# The Journal
of the
# Astronomical Society of South Africa.

Vol. I. NOVEMBER, 1925. No. 6.

## PRESENT-DAY PROBLEMS OF ASTRONOMY.

(Presidential Address, Session 1924-25.)

By J. K. E. Halm, Ph.D., F.R.A.S., F.R.S.E.

The history of Astronomy during the last three centuries is a record of continuous progress. Since the days of Kepler and Newton no period can be pointed out when advance in one or other of its branches was entirely suspended. But the centre of most rapid progress has shifted from time to time. It was natural, for instance, that the discovery of the law of gravitation and its fundamental bearing on the motions of the bodies governed by the attractive force of the sun should lead, in the earlier days, to a concentration of efforts in the direction of establishing the dynamics of our solar system. Here was an inexhaustible field for the mathematician who by ever-increasing refinements in his analytical methods endeavoured and succeeded to account for the complex motions of the constituent members of our system as the manifestations of that one, still mysterious, force called *gravitation*. This branch of astronomical science, as you know, held its sway predominantly up to the middle of last century.

As an illustration of the state of astronomy in those early days, an introductory address circulated prior to the first meeting of the Royal Astronomical Society in 1820 contains the following paragraph:—

> "Beyond the limits of our system all at present is in obscurity. Some vast and general views on the construction of the heavens and the laws which may regulate the formation of sidereal systems have, it is true, been struck out; like the theories of the earth which have so long occupied the speculations of geologists, they remain to be supported or refuted by the slow accumulation of a mass of facts."

Speculations on the structure of the worlds outside the confines of our solar system had in those days to be conducted on lines of purely deductive reasoning, unguided and unchecked by facts of observation, because at that time the instrumental weapons of attack necessary for the acquirement of such facts were wanting. The latter half of the nineteenth century, however, marked an important turning-point in astronomical development. The improvements in our instrumental equipments, in both the size and optical accuracy of our telescopes, the greater precision of the instruments with which the positions of the stars in the sky are measured, the discovery of the spectroscope and the introduction of photography, have enabled us now to extend our researches from the little system of celestial bodies ruled by the sun into the vast recesses of the universe. This expansion of our ideas has become possible by the collection of new facts which now instil the hope that a penetration into the constitution and structure of the universe of which our own system is only an insignificant member is a possible goal for intellectual aspirations. Although the problems of gravitational astronomy are by no means abandoned, and indeed have assumed renewed importance in the light of the theory of relativity, a fresh field has been opened to investigations of the properties of the vast host of celestial bodies which we comprise under the name of "fixed stars."

Now, you will agree that this designation in itself challenges at once the thoughtful mind to the investigation of a very great problem. To the ancient philosopher picturing the stars as openings in a solid sphere, the idea of *fixed* stars was a logical conclusion naturally resulting from this assumption. The modern conception of stars as isolated bodies separated from one another by vast interstices of empty space, on the other hand, is clearly not reconcilable with the assumption of rigid connections between them. Our mind is *a priori* satisfied that these isolated bodies should possess freedom to move through space. But if this conclusion is conceded, the great question arises: What are the laws regulating these motions? Are they the result of purely fortuitous circumstances under which the stars were originated, or are there indications of *properly directed* original impulses which reveal themselves now in *systematic* motions common to separate groups and families? In other words: Is *chaos* or *system* the ruling factor? An answer to these questions is the first and principal problem of modern astronomy which I intend to outline to you to-night.

You will readily understand that if the stars shift their positions relatively to each other, their projections on the sky, that is, the apparent positions in which we see them, will alter in course of time. We should therefore expect a gradual change in the geometrical outlines of the "constellations." But, although we now know that the velocities with which the stars move through space are considerable, we must at the same time bear in mind that their distances from us are so great that their dis-

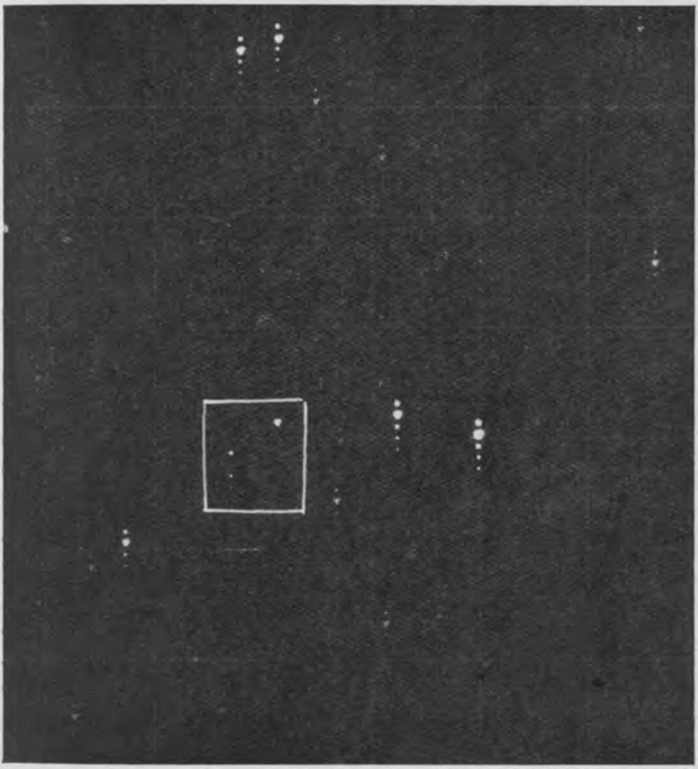


FIG. 1.

placements on the sky are represented, on the whole, by very minute arcs. A long time would therefore have to elapse before the accumulated motion would be sufficiently great to be appreciated by the unaided eye. There are, of course, exceptions to this rule, when a star, either through exceptionally large motion or through relative nearness to our system, is transferred across the sky at a rate much greater than the average. An interesting example of this kind is shown in Fig. 1.

It represents a region of the sky situated in the Cape Astrographic Zone. Of this region two photographs had been taken, one about 20 years ago and the other recently. The older plate was taken in the ordinary way with film towards the object glass, while the recent plate was taken with its glass side towards the object glass, proper care being given to the focal adjustments. On the new plate four exposures of different durations were made, resulting in four images of different brightness arranged along a line in the vertical direction. The gap between the two brightest images has been given twice the length of those between the fainter images. On the older plate, on the other hand, three exposures of equal duration were made, the images being arranged in the form of a small isosceles triangle. The two plates were oriented against one another in such a manner that the triangle of the older plate fell midways between the two brightest exposures of the new plate.

Now you will readily understand that if, during the interval of 20 years, the positions of all the stars had remained unaltered, the relative positions of the old and new images would be exactly the same for all stars. The photograph shows that this is apparently the general state of affairs, with one notable exception, however, which has been enclosed in the square shown in the picture. This particular star has therefore moved with an exceptionally high speed over a considerable portion of the field (in fact, it possesses the second greatest proper motion so far known).

It would be wrong to conclude, however, that this is the only star in that particular region possessing motion, and that all the others deserve to be called "fixed" stars in the rigid meaning of the word. A comparison of two photographs separated by an interval of 200 instead of 20 years would reveal most probably a great number of stars having sensibly shifted their positions. The picture is interesting in two respects. First, it demonstrates clearly the existence of star motion, and, secondly, it shows the enormous length of time required for the detection and accurate determination of such motions in the majority of cases.

It is therefore not astonishing that centuries of untiring patient labour were required to obtain reliable determinations of star motions in sufficient numbers to derive from them definite conclusions regarding the general movements of the universe. From the middle of the 17th century, when Bradley undertook the first comprehensive series of exact star positions with the transit instruments of the Greenwich Observatory to the present day, the principal work of all our great Observatories has centred on the reliable determinations of the positions of at least the brighter stars at various epochs; and careful comparisons of these results undertaken by such eminent authorities as Auwers, Newcomb and Boss have now supplied us with data sufficient at least to obtain a first hazy glance at the general plan according to which star motions are arranged.

Let us now try to comprehend the methods along which research has proceeded. Let us assume that a certain region of the sky contains a considerable number of stars for which the motions across the sky have been determined by the long-continued labours of astronomers. Let, for clearness' sake, some of these motions be represented on the following diagram

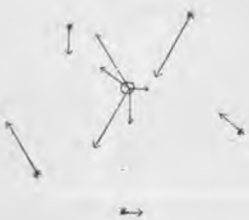


FIG. 2.

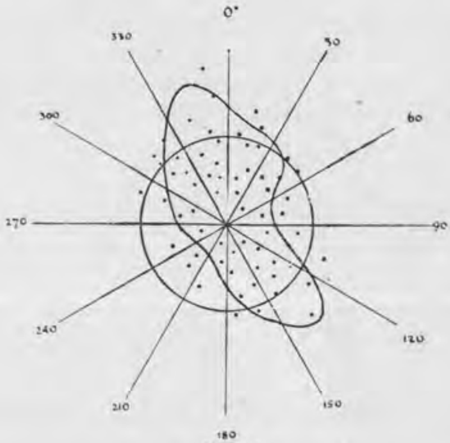



FIG. 3.

(Fig. 2) by the arrows attached to the star points. As the position of the star on the diagram is irrelevant, since the only quantities under consideration are the arrows both in length and direction, we may transfer these arrows to the centre of the region marked by the letter O. Let us now draw a circle (Fig. 3) with O as centre, and divide the circumference of the circle into even arcs, say 30° in width. Each of the sectors 0-30°, 30°-60°, etc., will contain a certain number of arrow heads. Now, if we draw lines from O through the centres of the sectors, and if we choose the lengths of the lines in proportion to the number of arrows found in the sector, then, by joining the end-points of these lines together, we obtain a closed curve such as is roughly indicated in the diagram.

It is on the geometrical character of these curves that our conclusions as to the motions of the stars are based. Let us try to realize the nature of the curves in some simple instances. Let it be supposed, for instance, that all the sectors contain the same number of arrows, which, of course, means that motions of stars are *equally* possible in all directions, *i.e.*, are distributed at random. In this case the lines drawn through the centres of the sectors would all be of equal length, and consequently the curve drawn through their end-points would be a circle. (Fig. 4.)

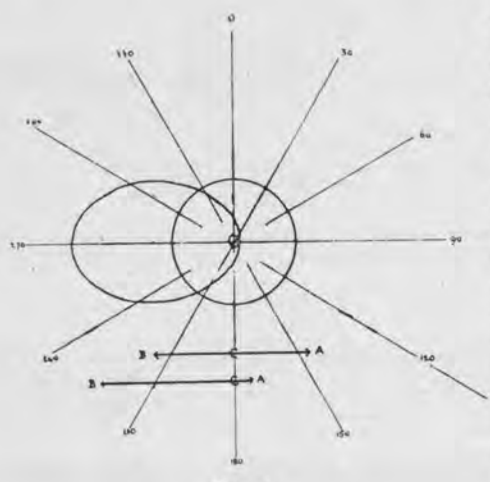


Fig. 4.

Now it has been assumed by the older school of astronomers that such a random distribution of motions actually represents the true facts of nature. It might therefore be argued that, if the assumption of these astronomers were correct, we should find the circular distribution confirmed by observation. This view could, however, only be accepted if our own system from which all these phenomena are observed were at rest in relation to the stars. But since our sun represents a star endowed with a motion through space similar to those of other stars, it must necessarily impress its motion on those of all the stars around us. For instance, take two stars, A and B (see Fig. 4), A moving to the right, B to the left, as seen by an observer who is at rest with regard to the point C. Now, if the viewpoint of the observer travels to the right in the direction of A, then obviously the departure of A from C must be retarded and that of B enhanced so that the actually observed motions are shown in the second line.

Let us apply this consideration to the diagram above. The circular distribution on this diagram, as already said, applies to the case that the stars in our region can move with equal chance in all directions if viewed by an observer who is fixed relatively to the point O. But if the observer moves from left to right, then obviously the chances for moving into the left half are enhanced. Instead of a circle we now find the numbers represented by an elongated curve resembling an ellipse, having its maximum elongation in the direction exactly opposite to the motion of the observer. The mathematical character of this curve, which may be properly called the distribution curve, has been first formulated by Prof. Eddington, who is the author of this ingenious and lucid method of investigation.

We have now arrived at a very definite conclusion. If, as the older school of astronomers surmised, the relative motions of the stars among themselves are entirely haphazard, *i.e.*, equally possible in all directions, and if our system moves through this chaotic universe, then the observed distribution curve should be represented by a figure such as is shown in the elongated curve of our diagram.

You will understand, of course, that the appearance of this figure will not be the same for all regions of the sky. It will appear most elongated in regions lying at right angles to the direction of the sun's motion, because there the effect of our own motion will be greatest, and it will be circular at two points, the so-called *apex* towards which the sun is travelling, and the *antapex* from which it is receding. Hence both the length and direction of the elongation will serve as a measure of the motion of our own system. You will readily understand that since the elongation always lies in the direction of our own motion, it must lie on a great circle which, if drawn out over the sphere, will pass through the apex and antapex. Hence the method described offers the necessary means of determining these two points.

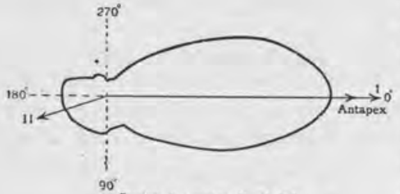
Now let us remember that all these explanations are so far based on abstract reasoning. We have described what should be expected if a certain assumption regarding the motions of the stars could be accepted, viz., the assumption that these motions are entirely chaotic, haphazard, or chance motions.

FIG. 5.

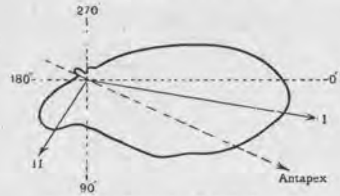
Let us now examine a distribution curve actually observed. I select one derived by Prof. Eddington in his investigation of the Groombridge Catalogue (Fig. 5). The region selected is at $16^h$ R.A. and $+54°$ Dec. You will notice that although we have to deal with a highly elongated curve as before, the observed curve differs very markedly from the theoretical curve, especially if you compare the positions of the point O. In the latter case this point was situated very close to the circumference, whereas here we find it considerably displaced into the interior. Any attempt to adapt the two curves to each other will leave differences which cannot possibly be attributed to errors of observation.

