The Journal
of the
Astronomical Society of
South Africa.

Vol. 2. NOVEMBER, 1926. No. 1.

THE STRUCTURE OF THE ATOM.*

By B. F. J. Schonland, M.A., Ph.D., F.R.S.S.A.

The molecular theory of matter has taught us that matter of all kinds is made up of minute particles, and that these particles may be divided up into a limited number of types—the 92 atoms of the 92 known chemical elements. These atoms are in size beyond the limit of the microscope, having a diameter of the order of one hundred-millionth of a centimetre. Atoms of different elements differ in size and mass and chemical properties from one another.

It is natural that, very early in the history of the atomic theory, expression should have been given to the feeling that these atoms were themselves built up of smaller, subatomic units, the number and arrangement of which determine the properties of the different kinds of atoms. Such an idea is suggested by the strong similarity in the properties of elements such as chlorine, bromine, and iodine, which seems to imply that their atoms have some resemblance to one another. The rhythmical connection between many of the properties of atoms and their masses, stated in what is called the Periodic Law, emphasises this idea, and suggests that atomic architecture shows recurrent features.

The work of the last thirty years has shown this view to be correct—for the 92 chemical atoms are indeed complicated structures composed of but two subatomic units or bricks. Thus it has been found that matter of every kind, when exposed to certain agencies such as heat, ultra-violet light, X-rays, or the electric discharge, gives out negatively electrified particles of subatomic dimensions. These particles are always the same whatever may be the source from which they are derived; those from hydrogen, for example, are identical with those from lead. They are called "electrons," and are constituent parts of the atom of every element. An electron carries a negative charge

---

* An address delivered at the Annual Meeting of the Society on 1926, July 28.

of $4{\cdot}774 . 10^{-10}$ electrostatic units, and has a mass 1/1846th part of the mass of the lightest atom, that of hydrogen. Its radius, assuming it to be spherical, is about $2 . 10^{-13}$ cms., or 1/50,000th of the radius of an atom.

Since matter in its ordinary state is not electrically charged, it is not surprising that the other constituent of the atom is a positively charged particle. It is found to have a charge numerically equal to that carried by the negative electron, and a radius probably much less than that of an electron. It differs, however, from its negative counterpart in having a mass which is practically equal to that of a hydrogen atom. This, the other and by far the heavier building-stone of matter, is called a "proton."

Some idea of the size of these particles, the only two real "elements," may be got by supposing an atom to be magnified until its diameter is equal to that of the earth's orbit. On this scale the negatively charged particle, the electron, would have a diameter about half that of the earth itself, and the positively charged proton would be even smaller—perhaps no more than two miles in diameter. The mass of an electron is $8{\cdot}97 . 10^{-28}$ gms., its radius probably $1{\cdot}85 . 10^{-13}$ cms., so that its "density," calculated in the usual way, must be 34,000,000,000. High as this figure is, it is at least 2,000 times smaller than the density of a proton. It is evident that to build ordinary matter, with its average density of about 5·5, from such bricks, they must be very sparsely distributed.

It has been shown that the mass of an electron can be wholly ascribed to the electric charge which it carries. If the same is true of a proton, ordinary matter is simply an aggregate of electrical charges, and so is a form of energy. Some speculations as to the source of stellar energy suggest that in the interior of a hot star we are witnessing the annihilation of matter and the transformation of the concentrated electromagnetic energy, of which it is composed, into the more familiar form of waves of heat and light.

It would take too long to attempt to show you how, by a long and laborious chain of work, the present state of knowledge as to atomic architecture has been reached. I propose to adopt the opposite course, and to try to show how the established structure of the atom fits in with experimentally ascertained facts. This structure has been called the Rutherford-Bohr atom, after the two men who have been largely responsible for its discovery.

The atom is a planetary system in which the planets are negative electrons, which revolve around a central positively charged nucleus. An atom of an element of atomic number* N consists of N negatively charged planets revolving round a

---

* The atomic number of an element is its number in a table of the elements arranged in order of ascending atomic weights.

nucleus carrying N positive or proton charges. Thus the simplest and lightest atom, hydrogen, which has an atomic number 1, consists of a single electron revolving round a single proton. The next element, helium, has an atom composed of two electrons revolving round a nucleus carrying two positive proton charges. Gold, the 79th element, has a nucleus carrying a positive charge equal and opposite to the total negative charge on all its 79 planets.

In the atomic planetary system the gravitational forces calculated from Newton's law are easily shown to be quite negligible in comparison with those due to the electrical attractions and repulsions involved. There is, however, a formal resemblance between our solar system and the atom, because the law of force in both cases is that of the inverse square. There is one difference—in the atom the negatively charged planets repel each other, while in the solar system they are attracted not only by the sun but by each other.

Except in the case of hydrogen, the positive nucleus is a complex system in itself. Its contains both positive and negative charges, both protons and electrons, and the observed positive charge upon it is a "nett" charge. In the case of oxygen, for example, the nucleus consists of 16 protons and 8 electrons all packed together and giving a nett nuclear charge of 8 proton units. If we compare the weights of an oxygen and of a hydrogen atom the electrons in both cases can be ignored, and the former should weigh 16 times as much as the latter.

In spite of its complexity, the atomic nucleus occupies a space not much larger than that filled by a single electron. The atomic nucleus of gold, for example, contains 197 protons and 118 electrons, and yet has been found by direct experiment to have a diameter of about 10^{-12} cms., only five times the probable diameter of a single electron. How this complex structure can fit into such a confined space is little understood, but is the subject of much investigation at the present time.

We may obtain a useful picture of atomic structure by supposing the atom of, say, oxygen magnified until its diameter coincides with that of the earth's orbit. Viewed on this scale, it would consist of a central sun or nucleus of diameter about equal to that of the earth itself, carrying a nett charge of $+8$ proton units, and of eight negative planets of diameter about half that of the earth revolving round it. Two planets or electrons would be in orbits of the size of that of Mercury, and the remaining six in orbits similar to that of the earth. The planets would in this case all have masses equal to about 1/30,000 part of the mass of the nucleus. It is clear that the atom, and so matter itself, is like the Irishman's net, mainly composed of "holes"—an exceedingly tenuous structure whose impenetrable portions are extraordinarily minute compared with the penetrable portions.

These facts have been established by a process of direct experiment which will require but little explanation to this audience, for it consists of examining the effects produced by firing "comets" into the atomic system. Consider what would occur if a charged body of mass, dimensions, and charge, of the same order as those of the central nucleus or sun, were fired at a speed of some 19,000 miles/sec. through the atomic system I have described. The comet would experience and exert forces from and on both nucleus and planets. These forces would, as we have seen, be electrical and not gravitational in origin. Our comet would be moving so fast that its passage through the atomic system would not appreciably deviate it from its course unless it chanced to pass very near to the nucleus. It is more likely to approach near to a planet, in which case it would throw it out of its orbit and perhaps cause it to leave the atomic system altogether. It is easy to see that a slower comet would be more likely to suffer deviations from its path, and would also do more damage to the planetary system. It stays a longer time in the system, and the forces of attraction or repulsion have a longer time in which to act. Again, a lighter comet travelling at much the same speed as the one we have considered would be still more deviated from its path, but would have a less disastrous effect on the planetary electrons.

By a piece of great good fortune two different kinds of comet are available for this purpose. The disintegration of radioactive substances gives rise to high-speed "comets" of the kind we have discussed. The heavy comet is the α particle, and consists of the nucleus of a helium atom. The lighter comet is the β particle, and is simply a high-speed electron. The passage of these subatomic particles through atomic systems has been the subject of much study by many observers using a variety of methods. One of these, while not the most accurate, is very striking and definite in its results. It consists in photographing the path of a comet in its passage through thousands of atoms of a gas. Such photography is rendered possible by the fact that every time a "comet" throws an electron or "planet" out of an atom, the ejected planet and also the residue of the atom are electrically charged. It was discovered by C. T. R. Wilson that such electric charges, minute as they are, can serve as centres of condensation for super-saturated water-vapour. Accordingly *every* dislodged planet and *every* despoiled atom in the path of the comet can be made visible by the condensation of a small drop of water on it.

[Here lantern slides of the tracks of α and β particles were shown.]

By methods of this kind the main features of atomic structure, as already stated, have been elucidated. The study of the deviations of massive comets by atomic nuclei enables the charge and dimensions of the nucleus to be determined. The study of the ejection of planetary electrons gives information as to their number and position and orbit in the atom. Both nuclear and planetary encounters afford information as to the law of force prevailing at these minute distances.

At this stage an important point must be emphasised. If the atomic system were to lose one planetary electron, or to be "ionised," to use the correct technical term, its individuality is not then permanently altered. The residual atomic system or ion is, it is true, similar in many respects to the completed atom of the element immediately preceding it. But the ionised system has a positive charge since it has lost an electron, and will therefore sooner or later attract another electron to fill the gap produced by its predecessor's departure. Usually, if one atom is ionised, a great many others are in a similar state—so that the capture of a fresh electron is not a matter of much difficulty. Thus the characteristics of an atom are only temporarily altered by ionisation, even in the extreme case when all the planetary electrons are lost.

The whole individuality of the atom lies in its nucleus. If this alters its charge, the atom becomes a new and different one, for a change in nuclear charge involves a permanent change in the number of planetary electrons circulating round it. Such an alteration in the nucleus is rare in the case of the ordinary elements, but it occurs spontaneously in the case of the 11 most complex elements, of which radium is the most celebrated. The nucleus of the atom of uranium is the most complex one* known to exist. It breaks up spontaneously with the emission of an α particle from its nucleus, and becomes a new element uranium X_1. This in turn breaks up only to produce a long line of unstable descendants, one of which is radium. Finally, this unfortunate family begets a simpler and more stable element, lead.

