would be a second less marked minimum half way between each pair of principal minima. But no such secondary minimum has, so far as I am aware, been observed; and we may therefore conclude that the eclipsing body has no light of its own, or at most is very feebly luminous.

The conclusions arrived at from this rough analysis of the light changes of Algol are :—

1. That there are two bodies revolving round each other.

2. That a complete revolution takes place in 2·86 days.

3. That the plane of the orbit passes through, or very near, the earth.

4. That one of the bodies is dark.

5. That the size of the disc of the dark body cannot be less than $\frac{3}{4}$ of that of the bright one.

We are not able to say whether the dark body passes directly between us and the bright one, or a little above or below the latter; but if we were able to say whether there is or is not a period of steady minimum, we should be able to answer this question.

The Motions of the Stars.

By H. G. Tomkins, F.R.A.S.

The object of this paper is to bring before Members of the Society some of the results of recent investigations of stellar motions with special reference to the theory of Professor Kapteyn regarding the two drifts of stars, and the researches of Mr. Eddington of the Greenwich Observatory. The subject is a very difficult one, and the methods of research are highly technical. Those who wish to study the papers in detail can do so in the monthly notices of the Royal Astronomical Society. In this paper I have set out with a brief history of the idea of stellar motion, and have then indicated from Mr. Eddington's papers the graphical method adopted by him of making the investigation and the main conclusions he has arrived at.

If we watch the heavens from night to night, month to month, and year to year, we notice that the same stars are not always in the same part of the sky above us, and that a star which is to be seen in one direction at one part of the night or year is not in that direction at another. From this we are led to infer that the stars are not immoveable, but have motion. In the early days of astronomy, it was believed that the sun and the stars were fixed in a crystal sphere, which revolved round the earth as its centre. This notion, of course, presupposed the earth to be at rest, and the sun and stars all to be themselves in motion. It soon came to be recognised, however, that most of this apparent motion would be evident if the earth were in motion and the sun and stars at rest, and Copernicus put forward the correct solution of the problem when he declared the sun, and not the earth, to be the centre of our system, and the earth and planets to be revolving round it. This was at once a recognition of the fact that the motion of the stars might be of two kinds—apparent, due to movement on the part of the earth; and real, due to proper motion of the stars themselves. We are familiar with the former in the rising and setting of the stars, due to the diurnal rotation of the earth, and in the change of the positions of the constellations due to the revolutions of the earth in its orbit during the year. Other less familiar changes are those due to precession and aberration. The effect of the precession of the equinoxes round the ecliptic in its period of 25,868 years is visible in the apparent approach of some stars to the pole and the recess of others. The period is a long one, but the effect is visible after a moderate time.

The present pole star, with which most of us are well enough acquainted, is now about 1° 24′ from the pole. Not so very long ago in point of astronomical time it was about nine times that distance away. At the time of the erection of the Great Pyramid α Dacornis was the pole star, and it is an established fact that the passage way into it was built so that at the bottom this star was visible at its lower culmination.

Aberration, which is due to the time taken by the light of a star to reach the earth, is also another source of apparent motion, and there are others. It is not the purpose of this paper, however, to deal with these apparent motions, and they have only been mentioned in order that they may be excluded from the consideration of the motions of the stars themselves. It is the *real* motions of the stars (as far as we can fathom them) that we are now concerned with. The first astronomer to conceive that beside the apparent motion of the stars, there might be real motion, of the bodies themselves, and to suggest a measurement of it, was Halley of Comet fame in the year 1718. He directed special attention to Arcturus as well as other stars. Perhaps it may now be explained that it is one of the objects of the numerous catalogues of stars which have for so many years been compiled by observatories to try and detect motion of this kind. The place of a star is fixed by its right ascension and declination as it would be seen from the earth's centre, in arriving at which the effect of sources of *apparent* alteration of place due to the earth, the earth's atmosphere, etc., are taken into account. If, after the lapse of years, the place is again calculated from observation and found to differ from what it was at first, it is evident either that the star has itself moved, or else that it and other stars have moved; or, thirdly, that the whole of one solar system has moved—that is, that the sun with its planets (including the earth) is moving through space. This motion is called proper motion, and it is this which we have now to consider.