But if we look more closely, we find that our present curve can be very closely represented by *two* curves of the former kind, which are shown in the figure by the dotted lines.

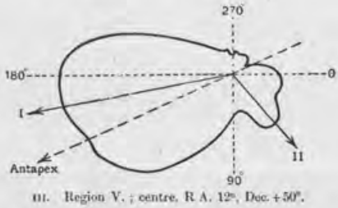
Now, this remarkable phenomenon of a *duplex* nature of the observed distribution curves is noticeable in all regions of the sky, typical examples of which are shown in Fig. 6. Further, if we construct the constituent dotted curves in every case, and if we extend their lines of greatest elongation to great circles, we find that each family of such great circles intersects each other in two opposite points which represent the apparent apices of two separate families or drifts of stars. The points of intersection for each drift are shown on the following diagram (Fig. 7), taken from Prof. Eddington's book: "Stellar Movements and Structure of the Universe" (p. 99).



I. Region I ; centre, North Pole.



II. Region II ; centre, R.A. 0h, Dec +50°.



III. Region V. ; centre, R.A. 12h, Dec. +50°.

FIG. 6.

The evidence of the diagrams is, on the whole, so convincing that we do not hesitate to abandon the older conception of a random distribution of star motion, and to place in its stead the modern conception according to which there are at least two separate streams of stars passing through one another.

This is a meagre outline of the celebrated two-drift theory announced by Kapteyn at the meeting of the British Association here in Cape Town in 1905. It is interesting to note, however, that Kapteyn's conclusions had already been foreshadowed by another astronomer ten years prior to their first public announcement. In 1890 Prof. Kobold, of the Strassburg Observatory, had undertaken the discussion of the proper motions of the stars contained in Bradley's catalogue, and derived by Auwers in his celebrated Reduction of Bradley's observations. By using a method suggested by Bessel, but till then not employed by other astronomers, he arrived at the conclusion that his results could only be reconciled with the older determinations of the sun's motion by assuming stars to shew equal preference for forward and backward motion along a certain direction, a statement which in substance is equivalent to the two-drift hypothesis. I give this historical information with some personal interest because I happened to be associated with Prof. Kobold at that time, and I can still recall the thrill of excitement with which his first verbal announcement of his discovery was received by his colleagues in the computing room of the Strassburg Observatory.

Now, although the two-drift theory goes far in explaining the facts of observation, let me warn you, however, against its

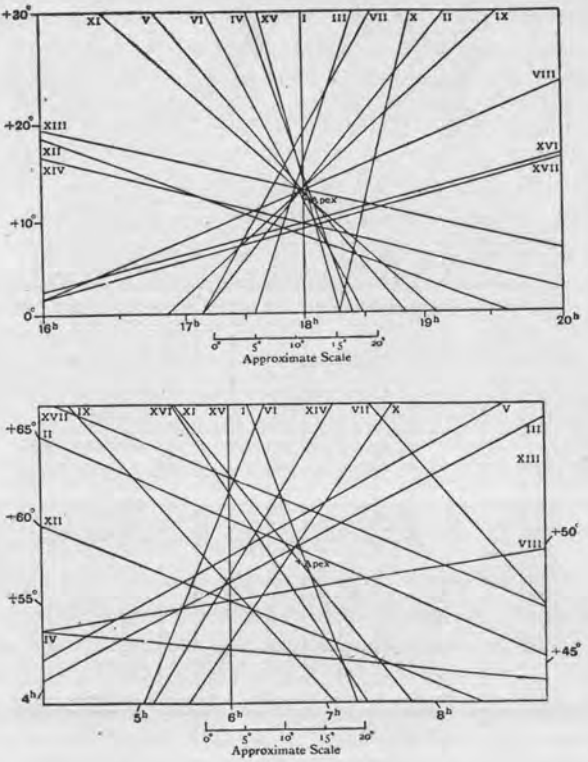



FIG. 7.

acceptance as the final explanation of star streaming. The further we penetrate into the subject, the more we become convinced of having reached only a first rough approximation. Many years ago I pointed out the presence of at least one other important star drift, chiefly comprising the more distant stars. This drift O is characterized by the property that it shows no motion relatively to the universe as a whole, that it may be therefore considered to be at rest in space, and that all the stars of the Orion type belong to it.

But I am convinced that even the more complicated machinery of three streams of stars does not represent the motions of the universe in their entirety. They are only the most prominent manifestations of star motion in the particular portion of the universe of which our sun at present forms a member. The existence of star drifts other than the three mentioned, though less prominent in recognized membership, may, indeed, be accepted as an assured fact of observation. One of the most interesting of these "Astronomical Associations" is the Ursa Major group. It has long been known that five stars of the Plough form a connected system. Prof. Hertzsprung has shown that a number of stars, selected over a great area of the sky, are members of the same society, the most interesting of these being *Sirius*. Perhaps the most remarkable of these moving star-clusters is the star stream in the constellation of Taurus. Thirty-nine members of this group have been identified, but there can be no doubt that many fainter stars in this region whose motions have not yet been examined may belong to it.

On the following plate (Fig. 8) the motions of these 39

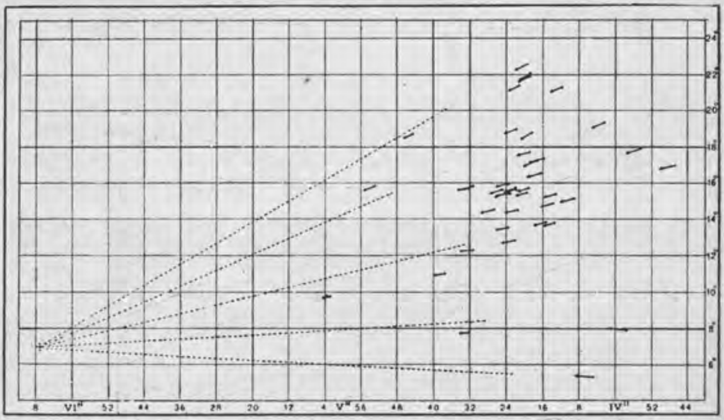


FIG. 8.

stars are indicated by the small arrows. You notice that all these arrows point with great accuracy to the cross marked on the left-hand side of the diagram. But such convergence on the sphere signifies parallelism of motion in space. Hence all these stars actually move with equal speeds in parallel directions, and there can be no doubt that in time to come the stars will appear as a small cluster situated at the point of convergence and similar to the globular clusters we are familiar with. In the presence of this fact we may well ask whether the clusters which adorn the nocturnal sky are star streams viewed by us from an enormous distance, and, conversely, whether the three star streams which we have located are globular clusters amongst which we are moving at present. It may well be that further progress in the analysis of star motion may eventually resolve the universe into a great number of star families, which for some reason are held together by a common bond of motion. Certainly our present knowledge affords only a very superficial glance into the structure of the universe, and if we consider that this meagre result is the outcome of centuries of continuous and arduous vigils night after night, we realize the enormity of the problem in front of astronomical research.

But let us revert from the despondent outlook on what we do not know to the more cheerful tale of what we have achieved. My account of the labours of astronomers spent on solving the question of star motion would be sadly deficient if I were to omit the valuable assistance received from spectroscopic research. I had several opportunities in the past at our meetings of speaking on the way in which we obtain knowledge of star motion by means of the spectroscope. You will remember that this is achieved by observing the displacements of the dark absorption lines of the star's spectrum from their normal positions. The amount of this displacement either towards the red or the violet part of the spectrum indicates the relative motion of the star, expressed in kilometers or miles per second, either from us or towards us.

Hence, whereas our previous considerations were concerned only with that part of the star's motion which is projected on the sky *at right angles* to the line of vision, called the *transverse* motion, the spectroscope supplies us with information regarding the motion *along* the line of vision, the *radial* motion. It thus affords means of testing independently the results of drift motion obtained from the transverse motions. I shall now endeavour not to tax your patience too severely by a short account of our achievements in this direction.

Let us assume again, as before, that the stars among themselves are in a *chaotic* condition of motion. Let us imagine them to behave similarly to the molecules of a gas flying about in all directions with greater or lesser speeds. Now we know what an observer would have to expect if he were capable of observing the motions of the molecules. If he would note down the number of molecules with motions towards or from him less than one yard per second, say, and again the number found between 1 and 2 yards, and so on, and if he would trace out these numbers on a diagram (Fig. 9), by taking the speeds as the horizontal co-ordinates and the numbers as the vertical co-ordinates he would find a curve such as is shown by the middle curve in the diagram.

On the right-hand side of the highest point of this curve the numbers are noted of those molecules whose motion is directed towards the observer, and *vice versâ,* on the left-hand side those which are moving from him. The curve here shown is known as the *error-curve*. He would find that the molecules with small speeds outweigh considerably those with large velocities. This is indicated by the progressive approach of the curve to the horizontal line on either side. He would also find that the curve is symmetrical to the centre because there are even chances for the molecules to move either towards or from him.

Suppose, now, the observer moves with a certain speed, say, 20 yards per second, away from the gas. You will readily understand that in his observations his own motion now impresses itself upon those of all the molecules. A molecule which showed no motion in the first experiment would now be observed to possess a motion of 20 yards away from the observer. Generally, the change of conditions between the first and second experiment can be fully represented by shifting the curve 20 yards towards the right.

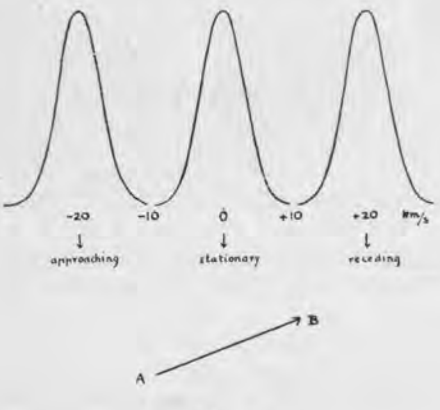



FIG. 9.

Therefore, an observer moving in a gas in the direction AB would find for the molecules in his back the curve on the right-hand side of the diagram, for the molecules in his front the left-hand curve, and for molecules at right angles to his motion the middle curve.

The displacements of the centres of the curves would show the amount of his own motion. And by observing such curves in various directions he would be enabled to determine his own motion both in amount and direction.

Now the older view on the motions of the stars is exactly comparable with the conditions applying to a gas. If we substitute "star" for "molecule," my description will therefore convey to you the procedure adopted by astronomers for determining the sun's motion from radial velocities.

The interesting question now arises: How far would these conditions be altered in the case of a gas or a universe in which the motions are clearly divided into *two* streams? Well, as before in the case of the transverse motions, instead of dealing with single curves, we would find duplex curves such as are shewn in the next diagram (Fig. 10). The curves obtained from two drifts would be generally characterized by showing *two* maxima instead of *one*.

Let us now examine the results of observation with the view of ascertaining how far they bear out the three-drift hypothesis recorded in the transverse motions.

For this purpose I may be allowed to quote a few results of an investigation which I published five years ago in the Monthly Notices of the R.A.S. I was chiefly interested then in the motions of the stars themselves, and not in the motion of our own system, which therefore was eliminated in each individual case by well-known formulæ and data prior to the investigation. The curves I am exhibiting refer, therefore, to phenomena noticed by an observer who is supposed to be at rest in relation to the centre of the stellar system.

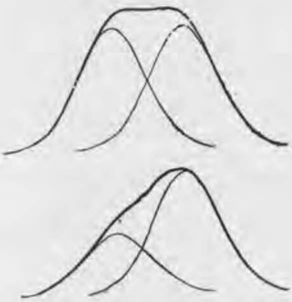


FIG. 10.

The material on which the investigation is based is contained in a comprehensive Catalogue of Radial Velocities compiled by Mr. Voute during his stay at the Royal Observatory. My principal object was to find in how far the three-drift phenomenon was evidenced by stars of different spectral types. In the discussion of the transverse motions I had found that the stars of type B, *i.e.,* the most luminous and hottest stars, were members exclusively of the 3rd drift, or drift O. It was, therefore, important to find first whether the radial velocities confirmed this result, and secondly, whether the stars of the cooler types A, F, G, K and M should show evidence of this drift in addition to the two other principal drifts.

For this purpose the stars were subdivided into four groups, according to type, viz., a B group, an A group, an FG group, and a KM group. In each of these groups the numbers of stars were counted whose radial velocities lay between 0-5 km., 5-10 km., etc., both in the positive and negative direction. The curves thus obtained are shown in Fig. 11.

You will at once notice remarkable differences between these curves. The B-curve, for instance, apart from a very slight hump on the extreme left, exhibits exactly the phenomenon we should expect if these stars belonged to one single drift, a result which is in accordance with the conclusions to which the investigation of the transverse motions had led regarding this particular class.

In contrast to this the later types show evidence of two very pronounced humps pointing at first sight to the presence of two drifts intermingled with one another. The component curves of these drifts are indicated by the dotted lines. But on closer investigation it was found that the two dotted curves combined were not yet capable of representing satisfactorily the observed curves in their middle portions. They left residuals which are represented in the curves shown in Fig. 12. There cannot be the slightest doubt that these curves are due to a third drift which is most prominent in the B stars and least pronounced in the stars of type FG.

In other words, the investigation of the radial velocities shows clearly the presence of *three* distinct star drifts, and thus confirms in every respect the results derived from the transverse motions.

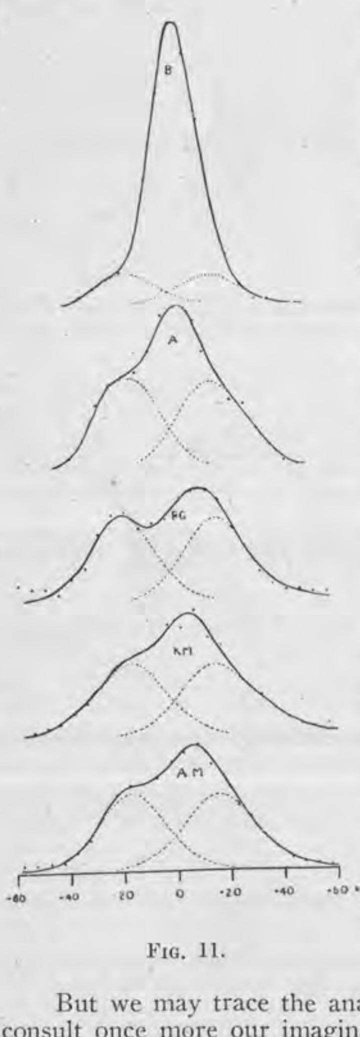



Fig. 11.