It has not been found possible, as yet, to affect the rate of disintegration of these radioactive elements in any way whatever. Experiments have, however, been successfully made by Rutherford to accomplish the artificial disintegration of the nuclei of the ordinary elements. The method consists in firing the swiftest and most massive comets we possess—fast α rays—through matter. Some of these comets, about twenty in every million, will make a "head-on" collision with an atomic nucleus. The result of such a collision, in the case of most atomic nuclei, is simply that the positively charged α particle is repelled backwards by the positively charged nucleus. But in the case of seven atoms, amongst which are those of nitrogen and aluminium, it was observed that the nucleus was unable to stand the shock, and was partially disintegrated. There emerged from the bombarded material a number of fragments of these shattered nuclei which, when examined, proved to be protons.

---

* 238 protons and 146 electrons are in its nucleus.

These remarkable experiments constitute a realisation of the alchemist's dream of the conversion of one chemical element into another. The charge upon the nucleus is altered as a result of the catastrophe which has overtaken it, and the number of planetary electrons will alter to conform to the new nuclear charge.

[A Wilson photograph was shown of the track of a "comet" which disintegrated an atomic nucleus.]

The energy possessed by the proton can be measured, and the remarkable result emerges that this nuclear fragment has in many cases more energy than could have been given to it by the α ray by direct collision—30 per cent. more in the case of aluminium. This extra energy probably comes from the nucleus itself, and must be part of the huge store contained therein. That there is such a store of energy is shown by the energy of the rays emitted by radioactive substances, whose nuclei are spontaneously disintegrating. That it is extremely difficult to unlock is shown by these experiments of Rutherford. Speculation on the utilisation of subatomic energy has to some extent died down as a result of these experiments, for the possibilities of its achievement seem as remote as they are dangerous. In the astronomical world it has been evoked as a source of stellar energy, but it appears that there is an unfortunate conflict of experimental evidence on the point.

We have so far dealt only with the results of Sir Ernest Rutherford and his school, but perhaps the most remarkable development of the theory of the atom has arisen in explaining the connection between atomic structure and the emission and absorption of light and X-rays. This is largely due to the Danish physicist Bohr. It is well known that every element, and so the atom of every element, possesses a characteristic spectrum. In the visible region these spectra are often exceedingly complicated, and they extend into the infra-red, the ultraviolet, and the X-ray region of wave-lengths. All these "characteristic radiations" of the atom are now well known to be electromagnetic waves, differing only in wave-length from those sent out by a wireless transmitter. That they originated in the motion of the planetary electrons has long been known, but no explanation of their characteristic and invariable nature was possible until, in 1913, Bohr put forward a new and startling hypothesis. This depends upon the statement that the planetary electrons in the atom are revolving under dynamical laws quite different from those which govern such systems as have previously been examined. The new "quantum" conditions for the revolution of a planetary electron are at first sight of the most arbitrary kind. They lay down certain specified orbits in which the electrons are permitted to revolve, certain specified planes in which these orbits are to lie, and specified eccentricities and rates of precession of elliptical orbits. Only in these orbits, planes, and with these eccentricities and rates of precession can the planetary electrons exist. These apparently arbitrary conditions for planetary motion are now known to be derivable from one very fundamental dynamical law, a law which had not previously been suspected because all previous observation has been made on matter in bulk. It is only when we deal with individual electrons and protons instead of billions and billions that a new world of dynamics is revealed.

In each orbit specified by these "quantum" conditions, a planetary electron possesses a different amount of energy. The nearer it is to the nucleus, generally speaking, the less its energy, by which I mean the sum of its kinetic and potential energies.

The process of the emission of light waves by such an electron is as follows:—When suitably stimulated by some agency, an electron which is in an orbit A will receive energy enough to move it further from the nucleus to some outer orbit B. The inner orbit A is then vacant, and under the attraction of the positively charged nucleus either the original electron, now in orbit B, or some other electron in an outer orbit C, will move back into the orbit A. In such a move energy is gained by the electron. According to Bohr's theory the whole of this energy is radiated out as light (or X-rays) of a definite wave-length λ, which is given by the equation

$$\lambda = {}^{\kappa}\!/_{E_B - E_A} \quad \text{or} \quad {}^{\kappa}\!/_{E_C - E_A}$$

according as the jump is from orbit B to orbit A or from orbit C to orbit A.

In this equation E_A, E_B, and E_C, are the energies of an electron executing orbits A, B and C respectively, and κ is a constant, the value of which is known.

The theory therefore accounts for the characteristic wave-lengths of the emission spectrum of an atom in terms of the definite and characteristic nature of the planetary orbits in the atom.

Generally speaking, the absorption spectrum of an element is explained in the same way. The atom will absorb light of a wave-length λ if it enables a planetary electron to jump outwards from an orbit A to a vacant orbit B, where

$$\lambda = {}^{\kappa}\!/_{E_B - E_A}$$

In the case of the atom of hydrogen, which has only one planet, Bohr and Sommerfeld have calculated the specified orbits in full detail, and hence derived the wave-lengths of the spectral lines with an accuracy of one part in 200. Moreover, the existence of a new series of lines in the infra-red has been predicted and the prediction confirmed by measurements in this region. The success of the theory in dealing with the hydrogen spectrum has been remarkable.

In the case of more complicated atoms a direct mathematical analysis of the orbits is quite hopeless, a problem of *n* revolving bodies where *n* is greater than two and even reaches ninety-two. The exact prediction of the spectrum of elements other than hydrogen can therefore not be expected. But the reverse process, the utilisation of the observed spectrum to find out the nature of the electronic orbits, has already led to results of the greatest importance. It is possible to determine from the wave-lengths of the lines in the spectrum of an element the nature of the planetary orbits which gave rise to those lines, and in this way to determine to some extent the planetary structure of even the most complicated atoms.

In this way the planetary orbits shown in the table below have been determined. In this table the first orbits are those nearest to the nucleus, and the last are on the periphery of the atom. The first column contains the usual name by which the orbit or group of orbits is known. The second states whether, disregarding perturbations, the orbit is a circle or an ellipse, and the third shows the number of planetary electrons revolving in orbits of a particular type. The table gives the atomic structure of the gas niton, which has 86 planetary electrons.

NITON (86).

Orbit.		Nature of Orbit.	Number of Electrons in such Orbits.
K		Circle	2
L	L_1	Ellipse	2
	L_2	,,	2
	L_3	Circle	4
M	M_1	Ellipse	2
	M_2	,,	2
	M_3	,,	4
	M_4	,,	4
	M_5	Circle	6
N	N_1	Ellipse	2
	N_2	,,	2
	N_3	,,	4
	N_4	,,	4
	N_5	,,	6
	N_6	,,	6
	N_7	Circle	8
O	O_1	Ellipse	2
	O_2	,,	2
	O_3	,,	4
	O_4	,,	4
	O_5	,,	6
P	P_1	Ellipse	2
	P_2	,,	2
	P_3	,,	4

This discovery of the arrangement of the planetary electrons promises to be of great value in explaining the chemical properties of the elements. These are determined by what may be loosely called the "affinity" of one atom for another. But chemical combination consists of the "interlocking" of the outer electrons of two or more atoms, and consequently the chemical affinity is determined by the degree of strength with which a nucleus binds its outermost electrons to itself. Thus chemical properties depend upon the nature of the outermost orbits and the number of electrons in these orbits. The following tables must suffice to show that substances with similar chemical properties have similar arrangements of outermost electrons. The number of outermost electrons is shown in heavy type.

A close examination of these results, which are all derived from optical and X-ray spectra, throws much light on chemical problems. One of the immediate triumphs of the theory was the prediction of the chemical properties of a previously undiscovered element with 72 planetary electrons. By the aid of this forecast the element, hafnium, has been discovered in considerable quantity.

These tables have, however, another application of more interest to astronomers. The usual optical spectra of the elements, like their chemical properties, are largely determined by the outermost electrons. It has been shown how the emission of the optical spectrum involves (*a*) the displacement of one of these electrons to another orbit further out, and (*b*) the return of this electron, or another one, to the original orbit. During (*b*) a line of wave-length depending upon the nature of the orbits of departure and arrival will be radiated. The "series" of lines thus emitted constitute the typical *arc* or *flame* spectrum of the element.

Now the atom under special conditions may have had one electron removed, or be "singly ionised." In this case the process (*b*) will lead to the emission of a quite different spectrum, for the permissible orbits of revolution for the returning electron are now quite different. This spectrum, emitted from an atom which is at the moment singly ionised, is called the *spark* or the *enhanced* spectrum. Similar considerations apply to the lines emitted by an atom which originally lost 3, or 4, electrons, and is at the moment of emission doubly or trebly ionised. All these spectra will differ from one another. In the case of silicon all four spectra have been measured in the laboratory by Fowler, and all four are present in different stellar spectra.

Consider an atom which normally has N planetary electrons: when emitting its arc spectrum it still has N electrons, but when emitting its spark spectrum it will have only N — 1. We should therefore expect that its spark spectrum should be similar to the arc spectrum of the atom immediately preceding it, which has N — 1 electrons in its normal state.