In the year 1760 J. Tobias Mayer, from a comparison of his own observations with those made by Römer about 50 years before, found a small number of stars which exhibited differences of position such as have been referred to above. In 1776 Maskelyne and later on others also published lists of the same kind. In 1781 Prevost and in 1783 Herschel took up the subject, and as a result they both concluded that the sun was with its planets in motion in space, and that the whole system was drifting towards the constellation Hercules. This was merely an indication of linear motion. There was no evidence of any orbit in which the sun might itself be revolving in the same way as the earth does round the sun. It is recognized, however, that the motions of heavenly bodies, as far as we can measure them, obey the laws Kepler from which an orbit would be expected. Probably the reason why nothing of the kind has yet been detected is that the distances involved in this tremendous problem are too great, and the periods over which our observations extend are far too short to give any indication of anything beyond linear movement. Future generations—if the records now being compiled live so long—may be able to obtain such evidence: it is doubtful, however, if anything of the kind will be possible for many centuries yet.

Coming to more recent years, Mr. Procter called attention to the subject and pointed out that the fact of the proper motions of stars near one another being nearly the same, supported the assumption that the stars themselves must be in actual motion as distinguished from solar motion. This was another step in advance. Hitherto the motions had been held to indicate the motion of the solar system among the stars; now it was conceived that motion might also exist among the stars themselves—in fact that, instead of being a fixed universe, it might be composed of multitudes of suns or solar systems, including our own, all moving among each other, something perhaps after the idea of the molecules and atoms which we meet with in other sciences.

This was the stage at which the subject stood when Professor Kapteyn and Mr. Eddington began their investigations a few years ago. The idea was that the motions of the stars were at random, and attention was chiefly given to the determination of the movement of our own solar system in space among the stars. Kapteyn's investigations of Bradley's catalogue of proper motions of stars, however, have resulted in the production of evidence to show that the motion of the stars is not at random, and, when all are considered together relative to the sun, he finds evidence of two great streams of stars moving in two fairly well marked directions. I cannot do better than quote a paragraph from Mr. Eddington's first paper on these motions. He says: "Relative to the sun he (Kapteyn) finds two 'favoured' directions of motion instead of one. Kapteyn suggested that there are two systems or 'drifts' of stars; these two drifts are in motion relative to one another. If the whole universe forms one system (or one chaos), we can speak of its motion relative to the sun; but it is more natural, though perhaps misleading, to speak of the sun's motion relative to it. But if there are two systems, we may as well drop the idea of the solar motion altogether, and speak of the motions of the two drifts relative to the sun."

It seems to me that this puts the case very clearly. Kapteyn considers that the stars move in two great streams or drifts, and Eddington has submitted the theory to searching tests.

Briefly, his method has been to assume the motions to be in any direction: then to examine other catalogues than the one selected by Kapteyn, and to see mathematically and graphically whether there is evidence of the two streams.

Now, suppose that on an examination of the catalogue it is found that the number of stars having a proper motion in any number of given directions is the same, and supposing we took a centre and drew radii from it to represent those directions and made the length of those radii equal to the number of stars moving in each direction, we should then have a graphical representation of the whole, and as the numbers of stars were equal in all directions it would be a sphere. Supposing now a small region of the sky is taken, it can be considered as approximately plane, and ignoring the motions in the line of sight, the resulting graph would be a circle.

Next, let us suppose the sky to be divided up into a number of three small regions, each to be investigated separately, we can then in the same way represent the state of affairs of each by a diagram. Suppose that the number of stars moving in the various directions are not equal, then, if we draw a radius vector in the directions proportional to the number of stars having proper motions in that direction, we shall obtain graphs of shapes other than circles.

