80 mm. For this to produce an eccentricity of 5 mm, therefore means an added weight of 1/160 of the weight of telescope. The extreme size of plate is limited by the dimensions of the holder and, in any case, no possible addition can amount to more than a minute fraction of this quantity. It is also clear that no practicable variation in the thickness of the plate can produce any appreciable eccentricity, so that no special precautions are required as to the type of glass used.

As all the errors of Class A can thus be rendered negligible, while those of Class B are always inappreciable, there remains only the change of scale due to the action of varying temperature to be considered and allowed for in the reductions. No complete discussion of this is possible until a number of plates have been measured, and until it has been ascertained within what limits temperature can be maintained constant during exposure.

It would obviously lead to great simplification of work in the reductions if the change of focal length could be computed as due directly to the expansion of the telescope under the ordinary law, and consequently if the correction to the measured position of a star trail could be computed as a linear function of the difference of expansion of brass and glass. This would assume, what is probably true within practical limits of error, that the temperature change introduces no distortion into the field. It would be necessary to ensure that the plate is always held during exposure in the same way, i.e. either with the centre fixed or with one end fixed so that it will always expand and contract in the same direction. This condition presents no difficulty.

The results obtained with the instrument will form the subject of a further communication.

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_The Great Sun-spot Group and the Magnetic Storm, 1920_  
_March 22–23._ By the Rev. A. L. Cortie, S.J. (Plate 7.)

1. Life-History of the Sun-spot Group.—The life-history of the great sun-spot group, which crossed the sun's visible disc 1920 March 16–29, presents several points of interest both in itself and in its connection with the exceptionally violent magnetic storm of March 22–23. The first appearance of the group was as a very small spot near the sun's following limb, 1919 December 27. It was accompanied by a few flecks of bright faculae. Its position was latitude -5°5, and longitude 112°. As it crossed the disc, December 27–January 5, it developed into an important bipolar group, in mean latitude -6°, and extended from longitude 96° to longitude 113°. The appearance of the group is shown on the accompanying chart. The stream of spots was lying parallel to the sun's equator. Its greatest, disc-area during this appearance was 900, in units 1/5000 of the visible hemisphere.

At its next appearance, 1920 January 21–February 3, the
group was in the form of a fine long stream of spots, extending from longitude 108° to longitude 133°, and it had just doubled its apparent disc-area. The stream, which at its former appearance had been parallel to the solar equator, was now inclined to it at an angle of about 45°.

At the third return, February 17–26, the group had almost died away, and there remained but one small spot followed by scattered dots. The apparent disc-area had dwindled from 18° to 0°6 unit. This small group was surrounded by very extensive faculae, which covered a very large area of the sun’s surface, when the group was dying out near the sun’s preceding or W limb, on February 26. The mean position of the principal spot was latitude $-6^\circ0$, longitude $131^\circ$. It occupied, therefore, a position which was within one degree of the centre of the very great group which appeared at the next rotation.

This revival of the group, March 16–29, was on an immense scale. The group was the greatest seen since the group of 1917 August, and very nearly equaled it in total disc-area. It covered 34 units. Its mean latitude was $-6^\circ0$, and it extended in longitude from $114^\circ$ to $150^\circ$. The extreme length of the group was therefore $36^\circ$, and the breadth, if a small companion group be included as part of the general disturbance, was $10^\circ$ in latitude. The centre of the leader spot was in longitude $143^\circ$, and that of the following spot in longitude $114^\circ$. The intermediate positions were occupied by many smaller nuclei surrounded by extensive penumbra. It now lay parallel to the sun’s equator.

The comparison of the positions of the group in the first and second appearance shows a latitudinal drift in the following portion of the group, and suggests a rotation of this portion of the group in a clockwise direction. If this is indicative of a magnetic field, it would appear that it ought to be such as would show southern magnetic polarity. It is not at all unlikely that the strong magnetic fields of sun-spots, and the general magnetic field of the sun, are due to the surface motions as indicated by the flow of the spots and of the faculae.

