Outline of Work on Variable Stars.

By the Director of the Section.

By a 'Variable' Star is meant one of which the apparent brightness as seen from the earth is not constant. No other kind of change—such, for instance, as change of position—is taken into account when we are considering the variability of stars.

The brightness of a star is expressed by a number which is called its magnitude. This does not mean magnitude in terms of measurable dimensions, for not even in the largest telescopes have any stars discs of sensible size—they are all mere points of light. Star magnitudes are merely numbers by means of which they can be classified according to the amount of light that we receive from them. This amount of light may depend on the inherent brightness of the stars, or on their distance from us; but in assigning magnitudes we are not concerned with the causes of the differences, but merely with what we see. The numbers denoting magnitudes increase as the brightness of the stars diminishes: thus a big star has a small number assigned to it, a first magnitude being brighter than a second, a second than a third, and so on.

In early days a rough classification into first, second, third, etc., magnitudes was all that was attempted; but by degrees this has been refined upon, and now a star magnitude is given to one or even two places of decimals.

Thus a standard first magnitude star will have the number 1 assigned to it, a second magnitude star the number 2, and so on; and between them will be stars of magnitudes, such as 1·25, 1·60, 2·38, etc. A number, such as 1·25 for instance, implies that the star is less bright than a first magnitude and brighter than a second magnitude, and that on the scale of brightness it lies one quarter of the way from 1 towards 2.

The most generally accepted scale of brightness connecting the magnitude with the amount of light received, is that proposed by the late Mr. N. R. Pogson, the eminent astronomer who was for so many years in charge of the Government Observatory in Madras.

He proposed a factor of 2·512, used in the following way:—Given a standard star of any magnitude as a starting point, a star one magnitude above it on the scale will be one from which we receive 2·512 times as much light as we do from our standard; or, if we go down the scale, then a star one magnitude below the standard will give an amount of light = that of the standard divided by 2·512; a star two magnitudes below the standard will give an amount of light = that of the standard divided by $(2\cdot512)^2$, and so on.

The logarithm of $2\cdot512 = 0\cdot4$, hence log. $(2\cdot512)^5 = 2\cdot0 =$ log. 100.

Therefore the light we receive from a 6th magnitude, being = light from a 1st magnitude $\div (2\cdot512)^5$, is $\frac{1}{100}$ of the light of a 1st magnitude, and the light from an 11th magnitude is $\frac{1}{10000}$ of that of a 1st magnitude; that is to say a descent of five magnitudes divides the light received by 100, and so on.

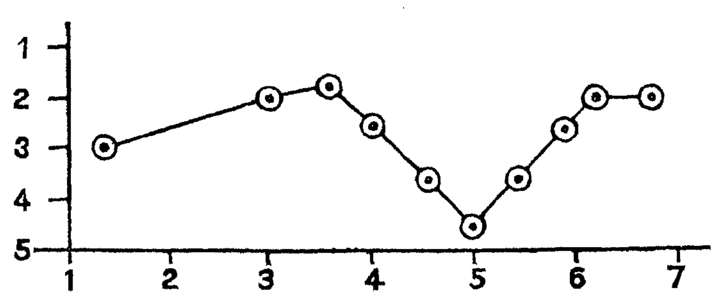
There are stars of greater brightness than those of magnitude 1; if a star gives $2\cdot512$ times the light of a 1st magnitude, it is said to be of magnitude 0, and one giving $2\cdot512$ times the light of a 0 magnitude would be said to be of magnitude -1.

The majority of the stars shine with a steady blaze, but so long ago as the year 1596—speaking of European Astronomy, of the much older Indian science, the writer has unfortunately no knowledge—the first variation in a star's brightness was observed. This was in the case of the remarkable star ° Ceti, or Mira. Some 70 years later the variability of β Persei (Algol) was discovered, and since then new variables in ever increasing numbers have been recorded. At the present day the number of known or suspected variables is very large.

The next step, after having learned that the brightness of many stars is variable, is to follow the course of the changes and to record them in such a way as to throw light on their nature, and, if possible, to reveal the laws which govern them.

The process of recording the variations is called "drawing the light-curve" of the star. This is done as follows :—

A horizontal line is drawn and divided off into equal parts to represent intervals of time, and a vertical line is marked off to represent star-magnitudes.



If now at a time half way between epochs 1 and 2 (for instance) the magnitude of the star is 3, we plot a point vertically above 1·5, and in a horizontal line through 3. A later observation at time 3 shows, we may suppose, that the star was then of magnitude 2; this gives another point. By continuing the observation and noting the star's magnitude at different times we obtain a series of points, indicated in our imaginary diagram, and by joining them we obtain a curve which represents graphically the course of the star's variation. This is called its light-curve.

The above is, the writer believes, the way in which light-curves are invariably plotted—that is to say, with a vertical scale of equal parts to represent magnitudes. This seems to imply that the loss of light is the same in amount for each drop of one magnitude, which is not the case. Such a curve is not, strictly speaking, a light-curve; it is a magnitude-curve. To obtain a true light-curve, one should first decide on the number of parts of the selected scale to represent the light of a first (or other) magnitude star, and then the numbers to represent the light of lower magnitudes would form a series in descending geometrical progression.

True light-curves would have flatter minima and steeper maxima than magnitude-curves.

However, since the simple method of plotting by magnitudes is in general use, it will be well for the Astronomical Society of India to adhere to it.

The light-curves—using the term in the customary way—of many stars have been drawn, and it has been found that the curves fall into four principal classes, denoting variable stars of four different kinds. They are :—

(1) Algol type.
(2) Short period, non-Algol.
(3) Long period.
(4) Irregular.