Considering the stars to belong to one drift and proceeding in this manner, we obtain figures such as the following for four variations in the number of stars in given directions :—

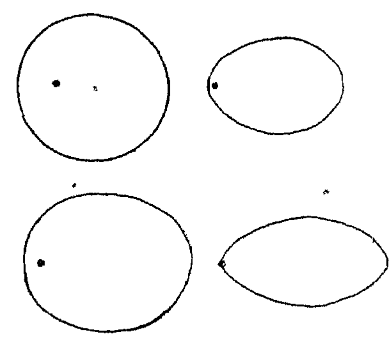

Fig 1

They are of course types of the graphs which might be obtained, and it will be noticed that the maximum is always opposite to the minimum, thus indicating the single drift. On this basis Eddington divides up the portion of the heavens which he has investigated into seven regions, and the resulting graphs obtained are as follows :—

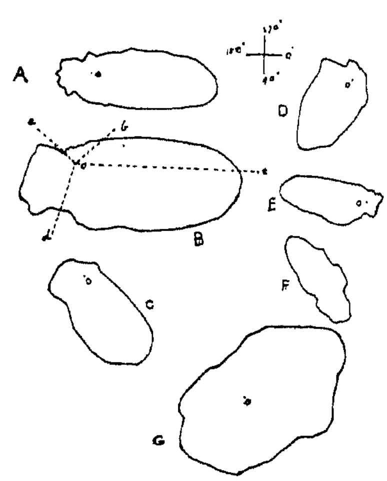

Fig 2

It is quite evident that something is at work in these curves, which makes them differ in a remarkable manner from those in Fig. 1. Taking Mr. Eddington's own explanation of one of them—"Let us consider, for example, the curve and compare it with the theoretical single-drift curves of Fig. 1. Perhaps the most remarkable feature is the extraordinary minimum between *o a* and *o b*. The number of stars having directions of motion within this right angle is found on reference to be only 63 out of 862. But the curve differs completely from the theoretical curves, in that the maximum is not by any means opposite to this, but is along *o c*; in fact there is a sort of secondary minimum along *o d*, where we should have expected the maximum to be."

There is no resemblance whatever between the curve β to those in Fig. 1 based on the single drift, nor has Mr. Eddington been able to bring them into any sort of agreement on that basis. Likewise the other regions also differ largely with the types of the curves of Fig. 1.

Mr. Eddington, therefore, proceeded on the basis of two drifts as suggested by Professor Kapteyn, and as a result obtained the following diagrams, which agree well with those drawn up from the catalogues. He obtains a remarkable

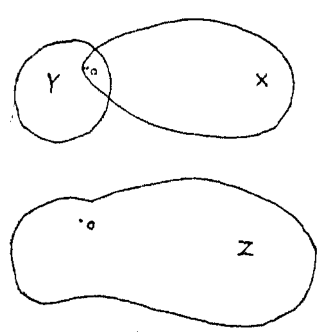

Fig 3

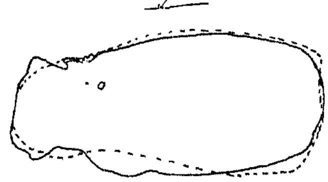

Fig 4

correspondence between the curves of Z in Fig. 3 and β of Fig. 2, which he brings home by direct comparison of the two in Fig. 4.

The curve Z corresponds to a mixture of the stars of two drifts.

Thus far in 1906, therefore, Eddington's researches bear out the theory of Kapteyn. Recently another catalogue has been published by Professor Bose containing 6,188 stars, and Eddington has examined these by the same methods as before. In the meantime research had shown that beside the two main streams there were certain local streams and "moving clusters." The chief of these are the stars of Orion, Ursa Major, Taurus and the Pleiades. Eddington omits these in his recent paper, and for the purpose of the remainder he divides the sky up in 17 regions.

I give below the result he obtains in one of these regions in Fig. 5 A:

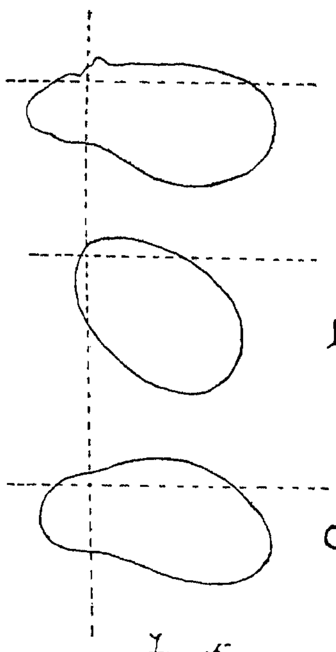

Fig. 5

The nearest approximation he can obtain on the hypothesis of random distribution together with solar motion is β It is obviously unlike. On the two-drift basis, however, we have C, and it is seen at once that a strong correspondence exists, and so on with the other regions.