I. Inert Gases.

Element.	No.	K.	L.	M.	N.	O.	P.	Q.
Helium	2	**2**	—	—	—	—	—	—
Neon	10	2	**8**	—	—	—	—	—
Argon	18	2	8	**8**	—	—	—	—
Krypton	36	2	8	18	**8**	—	—	—
Xenon	54	2	8	18	18	**8**	—	—
Niton	86	2	8	18	32	18	**8**	—

II. Alkali Metals.

Element.	No.	K.	L.	M.	N.	O.	P.	Q.
Lithium	3	2	**1**	—	—	—	—	—
Sodium	11	2	8	**1**	—	—	—	—
Potassium	19	2	8	8	**1**	—	—	—
Copper	29	2	8	18	**1**	—	—	—
Rubidium	37	2	8	18	8	**1**	—	—
Silver	47	2	8	18	18	**1**	—	—
Caesium	55	2	8	18	18	8	**1**	—
Gold	79	2	8	18	32	18	**1**	—

That this is so is shown most clearly by the elements hydrogen and helium. The latter has a spark spectrum which is practically identical with the Balmer series of hydrogen, part of the arc spectrum of this element. It was, in fact, long thought that this series of lines first found in ζ Puppis was due to hydrogen, but it is now certain that they arise from helium with but one electron. In the same way the 1st or arc spectrum of sodium, the 2nd or spark of magnesium, the 3rd of aluminium, and the 4th of silicon, have a common structural resemblance, for they all arise from atoms which at the moment of emission have 11 planetary electrons. These considerations have an important application in astronomical physics, which can perhaps be best illustrated in the case of the sun. In the spectrum obtained from the sun's photosphere only 36 of the 92 elements we know of show themselves by their characteristic arc spectra. For example, rubidium and cæsium appear to be absent and potassium is weak, while sodium is strongly in evidence. The explanation of the apparent absence of the first two elements was given by Saha as follows: rubidium and cæsium, if present, are in the singly ionised condition, and consequently in a position to emit not their characteristic arc lines, but another spectrum which, since it lies in the ultra-violet region, has escaped the usual methods of observation.

The question then arises as to what conditions will favour the production of spark or enhanced lines and weaken the intensity of the ordinary arc spectrum of an element. Three factors are involved: (1) high temperature, (2) weak binding of the outermost electrons to the rest of the atom, and (3) low pressure. A high temperature is necessary for the general agitation of the atoms to reach such a pitch that collisions may result in the dislodging of more than one electron, while a weak binding of at least two outer electrons will facilitate this double ionisation. Finally, a low pressure will make it unlikely that an ionised atom will recapture more than one electron very quickly. The first and third of these factors depend upon the nature of the star, and the second upon the nature of the element whose spectrum is being looked for.

Thus calculation shows that when the pressure in the star reaches one atmosphere, the following temperatures are necessary for 50 per cent. of the atoms of an element to be singly ionised, and thus capable of emitting or absorbing their enhanced or spark spectrum.

Sodium	7200°C.
Potassium	6300°C.
Rubidium	6000°C.
Cæsium	5700°C.

These very general considerations may serve to indicate how a systematic examination of stellar spectra promises to be of great value in determining stellar temperatures. The presence or absence of certain series of lines in the stellar spectrum indicates the condition of ionisation of the gas concerned, some lines only appearing when a sufficiently large proportion of the atoms are ionised (by the loss of one, two, or three electrons), and some lines disappearing only when practically all the atoms are ionised.

Further than this I will not trespass into a field which is as yet in its infancy, except to draw your attention to the agreement between the values of stellar temperatures thus derived, and those found by quite other methods. These are shown in the table below:

Spectral Type.	Temperature from Energy-distribution Curve (Sampson).	Temperature from Study of Ionisation and Spectra (Fowler and Milne).
Bo	25,000° A	26,500° A
Ao	13,100°	10,000
Fo	8,900	7,500
Go	6,200	6,000
G5	5,100	5,300
Ko	4,200	4,500
Mo	3,400	3,000

One further remark may be made. As the temperature of a star gets higher, the chance of ionisation increases, and given a high enough temperature, it is quite likely that an atom will lose a great many (perhaps all) of its planetary electrons. Under such conditions the effective radius of the atom is much diminished, and almost naked nuclei will take the place of the complex systems we have discussed. Thus at the enormous temperatures which prevail in the interiors of many stars, the atoms will have very small radii, and in spite of being compressed more tightly than the atoms of a solid, will still behave as the atoms of a gas. The recent announcement of the existence of a star with a density of 70,000, and which obeys the gas laws, is explicable in this way, and indeed is not surprising when we reflect that the impenetrable portion of the atom has a density of 34,000,000,000. One is tempted to remark that the atoms discard their outer garments owing to the excessive heat.

This concludes what I fear is an unsatisfactory account of a very marvellous achievement, for, in spite of your kind attention, it is impossible to convey to you in an address of this kind much impression of the *reality* of these minute structures. A conviction of this kind can only be gained by a study of the methods employed to unravel the problem, and by appreciation of the accurate quantitative agreement on fundamental points revealed by quite different methods of experiment.

CIVIL TIME SUN-DIALS.

By P. D. Strachan, M.A., M.D.

The term, "Civil Time Sun-Dials," which forms the title of this paper, is used to denote types of sun-dial which give the legal civil time without calculation, no addition or substraction for difference of longitude or for equation of time being required. As explained by Dr. Halm in the instructions issued to members with directions for the making and setting up of his admirably simple and ingenious universal dial, corrections for longitude and for equation of time have to be applied to the local sun time to obtain the legal civil time.

It is assumed that readers are familiar with the general principles on which the commoner types of dial are constructed. The writer regrets that he is unable, for the benefit of those who lack an elementary knowledge of the subject, to mention any English monograph which is not possibly out of print. The article on dials in the Encyclopædia Britannica is very good, but it does not give simple explanations of graphic solutions which any intelligent reader could understand: a knowledge of spherical trigonometry is assumed. The best work on sun-dials known to the writer is that by M. G. Bigourdan, published under the title, "Gnomonique," by Messrs. Gauthier Villars et Cie, of Paris. It contains the most lucid explanation of graphic constructions which the present writer has ever seen, and it gives the trigonometrical solutions as well.

Dr. Spencer Jones has kindly referred the writer to one English work, "The Book of Sun-Dials," by Margaret Gatty, third edition, with additions by H. K. F. Eden, Eleanore Lloyd and Wighan Richardson, which appeared in 1890, and one German work, "Gnomonik," by J. J. Littrow, of the Vienna Observatory (1838). The Encyclopædia Britannica gives an extensive list of books ancient, medieval and modern.

Graphic constructions are useful for the purpose of enabling non-mathematical readers to understand the principles. The writer, however, does not recommend them in practice. To get by means of a graphic construction a result free from serious errors one requires to be an expert draughtsman, and to use good drawing instruments. The trigonometrical calculation of the value of each angle gives a numerical result free from sensible error. The angle is then measured on a circle by means of its chord. Only two measurements are required, the radius of the circle, which is arbitrary, and the length of the chord, and both of these measurements are rectilineal. The use of protractors should, if possible, be avoided. For the benefit of those who can do trigonometrical computations with the aid of logarithms, or more conveniently, with a slide-rule, the following formulæ are given:—

For the equatorial dial $x = A$;
For the horizontal dial $\tan x = \sin L \tan A$;
For the vertical dial facing North or South $\tan x = \cos L \tan A$;

where x is equal to the angle between any time line on the dial and the noon line, L equals the latitude, and A equals the hour angle of the Sun before or after noon, measured at the rate of 15° to every hour.

For the chord:—$\text{Chd } A = 2\, r \sin \frac{A}{2}$;

where A is any angle, and r is equal to the radius of the circle. A good table of chords for unit radius is contained in Chambers' "Mathematical Tables."

In the ordinary theory the Sun is treated as if it were a point of light. A refinement which is not always mentioned consists in taking into account the apparent angular diameter of the Sun, which amounts to about half a degree. It is better to use the edge of the umbra than that of the penumbra as the time indicator, the former being better defined. In the forenoon the edge of the umbra corresponds to the western edge of the Sun; in the afternoon, to the eastern. Consequently the hour angle used in the construction or calculation ought to be a quarter of a degree less than the true hour angle of the Sun's centre. The time difference due to a radius of a quarter of a degree amounts to one minute when the Sun is on the equator, and never much exceeds a minute. Where the time indicator is the shadow of a stretched thread or wire, or an image of the sun, no such correction is required; for here the indicator is the centre, not the edge.

A final practical hint may here be given:—

To prevent irretrievable mistakes in the engraving of the lines on stone or metal, it is well to draw the dial first on paper, and to engrave the lines through the paper; but the paper must be pasted upon the dial surface, and allowed to dry, before the drawing is made; otherwise, serious distortions may occur.

We now proceed to a discussion of the subject matter proper of this paper.

The question of longitude may be dismissed in a few words.

There are two ways of correcting any dial for the difference of longitude. The first method is by displacing all the time lines so as to make them fast or slow by the required amount. To make fast, the hour angles used in the construction or calculation are increased before noon and diminished after noon by an amount equal to the difference between the longitude of the standard meridian and the longitude of the place where the dial is to be set up; to make slow, the same process is reversed. In South Africa the standard meridian for time is 30° East of Greenwich, and passes through Natal not far from Pietermaritzburg. For instance, to draw the line for 9 a.m. on a dial to be set up at longitude 25° E., one makes it fast by using the hour angle 50° instead of 45°. On the same dial the hour angle used for 3 p.m. would be 40°. The hour angles referred to are, of course, hour angles of the Sun, not the angles on the dial, which, except in the case of the equatorial dial, differ from the Sun's hour angle by variable amounts.

The second method consists in rotating the whole dial about its style-axis or an axis parallel thereto through an angle equal to the difference of longitude. The dial then becomes in all its parts oriented in the same way as a similar dial fixed in its normal position at the same latitude but at the longitude of the standard meridian, and will consequently show the same time as such a dial at the same instant, the parallax of the sun being negligible. Of these two methods, the first is to be preferred for fixed dials, the second for universal portable dials.