But it further appears that these drifts are mixed in very different proportions. The B type stars belong pre-eminently to the 3rd drift, the stars of type FG almost entirely to the other two drifts known as drifts I and II. It is undoubtedly more than a mere coincidence that the former group comprises the most distant stars, and the latter those nearest to our own system. It would seem, therefore, that the 3rd drift makes itself felt only at great distances from our viewpoint, whereas drifts I and II represent the conditions of star motion in the vicinity of the sun.

You will admit that the analogy between the motions of the stars in the universe and the motions of the molecules in a gas has carried us a good length in comprehending the essential character of star motion. The one drift hypothesis is analogous to the conditions prevailing in a gas whose molecules move entirely at random. The two and three drift theory has its counterpart in the case of a gas agitated by stirring in such a manner that internal streams of molecules are engendered moving in different directions.

But we may trace the analogy even a step further. Let us consult once more our imaginary observer who is recording the motions of the molecules. Let us assume that he is observing a gas containing two elements, such as hydrogen and oxygen.

He is supposed to be in a position to distinguish between the two, and therefore to draw the error-curve for each element separately. Now, what he will observe is shown in Fig. 13. The curve for the heavier element oxygen is much steeper and more constricted than that for the lighter element hydrogen. And he will further find this remarkable result: If he takes in both cases the average of all the speeds he has observed, irrespective of whether the motion is towards him or away from him, and if he squares this speed and multiplies the figure obtained into the mass of the element, he will find that the product will be the same in both instances.

The interesting question now arises: Is this remarkable relation between mass and speed, which is known as Maxwell's law, and constitutes one of the fundamental theorems in the theory of gases, also applicable to the case of the universe?

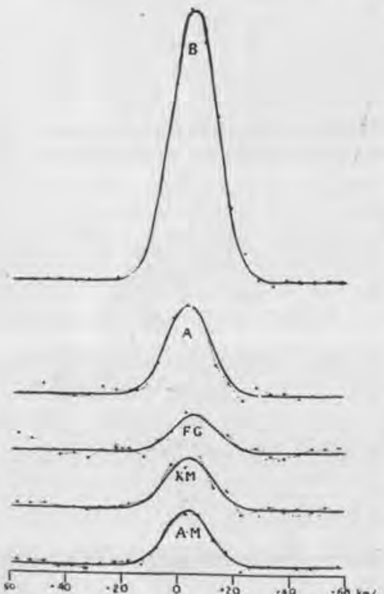



FIG. 12.

Now, when averaging the speeds of the stars of different spectral types Campbell and Boss have found that the speeds increase as we proceed from type B to type M. The inference would be that the masses decrease in such a manner that the product of the mass into the square of the speed would be the same for all spectral types. The test depends naturally on our knowledge of the masses, an information for which we have unfortunately to rely on a very limited material supplied by binary stars.

In a paper published in the Monthly Notices 14 years ago I was bold enough to announce the existence of Maxwell's law in star motion on the basis of the knowledge of star masses then at our disposal. The attempt was naturally criticized on account of the scantiness of the material on which it was based. But in the meantime our knowledge of the masses of the stars has been considerably increased, and my original announcement has been vindicated to such an extent that Prof. Seares, of the Mt. Wilson Observatory, has actually accepted the Maxwellian law as a reliable basis for deriving the masses of the stars from the velocities.

But we may pursue the analogy between gas and universe even further. In the light of modern physical science the atom is no longer the indivisible last unit of matter, but is in itself a complex structure consisting of much smaller constituents.

According to modern conceptions it consists of a nucleus charged with positive electricity surrounded by smaller particles, the electrons, which are the bearers of negative electricity. Physicists tell us that these electrons spin round the central orb in accordance with exactly the same laws which govern the motions of the planets round the sun. The atoms appear to be analogous to the solar system, and the assemblage of atoms called a gas to the stellar universe. The establishment of this similarity in structure and motion between the infinitely small and the infinitely great is certainly one of the most fascinating achievements of present-day science.

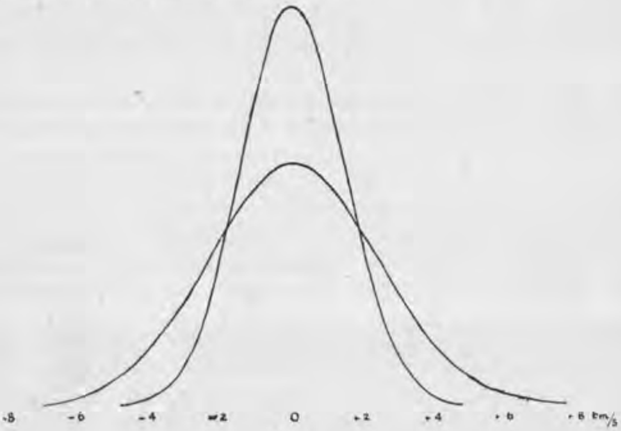



FIG. 13.

I have dwelt at some length on the methods derived by astronomers for investigating the motions of the stars among themselves. I hope to have convinced you of the difficulties besetting research in this direction. In the displacements of the star across the sky we are dealing with extremely minute quantities which become apparent only after long intervals of time, when by progressive accumulation they grow large enough to emerge from the accidental deficiencies of our observations. Even after nearly two centuries of constant assiduous work we stand only on the threshold of our knowledge of the systematic motions of the universe.

But I have by no means exhausted my subject. I have not dwelt on the knowledge we have gained in regard to the motion of our own system. It is the problem to find what portion of the visible motions of the stars in any region of the sky is due to the shift of our viewpoint on account of the motion of the sun. It is beyond the scope of this address to describe the methods employed for this purpose. Suffice it to say that astronomy can now give a fairly definite answer to this question. We know that our sun is moving towards a point of the sky situated approximately at 18 hrs. Right Ascension, and 34° Northern Declination, with a speed little short of 20 kms. per second. The results obtained both from the transverse and radial motions are in good agreement. There is some evidence that the apex of the solar motion depends on the apparent magnitudes of the stars selected for the investigation. This phenomenon, if real, would point to the fact that the drift motions of the stars are not the same throughout the universe. The assumption of *different* mixtures of drifts I and II, for instance, would have an effect on the position of the solar apex. But I must refrain from entering upon such intricate questions. What I should like, however, to emphasize is the important rôle played by the motion of the system in determining the *distances* of the stars. If you imagine that in the course of a single second we are transferred from one point of space to another 20 kms. apart, which means over a distance of about 4½ times the distance between sun and earth in one year, and 450 times that distance in a century, you will realize what an enormous base-line is at our disposal for measuring star distances. For instance, a star at the distance of our nearest neighbour α Centauri, and situated at right angles to our motion, would, in the course of 100 years, be shifted across the sky through an arc nearly 6 minutes in length. And if we consider that the error committed in the measurement of this arc is considerably less than 1/1,000 of the arc itself, it would appear possible to measure with certainty the arcs described by stars 1,000 times the distance of α Centauri, *i.e.*, at such remote points of space that their light would require from 4 to 5 thousand years to reach us.

Unfortunately, however, what we observe is the *combined* motion of ourselves and the star. Individually, the motion of the star is an unknown quantity, and hence it is clearly impossible to determine our own motion from a *single* star. Only when we consider a large number of stars, such as the members belonging to the same spectral class, or those shewing the same apparent brightness, or, again, those belonging to the same drift, can we separate our own motion from that of the stars under consideration. We may, for instance, find the displacements of the B-type stars as a whole, which are caused by our own motion. We find, for instance, that in a certain region of the sky this displacement amounts to about 3 seconds of arc in the course of a century. On the other hand, we know from the sun's motion what this displacement would be if the stars were situated at unit distance. We find that in this case the displacement would amount to 450 seconds per century. Hence we conclude that the B stars are on the whole at a distance of 450/3 or 150 units from us. Since light requires 3⅓ years to travel from unit distance to us, these stars are therefore at an approximate distance of 500 light years. But it would be entirely wrong to conclude that every member of that family was situated at that particular distance. Individually the stars may be widely scattered, and all we can say is that they occupy a probably large volume of space, the centre of which is at the calculated distance.

You will see from this example that, while the determination of star-distances from the sun's motion through space is valuable for statistical research, and has, indeed, greatly assisted us in researches into the general structure of the universe, the distance of individual stars cannot be ascertained. The only method available for this purpose is the observation of the minute displacements shewn by relatively near stars when viewed against their more distant neighbours from opposite points of the earth's orbit round the sun. Our base line is in this case the distance Sun-Earth, and the measured displacement is double the angle which is denoted as the *parallax* of the star.

Unfortunately, the insignificance of this base line as compared with stellar distances reduces the measurements of stellar parallax to an extremely small scale. You know that our nearest neighbour, $\alpha$ Centauri, shews a parallax amounting to only ¾ of a second of arc. And if you consider that the fiftieth part of this quantity is about the smallest parallax which can be determined with a reasonable amount of certainty, you will understand that our penetration into space is confined to a sphere round the sun, whose radius is not more than about 60-70 parsecs, or 200 light-years.

Now, staggering as such a distance may appear when expressed on our terrestrial scales, it is still small in relation to the depth of the visible universe. Out of the millions of stars surrounding us we have been able to secure so far only a few hundred with fairly reliable parallaxes, and though no doubt this figure will be augmented as the refinements in the art of observing increase, the objects of research will for all times be confined within a comparatively small region of space.

This serious limitation of our knowledge of star distances has always been before the minds of astronomers, stimulating their efforts to increase our knowledge by different methods of attack. Since it became obvious that the geometrical method to which I have alluded could not be materially extended, the only channel left open was a careful examination of *other* phenomena which would enable us to arrive at correct conclusions regarding the distances. Such phenomena are presented in the wireless messages sent to us in the form of light waves.

The intensity of light we receive from any source varies with the distance. It decreases, as you know, in proportion to the square of the distance. If, for instance, we measure the light received from an electric lamp one foot away, and then remove the lamp to such a distance that the light received is reduced to ¼, we conclude that the lamp has been placed at a distance of 2 feet.

Now, we can measure the brightness of a star as we actually see it at its correct distance. If, in addition, we could find means of determining its brightness as it would appear when transferred to *unit* distance, *i.e.*, its *absolute* brightness, then by comparing the two brightnesses a simple calculation would show how many unit distances the star is away from us.

The problem before the astronomer, therefore, was to find methods by which the *absolute* brightness of a star could be reliably fixed. The question he put to himself was as follows: I know the distances of a few hundred stars, and also their *apparent* brightnesses. I am thus in a position to calculate their *absolute* brightness. Now, is there any phenomenon inherent in the star's light which I can witness at whatever distance the star is placed, and which would serve me as a true indicator of its absolute brightness? If the observation of this phenomenon enables me to say with certainty what the star's brightness would be if placed at unit distance, then, knowing its apparent brightness, I can readily find its distance.

He, therefore, instituted a search among his few hundred stars for phenomena recognizable through the medium of their light, which indicated variations in intimate connection with their absolute brightness. He has succeeded so far in discovering two such phenomena, which have enabled him to extend his knowledge of distances far beyond the limits to which the geometrical method is applicable.

First, he found a class of stars whose light undergoes periodic fluctuations in a characteristic manner, a class known as the Cepheid Variables. He discovered that the period of this fluctuation of light is intimately connected with the absolute brightness, the brighter stars showing longer periods than the fainter. He found this connection between period and brightness so accurate and reliable that the period could be used as an indicator of the brightness with an accuracy of less than 1/10 of a magnitude. Hence, in whatever region of space such a variable appears, we shall always be able to ascertain its absolute brightness from the period of its light fluctuation, and knowing its apparent brightness, we shall then know at once its distance from us.

Now, such variables were found to be members of those striking assemblies of stars known as globular clusters, objects so infinitely remote from us that their parallax could not possibly be discovered by the geometrical method. Applying the method just outlined, the nearest of these clusters was found to be at a distance of 20,000 light-years, and objects of this class have even been discovered whose light reaches this planet only after 1,000,000 years of journey through space. From these facts you may imagine what an enormous measuring rod has been placed at our disposal.

The second discovery regarding the determination of the absolute brightnesses of stars is even more important. You know that the character of the spectrum of a star is mainly determined by the surface temperature. Two stars of the same temperature shew the same arrangement and pattern of the dark lines in their spectra. While this may be adopted as a general rule, closer examination and comparison of intrinsically bright and faint stars has, however, revealed the fact that the appearance of certain lines alters perceptibly with the absolute brightness. Now our few hundred parallax stars have enabled us to establish empirically the relation between the appearance of these lines and the absolute brightness with sufficient accuracy, so that by the study of the character of these lines in the spectrum of any star we may at once assign its proper absolute brightness and consequently its distance. It does not matter how far away from us a star may be, as long as it is sufficiently bright for observation of its spectrum. Already the spectroscopic distances or parallaxes of several thousands of stars have been determined by this method, and there is good reason to hope that eventually we shall become acquainted with the parallaxes of all stars down to the ninth or tenth magnitude.

The bearing of such knowledge on our conceptions of the structure of the universe would be colossal. At present these conceptions are based on the assumption that the absolute brightnesses are uniformly distributed throughout space.

The conclusion of Kapteyn and others as to the lens-shaped figure of the galactic system depends entirely on this assumption to which it is vitally bound. Naturally the assumption can be tested only when we know something of the *actual* luminosities of the stars scattered throughout a considerable portion of our universe. There is now well-founded hope that the spectroscopic method of determining these luminosities may be developed to such an extent as to supply a decisive answer regarding this fundamental assumption.

Until such time arrives it is perhaps wise to refrain from speculations on the structure of the galactic system.

I have no hesitation in asserting that the perfection of the optical methods which have recently been discovered for determining the absolute luminosities, and from these the distances of the stars, forms the outstanding problem of future astronomy.

