have been mounted, as a few minutes' scrutiny of a large star will show at once whether the figure is good or bad without removing the mirror from its tube. A high power must be used for large mirrors. Very large mirrors seldom have absolutely first-class figures for dividing double stars, but are sufficiently good for photography, as the halation hides the minor faults which make the difference between a perfect mirror and a good one. Until mirrors are figured with the same care as achromatics they will never give satisfaction; and I may add that a perfect flat is as essential as a perfect mirror. If the flat is concave it will give, slightly out of focus, an oval disc of light instead of a circle, and quite spoil the definition.

In conclusion, I should like to acknowledge my debt to Nichol's Cyclopaedia, published in 1837, and to Cooke's book on "Telescopic Objectives."

ART. LII.—*Southern Variable Stars.*

By C. J. WESTLAND, F.R A.S.

[*Read before the Astronomical Section of the Wellington Philosophical Society, 4th August, 1915.*]

IN choosing "Southern Variable Stars" for my title I wish to explain that I am referring to stars which are well situated for observation in New Zealand, but without excluding some which may be visible to a certain extent in Europe also. The southern stars are not nearly so well known as the northern ones, and this is true of the variable as well as the other stars. Still, there is much to be learnt about variable stars in both hemispheres, and with reference to this I may quote a statement made by Professor Pickering in addressing the British Astronomical Association in June, 1913 Out of 4,525 variable stars now known, 3,371 have been discovered at Harvard College Observatory, and out of all this number probably less than a hundred have had their periods and ranges of magnitude determined

The explanation of this is that a discovery is made by comparing two photographs taken on different dates, but determination of a star period requires prolonged observations for which no professional observer has time to spare Only amateurs can find the opportunities to collect the information, and, fortunately for them, the work does not require very elaborate instruments. The Variable Star Section of the British Astronomical Association has done much valuable work in this direction, and several of its most diligent members have only 3 in telescopes When a star reaches naked-eye magnitude a pair of field-glasses is more useful than a telescope, because it may be necessary to compare the variable with a star of known magnitude several degrees away. The field-glasses may be turned rapidly from one star to the other in a way that is impossible with the telescope

A good example of the long-period variables is the star R Hydrae It may be called a southern variable, for, although it is on the working list of the B A A Variable Star Section, the difficulties found in observing it made it impossible to determine either maximum or minimum until a year ago, when one member in South Africa and myself undertook observations of it. Our results showed that at maximum it rose to 4·4 and at minimum it fell to 9·3, so that at one period of its career it gives a hundred times as much light as at the opposite extreme

My own attention was called to this star in an unexpected way. In 1911 a comet appeared which passed through Hydra in November, and was among the comparison stars of R Hydrae for several days. I exposed a plate on it on the 25th November, and on examining the result afterwards I found the variable rather bright. It was really about the sixth magnitude at the time, and, as the exposure had been long enough to show ninth-magnitude stars, a star of sixth magnitude left a very distinct impression. I watched the star for several weeks, and saw it pass through a maximum in January, 1912.

This star follows a custom which is common among variable stars, in that it rises to maximum very rapidly, but falls slowly. The usual method

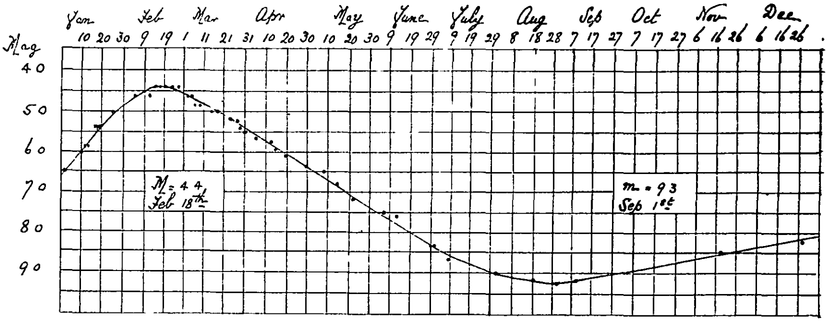

FIG. 1.—Curve of R Hydrae in 1913

of dealing with observations is to plot them on squared paper, making the horizontal scale represent time and the vertical scale show the magnitudes. Then the characteristic I have mentioned is expressed by saying that the rise is much steeper than the fall. The curve of this star in 1913 is shown in fig 1.