2. The Terrestrial Magnetic Phenomena.—The months of 1919 December, 1920 January and February, were magnetically quiet months. In 1919 December only two days, the 14th and the 15th, received the international magnetic character 2, which signifies highly disturbed; in 1920 January there was no day deserving that mark; and in February but three days, the 16th, 17th, and 24th.

The successive appearances of the spot-group were accompanied by a moderate movement of the magnets on 1920 January 1 (character 1), and a similar moderate disturbance on January 28. When the original disturbance was dying out there was a considerable magnetic storm (character 2) on February 24. The extreme range in declination, or horizontal direction, was 26°, and in horizontal force 115 $\gamma$ ($1\gamma=10^{-8}$ C.G.S. unit).

These disturbances occurred at 27-day intervals. The revival
of the sun-spot group in March was accompanied, March 22–23, again after a 27-day interval, by a magnetic storm of extreme violence. A full description of this storm, as recorded by the Stonyhurst magnetographs, was published in *Nature* for 1920 April 1.

The extreme ranges in the three magnetic elements were very great, in H.F. over $700 \gamma$, as the spot of light went beyond the limits of registration; in V.F. greater than $900 \gamma$, for a similar reason; and in D. the very great range of $2^\circ 40', which is most unusual. Violent and rapid oscillations were characteristic of this storm, exceeding $300 \gamma$ in H.F., and of $90', 120'$, and $150'$ in D. Some idea of the great violence of the storm may be obtained by a comparison of these readings with the mean values of H.F. and D. for all days during January and February, which were $40' \gamma$ and $9'5$. These violent oscillations were superposed on a general movement of the spots of light in sinuous S-like curves, the values of force, accompanied by a westerly swing of the direction needle, increasing during the daylight hours, and decreasing, accompanied by a reversed movement of the direction needle, during the night hours. The storm commenced by a sudden movement of the needles, at $9^h 6^m$ approximately, on March 22, and in its more violent phases lasted for about twenty-four hours.

In former papers* evidence has been adduced to show that the greater frequency of magnetic disturbances near the equinoxes is due, not to the position of the sun with regard to the earth's equator, but to the fact that, near the equinoxes, the heliographic latitude of the earth is in the sun's semi-equatorial plane—that is, in the region of the sun-spots.

Again, such heliographic positions of the earth are particularly favourable for the occurrence of magnetic storms, in the period after the maximum of a sun-spot cycle, when the mean latitude of the sun-spots is falling towards the solar equator. From a former study of "The Efficiency of Sun-spots in Relation to Terrestrial Magnetic Disturbances,"† it was shown that the "efficiency-ratio" of the numbers expressing the mean yearly number of magnetic disturbances, and the mean daily disc-area of spots, was three times as great in years when the latitudes of the spots were decreasing, after the maximum had been attained, as at the maximum of a spot-cycle.

In the present instance both these conditions obtained. The spot-group appeared near the equinox: it was in low S. latitude. Moreover, other conditions for a great magnetic storm were favourable. The earth's heliographic latitude at the time was only one degree below that of the mean latitude of the spot-group, and the spot-group of enormous size showed great internal disturbance.

But, it may be objected, the conditions of great size and internal disturbance, joined with low latitude and proximity to the heliographic position of the earth, existed at the second

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* *Monthly Notices, R.A.S., 73, 68, 1912; 76, 17, 1915.*

† *Ibid., 76, 16, 1915.*
appearance of the sun-spot, when the accompanying magnetic
disturbance was but of moderate intensity (character 1). At the
next, the February appearance, when the spot had dwindled to
very small dimensions, though it is true the faculae were most
extensive and the earth's heliographic relation to the spot was
somewhat better, the magnetic efficiency was increased, the
accompanying magnetic disturbance being quite considerable
(character 2).

