variables, no instrument is required—or, at most, an opera or a field glass—as in these cases the stars never become invisible to the naked eye. Many of the longer period variables, however, never rise above 5th or 6th magnitude, so that the aid of a telescope is essential, and the difficulty of identification is enormously increased.

In the case of Algol (Maps 1 and 4) the light remains very near constant at 2nd magnitude, except at intervals of a little less than three days, when it falls to 4th magnitude in a few hours, and regains its original brightness in nearly the same time. Particulars of the *minima* which can be conveniently observed are published monthly in *Knowledge*, or they may be obtained from the *Companion to the Observatory*. In this, as in the observation of other variables, the star must be compared with surrounding stars.

β Lyræ (Map 2) goes through a continuous cycle of changes in a period a little under 13 days, and during this time it has two maxima of magnitude 3·5, a minimum of 4·9, and a secondary minimum of 3·9, the period being reckoned from one principal minimum to another.

Mira (Map 4) is a long-period variable star (about 11 months), and will be well placed for observation at maximum during the next few years. From about 9th or 10th magnitude at minimum, this wonderful star occasionally becomes equal to a 2nd magnitude star, corresponding to a six-hundred-fold increase of its light. There will be no difficulty in identifying the star when it reaches the 6th magnitude, and afterwards its progress may be observed regularly until the maximum is passed. The period is somewhat irregular, but maxima may fairly be expected in

January and December, 1896, and November, 1897. It is very nearly in a line from α through δ Ceti, at nearly the distance from δ as the distance between them.

Full instructions for the systematic observation of variable stars, with a view of increasing our knowledge of the variations, will be found in the American monthly, *Popular Astronomy*, January and February, 1895.

New stars.—At times the astronomical world receives a fresh source of interest in the appearance of a so-called *new star* or *nova*. What looks like a star, in a place where no star was previously known to exist, has been discovered by some painstaking observer, and immediately nearly all the telescopes in the world are directed to it. Usually they are very short-lived, and in a few weeks become so feeble that they can only be seen in the most powerful instruments. The possessor of a small telescope will find some gratification in observing a new star if one should fortunately become visible, especially in noting the irregular fluctuations and subsequent rapid decline in its brilliancy.

It is worth remarking that the last new star visible in the northern hemisphere—Nova Aurigæ, 1892—was discovered by an amateur astronomer, Dr. Anderson, with no more powerful instrument than a pocket telescope. Obviously, a good star map, and an extended knowledge of the constellations, must form part of the outfit of the would-be discoverer of new stars.

CHAPTER IX.

DOUBLE STARS.

Doubles and Binaries.—It often happens that stars which appear single to the naked eye are seen to consist of two close components when observed with a telescope. These are the so-called double stars, and it is clear that there may be two causes for such appearances. First, two stars may happen to be very nearly in the same line of sight as seen from the earth, so that they appear side by side, although, seen from another part of space, they would appear widely separated. Next, two suns may be really close together, and bound together by the same law of gravitation that controls the movements of the planets in their courses; in such stars, continued observations will show changes in the apparent distance between the two stars, or in the line joining them, so that orbital movement is indicated. Stars of the latter class are called *binary stars*, to distinguish them from the *optical doubles*, to which reference has been made.

Though the component stars themselves are not capable of enlargement, it is evident that the higher the magnifying power, the wider apart will the stars appear in the telescope.

Some stars forming a gravitational system are triple; others quadruple. In many of the double stars the components are of nearly equal magnitudes, and in such cases the colours are usually pretty similar. In others the companion is much smaller than the primary, and very

frequently has a bluish colour, whether the principal star be white or yellow.

Double-star names.—Many of the stars already named are found to be double when seen with suitable telescopes, and the ordinary names suffice for purposes of reference. Thus Castor and ζ Ursæ Majoris are double. Others, not having such a term of reference, are conveniently indicated by their numbers in some of the best known and most complete catalogues of such objects. Usually the catalogues of Struve and Burnham are quoted, and these are so generally known among astronomers that the symbol Σ or β sufficiently refer to them. To simplify matters, however, the doubles referred to in this chapter are selected from naked eye stars.

Distance between components.—The apparent distance between the two stars which form a double is expressed in seconds of arc, of which 3,600 correspond to a single degree. The process of measurement involves the use of some form of micrometer in connection with the telescope, but although a few measurements have been made with instruments of two inches aperture, it is not likely that many of those who are prepared to provide themselves with an expensive micrometer would be content with an instrument of this size.

In the case of a binary star, it is possible to calculate the distance in miles between the two stars from the angular measurement, if they are not too far removed from the earth to permit a measure of their distance from us. Thus it has been determined that Castor is about a million times more distant than the sun; the mean angular separation of the stars when corrected for foreshortening, as determined from a series of micrometric measures of the distance between the two components, is found to be $7''\cdot5$; then the distance in miles between the two components is the length of $7''\cdot5$ measured on a circle of radius a million times the sun's distance. This will be found to be nearly 38 times the sun's distance. The period of revolution in this case is about a thousand years.