The correction for equation of time, being variable throughout the year, presents more difficulty, but the methods used are essentially the same as those described above. Analogous to the first method is the use of curved lines called analemmas. The use of an analemma is rendered possible by the fact that the Sun's declination changes throughout the year. If instead of the shadow of a line, the style-axis, we take as our indicator the shadow of a point in the style-axis, or the small image of the sun cast by a pin-hole somewhere in the style-axis, it will be observed that along any time-line the indicator moves backwards and forwards throughout the year with the changing declination of the Sun. The path of the indicator across the time-lines on any day can be determined from the known declination of the Sun. If on a number of dates throughout the year the position of the indicator at a particular civil time hour be marked by a point, and if all the points be joined by a free curve, we shall have the analemma for that hour of the day. The complete analemma for the whole year is an unsymmetrical elongated figure of eight. The points on the horizontal plane analemma are found by calculating the altitude and the azimuth of the sun at the civil time required. The altitude determines a circle, the azimuth, a straight line radial to the circle. The point sought is where the line cuts the circle. The detailed treatment of this problem is beyond the scope of this paper. The writer has one of these horizontal analemmas for the time, 8.50 a.m., on the parapet of his stoep. There are two pointed shadow-casters at different heights above the same centre on the stone, the higher for the summer half of the year, the lower for the winter, and the analemma is in two parts, broken off at the equinoxes. The higher point gives a more quickly moving shadow in summer.

The simplest analemma dial to understand and to make consists of a portion of a cylinder having as style a pointed rod fixed in its axis, or better, two axial pointed rods nearly meeting at their points. The indicator is the shadow of the one point or the centre of the bright space between the shadows of the two points, which are cast upon the concave or inner surface of the cylinder.

The cylinder when placed with its axis parallel to that of the Earth is an equatorial dial. Its sun-time lines are straight lines parallel to the axis, equally spaced for equal intervals of time.

These lines, corrected for longitude, are first drawn, say at intervals of ten minutes (time) or 2½°, on paper pasted to the cylinder. The length of the chord between any line and the noon line can easily be found graphically by dividing a circle equal to the circular cross section of the cylinder, or by calculation.

At right angles to all these lines is drawn a line representing the circular cross section of the cylinder through the space between the central pointers. This is the equinoctial line, along which the indicator passes on the days when the Sun is on the equator. Parallel to the equinoctial line are drawn from five to ten lines on either side of it, representing the paths of the indicator at various dates as far as the Solstices. The distances (d) of these lines from the equinoctial line can be calculated from the formula $d = r \tan \delta$, r being the radius of the cylinder perpendicular to a time line, and δ the Sun's declination on the date: or they can be obtained by a simple graphical construction. The dates are marked upon the path lines. In general there will be two dates of equal declination for each path line. The equation of time for each date is looked up, and a point is marked on the proper path line to one side or the other of a time line at a distance from it equivalent to the equation of time. The analemma is completed by joining all the points belonging to one time line with a free curve. In this type of dial all the analemmas have the same form, and have their corresponding parts running parallel to one another, so that when one has been completed the rest are easily drawn.

As the maximun and minimum equations of time amount to + 14 min. 24 sec., and — 16 min. 20 sec., on a dial divided into ten-minute intervals, the analemmas interlace in a confusing fashion. Each half of an analemma might be coloured differently, but, as colours are not durable, it is better to make two dials, one for the interval 21st June to 21st December, and the other for the other half of the year, or to engrave one set of half analemmas on a single dial, and have the other set engraved upon a thin metal cylindrical sheet, which can be clamped in position when its turn comes round. To make a cylindrical dial at a particular latitude show the time all day all the year round, the cylinder should be cut in such a way that its equinoctial circle is a half-circle, and the plane of section is horizontal when the dial is placed with its axis parallel to that of the earth. The line of section may be drawn empirically by drawing the equinoctial half-circle round the outside of the cylinder, placing the cylinder properly inclined in a bath, and pouring in water until the equinoctial half-circle is just immersed. The water-line is the line of section. Figure 1 presents the appearance of the engraved portion of a cylindrical dial rolled out flat, the cylinder having been cut for latitude 30°, and having its time lines displaced twenty minutes fast so as to show the time of longitude 30° east at longitude 25° east. A half analemma for 3 p.m. is drawn. The lines A, B and $C\ D$ are the cut edges of the cylinder. In a small figure they look like straight lines, but they are not really so. Near the equinoctial points O and O' they are nearly straight, and the angle L which they make with the 6 o'clock sun-time lines is equal to the latitude. If O be taken as the origin, and $O\ E$ as the axis of X, the equation of the curve A O B is $y = r \sin^{-1} (x \tan L/r)$.

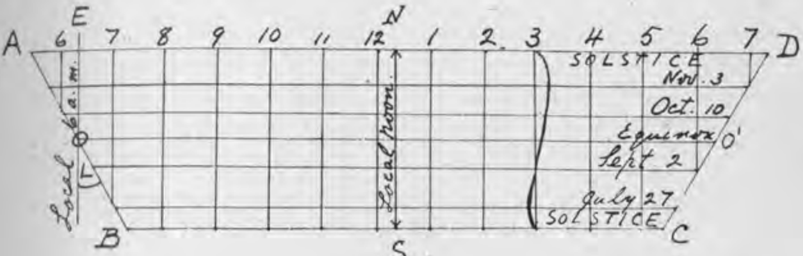

FIG. 1.

For any declination, δ, $x = r \tan \delta$.

The angle, $\sin^{-1} (x \tan L/r)$, must be expressed in circular measure. Within the limits of length required the lines are nearly straight. The above equations lead to a convenient formula for finding the number of hours before or after local noon at which sunrise or sunset takes place; the formula is $6 + {}^{1}/_{15} \sin^{-1} (\tan \delta \tan L)$, where the angle, $\sin^{-1} (\tan \delta \tan L)$, is expressed in degrees. If δ and L are in opposite senses, one of them must be put negative. The above formula can be used for finding points in the line of section of the cylinder. For the idea of putting analemmas upon a cylindrical dial the writer is indebted to an illustrated advertisement of the "Ferguson Solar Chronometer," which appears to be a dial of this type.

A very accurate form of analemma dial, the original form of which was invented by the Abbé Guyoux in 1826, is described and depicted at page 36 in M. Bigourdan's book. It was re-invented under the name "Solar Chronometer" by Flechet. It consists of an equatorially mounted disc capable of being turned about an axis through its centre. Near opposite ends of a diameter of the disc are two mountings perpendicular to its plane. One of these has a pin-hole, which projects a small image of the Sun upon a spherical surface upon the opposite mounting, on which is engraved an analemma with dates marked upon it. The time lines are engraved upon the margin of the disc. To obtain the mean time the disc is rotated until the centre of the spot of light comes upon that part of the analemma which corresponds to the date. The time is indicated by a line upon a fixed mounting adjacent to the margin of the disc. The same in principle is the sun-clock invented by Prof. W. E. Cooke, Government Astronomer of Sydney, N.S.W., and described in *Nature* of July 11, 1925, by Mr. F. Hope-Jones, Chairman of the British Horological Institute. In this dial the moving parts are ingeniously geared to the hands of a clock, which shows the time when the spot of light is brought to the analemma. A disadvantage of this type of dial is that, unlike other dials and clocks, it is not a going concern. It will show the time with great accuracy when gently urged to do so; left to itself it seems to stop.

In a work on Surveying by R. E. Middleton, O. C. Chadwick, and Col. J. du T. Bogle, which contains a good chapter on sun-dials (Part II, page 217), there is a description of an analemma dial which might be called the converse of the foregoing. The dial is an equatorially mounted hoop or short cylinder having the usual straight and parallel time lines on its concave surface. The axial style is the analemma. Instead of being a straight wire or edge, it is shaped like the revolution of a symmetrical analemma about its long axis. One edge or the other of the shadow cast upon the hoop is the part of the analemma corresponding to the season. The time is read from points where the time lines cut a continuous line midway between the two edges of the hoop. As the narrowest part of the style analemma should ideally be a point, an adjustment of the hoop by rotation, to compensate for the thickness, has to be made at the time when the reading crosses over. The making of the style symmetrical about its long axis is a compromise which leads to a slight error. This defect could be remedied by providing the dial with two interchangeable styles.

The writer would direct attention to a very interesting type of portable dial on cardboard which is well described in the Encyclopædia Britannica, and is said to have been invented by a Jesuit Father, De Saint Rigaud, in the early part of the seventeenth century. This dial determines the time from the altitude alone of the sun, and is provided with a plumb-line. A simple graphic construction is given, which is easy to execute accurately. The principle of the construction can hardly be understood without an elementary knowledge of spherical trigonometry. On any date the path of the knot or bead which indicates the time is a circle; consequently it is a simple matter to substitute analemmas for straight time lines by the usual process of finding a number of points. A set of half analemmas can be put on each side of the card. Many years ago the writer made one of these altitude dials for latitude 30° south, and provided it with analemmas. Its performance was not far inferior to that of a fixed dial, provided readings between 10 a.m. and 2 p.m. were excluded. In high latitudes the rate of change in the Sun's altitude is too small to render an altitude dial practically useful at any time of the day.

Besides being very interesting, fixed analemma dials have one great merit, viz., that once properly set up they continue to give approximate time without further attention. They present another advantage of minor importance, viz., corrections can be made for the mean refraction; for each point on a fixed analemma corresponds to a definite altitude of the Sun, and a point can be shifted along the azimuth line to correct for mean refraction. For altitudes above 10° refraction is of no importance. All analemmas have one defect which the writer has never seen mentioned: about the times of the summer and winter solstices the path of the indicator nearly coincides with the analemma curve, and the moment of crossing becomes uncertain. To remedy this defect it is necessary to draw a few normals to the curve with dates attached to them.

