The Journal
of the
Astronomical Society of
South Africa.

Vol. II. NOVEMBER, 1930. No. 5.

THE EXPANSION OF THE UNIVERSE.

By H. E. Wood, M.Sc., F.R.A.S., *Union Astronomer.*

(Presidential Address, Session 1929-30.)

The first astronomers looked upon the earth as a circular plane surrounded and bounded by the heaven which was a solid vault or hemisphere with its concavity turned downwards. The stars seemed to be fixed on this vault: the moon and later the planets were seen to crawl over it. (G. Forbes, History of Astronomy.)

A provisional estimate by Hubble of the distance of the Coma Berenices cluster of nebulae indicates a value of the order of 50,000,000 light years. (Annual Report of the Mount Wilson Observatory, 1928-29.)

The diameter of the star Antares, as determined by the 20-foot interferometer attached to the 100-inch Mount Wilson telescope, is about 400,000,000 miles. From this it may be deduced that the volume of this star is equal to that of 100,000,000 suns and that if it were brought to our solar system and substituted for our sun its boundaries would extend considerably beyond the orbit of the planet Mars.

These two statements may be taken to epitomise the modern view of the universe as contrasted with the ideas of the ancients. It may not be unprofitable to consider how this wonderful modern conception of the universe has arisen. When Galileo with his first crude telescope saw that the planet Jupiter had four attendant moons, his contemporaries refused to believe him and even would not look through his telescope to test his statement lest they should be convinced by their own eyes of the truth of that which they did not wish to believe. Science was then ruled by dogma, evolved from the imagination of the philosophers. Witness the attack made upon Galileo by one of his contemporary astronomers. "The satellites are invisible to the naked eye and therefore can have no influence on the earth, and therefore are useless and therefore do not exist." If this style of philosophy had prevailed, then at the present day we should still be living in the mental and material darkness of the Middle Ages. But slowly and surely the scientific method of the direct appeal to nature has led to the building up of a conception of the universe such as far exceeds the limits of human imagination and philosophising. Let us consider a few of the main steps by which we have advanced from the crude and simple ideas of the first astronomers to our present knowledge. The greatest obstacle to the general acceptance of the Copernican theory that the earth moved round the sun was the fact that such a movement would involve an annual parallax of the stars and none could be detected. Gradually it came to be recognised that this was due to the very great distance of the stars from the earth. Sir Isaac Newton (1642-1727) concluded that the parallax of the fixed stars must certainly be less than one minute of arc and that they therefore must be more than 360 times further away from the sun than the planet Saturn. And assuming that the fixed stars were equal to our sun in bulk and light, he concluded that their distance might be 100,000 times that of Saturn.

In December, 1725, the English Astronomer Royal, Bradley, set out to make a series of observations of the star γ Draconis in an attempt to measure its parallax. He obtained a set of observations which would give him a good normal place for that epoch and then, since no sensible change in the parallactic displacement of the star could be expected for some time, intended to allow a considerable interval to lapse before he repeated the observations. Out of curiosity, as he says, he made a further observation only a week later and was surprised to find that the declination of the star had changed and in a direction contrary to that which would be expected if the star had an annual parallax. Naturally he supposed that his observations were at fault and repeated them, only to find that they were perfectly correct and that the star was moving in an unexpected direction. Three years later, having studied the phenomenon minutely, and with different instruments, he published his conclusions that it was due to the progressive motion of light and the earth's annual motion in its orbit. He also concluded that the parallax of the stars, especially of γ Draconis, could not have been as great as one single second, and that, therefore γ Draconis is more than 400,000 times as far away as the Sun. So, in attempting to measure the parallax of a faint star, Bradley had not only reached a correct idea as to the lower limit of star distances, but had made the outstanding discovery of aberration due to the finite velocity of light.

Almost a century later the first reliable measures of the parallax of a star were made. In the meantime other attempts to determine the distances of the stars had been made. Galileo had suggested that two stars lying close together, but in reality separated by a great gulf of space, must shift their mutual positions when observed from opposite points of the earth's orbit, and several had acted on this suggestion, but with no success. Sir William Herschel appreciated the possibilities of this method and resolved "to examine every star in the heavens with the utmost attention and a very high power to collect such materials for this research as would enable me to fix my observations upon those stars that would best answer my end, i.e., to assign definite distances to the nearest stars." In a few years Herschel had published several catalogues of double stars, but it was still considered that they were purely optical phenomena or that their components lay by chance in the same line of sight from the earth. But after twenty years' observations, he was convinced that in at least 50 cases the proximity of the two stars was not fortuitous, but that the two stars were real binary combinations intimately held together by the bond of mutual attraction. Here again, in trying to solve one problem, an unexpected discovery was made, and Herschel had extended our knowledge of gravitation from the solar system to the stellar universe.

F. G. W. Struve in 1837 gave a list of stars for which, on account either of brightness combined with large proper motion, or in the case of double stars of rapid orbital motion, there was a probability of a measurable parallax. In this list was the double star 61 Cygni, which was selected by Bessel for an investigation of its parallax. With the Königsberg heliometer he measured the distances of two neighbouring faint stars from the point which bisects the distance between the two stars of 61 Cygni, making many sets of observations in a night and ultimately succeeded in obtaining a relative parallax of 0.″3136 with a mean error of 0.″0202. As a proof of the great accuracy of his observations, it may be quoted that the value now accepted for the parallax of this star from modern observations is 0.″300 with a probable error of 0.″005.

Before Bessel's observations had been made, Thomas Henderson, His Majesty's Astronomer at the Cape, had made many observations of the declination of α Centauri, and on his return to Scotland as Astronomer Royal had examined these observations for traces of parallactic displacement. He found that they indicated a parallax of about one second of arc, but withheld his results from publication until he had confirmed them from observations of the star's right ascension.

The great object had now been attained and the actual distances of some of the stars were measured. The method of measurement was perfectly simple, but the observations demanded the greatest refinement. Photographic methods of observation have now completely displaced the early visual methods and have made it possible to measure with certainty a stellar parallax as small as 0.″04, corresponding to a distance of about 80 light years or five million times the Sun's distance. Even for many of the bright stars, however, no measurable parallax had been found, so that more powerful methods available for the measurement of greater distances were wanted.

Such new methods were very soon forthcoming. Herschel, in his determination to measure the universe, finding that he was unable to measure the distances of the stars directly, had attempted to draw some conclusions from the brightness of the stars. If all the stars were of about the same size and had the same conditions of temperature and density, then their apparent brightness would simply depend upon their distance from us. Herschel realised that he could hardly make this assumption, but considered that if he dealt with very large numbers of stars and used average values, then his results would approximate to the truth. So from his method of star gauging, he found that our stellar system resembled a flattened disc extending to about 900 times the average distance of a first magnitude star in the direction of the Milky Way, and being only about one-fifth as extended in a perpendicular direction. No information, however, could be given for any individual star unless there were some means of finding its real brightness, as distinct from its apparent brightness.

The study of the spectrum given by a star led eventually to the possibility of measuring the real brightness or absolute magnitude of a star. It was known from experiments in the laboratory that the spectrum of a source of light depended upon the temperature of the source and that certain lines of the spectrum were strengthened, others weakened under different conditions of temperature. Differences of this nature were found in the spectra of stars whose parallaxes had been determined by the trigonometrical method. Since the distances of these stars were known, their absolute brightness could be deduced and so a correlation was found between the relative intensity of certain spectral lines and the absolute brightness of the stars. Then when the spectrum of a star of unknown distance was examined, an examination of the spectrum led at once to an estimate of its absolute magnitude, and when this was compared with its apparent magnitude, its distance could be calculated. And in this method, since it is only necessary to be able to examine the spectrum of the star, it does not matter how great the distance of the star may be. Hence with very large telescopes which will collect sufficient light from a faint star to produce a spectrum bright enough to be photographed, stellar distances can be measured far beyond the possibilities of the direct trigonometrical method.

Since this method of extending our knowledge of stellar parallaxes is indirect, confidence in the results obtained would be greatly strengthened if confirmation of them were forthcoming by different processes. Such confirmation has been supplied by the evidence of variable stars. Our President of two years ago, Dr. A. W. Roberts, dealt with this matter in his address to you and showed how the study of the Cepheid variables had provided a means of measuring their distances and again a method to which there was no limit. He remarked that " When he began variable star work, forty years ago, the issue was uncertain, the future line of march very uncertain. We had simply to go on." I am reminded of Argelander's appeal in 1844: "Therefore do I lay these hitherto sorely neglected variables most pressingly on the heart of all lovers of the starry heavens. May you become so grateful for the pleasure which has so often rewarded your looking upward, which has constantly been offered you anew, that you will contribute your little mite towards the more exact knowledge of these stars. May you increase your enjoyment by combining the useful and the pleasant, while you perform an important part towards the increase of human knowledge, and help to investigate the eternal laws which announce in endless distance the almighty power and wisdom of the Creator." It would almost appear from these words that Argelander had some foreshadowing of the important results which would ensue from variable star work, but no one could have predicted that the measurement of stellar distances would be included in these results. Many variable stars of the Cepheid type had been discovered in the small Magellanic Cloud and on classifying them Miss Leavitt, of Harvard Observatory, found a definite relation between the period of variation and the average apparent brightness of the star. Since the variables were all in the Magellanic Cloud, they were all approximately at the same distance and so the apparent brightness was proportional to the real brightness. So for any Cepheid variable, the period of variation measures the real brightness and hence the distance can be found. In this way the distance of the Hercules cluster was found to be 36,000 light years.

Moreover, Cepheid variables have been found in the spiral nebulae, variables which do not reach the eighteenth magnitude at their maximum. The distances of the Andromeda Nebula (M31) and of (M33) deduced in this way are found to be 870,000 light years—amazing figures, but figures which have been confirmed in other ways.

Consider some of the results which follow from a knowledge of the distance of the Andromeda Nebula. The absolute magnitude of the variable stars which appear in it may be deduced from their period of variation, and we know then that they must be great suns. Since it has been found that the luminosity of a star is related to its mass, then from the total luminosity of the nebula we can deduce its total mass and find that the nebula contains a mass equivalent to over 2,000 million suns. The spectroscope also tells us from the displacement of the lines that this massive system is apparently receding from our sun at the rate of 180 miles per second. This is a very surprising result, but more amazing figures have recently been obtained. Three nebulae in the Coma Berenices cluster of nebulae near the pole of the Milky Way have been observed to be apparently receding from the Earth with velocities of 2,800, 4,400 and 4,700 miles a second. Their distances are very much greater than that of the Andromeda Nebula and are of the order of 50 million light years. There is a very suggestive relation between the distances of these objects and their apparent velocities of regression—the more distant the object the more rapidly does it appear to recede from us. Here are two sets of observed facts to be expained—great systems of stars are apparently moving through space with tremendous velocities—and they all seem to be moving away from us. If it had been found that these galaxies had been moving in all sorts of directions, the matter would not be so difficult, but we cannot understand why they should all be receding from us as though the universe were actually expanding at a rapid rate. Professor de Sitter dealt with this problem at the special meeting of the Society held on July 26th, 1929, to welcome the visiting astronomers of the British Association. He said that the problem was one of which he did not know the solution, but he indicated the lines on which he is dealing with this problem, and following which I have no doubt he will soon reach the solution.