Position angles.—To completely specify the disposition of the components of a double star, a measure of the direction of the line joining them is as necessary as the distance between them. The direction is expressed by "position angle," *i.e.*, the angle from the north point measured through E., S., and W., the brighter star being taken as the central one. The position angles are reckoned from 0° to 360°, and in an astronomical telescope they are as follows:—

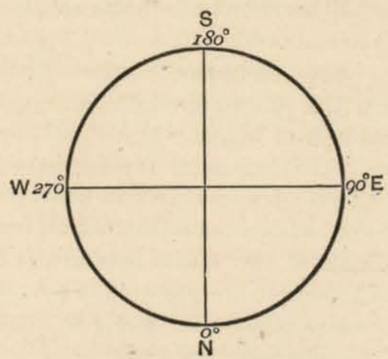


Fig. 12.—Illustrating position angle.

As in the case of the sun, the direction of the E. and W. line is that of the apparent movement of the star across the field, and the beginner must be careful not to confuse this with the horizontal.

A knowledge of the position angle is useful in cases where the companion is very faint, as the eye is not wearied by needless searching in the wrong direction.

Dividing power of 2-inch telescope.—The dividing power of a telescope is usually stated in terms of the angular distance between the two components of the closest double

which it will resolve. The size of the spurious disc, which has already been stated to vary inversely as the aperture of the object glass, determines the dividing power, so that a power of 100 on a 6-inch telescope will divide closer doubles than the same power on a 2-inch. The dividing power is found to be 4″·56 divided by the aperture of the telescope in inches, and a very perfect 2-inch should therefore separate stars no further apart than about 2·3 seconds of arc. This, however, is not likely to be realised with the average telescope, nor with very good ones, except on specially favourable nights, and for stars in which the brightness is not very great.

Selected list of double stars.—A very considerable number of double stars are capable of being resolved with a good 2-inch telescope by an observer who has gradually accustomed himself to this class of observation. The condition of the atmosphere is of the utmost importance in double star observing, if the object under examination is one at all difficult. If the double be a close one of nearly equal magnitudes, steadiness of the air is of first importance; when the companion is more distant, but relatively dim, clearness of the air is the more necessary. Most of the objects included in the table which follows will be found easy to separate on ordinary clear nights, but in a few cases some little difficulty may be experienced if the air is not very clear, or is unsteady, as the case may be. Some of the stars included may not be clearly resolved with the cheapest object glasses, but it has been thought worth while to include them in order to furnish tests for such lenses.

Some doubles are said to be best observed when it is not quite dark, or in moonlight; γ Leonis and γ Virginis are among these.

The various columns of the table need but little explanation; magnitudes, distance, and position angle have already been explained; colours are not as a rule very striking in a small telescope, but are included for the sake of completeness.

The column "power" is intended to give the observer some idea of the lowest power with which he may expect to observe any particular double; if the instrument be only provided with one eye-piece, giving him a power of 20, or of 30 when the field lens is removed, it will scarcely be worth while attempting those which this column indicates can only be seen with a power of 60. Judgment must also be used in regard to the weather. The column of remarks gives various notes as well as references to the maps, by numbers in brackets, indicating the situations of the stars.

The measures of position angle and distance are from recent sources, as in the case of binaries the values must obviously be changing, though not, as a rule, at a very rapid rate.

Ref. No.	Name.	Magnitudes.	Distance.	Positi'n Angle.	Colours.		Power.	Remarks. (No. in brackets refers to map).
			″	°				
1	γ Andromedæ ...	3, 5	10·3	62	Golden.	blue.	60	(4) Rather difficult with cheap lens.
2	ζ Aquarii	4, 4	3·2	323	Yell. wh.	yell. wh.	60	(4) Fine with good O.G., binary.
3	γ Arietis	4½, 5	8·8	178	Wh.	wh.	Fine 30	(4) The first double telescopically observed.
4	λ Arietis	5, 7	38	46	Wh.	bl.	Easy 20	(4)
5	π Boötis	5, 6	5·8	99			40-60	(2) Requires a pretty good object glass.
6	δ Boötis	3, 7	105	79	Yell.	bl.	Easy 20	(2)
7	ζ Cancri	5, 5½	5·5	122			Fair 60	(3) Triple in more powerful instruments.
8	ι Cancri	4½, 6½	30	307	Yell.	bl.	Easy 20	(3) Good contrast of colours.
9	α Canum Venat.	3, 6	20	228	Yell.	yell.	Fine 20	(1) Cor Caroli.
10	α Capricorni ...	3, 4	376	291			Naked eye.	(2)
11	δ Cephei	Var.5	41	192	Yell.	bl.	20	(1) A beautiful pair.
12	ξ Cephei	4½, 6½	6·8	282	Yell.	bl.	60	(1) Binary.
13	δ Corvæ	3, 8½	24·3	214	Yell.	bl.	30	(3)
14	β Cygni	3, 7	34	55	Yell.	bl.	Easy 20	(2) Splendid double with 2-inch.
15	61 Cygni	5, 6	21	89	Yell.	yell.	Easy 20	(2) An interesting pair; the first star of which the parallax was determined.
16	γ Delphini ...	4, 5	11	270	Yell.	bl.	30	(2)
17	ν Draconis ...	4½, 4½	61·7	313	Yell.	wh.	Fine 20	(1) A fine couple.
18	α Geminorum (Castor)	2, 3	5·7	230	Yell.	yell.	Good 60	(3) Binary. Fine, with power 80.