The Algol type of curve, so called after the celebrated star of that name, has the following characteristics :—There is considerable period without change, then a rapid descent to a minimum, a brief, often scarcely discernible, period of steadiness followed by a rapid rise to the former level: again a prolonged quiescence and then a repetition of the changes.

Curves of class 2 differ from the above in that there is no period of steadiness. The changes are continuous, but repeat themselves in a moderate time—less than about 70 days.

Class 3 is not sharply divided from class 2, but the period is much longer, extending from about 140 days up to several years.

There do not appear to be many, if any, stars with periods between 70 and 140 days in length. Hence the adoption of 70 days as a sort of rough limit to periods which are classed as short.

Class 4 consists of stars which either show no recurring periods in their variations, or periods of such length, or curves of such complexity, that no law has as yet been ascertained.

For the determination of the light-curves of stars the important thing is to secure a number of observations spread in a continuous manner over a long time: for this reason, co-operation is specially valuable, the gaps in one observer's record being filled by the results obtained by others in perhaps different localities where the vicissitudes of the weather have been different. It is also very important that the attention of a good many observers should be concentrated on a small number of stars.

The method of observing a variable star is very simple. It consists merely of making comparisons between the variable and neighbouring steady stars of which the magnitude is known.

The best plan—though it may not always be feasible—is to select two comparison stars, one somewhat brighter and one somewhat fainter than the variable, and to estimate by what fraction of the difference between the two steady stars the variable is fainter than the one and brighter than the other. Thus, if the comparison stars are A and B, we might estimate perhaps that V was fainter than A by about a quarter of the amount of the difference between A and B.

If, therefore, the magnitude of A were 3·4, and that of B 5·6; interval 2·2. The magnitude of V would be—

$$3{\cdot}4+2{\cdot}2\times\tfrac{1}{4}=3{\cdot}95$$
$$\text{or } 5{\cdot}6-2{\cdot}2\times\tfrac{3}{4}=3{\cdot}95.$$

The record of an observation should contain the following particulars :—

Date and Time—Stating whether Standard, or Calcutta, or other local time is given.

State of Sky—Good, inferior (cloudy or hazy), very poor. M should be added if there is moonlight and Tw if there is twilight.

Instrument—Eye, Binocular, Telescope, stating magnifying power.

Class of Observation—First class, moderate, poor.
Name of Star observed—
Names of Comparison Stars—
*The record of the observation.**

The first and greatest difficulty that confronts a beginner is that of identifying his stars. For that reason, in the programme of stars which is here put forward, visibility has been the chief consideration kept in mind.

Seven stars are selected as suitable to make a beginning upon. Particulars with regard to them are given in the following table and notes :—

Star.	R.A.		Declination.	Period.	Limits of Magnitude.
	H.	M.		D.	
β Lyræ ...	18	46	+33° 14′	12·91	$3\frac{1}{2}$ — $4\frac{1}{2}$
R (13) Lyræ ...	18	51	+43° 48′	46	4 — $4\frac{3}{4}$
η Aquilæ ...	19	47	+ 0° 43′	7·17	$3\frac{1}{4}$ — $4\frac{3}{4}$
S (10) Sagittæ ...	19	51	+16° 20′	8·38	$5\frac{1}{2}$ — $6\frac{1}{2}$
μ Cephei ...	21	40	+58° 16′	irregular	$3\frac{3}{4}$ — 6
δ Cephei ...	22	25	+57° 51′	5·37	$3\frac{3}{4}$ — 5
Algol (β Persei) ...	3	1	+40° 32′	2·87	2·2 — 3·7

For β Lyræ, see Plate VI of the Astronomical Society of India's Star Chart. This star is easily found, being near the conspicuous star α Lyræ (Vega).

Comparison stars. γ Lyræ magnitude 3·2
δ^2 Lyræ ,, 4·5

For R (13) Lyræ, see A. S. I. Chart I, on which it is marked 13.

Comparison stars. γ Lyræ magnitude 3·2
δ^2 ,, ,, 4·5
(16) ,, ,, 5·2

For η Aquilæ, see A. S. I. Chart VI.

Comparison stars θ Aquilæ magnitude 3·4
μ ,, ,, 4·7

* The above is taken from the Journal of the British Astronomical Association.

The constellation Sagitta is to be found on A. S. I. Chart VI, but the star S (10) is not marked, its position on that chart would be about 2 mm. to the left of the G in the word Sagitta, and 3 mm. below the e in 'neb.' There is a convenient comparison star (11) close to it, a little to the north and preceding—magnitude 5·3. These stars will be rather difficult to pick up with the naked eye, but will be easily seen with a binocular.

For o and μ Cephei, see A. S. I. Chart I.

Comparison stars.	ζ Cephei	magnitude,	3·5
	19 ,,	,,	5·2

Algol (β Persei) is also to be found on plate I.

Comparison stars.	α Persei	magnitude	1·9
	ϵ ,,	,,	3·0
	ν ,,	,,	4·0

Outline of Work for the General Section.

BY THE DIRECTOR OF THE SECTION.

It is suggested that an excellent object for observation by members of the General Section is the Sun.

Persons living in India are naturally very favourably placed for making such observations; moreover, the size and comparative nearness of the Sun make it possible for good work to be done even by those who are indifferently equipped as regards instruments.

For the sake of definiteness, I shall describe briefly a line of investigation along which members of the Society might with some advantage direct their attention, and which is likely to yield valuable data.

Spots on the Sun's surface have always been a fascinating subject for study, and the general observation of both sunspots and faculæ is open to everyone possessing a small telescope. Drawings of these disturbances in the luminous envelope of the Sun can always be obtained by the method described at the end of this article, while for those possessing larger instruments, there is an opportunity for more detailed study, with the help, possibly, of the photographic plate.

Such sketches or photographs are always of value, especially when the records extend from day to day as they should do.