Within the past few years our conception of the universe has expanded greatly. With the help of telescopes of large aperture and great light grasp, celestial bodies at very great distances from us are supplying us with new facts. When we try to interpret these new facts on the same lines as those on which we have explained our previously smaller universe difficulties and discrepancies arise. These difficulties and discrepancies lead on to further progress. Just as the deviations of Uranus from its computed orbit led to the discovery of Neptune as the unknown perturbing body, so in the case of the apparently discordant facts in relation to very distant bodies, their investigation will lead to new discoveries. It is quite possible that our conceptions of space geometry have been only approximately correct—but so nearly correct that the deviation from strict accuracy was not capable of detection when normal distances were in question. Now, however, in dealing with much greater magnitudes, what was hitherto incapable of detection becomes strikingly apparent, and the geometry of greater space must be investigated.

Our ideas as to the distribution of matter throughout space have recently undergone change. In 1889 Pickering discovered the first spectroscopic binary ζ Ursae Majoris by observing that the lines of its spectrum became doubled at intervals. In 1904 Hartman observed that in the spectrum of the spectroscopic binary δ Orionis the faint but sharp H and K calcium lines did not take part in the to and fro motions of the stellar lines resulting from the orbital motion of the star. This phenomenon was confirmed in the case of many other spectroscopic binary stars. Since these lines were not affected by the orbital motion of the star, it was evident that they could not have their origin in the star itself, and it was concluded that such stars were surrounded by an absorbing atmosphere which was not in immediate connection with the binary system. Plaskett's investigations of stellar spectra with the large Canadian reflecting telescope showed that the phenomenon of stationary calcium lines was not confined to spectroscopic binaries, but that it was to be observed generally in stars of early type. Quite recently Otto Struve has gone much further and has shown that the intensity of the so-called fixed lines increases with the distances of the stars. A star must be at least 100 parsecs or 326 light years away in order that these interstellar lines shall be visible at all and their intensity then increases with increasing distance. These discoveries suggested very strongly that the absorbing matter which gave rise to these lines was distributed generally throughout space. By showing that this interstellar matter takes part in the recently discovered rotation of the galaxy and by finding that the mean distance of the interstellar cloud is just half the mean distance of the stars, Plaskett has shown that the interstellar matter is more or less uniformly distributed through space.

These interesting conclusions have also been reached by Eddington from theoretical considerations. From a dynamical study of the average velocities of the stars, Eddington concluded that interstellar space must be filled with matter of a density of the order of 10^{-24} grammes per cubic centimetre. It will be interesting to try to realise what these figures mean. If all the interstellar matter inside a sphere of 40 miles radius were concentrated into one cubic centimetre, then the matter would be about as dense as the air in this room. This is one aspect of the matter. On the other hand, inside a sphere whose radius is 16 light years, there would, even with this almost inconceivably low density, be as much matter as there is in 128 suns equal to ours. We know that there cannot be very many stars inside such a sphere—probably not more than 30. Hence we conclude that the diffuse matter of space amounts to four or five times the amount of matter present in all the stars. Eddington has shown that this rarefied interstellar matter will produce the absorption effects found by Plaskett and Struve.

Thus the astronomer has now ready at his command another method for penetrating far into space. It is known now that as light travels through space, light of a particular wave length is absorbed in proportion to the depth of space traversed. Hence the amount of absorption measures the distance of the star in question, without any assumptions as to the nature or constitution of the star itself.

We now appear to be at the beginning of another astronomical epoch. At the dawn of thought, the Earth was the centre of man's universe. Gradually the conception arose of a solar system with our sun controlling the motions of a number of small attendant planets. Later it was recognised that our sun was just one of a great concourse of stars, which, like our sun, were all found to be moving through space. Since, on account of the great distances of the stars their apparent motions were small, the study of the systematic motions of the stars has necessarily grown slowly. Now the stage has been reached at which we conceive a general rotation of the galaxy, and we picture the vast assemblage of stars rotating in a period of about 200 million years round a centre buried somewhere in or behind the star clouds of Sagittarius.

THE OPPOSITION OF EROS.

By Dr. H. Spencer Jones, F.R.S.
Chairman, Solar Parallax Commission, International Astronomical Union.

Approaching the Earth at a speed of something like 15 miles per second, the interesting little minor planet, Eros, is rapidly getting nearer to us. It is in opposition to the Sun on February 17, 1931, but will actually be at its nearest to the Earth on January 30. For a few months most of the large telescopes of the world will be busy making observations of it.

Astronomers have been looking forward to this opposition of Eros for many years. Eros is but one of the several hundred minor planets; what is it which renders this particular planet and this particular opposition of special interest? Eros was discovered by Dr. Witt, of Berlin, in August, 1898. It was the 433rd minor planet to be found and at first did not promise to be of any more interest than many of those previously discovered. It soon began to attract attention when it was found that the period of its orbital motion round the Sun was very short, about 1¾ years—shorter than that of any other asteroid known at that or even at the present time. Eros, in fact, has proved to be the nearest to the Sun of all the minor planets, with a mean distance from the Sun of rather less than 1½ times the distance of the Earth, whereas the most distant known minor planet, Hidalgo, has a mean distance 5¾ times the distance of the Earth from the Sun.

The second interesting thing to be found about the orbit of Eros was that it was very eccentric. The distance of Eros from the Sun varies from 105 million miles to 166 million miles. At one end of its orbit it is well outside the orbit of Mars; at the other end it is well within it. If it should happen that the Earth was at its greatest distance from the Sun at the time that Eros was at its smallest distance, so that Eros would make its nearest possible approach to the Earth, the distance between the two bodies would be slightly under 14 million miles. Unfortunately this particular combination of circumstances rarely happens, and the closest approach which Eros has made to the Earth since it was discovered was in the year 1901, when the least distance was a little less than 30 million miles. Early in 1931, a much closer approach will take place; on January 30, Eros will be at a distance of only 16,200,000 miles—a close approximation to the nearest possible approach. It is the close approach of this little member of the solar system which astronomers have been long awaiting.

What is the special interest which attaches to such an event? It is hoped that the observations of Eros which will be secured during the next six months will enable the size of the solar system to be determined with an appreciably greater accuracy than ever before. The relative scale of the system is known with all desired accuracy. According to one of the laws of motion of a planet which were formulated by the astronomer Kepler early in the seventeenth century the squares of the periods of the planets are proportional to the cubes of their mean distances from the Sun. Thus, for instance, if a planet has a period of 125 years, its mean distance from the Sun will be 25 times that of the Earth, because the square of 125 is equal to the cube of 25. The periods of the members of the solar system can be determined with all desired accuracy and therefore, by means of this law of Kepler, the relative distances can be accurately determined. It is customary to express the distance of a body in the solar system in terms of the mean distance of the Earth from the Sun as a unit; the distances expressed in this way can be found without the measurement of a single distance.

The mean distance of the Earth from the Sun is the fundamental unit of distance for the astronomer. The astronomer uses the base line which is afforded by the motion of the Earth from one end of its orbit to the other to determine the distances of the nearer stars; these distances are usually expressed in the form of a parallax—the angle which the mean radius of the Earth's orbit subtends at the star. All the greater distances which are derived in various ways are based indirectly on the distance of the Earth from the Sun. There is at present an uncertainty in our knowledge of this distance of something like 300,000 miles. It is hoped that this uncertainty will be very materially reduced by the observations of Eros during the next few months.

How is the distance of Eros to be derived? The principle of all the methods is that Eros will be seen in a different direction in the sky from a point on the Earth's surface from that in which it would be seen from the centre of the Earth, supposing it to be possible for an observer to be placed there. If the observations are made at the same moment from two observatories widely separated on the surface of the Earth, Eros will be seen in a different position against the background of stars from the two observatories. By determining the relative shift and knowing the distance apart of the two observatories, the distance of Eros at the time of the observation can be calculated. The Cape Observatory will be co-operating with the Greenwich and Hamburg Observatories in such observations, using photographic methods, and the Union Observatory will be co-operating with the Berlin Observatory, using visual methods. As illustrating the size of the quantities which have to be measured, it may be mentioned that when nearest to the Earth, the relative displacement of Eros with reference to the stars, as seen from Greenwich and the Cape, will be about ·67 seconds of arc. This is a very large quantity compared with the small parallactic shifts with which the astronomer has to deal when measuring the distances of stars, and it is due to this large displacement that the circumstances of the coming opposition are so favourable for determining with great accuracy the distance of the Sun.

The disadvantage attaching to observations secured by two observatories in co-operation is that observing conditions may be favourable at one observatory and not at the other, so that there is a double chance of the value of the observations being impaired. But observations can also be made at one observatory in the evening, as soon as possible after sunset, and in the morning, as near as possible to sunrise. In the evening, Eros will be seen displaced in one direction as compared with the direction in which it would be seen from the centre of the Earth; in the morning, it will be seen displaced in the opposite direction. In effect, one uses the change of position of the observatory, arising from the rotation of the Earth, as a base-line, but matters are complicated by the fact that several hours elapse between morning and evening observations, during which time both the Earth and Eros have moved some distance in their orbits. Observations by this method can be made in addition to those of the former type and both the Cape and Union Observatories will participate in them. At the time of opposition, if Eros is observed at the Cape both evening and morning when it is at an altitude of 30°, the relative displacement due to the parallax of Eros will be about 73 seconds of arc. It would be possible to observe at a rather lower altitude and obtain even greater displacements, but there are disadvantages in observing at a very low altitude.

Most of the large telescopes in the world will be co-operating in the observations and the combination of the whole material should give an excellent determination of the distance of the Sun. The observations and their subsequent discussion are under the general arrangement of the Solar Parallax Commission, appointed by the International Astronomical Union. In 1900, two years after the discovery of the planet, when Eros came to about 30 million miles from the Earth, a similar but less extensive programme of observations was carried out, but so short a time had elapsed between the discovery and the near approach that it was not possible to make such adequate preparations as have been made in preparation for the approaching opposition.

The observations will prove of importance in another matter. It is generally assumed in elementary books that the Earth moves in an ellipse round the Sun, except in so far as it is perturbed by the other planets. This is not strictly accurate. It is the centre of gravity of the Earth and the Moon which moves in this way. Both the Earth and the Moon describe orbits round their common centre of gravity while this moves round the Sun. The movement of the Earth around the centre of gravity of the Earth and the Moon will be reflected in an apparent motion of Eros in the sky; the larger the mass of the Moon, the greater this apparent motion will be, and it is therefore possible to use it to derive the mass of the Moon. This mass is not known with very great accuracy at present and the observations of Eros should lead to a considerable improvement in the accuracy.

In October Eros will be in the constellation of Auriga and will appear like a star of the tenth magnitude. During December it moves eastwards and southwards through Leo Minor. By the middle of January it reaches the extreme eastern limit of the loop which it appears to describe amongst the stars. It will then be 14 degrees north of the equator and of the seventh magnitude. It continues to move rapidly southward, crossing the equator on January 27; it will be at its nearest to the Earth on January 30, when it is just south of the equator. Opposition will occur on

February 17, when it will be 19 degrees south of the equator, in Hydra. This constellation and the neighbouring constellation of Antlia into which Eros moves towards the end of February are very poor in stars, which will at times render the choice of suitable comparison stars difficult. At the middle of March, Eros reaches a stationary point at the western end of its loop and at its farthest south of the equator, 26½ degrees south. Thereafter it moves eastwards and slowly north.