Apart from the assistance we obtain in forming a more complete conception of the structure of the visible universe, to which I have just alluded, modern research into the *internal* constitution of the stars points now to the definite conclusion that the knowledge of two quantities only, viz., the *surface temperature* and the *absolute brightness*, will enable us to determine not only the distances, but also the *dimensions*, the *masses*, and the *densities* of the stars; in fact, all the physical data concerning the conditions of their birth and evolution. The determination of star temperature is a comparatively simple and straightforward matter. It can be derived from the colour-index, *i.e.*, from the difference between the apparent photographic and visual magnitudes, provided that these magnitudes are based on strictly scientific photometric determinations. The present difficulty lies in the determinations of the absolute brightness by the delicate spectroscopic method which I have indicated. Research in this direction is still in its infancy, but judging by the results already achieved, distinctly encouraging. Our choice clearly lies between either a complete standstill in our efforts of penetrating further into the depths of the cosmos, or a further development of the only method which holds out prospects for expansion of our knowledge.

The first requirement is naturally an ever-increasing accumulation of facts by which the method can be tested. We must secure first of all more distances of near stars by the ordinary geometrical method. In this respect we hail with satisfaction the erection of the American Observatory at Johannesburg, which will be chiefly devoted to the determination of parallaxes of southern stars, and which will work in this direction in close co-operation with the Royal Observatory. We secondly require an extension of observations of binary stars with the ultimate view of increasing our knowledge of star masses. Here again the foresight and liberality of American astronomers have provided fresh means for studying double-star phenomena in the Southern Hemisphere by the erection of an Observatory at Bloemfontein, which will support the great work to be undertaken by Dr. Innes at the Union Observatory with the new refractor. Thirdly, we have to concentrate our efforts on a close study of the spectra of stars, on the discovery of any particular features in the appearance of the Fraunhofer lines additional to those already discovered which show variations in accordance with the absolute brightness. And we stand, fourthly, in urgent need of more observations of variable stars of the Algol and Cepheid types. Let me assure you that the discovery and observation of the light curve of every new variable is of the very highest importance for astronomical progress in the directions which I have indicated. Here lies a field of research work in which professional Astronomy can be materially supported by organized efforts on the part of such Societies as ours. If, by unfolding before you a picture of some of the aims and purposes of modern Astronomy, I should have succeeded in convincing you that the efforts of our Variable Star Section are not only a pleasing and fascinating pastime for its members, but are also of the highest value for the furtherance of astronomical science in important directions, and if I should thereby have stimulated your devotion to this class of work, I should feel amply rewarded for my efforts of addressing you to-night on a vast subject.

However proud some of us may feel on the achievements of the human intellect, let this pride be tempered with a sense of becoming modesty when we approach the mysteries of the starry realms around us. Let us be aware that the face of Nature is still hidden from us—that so far we have barely touched the hem of her garment.

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## JUPITER.

By A. W. Long, F.R.A.S.

(*Seventh of a Series of Lectures on the Solar System by Members of the Cape Centre.*)

(*Concluded.*)

There is a very great contrast between the markings on Mars and those on Jupiter. Those on Mars are almost entirely permanent, so much so that maps have been constructed with fairly accurate detail, which, if we except the problematical canal markings, can be used by the observer with some confidence. In the case of Jupiter, while the equatorial belts remain more or less the same in bulk, the details of them and of all other markings on Jupiter are continually changing. A map of Jupiter is an impossibility. The markings we note to-night are not the markings we will see a month hence. There is, therefore, evidence here that we are not looking at the surface of a solid body. The globe of Jupiter, so far as we see it, at all events, consists of clouds and vaporous masses which appear to be agitated by fierce storms, judging from the ceaseless changes in the aspects of the disc we see.

The tempests which agitate the atmosphere of the Earth are all due to the heat of the sun, which warms the air, causing it to become lighter, and to rise, while surrounding cooler air rushes in to supply its place. The storms on Jupiter are vastly greater and more intense than those on the Earth, and, as Jupiter is so much farther from the Sun that the Sun's heat on Jupiter is only one twenty-seventh part as intense as on the Earth, the terrific storms on Jupiter must be due to another cause than the heat of the Sun. The only conclusion we can draw is that the planet still retains a large proportion of its primitive heat. The violent convulsions in the Sun due to his internal heat result in dark spots, which are usually in zones parallel to his equator, and in this respect are similar to the dark bands on Jupiter. The spectroscope tells us that the light reflected from the dark portions of Jupiter comes through a deeper layer of atmosphere than the light reflected from the bright parts. These dark patches are therefore at a lower level, and, judging from their ruddy colour, it may be that we are looking into a fiery interior.

It has been assumed that the white clouds and brighter shadings are the highest layers of cloud, the greyer ones being deeper down, and that very dark spots are rifts in these clouds which enable us to look on the actual surface of the planet.

There is one exceptionally prominent marking on Jupiter which has received a great deal of attention for upwards of half a century. It is shaped somewhat like an airship, and lies horizontally in a band of bright cloud. This region is known as the Great Red Spot.

It appears to have been noticed first by Dawes in 1857. It became a wonderfully conspicuous object in 1878, and excited a great deal of attention. It was then a faint rose colour, and measured 30,000 miles in length and 7,000 miles in breadth. Within a year it grew enormously until it stretched across about one-third of the planet's disc, its colour having changed to vermilion. Four years later it began to fade, and though in later years its colour deepened, it never regained anything like the distinction it attained in 1880.

Hooke, Cassini and others in 1664 and subsequent years observed a great spot which appeared and disappeared several times. This spot is supposed to be identical with the Great Red Spot of two centuries later, as it was in the same latitude of Jupiter, and had the same rotation period. Since 1878 the Great Red Spot has been regularly observed, and every change in its aspect has been carefully noted by quite a large army of observers. It is now a very feeble shadow of its former glory, but it may again acquire its ancient splendour by a repetition of the reinvigorating process that brought it into such great prominence in the 17th and 19th centuries.

It is suggested that the colour of the Great Red Spot indicates that this region is below the general level of the cloud surface we ordinarily see, and that the red light is partly inherent. The following description is by Miss Agnes Clerke:—"The red spot is attached, on the polar side, to the southern equatorial belt. It might almost be described as jambed down upon it; for a huge gulf, bounded at one end by a jutting promontory, appears as if scooped out of the chocolate-coloured material of the belt to make room for it. Absolute contact, nevertheless, seems impossible. The spot is surrounded by a shining aureola, which seemingly defends it against encroachments. . . . The formation thus constituted behaves like an irremovable obstacle in a strong current. The belt-stuff encounters its resistance, and rears itself up into a promontory or 'shoulder,' testifying to the solid presence of the spot, even though it may be temporarily submerged. The great red spot, the white aureola, and the brownish shoulder are indissolubly connected. . . . It is not self-luminous, and shows no symptom of being depressed below the general level of the Jovian surface. A promising opportunity was offered in 1891 of determining its altitude relative to a small dark spot on the same parallel, by which, after months of pursuit, it was finally overtaken. An occultation appeared to be the only alternative to a transit: yet neither occurred. The dark spot chose a third. It coasted around the obstacle in its way, and got damaged beyond recognition in the process." The gulf in which the red spot is placed is known as the Red Spot Hollow.

Powerful aerial disturbances noticed around the Great Red Spot in 1875 and later years, coupled with its colour, led to the conclusion that it was the reflection of enormous heat, the surface having been probably rent asunder at this region by a volcanic eruption; the fiery masses flooding an immense area. The hot currents sent up by them would have the effect of separating the clouds, and so allowing us to observe the fiery glow below.

Rev. T. E. R. Phillips considers that there is strong evidence favouring the idea that the Great Red Spot is "a vortex—analogous to a cyclone on the Earth, though its prolonged existence shows that it must be of great strength, and probably deep seated below the planet's visible surface. This theory is doubtless not free from objections, but it may be fairly said that it fits the facts better than any other."

Another very prominent marking which has been under close scrutiny since it was first noticed by Molesworth in 1901 is called the South Tropical Disturbance. Much of this object is of a durable character, but many changes in its extent and shape have been observed. It has been seen to change in length from 25 deg. to 180 deg., the increase representing more than 100,000 miles. It was Antoniadi who first drew attention to irregularities in the motion of the Red Spot caused by the well-named South Tropical Disturbance. These features of the planet are situated in the same latitude, and the South Tropical Disturbance periodically overtakes the Great Red Spot. The motion of the red spot is then accelerated as if the matter of the Disturbance pushes on the red spot as it flows round or below it.

Rev. Phillips, in presenting the Jupiter section report of the B.A.A. for 1923, says:—"The Red Spot Hollow was well defined throughout, and appeared as a whitish oval, with the dusky material of the South Tropical Disturbance surrounding it. On a few occasions after opposition, the Red Spot itself was seen, but it was very faint and difficult. The South Tropical

Disturbance was somewhat indefinite in certain longitudes, with an irregular and hazy boundary near the S. Temperate Belt. . . . The planet's disc generally showed very little colouring, but the Equatorial Zone became very white towards the close of the apparition."

A striking feature of the markings on the disc of Jupiter seen through large telescopes at times is a series of round white clouds "set side by side along one of the principal belts like a row of eggs." These are considered to be due to uprushes of vapour from deep down below the visible cloud surface of Jupiter. These may be successive eruptions from the same region, and as they come from a region of slow rotational motion to one of swifter motion they would tend to lag behind with reference to the direction of rotation: "Thus each new cloud-mass," says Proctor, "would lie somewhat in advance of the one expelled next before it; and if the explosions occurred regularly, and with a sufficient interval between each and the next to allow each expelled cloud-mass to lag by its own full length before the next one appeared, there would be seen precisely such a series of egg-shaped clouds, set side by side, as every careful observer of Jupiter with high telescopic powers has from time to time perceived."

That these clouds are really egg-shaped is seen by their aspect. "They are shaded on the side farthest from the Sun, in such a way as to show that they are rounded convexly towards the observer."

Jupiter's journey round the Sun occupies 11 years 314.9 days. His mean distance from the Sun is 482,716,000 miles. The eccentricity of his orbit is 0.048, so that his greatest, mean and least distances are approximately as 13, 12½, and 12. The best time to observe Jupiter is when he is in opposition, for he is then at his nearest to the Earth, and, being exactly opposite the Sun, comes to the meridian, or is at his highest elevation at midnight. We get the closest view of the planet when opposition occurs at the end of September. His greatest opposition distance is when that event occurs at the end of March. The difference between these extremes is about 50 million miles.

When Jupiter is at quadrature, that is, when a line from the planet to the Earth is at right angles to a line from Earth to Sun, he will be on the meridian at sunrise if the time of quadrature precedes opposition, and at sunset if quadrature follows opposition. The period from quadrature through opposition to quadrature amounts to about 170 days. During the greater part of this period, or for about four months, the planet appears to move backward in its journey as seen on the background of stars. This retrograde movement is caused by the quicker angular movement of the Earth, which is in the same direction. A similar effect may be observed when seated in a fast train which overtakes and passes a slower one. The slow train appears to move backward when referred to the distant scenery.

When Jupiter is in quadrature the line of sight from the Earth to the planet is inclined at its greatest angle to the line from the Sun to Jupiter, and Jupiter must then be to some degree gibbous, but this is not perceptible to ordinary telescopic vision. It can, however, be measured, and its effect may be observed. When satellites are occulted on the gibbous side they are seen to disappear before they come into contact with the luminous edge of the planet.

When Galileo in the beginning of the year 1610 first observed the satellites of Jupiter he supposed them to be stars seen in the same field of view. There were two on the east and one on the west of the planet. But on the following night, as he says, "moved I know not by what power," he found the three supposed stars all on the west side of the planet and closer together. According to the astronomical tables the planet should have been retrograding or moving towards the west, whereas it had apparently moved to the east. Galileo's first thought was that the tables were in error. The next night was cloudy, but on the following night he saw two of the stars on the east of the planet, and concluded that the third was behind Jupiter. He continued his observations, and soon became satisfied that the supposed stars were bodies travelling round Jupiter in the way the Moon travels round the Earth. On the seventh night he discovered a fourth satellite, which completes the number of those bright moons of Jupiter whose journeyings round the planet produce the interesting phenomena of occultation, eclipse and transit of the disc which delight all observers.

Galileo found that these satellites travel round Jupiter in orbits that are nearly circular, and so form with Jupiter a miniature solar system. Proctor points out that the system of Jupiter may be regarded as a much truer miniature of the system of terrestrial planets than of the entire solar system, and as an almost equally true miniature of the system of the giant planets.

Students of science did not readily accept Galileo's discovery. The mathematical Jesuit Clavius said that the satellites of Jupiter were the children of Galileo's telescope, but he frankly admitted his mistake when he observed them for himself. Others of feebler faith declined to look lest they might be perverted by what they saw. One of these sceptics died a little later, and Galileo expressed the hope that the doubter might see the satellites on his way to heaven.

When it was no longer possible to doubt the existence of Jupiter's satellites, it was argued that they did not revolve round the planet, but travel backwards and forwards behind the disc. Such opinions held with many until the middle of the seventeenth century. All doubt of the circular motion of the satellites was dispelled by Cassini's observations with object glasses of 100 and 136 feet focal length. With these he was able to see the satellites projected as small bright spots on the disc. He also found that their motions when so situated were such as would be due to an orbital motion, and not to that of a bright spot attached to the surface of the planet, and to make the assurance complete he discovered that the shadows they cast on the body of the planet are visible as small dark spots on the disc.

Galileo named these four satellites the "Medicean stars," after his noble patron, Cosmo de Medici. They were subsequently named Io, Europa, Ganymede and Callisto. The names are given in the order of their distance from the planet. The diameter of the smallest, Europa, is about equal to that of our Moon. Io is a little larger. Callisto is about as large as the planet Mercury, while Ganymede has about two-thirds the volume of Mars. Although three of these moons considerably surpass our moon in size, they are very small when compared with the vast planet to which they belong. The volume of the four satellites taken together is only equal to about 1/8000th of the volume of Jupiter.

These satellites do not give Jupiter as much light as is generally supposed. They reflect the light of a sun which is only one twenty-seventh the size of ours, and, with the exception of Satellite I (Io), they are at greater distances from Jupiter than our moon is from us. The entire span of the system is about 2½ million miles, or rather more than five times the extent of the Moon's orbit. The appearances of these satellites in the Jovian sky must be full of interest to the inhabitants, if any, of Jupiter. The first produces almost daily eclipses of the Sun in the equatorial regions. The three inner moons are eclipsed at each revolution so that they are never seen at their "full." The fourth is the only one that attains the full phase.