Ref. No.	Name.	Magni-tude.	Dis-tance.	Positi'n Angle.	Colours.		Power.	Remarks. (No. in brackets refers to Map.)
			"	°				
19	ζ Geminorum ..	4, 7	93	352	Yell.	bl.	Easy 20	(3) A variable star of small range.
20	α Herculis ...	3, 4½	4·6	114	Yell.	bl.	60	(2) Colours fine, but not very easy with 2-inch.
21	δ Herculis ...	3, 8	16·5	186	Wh.	reddish.	30	(2)
22	γ Leonis	2, 4	3·7	115	Yell.	yell.	Fair 60	(3) Requires a good O.G. ; binary.
23	α Libræ	3, 6	—	—	Yell.	wh.	20	(2) Very wide pair.
24	ε Lyræ	—	207	—	Wh.	wh.	Easy 20	(2) Each component is a close binary (the double-double star), but too difficult for 2-inch.
25	β Lyræ	Var. 7	45	149	Yell. wh.	bl.	Easy 20	(2) See variable stars.
26	ζ Lyræ	4, 6	44	149	Wh.	greenish.	Easy 20	(2)
27	δ Lyræ	4, 5	—	—	Orange.	wh.	Naked eye	(2)
28	11 Monocerotis...	6, 6	7·4	132	Wh.	yell. wh.	Pretty 30	(3)
29	δ Orionis	2, 6½	52	359	Bl. wh.	wh.	Easy 20	(3)
30	σ Orionis	4,7,6½	12·8,42	85,61	Wh. bl.	reddish.	Good 60	(3) A quadruple star, of which 3 are seen.
31	β Scorpii	2, 4	13·1	24	Wh.	lilac.	40	(2)
32	θ Serpentis ...	4, 4½	22	104	Yell.	yell.	Easy 20	(2) Splendid pair.
33	ζ Ursæ Majoris	2, 4	14·4	151			Good 20	(1) Beautiful double ; "Alcor" about 12′ distant.
34	α Ursæ Minoris	2, 9	18·6	210	Yell. wh.	bl.		(1) A difficult test for a 2-inch.
35	γ Virginis ...	3, 3	5·8	152	Yell.	yell.	30-60	(3) Binary ; distance ranges from 0·5 to 6·3. A power of 30 divides on good O.G.

Double stars visible in each month.—The following table will show which of the foregoing double stars are visible in each month, the numbers corresponding with those in the first column of the preceding list. This will be of assistance in preparing the working lists to which reference is made in Chapter II.

JANUARY - -	1, 3, 4, 7, 8, 11, 12, 18, 19, 28, 29, 30, 33, 34.
FEBRUARY -	1, 3, 4, 7, 8, 11, 12, 18, 19, 22, 28, 29, 30, 33, 34.
MARCH - - -	1, 7, 8, 11, 12, 18, 19, 22, 28, 29, 30, 33, 34.
APRIL - - -	5—9, 13, 15, 17, 18, 19, 22, 34, 35.
MAY - - -	5—9, 13, 15, 17, 22—27, 31, 33, 34, 35.
JUNE - - -	5, 6. 9, 13, 15, 17, 20—27, 31, 33, 34, 35.
JULY - - -	5, 6, 9, 11, 12, 14—17, 20, 21, 23—27, 31—34.
AUGUST - -	1, 2, 5, 6, 10, 11, 12, 14—17, 20, 21, 24—27, 32, 33, 34.
SEPTEMBER -	1, 2, 10, 11, 12, 14—17, 20, 21, 24—27, 32, 34.
OCTOBER - -	1, 2, 10, 11, 12, 14—17, 24—27, 34.
NOVEMBER -	1—4, 10, 11, 12, 14—17, 24—27, 34.
DECEMBER -	1—4, 7, 8, 11, 12, 18, 19, 28, 29, 30, 34.