What is this minor planet like, which is causing such a stir in the astronomical dovecot? It is a little body, only about 15 miles in diameter, which cannot be seen with the naked eye, even when at its nearest possible distance to the Earth. On the photographic plate, it will give an image which will be indistinguishable from a star image; in this respect it is much more suitable for observation than a large bright planet such as Mars which shows a perceptible disc. Eros rotates on its axis in something like five hours and its brightness varies during the rotation, doubtless due to different parts of the surface having different reflecting powers. The variation in brightness seems to change from one opposition to another, probably on account of the high inclination of the planet's equator. Variable star observers can give useful assistance by keeping Eros under observation for as long as possible and studying the variations in brightness. Eros is sufficiently bright to be seen in a small telescope. An ephemeris of the planet will be found in the *Monthly Notices* of the R.A.S., October, 1925.

At the opposition of 1900-01, Eros remained too far north of the equator to be accessible to southern observers. At the present opposition, it is at first accessible only to northern observers, then moves rapidly south, coming for a time within the range of observers in both hemispheres and gradually moving too far south to be observable from most northern observatories. As it is well south of the equator at opposition, the conditions are much more favourable for southern than for northern observers. There is the further advantage for southern observers that opposition occurs in the summer, when weather conditions are generally at their best, whilst the unfavourable observations which prevail during the winter months at most northern observatories may interfere considerably with the observations.

VISUALISING THE ORBIT OF A COMET.

By H. E. Wood, M.Sc., F.R.A.S., *Union Astronomer.*

When a new comet has been discovered, it is the usual practice to compute a preliminary parabolic orbit as soon as the three observations of the comet which are necessary for this purpose have been secured. This preliminary orbit will represent the movement of the comet along the short arc used in the computations, but may not represent the movement of the comet with any exactness over longer periods of time. However, it is usually found that from the preliminary orbit a general idea of the movement of the comet is obtained, enabling predictions to be made from which the comet may easily be found again and indicating how the comet will behave as regards changes of brightness. A great deal of information is thus concentrated in the few figures used to express what are termed the elements of the orbit. In the following notes a simple process is indicated, by means of which this information may be extracted.

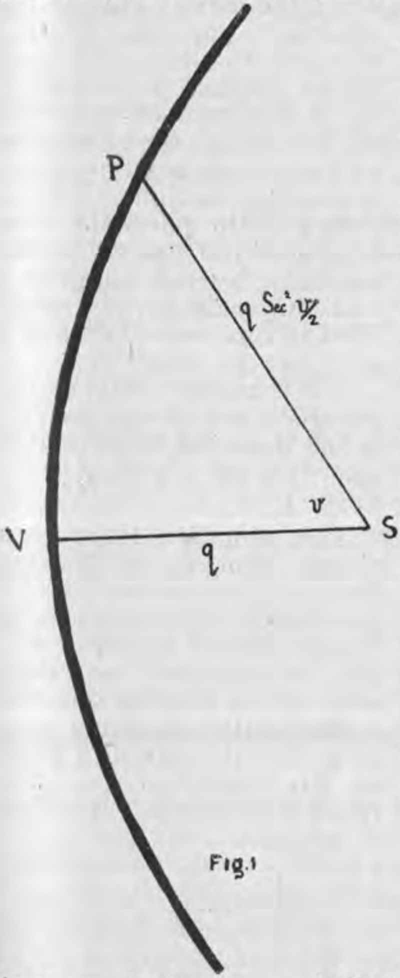


Fig. 1

(1) Constructing the Parabola.

The orbit fits the three observations of the comet to a parabolic curve, which has the Sun at the focus of the parabola. The elements of the orbit contain the quantity log q or sometimes the quantity q itself. This determines the distance between the focus and the vertex of the parabola on a scale, the unit of which is the mean distance of the Sun from the Earth. Thus if we have log $q = 9.8751$ or $q = 0.7500$, the vertex of the parabolic curve representing the path of the comet is three-quarters of an astronomical unit or about 70 million miles away from the Sun. This is the nearest approach of the comet to the Sun or its perihelion distance. In constructing a diagram of the orbit of the comet we have thus two starting points:—S representing the Sun and V the vertex of the parabola. The length of the line SV is determined by the quantity q and the scale to be chosen later to represent the Earth's orbit on the diagram.

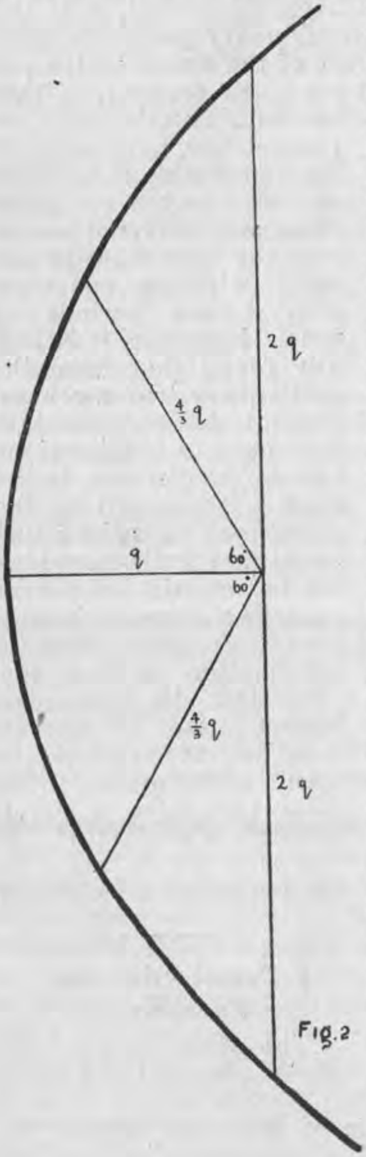


Fig. 2

If P is another point on the parabola and the angle VSP is "v" then the length SP is such that $SP = q \, Sec^2 \frac{v}{2}$ [Fig. 1.]

This equation leads to a simple process of drawing the parabolic curve. Place a protractor with its centre at S and mark off angles of 30°, 45°, 60° and 90° on either side of the central line SV.

The following table then gives the distance of a point on the parabola from the focus S in these respective directions:—

Direction	*Radius Vector*	
	Fairly accurate	*Rough value*
30°	1.072 x q	1.1 x q
45°	1.172 x q	1.2 x q
60°	1.333 x q	1.33 x q
90°	2.000 x q	2 x q
120°	4.000 x q	4 x q

It will be found quite sufficient to draw the parabola through the 5 points obtained by setting off the angles 60° and 90° on either side of SV and measuring a length $1\frac{1}{3}q$ along the 60° lines and $2\,q$ along the 90° lines. [Fig. 2.]

---

2. **Position of the Comet on the Parabola.**

The orbit elements give the time of perihelion passage, i.e., the time at which the comet is at the vertex of the parabola. To study the motion of the comet it is necessary to be able to indicate the times at which the comet is at other points on the parabolic curve.

If T is the time of perihelion passage and t the time at which the comet is at some point P on the parabola such that the angle VSP is "v" then these quantities are related by the equation:—

$$t - T = 82.2113\; q^{\frac{3}{2}} \left\{ \tan \tfrac{1}{2}v + \tfrac{1}{3} \tan^3 \tfrac{1}{2}v \right\}$$

In the following table this equation is worked out for certain values of the angle v:—

v	*Days from perihelion*
15°	$10.88 \times q^{\frac{3}{2}}$
30°	22.55
45°	36.00
60°	52.74
90°	109.62
120°	284.86

Thus if the perihelion distance of a comet is 0.75, then from tables or by using logarithms we find $q^{\frac{3}{2}} =$ 0.65, and so the comet is 30° from the vertex of the parabola about 15 days before and after the date of perihelion passage. Such a comet would be at 45° from the vertex at 23 days, at 60° at 34 days and at 90° at 71 days before or after perihelion. Thus if this comet passed through perihelion on 1930 August 15.0, we can give its positions on the parabola for June 5, July 12, July 23, July 31, August 15, August 30, September 7, September 18, October 25.

All calculations may be avoided by the use of the following table, which gives the number of days required by comets of different perihelion distances to move through given angles from the perihelion point:—

v \ q	0.2	0.4	0.6	0.8	1.0	1.5	2.0
15°	1	3	5	8	11	20	31
30°	2	6	10	16	23	41	64
45°	3	9	17	26	36	66	102
60°	5	13	25	38	53	97	149
90°	10	28	51	78	110	201	310
120°	25	72	132	204	285	523	806

Thus a comet whose perihelion distance is 0.8 units, will move in its orbit through an angular distance of 45° (i.e., VSP = 45°) in 26 days.

Relative Positions of the Comet and the Earth.

Up to now only the orbit of the comet has been considered. If we wish to study the motion of the comet as seen from the Earth it is obviously necessary that we must construct a diagram showing the orbits both of the Earth and the comet and also that the two orbits shall be correctly related to one another.

3. **Orbit of the Earth.**

The orbit of the Earth may be represented as a circle in comet diagrams. It may be divided at intervals of 20° and, from the point of view of an observer in the southern hemisphere, the graduations should increase in the clockwise direction. The graduations are to represent the longitude of the Earth in its orbit round the Sun, and in addition to the degree graduations we may add the dates at which the Earth has the corresponding longitudes.

At the vernal Equinox, March 21, the longitude of the Sun is 0°: hence the longitude of the Earth in its orbit is 180°. Hence the date March 21 is placed at 180°. Since the Earth covers 360° of its orbit in 365¼ days, its motion is about 1° per day. Thus the dates corresponding to each advance of 20° in longitude can easily be worked out, or, more simply, the dates can be obtained from the *Nautical Almanac*. [Fig. 3.]

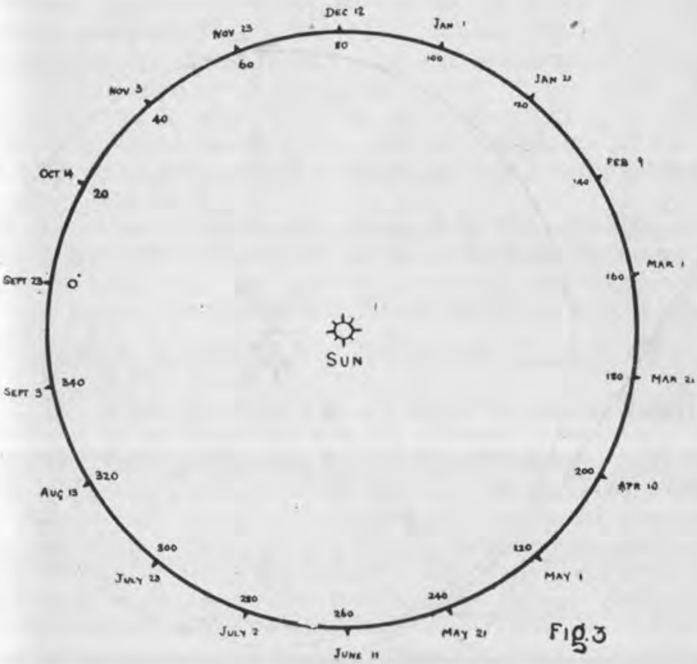
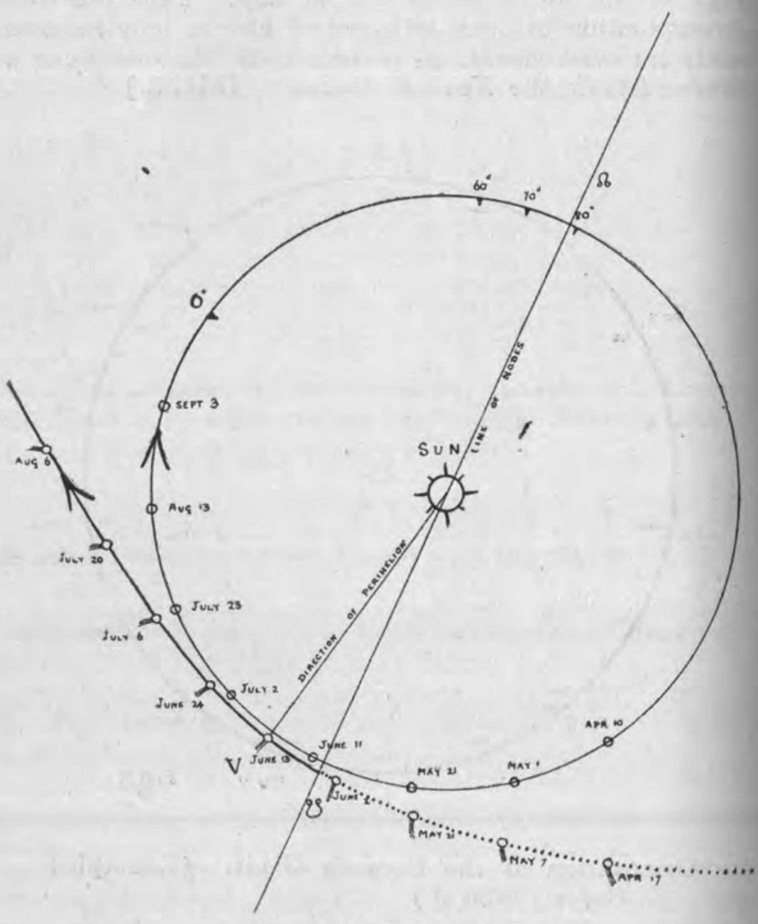