The orbits in which the satellites move are nearly in the plane of Jupiter's equator, which is almost coincident with that of the Earth. The satellites therefore appear to us in a small telescope as tiny stars lying along a line which passes through the centre of the planet. The space which Jupiter and his satellites cover in the sky is about equal to two-thirds the diameter of the Moon. Some claim to have seen these satellites with the naked eye, but it is certain that this is impossible to the ordinary observer. All four, however, may be seen as points of light with good field glasses when they are at greatest elongation, but it takes a powerful telescope to show their discs clearly.

Markings have been seen with telescopes of high power on the satellites. Io, the innermost, has a broad belt of light colour round its equator. It is said that ice-caps have been seen on Callisto and Ganymede, and lines resembling the canals of Mars have been observed on Ganymede. The moons, however, are at so great a distance from the Earth that even with the largest telescopes the most pronounced markings cannot be seen with much definiteness.

These moons as they circle around Jupiter are eclipsed when they pass into the shadow cast by the planet; they also disappear, or are occulted, when they pass behind the disc, and at other times they may be seen in transit over the face of Jupiter. Their shadows can be seen travelling over the disc as black spots. All these phenomena can be seen with 3-inch telescopes, but for a transit the instrument must be good and the seeing conditions well-nigh perfect.

These four moons not only differ among themselves in brightness, but, as Galileo himself discovered, they vary individually from time to time in the amount of light which they reflect. Callisto appears to change in reflective power according to the position which it holds in its orbit, which suggests that it rotates as our Moon does, once for each revolution in its orbit, thus keeping the same face always turned towards Jupiter, so that the surface turned towards the Sun varies with the position of the satellite in its orbit, and all parts of the surface may not have the same degree of light-reflecting power.

Flammarion, who studied the Jovian system very closely, believed that he had evidence of an atmosphere around the satellites of Jupiter, which led him to say: "If the central body is not inhabited, his satellites may be. In this case, the magnificence of the spectacle presented by Jupiter himself to the inhabitants of the satellites is worthy of our attention. Seen from the first satellite, the Jovian globe presents an immense disc of twenty degrees in diameter, or 1,400 times larger than the full moon. What a body! What a picture, with its belts, its cloud motions, and its glowing colouration, seen from so near! What a nocturnal sun!—still warm, perhaps. Add to this the aspect of the satellites themselves seen from each other, and you have a spectacle of which no terrestrial night can give an idea."

Beside the four Galilean satellites Jupiter has five others in his retinue. Satellite V, which was discovered by Professor Barnard in 1892, is the nearest to the planet, the distance between them being only half the distance separating our Moon from the Earth. A rough estimate places the diameter of this tiny object at 120 miles. It would take 9,000 of such little globes to make one of the Galilean satellites. Satellite V may only be seen in large telescopes under perfect conditions at its elongations, when it is about 30 seconds of arc away from the blaze of the giant primary. Speaking of its smallness, Miss Clerke says: "Its very insignificance raises the suspicion that it may not prove solitary. Possibly it belongs to a zone peopled by asteroidal satellites. More than fifteen thousand such small bodies could be furnished out of the materials of a single full-sized satellite spoiled in the making." Prof. Perrine discovered the sixth and seventh satellites by means of photography in 1905. These are very faint objects revolving in orbits far beyond those of the major satellites. The mean distance of Satellite VII is over seven million miles. Satellite VIII was discovered photographically by Mr. Melotte at Greenwich Observatory in 1908. This minute object is still more remote, and is most remarkable in that it has a retrograde motion, that is, it revolves round the planet in the contrary direction to the revolution of the other seven. The orbit of this satellite is more eccentric than that of any other in the solar system. It is about nine million miles from the planet when at its nearest, and about 20 million miles when farthest. The ninth satellite was discovered on the same photographic plate with Satellite VIII by Prof. Nicholson in 1914. This very tiny object is only of the 19th stellar magnitude. Its motion, like that of Satellite VII, is retrograde. Its orbit is also very eccentric, its distance from Jupiter varying from 14 to 23 million miles. The diameter of this diminutive world is given as 15 miles.

If the smallness of the inner satellite suggests the existence of a ring of asteroidal satellites close to the planet, surely there must be also an outer company of similar bodies, or, to judge by the extreme smallness of Satellite IX, it may be inferred that the Jovian system is bounded by a circle of meteorites.

The periods of revolution of these nine satellites of Jupiter vary from 11 hours 57½ minutes for Satellite V to 3.125 years for Satellite IX. The orbits of Satellites VI and VII are interlinked, the period of VI being 251, and that of VII 265 days.

Satellite V, the one nearest to the planet, has the distinction of being the swiftest moving satellite in the solar system. Its orbital velocity is 16½ miles a second. Its period of revolution is one hour longer than Jupiter's period of rotation, so that it rises in the east and sets in the west. It spends, however, five Jovian days in travelling from one horizon to the other.

The eclipses of Jupiter's satellites have been the means of revealing to us the fact that light, which was formerly believed to be an instantaneous flash, requires a sensible time to travel over very long distances. This discovery is due to Roemer, a young Danish astronomer, working at the Paris Observatory.

Eclipses of Jupiter's satellites were used in the 17th century for determining longitude at sea, and tables predicting them were constructed. It was found, however, that the eclipses did not always occur at the predicted times. Sometimes they would be a little in advance of the time-table and sometimes they would be delayed. Roemer set to work to discover the cause of these discrepancies, and in 1675 clearly proved that in proportion as the Earth receded from Jupiter in the course of its orbit, in the same proportion the eclipses of the satellites would be retarded beyond the time at which it had been calculated they ought to occur. On the other hand, the gradual approach of the Earth towards Jupiter was accompanied by a gradual return to punctuality of these phenomena. Roemer explained the seeming irregularity by assuming that light, instead of flashing through space instantaneously, had a movement of very great velocity, but yet took an appreciable time to travel over the great distance which separates Jupiter and the Earth. His conclusions were not accepted until many years after his death. They have been abundantly proved in many ways since, and the speed of light is now very accurately known, so that it is possible to construct tables which give the times of the eclipses accurately to the nearest minute.

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## ASTRONOMICAL SOCIETY OF SOUTH AFRICA.

Session 1924-25.

### Annual Report of the Council.

The Council, in presenting their Report for the year 1924-25, have to record another successful year's working of the Society. The membership at the 30th June, 1925, stands at 98 members and 18 associates, a total net increase of 11 on the year. The greater part of this progress is due to the increased membership of the Cape Centre, and the Council earnestly hopes that the Johannesburg members will not fail to see that the interests of astronomy are adequately supported by amateurs in that Centre. Friendly relations have been maintained with the Natal Astronomical Association.

The Presidential Address for the session 1924-25 will be delivered by Dr. J. K. E. Halm, at the present meeting.

During the year under review the Council met five times, the Johannesburg members of Council being represented by their alternates. No change in the personnel of the Council took place. The suggestion made last year by the then President, Dr. R. T. A. Innes, that steps should be taken with a view to the formation of a South African National Committee, as contemplated by the Statutes of the International Astronomical Union, is receiving careful consideration.

Mr. H. Spencer Jones and Dr. A. W. Roberts, two Vice-Presidents of the Society, have left for England to attend the meeting of the Union this year at Cambridge.

The Council desires to express the Society's thanks to the authorities at the Royal Observatory and the Union Observatory for their continued courtesy. The Union Astronomer has presented some additions to the series of Observatory Circulars.

Owing to unforeseen delays only one number of the Society's Journal was published during the year under review.

A further number has been distributed within the last few days. The Society exchanges copies of publications with kindred Societies, etc., and it is hoped that the Journal of the Astronomical Society of South Africa may make a worthy contribution to the literature on the subject. The Council invites members and associates to send articles for publication in the Journal; the Society's warm thanks are due to past contributors.

The sales of Dr. Halm's booklet on the Universal Sundial have been very successful, and, as previously arranged, a share of the proceeds has been paid into the Society's funds. Copies of the booklet are still obtainable from the Hon. Secretary.

Perhaps the best evidence of the Society's activities is shown in the reports of the Observing Sections, whose work has been vigorously carried on during the year. When, however, one considers the vast field of work open in the Southern Hemisphere, and the favourable skies enjoyed by most parts of the country, it is obvious that the number of our members undertaking organized work is much smaller than should be the case, and the Council would repeat its invitation for more volunteers. No one, however inexperienced, need fear that by joining one of the Observing Sections he would be at once called upon to carry out unduly arduous or exacting duties. Indeed, the regular pursuit of some particular line of observation soon becomes a fascinating task. It is hoped that more of our members and associates will endeavour to specialize on some line of work: by recording observations and communicating them periodically to headquarters much valuable information will be accumulated. Our ambition is that this Society, which is already becoming known for its work in certain directions, may make a yet greater contribution to the knowledge of the Southern heavens.

The Council would urge that every endeavour be used to increase our membership. Much interest is taken in astronomy by many people who are perhaps not aware of the existence of this Society. Members and associates are enjoined to try to secure new adherents from among their friends. The majority of the meetings of the Centres at Cape Town and Johannesburg are open to the public, and the various subjects discussed are dealt with in a way easily to be followed by the humblest student of astronomy. It is recognized that much good work has been done by amateurs, often in isolated places, who have carried out independent schemes of observation and research, but it is undoubtedly of advantage, especially for beginners, to be attached to a Society such as our own, and to have the benefit of expert advice.

Any applications from prospective members or associates should be addressed to the Honorary Secretary, Cape Centre (P.O. Box 2061, Cape Town), or to the Hon. Secretary, Johannesburg Centre (P.O. Box 2402, Johannesburg).

# Reports

FOR THE YEAR ENDED 1925 JUNE 30.

## COMET SECTION.

We have great pleasure in extending our thanks to all who have helped us in any way during the past year, but particularly to the Royal Observatory for help in observing various comets, for computing the elements and ephemeris of Comet 1925 b, and for early information of the discovery of new comets, which enabled us to pick up several of them at an early date; to the Union Observatory for continuous observation of Comet 1925 b; and to Mr. Mackenzie for much laborious work in connection with this comet.

Dr. W. Baade, of Bergedorf (who is renowned for his success in photographing faint comets), succeeded in getting Comet 1924 a (Reid) on a photographic plate at the end of September; it was then 16th magnitude.

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

Encke's Comet (1924 b) was discovered by Professor van Biesbroeck at Yerkes Observatory on July 31. Magnitude 16. It became an easy naked-eye object in the Northern Hemisphere.

Comet 1924 c (Finsler). This comet was discovered with field glasses on 1924 September 15. It was then a faint naked-eye object, but became much brighter later on. It was low down in the evening twilight, and came rapidly south. It was not seen by any amateur observer in South Africa as far as we know, but was observed at both the Royal and Union Observatories until it was lost in the sun's rays. A detailed description of this comet, with two photographs, may be found in *Popular Astronomy*, vol. xxxii, page 660. The comet had two tails, the principal one being about four degrees long.

Comet 1924 d (Wolf). Discovered by Prof. Wolf at Königsberg on 1924 December 23. It is described as an exceedingly faint fan-shaped nebulous object with a nucleus, but at its brightest was only about 16th or 17th magnitude, and could only be seen with very powerful telescopes. It was only observed a few times, but elements were computed which gave it an elliptical orbit, with a period of about seven years.

Comet 1925 a (Schain): Was discovered by Schain at Simeis Observatory, in the Crimea, on 1925 March 23rd. This comet was reported as 10th magnitude at date of discovery. It was very much fainter when seen by the writer in April. He found it a very difficult object, small, faint, with very little condensation. Several orbits have been computed, but as they differ considerably, and as the comet will be under observation for several months longer, final results will have to be deferred to a future report.

Comet 1925 b (Reid) was discovered by the writer at Newlands, near Cape Town, on 1925 March 24th. At discovery it was about 8th magnitude. (Now it is considerably brighter.) It was fairly large, very compressed in the centre, with a distinct nucleus. This comet has varied considerably since date of discovery. Sometimes it appeared as a small round nebulous patch with a very compressed centre, and at other observations it had a distinct broad tail, not always pointing away from the sun. It has also been observed without its tail, and surrounded by a large patch of haze. These various appearances have followed each other in quick succession since date of discovery.

Dr. Halm, of the Royal Observatory, has computed the following elements from early observations:—

$$\begin{aligned} T &= 1925 \text{ July } 30.777 \text{ G.M.T.} \\ \omega &= 258^\circ\ 48'.56 \\ \Omega &= 6^\circ\ 13'.49 \quad \Big\} \ 1925.0 \\ i &= 27^\circ\ 23'.49 \\ \log q &= 0.22218 \end{aligned}$$

Mr. Mackenzie, from observations made at the Union Observatory on March 28th, April 19th, and May 14th, has computed elements as follows:—

$$\begin{aligned} T &= 1925 \text{ July } 23.145. \\ \omega &= 257^\circ\ 37'.40. \\ \Omega &= 5^\circ\ 20'.14. \\ i &= 25^\circ\ 25'.30. \\ \log q &= 0.21194. \end{aligned}$$

We may be able to give more information about this comet in a future report, as it will be under observation for some time yet.

Comet 1925 c (Orkisz) was discovered in Poland on 1925 April 4th. This comet was about 8th magnitude at discovery, but became a fairly easy naked-eye object in the Northern Hemisphere, passing within eight degrees of the North Pole. It is now coming south, but as it is rapidly leaving the earth, there is no hope of our seeing it.

Comet 1925 d (Tempel's second periodical) was discovered by Stobbe (place not stated), on 1925 June 11th. It was seen by the writer on June 21st with difficulty, owing to thick haze. Since that time it has been observed under more favourable conditions. It is fairly large and bright, fan-shaped, with a distinct nucleus at the apex of the fan. It is at present in the Milky Way, but is quite easily seen in small telescopes.

Comets Schain, Reid, and Tempel II have still to come to perihelion, so that in all probability they will be under observation for several months yet. Anything further we may have to report will have to be deferred to a future date.

Comets Encke, Wolf and Schain, were all discovered photographically by professional astronomers.

The Donohoe Comet Medal of the Astronomical Society of the Pacific has been awarded to Mr. Reid for the discovery of Comet 1924 a.

The new Comet Catalogue prepared by Dr. Crommelin has just been published. It contains the orbits of all comets observed from the beginning of 1894 to April, 1925. It is published by the British Astronomical Association, and the price is one shilling and sixpence.

