no longer remain recognisable. It is improbable, therefore, that a nebula of the mass and dimensions considered, evolving along the lines here indicated, could still show the true spiral form, if it had begun to shed the matter now observed in the arms at an earlier date than 10^9 years ago.

If we consider the possibility of the galaxy having originally evolved thus, as a single huge spiral nebula, then, taking its greatest diameter to be 60,000 parsecs, its mass 10^{44} grammes, and ten convolutions as sufficient for its spiral form to have become unrecognisably degraded, we get something between 10^9 and 10^{10} years for the duration of its evolution, down to the time when it ceased to be recognisable as a spiral.

Thus it is obvious that with a period of 10^{13} years for the lives of the stars such a theory of the evolution of the spirals is hopelessly inadequate. There remains, however, the possibility that the latest values for the rate of expansion of the universe may call for a somewhat drastic revision of the time-scale; in this case, since the last word may still remain to be said on the subject of the masses and dimensions of the nebulæ, it seems just possible that by a judicious stretching the two ends may yet be enabled to meet without rupture. For instance, the long ages that must have elapsed during the formation of the original condensations in the primeval nebula, before the evolution of arms began, may partially bridge the gap.

In conclusion we may notice that 10^8 years is the order of the light time from the most distant nebulæ yet observed ; if, therefore, the time taken for the evolution of the arms were of the same order, we might expect to find statistically a decrease in the number of convolutions exhibited by spirals at greater and greater distances.

The author wishes to record his indebtedness to Mr. W. M. H. Greaves for his kind criticism and advice during the preparation of this paper.

A REMARKABLE VARIABLE STAR (V SAGITTÆ).

P. M. Ryves. (Plate 15.)

In 1902 L. Ceraski announced the variability of the small star which later received the designation V Sagittæ. Hartwig, from observations in 1903, suspected a period of 96 days, but Harvard subsequently pronounced the variation "often rapid and probably irregular," range 9·5 to 12·0 (1907). One hundred and thirty-eight observations made at Zaragoza in 1910 and 1911 confirmed the rapid character of the light-changes and revealed a periodic tendency.

V Sagittæ is not in the B.D. Its position for 1855 is R.A. $20^h\ 13^m\ 47^s$, dec. N. 20° 52′; approximate position for 1930, R.A. $20^h\ 17^m{\cdot}1$, dec. N. 20° 53′. The galactic co-ordinates are: long. 30°, lat. S. 10°.

This star has been strangely overlooked by observers and investigators. The present study is based on visual observations made by the writer on

1243 nights during the years 1910–12 and 1923–31. In order to preserve continuity during unavoidable absences from Zaragoza, some observations have been made at other localities—Madrid, 1924; Cambridge, 1925; Leyden, 1928; and on several occasions at Headley, England (Rev. T. E. R. Phillips's observatory).

Some trouble has been experienced with the reduction of the estimates, partly through the lack of reliable faint standards and also on account of a change in the observer's personal equation of position, which took place during the period covered by the observations and has necessitated the use of corrections with reversed signs after the change. During the critical period of the reversal (1927–28) no corrections have been applied. There is obviously some uncertainty about the individual deductions at this time, but since the comparisons are, whenever possible, arranged in such a way that position errors cancel out, the errors resulting from inadequate correction will generally be small.

The light-scale deduced from the observations has been adjusted approximately to the photometric scale of Harvard College Observatory by means of a photograph (enlargement of No. A 2758) sent me by the late Professor E. C. Pickering. On this photograph the magnitudes of several comparison stars are marked, but, as already stated, I have not much confidence in the values attached to the fainter stars, some of which appear to be sensibly overrated. One of the comparison stars is suspected of slight variability.

The observations of 1910 showed peculiar rapid oscillations within a range of about 2 magnitudes. It was obvious that, in order to bring out the true character of the light-curve, very frequent observations would be necessary, and as it was not possible to continue observing on an adequate scale, the work was abandoned in 1912 but was recommenced in 1923 and intensified three years later. During the past six years V Sagittæ has been observed on an average of 170 nights each year (least, 149; most, 213).