Fig. 3

4. **Orientation of the Comet's Orbit.** (Example: Comet 1930 *d*.)

It is now necessary to superpose the orbit of the comet on the orbit of the Earth in the diagram in their correct relations. The orbit of the comet is generally inclined to the orbit of the Earth and one of the elements given is the direction of the line through the Sun in which the two orbit planes intersect each other. The quantity ☊ or the *longitude of the ascending node* fixes this direction. In the preliminary orbit of the comet 1930 *d*, Ω = 78°. On the diagram a line is now drawn passing through the Sun (the centre of the Earth's orbit and the focus of the comet's parabolic orbit) and the longitude 78°. This line is termed the *line of nodes.* [Fig. 4.]



COMET 1930 d

FIG. 4

The quantity ω or the argument of the perihelion now enables us to place the direction of the comet's perihelion on the diagram. For comet 1930 *d* we have $\omega = 192°$, implying that the angle from the ascending node to the perihelion point measured along the orbit of the comet in its direction of motion is 192°. For the moment we ignore the inclination of the comet's orbit and measure the angle ω round the Earth's orbit. We must notice, however, if the inclination i is less or greater than 90°. If i is less than 90° we measure ω in the forward or clockwise direction; if greater than 90° ω must be measured backwards. Since the value of i for comet 1930 d is 21°, the motion of the comet is direct, so that ω is measured clockwise, and since $\Omega + \omega = 78° + 192° = 270°$, we find that the direction of the perihelion is towards 270°.

The perihelion distance for comet 1930 d is given by log $q = 0.0057$ or $q = 1.014$. In the direction of the perihelion we measure off a length equal to 1.014 times the radius used to describe the orbit of the Earth and so the comet is located at its perihelion point, which in this case is just outside the orbit of the Earth at V.

The parabola with its vertex at V is now constructed as described in §1.

The time of perihelion passage or T is 1930 June 13. Hence the comet was at V on June 13, and by using the table in §(2) we can find the times at which the comet was in some other positions in its orbit.

Thus if $q = 1.014$ $\quad q^{\frac{3}{2}} = 1.02$.

Hence the comet was:

15° from perihelion at 11 days before or after the date of perihelion, i.e., June 2, June 24.

30°	from perihelion at	23 days,	May 21, July 6
45°	,, ,, ,,	37 ,,	May 7, July 20.
60°	,, ,, ,,	54 ,,	April 20, August 6.
90°	,, ,, ,,	112 ,,	Feb. 21, Oct. 3.

The position of the comet is now marked on its orbit for these dates and also the position of the Earth over the period April to September.

5. **Inclination of the Orbit.**

It has to be remembered that the inclination of the orbit of the comet to the plane of the orbit of the Earth for comet 1930 d is 21°. As the line of nodes is the direction of the intersection of the two orbits, we must imagine the orbit of the comet to be rotated round this line through an angle of 21°. Since the elements of the orbit indicated that the ascending node was in direction 78°, the descending node (which is the only node appearing on our diagram) is in the direction 258°. Hence the comet was north of the ecliptic until it arrived at longitude 258°: then it passed to the south side of the ecliptic. This is indicated by representing the path of the comet as a dotted line when the comet is north of the ecliptic and as a continuous line when south of the ecliptic.

---

6. Deductions from the Diagram.

Since the comet and the Earth are practically moving together from April to August with the comet always away from the Sun, the comet is particularly well placed for observation through this period.

Since the comet first approached the Earth as it was coming towards its descending node, the comet would appear in the northern sky and would move southwards. Since the descending node is near the perihelion point, the comet will remain south of the ecliptic until it passes out of observation.

Since the comet is nearest the Sun on June 13 and nearest the Earth about the end of May, it will have brightened up rapidly after discovery since it was approaching the Sun and the Earth at the same time and would reach its maximum brightness about the end of May and beginning of June. After this time the comet would fade rapidly and probably not be observable after the beginning of September. Comet 1930 *d* made an unusually close approach to the Earth.

---

7. Example of Retrograde Motion: Halley's Comet.

If the inclination of the orbit of a comet to the ecliptic is greater than 90°, then in constructing the plane diagram the orbit of the comet has to be turned over past 90° and so the projected direction of motion of the comet becomes reversed or counter-clockwise. Hence after we have marked the direction of the ascending node of the comet's orbit, we must move through the angle ω in the counter clockwise direction to find the direction of perihelion.

With this exception, that ω is measured counter-clockwise when i exceeds 90°, all orbits are dealt with in exactly the same way.

The orbit of Halley's comet is determined by the following (rough) elements:—

$$\begin{aligned} T &= 1910 \text{ April } 20 \\ \omega &= 112^\circ \\ \Omega &= 57^\circ \\ i &= 162^\circ \\ \log q &= 9{\cdot}7688 \\ \text{or } q &= 0{\cdot}5872 \end{aligned}$$

The diagram, Fig. 5, is constructed from the parabolic elements exactly as has been described and shows the path of the comet from March to June 1910. It is apparent that the comet would hardly be visible during March, as it would lie almost in the same direction as the Sun as seen from the Earth. Early in April the comet would have moved sufficiently far away from the Sun, as seen from the Earth, and would be

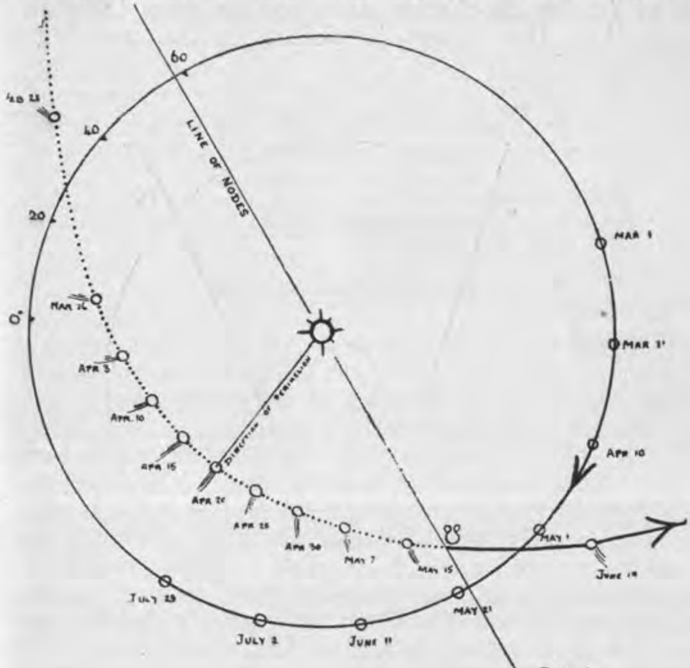


Fig. 5

ORBIT OF HALLEY'S COMET 1910.

observable in the morning sky (see next section). The comet passes perihelion on April 20, but it is then still rushing to meet the Earth, so that its greatest brightness will not occur until late in May, when the comet is close to the Earth. Just after May 15 it will be seen that the comet is passing through the ecliptic and that the Earth is also nearly in the same direction as the comet. This suggested the possibility of a transit of the head of Halley's comet across the face of the Sun and also of the sweeping of its tail across the Earth. Also at this time the comet would pass from the morning sky into the evening sky. After this date the comet would fade very rapidly, as it is not only leaving the Sun, but is moving directly away from the Earth.

8. **Morning or Evening Sky Object.**

If in the diagram the comet is situated on the left of the line joining the Earth and the Sun, the comet is to be seen in the morning sky. If the comet lies on the right of this line, or, in other words, the line has to be rotated in the clockwise direction to pass through the comet, then the comet is visible in the evening sky. [Fig. 6.]

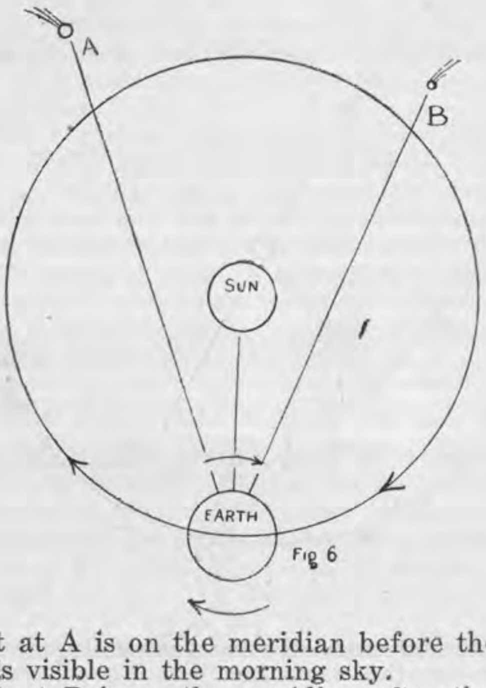


Fig 6

Comet at A is on the meridian before the Sun and therefore is visible in the morning sky.

Comet at B is on the meridian after the Sun and therefore is visible in the evening sky.

9. **Comets and Meteors.**

When a comet is passing through either its ascending or its descending node, it is at that moment in the plane of the ecliptic, i.e., in the plane of the Earth's orbit. If it should happen that at the same time the distance of the comet from the Sun is one unit, then the comet is actually crossing the path of the Earth at that moment. The Earth may at this time not be in the vicinity of this point, but at some time or other it must pass through this point. It is now considered that there are always large numbers of meteoric particles scattered round the orbit of a comet and moving in its orbit; so that whenever the Earth actually passes through the orbit of a comet meteoric showers are probable. If a diagram is drawn representing the orbit of comet 1866 (1) it will be found that the orbit of the comet intersects at its descending node the orbit of the Earth. It will also be found that the Earth passes the point of intersection about the 13th November in each year, and it is at this time that the Leonid meteors occur. On November 27th in each year the Earth crosses the track of the missing Biela's comet and the Andromedid meteors appear on that date.

Obituary.

MR. ALFRED BULL.

