The Variability of Stars.

By Lt.-Col. Lenox Conyngham, R.E., F.R.A.S.

It has occurred to me that it may be of interest to those members who are taking up the observation of variable stars to hear a short account of the way in which the observations are used in deducing the cause of the variations from the light curves. I shall confine myself to stars of the Algol type.

fig. 1

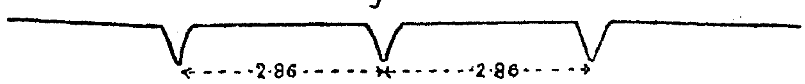
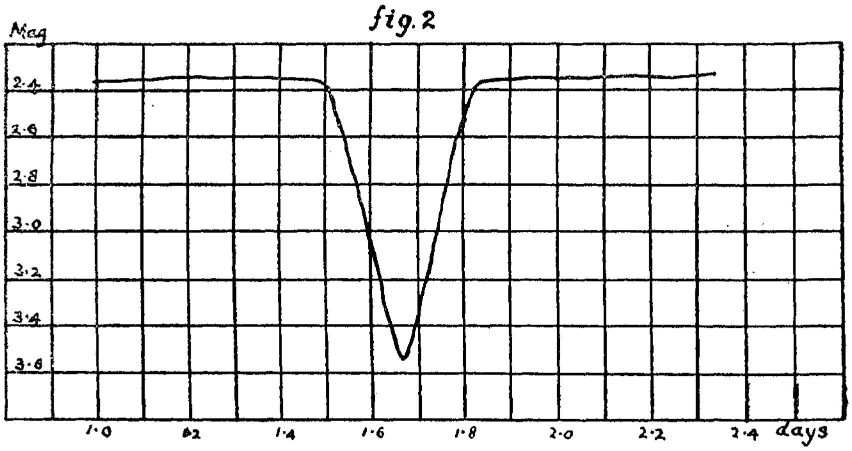


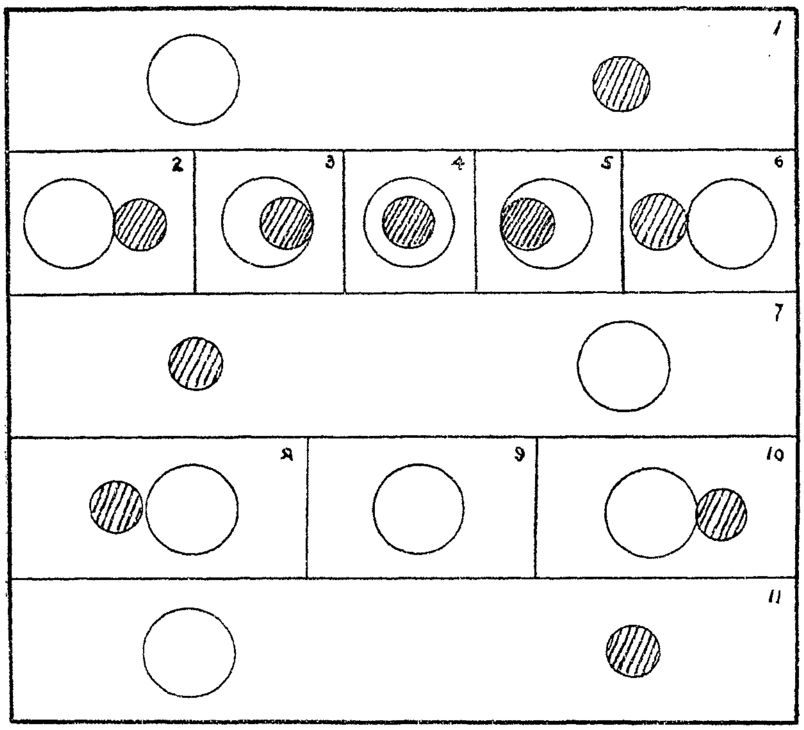
fig. 2



The light curve of Algol is of the form shewn in Figs. 1 and 2. The characteristics are a long period of maximum brightness without variation, followed by a rapid descent to minimum; an equally rapid rise to maximum, followed by a repetition of the long steady period, and then by the same cycle of changes. In other words, we have a considerable time during which the star shines steadily without interference, and then a partial shutting off of the light; this suggests an eclipse and leads us to the idea of a dark body passing in front of a bright one.

