follow one another at the rate of $n$ per second, the number of images simultaneously visible will be about $n/8$, since the luminous image produced by each separate flash persists for about an eighth of a second after the flash itself has ceased. The result of these effects is the appearance of a gorgeous revolving star.

If the tube is made to rotate very slowly, there occurs a different and very curious phenomenon, which, so far as I know, has never hitherto been noticed. The tube used in my experiments was thirteen inches long, and contained various devices in uranium glass; the induction-coil had a resistance of 1400 ohms, and was worked by a single large bichromate cell. When the rotation is performed at about the rate of one turn in three seconds, the luminous images of the tube are almost superposed, forming a bunch which is slightly spread out at the ends. But about 40° behind the bunch, and separated from it by an interval of darkness, comes a *ghost*. This ghost is in shape an exact reproduction of the tube: it is very clearly defined, and distinctly shows every detail of the uranium glass devices. But the colour is entirely changed, the violet tint of the luminous bulb and the bright green fluorescence of the uranium glass being replaced by a uniform steel gray. If the rotation is stopped, the ghost still moves slowly on, and, after the lapse of about half a second, disappears in coalescing with the luminous tube. The phenomenon may be diagrammatically represented by the letter X, the thick stroke being the bunch of luminous images, and the thin stroke the spectral attendant. The direction of the motion is supposed to be opposite to that of the hands of a watch when seen from above. If the rate of rotation is too slow, the ghost approaches the luminous bunch so closely as to be obscured by its superior brilliancy; while, if it is too fast, the image becomes blurred and ill-defined. The strength of the inducing current should be regulated by trial. With too strong a current the effect is the same as when the rotation is too slow; with too weak a current the image is rendered feeble. Generally speaking, the best results are obtained with a somewhat weak current.

The experiment has been witnessed by a dozen persons, all of whom, with the exception of one adult, and the doubtful exception of a child, at once saw the spectral image. It is almost ludicrously difficult for those who are able to see it, to understand how any one else could possibly fail to do so.

This curious effect clearly belongs to the class of spectral images or "ocular spectra," which result from looking at a bright object, persistence of vision in the ordinary sense of the term having nothing to do with it. I proved this to be the case in a very simple manner. The vacuum tube being at rest in a feebly-lighted room, I concentrated my gaze upon a certain small portion of it while the discharge was passing. The current was then interrupted, and the luminous image was almost instantly replaced by a corresponding image which appeared to be intensely black upon a less dark background. After a period which I estimated at from a quarter to half a second (probably more nearly the latter), the black image again became luminous, assuming the characteristic steel gray colour: this luminous impression lasted but for a small fraction of a second, and the series of phenomena terminated with its disappearance. I found the effect to be most clearly marked when a narrow portion of the tube was observed; the definition of the spectral image was then exceedingly sharp, even the striæ being represented with perfect distinctness. It was also found desirable to make the preliminary illumination as short as possible, a single flash being generally sufficient to produce the phenomena. This is more easily effected by a judicious manipulation of the contact-breaker than by means of a key, or of the commutator attached to the coil. I may add that it is by no means certain that a person who is altogether new to the subject will at first be able to see the appearances last described, even when he knows exactly what to expect. They belong to a class of phenomena which in ordinary life we habitually train ourselves to disregard, and our persistent neglect makes it difficult to perceive them when we desire to do so. With a little patient attention the difficulty will probably disappear.[1] It was probably owing to my constant habit of studying visual impressions that the appearance of the ghost attracted my notice in the first instance.

The series of phenomena seem to be due to an affection of the optic nerve which is of an oscillatory character. Abnormal darkness follows as a reaction after the luminosity, and again after abnormal darkness there is a rebound into a feebler luminosity. Following this idea I have endeavoured to detect the existence of a second ghost as the result of a further rebound, but hitherto without success.

It is an interesting fact, as proved by these experiments, that the formation of a spectral image does not occur until the expiration of a measurable interval of time after the exciting cause has ceased to operate.