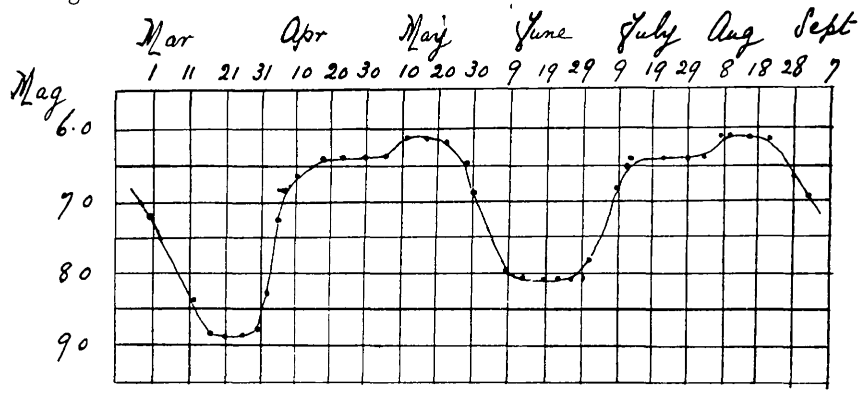

FIG. 2.—Curve of T. Centauri in 1913.

A peculiarity in the period of R. Hydrae is that it is growing decidedly shorter. The observations of last year show that only 409 days elapse between one maximum and the next, whereas all books of reference at present give the period as 425 days. Mr. Gore's book states that the period was 500 days in the year 1708, 487 days in 1785, 461 in 1857, and 437 in 1870.

There are a good many variables whose curves are similar to that of R Hydrae. A few of these curves—Mira Ceti, R. Leonis, and others—are given herewith * Fig. 2 is the curve of a southern star, T. Centauri,

* Other diagrams and lantern-slides were shown at the meeting

classified as a long-period variable, but its changes take much less time than the others just mentioned—apparently about thirteen weeks. This star has a larger measure of irregularity in its behaviour One peculiarity I have noticed myself is that a week or two before the fall sets in, when the star is usually at a fairly flat maximum, it seems to rise quite suddenly about half a magnitude and then plunges rapidly down to its minimum The maximum on this curve is more like a cairn on the top of a hill than the hill-top itself.

Fig. 3 shows the curve of T. Gruis, in which the usual rapid rise and slow fall is not to be found. There is even a suspicion that the fall is the steeper part of the curve, and, if this is correct, it is a very unusual feature in variable stars

The star R. Normae has the reputation of showing two maxima and minima In my own experience, however, the range of variation has been so small that the curve is rather flat and shows no well-marked peaks of maximum

All the stars I have mentioned so far are included in the second class of variables—namely, the long-period variable stars. The others of the five

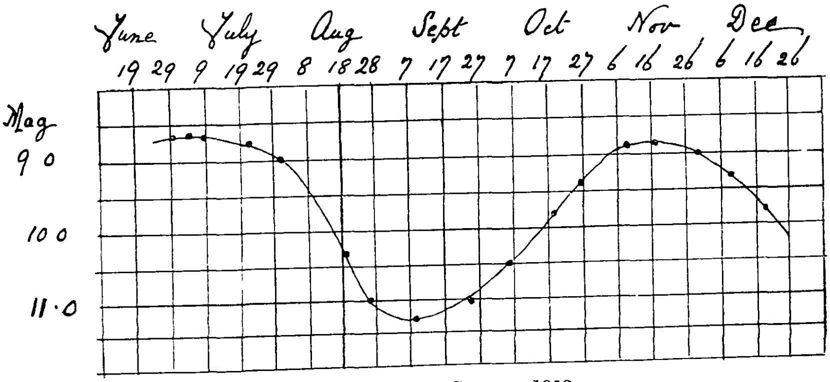

FIG. 3 —Curve of T Gruis in 1913.

classes are—(1) Temporary stars, (3) irregular variables; (4) short-period stars; (5) eclipsing stars The fourth class has certain subdivisions, and sometimes two other classes are added—cluster variable and suspected variable.