By the death of Mr. Alfred Bull, older members of the Cape Centre will feel that they have lost a personal friend. Recently, owing to domestic ties, he was unable to attend the meetings of the Centre, but in earlier days his breezy, jovial presence always brought with it a feeling of cheer and good fellowship into the room.

Mr. Bull was one of the enthusiasts who helped to refloat the old Cape Astronomical Society in the days of the Great War. For some years he acted as its librarian. In that office he gave sterling and unobtrusive service. When funds were not available, he would have recourse to his own pocket. The Cape Centre's set of volumes of the British Astronomical Association's Journal was bound entirely at his expense; the pointer used at lectures was another of his gifts. When making any gift he invariably insisted on its anonymity. But the pointer is to be mounted and inscribed with his name "In Memory."

Mr. Bull sometimes contributed papers to the monthly meetings of the Centre. He was particularly interested in the scintillation of the fixed stars, and one of his papers was on this subject. In it he described his own observations and ideas. Other papers were on "Neptune," "Light," "The Zodiacal Light" and "Sunspots."

Mr. Bull died on June 6, 1930. The Society has lost a cheerful giver, an ardent astronomer and a splendid friend.

Reviews.

"The Universe Around Us." By Sir James Jeans, M.A., D.Sc., LL.D., F.R.S. [Pp. x. + 532 with 24 plates and 24 figures.] (Cambridge: At the University Press; 1929. Price 12s. 6d. net.)

The general public and the cause of science are both under a debt of gratitude to those men of science who, like Sir James Jeans, spare time to expound in a clear manner and with an attractive literary style some of the developments of modern science—the general public because it is provided with an authoritative account by one who has been foremost in the developments with which he has to deal, and the cause of science because it is through such works as this that the achievements of modern science become appreciated and understood by the layman. Such appreciation cannot fail to react to the advantage of science. We have recently seen in this country Government support withdrawn from scientific research as a petty measure of economy; if the public had been sufficiently educated to the importance to the country of scientific research, such a short-sighted policy would not for a moment have been tolerated.

This volume commences with a brief outline of the development of astronomy, which is followed by a chapter summarising the observational material arranged in rough chronological order. As Sir James Jeans points out, this is also the order of increasing telescopic power or again of seeing further and further into space. So from the solar system we pass to the galactic system, nebulae, extra-galactic nebulae, the distances of the stars, the photographic epoch, groups of stars, binary and variable stars and sounding space. Modern astronomy is so bound up with modern physics that an account is next given of modern views of atomic structure. This is followed by a chapter in which a time-scale for the universe is developed; the age of the earth is first discussed, then the age of the stars, the maintenance of the Sun's radiation and the source of stellar energy.

A fascinating chapter, entitled "Carving out the Universe," is devoted to a scheme of cosmology. The origin of the great nebulae is discussed and then the formation of condensations in the nebulae leading to the birth of stars. Binary systems present certain difficulties and receive separate treatment. Finally, the origin of the solar system and of planetary satellites—in some respects the most difficult feature in the heavens to explain —is fully dealt with. Sir James proceeds to discuss the evolution of a star after it has been born. It is his own theory of liquid stars which is expounded; there are alternative theories which are barely hinted at. Objection might be raised to this limitation, but there is much to be said in justification, even if Jeans's own theory should subsequently be disproved. The various theories have much in common in their fundamental ideas, and to follow one particular theory in detail clarifies the argument and gives a connected, coherent picture.

The final chapter is entitled "Beginnings and Endings." As to the ending, Sir James takes the view that the universe is like a clock running down, to stop only when every atom that can be annihilated has been annihilated and with the resultant energy wandering for ever round space—an unsatisfying conception, but difficult to upset if the second principle of thermodynamics is held to be true throughout the universe. The beginnings are more difficult to deal with: it is held to be clear that the present matter of the universe cannot have existed for ever, but no coherent picture is provided or can be provided of what there was before matter was formed. The volume concludes with some interesting speculations about life and the universe and the future prospects of the Earth.

The volume is well printed and provided with some excellent reproductions of astronomical photographs. It is a book to read and then to read again, and having done so one cannot fail to have caught something of the wonder of modern astronomical discovery.

"Stars of the Southern Heavens." By James Nangle, O.B.E., F.R.A.S. [Pp. ix. + 127 with 6 maps and 6 plates.] (Sydney: Angus and Robertson; 1929. Price 5s. net.)

To those who are anxious to become familiar with the southern sky, this small volume will provide the assistance they require. Most books which deal in a popular form with the constellations have been written for observers in the northern hemisphere, and do not deal with the constellations which are not visible from middle northern latitudes. Mr. Nangle, the Government Astronomer of New South Wales, has met a real need by writing this book. It is based upon a number of articles which were published originally in a weekly newspaper and many requests were received for their republication in book form.

The first several chapters deal with miscellaneous matter, star magnitudes, spectral classification, variable and double stars, the Milky Way, the constellations and star catalogues. Six chapters then follow, each accompanied by a star map, dealing with the star-groups visible in the southern sky at two-monthly intervals. Only objects which are visible with the naked eye or with a pair of field glasses are described. Those who do not possess a telescope need not be deterred from observing the skies; under Mr. Nangle's direction they will find much to interest them. Technical terms have in general been avoided, but where introduced have been fully explained.

There is little doubt that this volume only requires to become known in order to secure a wide circulation in the southern hemisphere.

" A Source Book in Astronomy." By Harlow Shapley, Ph.D., LL.D., and Helen E. Howarth, A.B., A.M. [Pp. xvi. + 412 with numerous illustrations and figures.] (New York and London: McGraw-Hill Book Co.; 1929. Price 20s. net.)

This volume forms the first of a series of source books in the history of the sciences, which aim to present the most significant passages from the works of the most important contributors to the major sciences during the last three or four centuries.

In the present volume, prepared by Professor Harlow Shapley and Miss Howarth, there are given quotations from the writings of 63 astronomers beginning with Copernicus and ending with 1900. The passages have been translated into English where necessary. The volume succeeds in giving a pretty comprehensive summary of the principal contributions to astronomy during the past four hundred years. For the benefit of the non-astronomical and general reader, it has been necessary to exclude mathematical and highly technical articles; this will account for the omission of such names as Hansen and Delauney. An exception to this rule is the inclusion of the classical work of Gauss on the method of least squares.

The volume includes some of the greatest treasures to be found in astronomical literature, many of which have not hitherto been easily available. Mention may be made of Tycho Brahe's account of his observations of the new star of 1572; of Kepler's discovery of the laws of planetary motion; of Galileo's account of his discovery of Jupiter's satellites and of other astronomical observations; of Horrox's account of the first observation of a transit of Venus (much of the charm of the original account in Latin is lost in the translation given); of Huyghen's observations of the ring around Saturn. But it is difficult to know where to stop, for one is tempted to refer to most of the extracts which are included. The authors remark that " many of the important discoveries, interpretations, and theories of the past have been lucidly and beautifully set forth "; quite apart from their importance in the history of astronomy, the reading of some of these extracts is sheer delight. Reproductions of many portraits are given and both diagrams and illustrations which accompany the originals of the various extracts are reproduced. The volume can be strongly recommended to astronomers in particular, but also to all who are interested in the history of science.

" The Pageant of the Skies." A Handbook of Astronomy. By Willem J. Luyten. [Pp. xvii. + 300 with 16 plates and 16 figures.] (London: Stanley Paul & Co. (1928); 1930. Price 7s. 6d. net.)

There seems to be no limit to the absorption by the reading public of general descriptive books on astronomy. The past few years have witnessed a rapid outpouring of such books; it is a healthy sign, pointing to a widened interest on the part of the public. For this, the rapid development of the subject during the past decade is largely responsible. The new outlook of physics in many directions has caught the public interest, and this, in turn, has stimulated interest in the closely associated subject of astronomy.

Dr. Luyten's book follows upon conventional lines, dealing first with the Earth, the Sun, the Moon and the other members of the solar system and then with the stars and their motions, double and variable stars, clusters and nebulae, stellar evolution, the Milky Way, island universes and the past and future. Written in a popular but attractive style, with many apt similes and illustrations, it will probably appeal more to the non-astronomical than to the astronomical reader. It is well illustrated and the price is sufficiently low to ensure a wide circulation. Frequently, books of this type are sold at a price which seriously curtails their circulation and then they fail to achieve their purpose. We do not think that Dr. Luyten's book will be numbered amongst these.

Astronomical Society of South Africa.

SESSION 1929-1930.

Annual Report of the Council.

In presenting its report for the Session 1929-30 the Council is again able to record a successful year. The membership at the 30th June, 1930, stands at 121 members and 13 associates.

The retiring President, Mr. H. E. Wood, M.Sc., F.R.A.S., Union Astronomer, will take as the subject of his Presidential Address, "The Expansion of the Universe."

The Council has met four times during the year, those members residing away from Cape Town being represented by their alternates. Mr. W. B. Jackson, M.Sc., was nominated as a representative of the Society on the South African National Committee in Astronomy in place of the late Dr. J. Moir. Friendly relations have been maintained with the Natal Astronomical Association.

The most important event of the Session was the Conversazione which was arranged for the 16th July, 1929, in order that members of the Society and their friends might have an opportunity of becoming acquainted with the visiting astronomers who were attending the South African Meeting of the British Association. Short addresses were given by a number of the visitors, and their work will be followed with greater interest since we have been privileged to hear them describe the various researches on which they are engaged.

During the Session Vol. 2, No. 4 of the Journal was issued. This number has received very favourable notice, one of its features which has attracted attention being a report of the addresses given at the Conversazione, which thus forms a permanent record of that unique occasion.

The Observing Sections have continued their work during the Session. The Council would like to express its appreciation of the practical work carried out by the Directors and members of these Sections. Mr. Forbes and Mr. Blathwayt are to be congratulated on their cometary discoveries during the Session. The observations made by the Variable Star Section are communicated regularly to Harvard College Observatory and are frequently referred to with due acknowledgment in the publications of that institution. Reference should also be made to the long series of occultations recently published by the Union Observatory, which contain many valuable observations made by the late Dr. Moir, who was an active member of the Society. It is by such enterprise that the Society is becoming known and is also fulfilling one of its aims. While it is the case that the important researches in the southern hemisphere, which can be undertaken only by established and organised Observatories, are now receiving more attention, the Council would point out that there are still opportunities for amateur observers to do work of real value on the southern sky, and the Observing Sections exist to give the necessary advice and help and to see that observations and results are recorded and circulated.

The Society is in a position to note with pleasure a further increase in the number of observatories to be established in South Africa. The establishment at Windhoek, through the co-operation of several German observatories, of a southern observing station has been decided upon. The Leiden Observatory intends to erect a large twin photographic refractor at Johannesburg. The proposed transfer of the Radcliffe Observatory from Oxford to South Africa has encountered legal and other difficulties. The provision of a large reflecting telescope, with adequate spectroscopic equipment, is under consideration. Such a telescope could make observations complementary to those made at the Dominion Astrophysical Observatory in British Columbia. Observations of this nature in the southern hemisphere are urgently needed. In the interests of astronomy, the Council hopes that the transfer of the observatory will be approved. Meanwhile the suitability of a site near Pretoria is being thoroughly investigated. The Council notes with satisfaction that a 60-inch reflector will shortly be erected at the Boyden Station of Harvard Observatory, near Bloemfontein. It may be mentioned that the Harvard astronomers there have reported that observing conditions during 1928 were distinctly superior to those at Arequipa during the previous years. The South African climate is thus fulfilling its promised contribution towards the success of these undertakings.