SHELFORD BIDWELL

## *JUPITER*

DURING the present opposition of this planet, the details of the belts and spots have continued to furnish materials of great interest. Some very obvious modifications have occurred since the previous year, and several curious new features have become conspicuous. The great red spot has surprised us by its extended duration. As early as 1882 it lost such a considerable depth of tone that its obliteration seemed imminent, but it has lingered on, until now its existence appears likely to be indefinitely prolonged, though under visible conditions far less imposing than at an earlier stage. All that at present remains of this remarkable formation is a dusky elliptic ring, darkest at the following end, and only well seen under good definition. Whether this ellipse is identical with similar appearances delineated by Dawes in 1857, Huggins in 1858, and Gledhill in 1869, 1870, and 1871 is involved in doubt, because of the lack of intermediate observations. We have no definite information as to what became of the various objects alluded to. It is very possible that they severally represent an object of considerable permanency. The changes such as observed may have been induced by atmospheric interference. There is every indication that the dense vaporous envelopes of this planet are rapidly variable, especially in the zone included by the two equatorial belts, and that the chief features undergo singular fluctuations, some of which may possibly be of periodical character.

The particular objects drawn by Dawes and others suggest a close relationship to the red spot as it now appears. There is far from being an actual coincidence either in the positions or forms of the features here sought to be connected, but small differences must actually occur in results based on estimation. A sufficient likeness is established between them to show that further investigation may have an interesting outcome as affirming the theory of recurrent markings of identical form. There is, however, an inability to trace the history of these singular objects, owing to the meagre number of observations available. This is a circumstance much to be regretted. Markings of specially interesting character deserve something more than mere record. They should be persistently watched during several oppositions, if possible, for it is only by this continuity of records that the really important questions affecting them admit of settlement. The red

[1] The adult who failed to see the ghost is totally unable to perceive the subjective images in complementary colours, which generally result from gazing at brightly-coloured objects. Her general powers of vision are decidedly above the average, and she is in no degree colour-blind. The doubtful child is a daughter of this adult. A younger child can certainly see the phenomenon.

spot has now been followed since 1878, and though apparently on the verge of absolute extinction, it may yet linger on a considerable time in its present feeble aspect until possibly it is again enabled to obtrude upon general notice as an object of great prominence. It may not return under precisely the same outline as formerly, or exhibit the same depth of tone or degree of colouring, for, doubtless, some new development is to be anticipated on this disturbed region of the planet. In case of any distinct reappearance it will be important to determine that it occurred from the exact position so long tenanted by the old spot. The motion of this feature has been so thoroughly followed during the last seven years, that it will be feasible to compute its predicted place with great nicety in future months. In the mean time, and until the spot finally withdraws from reach, the same necessity exists as before of recording the times of its passages across the central meridian of Jupiter. And even assuming the total extinction of the spot, and that its place immediately south of the great equatorial south belt should resume the unbroken zonal arrangement existing in other longitudes, it will be necessary to re-examine this region occasionally for traces of any subsequent outbreak from the same focus.

During the last three years this object has given a rotation period of 9h. 55m. 39·1s., which has been steadily maintained throughout each opposition, subject to some minor disturbances partly due to errors of observation. The first few years of its existence it showed an increasing retardation of motion, which lengthened the period from 9h. 55m. 34s. to that already quoted, but, contemporarily with the decay of the spot in 1882, the velocity ceased to slacken, and the results accumulated during the past few oppositions prove it to have been equable in a marked degree.

With reference to the equatorial white spot some striking phenomena have been presented during the past winter. Between October 4, 1884, and January 13, 1885, its motion appears to have increased in an alarming ratio. The spot continued to rush on far in advance of its computed places, and all the while exhibited a more brilliant appearance than at any preceding epoch since the autumn of 1880, when it first came under systematic observation. The form and appearance of the spot have been so special as to prevent any confusion in mistaking it for other white spots in nearly the same latitude. Between October 4 and January 13, 1885, the rotation period was 9h. 49m. 51·95s., but the great increase in velocity evidently occurred towards the end of November. Between November 21, 1884, and January 13, 1885, the period was only 9h. 49m. 38·45s., or 34 seconds less than the mean period of 9h. 50m. 12·25s. shown by the same spot during the two preceding years.