In the second type of Civil Time Dial to be discussed the correction for equation of time is made by a rotation of the whole dial about its style axis or an axis parallel thereto, as described above for longitude. Cylindrical equatorial dials capable of rotation have been provided with arcs divided into time intervals. Such dials require reference to a table of equations of time, which may be printed upon the dial supports. It is more convenient to have all the data engraved upon the dial in the form of dates only. As the maximum rotation of the dial out of its zero position for equation of time is only a little over four degrees, there is no room upon a single short arc for all the dates required. On pp. 37 to 39 of M. Bigourdan's book are diagrams of a rotatable cylindrical dial and an ingenious device for distributing the dates. On a plate curved concentrically with the axis of rotation, and attached to the upper part of the south end of the cylinder, is inscribed a closed curve shaped like a kidney bean (Figure 2). The curve is divided into twelve parts numbered in the order of the months of the year, and each month is divided by two dots into three parts. The dial is kept corrected by rotating the cylinder until a fixed knife-edge is opposite to the part of the curve corresponding to the date. The length of the bean, being parallel to the axis, is arbitrary, but the width at various levels depends upon the amount of rotation required for two dates on opposite sides of the figure. Figure 2 is not a copy of M. Bigourdan's figure: it is reversed for the southern hemisphere. M. Bigourdan's figure appears to have been incorrectly drawn. In particular, the equation of time for the month of February is relatively too small.

Fig 2.

A dial designed by the writer, and mechanically constructed for him by Mr. A. B. Roberts, of the Bloemfontein Post Office, is provided with a device similar in principle to the above.

This dial, which is a fixture at Botsabelo, is a square vertical brass plate facing north and south, and having the required number of time lines on both faces, the division being into ten-minute intervals. The dial plate is supported by an ordinary two-edged style, which passes through it. The style has rounded ends passing through holes in tripod supports formed of copper plates, 2 inches broad and ⅛ inch thick. The foot of each tripod leg is creased and bent at the correct angle to enable the tripod to rest flat upon the horizontal stone to which it is bolted.

The difference in height between the south and the north tripod is, of course, equal to the length of the style multiplied by the sine of the latitude. The tripod leg next the south is perpendicular to the style, the rounded end of which passes through it. To this end of the style is rivetted a long narrow brass lever consisting of a plate ½ inch broad with a short arc containing a concentrically curved slot at its lower end. The lever, which is movable over the south face of the tripod leg, effects the rotation of the dial. The date devices are engraved upon the lever and upon the tripod leg. On the lever are engraved thirteen rectangular partitions, six on the west side of its middle line, numbered from above downwards 1, 2, 3, 9, 8, 7, and seven on its east side, numbered downwards 12, 11, 10, 9, 4, 5, 6; these numbers correspond to the months of the year. On the tripod leg is a series of horizontal lines on each side of the lever, each of which has a number of a day of a month stamped upon it, and is carried inwards to the point where the edge of the lever should be to give the dial the rotation for the day. The inner ends of the lines are joined by free curves, on which intermediate dates may be interpolated. The dial is set, not oftener than twice a week, by bringing the edge of the lever at the month's partition to the point on the adjacent curve corresponding to the day of the month, and clamping the lever to the tripod leg by means of a wing-nut on a screw bolt passing through the slot in the arc. Perpendicular to the main plate are fixed three narrow accessory plates, viz., a horizontal bottom plate and two vertical side-plates having engraved upon them the time lines of a horizontal dial and two vertical dials facing east and west respectively. One or another of these plates takes a good shadow when the sun is too near the prime vertical to illuminate the main plate properly. All the time lines are placed nearly ten minutes fast for the longitude correction. This dial has been found to agree to within about one minute with the time determined from observations of the Sun's altitude with sextant and artificial horizon on several occasions throughout the year. In higher latitudes a horizontal dial mounted in the same way would be better, and at most latitudes it presents the advantage of showing the time practically all day all the year round on one plane surface.

In conclusion, a few words may be said about methods of setting a dial correctly in azimuth without the use of precise instruments like the sextant or theodolite. If the correct time be known, any otherwise properly oriented dial may be set correctly by turning it in azimuth until it shows the kind of time for which it has been constructed. In conjunction with a watch, a dial may be used as a substitute for a magnetic compass, *e.g.*, placed upon a surveyor's plane table, a true meridian having been drawn upon the map.

Dials like Dr. Halm's, or like the equatorial cylinder described above, which have a point indicator and its dated path lines, can be correctly oriented in both azimuth and inclination to the horizontal by changing the orientation until the indicator remains all day upon the path line proper to the date. This method is independent of a knowledge of the correct time, but if such knowledge is available it should be used both as a check and to hasten the process.

For other types of dial, if the correct time be not known with certainty, it is necessary to draw a meridian line, from which the time of local noon can be determined by means of the shadow of a plumb line. For this purpose the method of equal altitudes of the Sun, described in the Encyclopædia Britannica, is practically accurate. The method of aligning two plumb-lines on the north pole star near the time of its upper or lower culmination is not available in the southern hemisphere. As a substitute for this method in the southern hemisphere the writer has devised the following: Hang two plumb-lines in the usual way from loops passing round rigid horizontal bars pointing east and west, one to the north, the other to the south of a horizontal platform between them. Calculate the times of upper culmination of two stars, one north of the equator, the other in the south, which culminate on the same night, and which will not be too near the zenith at the times of culmination. At the time of the first culmination, as indicated by the watch, align the plumb-lines on the star, and draw a provisional meridian on the surface between the plumb-lines by stretching a cord across them. Do the same at the time of the second culmination. If the watch be correct, these provisional lines will coincide or be parallel, and will be true meridians. If the watch be fast or slow, they will make an acute angle with one another. The true meridian lies somewhere between these lines, and nearer to the one corresponding to the star of which the azimuth changes less rapidly. A provisional meridian may be drawn between the lines, and the watch may be partly corrected next day with the help of the meridian line drawn. The experiment may be repeated night after night until the watch is quite correct.

AN ARTICULATED TRIPOD STAND FOR A TELESCOPE.

By A. F. I. Forbes.

This is a drawing of a Tripod Stand, and is the cheapest and best type of stand to use with an ordinary small telescope. Of its various forms the one here shown is the simplest, and it can easily be made by any amateur. Any suitable kind of hard wood can be used. If the pieces of wood are obtained made to size, the bolts purchased at an ironmonger's, then the only thing required to construct it is a tool to bore the holes.

Make three sets of Fig. 1 say 5 ft. 6 in. long and form joint *c* — *c* with small bolts. Join together at foot. Then string them on a pivot bolt *D*, Fig. 2, or any other fitment that is suitable for the intended telescope, and the whole thing is complete ready for use.

By simply slackening the wing nut *e* the stand can be set up in azimuth, or equatorially in any part of the Earth similar to the positions shown in Figs. 3, 4, and 5. There are several other surprising movements and positions it can take up which can soon be found out on trial.

It is a most accommodating apparatus, will adapt itself to any uneven ground, stand firm and secure, and for transportation it will fold up flat as in Fig 2. Not only is it suitable as a telescope stand; it is excellent for a camera, a level, a plane table, or anything requiring a tripod stand.

It may have more than three legs, and the fourth can be made adaptable for different purposes.

ARTICULATED TRIPOD STAND FOR TELESCOPE.

DESIGN FOR WOOD CONSTRUCTION.

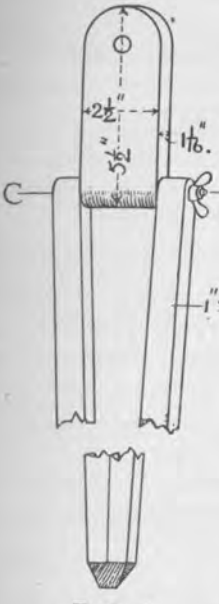

FIG 1.

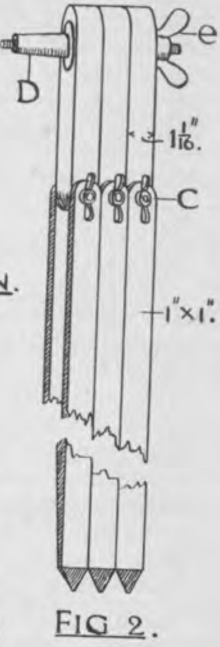

FIG 2.

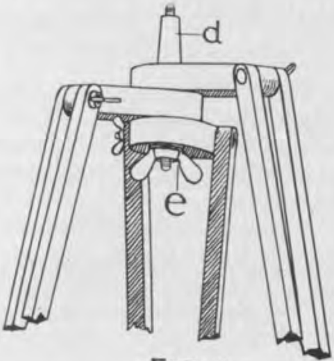

FIG 3.

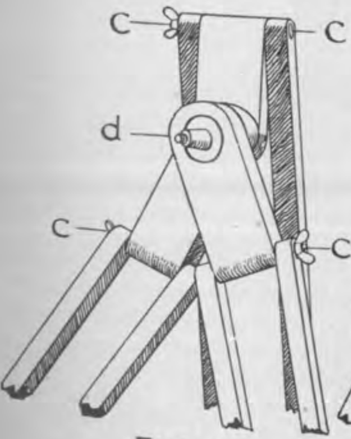

FIG 5.

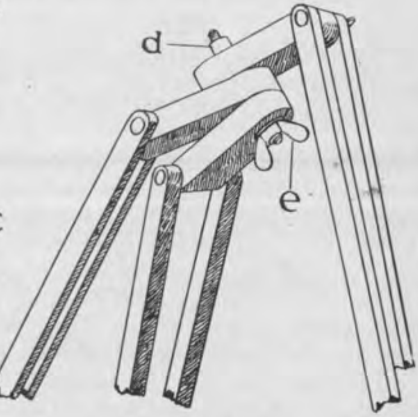

FIG 4.

A.E.I.F.
10.8.26.

ASTRONOMICAL SOCIETY OF SOUTH AFRICA.

Session 1925-26.

ANNUAL REPORT OF THE COUNCIL.