Our membership includes several of the oversea astronomers now stationed here, and a cordial invitation is given to all persons interested in astronomy—either as beginners or experts, amateurs or professionals—to apply for particulars of membership 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), who will be glad to supply the necessary information.

REPORTS OF SECTIONS

For the Year Ended 30th June, 1930.

COMET SECTION.

Following two years of a dearth of comets, this year in contrast has been a stirring one on account of the many new discoveries. Eight new comets were discovered, also one whose trail was found on a photographic plate, taken in America, but which could not be traced further. The work of the section has received much help and encouragement from the Directors and Staffs of the Royal and Union Observatories and this has done much to stimulate the efforts of our workers in the hours when results seemed far off. We thank them all for what they have done for the Section.

Mr. T. B. Blathwayt, of Johannesburg, has kept a good watch on the sky and reports having spent from 120 to 150 hours in systematic work during the year. We feel confident in the thoroughness of his work when we know that Comet 1930d, which was first discovered at Hamburg, was so quickly picked up by him immediately it crossed the Equator into our regions—outracing its own ephemeris.

Your Director has gone over the greater part of the southern skies once a month, but the Section needs more workers, especially for portions of the sky that the present workers cannot easily observe.

Several periodical comets were due to return this year, amongst them being Daniel's and d'Arrest's. Ephemerides of these were published in the *B.A.A. Journal* giving positions south of the equator. Some of our members searched for them, but without result. It will be remembered that the late Mr. W. Reid rediscovered d'Arrest's comet at its last return in 1923, when it was a very faint object, and had been almost given up for lost.

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

Comet 1929b (Neujmin) was discovered on the 2nd August at Simeis by Mr. G. Neujmin. Its magnitude at discovery was 14. Dr. A. C. D. Crommelin gives it a period of 10.79 years.

Comet 1929c (Forbes) was discovered at Rosebank, Cape, by your Director, on the evening of 1st August. At discovery it was about the 10th magnitude, was small and moving very slowly. It had a sharp, stellar-like nucleus, but at times this nucleus seemed to become larger and not so bright. Mr. H. E. Wood secured early photographs and computed a preliminary orbit, which showed that the comet had passed perihelion some two months before discovery. In the *B.A.A. Journal* Dr. Crommelin gives the following orbit:—

T	1929	June	25·4941	U.T.
ω	258°	46′	3″·7	1929·0
Ω	25	47	20·8	1929·0
i	4	36	19·5	1929·0
ϕ	33	43	6·4	
log q	0·1831695			Period 6·34422 years.

It was photographed by Prof. G. van Biesbroeck as late as 21st and 22nd November. It was then very diffused and of magnitude 16.5.

Comet 1929d (Wilk). This comet was discovered by Mr. Wilk, of the Cracow Observatory, on 20th December. It was of the 7th magnitude at discovery. After passing the Sun it came into the southern skies, but though its position was intimated to members, no report of it having been seen was received. It was too near the Sun to be an easy object.

Comet 1930a (Peltier and Schwassmann Wachmann) was discovered independently at Ohio and at Bergedorf. It was of the 11th magnitude, had a very high inclination and was moving rapidly. On 14th February it was nearest the Earth, the distance being 20 millions of miles.

Comet 1930b (Beyer). This comet was discovered by Herr M. Beyer on a photographic plate exposed on 26th February. Images were afterwards found on six plates exposed on earlier dates at Neubabelsberg and Harvard. It was found to have an elliptical orbit with a period of 640 years.

Comet 1930c (Wilk). Another new comet discovered by Mr. Wilk at Cracow on 21st March. Magnitude 7 at discovery, it reached the 4th magnitude on 25th March, but was too far north to be seen from our latitudes.

Comet 1930d (Schwassmann-Wachmann) was discovered on 2nd May by Drs. Schwassmann and Wachmann at Bergedorf. It was magnitude 7 at discovery and travelled south, crossing the equator on 2nd June. It was picked up by Mr. T. B. Blathwayt at Johannesburg on the same date. As no orbit or ephemeris of its position was available at the time, it was at first thought to be a new discovery. It was then near perihelion and of the 6th magnitude with a bright nucleus. It was moving at the very rapid rate of 3½ degrees a day. Mr. Blathwayt reports that when he first saw it he thought it was a spiral nebula seen edgeways. Mr. R. Watson made out a tail about 11 minutes of arc in length.

Comet 1930e (Forbes) was discovered by your Director at Rosebank, Cape, on 29th May. It appeared as a small round nebulosity with only a faint suggestion of a nucleus. Examined with a high power it showed a slight granulated appearance. It was magnitude 9, reaching the 7th magnitude when near Fomalhaut. From observations on 3rd, 8th and 13th June, Mr. H. E. Wood deduced the following parabolic orbit:—

T	1930	May	10·4018	U.T.
ω	320°	55′	20″.7	1930·0
Ω	278	17	15·3	1930·0
i	97	4	27·7	1930·0
q	1·15239			

From these elements Mr. A. W. Long computed an ephemeris and this proved very useful to members, enabling them to pick it up easily again on the 27th of the month after the Moon was gone.

The Donohoe Bronze Medal of the Astronomical Society of the Pacific was awarded to your Director for the discovery of comet 1929c.

A. F. I. Forbes,

Director.

VARIABLE STAR SECTION.

I am pleased to be able to report excellent progress during the year ending 30th June, the observations received totalling 3,270 observations of 115 variables, an average of over 28 observations per variable. Mr. Houghton's fine contribution was particularly helpful, and brought our output well above last year's total.

The observations are divided among the members of the Section as follows:—

H. E. Houghton . .	1,690	observations	of	83 variables.
W. H. Smith	480	,,	,,	84 ,,
G. E. Ensor	1,020	,,	,,	112 ,,
Miss C. Orpen . . .	55	,,	,,	20 ,,
H. Hayman	25	,,	,,	9 ,,

H. E. Houghton used a 3½in. refractor, W. H. Smith a 4in. refractor, G. E. Ensor a 6½in. reflector, Miss C. Orpen 3in. and 6in. refractors, and H. Hayman a 4¼in. refractor.

NOTES.

S Apodis.

This irregular variable, after the faint minimum of 1928-29, has nearly regained its normal brightness of magnitude 10.0. Its present magnitude is 10.3.

RY Sagittarii.

This interesting irregular variable, normally of magnitude 6.5, began to fade rapidly in March last. On March 27 Peltier, in the *Popular Astronomy* lists, estimated it as magnitude 8.0. On March 31, Houghton's estimate was 8.1; on April 21, 9.2; and on April 30 he reported the star as "not seen." No magnitudes are given on the Harvard chart of the field, below 10.0. A number of faint comparison stars on the chart are designated by letters only, without visual magnitudes.

On June 30 the variable was still recorded as "not seen." It is being carefully watched for reappearance.

Previous minima have been recorded in 1888, 1894, 1899, 1916-18, and 1921-24; no information is available with respect to the magnitudes at these minima. Two minima appear in the records of our Section; one of 9.4, on July 4, 1924, and one of 9.2, on November 20, 1926.

It is interesting to note that RY Sagittarii was discovered by the late Col. Markwick, who was Director of the Variable Star Section of the B.A.A. from 1899 till 1909. The following particulars relating to the discovery of the variability of the star have been taken from the *Journal of the B.A.A.*, Vol. 35, No. 9, 1924-25.

"In 1923, July 14, Markwick observed the star Co. D.—33° 14076, estimating it to be of magnitude 7.0, and a little brighter than the adjacent star —33° 14068. In August he found it fainter than this star, and by September 12 it had become invisible in his binoculars, and fainter than 9th magnitude. He therefore included it in a list of 42 stars suspected of variability, which he forwarded to Prof. Pickering.

A report was sent to him that an examination of several photographs failed to show any sign of variability.

A few days later, however, a star having a peculiar spectrum was discovered by Mrs. Fleming at Harvard.

All plates of the region were examined, and its variability established. This was about to be published in a circular, when it was found to be identical with Markwick's star in Sagittarius. It was therefore reported to him for announcement, and he authorised the publication in *H.C.O. Circular* 7, which supplies the information here recorded.

Subsequent observations have shown RY Sagittarii to be a southern replica of R Coronae Borealis. Like the latter, after remaining steady at about magnitude 6.5 for many months, its light fades suddenly and irregularly, sometimes below the 13th magnitude.

Its spectrum, classed as Gop, contains bright lines which show evidence of change.

It would be a fitting tribute to Markwick's memory if members in the southern hemisphere would devote more attention to this interesting variable, his chief discovery."

Nova Pictoris.

This nova has remained fairly steady during the year at magnitude 8.0-8.3. The following particulars of measurements made at the Bosscha Observatory, Lembang, Java, have been kindly supplied to your Director by Dr. van den Bos, of the Union Observatory:—

"This is the first opposition in which micrometer measurements of the two companions, discovered by W. S. Finsen at the Union Observatory, Johannesburg, have been obtained at another observatory.

Dr. J. Voûte, with the new 23½in. refractor of the Bosscha Observatory, made good measures on four nights. The results agree closely with those obtained at the Union Observatory.

The measures 1928-30 show no change in the direction of either companion, but a decided increase in the distance of both; 1928, 0″.4; 1929, 0″.6; 1930, 0.″8. More striking than this even is the fading of the two companions with respect to the central star. The difference in magnitude between A (central) and B (north following) was estimated 0.2 (1928 early); 0.5 (1928 late); 1.7 (1929); 2.0 (1930); and between A (central) and C (south preceding), 1.0 (1928); 2.0 (1929); 2.5 (1930).

This fading of the companions B and C would account for most, if not all, of the decrease in the combined brightness as observed by the variable star observers, so that the central star seems to have remained nearly constant for the past three years.

The image is still very nebulous, or rather enveloped in nebulosity, but in good definition the companions appear star-like.

It is not unlikely that Nova Pictoris will develop into a triple system of the same type as the old nova, Eta Argus; where we have at present a nebulous 8th magnitude primary with two 11th magnitude companions at 1″, discovered by Dr. Innes with the Union Observatory 9in. refractor."

Variable Star in Piscis Austrinus.

V. Tshernov, of Krementshoug, Ukraine, U.S.S.R., requests southern observers to pay attention to a star Co. D. 27° 15938. The R.A. of this star is 22h 24.2m. Declination 27° 37′ S. He states that 33 observations from August, 1926, to December, 1927, showed a variation in brightness from magnitude 5.8-6.3.

Variable Comparison Star in Field of T Phoenicis.

M. Dartayet, of the La Plata Observatory, Argentine, has issued the following notice to southern variable star observers:—

"The comparison star *h* of the sequence of this variable has shown that it also is a variable of the eclipse type, whose minima occur towards the Julian dates:—

2425859.344   5.4129. E.

It varies between magnitudes 12.4 and 14.0. Its discovery was communicated in *A.N.* 5676, with the provisional designation of 409. 1929.

It is recommended to observers of T Phe not to use star *h* in their comparisons, and to choose the method of Argelander in this part of the sequence, the star not having the brightness assigned to it. The undersigned proposes to follow the observation of this new variable, and to publish definite results."

According to the note in *A.N.* 5676 the suspected star *h* is shown on the Harvard chart as magnitude 13.2.

G. E. ENSOR,
Director.

MAXIMA AND MINIMA, 1929-30.