One conclusion, however, derived from a comparative study of
sun-spots and terrestrial magnetic phenomena in a review of the
greater magnetic storms in the period 1898–1911,* was thus stated:
"If we suppose that the ionisation of the upper atmosphere is a
condition for a magnetic storm, then it may well be that the pro-
cess is a gradual one as spots begin to grow in number and magni-
tude, until the advent of a specially active or large spot suffices to
bring about a great magnetic storm." The process may be likened,
by analogy, to that of charging up a condenser to a potential
difference of discharge. In the present instance there had been a
very marked drop in the values of the monthly ranges of the
magnetic elements since 1919 October. We may, therefore,
reasonably suppose that the ionisation of the upper atmosphere of
the earth, due to the successive presentments of the disturbed
sun-spot region, was not sufficiently great in December and January
to precipitate a very great storm, though there were moderate dis-
turbances. The conditions were better in February, when a highly
disturbed condition of the magnets corresponded with the third
appearance of the disturbed area on the sun. The climax was
reached in March, when all the conditions, of a great disturbed
sun-spot region, of a favourable heliographic position of the earth,
and of a highly charged condition of the upper atmosphere, were
realised.

Any one of these three conditions might of itself be sufficiently
pronounced to precipitate a magnetic disturbance. This would
account for the disparity not unfrequently observed between the
area of a spot and the magnitude of the accompanying magnetic
storm, as also the occurrence of magnetic disturbances when no
spot was observed. The region on the sun might still be mag-
netically active, the activity being denoted by the faculae and the
flocculi. Or again the clouds of ions ejected in former rotations
might remain undissipated, in which case a relatively small solar
disturbance would be sufficient to precipitate a storm.

Sometimes a large spot is observed without the concurrence of
a magnetic storm. But a spot can be of large area and at the
same time not very active. The active type of sun-spots is type
II. of my classification;† identified by Professor Hale as bipolar
spots. The large round spot is frequently quiescent.

The due consideration of these three conditions, activity of
sun-spot region, favourable position of the earth, and degree of

Dr. J. K. Fotheringham, Note on the ionisation of the earth's atmosphere, would account satisfactorily for most of the anomalies observed.

The observational data of the present investigation are summarised in the following table:

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<tr>
<td>Appearance</td>
<td>Date.</td>
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<td>I.</td>
<td>1919 Dec. 27-Jan.  5</td>
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<tr>
<td>II.</td>
<td>1920 Jan. 21-Feb. 3</td>
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<tr>
<td>III.</td>
<td>„  Feb. 17-Feb. 26</td>
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<td>IV.</td>
<td>„  Mar. 16-Mar. 29</td>
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Stonyhurst College Observatory:
1920 April 6.

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In his paper entitled "The Chief Cause of the Lunar Secular Acceleration," *M.N.*, 80, 309-317, Dr. Jeffreys uses for the excess of the lunar acceleration over its theoretical value the value \(+4.5°5 ± 0°70\) per century found by Miss Longbottom and myself from the ancient occultations and conjunctions, and deduces from this a solar acceleration of \(+0°78 ± 0°12\) on the theory of tidal friction contained in his paper. He compares the latter with the value \(1°93 ± 0°27\) deduced by me from the ancient equinox observations, and makes the suggestion that either an unknown cause is producing an acceleration of the Sun or that about half the observed solar acceleration is in error.

The observed values used by Dr. Jeffreys are the only values for the lunar acceleration found independently of the solar acceleration, and for the solar acceleration found independently both of the lunar acceleration and of the acceleration of the node of the Moon's orbit, but values obtained from other groups of observations may be used to confirm these or to suggest what errors are possible. I have, therefore, thought it may be worth while to throw the results indicated by different methods together, without waiting for a detailed examination of each group, especially for the benefit of those who may wish to approach the question from another side than that of the ancient observations.

**Times of Lunar Eclipses.**

The times of lunar eclipses should give us the difference between the lunar and solar accelerations. For reasons given in

* *M.N.*, 75, 393.

† *M.N.*, 78, 423.

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