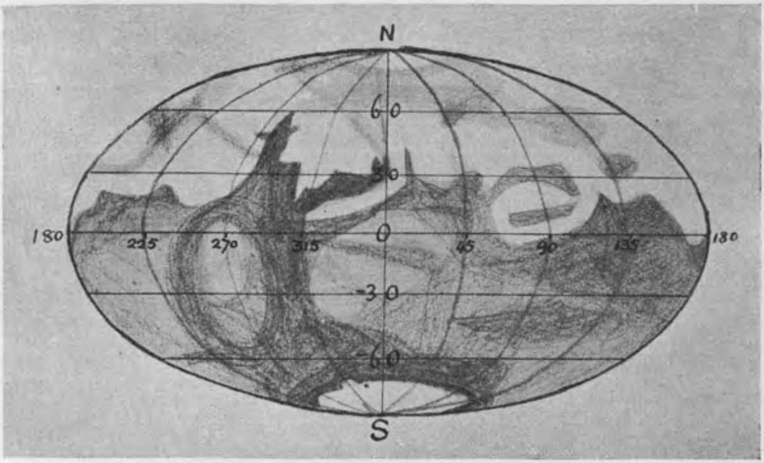
WILLIAM REID.

## MARS SECTION.

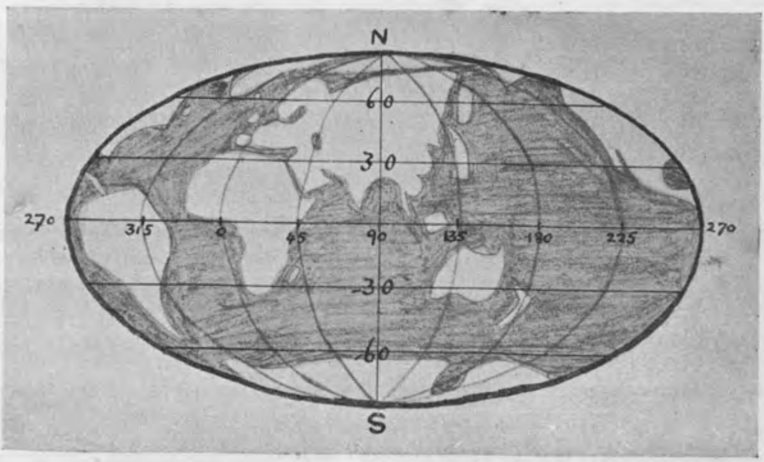
The organization of this Section was the same as in 1923. Simultaneous observations were made whenever important features of Mars were in front at convenient hours: as a result of the favourable opposition and the general prevalence of good weather, these simultaneous observations have covered practically the entire surface of Mars, except, of course, the region near the North Pole, which was turned away from the Earth all through 1924. It is consequently possible to submit a composite map of Mars as seen by the South African amateurs. This map is presented on the elliptical 360° plan, and is accompanied by a similar plan of the Earth as seen from Mars (see *Encyc. Brit.*, 1910, xvii, 661) with Earth-longitude 90° in the centre. An interesting resemblance between the combination of the *Syrtis Major* and *Sinus Sabæus* and the combination of North Atlantic Ocean and Mediterranean Sea is thus brought out. The resemblance would be quite marked if a map of the Earth taken somewhat below sea-level were made.

Only vague traces of "canals" were seen in the Northern Hemisphere, and only one observer saw any marking on *Hellas*. This marking appeared to divide it into two circles with their equatorial edge in common. All observers, however, saw the grey spots in the Northern Hemisphere at longitude 45° and 210°, though all saw them differently, because they had very little contrast. According to Pickering, this was not the Martian season for seeing "canals" easily. He states that the proper season is near Martian Northern Hemisphere midsummer, when the *North* Pole is melting. This occurred in 1924 a long time before opposition (which occurred in Martian mid-November), when Mars was too small for amateurs' telescopes. It will recur early in 1926, but Mars will again be very far away.

The melting of the South Pole of Mars was a strikingly rapid phenomenon. At the beginning of June, I estimated it to cover 50° of arc of the disc; at the end of July it covered 25° to 30° of arc (longer axis one-fifth of planet's diameter), and at the end of September it was a small spot inside the rim




Composite Map of Mars, 1924.




Map of Earth on same Plan.

only about one-twelfth of the diameter. A very marked black ring surrounded it in July as the melting commenced to be rapid. This ring disappeared before opposition. A striking finger-like projection developed on the pole near the time of opposition (August 23rd) pointing at the *Syrtis Major*. This is shown on the detailed drawings, but cannot be adequately represented on the composite picture. Earlier in the year a similar projection was seen in longitude 180°. It is to be noted that the composite map does not show Martian latitude 25° South in the middle as all the detailed maps show: it was necessary for simplicity of drawing to put the equator in the middle. Hence, for example, the composite map does not show the large extent to which the *Syrtis Major* covered the northern section of the disc. . Probably the point of *Syrtis* was within one-tenth diameter of the northern edge of the disc.

The writer had the pleasure, through the invitation of Mr. H. E. Wood, of viewing Mars through the Union Observatory 9″ refractor on the opposition night, and secured two drawings showing much more detail than he could see even after long practice in his own 4″.

On the 6th September, at 11 p.m., Mars was quite close to a star. At this stage the northern margins of the "seas" were very dark, there being very little contrast elsewhere. This supports the idea that vegetation of dark colour grows as soon as the pole melts freely. On the 15th September the writer was on holiday in Durban, and Mr. D. L. Forbes took infinite trouble to see that a good view through the 8″ refractor was obtained. By luck one evening of superexcellent definition was met with, and the writer saw the *Lacus Solis* adequately for the first time in his life. It is very striking, but had very little contrast. The writer has never seen it clearly in his 4″. It is a larger marking than is usually depicted (see Fig. 9). A good view of the *Margaritifer Sinus* was later obtained: it was evidently much larger and more pointed than it had been in July, when it had too little contrast to be seen.

The writer's last observation was on 17th October, when Mars was very gibbous, and nothing could be seen but the *Mare Cimmerium* as a very dark and rather narrow line. Mr. Wickes, of Durban, using the 8″, observed right up to the middle of November. The Martian Southern midsummer was on 6th October.

The writer on August 7th observed the disc with its minimum of dark markings, and took the opportunity after sunrise of making a daylight colour comparison of Mars with various coloured objects also held against the blue sky. Gold alloyed with copper to 18 carat appeared to agree most closely with the land-surface colour of Mars. All through, the *Sinus Sabæus*, the long narrow marking (resembling an ostrich's neck and head with beak open), was the darkest one seen (see, *e.g.*, Figs. 55 and 48).

As mentioned last year, nearly all the good observations of the parts of Mars which have little contrast were made with a light sky (sunrise or sunset). At this opposition it was possible to magnify Mars with a 4″ telescope up to four times the naked-eye diameter of the moon, but the air is seldom steady enough for the observer to benefit by this large view: the use of either salmon-pink or olive-green gelatine screens of not too deep a shade is of value in increasing the contrast when the air is good enough.

Last of all a close conjunction of Mars, Uranus, and a bright star was observed on 27th November. Uranus was observed to be greener than the markings on Mars.

About 90 drawings in all were received from members of the Section: those reproduced are arranged so as to have the South Pole at the top.

James Moir,
*Director.*

## NOTES ON THE DRAWINGS OF MARS.

By James Moir, D.Sc., M.A., F.R.S.S.A.

In the following table column I gives the number of the figure, column II the name of the observer, column III the aperture of the instrument, column IV the date of observation, column V the longitude of the central meridian.

| *Fig.* | *Observer.* | *Aper.* inch. | 1924. | *Long.* |
|---|---|---|---|---|
| 1 | M. Deas | 8 | Aug. 12 | 33 |
| 2 | G. C. Fox | 10¼ | Aug. 26 | 35 |
| 3 | D. L. Forbes, C. F. Wickes | 8 | Sept. 17 | 60 |
| 4 | J. Moir | 4 | Aug. 10 | 61 |
| 5 | B. F. Jearey | 5 | Aug. 23 | 66 |
| 6 | G. C. Fox | 10¼ | Sept. 18 | 71 |
| 7 | D. L. Forbes, C. F. Wickes | 8 | Sept. 17 | 76 |
| 8 | D. L. Forbes, C. F. Wickes | 8 | Sept. 15 | 88 |
| 9 | J. Moir | 8 | Sept. 15 | 88 |

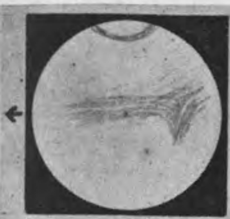


FIG. 1

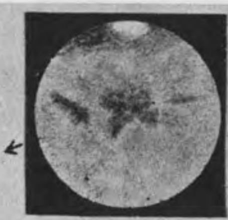


FIG. 2


FIG. 3

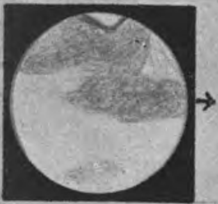


FIG. 4

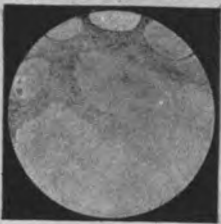


FIG. 5


FIG. 6

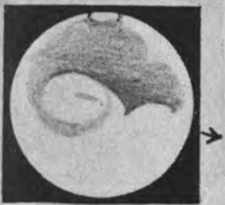


FIG. 7


FIG. 8

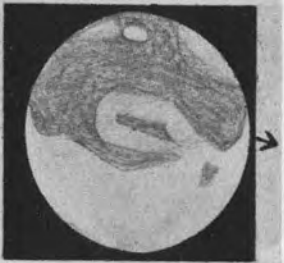


FIG. 9


FIG. 10

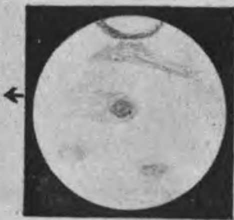


FIG. 11


FIG. 12

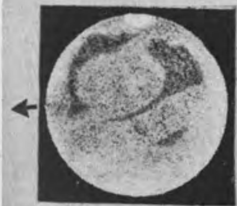


FIG. 13

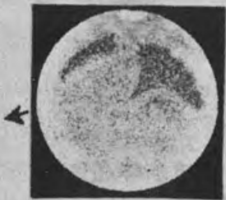


FIG. 14

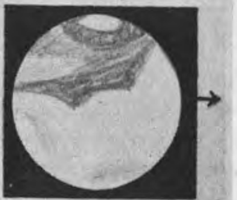


FIG. 15

Drawings of Mars, 1924.

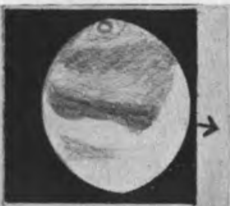


FIG. 16

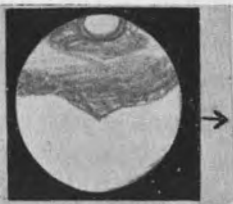


FIG. 17

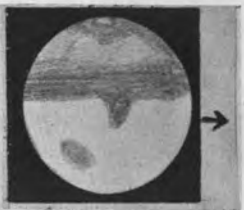


FIG. 18

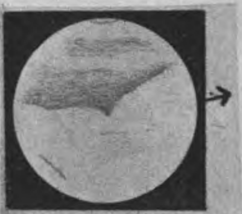


FIG. 19

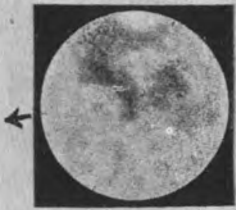


FIG. 20

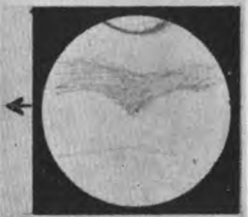


FIG. 21


FIG. 22

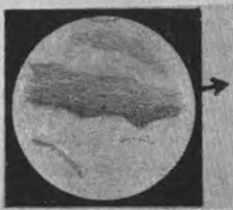


FIG. 23


FIG. 24


FIG. 25


FIG. 26

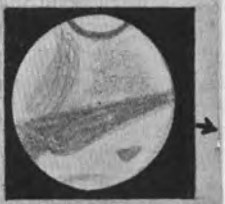


FIG. 27


FIG. 28

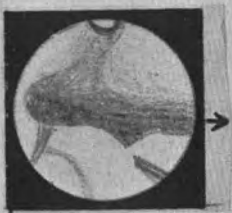


FIG. 29


FIG. 30

Drawings of Mars, 1924.