In presenting their Report for the year 1925-26 the Council have again to record a successful year's working of the Society The membership at the 30th June, 1926, stands at 98 members and 12 associates, a decrease in the latter of six during the year.

Owing to his absence from South Africa, the retiring President, Mr. William Reid, will not be able to deliver his Address at the Annual Meeting. Mr. Reid hopes to have an opportunity of giving the Address at a later date.

During the year under review the Council met four times, those members of Council residing away from Cape Town being represented by their alternates. The Honorary Secretary wishes to thank those who attended to the Society's correspondence, etc., for several months during his absence. Friendly relations were maintained with the Natal Astronomical Association.

The last Journal (which completed Volume I. of the Society's publications) was larger and proved more costly than usual, and it has not been found possible to issue more than one Journal during the present Session. An increase in our membership would place more funds at the disposal of the Council, and enable a more regular publication to be undertaken. The Council invites members and associates to send articles for publication in the Journal; our thanks are due to past contributors.

The Council also desires to express the Society's thanks to the authorities at the Royal Observatory and the Union Observatory for their continued courtesy. The Union Astronomer has presented some additions to the series of Observatory Circulars. The Society exchanges copies of publications with kindred Societies, etc., and it is encouraging to note that the Journal has more than once been quoted as an original source of information.

A suggestion has been made that the Society should issue Circulars giving early information of new and expected comets, etc., to supplement the reports which appear in the Press. The Council would be glad to undertake such a service, but at present the publication of the Journal demands all the funds available, and the question of such circulars must be deferred. The Director of the Comet Section has, however, expressed his willingness to communicate recent news as received to any member or associate who signifies a desire to be kept informed.

Our members will recall that Dr. R. T. A. Innes, in his Presidential Address to the Society in 1924, strongly advocated the formation of a South African National Committee of the International Astronomical Union. The Council is gratified to report that, through the agency of the Research Grant Board recently appointed by the Government, active steps are being taken to form such a Committee. It is expected that the Committee will include the Union Astronomer, H. M. Astronomer at the Cape, the Astronomer in charge of the Yale Observatory at Johannesburg, and representatives of the Royal Society of South Africa, the Astronomical Society of South Africa, and the Research Grant Board. At the request of the Board the Council have nominated three representatives: Mr. A. W. Long, Dr. J. Moir, and Mr. W. Reid. It may be noted that similar Committees are contemplated for other branches of Science. The Council feels it a source of pleasure that this Society has been recognized by the Government as possessing standing and influence in astronomical matters.

The Society was glad to learn recently that Dr. A. W. Roberts, one of its Vice-Presidents, and an outstanding figure among amateur astronomers in this country, is considering the publication of his observations of Variable Stars extending over many years. In congratulating Dr. Roberts on this decision, the Society expresses its appreciation of his great diligence and experience which have been an inspiration and help to many.

Astronomers in the Northern Hemisphere frequently regard with envy the excellent observing weather generally enjoyed in South Africa. Further evidence of the high opinion held of our climate is shown by the proposed establishment of another American Observatory in this country, Dr. C. G. Abbot, of the Smithsonian Astrophysical Observatory, having selected a site in South-West Africa for the erection of an observatory to study the solar radiation and its effect on the weather.

There is little doubt that we are favoured by nature in the matter of clear weather and moderate variations of temperature, and it is therefore important that full advantage should be taken of these benefits. Whilst our Observing Sections are in general active and industrious, the Council feels sure that the number of members attached to one or other of the Sections can be increased and a larger output result. Although it is perhaps too much to expect our members or associates to specialise in one branch of Astronomy to the exclusion of others, yet systematic observation of the various phenomena is essential if a real advance in knowledge is to be expected. The Comet Section in particular is well worthy of support; an authority on Comets has recently stated that: "South Africa is doing more than its duty in Comet discovery," and we hope to retain that good opinion.

The Society would welcome an increase of members and associates, and extends a hearty invitation to persons interested, as observers of the heavens or students of astronomy, to join the Society. Any application should be addressed to the Honorary Secretary of the Cape Centre (P.O. Box 2061, Cape Town), or to the Honorary Secretary of the Johannesburg Centre (P.O. Box 2402, Johannesburg).

Reports

FOR THE YEAR ENDED 30TH JUNE, 1926.

COMET SECTION.

We have great pleasure in congratulating our Transvaal friends on their success in discovering two new comets during the past year, the first by Mr. G. E. Ensor at Pretoria, and the second by Mr. T. B. Blathwayt at Johannesburg. We hope that they will continue the "good work," and that it may be our pleasant duty to record other Transvaal comets in future years.

The following comets, recorded last year, were followed for some time after the date of our last report:—

Comet 1925 a (Schain-Comas Sola). This comet was picked up and followed for some time in the morning sky. It was always a very faint object, and only just visible in a six-inch glass.

Comet 1925 b (Reid). This comet almost attained naked-eye visibility. It was kept under observation until December, when it became badly placed for observation by the discoverer. The latest observation at present recorded is by Professor G. van Biesbroeck on 1926, January 12. The following orbit has been computed by Mr. C. J. Merfield, using observations from 1925, March 30, to September 25:—

T (1925 U.T.) =	July 29.87740
ω	259° 16′ 55″.7
Ω	5 59 43 .0
i	26 58 17 .6
Log q	0.2130414
Period	6,910 years
Equinox	1925.0

Comet 1925 d (Tempel (2) Periodical). This comet was followed until September, when it became very faint and difficult to follow. In our last report it was described as fan-shaped; it soon lost this shape and became a large round nebulous patch, with a small but distinct nucleus in the middle. Later it gradually became smaller with a central condensation.

The following comets have been discovered since the date of our last report:—

Comet 1925 e (Wolf's Periodical) was successfully photographed by Dr. W. Baade, of Bergedorf, on the evening of July 13-14, its magnitude then being 15.

Comet 1925 f (Borrelly's Periodical) was discovered by Schaumasse at Nice on August 14. It was of magnitude 12.

Comet 1925 g (Brooks' Periodical) was detected on its return by the Russian astronomers. The first observation was made by Schain, at Simeis, in the Crimea, on September 9.

Comet 1925 h (Faye's Periodical) was discovered photographically by Dr. Baade at Bergedorf on October 20. Once the accurate place was known, faint images of the comet were found on earlier plates taken on August 29 and September 15. The magnitude was about 13 in all cases.

Comet 1925 j (van Biesbroeck). This new comet was discovered on November 16 by Professor van Biesbroeck at Yerkes Observatory while observing other comets, its magnitude being between 7 and 8. A very good account of the discovery, and a description of the comet, may be found in *Popular Astronomy* for April. The comet was observed by Messrs. Smith and Forbes in the Constellation Leo. Both observers describe it as being small, rather faint, and with slight condensation in the middle.

Comet 1925 k (Peltier-Wilk). This new comet was discovered by Mr. L. Peltier at Delphos, Ohio, on November 14, and independently by Mr. Wilk at Cracow on November 19. It was then of the 8th magnitude. Dr. Crommelin states that he observed it on December 5 in twilight. It was bright with a decided central condensation.

Comet 1925 l (Ensor). This new comet was discovered by Mr. G. E. Ensor (one of our members) at Pretoria on December 13 while engaged on Variable Star work. At discovery the comet was between the 7th and 8th magnitudes, and it had a distinct nucleus with a short tail. It was followed until near the end of 1926 January, at which time it was almost visible to the naked eye. It was a very beautiful object, with a very distinct nucleus surrounded by a large coma, and having a bright tail over a degree in length. About this time it was lost in the evening twilight, and was never again seen in South Africa. After passing the Sun it lost all its individuality, and when seen in England was simply a large faint nebulous patch filling the whole field of the telescope. The following preliminary orbit was computed by Mr. H. E. Wood, of the Union Observatory, and published a few days after discovery:—

$T = 1926$ February 12.44

ω	353° 44′
Ω	282 17
i	122 52
q	0.335

Comet 1926 a (Tuttle's Periodical) was discovered by Dr. Baade at Bergedorf on January 12, magnitude 15.5.

Comet 1926 b (Blathwayt). This new comet was discovered by Mr. T. B. Blathwayt at Braamfontein, near Johannesburg, on January 16, magnitude 11, At discovery it was a rather large, irregular and faint nebulosity. It continued a rather faint object, but was well observed in both hemispheres. From observations on January 16, 19, and 21 the following preliminary orbit was computed by Mr. H. E. Wood:—

$T =$ 1926 January 3.06
ω 328° 26′
Ω 136 5
i 128 21
q 1.347

The following have contributed to this report: The Royal and Union Observatories, Messrs. Blathwayt, Ensor, Forbes, Mackenzie, and Smith. We are also indebted to Dr. A. C. Crommelin for information contained in the *B.A.A. Journal*, and to *Popular Astronomy*, which contains much useful information about comets.

The Donohoe Comet Medal has been awarded to Messrs. Reid, Ensor and Blathwayt for the discovery of Comets 1925 b, 1925 l, and 1926 b respectively.

William Reid,
Director.

VARIABLE STAR SECTION.

I am pleased to be able to report continued activity by the Section, 2,192 observations having been recorded. This is 152 less than last year's total, and can perhaps be accounted for by the absence of Mr. A. W. Long's contributions. His overseas trip occasioned pressure of work prior to leaving, thereby preventing his observing. We hope that on his return he will resume his valuable work at the telescope.

Mr. Houghton was also unable to use his telescope for a period of three months.

Fortunately Mr. Ensor came to the rescue, and helped along the work of the Section.

No new observers have been added to the list since my last report. Application was made by a member of the Society, to whom charts were forwarded and full instructions given, but so far no observations have been received. We hope next year to see his name on the list.