If we imagine two bodies revolving round each other, or, more precisely, each revolving round the centre of gravity of the two, they will occupy successively the positions shewn in Fig. 3; and an observer, situated in the plane

fig. 3

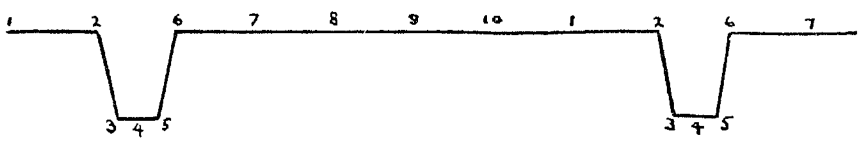


of their orbit, would see, if he were near enough, at stage 1 the dark body D moving towards the bright one B: at 2, the two discs would apparently be in contact, and D would begin to cut off part of B's light: at 3 D is producing the maximum of obscuration, and it continues to do so till 5 is reached, when it begins to pass off again: at 6 D is in apparent contact again and no light is cut off: at 7 D has reached its greatest distance from B and begins to return towards it: at 8 there is again apparent contact, but now D is further away from the observer than B and begins to pass behind it: at 9 D is altogether behind B and cannot be seen at all: at 10 it has emerged again and is seen once more in apparent contact: at 11 it has reached its greatest distance to the right and is in fact at position 1 again.

Now let us translate these appearances into a light-curve.

From 1 to 2 (*vide* Fig. 4) there is no interference and the curve is a straight line. At 2 the shutting off of light begins

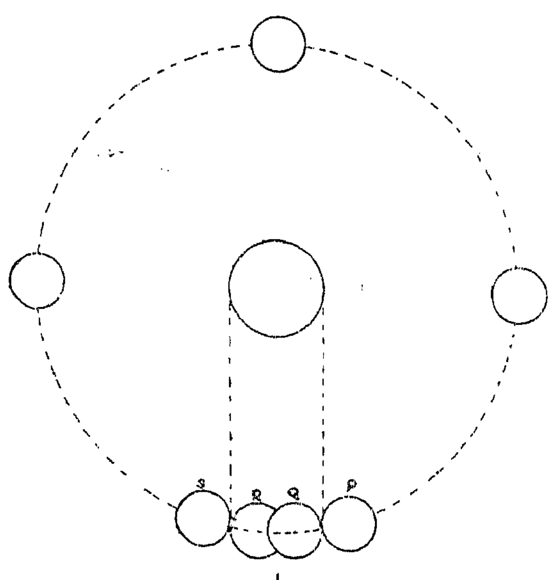
fig. 4



and the curve begins to drop; it continues to do so until first internal contact, stage 3, is reached. From this point to stage 5 the observation is steady and the curve is again straight line. From 5 to 6 the light increases and the curve rises. From 6 through 7, 8, 9, 10, 1 and 2 no change in the light occurs, and the curve is a straight line; and then we arrive at a second eclipse.

In this rough way a curve not very unlike that of Algol has been obtained, but in the Algol curve there is no straight portion at minimum; the curve dips to a certain point and then at once begins to arise again. This part of the curve must therefore be more closely examined.

fig. 5



In Fig. 5 the positions are shewn as seen from a point above the plane of the orbit, the direction of the observer being shewn by the arrow.

The part of the orbit during which the eclipse is seen is only the small portion between P and S, and only from Q to R is the whole of the dark disc projected on the bright one. The length of the straight piece of the curve at minimum brightness only corresponds to this small portion of the orbit,—roughly, in the above diagram, $\frac{1}{40}$ part of the whole. It is evident, therefore, that in Fig. 4 its length has been much exaggerated. Moreover, in the diagram the dark body has been drawn smaller than the bright one; if it were exactly the same size, then in the diagrams of the stages (Fig. 3), 3, 4 and 5 would coalesce. There would be a diminution of the light down to momentary total extinction, and then the increase would at once begin. I may remark in passing that this consideration brings to light an inconvenience in the use of magnitude-curves instead of true light-curves, to the difference between which I drew attention in the Journal for November. The magnitude-curve of a star which suffers total extinction cannot be drawn, for since the number expressing the magnitude of a totally extinguished star is infinite, we should require an infinite piece of paper to contain the curve. On a true light-curve the point representing total extinction is merely the zero of the adopted scale.

To return to the question of the length of the period of steady minimum, the matter can be approached in another way. We have seen that this length must depend on the relative sizes of the two bodies. The ratio between these can be estimated from the amount of the loss of light that takes place. The magnitude of Algol at maximum is about 2·3 and at minimum about 3·8—a fall of 1½ magnitudes. A fall of 1 magnitude means that the light is divided by 2·516; a fall of 1½ magnitudes means that it is divided by