Desig.	*Variable*	*Phase*	*Magn.*	*Civil Date*	*Julian Date*
001032	S SCL	Max	7.1	1929 Oct. 23	5908
001862	S TUC	Max	10.1	1930 Jan. 26	6000
002546	T PHE	Max	8.5	1929 Sept. 4	5859
005475	U TUC	Max	8.7	1929 Oct. 23	5908
025751	T HOR	Max	7.9	1929 Sept. 28	5883
025050	R HOR	Min	12.8	1929 Oct. 21	5906
	do.	Max	5.4	1930 April 5	6072
043263	R RET	Max	8.1	1930 May 2	6099
044349	R PIC	Max	6.9	1929 Dec. 18	5964
	do.	Min	9.0	1930 Mar. 10	6046
050022	T LEP	Max	8.0	1930 Jan. 30	6007
050848	S PIC	Max	8.5	1929 Nov. 14	5930
051247	T PIC	Max	9.0	1930 Mar. 3	6039
051533	T COL	Max	7.2	1929 Oct. 26	5911
	do.	Min	12.3	1930 Feb. 26	6034
054629	R COL	Max	9.9	1929 Nov. 20	5936
070772	R VOL	Max	10.4	1929 Nov. 28	5944
073173	S. VOL	Max	8.9	1930 June 7	6135
074241	W PUP	Max	8.6	1929 Nov. 18	5934
	do.	Min	12.2	1930 Jan. 9	5986
	do.	Max	8.1	1930 Mar. 8	6044
	do.	Min	12.1	1930 May 16	6113
082476	R CHA	Max	7.5	1929 Dec. 19	5965
092962	R CAR	Min	10.0	1929 July 31	5824
	do.	Max	5.0	1929 Dec. 25	5971
	do.	Min	10.0	1930 May 24	6121
095663	RV CAR	Max	11.3	1930 April 17	6084
100661	S CAR	Max	5.7	1929 Dec. 27	5973
	do.	Min	8.9	1930 Mar. 4	6040
	do.	Max	5:6	1930 May 17	6114
101058a	Z CAR	Max	10.6	1929 Dec. 18	5964
101153	W VEL	Max	8.8	1930 Mar. 31	6067

Desig.	*Variable*	*Phase*	*Magn.*	*Civil Date*	*Julian Date*
103270	RZ CAR	Max	10.3	1929 Nov. 30	5946
111561	RY CAR	Max	10.6	1930 June 17	6145
111661	RS CEN	Max	8.3	1930 Feb. 6	6014
115058	W CEN	Max	8.5	1929 Aug. 24	5848
	do.	Max	8.0	1930 Mar. 22	6058
122854	U CEN	Max	8.4	1930 April 16	6083
131283	U OCT	Max	8.2	1929 Aug. 11	5835
	do.	Max	8.2	1930 June 6	6134
132422	R HYA	Min	10.0	1930 June 22	6150
132706	S VIR	Max	6.6	1929 June 15	5778
133155	RV CEN	Min	10.3	1930 Feb. 23	6031
133633	T CEN	Min	7.1	1929 July 31	5824
	do.	Max	6.1	1929 Sept. 4	5859
	do	Min	8.6	1930 Jan. 26	6003
	do.	Max	6.3	1930 Mar. 9	6045
	do.	Min	7.9	1930 April 28	6095
	do.	Max	6.1	1930 June 7	6135
134236	RT CEN	Min	13.0	1930 May 10	6107
134536	RX CEN	Max	10.2	1930 Jan. 27	6004
134677	T APS	Max	10.0	1929 Dec. 9	5955
140959	R CEN	Min	8.1	1929 Aug. 6	5830
	do.	Min	10.6	1930 April 21	6088
151822	RS LIB	Max	7.9	1929 Aug. 2	5826
	do.	Min	12.3	1930 June 26	6154
152849	R NOR	Max	7.0	1929 Sept. 28	5883
155823	RZ SCO	Max	8.6	1929 Aug. 5	5829
	do.	Min	12.2	1930 Mar. 25	6061
	do.	Max	8.5	1930 June 3	6131
161122a	R SCO	Max	10.1	1930 May 4	6101
161122b	S SCO	Max	9.7	1929 June 30	5793
	do.	Max	11.2	1930 June 20	6148
164844	RS SCO	Max	6.0	1930 June 21	6149
165030a	RR SCO	Max	5.7	1929 Sept. 21	5876
	do.	Max	6.0	1930 June 19	6147
172486	S OCT	Max	8.2	1929 Dec. 31	5977
174551	U ARA	Max	8.5	1929 Sept. 20	5875
	do.	Max	8.2	1930 May 13	6110
180363	R PAV	Max	8.7	1929 Oct. 21	5906
	do.	Max	7.8	1930 May 31	6128
195142	RU SGR	Max	7.2	1929 Aug. 6	5830
204954	S IND	Max	8.1	1929 July 5	5798
221938	T GRU	Max	8.4	1929 Dec. 25	5971
223462	T TUC	Max	8.2	1929 Oct. 26	5911
232746	V PHE	Max	9.2	1929 Oct. 23	5908
235265	R TUC	Max	8.7	1930 Jan. 23	6000

MARS SECTION.

Mars was not in opposition during the period under review and your Director regrets to report that satisfactory observations of the planet could not be obtained owing to its great distance.

Adverse weather conditions at the Cape made observing extremely difficult, and it is not surprising that observational notes were not sent in by any of our Cape members.

A number of drawings were received from Miss H. L. Troughton, of Johannesburg, who did good work during the 1924 and 1926 oppositions. A drawing of Syrtis Major made by her on December 12, 1929, at 11.30 p.m., shows a very prominent dark spot. During the 1924 opposition your Director noticed similar dark markings on Sinus Sabaeus, Dawes' Forked Bay, Solis Lacus and Syrtis Major. These markings were seen to dissipate during a period of three to five hours and were possibly due to cloud formations. The marking drawn by Miss Troughton, however, appears to be permanent.

B. F. JEAREY,
Director.

CAPE CENTRE.

SIXTEENTH ANNUAL REPORT, 1929-30.

Your Committee, in presenting this, the Sixteenth Annual Report of the Centre, have to record a period of continued activity and progress during the year now ended.

It is with sincere regret that your Committee have to record the loss through death of two esteemed members, viz., Dr. P. G. Gundry and Mr. Alfred Bull, the latter gentleman having acted as Librarian to the Centre from 1917 to 1920. Nine names have been added to the roll of membership. Seven have been deleted owing to resignation and other causes. There is now a total of 97 on the roll (89 members and 8 associates), an increase of two on the total in the last report.

The Centre has secured more convenient accommodation and its meetings are now held at the rooms of the Mountain Club of South Africa—Benson House, 47a, Long Street, Cape Town. During the period under review there have been nine ordinary meetings of the Centre. Your Committee have met five times.

The following addresses and papers were submitted at the ordinary meetings, viz.:—

"Alleged Influences of the Moon": Dr. D. G. McIntyre.
"The Rotation of Venus": Mr. H. E. Houghton, F.R.A.S.
"Gondwanaland": Mr. H. C. Mason.
"The Milky Way": Mr. A. G. Hoyer.
"The New Moon and Earthshine on the Moon": Mr. A. W. Long, F.R.A.S.
"The Satellites": Mr. H. C. Mason.
"Planispheres and Charts": Mr. A. W. Long, F.R.A.S.
"The Planetarium": Mr. Bert F. Jearey, F.R.A.S.
"Sites of Old Observatories at the Cape": Mr. T. MacKenzie, F.R.A.S.
"Effect of Sunspots on the Weather": Mr. M. H. N. Crowther, B.A.
"The Sunspot Cycle—How the Earth Responds to it": Mr. R. Watson.
"Time of Occultation of a Star by the Moon": Dr. P. Strachan.
"Motions of the Earth": Dr. J. K. E. Halm, F.R.A.S.
"Anomaly": Mr. T. MacKenzie, F.R.A.S.
"Masses of the Planets": Dr. H. Spencer Jones, F.R.S.
"The Universe as a Physicist sees it": Mr. A. E. Bleksley, M.Sc., F.R.A.S.
"The New Planet": Mr. H. Horrocks, M.A., F.R.A.S.
"The Trans-Neptunian Planet": Dr. R. T. A. Innes, F.R.A.S.
"The Green Ray": Dr. R. T. A. Innes, F.R.A.S.
"Star Catalogues and Charts": Mr. H. E. Houghton, F.R.A.S.

By the kind invitation of His Majesty's Astronomer an Observational Meeting was held in the McClean Observatory on February 23, 1930, when the Victoria Telescope was placed at the disposal of members for observation. Members greatly appreciate this privilege.

The Committee have pleasure in recording the discovery of two comets by Mr. A. F. I. Forbes since the issue of the last Annual Report, in which a comet discovered by him was also recorded. Mr. Forbes has thus three comet discoveries to his credit, all of which were found within a period of eighteen months.

The finances of the Centre continue to be satisfactory.

Notes with charts of the sky continue to be published monthly in the *Cape Times,* these being contributed by Mr. A. W. Long, and an addition has been made by the insertion of a diagram showing the positions of the planets in their orbits during the month. Articles in Afrikaans by Mr. T. MacKenzie are published in *Die Burger* at intervals. Both series of articles are greatly appreciated by members and the public generally.

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1930.

Income.	£	s.	d.
To Balance in Hand, 30th June, 1929	7	2	7
„ *Subscriptions*—			
Arrears 6 16 6			
Current Year 54 18 9			
In advance 2 17 8			
	64	12	11
„ Subscriptions to *Cape Times* ..	1	1	6
„ Commissions on Cheques	0	4	6
	£73	1	6

Expenditure.	£	s.	d.
By Contributions to Headquarters ..	32	6	5
„ Rent of Meeting Room	10	10	0
„ Rent of P.O. Box	1	5	0
„ Typewriting and Stationery	4	17	6
„ *Cape Times* and Postage to Country Members ..	5	16	0
„ Advertising Meetings	0	15	0
„ Secretary's Expenses	3	6	10
„ Treasurer's Expenses	0	11	8
„ Bank Charges ..	1	11	6
„ Balance	12	1	7
	£73	1	6

Johannesburg Centre.

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1930.

Income.	£	s.	d.
To Balance on hand as			
„ at 30th June, 1929	29	9	2
„ Subscriptions . ..	22	1	0
„ Donations	0	10	6
	£52	0	8

Expenditure.	£	s.	d.
By Contributions to Headquarters ..	11	0	0
„ Periodicals	3	1	0
„ Engraving Block .	3	10	0
„ Postages and Stationery	0	6	9
„ Bank Charges .. .	0	11	5
„ Balance	33	11	6
	£52	0	8

Astronomical Society of South Africa.

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1930.

Income.	£	s.	d.	*Expenditure.*	£	s.	d.
By Balance 30-6-29 ..	28	8	2	To Printing Journal (Vol. 2, No. 4) .	52	10	6
„ 50% Subscriptions (Cape Centre) ..	32	6	5	„ Printing and Stationery	2	8	0
„ 50% Subscriptions Johannesburg Centre) ..	11	0	0	„ Case for Variable Star Register ..	0	6	9
„ Sale of Journals .	1	15	6	„ Rent	1	10	0
„ Sale of Sundial .	2	13	4	„ Postages	2	14	1
„ Donation Natal A.A.	5	0	0	„ Bank Charges ..	0	2	3
„ Donations to cost of Conversazione	17	4	6	„ Cost of Conversazione	15	4	0
				„ Membership Roll Book	1	0	6
				„ Cost of Block ..	0	9	0
				„ Balance carried forward	22	2	10
	£98	7	11		£98	7	11

Examined and found correct:
E. J. STEER.
30th June, 1930.