CHAPTER X.

STAR CLUSTERS AND NEBULÆ.

Naked eye groupings.—In certain parts of the heavens it is observed that stars tend to group themselves very closely together. The Pleiades, for example, is a very familiar instance, and even though the brighter stars of this well-known group must be immensely distant from each other, there is little doubt that they form part of one stellar system. The magnificent aspect of this group when viewed with a power of 20 on our small instrument, or even in an opera glass, cannot fail to impress all who behold it.

Similar groupings, but less conspicuous, occur in other parts of the sky.

The Milky Way or **Galaxy.**—In our large towns it is but rarely that the Milky Way is seen to advantage, but in the open country, where the air is not defiled with smoke, it is perhaps one of the most striking features of the evening sky. To the naked eye it appears as a filmy nebulous luminosity—the "fire mist" of the old astronomers—but even with the smallest optical aid it is seen to consist of a multitude of small stars defying enumeration. According to recent investigations, the form of the Milky Way, as it appears to the naked eye, corresponds very closely with the distribution of stars of the 9th to the 15th magnitude, and these stars are probably comparatively small ones at not much greater distances than those which are higher in the scale of magnitude.

The sweeping of the telescope across the Milky Way, observing the infinite variety in the stellar tracings, will afford the student a vast amount of pleasure, and give him, besides, food for reflection on one of the great problems now occupying the minds of astronomers—the "Construction of the Sidereal Universe," what its length, breadth, and depth may be, and what is the relation of our solar system to this larger system of the stars.

Star Clusters.—From one point of view the Milky Way may be looked upon as an immense star cluster, but there are many clusters of a somewhat different order, many of them in the Milky Way itself. In these the stars are of nearly the same order of brightness, and very close together, sometimes so close, even when seen with very large telescopes, that the cluster can only be described as consisting of so much "star-dust." These very compressed clusters often exhibit a more or less globular form, condensing towards the centre, and such clusters are hence known as *globular clusters.*

In other cases the clusters are not quite so compact, and the distribution of the stars shows no marked regularity. The old idea that in these clusters we are looking upon distant universes is now almost abandoned, as they have been shown with much probability to form a part of the sidereal system to which our sun belongs.

Many of these star clusters come within reach of a 2-inch telescope, but in some cases—where the component stars are very close—they only appear as unresolved patches of luminosity. A selection of clusters is given in the appended table, with particulars as to when and where they are to be seen.

The earliest catalogue of star clusters and nebulæ was drawn up by Messier, and since this naturally includes most of the more conspicuous of these objects, it is still common to employ the numbers in Messier's catalogue for purposes of reference. Thus, 15 M. Pegasi indicates that the cluster in question is No. 15 in Messier's catalogue, and that it occurs in the constellation Pegasus. Clusters not included in Messier's catalogue are designated by their numbers in the "New General Catalogue" of clusters and nebulæ, a revision of Herschel's catalogue, by Dr. Dreyer.

In general, the best views of these objects will be obtained by using a low power, as 20 on our 2-inch telescope.

Most of the clusters named are dimly visible to the naked eye on very clear nights, and it is hoped that the directions given will facilitate the search for them.

Name of Cluster.	Visible.	How to find.	Remarks.
The Pleiades.	Oct.-Mar.	In Taurus (Map 4).	Magnificent field.
M 44. Cancri (Præsepe).	Dec.-May.	Almost midway between Regulus and Pollux (Map 3).	Visible to naked eye. Easily resolved into stars. Fine cluster for 2-inch.
M 3. Canes Venatici.	April-July.	Between Cor Caroli and Arcturus, a little nearer the latter (Map 2).	Bright globular cluster, looks like a nebula in 2-inch. Interesting object.
Cluster in Serpentis (N.G.C. 6633).	July-Sept.	About one-third of the way from θ Serpentis to α Ophiuchi (Map 2).	Visible to naked eye.
M 8. Sagittarii.	Aug.-Sept.	In a line through π Scorpii and Antares to a little more than twice the distance between them (Map 2).	Visible to naked eye. Fine regions for low powers.
M 13. Herculis.	June-Sept.	About $\frac{1}{3}$ of the distance from η to ζ Herculis (Map 2).	Magnificent globular cluster, visible to naked eye. Looks like a nebula in 2-inch.
M 14. Canis Majoris.	Dec.-Mar.	About 4° S. of Sirius (Map 3).	Good globular cluster. Resolved into stars.
M 15. Pegasi.	July-Nov.	About 4° W.N.W. of ϵ Pegasi (Map 4).	Globular; like a small comet.
Double Cluster in Perseus (N.G.C. 869, 884).	Aug.-Feb.	About $\frac{1}{2}$ way between γ Persei and δ Cassiopeiæ (Map 1).	Visible to naked eye. Gorgeous with low powers. Easily resolved.
M 34. Persei.	Sept.-Mar.	About midway between γ Andromedæ and κ Persei, a little nearer the latter (Map 4).	Splendid field of stars. "One of the finest of its class."—(*Webb*).
M 35. Geminorum	Dec.-April.	Nearly half-way from ϵ Geminorum to ζ Tauri (Map 3).	Excellent with 2-inch.
M 80. Scorpii.	May-July.	Nearly midway between Antares and β Scorpii (Map 2).	"Like a comet." —(*Webb*).