$$(2{\cdot}516)^{1\frac{1}{2}} = 4 \text{ nearly.}$$

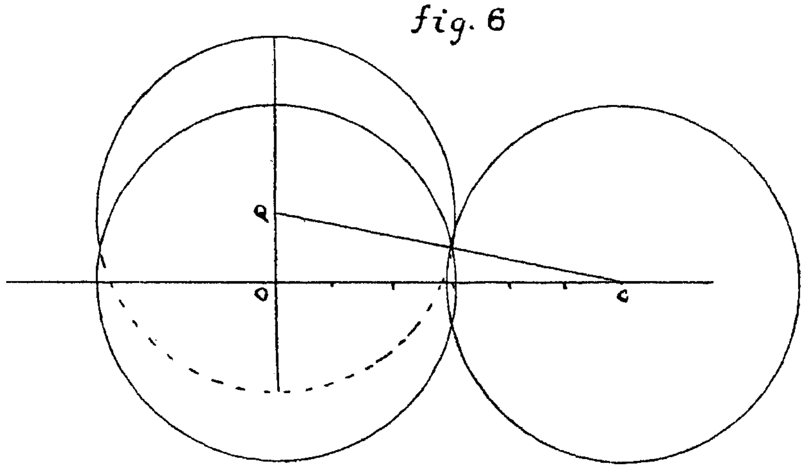
That is to say, at minimum only ¼ of the light is left, or ¾ are cut off. Hence the sizes of the discs are as 4 to 3, the bright one being the larger; that is to say, their diameters are as 2 to 1·7.

Many other considerations, however, would have to be taken into account before any reliance could be placed on these figures. I will only touch on two of these.

In the diagrams, it has been assumed that, as seen from the earth, the dark body passes directly in front of the bright one; but it is by no means certain that this is the case. The plane of the orbit may only pass near the earth, not through it, and thus the dark body would only be partially effective in obscuring the bright one.

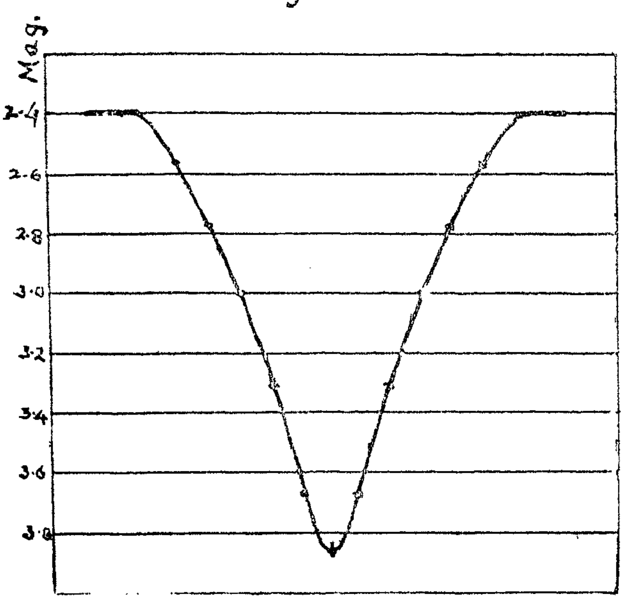
We know that the dark body cannot be less than $\frac{3}{4}$ the size of the bright one: let us suppose that they are of equal size and examine what must take place. At the moment of maximum eclipse one-quarter of the bright disc is visible, hence it can be shewn that the centre of the dark disc must at that moment be about four-tenths of the radius below the centre of the bright one.

fig. 6



Drawing a horizontal line through the centre of the dark disc (see Fig. 6), and marking the position C of its centre when first contact occurs, all the changes in the light of the star, from the beginning to the middle of the eclipse, occur while the centre of the dark disc moves from C to O. If we divide CO into any number of equal parts and measure, or compute the distances from Q, the centre of the bright disc, to the points of division, we may calculate the amount of the bright disc that is hidden at each successive position of the dark one, and so draw the light-curve of the variation. In order, however, to make a comparison with the curve of Algol obtained by observation, this light-curve must be converted into a magnitude-curve. I have determined the magnitude of the bright star at 6 points intermediate between C and O, and Fig. 7 shows the resulting curve. It is very similar

Fig. 7



to the curve shewn in Fig. 2. It is to be noted that in such a case as I have been supposing there is no steady period at minimum. It would be of great interest to know whether in the Algol curve there is or is not a small period of steadiness at minimum brightness. The curve shewn in Fig. 2 is not derived from a sufficient number of observations to clear up this question, but I have no better one at hand.

There is another point that requires attention. It was supposed that the eclipsing body was dark, but it may be asked whether this is necessarily the case.

Might it not be a body less brilliant than the bright body, but still having some light of its own ?

For instance, if it were the same size as the bright body and totally eclipsed the latter, but itself possessed a brightness equal to ⅓ of that of bright disc, we should then, when both are fully visible, receive a light of 3 from the one and 1 from the other, or 4 in all ; but when the darker of the two eclipses the other we should receive only the light of the less bright one, or a light of 1, which would agree with the observed change. But in this case, when the darker body is behind the brighter, we should receive only the light from the latter ; that is to say, a light of 3, and there 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 ⅞ 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