The need for frequent observations at all costs (even an inferior estimate being often valuable) necessarily entails a low average weight, since estimates must often be made under unfavourable conditions, and this makes it necessary to seek for some indication as to how much reliance can be placed on the estimates. A study of the probable errors, or divergences from a smooth curve, which with a more regular or slowly changing star would provide a measure of accuracy, in the case of V Sagittæ can tell us little, since, on account of the irregular and unexpected nature of the variations, the divergences may represent real changes in the star's light. However, there are other ways of gauging the probable magnitude of the accidental and short-term errors which principally concern us. For example, the observations may confirm one another. When a smooth curve is drawn, indicating the general trend of the light-change, the dots representing the observations naturally fall at various distances from the curve, a random distribution suggesting errors as the cause of the scattering; but when several dots fall systematically in line, in a manner precluding a chance origin, we may safely conclude that they indicate a real irregularity in the star's variation, however small the amplitude may be, and by analogy other less conclusively revealed irregularities may be assumed to be real. Our curve shows several examples of this kind of mutual confirmation. Thus in 1926, J.DD. 2424,688–696, five observations indicate a fall of 0·4 magnitude; and a little later, days 2424,704–708, a rise of only 0·25 magnitude is beautifully shown by five observations in series mutually confirmatory. In 1927, J.DD. 2425,032–39, the very regular distribution of the observations during the fall may be noted. Eight observations in 1929 are distributed along a pause and rise of 0·4 magnitude, and in 1931 several similar cases are evident, *e.g.* days 2426,503–508, five observations along a fall of 0·4 magnitude (slightly irregular); days 2426,530–533, four observations on a rise of 0·25 magnitude; and days 2426,617–627, ten observations showing the star stationary, falling slowly, then more rapidly. There are many other such cases where, in tracing a most probable curve, the observations are in almost perfect agreement or within less than 0·1 magnitude of such agreement.

The reality of most of the minor sinuosities in the curve is supported by the way in which similar forms recur. We have numerous cases of (1) small secondary minima, a rapid fall followed immediately by a recovery equally rapid or nearly so, the whole very similar to the larger minima; (2) curious halts on the rise but seldom on the fall; (3) complete oscillations (*e.g.* fall-recovery-rise-return to smooth curve); and (4) the remarkable recurrence of subsidiary maxima and minima at intervals which are approximately constant during a considerable period of time (see later). Lastly, in spite of the general persistence of rapid fluctuations, there occur brief intervals of quiescence, and then it is found that the observations cluster along the smooth curve in a satisfactory manner. For example, in 1926, J.DD. 2424,731–736, a pause, quite unexpected by the observer, in the middle of a rapid rise; estimates on 5 consecutive nights are within 0·02 of their mean. The same year, days 2424,837–847, a pause between rapid rise and fall; seven consecutive observations within 0·03 of a smooth curve. In 1929, days 2425,782–815, seventeen observations showing a gradual rise are all within 0·1 of a straight curve. In 1930, days 2426,212–224, the very small oscillations, possibly due to errors of observation, at beginning of rise, give substance to the larger but still small fluctuations of the preceding days, and a similar series of accordant observations denoting another such quiet interval between more agitated periods occurs in the following year, days 2426,509–522.

From the above evidence it may be concluded that the accidental errors are generally not more than one-tenth of a magnitude, though of course larger errors are sometimes present, especially when the star is faint or badly situated, and that the majority of the minor sinuosities of the curve outside these limits represent real changes in the star's light. According to these tests the observations appear to be considerably better than was expected.

Character of the Variation.—The most noteworthy feature is the rapid fluctuation in brightness superimposed on the slow general light-change, which it sometimes masks to a greater or less extent. V Sagittæ has been observed to decrease $1^m.4$ in 1 day and 2 magnitudes in 3 days, and to rise $0^m.9$ in 1 day and $2^m.1$ in 5 days. The characters may be described as follows :—

1. *A slow variation of a periodic character* and range of 2 magnitudes can be disentangled from the short-term and irregular fluctuations. The period is about 18 months (530 days suits the observations best), but there are irregularities. In 1924 the usual minimum did not take place. Part of the rise to maximum is generally rapid.

2. *A secondary variation*, which may be described as a tendency for the maxima to take the form of three peaks separated by intervals of about 130 days. After the faint period the light increases to a principal maximum (first peak) of perhaps magnitude 10·5, soon falls again to median magnitude or somewhat lower, rising to a second and generally to a third maximum usually fainter than the first. The interval is on the average about 130 days, but varies considerably. In the last two cycles these secondary maxima were well defined, but in 1928, though present, they are only slightly indicated, and in 1926 there are two smaller maxima wedged in between them. The feature, however, is quite distinct.