Nebulæ.—It will be easily understood that compressed star clusters, when seen with small telescopes, will appear as dim patches of light with little or no signs of resolvability, although they might easily be resolved with telescopes of sufficient power to deal with them. At one time it was imagined that what are now termed "nebulæ" were simply star clusters in which we were unable to distinguish the separate constituents. It has been abundantly demonstrated, however, that true nebulæ, putting on the appearance of clouds, do really exist, and that they cannot be resolved into stars with any power whatsoever. The spectroscope shows many of them to be quite distinct from clusters. At the same time there are still very many which require further investigation before it can be said whether they are really nebulæ or star clusters. Hence, clusters and nebulæ are usually catalogued together. This difficulty will be impressed on the observer after a comparison of such a cluster as the Præsepe, which is easily resolved, with one like M. 3 Canes, which, in a 2-inch telescope, puts on the appearance of a nebula or a small comet.

Although two nebulæ are bright enough to be visible with the naked eye, there are very few which can be profitably scrutinised with a 2-inch telescope. Nevertheless the student may for himself observe the telescopic difference between a nebula and a star cluster, and this will form a valuable supplement to his reading.

Of the nebulæ referred to in the following list, the first and second are the most important and most easily observed. The others may present some little difficulty to the beginner, and the precaution should be taken to keep the eyes from strong lights for some little time before looking for them. Faint nebulæ are more readily found if the telescope be moved so that the image moves at a moderate rate across the field, and when once centred, a little patience in continuing to observe will be rewarded by the appearance of greater details; one does not see everything at the first glance.

Name of Nebula.	Visible.	How to find.	Remarks.
Great Nebula in Orion (M 42).	Dec.-Mar.	(Map 3.)	The finest nebula in the heavens. Surrounds a group of 4 stars forming the so-called "Trapezium." These may all be seen clearly separated with a power of 80.
Great Nebula in Andromeda (M 31).	Aug.-Feb.	(Map 4.)	Appears as a dim nebulosity, brightening towards the centre. Easily seen with naked eye on clear moonless night.
Dumb-bell Nebula (M 27 Vulpeculæ).	July-Nov.	About 3° N. of γ Sagittæ (Map 2). A little S. of a 5th mag. star.	Not very striking in 2-inch, but fine region.
Planetary Nebula in Aquarius.	July-Nov.	In a line from α through β Aquarii about its own length (Map 4).	About half the apparent diameter of Jupiter. Bluish green. Bears magnifying like a planet.
Ring Nebula in Lyra.	May-Nov.	About one-third of the distance from β to γ Lyræ (Map 2).	Faintly seen on very good nights, but the student must not expect to see a large ring.

MATERIALS FOR MAKING UP TELESCOPE AS DESCRIBED IN FOREGOING PAGES.

SUPPLIED BY GEORGE PHILIP & SON,

32 FLEET STREET, LONDON.

		Net Prices. s. d.
*1.	2⅛ inch diameter, 30 inch focus Achromatic Object Glass ... 1 ,, ,, 3 ,, ,, Lens for eye-piece ... ... 1 ,, ,, 1 ,, ,, ,, ,, ...	5 6
2.	1 ,, ,, 1½ ,, ,, Lens for extra eye-piece ...	1 0
3.	½ ,, ,, ½ ,, ,, ,, ,, ...	1 0
*4.	Thin Brass Disc, 1 inch diameter, with hole ⅛ inch diameter for eye-piece	0 1
5.	Thin Brass Disc, 1 inch diameter, with hole ¼ inch diameter for extra eye-piece	0 1
*6.	Paper Mache Tube, 24 inches long and 2⅛ inches diameter. Blacked inside	2 6
*7.	Set of 5 Paper Mache Tubes for eye-piece, object glass cell, and draw tube. Blacked inside	3 6
†8.	Set of 4 Wooden Rollers for making tubes last named ...	1 6
9.	Bottle of Ink for blacking internal parts, with brush	1 0
10.	Dark Glass for viewing the sun directly	1 0
11.	Screen for Projection of the Sun's image	5 0
12.	Complete Telescope without Stand, one eye-piece magnifying 20 times	21 0
13.	Extra Eye-piece, magnifying 40 times	5 3
14.	Tripod Telescope Stand, with vertical and horizontal adjustment, made of beechwood, well finished (for garden use) ...	12 6
15.	Extra piece for attaching Holder to top of Window Sash ...	4 6

* Parts essential for making Telescope.

