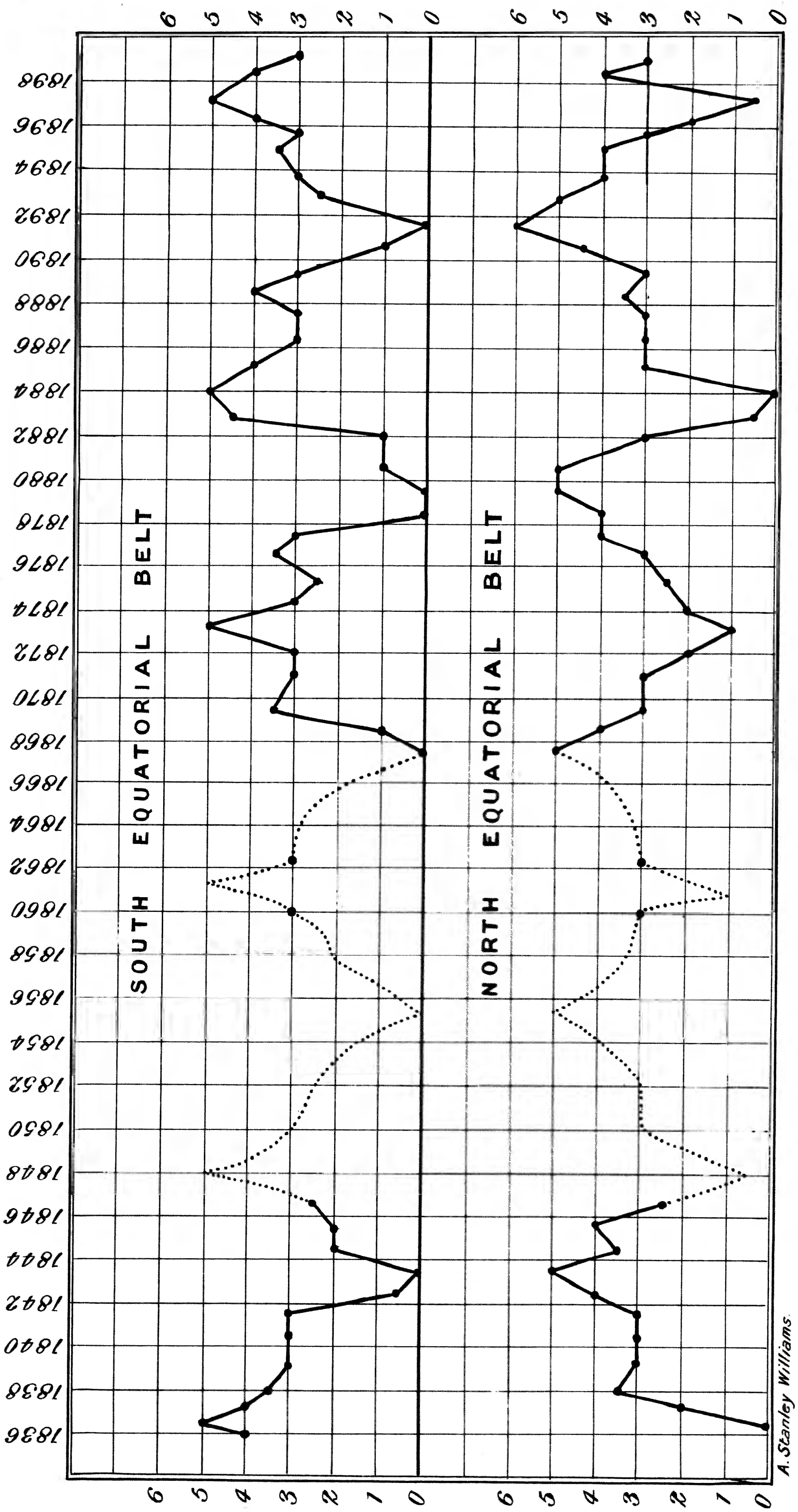
Abbreviations—continued.