When the first intimation of this great increase of speed forced itself upon my notice, I at once resolved to obtain as many observations as possible, in order to assure myself more certainly of the fact. Much cloudy, wet weather ensued, but I observed the spot on fourteen occasions between November 27 and January 13. A lengthened period of overcast skies then supervened, and I saw nothing more of Jupiter until January 27, when the place of the spot, computed on the basis of my prior observations, appeared absolutely vacant. About 15° E. there was, however, a remarkably brilliant spot, the exact counterpart of the one previously observed. Then arose the question of identity. Could the velocity have become so much retarded in the fortnight's interval from January 13 to 27 as to have occasioned so considerable a displacement in longitude? From my observation on January 13 and several preceding nights the spot had shown an increasing disposition to slacken, and, from records obtained in previous years, the motion was known to fluctuate in the most unaccountable manner. In the seventeen days from September 30 to October 17, 1881, I noted the spot underwent a sudden translation of 11°·6 in the direction of east longitude. The fact was independently confirmed by Prof. Hough at Chicago and Mr. Stanley Williams at Brighton. The most obvious departures from the mean rate of motion have been detected in other instances, and I am therefore led to conclude that the objects observed on January 13 and 27, 1885, were, notwithstanding their discordance of position, really identical objects. The consistent brilliancy of the marking alluded to, for several months before the cloudy period set in, is entirely opposed to the idea that it could have suddenly disappeared. And the real displacement is not so large as the limiting observations suggest. Deriving a mean from my results near January 13 and 27, I obtain the following figures:—

| 1885 | Spot precedes 1st meridian m. | Long. (878° 34) |
|---|---|---|
| Jan. 7 to 13, mean of 7 obs. ... | 64·0 | 321·0 |
| Jan. 27 to Feb. 6, mean of 6 obs. ... | 46·4 | 331·4 |

Adopting this mean, we practically eliminate errors in single observations, and in the present case it is fortunate I obtained so many transits just before and after the period of cloud. The real displacement is seen from this comparison to be only 10°·7, which is quite within the limits of previous experience. And if the fact of identity had not been rendered a very tenable hypothesis by past observation, I should have regarded the brilliant appearance of the spot and its comparative isolation as conclusive. Moreover, during the period that this object continued moving so rapidly, I often carefully examined the place where, had no change occurred, it must have been presented, but no object having a remote likeness to the old spot could be detected. Having observed this feature on the central meridian on more than 200 nights, I am familiar with its usual aspect, and could not possibly have overlooked it, on the many occasions when I looked for it in vain, had the spot retained the approximate place assigned to it from the observations of preceding years.

Let us now analyse the degree and period of the remarkable velocity alluded to. Arranging my observations into short intervals, the following are the rotation-periods severally derived from them:—

| 1884 | Interval in Minutes | Spot gained on 1st. Mer. m. | Spot gained in Long. ° | Number of Rotations. | Period. h. m. s. |
|---|---|---|---|---|---|
| Oct. 4 to Nov. 7 ... | 48,985 | 6·5 | 4·0 | 83 | 9 50 7·55 |
| Nov. 7 to Nov. 21 ... | 20,064 | 3·5 | 2·1 | 34 | 9 50 6·07 |
| Nov. 21 to Nov. 27 ... | 8838 | 15·1 | 9 2 | 15 | 9 49 11·85 |
| Nov. 27 to Dec. 9 ... | 17,098 | 17·4 | 10·6 | 29 | 9 49 36·25 |
| Dec. 9 to Dec. 18 ... | 12,970 | 13·8 | 8·5 | 22 | 9 49 34·61 |
| Dec. 18 to Dec. 24 ... | 8843 | 9·3 | 5·6 | 15 | 9 49 35·05 |
| Dec. 24 to Dec. 31 ... | 10,023 | 9·5 | 5·8 | 17 | 9 49 38·72 |
| Dec. 31 to Jan. 8 ... | 11,208 | 4·6 | 2 8 | 19 | 9 49 57·73 |
| 1885 | | | | | |
| Jan. 8 to Jan. 13 ... | 7078 | 3·5 | 2·2 | 12 | 9 49 54·75 |
| | | Lost | Lost | | |
| Jan. 13 to Jan. 27 ... | 20,089 | 24·9 | 15·2 | 34 | 9 50 56·19 |
| Jan. 27 to April 19 ... | 118,042 | 9·7 | 5·7 | 200 | 9 50 15·16 |