† Alternative to No. 7.

GEORGE PHILIP & SON'S

ASTRONOMICAL BOOKS, APPARATUS, &c.

Atlas of Astronomy. Containing 72 beautifully executed plates, with explanatory letterpress, and complete Index. By Sir Robt. S. Ball, F.R.S., Lowdean Professor of Astronomy and Geometry at the University of Cambridge; author of "Starland," "The Story of the Heavens," etc. Small 4to, handsome cloth gilt cover, gilt edges ... ... *s.* *d.* 15 0

"Sir Robert Ball has always found time to do very much for the amateur astronomer besides his more serious work, but it is doubtful whether any of the very many of the books which bear his name will rival in popularity and utility the latest. . . . Small in size, it is yet admirable in detail, and so clear, well arranged, and comprehensive, that not only the beginner, but the far more advanced student will find it of extreme value."—*Daily Graphic.*

The Moon, a full Description and Map of its principal Physical Features. By Thomas Gwyn Elger, F.R.A.S., Director of the Lunar Section of the British Astronomical Association, ex-President Liverpool Astronomical Society. Royal 8vo, cloth. Price net 5 0

The *Scotsman* says—"With its admirable map and its complete survey of the ground occupied by the more prominent stenographers of this country and the Continent, cannot miss a hearty welcome from all who are interested in this important branch of astronomical knowledge."

Extract from Preface.—Great care has been taken in the preparation of the map, which, so far as the positions of the various objects represented are concerned, is based on the last edition of Beer and Madler's chart, and on the more recent and much larger and elaborate map of Schmidt; while as regards the shape and details of most of the formations, the author's drawings and a large number of photographs have been utilised. Even on so small a scale as eighteen inches to the moon's diameter, more detail might have been inserted, but this at the expense of distinctness, and hence would have detracted from the value of the map for handy reference in the usually dim light of the observatory, without adding to its utility in other ways. Every named formation is prominently shewn: and most other features of interest, including the principal rill-systems, are represented, though, as regards these, no attempt is made to indicate all their manifold details and ramifications, which, to do effectually, would in very many instances require a map on a much larger scale than any that has yet appeared.

Map of the Moon. In One Sheet. By T. G. Elger, F.R.A.S. On sheet, net 2s. 6d., mounted on millboard and varnished ... 4 0

Handy Book of the Stars used in Navigation. How to find them, and how to use them in getting the Ship's Position and Correction of the Compass. By Captain W. B. Whall. Oblong 4to, cloth 7 6

"Just what the young star navigator wants."

Astronomy for Every-Day Readers. By B. J. Hopkins, F.R.A.S. With numerous Illustrations. Crown 8vo, paper boards 1 0

Cloth gilt 1 6

The Wonders of Nature—chiefly Astronomical. By Professor Rudolph, U.S. New and revised edition by Alexander Brown, LL.D. Crown 8vo, with 16 Illustrations, cloth gilt ... 2 6

A Short History of Astronomy, with Vocabulary of Astronomical Terms, and the Distances, Densities, and Magnitudes of the Sun, Moon, and Planets. By George Knight net 0 6

POPULAR AIDS TO THE STUDY OF

ASTRONOMY.

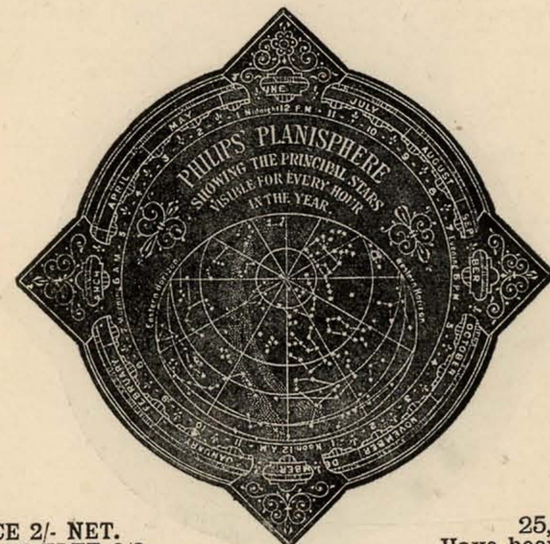
A NEW AID TO THE STUDY OF THE STARS.

PHILIPS'

REVOLVING PLANISPHERE,

SHEWING

The principal Stars visible for every hour in the year.



PRICE 2/- NET.
POST FREE 2/3.

25,000 Have been Sold.