Gf. = H. F. Griffiths.	Mg. = E. Mengering.
Gl. = J. Gledhill.	Mi. = A. F. Miller.
Gn. = W. Godden.	My. = K. Mysz.
Go. = W. Goodacre.	N. = L. Niesten.
Gr. = N. E. Green.	Ni. = A. A. Nijland.
Gro. = C. Grover.	O. = J. M. Offord.
Gt. = — von Gothard.	P. = T. E. R. Phillips.
Gy. = T. P. Gray.	Pe. = T. Perkins.
H. = W. J. Hall.	Pr. = C. W. Pritchett.
He. = A. Henderson.	Q. = F. Quénisset.
Hi. = G. D. Hirst.	R. = J. Rheden.
Hl. = A. S. Herschel.	Rd. = — Ringwood.
Ho. = E. S. Holden.	Ri. = A. Riccò.
Hs. = E. Holmes.	Rl. = H. C. Russell.
J. = W. E. Jackson.	Ry. = R. J. Ryle.
K. = J. E. Keeler.	S. = J. H. Schroeter.
Ke. = P. H. Kempthorne.	Sa. = E. Salter.
Ki. = R. Killip.	Sc. = H. Schwabe.
Kl. = H. J. Klein.	Sh. = C. F. Smith.
Kn. = E. B. Knobel.	Sm. = D. Smart.
Kt. = G. Knott.	T. = F. Terby.
L. = O. Lohse.	Td. = C. Todd.
La. = W. Lassell.	To. = H. J. Townsend.
Le. = R. G. Leigh.	W. = A. S. Williams.
M. = H. MacEwen.	Wa. = W. R. Waugh.
Ma. = A. M. Mayer.	We. = T. W. Webb.
Me. = J. Meller.	Wh. = Mary M. Whitney.

The results contained in the preceding table have been laid down upon the accompanying diagram (see Plate 8), in which the horizontal lines represent degrees of redness according to the adopted scale. This diagram shows clearly the very striking variations in the redness of the two belts. The maxima and minima, it will be observed, are particularly well marked, and it is remarkable how the maximum redness of one belt always synchronises almost exactly with the minimum redness of the other. The range of variation is in reality even greater than that shown by the diagram, since at the time of minimum most observers describe the belts as appearing distinctly bluish, whereas both in the diagram and the table no account has been taken of this bluish tinge. The degree of redness at the times of maximum is also probably underrated, since there are usually some observers who notice the red colour at such times, but who are relatively deficient in colour perception. In some maxima, at least, the red colour has certainly been little inferior in intensity to that of the red spot when at its reddest. The belts at such times bear considerable resemblance to a bar of red-hot iron.

Where the observers are so numerous, there is naturally some diversity at times in the exact tints or degree of redness. This is more especially the case in the intermediate stages, when the red colour is not very deep. But at the times of maxima and minima the colours are so pronounced and strikingly contrasted that the observers are then practically all in agreement. There are a



COLOUR CHANGES OF JUPITER'S BELTS.

few instances of observers being apparently deficient in colour perception, and one or two cases which are suggestive of colour blindness.

As already stated, the time of maximum redness of one belt corresponds to the minimum of the other. The diagram shows that this correspondence is so exact that for the purpose of computing the period of variation it will be sufficient for all practical purposes to consider the variations of one belt only. There are eight observed maxima and minima, the times of which are given below.

Observed Times of Maxima and Minima.

N. Equat. Belt.		S. Equat. Belt.
Minimum	1836·36	Maximum
Maximum	1843·50	Minimum
Maximum	1867·70	Minimum
Minimum	1873·22	Maximum
Maximum	1879·72	Minimum
Minimum	1884·03	Maximum
Maximum	1891·72	Minimum
Minimum	1897·25	Maximum

These are the times corresponding to the extreme variations as actually observed, as it is doubtful whether any improvement in these times would result from consideration of the form of the colour curve. In a few cases, where there is a slight difference between the times for the two belts, the mean of the two has been taken.