W. H. SMITH, *Hon. Treasurer.*

NOTES.

Pluto.—On March 12 last, the following message was sent from the Lowell Observatory, Flagstaff, Arizona, to the Harvard Observatory for distribution to astronomers:—

> "Systematic search begun years ago supplementing Lowell's investigations for trans-Neptunian planet has revealed object which since seven weeks has in rate of motion and path consistently conformed to trans-Neptunian body at approximate distance he assigned. Fifteenth magnitude. Position March twelve days three hours G.M.T. was seven seconds of time west from Delta Geminorum, agreeing with Lowell's predicted longitude."

In a Lowell Observatory circular, it is stated that the object was first recorded on the search plates of 1930, January 21, 23 and 29, obtained with the new Lawrence Lowell telescope, which was specially designed for the search for a trans-Neptunian planet. The planet was found by Mr. C. W. Tombaugh with the aid of the blink comparator.

Following upon this announcement, the object was widely observed until it was too near the Sun, and in South Africa photographs were secured at the Cape and Union Observatories. Owing to its north declination (+22°) the object is better placed for northern observatories. The trans-Neptunian nature of the object was soon established, the observations enabling the distance, inclination to the ecliptic and longitude of the node to be determined with considerable accuracy. But the eccentricity of the orbit, the semi-major axis and the period were practically indeterminate, owing to the small arc available. It was possible, however, for a search ephemerides to be computed and the planet has been found on plates obtained at Mount Wilson on 1919, December 28, 29, 30; at Yerkes on 1921, January 29, and 1927, January 6; and at Uccle on 1927, January 27. With the aid of these observations a sufficiently long arc is available to derive elements which must be very near the truth.

The following elements have been computed by E. C. Bower and F. L. Whipple of the Berkeley Astronomical Department (*Lick. Obs. Bulletin* No. 427):—

T	1989 Feb. 27·473			
ω	113°	8′	26″·1	1930·0
Ω	109	21	36·9	1930·0
i	17	8	57·0	1930·0
e	0·253741			
P	249·1661 years			
a	39·59673			

It may be noted that the periods of the three outer planets, Uranus, Neptune, and Pluto, are approximately 84, 165 and 249 years, or closely in the ratio 1 : 2 : 3.

The name Pluto for the new planet was suggested by Miss Virginia Burney, of Oxford. Prof. Turner telegraphed the suggested name to Flagstaff and Dr. Slipher has announced that the name was given in consequence of this suggestion. Besides being appropriate in itself, it has the further recommendation that the two first letters are the initials of Percival Lowell, the founder and first Director of the Lowell Observatory. Dr. Slipher suggests a combination of these letters in the form ♇ as the symbol for the planet. It is of interest to note that Miss Burney is the great-niece of Dr. Madan, who suggested the names Phobos and Deimos for the satellites of Mars.

It is announced from the Lowell Observatory that Pluto does not have the blue colour of Neptune and Uranus, but is yellowish, more like the inner planets. Neither in brightness nor apparent size is it comparable with Neptune. Low albedo and high density are suggested. It has been found at Mount Wilson that the spectrum is approximately of solar type.

The agreement between the derived elements and the elements of Professor Lowell's predicted orbit (based on a study of the residuals between theory and observation of the planet Uranus) are unexpectedly close. They may be compared as follows, the comparison being with the elements given above:—

	Predicted.	Observed.
Longitude of perihelion (1930 equinox)	205°	222°
Time of perihelion passage	1991.2	1989.2
Eccentricity	0.202	0.254
Period (years)	282	249
Inclination to Ecliptic	10°	17°

The only serious errors are in the mass, which Lowell estimated as six times that of the Earth, and in the stellar magnitude, which he estimated as 12. Pluto is of the 15th magnitude and it is improbable that its mass is greater than that of Mars. In view of this discordance, the question has been raised whether Lowell's forecast may not be wholly illusory and the above agreement a matter of pure chance.

Professor E. W. Brown has made an important contribution to this question. The few early residuals before 1783 between the observed and computed positions of Uranus are large, the later and more accurate residuals are generally small. Professor Brown has considered the following problem: " What are the elements of a planet of given mass and between given limits of distance which will produce small *apparent* perturbations on another planet during a given interval of time, with much larger apparent perturbations outside that interval? " He shows that the derived mean longitude, longitude at perihelion and time of perihelion passage, under the postulated conditions, must be very close to the values which Lowell actually derived by extensive computations, and that the values of the eccentricity, mean distance and mass substantially depend upon the early observations, which are affected by large probable errors. Professor Brown's investigation was published before the orbit of Pluto was accurately known and explained why the predictions of the trans-Neptunian planet by Gaillot, Lau, W. H. Pickering and Lowell were possible from the very small residuals in the longitude of Uranus and why the predictions agreed so well amongst themselves. Looked at from the converse point of view, it appears that the orbit of Pluto happens to be so placed with respect to that of Uranus, that the residuals of Uranus must necessarily be small during the period 1783 to 1910, and hence the agreement between the predicted and observed longitudes, longitude of perihelion and time of perihelion passage. The deduced mass may be seriously in error on account of the inaccuracy of the early observations of Uranus and the agreement between the predicted and observed distances and eccentricity may be a matter of chance.

H.S.J.

The Green Ray.—Twice in eight sunsets in May, 1930, this has been seen from Sea Point, once near sea level and once from the High Level Road. It was not, however, green, but decidedly bluish or blue or blue violet. In both cases it lasted several seconds. Before or just as the Sun disappeared, the atmospheric corona became blue at each end and as the Sun sank and the ends of the corona began to close in, the two blue ends approached each other, and at coalescense seemed to jump up for a moment. A 6-power prism glass was used.

The sunsets were golden orange and cloudless, with some mirage. Cloud seems to inhibit the appearance of the phenomenon entirely.

At Sea Point, and no doubt elsewhere, with an ocean horizon, the Sun may set twice, and it is this which gives rise to the " bar " effect. It sets twice because there are two perfectly definite horizons, the lower the water horizon, the higher (by about 10ft.) of fog, faintly visible, which may be a layer of very wet air.

An early reference to this " ray " will be found in Froude's " Leaves from a South African Journal," 1874, August 29: " Last night we had a remarkable sunset. The disk, as it touched the horizon, was deep crimson. As the last edge of the rim disappeared there came a flash, lasting for a second, of dazzling green—the creation I suppose of my own eyes."

R.T.A.I.

Astronomical Society of South Africa.

OFFICERS AND COUNCIL, 1930-31.

President: Captain D. Cameron-Swan, F.R.P.S., F.S.A. (Scot.), Strathmore, Kalk Bay, C.P.

Vice-Presidents: H. Spencer Jones, M.A., Sc.D., F.R.S.; R. Watson; H. E. Wood, M.Sc., F.R.A.S.

Hon. Secretary: S. Skewes, M.A., B.Sc., P.O. Box 2061, Cape Town.

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

Members of Council: H. Horrocks, M.A., F.R.A.S.; H. E. Houghton, F.R.A.S.; W. B. Jackson, M.Sc.; A. W. Long, F.R.A.S.; H. W. Schonegevel; Miss H. L. Troughton.

Alternate Members of Council: D. C. Burrell, A. F. I. Forbes, H. C. Mason, D. G. McIntyre.

Hon. Auditor: E. J. Steer.

DIRECTORS OF OBSERVING SECTIONS.

Comet: A. F. I. Forbes, "Park Villa," Hermanus.

Computing: R. T. A. Innes, D.Sc., F.R.S.E., F.R.A.S., 26, Pope Street, Johannesburg.

Mars: B. F. Jearey, F.R.A.S., F.R.M.S., Villa Carina, Alexander Road, Muizenberg.

Meteor: T. MacKenzie, F.R.A.S., 46, Market Street, Grahamstown.

Variable Stars: G. E. Ensor, Pretoria Hospital, P.O. Box 201, Pretoria.

Hon. Editor: H. Spencer Jones, M.A., Sc.D., F.R.S., Royal Observatory, Cape of Good Hope.

Hon. Librarian: D. C. Burrell, Pinelands, Cape Town.

COMMITTEE OF CAPE CENTRE.

Chairman: H. Horrocks, M.A., F.R.A.S., Royal Observatory, Cape of Good Hope.

Vice-Chairman: H. C. Mason.

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

Hon. Treasurer: A. F. I. Forbes.
Committee: Major D. A. Fairbairn; B. F. Jearey, F.R.A.S.; A. W. Long, F.R.A.S.; D. G. McIntyre; R. R. Pratt, B.Sc., A.M.I.C.E.
Hon. Auditor: E. J. Steer.
Hon. Librarian: D. C. Burrell.

COMMITTEE OF JOHANNESBURG CENTRE.

Chairman: J. D. Stevens, P.O. Box 1782, Johannesburg.
Hon. Secretary: A. Forrest, P.O. Box 2402, Johannesburg.
Hon. Treasurer: W. Geddes, P.O. Box 2402, Johannesburg.
Committee: Mrs. W. B. Jackson, Miss H. L. Troughton, T. Beamish, W. B. Jackson, M.Sc.; H. E. Wood, M.Sc., F.R.A.S.; W. M. Worssell, F.R.A.S.

NEW MEMBERS.

Andrews, W., Tircrievan, Clifton Road, Mowbray.
Bleksley, A. E., M.Sc., F.R.A.S., Mowbray Hall, Mowbray.
Fairbairn, Major D. A., O.B.E., Durban Club, Durban.
*Farre, A., Milner House, Rhodes University College, Grahamstown.
Heyes, E., 311, Beach Road, Sea Point.
Johnston, W., Agent, Parow.
Luckhoff, Rev. D., Stellenbosch.
Shepherd, Mrs. C. E., 41, Arnold Street, Observatory, Cape Town.
Wassenaar, Dr. J. J. S., Main Street, Pilgrims Rest.

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

Bentley, W. W., Campall Glen, Umhlali, Natal.
Cowen, G., Glenhope, Mount Frere, C.P.
Eaton, W., Brombow, Meyerton, Transvaal.
Kerrich, J. E., M.A., F.R.A.S., University of the Witwatersrand, Johannesburg.
Lawn, J. R., 133, Exton Road, Bloemfontein.
McIntyre, D. A., M.B.E., J.P., Fairfield Hotel, Wynberg.
McIntyre, D. G., c/o Syfret's Trust Co., Ltd., 24, Wale Street, Cape Town.

Orpen, Miss C., B.Sc., Royal Observatory, Cape Town.
Ritchie, A., Belvedere Hotel, Langebaan, C.P.
Roberts, A. W., D.Sc., F.R.S.E., F.R.A.S., Native Affairs Commission, Pretoria.
Wallis, A. H., C.E., J.P., F.R.Met.Soc., Civil Service Club, Cape Town.
Williams, J., c/o Petersen's Surgical Dept., Castle Street, Cape Town.

*Associate.

The Society acknowledges the receipt of publications, etc., from the following:—New South Wales Branch of the British Astronomical Association; Vereinigung von Freunden der Astronomie und kosmischen Physik; Antwerp Astronomical Society; Harvard College Observatory; University of Durham Philosophical Society; Lick Observatory; South-West Africa Scientific Society; Argentine Astronomical Society; Argentine Association of Friends of Astronomy; University of Tartu (Dorpat) Observatory; Bosscha Observatory, Lembang; Union Observatory, Johannesburg; West of Scotland Branch of the British Astronomical Association; Engelhardt Observatory, Kasan.