This novel Planisphere consists of a circular disc on which the principal Stars visible from our latitude are clearly indicated. By means of an exceedingly simple arrangement the disc may be made to revolve in such a way as to show only those stars visible at any given time. In addition to this may be shown the varying time of sunrise and sunset during the whole year.

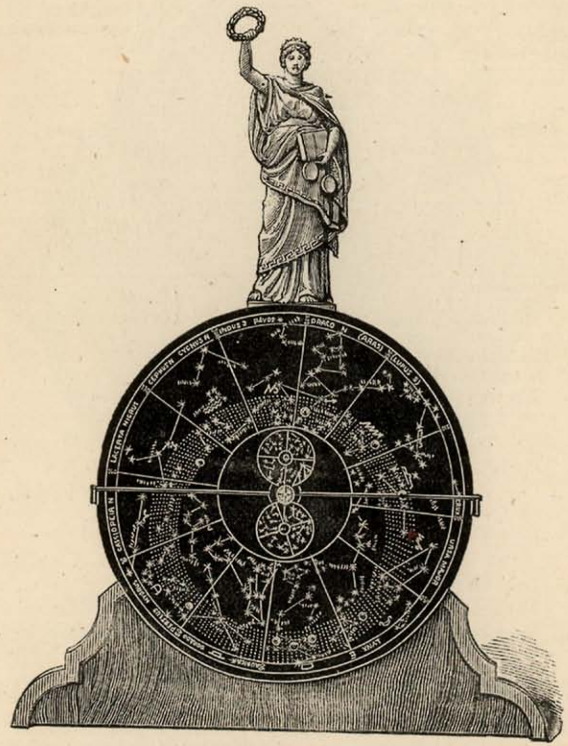
The Stars are clearly shown in white on a dark ground.

The Publishers invite the attention of all interested in Astronomy to this *unique* and *cheap* publication, which, it is hoped, will tend to popularise and simplify the study of the Heavens.

An Edition of this Planisphere may also be obtained, printed on a tough transparent Paper, and fitted with a portable compartment for holding a candle, which, when lighted, makes all the stars clearly visible, and may be used at night time in the open air.

PRICE COMPLETE 2/6 NET.

	s. d.
The Celestium, or Patent Astronomical Calendar, designed by A. W. Molesworth, B.A. For recording and illustrating, in miniature, the daily and hourly positions of the heavenly bodies as they pass through the Signs of the Zodiac. With descriptive pamphlet ... ...**A. DISC FORM,** from **10s. 6d.** to	30 0
——— **C. CLOCK FORM,** or Stellar Celestium Clock, rotating by clockwork, showing the rising and setting of the stars and planets, with the proper motions of the latter in the opposite direction, and the simultaneous motion of the Polar constellations of both Hemispheres that never rise or set for us	147 0



AN UNRIVALLED ATLAS FOR TEACHERS.

Edited by J. SCOTT KELTIE, H. J. MACKINDER, M.A., and E. G. RAVENSTEIN, F.R.G.S.

PHILIPS' SYSTEMATIC ATLAS,

PHYSICAL AND POLITICAL,

SPECIALLY DESIGNED FOR THE USE OF

HIGHER SCHOOLS AND PRIVATE STUDENTS.

Containing over 250 Maps and Diagrams, in 52 Plates, with an Explanatory Introduction, and a Complete Index of 12,000 Names.

BY

E. G. RAVENSTEIN, F.R.G.S.

Handsomely bound in cloth, imperial 4to, Maps flat, or the Maps folded in 8vo, price 15s.

CLASSIFIED SUMMARY OF CONTENTS.

	No. of Maps and Diagrams.
I. Mathematical Geography and Astronomy	13
II. Physical Geography—	
General Maps...	7
Contoured Maps	16
Sections	10
River Basins	2
Geological Maps	4
Volcanoes	4
Ocean Currents	5
Co-Tidal Line	2
Temperature of the Ocean	3
Salinity of the Sea	1
Climatology	10
Magnetic Phenomena... ...	3

	No. of Map and Diagrams
II. PHYS. GEOGRAPHY (*cont.*)	
The Geographical Distribution of Plants	12
The Geographical Distribution of Animals...	17
III. Political Geography –	
General Maps...	3
Languages and Religions...	9
Density of Population ...	12
Parts of Europe	63
Parts of Asia	13
Parts of Africa	10
Parts of Australasia and the Pacific	9
Parts of America	27

CLEMENTS R. MARKHAM, Esq., C.B., F.R.S., President of the Royal Geographical Society, says:

"Arranged with very great care and ability, and admirably executed."

"THE ATHENÆUM" says:

"Mr. Ravenstein has compressed a wonderful amount of information into the fifty-two plates of his Atlas. The spelling of the names themselves seems faultless, and we have failed to find any flaw in the index."