From the four observed minima of the north equatorial belt the mean period of variation, derived by the method of least squares, is 12·14 years; and from the four maxima the mean period is 12·03 years, with the following residuals C—O in each case.

Minima. Years.	Maxima. Years.
−0·07	−0·09
−0·51	−0·05
+0·82	−0·04
−0·26	−0·01

The mean of these two values is 12·08 years. According to Professor Young's *General Astronomy* the length of a sidereal revolution of *Jupiter* is 11·86 years. The above mean period of variation agrees so closely with this that it is probable, or at least possible, that in the long run the two exactly correspond. If future observation should show that this is actually the case, it would seem that the variation in colour is a seasonal phenomenon,*

* At present the colourless, or bluish, phase of a belt occurs a short time after the autumnal equinox of the hemisphere in which such belt is situated.

and that the solar influence upon the changes which we observe upon the surface of *Jupiter* is greater than has been generally supposed, notwithstanding the distance of the planet from the Sun and the small inclination of the plane of its equator to the plane of its orbit. It seems certain, however, that the variation in colour can have no relation to the Sun-spot period, as was at one time thought might be the case with regard to the changes of colour of the bright equatorial zone. It should be mentioned here that the colour changes observed by Mr. John Browning and others in 1869–72 are quite distinct from those investigated in this paper. The former related to the bright central zone comprised within the two dark equatorial belts, whilst the latter refer to the changes in colour of the two last mentioned dark belts. The interesting subject of the relationship of the colour changes of the other dark belts and bright zones to those now under consideration has not yet been fully worked out. It may be mentioned, however, that the variations in the intensity of the colour of the red spot may possibly have some connection with the changes of the two equatorial belts. The red spot was near a maximum of redness in 1879–80, and there were minor maxima in 1886 and 1892. In 1897 there was also perhaps a feeble temporary increase in redness. All these times nearly correspond to a maximum redness of one or other of the two equatorial belts. In 1873, also, the reddish colour of the spot attracted particular notice at Lord Rosse's Observatory. The peculiar "tawny" hue, which sometimes characterises the bright equatorial zone,* seems to occur chiefly at the intermediate phases, when both the equatorial belts are moderately red.

The results of the present investigation may be shortly summarised as under :—

(1). The S. equatorial belt varies in redness periodically, the period of a complete change being 12·08 years.

(2). The N. equatorial belt undergoes a similar periodical variation in colour, and in the same period.

(3). The variations are so related that when the S. equatorial belt is at a maximum of redness the N. equatorial belt is at a minimum, and *vice versa*.

(4). The formulæ for finding the times of maxima and minima are :—

$$\left.\begin{array}{r}\text{Min. redness of S. Equat. Belt}\\ \text{Max. redness of N. Equat. Belt}\end{array}\right\} = \overset{\text{Years}}{1867{\cdot}65} + 12{\cdot}08E.$$

$$\left.\begin{array}{r}\text{Max. redness of S. Equat. Belt}\\ \text{Min. redness of N. Equat. Belt}\end{array}\right\} = \overset{\text{Years.}}{1872{\cdot}71} + 12{\cdot}08E.$$

(5). The interval from maximum redness of the N. equatorial belt to a minimum is a little shorter than the interval from

* Visible at the present time, and also last year.

minimum to maximum. The opposite is the case with regard to the other belt.

Computed times of maxima and minima.

N. Equat. Belt.		S. Equat. Belt.
Maximum	1903·88	Minimum
Minimum	1908·95	Maximum
Maximum	1915·97	Minimum

Addendum.