The short-period stars are more difficult to observe, because they change so rapidly that unless the observations are frequent they teach us nothing Of course, they require continuous good weather also Three good specimens of their class are Kappa Pavonis, S Trianguli, and S Normae I have watched these for several weeks while the weather was suitable, and found them wonderfully regular both as to period and range of magnitude. The period of S Trianguli is six days; the other two take nine days. There are a few stars whose periods cannot be classified as either long or short, being about thirty or forty days, which is between the two classifications The only one I know among the southern stars is l. Carinae, which is said to vary between 3·3 and 5·5 in thirty-five days I have not seen it brighter than 3·8 or fainter than 4·5, and its period is apparently something just over a month, and may be perfectly regular.

The absolute regularity of the short-period stars gives us the first hint as to the reason of their fluctuations, for when we say their changes are as regular as the flow of time we say they are as regular as the earth's rotation. If we suppose that stars are sometimes brighter on one side than the other we have a ready explanation of a regular variable star. Stars of the Eta Aquilae type—that is, spectroscopic binaries which do not eclipse one another—can also be explained on this hypothesis, because if they always turn the same face towards one another, as the moon does to the earth, the period of variability must be equal to the period of revolution, just as the spectroscope shows. Notice also that if the periods of rotation were otherwise they would explain an apparently irregular variable. The two brightest sides turned earthwards would produce the extra-bright maxima, and the two darkest sides would in the same circumstances give the extra-dark minima. These would be the two extremes of brightness, and if the rotation periods were very unequal the intermediate values would be irregular both as regards time and brightness.

No theory of rotation will account for long-period stars which take months to complete their fluctuations. Mira Ceti and several others are known to undergo physical changes, and at the last maximum of this star I saw the hydrogen line of wave-length 4340 bright without any difficulty, although I have only a 4 in. telescope to collect light for my spectroscope.

The method of magnitude rating consists of comparing the variable with stars situated near it. Charts of the fields surrounding these stars are obtainable, so that identification of the stars is easy, and the magnitude of each comparison star is given. The observer finds it convenient to memorize the stars he makes use of, because the eye loses some of its sensitiveness if it has to leave the telescope and study a chart by lamplight. But after the observer has looked over the stars of known magnitude his eye is in tune. I use this metaphor purposely, because the conditions are similar to those of the ear when it has heard certain notes of the scale played: it is able to pick out the intermediate notes. Similarly, the eye can tell the magnitude of a variable whose brightness is intermediate between two stars of known magnitude, provided that care is taken to get the eye into that condition and to let it work under the best circumstances.

ART LIII.—*The Distribution of Titanium, Phosphorus, and Vanadium in Taranaki Ironsand.*

By W. DONOVAN, M.Sc.

[*Read before the Technological Section of the Wellington Philosophical Society, 10th November, 1915.*]

THE present writer, in the course of an analysis of ironsand from Patea two years ago, found the amount of phosphorus present to be 0·11 per cent. The highest previously recorded percentage of phosphorus in Taranaki ironsand was 0·039 per cent., returned by Dr. J. S. Maclaurin in 1902 from a New Plymouth sand forwarded by Mr E. M. Smith.* It seemed important to ascertain whether the high result was accidental, or abnormal in any way, or whether the ironsand deposits generally contain more phosphorus than has hitherto been supposed. In view, too, of the fact that the commercial utilization of the sands would seem to depend on the

* Thirty-sixth Annual Report, Colonial Laboratory, p. 7.