Taking now the directions of the first drift shown by the 17 different regions and combining them, it is seen that they all converge towards one apex. Fig. 6 shows this in a remarkable manner.

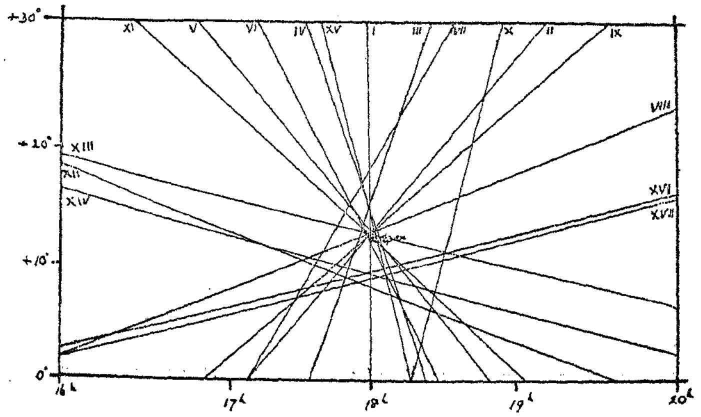

Fig 6. Convergence of the directions of Drift I from the 17 regions.

Similarly with drift II, though in this case the convergence is not so strongly marked. Even so, however, the evidence is as strong as it would be supposing we took a case on the earth and drew great circles from 17 points uniformly distributed over the earth and found that every one of them passed across the Sahara.

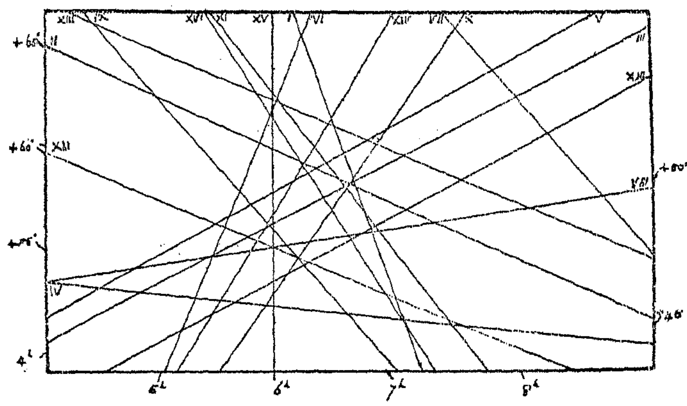

Fig 7 Convergence of the directions of Drift II from the 17 regions.

The positions of the apices thus derived are R.A. 90°.8 Dec.—14°.6 for Drift I and R.A. 287°.8 Dec.—64°.1 for Drift II, which agree closely with similar positions found by Professor Bose from the same catalogue by other methods.

The conclusion we must draw therefore from these remarkable researches is that the visible universe consists of stars composing in the main two great streams, one of which is travelling in the directions just mentioned.

The Crater Clavius as viewed by an Observer on the Moon.

By U. L. Banerjee, M.A.

In my last paper I dealt with the Crater Plato, which is a walled circular plane 60 miles in diameter, with comparatively level interior bed, surrounded on all sides by a mountainous ring varying in height from 3,000 to 3,800 ft. I shall now describe another crater named Clavius, situated between 9° to 21° long. and 55° to 63° lat. It is 142·6 miles in diameter, having an area of 16,000 square miles, surrounded by an elevated mountainous range, the average height of which varies from 9,000 to 13,000 ft. above its plane.

Its western wall rises with a gentle slope from the elevated regions on the west and falls abruptly into a broadly terraced declivity to the interior of the crater, the general elevation there being 12,000 ft. This wall, running northwards, rises abruptly into a lofty peak υ some 17,300 ft. high, situated at the north-western corner of the crater, and then slopes down to an elevation of 9,000 ft. on the north.

Opposite this lofty peak υ and on the east side is another peak ϵ 16,800 ft. high; here the wall again gently slopes down reaching a height of 10,000 to 13,000 ft. throughout the entire south-eastern part, and then terminates into another peak α 16,800 ft. high on the south. Thus the plane is practically surrounded by a chain of mountains, with 3 lofty peaks, the view of which may be graphically represented by spreading out the walls in a straight line thus :—