| *Fig.* | *Observer.* | *Aper.* inch. | 1924. | | *Long.* |
|---|---|---|---|---|---|
| 10 | G. C. Fox | 10¼ | Sept. | 16 | 92 |
| 11 | M. Deas | 8 | Aug. | 17 | 97 |
| 12 | G. C. Fox | 10¼ | Sept. | 16 | 101 |
| 13 | G. C. Fox | 10¼ | Sept. | 17 | 118 |
| 14 | G. C. Fox | 10¼ | Sept. | 18 | 132 |
| 15 | J. Moir | 4 | Aug. | 2 | 147 |
| 16 | J. Moir | 4 | Oct. | 17 | 151 |
| 17 | J. Moir | 4 | July | 31 | 157 |
| 18 | J. Moir | 4 | Sept. | 6 | 167 |
| 19 | D. L. Forbes<br>C. F. Wickes | 8 | Sept. | 5 | 169 |
| 20 | G. C. Fox | 10¼ | Aug. | 13 | 173 |
| 21 | M. Deas | 8 | Aug. | 10 | 174 |
| 22 | B. F. Jearey | 5 | Sept. | 11 | 187 |
| 23 | D. L. Forbes | 8 | Sept. | 3 | 190 |
| 24 | D. L. Forbes | 8 | Aug. | 10 | 194 |
| 25 | B. F. Jearey | 5 | Sept. | 3 | 196 |
| 26 | D. L. Forbes<br>P. Albertini | 8 | Sept. | 4 | 204 |
| 27 | J. Moir | 4 | July | 24 | 214 |
| 28 | D. L. Forbes | 8 | Sept. | 2 | 235 |
| 29 | J. Moir | 4 | Sept. | 1 | 240 |
| 30 | J. Moir | 4 | Oct. | 3 | 244 |
| 31 | C. F. Wickes | 8 | Aug. | 3 | 246 |
| 32 | G. C. Fox | 10¼ | Sept. | 4 | 254 |
| 33 | B. F. Jearey | 5 | Aug. | 28 | 256 |
| 34 | G. C. Fox | 10¼ | Aug. | 28 | 266 |
| 35 | J. Moir | 4 | Oct. | 2 | 276 |
| 36 | G. C. Fox | 10¼ | Aug. | 28 | 278 |
| 37 | C. F. Wickes | 8 | Nov. | 10 | 289 |
| 38 | C. F. Wickes | 8 | July | 27 | 291 |
| 39 | J. Moir | 9 | Aug. | 23 | 291 |
| 40 | G. C. Fox | 10¼ | Aug. | 28 | 292 |
| 41 | D. L. Forbes | 8 | Aug. | 31 | 295 |
| 42 | C. F. Wickes | 8 | Aug. | 31 | 311 |
| 43 | C. F. Wickes | 8 | Sept. | 29 | 312 |

| *Fig.* | *Observer.* | *Aper.* inch. | 1924. | | *Long.* |
|---|---|---|---|---|---|
| 44 | G. C. Fox | 10¼ | Aug. | 29 | 314 |
| 45 | J. Moir | 4 | Aug. | 20 | 318 |
| 46 | M. Deas | 8 | Aug. | 20 | 319 |
| 47 | G. C. Fox | 10¼ | Aug. | 29 | 325 |
| 48 | J. Moir | 9 | Aug. | 23 | 328 |
| 49 | D. L. Forbes | 8 | Aug. | 20 | 330 |
| 50 | G. C. Fox | 10¼ | Aug. | 29 | 336 |
| 51 | B. F. Jearey | 5 | Aug. | 19 | 350 |
| 52 | B. F. Jearey | 5 | Aug. | 23 | 352 |
| 53 | G. C. Fox | 10¼ | Aug. | 23 | 357 |
| 54 | D. L. Forbes | 8 | July | 20 | 0 |
| 55 | D. L. Forbes, C. F. Wickes | 8 | Sept. | 29 | 7 |
| 56 | G. C. Fox | 10¼ | Aug. | 23 | 15 |
| 57 | G. C. Fox | 10¼ | Aug. | 19 | 16 |
| 58 | J. Moir | 8 | Sept. | 17 | 17 |
| 59 | J. Moir | 4 | Aug. | 14 | 18 |
| 60 | G. C. Fox | 10¼ | Aug. | 23 | 29 |

[Deas and Fox use Reflectors.]

Where the arrow points to the left, the view is the normal astronomical telescope view, and where it points to the right the view is through a star diagonal. Since Mars was near the zenith many of the diagonal views were necessary for comfort of observation.

Figures 1 to 4.—The prominent triangular feature is *Margaritifer*, which was invisible or undeveloped before opposition. The faint object with the slit in it is *Lacus Solis* (right in Fig. 2, left in Fig. 3). Moir never saw it in 4", but easily in larger instruments. Faint undefined objects in the N. Hemisphere appear for the first time after opposition: these were very prominent in 1918-22, but are now faint. The S. Pole is large in early August (Figs. 1 and 4), and small in September (Fig. 3). In Fig. 2 the left object lies on the zero meridian.

Figures 5 to 14.—*Lacus Solis* prominent near centre, but the pictures vary tremendously: it is a marking of characteristic shape but little contrast. Moir's drawing with the Durban 8" is the best (Fig. 9): the definition at the time was "the best ever": yet the disagreement with Forbes and Wickes (Figs. 7 and 8), working alternately at the same time, is most interesting


FIG. 31

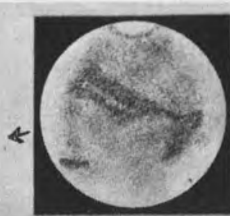


FIG. 32

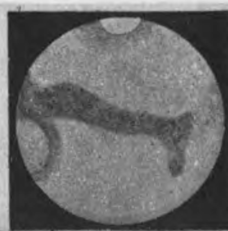


FIG. 33

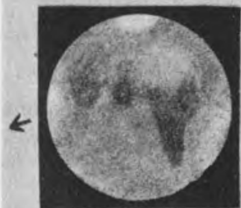


FIG. 34


FIG. 35


FIG. 36


FIG. 37


FIG. 38


FIG. 39


FIG. 40


FIG. 41


FIG. 42


FIG. 43


FIG. 44


FIG. 45

Drawings of Mars, 1924.

FIG.46

FIG.47

FIG.48

FIG.49

FIG.50

FIG.51

FIG.52

FIG.53

FIG.54

FIG.55

FIG.56

FIG.57

FIG.58

FIG.59

FIG.60

Drawings of Mars, 1924.

as showing the personal factor in all drawings of faint objects. The object between *Margaritifer* and *Lacus Solis* is *Aurora Sinus*: it forms the left margin of *Lacus Solis* in Fox's drawings (Figs. 10, 12, 13 and 14)—see right of Moir's Fig. 9.

Figures 15 to 24.—The pointed projections on the other side of *Lacus Solis* were shown by all the observers, and were very dark. The first is *Mare Sirenum* and the second *Mare Cimmerium*. Their north edge became darker from July to September as the S. Pole melted and the water moved towards the equator. Fig. 16 is Moir's last Mars drawing, and shows the pale "island" *Hesperia*.

Figures 25 to 28.—These are much the same, but all observers show a conspicuous marking in the N. Hemisphere, though all saw it differently. It is the canal intersection or oasis, level with the *Syrtis Major*.

Figures 29 to 34.—This marking persists at the side, and the *Syrtis Major* appears at the back edge (following). The large light patch *Hellas* (50 per cent. larger than the pole) also appears above it in the S. Hemisphere.

Figures 35 to 38.—The *Syrtis* and *Hellas* were easily seen by all the observers. Fig. 36 (Fox) is super-excellent, particularly like the real thing. Any markings on *Hellas* (which was four times the area of the pole at opposition) were of the faintest, and were only seen by Fox. Wickes secured the last drawing of it on the 10th November (Fig. 37).

Figures 39 to 41.—The same features are shown. Moir's drawing through the Union Observatory 9″ (Fig. 39) on the opposition night shows more detail, including the projection on the pole.

Beginnings of "canals" were seen, but no more.

Figures 42 to 49.—This is still similar, but *Syrtis* goes off the disc and *Sabæus*, the zero meridian, comes on. *Syrtis* goes very far north: this is not properly shown in Figs. 44 and 47, but correctly in Figs. 43, 45, 46 and 48. Fig. 48 was through the Union Observatory telescope, and again shows the point on the pole.

Figures 50 to 55.—The *Sinus Sabæus*, a dark thin marking like the neck of a swan gaping, is in the centre here. Figs. 53 and 55 are excellent.

Figures 56 to 60.—Here *Sabæus* and *Margaritifer* appear and so join up with the beginning.

## VARIABLE STAR SECTION.

It is gratifying to report that the work of the Section is still on the up-grade, this year's total of observations recorded being the second highest since the formation of the Section in 1917.

The maximum was attained in 1919, the number of observations being 2,687. After a minimum of 867 in 1922 there has been a gradual rise until this year, when the satisfactory total of 2,344 observations has been obtained.

We hope that next year still better results will be recorded.

In order to accomplish this it is necessary to have more observers, so if any member with a telescope lying idle wishes to help in this interesting and valuable sphere of observation, charts will be supplied by the Director on application being made, and every possible assistance will be given to the beginner by the older observers.

One new observer has been added to the list since the last report, viz., Mr. G. E. Ensor, who has commenced observing at Pretoria.

The total of 2,344 observations is distributed amongst the following observers: G. E. Ensor, 8; H. E. Houghton, 716; A. W. Long, 508; W. H. Smith, 1,112.

A list of maxima (M) and minima (m) deduced from the observations is appended. In most cases the minima were too faint to be observed.

W. H. Smith,
*Director.*

| Designation. | Star. | | Magn. | Date. |
|---|---|---|---|---|
| *001862* | S Tucanæ | M | 8.9 | 1924, Oct. 26. |
| *002546* | T Phœnicis | M | 9.7 | 1925, Jan. 20. |
| *005475* | U Tucanæ | M | 8.4 | 1924, Oct. 7. |
| *025050* | R Horologii | M | 6.1 | 1924, Aug. 31. |
| *043263* | R Reticuli | M | 7.2 | 1924, Dec. 30. |
| *051247* | T Pictoris | M | 8.2 | 1925, Mar. 28. |
| *051533* | T Columbæ | M | 7.6 | 1924, Dec. 4. |
| ,, | ,, | m | 12.1 | 1925, Mar. 16. |
| *074241* | W Puppis | M | 8.7 | 1924, Dec. 16. |
| ,, | ,, | m | 12.6 | 1925, Jan. 28. |
| *082476* | R Chamæleontis | M | 8.2 | 1924, July 10. |
| *092962* | R Carinæ | m | 10.0 | 1925, April 5. |
| *094953* | Z Velorum | M | 7.9 | 1924, Dec. (?). |
| *100661* | S Carinæ | M | 6.0 | 1924, Aug. 16. |
| ,, | ,, | M | 5.5 | 1925, Jan. 20. |
| ,, | ,, | m | 9.0 | 1925, Mar. 28. |
| ,, | ,, | M | 5.5 | 1925, June 22. |

| Designation. | Star. | | Magn. | Date. |
|---|---|---|---|---|
| *131283* | U Octantis | M | 8.0 | 1924, Aug. 19. |
| *133633* | T Centauri | M | 6.2 | 1924, Sept. 17. |
| ,, | ,, | m | 8.6 | 1925, May 10. |
| ,, | ,, | M | 6.2 | 1925, Mar. 28. |
| *134677* | T Apodis | M | 9.0 | 1924, Nov.-Dec. (flat). |
| *140959* | R Centauri | M | 5.9 | 1924, Oct. 1 (very flat). |
| ,, | ,, | M | 5.4 | 1925, May 11 (very flat). |
| *151822* | RS Libræ | M | 7.7 | 1925, May 3. |
| *153654* | T Normæ | M | 6.7 | 1924, July 6. |
| ,, | ,, | M | 7.1 | 1925, Feb. 18. |
| *155823* | RZ Scorpii | M | 8.4 | 1925, April 24. |
| *164844* | RS Scorpii | M | 6.0 | 1925, Mar. 29. |
| *180363* | R Pavonis | M | 8.1 | 1924, Oct. 16. |
| ,, | ,, | M | 8.1 | 1925, May 18. |
| *193972* | T Pavonis | M | 7.8 | 1925, May 11. |
| *221938* | T Gruis | m | 11.0 | 1924, July 6. |
| ,, | ,, | M | 8.6 | 1924, Sept. 26. |
| ,, | ,, | m | 11.1 | 1924, Nov. 30. |

### Nova Pictoris, 1925.

Nova Pictoris was discovered by Mr. R. Watson, at Beaufort West, C.P., on 1925 May 25, at 5.50 a.m. (S.A.S.T.) in the position R.A. 6 hrs. 35 mins., Dec. 62° 34′ S., when about magnitude 2.3.

After verifying his discovery, Mr. Watson immediately wired to the Royal Observatory, thus enabling a photograph of the spectrum to be obtained while the nova was on the rise.

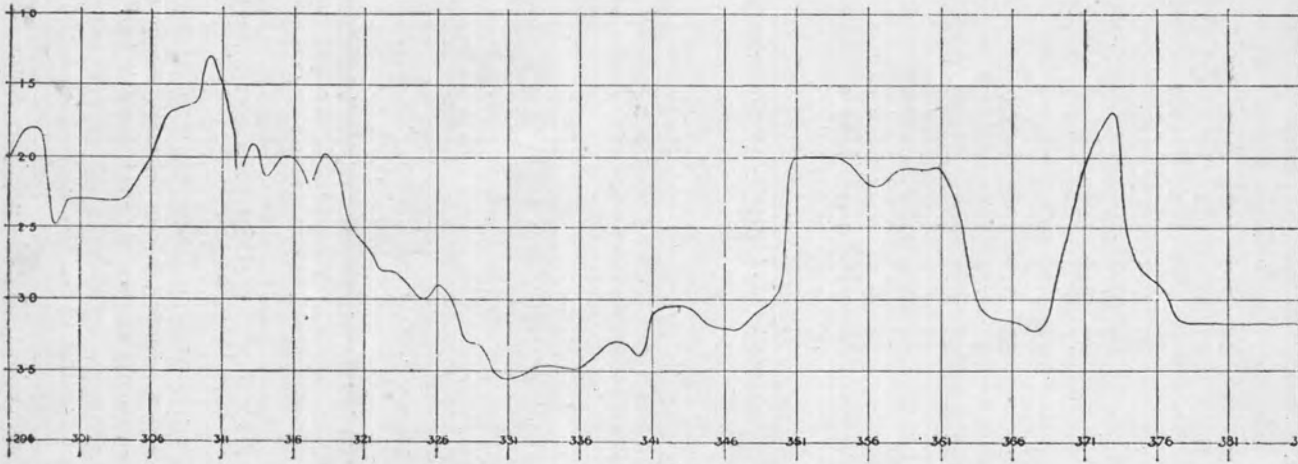
In spite of bad weather and cloudy skies a fairly continuous set of observations has been obtained by a few observers, from which it appears that the nova brightened up to magn. 1.7 on May 26th; by the 28th it had dropped to 2.6 magn. It rose again slightly to 2.3 magn., and remained steady until June 4.

It then commenced to rise again, with slight fluctuations, until June 8, when it reached a maximum of 1.3 magn. (or brighter than Beta Crucis, nearly equalling Alpha Crucis). The following evening it equalled Beta Crucis, after which it fell to 2.0 magn. and remained fairly steady until June 20, when its magn. was about 2.8. By the 28th it had fallen to 3.5 magn., slightly fainter than its companion star, Alpha Pictoris.

On July 6 it again equalled Alpha Pictoris, magn. 3.3. By the 9th it had risen to 2.8 magn. A week later it had dropped again to magn. 3.3.

At the time of writing (July 18) its magnitude equals that of Beta Hydri (3.0).

Continued observations should produce some interesting features relating to this rare phenomenon.




LIGHT CURVE OF NOVA PICTORIS.

May 25—August 23, 1925. Julian date 242 4296—4386.

From observations by G. E. Ensor, A. W. Long, William Re[illegible] W. H. Smith, and R. Watson.