Fifty-nine Long Period Variables are being regularly observed by the Section, and results are forwarded every month to Harvard College Observatory. I would emphasise again the need of more observers. The work is interesting for the observer and valuable to the professional astronomer who is engaged in investigating the causes of the stars' varying brightness. The more independent observations obtained, the more reliable the light curve, and therefore more reliable data are provided for the investigator to work upon.

The total of 2,192 observations is distributed amongst the following observers: G. E. Ensor, 631; H. E. Houghton, 613; W. H. Smith, 948.

NOVA PICTORIS, 1925.

Nova Pictoris has been beyond naked-eye observation for some time, and observations were temporarily dropped pending the arrival of a photographic chart of the telescopic field with magnitudes of suitable comparison stars from Harvard.

This has been received, and copies have been distributed to the members of the Section, who will recommence observing as soon as the Nova is conveniently placed for observation.

W. H. SMITH,
Director.

CAPE CENTRE.

ANNUAL REPORT, 1925-6.

Your Committee, in presenting this, the Twelfth Annual Report, have to state that the year now closed has been uneventful. Four new members have been added to the roll, eight members and associates have been struck off. The total membership is now eighty-five.

MEETINGS.

During the period under review there have been seven ordinary meetings, at which the following lectures and papers were presented and discussed:—

"The Nebular Hypothesis," Mr. H. W. Schonegevel.
"Astronomy of the Twentieth Century," Mr. A. W. Long, F.R.A.S.
"The Meeting of the International Astronomical Union at Cambridge," Dr. H. Spencer Jones, M.A., Sc.D., F.R.A.S.
"Alpha Centauri," Mr. D. G. McIntyre.
"Variable Stars," Mr. H. E. Houghton.
"Mars Photographed with Light of Different Colours," Capt. D. Cameron-Swan, F.R.P.S.
"Evolution of a Star—Old Views and New," Dr. H. Spencer Jones, M.A., Sc.D., F.R.A.S.

In February the usual observational meeting was held (with the kind permission of His Majesty's Astronomer) in the dome of the seven-inch Equatorial at the Royal Observatory.

ARTICLES IN THE PRESS.

Monthly notes with charts of the sky have been published in the *Cape Times* as in previous years, and articles in Afrikaans on astronomical phenomena continue to be published in *Die Burger*, both series of articles being contributed by members of the Centre.

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1926.

RECEIPTS.				£	s.	d.
Balance in hand, 30th June, 1925				20	7	5
Subscriptions—						
Arrears ...	1	11	6			
1925-26	44	17	9			
1926-27	1	11	6			
				48	0	9
Five copies of Journal ..				0	5	0
Commission on cheques .				0	3	3
				£68	16	5

PAYMENTS.	£	s.	d.
Contributions to Headquarters under Art. IX (i) of Constitution	24	0	4
Ex credit balances ...	0	10	6
Donation to Headquarters	10	0	0
Five copies of Journal..	0	5	0
Rent of Meeting Room	10	0	0
Rent of P.O. Box	1	5	0
Typewriting and Stationery	5	8	3
Copies of *Cape Times* and postage to country members..	3	15	5
Secretary's expenses ...	2	2	2
Treasurer's expenses ...	0	7	4
Bank charges, etc.	1	0	2
Advertising	0	15	0
Books for Library.. ...	1	18	6
Balance in hand, 30th June, 1926	7	8	9
	£68	16	5

JOHANNESBURG CENTRE.

ANNUAL REPORT, 1925-1926.

The Session now closed is memorable for the discovery by Transvaal astronomers of three celestial bodies, viz., a minor planet by Mr. H. E. Wood, and two comets by Messrs. G. E. Ensor and T. B. Blathwayt respectively.

Six new members have been added to the Society and one member has resigned.

Visits have been paid quarterly to the Union Observatory, but owing to pressure of work at that station these will have to be curtailed in the future.

The attention of members is drawn to the fact that the copies of the periodicals which are circulated amongst members never return to the Secretary, and are seldom received by members whose names are at the end of the list.

In December Mr. W. B. Jackson, M.Sc., gave a paper dealing with the sunrise and sunset table in the Nautical Almanac, and the method of using this for places in the Southern Hemisphere.

At the March meeting Mr. J. D. Stevens gave a paper on "How the Distances of Stars are Determined."

At the May meeting Dr. J. Moir gave a demonstration of how the spectroscope is used in terrestrial analysis and subsequently applied by means of photographs to the study of the composition of the gases contained in the heavenly bodies.

The Committee desire to record their thanks to Dr. Innes and Mr. Wood for their kindness in entertaining members at the Observatory in spite of the recent shortage of staff and pressure of work.

The Committee have also to record with great regret the resignation of their Secretary, Mr. W. Eaton. After carrying on the duties for five years Mr. Eaton found that his absence from town necessitated his relinquishing the office. The Committee are pleased to be able to report that Miss H. L. Troughton has kindly undertaken the duties of Secretary, and to her the Committee is greatly indebted.

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1926.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
Balance in hand, 30th June, 1925	16	9	8	Contributions to Headquarters under Art. IX (i) of Constitution	11	0	9
Subscriptions— 1924-25 .. .. 6 16 6 1925-26 .. .. 15 15 6 1926-27 .. .. 0 10 6	23	2	6	Subscriptions to *Observatory* and *Popular Astronomy*, and Sundries (Mr. Eaton) ..	3	1	0
Cheque unpaid (post-dated)	2	2	0	Sundries (Miss Troughton)	2	0	0
Dr. J. Moir (for B.A.A.)	0	2	6	Cheque unpaid (post-dated)	2	2	0
				Commission and Bank Charges..	0	12	2
				Typing Circulars	0	5	0
				Stationery and postage (Mr. Geddes)	0	9	0
				Balance in hand, 30th June, 1926	22	6	9
	£41	16	8		£41	16	8

Astronomical Society of South Africa.

STATEMENT OF INCOME AND EXPENDITURE FOR THE YEAR ENDED 30TH JUNE, 1926.

INCOME.	£	s.	d.
Balance in hand, 30th June, 1925	27	13	8
50 p.c. Subscriptions, Cape Centre	24	10	10
Do., Johannesburg Centre	8	13	6
Donation, Cape Centre	10	0	0
Do., Natal Astron. Association (2)	10	0	0
Do., Dr. J. Moir	3	17	0
Sale of Journals	1	12	9
50 p.c. profits on sale of "Universal Sundial"	1	17	0
Sundry postages	0	1	2
	£88	5	11

EXPENDITURE.	£	s.	d.
Printing Journal—			
Vol. 1, No. 5	21	5	6
Vol. 1, No. 6	49	10	8
Sundry printing and stationery	2	7	0
Postages	3	12	2
Bank charges	0	15	8
Balance in hand, 30th June, 1926	10	14	11
	£88	5	11

Audited and found correct.
E. J. STEER.

W. H. SMITH,
Hon. Treasurer.

SOUTH AFRICAN NATIONAL COMMITTEE ON ASTRONOMY.

The formation of a National Committee on Astronomy for South Africa, under the ægis of the Research Grant Board, is referred to in the Report of the Council on p. 25. This Committee has been constituted as follows: —

Union Astronomer	Dr. R. T. A. Innes.
H.M. Astronomer at the Cape	Dr. H. Spencer Jones.
Yale University Astronomer	Dr. H. L. Alden.
Nominated by the Astronomical Society of South Africa	Mr. A. W. Long. Dr. J. Moir. Mr. W. Reid.
Nominated by the Royal Society of South Africa	Dr. A. W. Roberts. Dr. J. K. E. Halm. Mr. H. E. Wood.
Nominated by the Research Grant Board	Sir Robert Kotze. Prof. J. T. Morrison.
Nominated by the S.A. Association for the Advancement of Science	Mr. W. H. Cox.

Reviews.

"Meteors." By Chas. P. Olivier, Associate Professor of Astronomy at the University of Virginia. [Pp. xix + 276, with 23 plates.] (Baltimore: Williams and Wilkins Co.; London: Baillière, Tindall and Cox, 1925. Price 30s. net.)

The literature of astronomy is singularly deficient in books dealing with the subject of meteors. More than half a century has elapsed since the publication of Schiaparelli's well-known "Sternschnuppen," for long a classic on the subject. Professor Olivier has performed a valuable task in bringing Schiaparelli's work up to date, and incorporating the results of meteoric observation during the past half-century. The result is a volume which will doubtless be the standard work of reference on the subject for many years.

The routine observation of meteors is a branch of astronomy which has to a large extent been left to the amateur. The value of regular systematic observations was evidenced by the award in 1898 by the Royal Astronomical Society of its gold medal to Mr. W. F. Denning, the doyen of meteor observers, and the recent discussion of these and other observations by Lindemann and Dobson has led to interesting and startling conclusions with regard to the temperature and constitution of the upper atmosphere. It is greatly to be regretted that in South Africa, with its clear skies, the observation of meteors is entirely neglected. Two enthusiastic observers, working in conjunction, would soon reap a rich harvest.

Professor Olivier is one of the few professional astronomers who has devoted much time to the observation of meteors, and he is therefore particularly well qualified to write this book. The technique of observation is carefully explained, and methods of computing the heights and orbits of meteors are described. Any person desirous of commencing meteoric observations will, therefore, find all the instruction he needs in this volume. Several chapters are devoted to the more famous meteor showers. Other subjects discussed include the formation of meteor streams from comets, the origin of meteors, and the meteoric theory of the lunar craters. A full account is given of the subject of stationary radiants.

The mathematical portions of the book are not numerous, and are in general segregated. The non-mathematical reader can therefore omit them without detriment to the general argument. The volume can be recommended to all who are interested in, or who desire to become interested in, meteoric astronomy.

"The Earth and the Stars." By Dr. C. G. Abbot, Director of the Smithsonian Astrophysical Observatory. [Pp. xi + 264, with 33 plates.] (New York: D. van Nostrand Co.; London, Chapman and Hall, Ltd. 1926. Price 15s. net.)