"THE STANDARD" says:

"Special attention appears to have been given to the geographical aspect of politics and commerce, and the value of the Atlas as a practical work of reference is increased by a clear and well-arranged index of twelve thousand places."

Dr. H. R. MILL, F.R.S.E., Librarian Royal Geographical Society, says:

"The Physical Maps are remarkably clear, and the letterpress contains information which I have never before seen in a connected form or in any form so clearly and concisely put."

SCHOOL EDITION
OF
PHILIPS' SYSTEMATIC ATLAS
POLITICAL AND PHYSICAL,

SPECIALLY DESIGNED FOR TRAINING COLLEGES AND PRIVATE STUDENTS.

Containing 170 Maps and Diagrams in 41 Plates, and a Complete Index of over 12,000 Names.

By E. G. RAVENSTEIN, F.R.G.S.

Imperial 8vo, handsomely bound, cloth, price 10s. 6d.

THIS Edition is designed for the use of Students in Higher Schools and Training Colleges, who, desiring a book adequately treating of Geography in its physical and political aspects, will find all that they require in one at once more moderate in price and less exhaustive than the ordinary edition of the SYSTEMATIC ATLAS.

With this view the present edition, although an abridgment of the original work, contains all the general Maps, so that it may be used in conjunction with the more expensive book; and care has been taken to include, in addition to others, those plates which deal with the aspects of Physical Geography of more special educational interest, such as contoured Maps of the continents and the British Isles, and charts of the Ocean Currents and the Atlantic Ocean.

PHILIPS'
HANDY VOLUME ATLAS
OF THE
WORLD,
Containing Seventy-two New and Specially Engraved Plates, with Statistical Notes and Complete Index.

By E. G. RAVENSTEIN, F.R.G.S.,

Hon. Fellow of the Geographical Societies of Edinburgh, Amsterdam, Lisbon, and Frankfurt-on-Main.

Neatly bound in Cloth, with rounded corners. Size when closed, $6\frac{1}{4}$ *by* 4 *inches,* 5/.

Or in French Morocco, gilt edges, in cardboard box, 7/6.

The notes accompanying each Map do not pretend to supersede a geographical text-book, but merely to supplement it. The areas and populations of the various countries are given in accordance with the most trustworthy information, and an attempt has beeen made to classify mankind according to religions and languages.

LANTERN SLIDES AND APPARATUS.

GEOGRAPHICAL LANTERN SLIDES.
Arranged under the direction of the Curators of the Educational Museum belonging to the Teachers' Guild and the Headmasters' Association.

Philips' Maps, Political, Physical, and Commercial.
A set of 114 Maps and Diagrams, by far the best that has been issued as lantern slides. Most of those previously sold, besides being antiquated, contain far too much detail, and when projected upon the screen, appear as a confused mass of unintelligible names, lines, etc., whereas those in this series have the coast lines, principal rivers, mountain chains, and chief towns boldly marked.

In the case of the Political Maps, boundaries are clearly shown; whilst in the Physical Series the heights of the land are shown in tints of colour; and in the Special Railway Maps, only the principal lines of railway are indicated.

Nearly the whole of the names, and most of the details, when shown as a 9-ft. Map upon the screen, can be read at a distance of 20 ft.; and if enlarged still more, could be easily distinguished at a greater distance.

Price—Plain, 1/-; Well Coloured, 2/6 each.

Geographical Association Slides.
A Series of about 248 Lantern Slides, consisting of Coloured Maps, Diagrams, and Sections to Illustrate the Physical and Commercial Geography of the Continents and the British Empire.

Price—Coloured, 3/- each.

Greswell's "British Colonies."
A New Series of 159 Lantern Slides, selected and arranged to illustrate the "British Colonies and their Industries," by the Rev. WILLIAM PARR GRESWELL. Many of the Subjects have been specially Photographed for this set, and great care has been exercised in selecting the most typical views suitable for teaching purposes.

Price—Plain Photographic Slides 1/-; Coloured, 2/6 each.

Physiography.
An entirely New Series of about 150 Slides, specially selected and arranged by R. A. GREGORY, to illustrate the Syllabus of the Science and Art Department. As far as possible the subjects are direct Photographs from nature.

Price—Plain Photographic Slides, 1/-; Coloured, 2/6 each.

Geography of	*EUROPE*	*140 Slides.*
,,	*ENGLAND AND WALES* ...	*202* ,,
,,	*SCOTLAND*	*81* ,,
,,	*IRELAND*	*78* ,,
,,	*INDIA*	*54* ,,
,,	*AUSTRALIA*	*46* ,,

IN PREPARATION.

Sets on France, Spain, Norway, Russia, South Africa, etc., etc.

Detailed Catalogue of Lantern Slides, Post Free 3d.

TELESCOPIC ASTRONOMY.