## CAPE CENTRE.

### Annual Report, 1924-25.

Your Committee, in presenting this, the Eleventh Annual Report, are able to record the continued progress of the work of the Centre during the year now closed.

### Meetings.

During the period there have been one special and eight ordinary meetings of the Centre. Your Committee have met nine times.

In February the usual Observational Meeting was held at the Royal Observatory. The thanks of the Centre is tendered to His Majesty's Astronomer for this privilege.

The following lectures and papers were read and discussed at the ordinary meetings, viz.:

- "The Amateur's Telescope and its Work," Mr. W. H. Smith.
- "The Death of the Earth and the Birth of Life on Venus," Capt. D. Cameron-Swan, F.R.P.S., F.S.A.Scot.
- "The Southern Cross," Mr. A. W. Long, F.R.A.S.
- "An Early Nineteenth-Century Astronomer," Mr. H. E. Houghton.
- "Meteorites," Mr. H. W. Schonegevel.
- "The Herschel Obelisk," Mr. D. G. McIntyre.
- "Graphs and Graphics," Mr. A. F. I. Forbes.
- "The Habitability of Mars," Mr. B. Jearey.
- "Comets," Mr. A. W. Long, F.R.A.S.
- "The Interference of Light and its Application to Astronomy," Mr. H. Spencer Jones, M.A., B.Sc., F.R.A.S.
- "Novæ," Mr. A. W. Long, F.R.A.S.
- "Note on the Discovery of Nova Pictoris," Mr. R. Watson.

### Membership.

During the year thirteen ladies and gentlemen have been added to the list of members. There are now seventy-two members and seventeen associates, making a total of eighty-nine as compared with seventy-six at the commencement of the session.

### Discoveries and Observations.

Two discoveries of an important nature have been made by members of the Centre during the year, viz.:—

1. The discovery of a new Comet in March, 1925, by Mr. William Reid, this being the seventh comet discovered by him.
2. The discovery of a nova in Pictor on May 25, 1925, by Mr. R. Watson, the discoverer of Nova Aquilæ of 1918.

Much useful work is being done in the observation of Southern Variable Stars by Messrs. W. H. Smith, A. W. Long, G. E. Ensor, and H. E. Houghton.

The near opposition of Mars in August last afforded special opportunity for observing Martian details, and numerous drawings have been made by Major G. C. Fox, Captain D. Cameron-Swan, and Messrs. M. Deas, D. L. Forbes, and B. Jearey. A selection of these drawings will be published in an early issue of the Society's Journal.

Reports of observations of the Total Eclipse of the Moon of August 14, 1924, by members of the Centre, are being published in the Society's Journal.

ARTICLES IN THE PRESS.

"Monthly Notes," together with charts of the sky, are published in the *Cape Times* as in previous years. These are contributed by Mr. A. W. Long, F.R.A.S.; and articles on astronomical phenomena, in Afrikaans, contributed by Mr. T. Mackenzie, are published regularly in *Die Burger*.

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1925.

| *Receipts.* | | £ | s. | d. |
|---|---|---|---|---|
| Balance in hand, 30th June, 1924 ... ... ... | | 14 | 3 | 2 |
| Subscriptions— | | | | |
| Arrears ... | 2 12 6 | | | |
| 1924-25 ... | 51 3 9 | | | |
| 1925-26 ... | 0 10 6 | | | |
| | | 54 | 6 | 9 |
| Copy of Journal ... ... | | 0 | 1 | 0 |
| Commission on Cheques | | 0 | 8 | 9 |
| To credit of members | | 2 | 0 | 0 |
| | | £70 | 19 | 8 |

| *Payments.* | £ | s. | d. |
|---|---|---|---|
| Contributions to Headquarters under Art. IX (i) of Constitution | 27 | 3 | 4 |
| Copy of Journal ... ... | 0 | 1 | 0 |
| Rent.. ... ... ... ... | 10 | 0 | 0 |
| Rent of P.O. Box ... | 1 | 5 | 0 |
| Typewriting ... ... ... | 3 | 16 | 0 |
| Stationery.. ... ... ... | 0 | 14 | 0 |
| Copies of *Cape Times*, and postage to country members ... ... | 3 | 7 | 6 |
| Secretary's expenses .. | 2 | 10 | 8 |
| Treasurer's expenses .. | 0 | 11 | 9 |
| Bank Charges ... ... | 0 | 18 | 6 |
| Electric light at Committee Meetings.. ... | 0 | 4 | 6 |
| Balance in hand, 30th June, 1925 ... ... ... | 20 | 7 | 5 |
| | £70 | 19 | 8 |

## JOHANNESBURG CENTRE.

ANNUAL REPORT, SESSION 1924-25.

The year's work locally calls for little comment. It is pleasant to record that two new members were enrolled, and that no resignations were tendered.

Apart from the quarterly visits of members and their friends to the Union Observatory, two meetings were held. In January Mr. A. E. Val Davies, M.I.E.E., gave a paper on "The Prediction of Tides," and at the May meeting Dr. J. Moir, M.A., D.Sc., Director of the Mars Section of the Society, gave an exhibition of 70 drawings of Mars made during the last opposition, and executed by members of the Society.

The Committee desire to record their thanks to Dr. R. T. A. Innes and Messrs. H. E. Wood and W. M. Worssell for entertaining members and their friends at the Union Observatory, and also for furnishing copies of the *Union Observatory Bulletin.*

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1925.

| *Receipts.* | | £ | s. | d. | *Payments.* | £ | s. | d. |
|---|---|---|---|---|---|---|---|---|
| Balance in Hand, 30th June, 1924 ... ... ... | | 16 | 8 | 5 | Contributions to Headquarters under Art. IX (i) of Constitution— | | | |
| Subscriptions— | | | | | Arrears .. .. .. .. | 4 | 11 | 9 |
| 1923-24 ... | 5 14 6 | | | | Current year ..... ... | 9 | 13 | 9 |
| 1924-25 ... | 14 3 3 | | | | Secretary's expenses, rent, etc. ... ... ... | 2 | 10 | 0 |
| 1925-26 ... | 0 10 6 | 20 | 8 | 3 | Typing ... ... ... ... | 0 | 11 | 0 |
| For B.A.A. Handbooks | | 0 | 4 | 6 | Printing.. ... ... ... | 1 | 15 | 0 |
| Exchange ... ... ... | | 0 | 1 | 9 | Subscription to British Astronomical Association, etc. ... ... ... | 1 | 3 | 0 |
| | | | | | Bank charges and Commission.. ... ... ... | 0 | 8 | 9 |
| | | | | | Balance in hand, 30th June, 1925... ... ... | 16 | 9 | 8 |
| | | £37 | 2 | 11 | | £37 | 2 | 11 |

# Astronomical Society of South Africa.

STATEMENT OF INCOME AND EXPENDITURE FOR YEAR ENDED JUNE 30TH, 1925.

| *Income.* | £ | s. | d. | *Expenditure.* | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| Balance brought forward, 30/6/24.. ... | 11 | 15 | 9 | Printing Journal ... | 24 | 9 | 3 |
| 50 p.c. Subscriptions (Cape Centre). ... | 27 | 3 | 4 | Blocks, Designs of Mars ... ... ... | 2 | 0 | 6 |
| 50 p.c. Subscriptions (Johannesburg Centre) ... ... ... | 9 | 13 | 9 | Postages and Sundries ... ... ... | 3 | 4 | 9 |
| 50 p.c. Subscriptions (J'burg Bal, 1923-24) | 4 | 11 | 9 | Printing and Stationery ... ... | 3 | 17 | 6 |
| Sale of Journals .. | 2 | 6 | 8 | Electric Light for Council Meetings . | 0 | 6 | 0 |
| Donation (Natal A.A.) ... ... ... | 5 | 0 | 0 | Bank Charges.. ... | 0 | 16 | 10 |
| 50 p.c. Profits on Sale of Universal Sun Dial... ... ... | 1 | 17 | 3 | Balance carried forward.. ... ... ... | 27 | 13 | 8 |
| | £62 | 8 | 6 | | £62 | 8 | 6 |

Audited and found correct.
E. J. STEER.

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

July 1st, 1925.

# Reviews.

"Relativity and the Electron Theory." By E. Cunningham, M.A. Second edition. [Pp. vii + 148, with 10 diagrams.] (London: Longmans, Green & Co. Price, 10s. 6d. net.)

The first edition of this book appeared in 1915, before the generalised theory of relativity had been formulated. The author set out to trace the relationship between the (restricted) theory of relativity and the electron theory, out of which it had originated. This portion of the subject remains substantially unaltered in the new edition, but an account of the generalised theory has been added. The treatment is lucid and concise, and does not demand an extensive mathematical equipment on the part of the reader. The physical bases which form the foundation of the theory are kept in the forefront whilst the mathematical framework is lightly sketched in. The treatment of the crucial phenomena is elementary but adequate. At the time the book was written, Einstein's prediction with regard to the spectral shifts had not been confirmed, and the author took the view that failure to find such shifts would not weaken the theory. This was in opposition to the view of Einstein and Eddington. It is well known now that the predicted shifts have been adequately confirmed. The volume can be recommended to readers with a modest mathematical equipment who desire to make a study of the theory of relativity.

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"Relativity: A Systematic Treatment of Einstein's Theory." By J. Rice, M.A. [Pp. xv + 397.] (London: Longmans, Green and Co. Price, 18s. net.)

This is not a book for the lay reader. It is intended for the University undergraduate who is taking courses in physics and mathematics, and has been so planned that the study of the book can be commenced as soon as the student has become acquainted with the elements of dynamical science. It should therefore serve a very useful purpose. Instead of the student completing his course, getting his ideas fixed, and then having them completely upset by the study of relativity, he adjusts himself to and familiarises himself throughout his training with the new ideas. The author is a teacher of experience, and has taken pains to smooth away the difficulties of the student. The result is a volume which admirably fulfils the author's aim.

The author has not been content to carry the exposition of the theory merely to the point required by the University student; he has proceeded to give an account of some of the more recent and more speculative developments of the theory—which are suitable for post-graduate reading—such as the cosmological speculations of Einstein and de Sitter, and the attempts by Weyl and others to derive a theory of the electromagnetic field from the treatment of the metric field of space-time.

To all students of relativity theory, who possess the necessary mathematical equipment, this volume will be found invaluable. Particularly can it be recommended to University teachers, who will find it a great aid in enabling them to introduce relativity ideas into their courses at a suitably early stage.

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## NOVA PICTORIS.

In Harvard College Observatory Bulletin No. 823 is given an account of the early photographic history of Nova Pictoris. Prior to 1925, the photographic magnitude of the nova was 12.75; the earliest Harvard photographs of the region were obtained in 1889 and 1890, and photographs are available for every year from 1894 to date. No variation in the brightness of the star during that period is revealed. The star was of normal brightness on December 26, 1924. Photographs on January 4, 11, 13, 1925, do not show the star, but indicate that it was fainter than eleventh magnitude, and probably of normal brightness. On April 13, 1925, six weeks before discovery, it was of the third magnitude. This indicates that the rise to maximum was even slower than hitherto realised, and emphasises the unusual life history of the nova.

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# Astronomical Society of South Africa.

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OFFICERS AND COUNCIL, 1925-26.

*President*: William Reid, "Glen Logie," Camp Ground Road, Rondebosch.

*Vice-Presidents*: H. Spencer Jones, M.A., Sc.D., B.Sc., F.R.A.S., Senator the Hon. A. W. Roberts, D.Sc., F.R.S.E., F.R.A.S., H. E. Wood, M.Sc., F.R.A.S.

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

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

*Members of Council*: W. Eaton, W. B. Jackson, M.Sc., J. K. E. Halm, Ph.D., F.R.A.S., A. W. Long, F.R.A.S., W. H. Schonegevel, R. Watson.

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

*Auditor*: E. J. Steer.

DIRECTORS OF OBSERVING SECTIONS.

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

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

*Meteor*: D. G. McIntyre, "Kolara," Kenilworth (Tel. 1052, Wynberg).
*Variable Stars*: W. H. Smith, "Arum Villa," Plumstead.
*Editor of Journal*: H. Spencer Jones, M.A., Sc.D., B.Sc., F.R.A.S., Royal Observatory, Cape of Good Hope.
*Librarian*: The Secretary.

## COMMITTEE OF CAPE CENTRE, SESSION 1925-6.

*Chairman*: H. Spencer Jones, M.A., Sc.D., B.Sc., F.R.A.S., Royal Observatory, Cape of Good Hope.
*Vice-Chairman*: Capt. D. Cameron Swan, F.R.P.S., F.S.A.Scot., "Strathmore," Kalk Bay.
*Hon. Secretary*: H. W. Schonegevel, 4, Morley Road, Observatory.
*Hon. Treasurer*: A. F. I. Forbes, "Craigie Brae," Liesbeek Road, Rosebank.
*Committee*: W. C. Cooper, B. Jearey, A. W. Long, F.R.A.S., W. Reid, W. H. Smith.
*Acting Librarian*: C. H. de la Rey Roux.
*Hon. Auditor*: E. J. Steer.

## COMMITTEE OF JOHANNESBURG CENTRE, 1925-6.

*Chairman*: W. B. Jackson, M.Sc., P.O. Box 4570, Johannesburg.
*Hon. Secretary*: W. Eaton, P.O. Box 2402, Johannesburg.
*Hon. Treasurer*: W. Geddes, 86, Kimberley Road, Judith's Paarl.
*Members of Committee*: T. Beamish, F. C. S. Haden, J. Moir, M.A., D.Sc., F.I.C., J. D. Stevens, W. M. Worssell, F.R.A.S.

## ASTRONOMICAL SOCIETY OF SOUTH AFRICA.

### New Members.

Butler, J., c/o *Cape Times*, Cape Town.
Levitt, M. L., P.O. Box 30, Windhoek.
Lowry, Mrs. M. C., Umtata.

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

Davis, J. B., Box 10, Coligny, Transvaal.
Forbes, D. L., 94, Florida Road, Durban.
Moir, James, M.A., D.Sc., F.I.C., 48, Ditton Avenue, Auckland Park, Johannesburg.

The Editor acknowledges the receipt of the following:—

*Harvard College Observatory Bulletin, Nos.* 819 *and* 820; *L'Information Astronomique, Bordeaux, Sept. and Oct.*, 1924; *Gazette Astronomique, July*, 1925.

# INDEX TO VOLUME I.