3. *The Rapid Fluctuations.*—Apart from some very brief intervals, short-term variations, irregular or semi-periodic, are taking place all the time. During the period of general faintness (normal minimum) they are of somewhat smaller range except for occasional deep minima of short duration, which, incidentally, constitute the absolute minima of the star. The most pronounced fluctuations take place just after the light has increased to principal maximum and on the decline to the secondary minima. (In 1926 the light fell in 3 days from 11·3 to 13·0, climbed up to 10·4 in the next 20 days, falling again in 3 days to 11·9.) At other times there are rapid oscillations with periods of 10 to 15 days and large amplitudes ($1\frac{1}{2}$ magnitudes in 1910, 2 magnitudes in 1930).

These fluctuations take several forms, the most common being a subsidiary minimum often of about 10 days' duration and of various depths from the smallest recognisable to $1\frac{1}{2}$ magnitudes. A maximum of similar dimensions is less frequent, as is also a complete oscillation, *e.g.* fall-recovery-rise-return to mean curve. Somewhat similar is a continuous zig-zag variation, but more commonly there is a tendency for the light to remain constant for a few days whenever it reaches the neighbourhood of the smooth curve, thus separating the divergences into distinct maxima and minima. This tendency to pause at about the magnitude of the smooth curve may explain some of the pauses so frequently observed on the rises.

An interesting point in connection with all these short-term variations is the fact that, however violent they may be and however large the range, they generally do not alter the general trend of the long-term variation. For example, the light may be decreasing at a rate of one magnitude in 50 days when there occurs a narrow minimum lasting 10 days. If the amount of the sudden fall is one magnitude, the recovery will be not one magnitude, but four-fifths—that is, to the magnitude which the star would have reached if the narrow minimum had not occurred. This seems to show quite clearly that the origin of the rapid fluctuations is very superficial and quite independent of the slow long-term variation of which the origin is more deep-seated. The short-lived character of the rapid fluctuations is suggestive of condensation, although the amplitude is rather large, and it is difficult to imagine how a solid or liquid cloud sufficiently dense to cut off perhaps nine-tenths of the star's light can become dissipated in a few days.

Abortive Maxima and Minima.—Among the narrow or subsidiary maxima and minima there are many cases of failure to reach the obvious goal, due to a sudden reversal in the direction of the light-change. The *amount* of change is often just about sufficient to complete the phase, but the sign is reversed.

Periodicities.—The period of 530 days requires confirmation by future work. It suits the observations of recent years and also those of 1910–11, but the agreement is not conclusively indicative of permanency. The secondary period of 130 days, if increased to 132½ days, or one-quarter of the former, might be considered as the true period on the assumption that every fourth maximum is generally reversed, becoming a minimum. The same cause may be supposed to produce either a maximum or a minimum, some other factor deciding which it is to be. That something of this kind happens seems evident from the phenomenon of abortive maxima. In our Sun increased activity produces bright faculæ and dark spots, and it is often difficult to decide whether the Sun is brighter or fainter on that account. On the other hand, the interval between the primary maximum and the first secondary appears to be somewhat longer than that intervening between the two secondaries, which would suggest subsiding pulsations rather than a constant periodic term.

The smaller fluctuations sometimes show a marked periodicity, which is different in different seasons. In 1910 a period of 12 ± days was in evidence, in 1927 one of 17 to 18 days, and in 1928 a very constant period of 16 days was in operation.

The possibility that V Sagittæ may be a nova or closely allied to that class is suggested by its light-curve and its position on the border of the Milky Way. The following points of similarity may be mentioned: (1) A period of faint light during which small irregular variation takes place; (2) a rapid rise to a principal maximum; (3) a rather rapid decrease and subsequent recovery to one or two secondary maxima; (4) rapid oscillatory or semi-periodic fluctuations as the light declines.

Unfortunately there is no information concerning the spectrum of V Sagittæ. A request that the spectrum should be photographed at observatories in Canada and Scotland was in both cases unfavourably entertained.

Zaragoza, Spain:
1932 *February.*