The period of really great acceleration extended over forty days (November 21 to December 31), and it is remarkable that in the mean time the spot had completed exactly one revolution of Jupiter relatively to the red spot. In fact, the sudden increase and diminution of velocity occurred with the white spot following the red about 2h. 44m., so that there was a difference of 100° in the longitude. The maximum speed appears to have been shown between November 21 and 27, when the rotation-period was one minute less than the mean of the two preceding years. But my observation of November 21 was considered rather late, and the interval being a very short one of only six days, would originate a rather large error. But the four short intervals, from November 27 to December 31, exhibit a singular consistency in the resulting periods, the mean being 9h. 49m. 36·16s., which proves the real increase of speed to have been 36·09s. in

each rotation; and, if we amalgamate the two preceding periods, from November 7 to November 27, we get a mean of 9h. 49m. 38·96s., which is closely accordant.

In the forty days, November 21 to December 31, the spot gained 65·1m. = 39·7° upon Mr. Marth's central meridian (*Monthly Notices*, vol. xliv. No. 9), based on the period of 9h. 50m. 12·25s. The spot must therefore have moved 28,700 miles to the westward at the rate of 717 miles per terrestrial day, and 294 miles per Jovian day. Then after January 13 it suddenly retrograded if we accept the

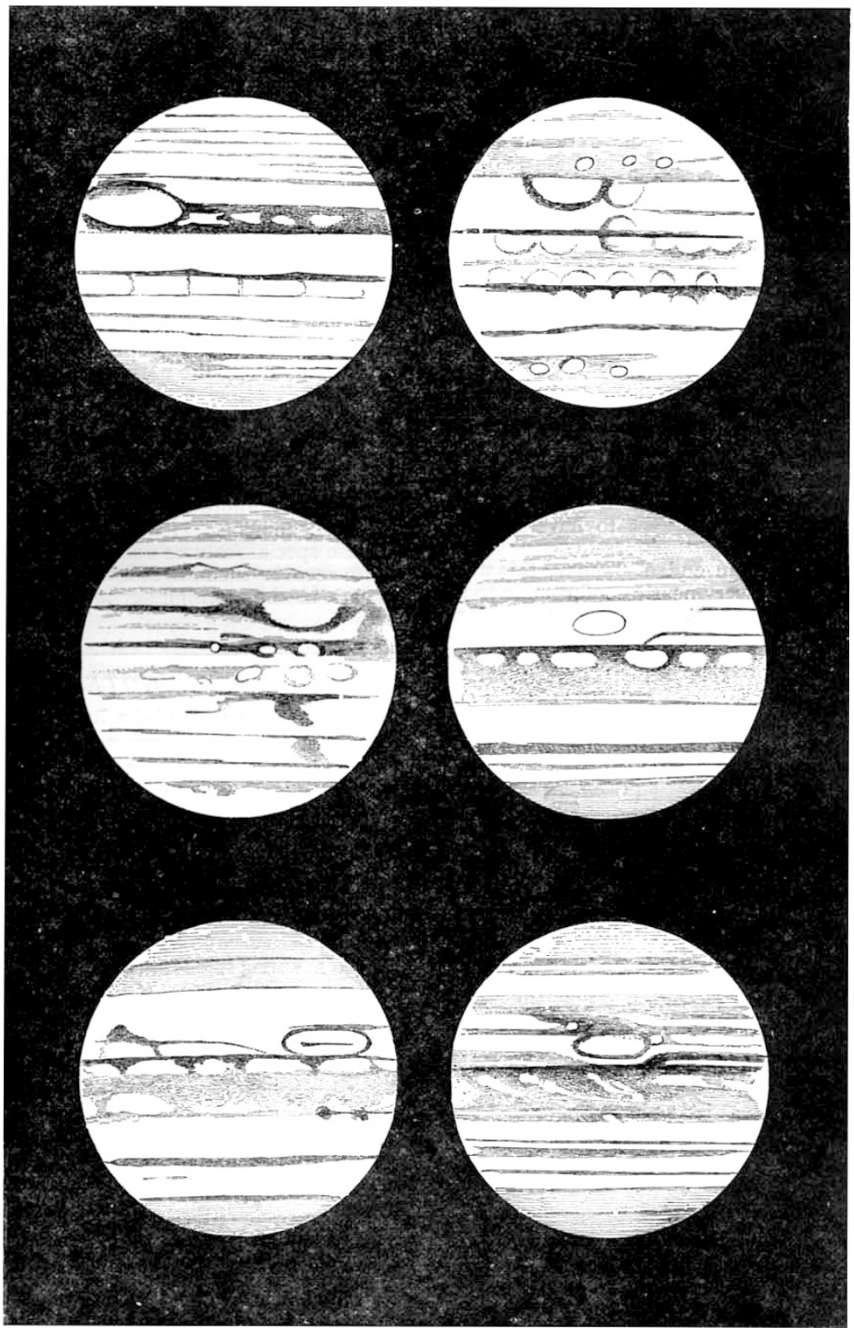

FIG. 1.—Probably recurrent markings on Jupiter. I. 1857, November 27 (Dawes). II. 1859, December 29, 10h. 50m. (Huggins). III. 1858, March 2, 9h. (Huggins). IV. 1870, January 23, 8h. 20m. (Gledhill). V. 1872, February 2, 10h. 30m. (Gledhill). VI. 1885, February 25, 12h. 50m. (Denning).

identity of the spots observed on January 13 and 27; so that in the fourteen days it lost nearly 11,000 miles, which is greater than the rate of its previous excess. But since the end of January the motion has steadied down to its normal degree, and thus we find the period closely agreeing with that adopted by Mr. Marth.

The motion of this brilliant white spot prior to January 13 is involved in no doubt whatever, so that the question of its identity with the one observed on January 27 is an entirely separate one, and cannot affect the remarkable phenomena, which the increased velocity exhibited, except as to the retrogressive motion