This book has been written for non-technical readers, and is worthy of a wide circulation amongst the general educated public. The author has the gift of popular exposition, and is able to deal with subjects such as the constitution of the stars and the structure of the universe in a manner that will enable those to whom these subjects are entirely new to understand without difficulty the bearings of modern work on these subjects.

The title of the book is somewhat misleading, and does not give a proper indication of its scope. The early chapters are to a large extent historical: there follows two chapters devoted to the Earth, Moon and planets, and three to the Sun. The next two chapters deal with the calendar, star-places and the constellations, and the remaining four chapters are concerned with stellar astronomy.

The author throughout gives his readers the benefit of the latest views held on the subjects discussed, and where debatable matters are concerned, he states the position fairly. Thus his conclusion with regard to the habitability of Mars is: "Very possibly Mars supports life, but very improbably is this life abundant or of high order." To go beyond this would be to enter the realms of speculation.

The volume is not without its mistakes and misprints, which in general are trivial and not seriously to the detriment of the argument. Those readers who require a pleasantly written and up-to-date account of the general field of astronomy, in which particular attention is paid to the application of modern physical methods, and which is also non-mathematical and easy to read, cannot do better than to purchase Dr. Abbot's volume.

"Stellar Atmospheres." By Cecilia H. Payne. [Pp. ix + 215, with 10 figures.] (Cambridge, Massachusetts; Harvard Observatory. English agents: W. Heffer and Sons. Ltd., Cambridge, England. 1925. Price 12s. net.)

This volume forms a new departure in the publications of the Harvard Observatory. It is intended to publish a series of monographs in the form of books, each dealing with a subject in which a large amount of original investigation is being carried on in the Observatory. Part of the expenses of publication will be defrayed from special funds, and the volumes will be sold below the cost of publication. The volume under review is the first of these monographs.

Its sub-title is "A Contribution to the Observational Study of High Temperature in the Reversing Layers of Stars." The interpretation of stellar spectra from the standpoint of thermal ionization is a development of the last few years, which may be said to date from Saha's early papers in the *Philosophical Magazine* in 1920-22. Since then the subject has been extensively developed, largely by Milne, Fowler, Rosseland and others on the theoretical side, and the conclusions derived from it have been found to be in excellent agreement with the results of observation.

Miss Payne has herself contributed largely to the observational side of the subject, and writes with authority. The volume is divided into three parts. Part I, "The Physical Groundwork," deals with the laboratory basis of astrophysics, the stellar temperature scale, pressures in stellar atmospheres, the source and composition of the stellar spectrum and elements and compounds in stellar atmospheres. Part II, "Theory of Thermal Ionization," gives a critical discussion of the theory, of the observational material for its testing, and of the scale of temperatures of stars deduced from it. Part III is concerned with additional deductions from the theory, and with special problems.

This volume is not for the general reader, but is one for serious study by the thoughtful student. It is free from mathematics, and therefore should appeal to the practical student. The subject is one which is growing rapidly, and a general understanding of it is necessary to those who desire to follow the trend of modern investigation. Dr. Schonland's article in the present issue may be recommended as a fitting introduction to it, and those who are desirous of pursuing the subject further can take no better guide than Miss Payne's monograph.

"The Graphic Construction of Eclipses and Occultations." By W. F. Rigge, S.J., Creighton Observatory. [Pp. 157 + 48 figures.] (Chicago: Loyola University Press, 1924. Price 2 dollars.)

The standard method of computing eclipses and occultations is that of Bessel. The mathematical theory of this method appals the general reader, to whom the subject is apt to remain a bag of mysteries. Father Rigge's book is therefore of value in that it should assist in giving a clear geometrical conception of the phenomena involved. For many purposes, the accuracy obtainable by a graphical construction suffices; with the aid of this volume, approximate predictions for any place can be quickly made.

The prediction of lunar eclipses, of solar eclipses for a given place, and of occultations, are described, as well as the construction of eclipse maps. The chapter dealing with the latter is perhaps the most valuable in the book, and will repay careful study. It shows very clearly the general mechanism of a solar eclipse, and will considerably assist the reader to understand the eclipse maps in the *Nautical Almanac.*

The graphical methods expounded by Father Rigge appear to be sound, but where graphical methods are departed from the volume cannot be strongly recommended. It is unfortunate that the printing is poor, and that the proof-reading has been very slipshod.

Astronomical Society of South Africa.

OFFICERS AND COUNCIL, 1926-27.

President: H. Spencer Jones, M.A., Sc.D., B.Sc., F.R.A.S., Royal Observatory, Cape Town.

Vice-Presidents: Alex. Forrest, William Reid, Senator the Hon. A. W. Roberts, D.Sc., F.R.S.E., F.R.A.S.

Hon. Secretary: H. E. Houghton, P.O. Box 2061 (Tel. 2992. Central), Cape Town.

Hon. Treasurer: W. H. Smith, "Arum Villa," Plumstead.

Members of Council: Capt. D. Cameron-Swan, F.R.P.S., F.S.A.Scot., W. Eaton, J. K. E. Halm, Ph.D., F.R.A.S., W. B. Jackson, M.Sc., A. W. Long, F.R.A.S., H. W. Schonegevel.

Alternate Members of Council: W. H. Cox, A. F. I. Forbes, B. F. Jearey, D. G. McIntyre.

Auditor: E. J. Steer.

DIRECTORS OF OBSERVING SECTIONS.

Comet: W. Reid, "Glen Logie," Camp Ground Road, Newlands (Tel. 597, Claremont).

Mars: J. Moir, M.A., D.Sc., F.C.S., 48, Ditton Avenue, Auckland Park, Johannesburg.

Variable Stars: G. E. Ensor, X-ray Dept., Pretoria Hospital, Pretoria.

Editor of Journal: The President.

Librarian: A. F. I. Forbes, "Craigie Brae," Liesbeek Road, Rosebank.

COMMITTEE OF CAPE CENTRE, SESSION 1926-27.

Chairman: Capt. D. Cameron-Swan, F.R.P.S., F.S.A.Scot., "Strathmore," Kalk Bay.

Vice-Chairman: D. G. McIntyre, "Kolara," Kenilworth.

Hon. Secretary: H. W. Schonegevel, P.O. Box 2061, Cape Town.

Hon. Treasurer: A. F. I. Forbes, "Craigie Brae," Liesbeek Road, Rosebank.

Committee: A. W. Long, F.R.A.S., H. C. Mason, W. Reid, S. Skewes, M.A., B.Sc., W. H. Smith.

Librarian: S. Skewes, M.A., B.Sc.

Auditor: E. J. Steer.

COMMITTEE OF JOHANNESBURG CENTRE, SESSION 1926-27.

Chairman: Alex. Forrest, 44, Garden Road, Orchards, Johannesburg.

Hon. Secretary: Miss H. L. Troughton, P.O. Box 2402, Johannesburg.

Hon. Treasurer: W. Geddes, 86, Kimberley Road, Judith's Paarl.

Committee: T. Beamish, F. C. S. Haden, J. Moir, M.A., D.Sc., F.C.S., J. D. Stevens, W. M. Worssell, F.R.A.S.

ASTRONOMICAL SOCIETY OF SOUTH AFRICA.

New Members.

Bentley, W. W. Helmsley, Umhlali, Natal.

Blathwayt, T. B., P.O. Box 7532, Johannesburg.

Brown, Miss E., 4, Middle Street, Boksburg.

Burden, A. C. N., 11, Victoria Avenue, Parktown, Johannesburg.

* Burrell, D. O., c/o B. Lawrence and Co., Ltd., Buitenkant Street, Cape Town.

Gahan, Rev. W. H. T., The Vicarage, Winterton, Natal.

Mills, D. Gordon, 41-42, General Estate Chambers, Adderley Street, Cape Town.

Shipton, Miss D. M., 61, Market Street, Boksburg.

Skewes, S., M.A., B.Sc., The University, Cape Town.

The addresses of the following are now as stated below:—

Beamish, T., 84, Ferreira Street, Turffontein.

Bosman, D. F., P.O. Box 2774, Cape Town.

---

* Associate.

Buchanan, J., S.A. Railways, Doornfontein.
De Kock, R. P., " Spiddal," Dalebrook Road, Kalk Bay.
Eaton, W., Room 29, Railway Headquarters, Johannesburg.
Forrest, A., 44, Garden Road, Orchards, Johannesburg.
Graham, Rev. A., Pietermaritzburg.
Hudson, J., " Seahurst," St. Patrick's Road, Sea Point.
Larkin, W. T., " Inverkip," High Level Road, Green Point.
Mason, H. C., City Hall, Cape Town.
Schonegevel, H. W., c/o Messrs. Lennon, Ltd., Adderley Street, Cape Town.
Skjellerup, J. F., P.O. Box 676E, Melbourne, Australia.
Troughton, Miss H. L., P.O. Box 2402, Johannesburg.

Any changes of address should be notified to the Hon. Secretary, P.O. Box 2061, Cape Town.

OBITUARY.

We regret to record the death at Durban in April last of Mr. G. A. Champion, at the age of 72. He had been a member of the Society since 1923, and was also a foundation member and Vice-President of the Natal Astronomical Association. As well as being a keen amateur astronomer, he was identified with many interests in Durban, and his loss has been keenly felt.

The Editor acknowledges the receipt of the following:—

Harvard College Observatory Bulletins, Circulars and Reprints; Lick Observatory Bulletins; Gazettes Astronomiques, Antwerp Astronomical Society; *Die Himmelswelt,* Berlin; *Star Places,* 2nd Series; *Astronomische Nachrichten,* Kiel; Notices, etc., New Zealand Astronomical Society; etc., etc.