The reality of these periodical changes of colour will be apparent to anyone who will take the trouble to consult some of the authorities quoted in the last column of the table of the mean redness of the belts. The *coloured* drawings referred to in the following list will, however, show this at a glance. In 1879 the drawings by Professor T. Bredichin published in the *Bulletin de la Société Impériale des Naturalistes de Moscou*, Année 1879, Part 2, p. 370, and in the *Annales de l'Observatoire de Moscou*, vol. vi., p. 95, show the N. equatorial belt ruddy and the S. equatorial belt bluish (or greenish). The drawings by Dr. F. Terby, published in the *Bulletin de l'Académie Royale de Belgique*, 2^{me} série, tome xlix., No. 3, show the N. equatorial belt of a very deep red colour, whilst the S. equatorial belt is colourless. A similar difference in tint is indicated by the photographs of *Jupiter* by Dr. Common, published in the *Observatory* for 1880 February. In these the ruddy N. equatorial belt is very dense and conspicuous, whilst the bluish S. equatorial belt is almost invisible, showing that photographically its light differed materially in intensity from that of the other belt. In 1884 the drawings by Dr. Terby, published in the *Mémoires Cour. et Mém. des Savants Étrangers, publiés par l'Académie Royale de Belgique*, tome xlix., show the S. equatorial belt very red, whilst the N. equatorial belt is colourless. The drawings made by the same observer in 1891 and published in the *Bulletin de l'Académie Royale de Belgique*, 3^{e} série, tome xxii., p. 378, show the N. equatorial belt red, whilst the S. equatorial belt is now again devoid of red colour. Last, but by no means least, the coloured drawings published in Gruithuisen's *Astronomisches Jahrbuch* for the year 1845 (vol. vi.), show a complete half cycle of changes, from a minimum of the N. equatorial belt and maximum of the S. equatorial belt, to a maximum of the N. equatorial belt and a minimum of the S. equatorial belt. There are also numerous other coloured drawings published showing both belts red coloured, and relating to the intermediate stages between the epochs of maxima and minima.

At the present time the belts are in one of these intermediate stages. Both belts are of a moderately deep red colour, and are nearly equally red, though the S. equatorial belt usually appears distinctly a little redder than the N. equatorial belt. The next epoch of maximum and minimum will occur in 1903, and I venture to predict that in that year the N. equatorial belt will be intensely red, whilst the S. equatorial belt will then appear colourless, or even of a bluish tint.

Photographs of the Radiant of the Leonid Meteors, and Attempts to Photograph the Meteor Stream. By Isaac Roberts, D.Sc., F.R.S.

The part of the sky around the radiant point of the Leonid meteors was closely watched during the night of the 13th and morning of the 14th November last, and during an interval of absence of clouds four photographs were obtained, two with the 20-inch reflector, and two with the 5-inch lens camera.

Clouds overcast the sky until two o'clock on the morning of the 14th, and then clearness set in, which continued till day-break. During that interval the four photographs were taken—two with simultaneous exposures of two hours, and two with ninety minutes'.

Only two Leonid meteors fell during the three and a half hours' interval, and they did not become luminous within the range of the camera photo-field of $7\frac{1}{2}$ degrees radius from the radiant, and consequently they were not photographed, but their directions with reference to certain stars were determined by sight. No other interval was suitable for photographic work during the passing of the stream.

On examination of the plates two nebulæ were discovered in close proximity to the radiant; and the following are their co-ordinates as deduced from the star *D.M.* No. 2164, zone 22° north, R.A. $9^h\ 54^m\ 44^s{\cdot}4$, Dec. north 22° $39'{\cdot}7$, Epoch 1855. The nebulæ are in the positions R.A. $9^h\ 55^m\ 54^s{\cdot}8$, Dec. north 22° $59'{\cdot}4$, and R.A. $9^h\ 55^m\ 54^s{\cdot}8$, Dec. north 22° $58'{\cdot}7$.

The northernmost nebula is a well-defined star of about 13th magnitude, surrounded by a halo of faint nebulosity; and the other nebula, which is 42 seconds of arc south of it, resembles a star of about 16th magnitude, elongated nearly in *preceding* to *following* direction. These nebulæ are not referred to in the catalogues. I thought it possible that they were connected with the meteor stream, but another photograph taken on December 9 (25 days later) showed no change in their position, and therefore they could not be connected with the meteors.

Attempts to Photograph the Meteor Stream.

The Ephemeris of the denser part of the meteor stream which was prepared, under the directions of Dr. G. Johnstone Stoney and Dr. Downing, by Mr. Wright and other computers at the