which subsequently occurred. The question of identity may be definitely settled if any observations of the spot during the interval from January 13 to 27 are forthcoming from foreign observatories. In this part of England the sky was densely overcast at night during the whole of that time. If Prof. Hough at Chicago or some other systematic student of the planet can supply the missing links for the period referred to, it will be most important to ascertain how far they corroborate the assumed identity of the markings in question.

These white spots are liable to great variations in apparent brilliancy at short intervals; so that, unless an observer is very careful to discriminate between objects approximately situated, he is certain to introduce complications into his results. But, in regard to the conspicuous white spot which has been the subject of so much comment during the last few years, I have never found much difficulty in following it, because of its special character. Occasionally smaller spots slightly nearer the equator are seen on each side of it, but the leading spot of the trio is so bright and almost invariably shows a bright trail running from its north-east side towards the equator, that it may be readily identified. During the observations between October 4, 1884, and January 13, 1885, of the present opposition the extreme brilliancy of the spot was very noticeable, and the observations were pursued without any liability to error. I fear, however, that, morning observations being rendered necessary by the position of the planet in November and December will have enabled the singular vagaries of the white spot to have generally eluded notice.

It is curious that since the end of January this white spot has maintained a rate very nearly conformable to the first meridian of 9h. 50m. 12·25s., computed by Mr. Marth from the observations between 1882 and 1884; but there occurred a sudden deviation between March 14 and 18, amounting to some 8°. These singular displacements cannot be induced by changes in the form of the object, and they are far too considerable to be referred to errors of observation. Between February 9 and 16, 1882, Prof. Hough noticed an acceleration of $6\frac{3}{4}°$.

The verification and true cause of these variations can only be efficiently sought out by frequent and very accurate observation. Our own climate is very ill-adapted to an investigation of this kind where the most essential point consists in closely consecutive results. What we need is an almost unbroken series. It is to be earnestly hoped that some attention will be devoted to this important work at the Lick Observatory, where "the elevation is 4200 feet above the sea, and *for six or seven months of the year every night is clear!* The position thus commands natural advantages (in this work of far more importance than instrumental advantages) which would enable it to obtain some most valuable evidence bearing on the question of the remarkable variations affecting the white spots on Jupiter. Near the time of opposition they might be observed every night, and it is this consecutive, close treatment that is required before the phenomena will really admit of satisfactory discussion.

The question arises whether the whole southern belt partakes in these erratic and apparently frequent variations of speed, or whether they are confined to proper motions affecting the individual spots at different times. If several markings were made the subject of contemporary study it might soon be determined whether they exhibited uniform displacements, and, if so, it would have to be admitted that the whole equatorial atmospheric current is subject to the singular onrushes and alternating lulls which our recent observations have demonstrated.

Of the new features presented during the last few months the most striking are:—

(1) The appearance of large, bright spots indenting the north edge of the great northern equatorial belt. A peculiarity of these objects is that lines of light flowing from their west sides divide the dark belt and finally emerge near the equator, where they became indefinite. These spots show a rotation period only a few seconds less than the red spot.

(2) The outbreak of dark, reddish spots, elongated in longitude, upon the narrow belt which became visible in 1882, immediately outlying the great belt. The depression north of the red spot was formed by the ends of this belt suddenly dipping northwards before reaching the spot where they became blended with the old belt. The spots now visible here are very plain and will probably increase until finally their material is dispersed around the planet and the belt becomes much darker than before. The individual spots should be carefully watched to ascertain whether this is their ultimate development. The rotation period they have hitherto shown is precisely the same as that of the red spot. One of the most conspicuous of these new spots is about 10,000 miles long; it follows the red spot 1h. 48m., so that its longitude is 66° east.

(3) The fading away of the west shoulder of the depression north of the red spot. This is now very obvious, and extends along the narrow belt far to the west of the red spot. It remains to be seen whether this decadence will continue now that various other regions of the belt exhibit a confluent eruption of dark spots.

The several features referred to are of extreme interest, as suggestive of peculiar forms of atmospheric disturbance and as affording fresh materials for students of Jovian phenomena. It will be necessary to follow each of these special features during the two ensuing months, and to recover them, if still visible, when the planet reappears in the morning sky towards the end of October next.

W. F. DENNING

## NOTES

AT the *conversazione* of the Royal Society on Wednesday evening last week, the Fellows, we are sure, were all glad to see their President back again, in renewed health, after his long absence. Prof. Huxley had to welcome a very large number of guests, and some of the objects exhibited were of much interest. Prof. H. N. Moseley exhibited a collection of Pueblo Indian pottery, charms, prayer-sticks, &c., from Zûni, New Mexico; Gen. Strachey, an instrument for drawing curves of sines adapted to graphical representation of the harmonic components of periodical phenomena; Mr. W. T. Thiselton Dyer lent some beautiful flowering specimens of Himalayan rhododendrons (the small, rosy-pink *R. glaucum* and the large, velvety-white *R. nuttalli*), a fruiting branch of coffee, and the various vessels and implements used in the collection and preparation of Para india-rubber; iridio-platinum weights, with a density of 21·5660, absolutely adjusted, and a piece of platinum wire ·00075 of an inch, prepared by drawing, &c., were exhibited by Mr. G. Matthey; the Linnean Society lent a remarkable set of drawings from the collection of Lady Impey, at Calcutta, painted by a native of Patna towards the end of the last century, and still in perfect preservation; the Anthropological Institute contributed ethnographic photographs of various races; and there were many highly interesting philosophical instruments shown.

THE Council of the British Association have nominated Prof. J. Struthers, M.D., as a Vice-President of the Association for the Aberdeen meeting, and have added the name of Prof. J. Stirling, M.D., D.Sc. (Aberdeen) to the list of those nominated for the Vice-Presidency of Section D.

AT the invitation of Prof. Flower, a meeting of the Essex Field Club will be held on Saturday afternoon, May 16, at 3.30, in the Lecture Room at the Zoological Gardens, when the Professor will speak of the principal objects of interest in the