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SUN-SPOTS AND MAGNETIC STORMS

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PROBABLY the most fascinating characteristic of sun-spots is that of rapid change. Some show changes from week to week, some day to day, and in some cases the appearance changes even from one minute to the next. And it is only natural that, from the very first, men have tried to connect these changes with occurrences upon the Earth. Attempts have been made to correlate sun-spot activity with a large number of variable phenomena—such as rainfall, earthquakes, the price of wheat and so forth—without reaching any conclusions that have been generally accepted. In fact, of all the influences which sun-spots have been suspected of having upon the Earth, only one is so definite that the connection is unquestioned. It is the relationship between sun-spot activity and disturbances of the Earth's magnetic field.

On January 19, 1926, an enormous group of spots came over the northeastern edge of the Sun and was brought into view by the Sun's rotation. (A photograph of the group is shown in Leaflet 13.) When near the central meridian of the Sun the group could be seen easily by the naked eye, with the aid of a piece of smoked glass. Later the Greenwich Observatory in England reported that it was the largest spot they had measured since their records began in 1874. On January 26, about two days after the spot had crossed the central meridian, the most intense magnetic storm that had been experienced in five years took place. Telegraph and telephone companies reported difficulty all day in getting messages through, and radio experts said the evening was one of the worst in their experience. The trans-Atlantic wireless tests were then being conducted, and from newspaper accounts the trouble was general, being popularly attributed to the remarkable aurora.

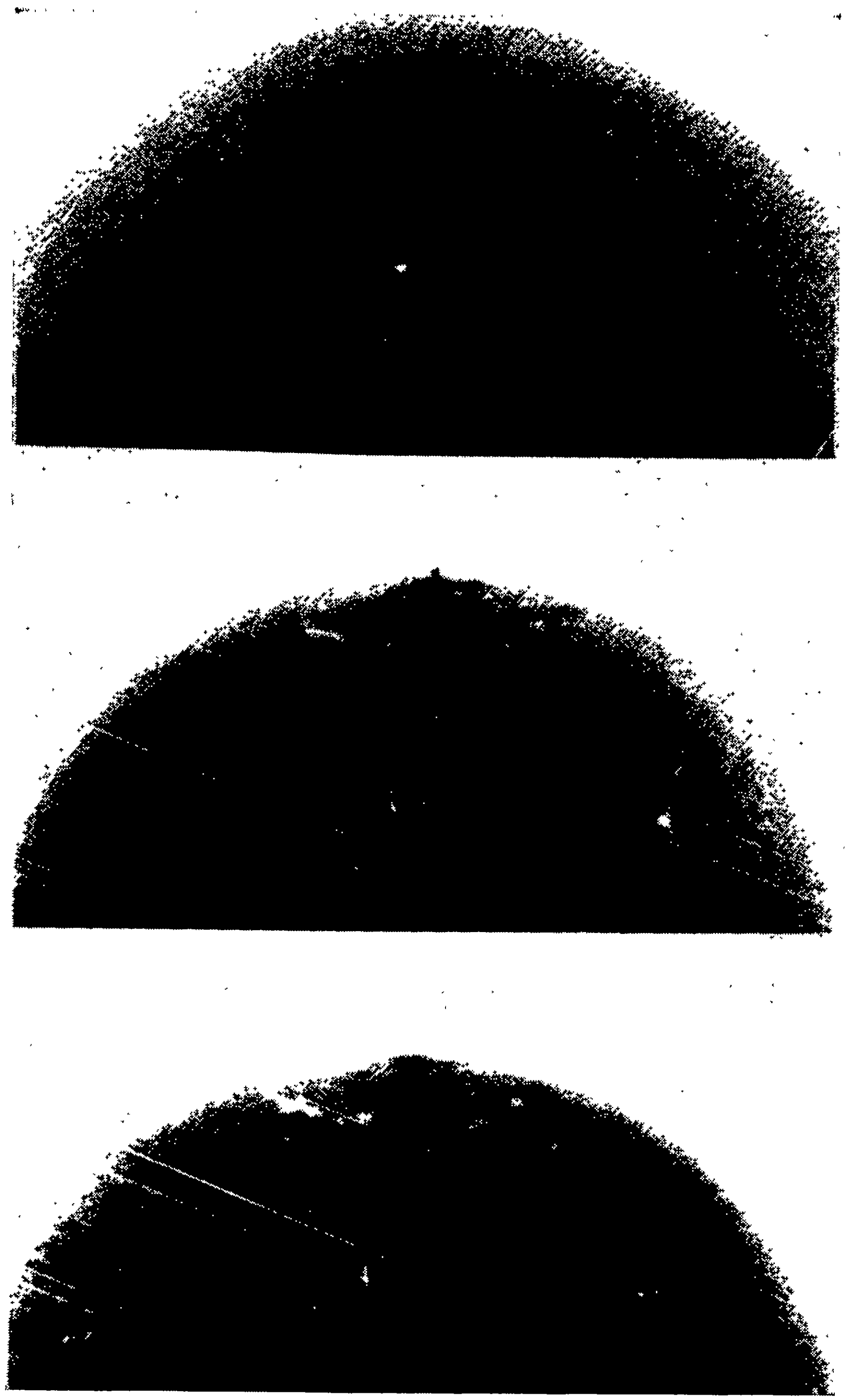
By a fortunate coincidence, Dr. Hale of the Mount Wilson Observatory had just completed preliminary tests of his spectrohelioscope, an instrument which made it possible for the first time to observe visually the entire disk of the Sun in the red light of the hydrogen chromosphere. Although the apparatus was still in an undeveloped state, he was able to detect on January 24 a large, bright, eruptive area showing rapid changes in form. The next day a new and extremely brilliant outburst was observed, together with sudden changes in the bright and dark clouds of hydrogen gas near the spot. In this particular case, the evidence is strong that the large spot was in some way responsible for the terrestrial magnetic disturbance.

The magnetic storm of January 26, 1926, is only one of several that might be cited to show that very large magnetic storms and very large spots are associated more frequently than can be due to mere chance alone.

If we consider only those magnetic disturbances classified as "very large," then it is almost always true that they start within four days of the central meridian passage of a group of "naked eye" sun-spots. But embarrassing exceptions have been known to occur.

If we take the 65 storms classified as "large" from 1874 to 1934 it becomes increasingly difficult to connect all of them satisfactorily with some unusual form of solar activity, and if we go a step farther and include the 419 small magnetic storms recorded in the same time, the relation between solar activity and individual magnetic storms seems to be almost purely accidental. If now we disregard the question of a direct connection between individual spots and magnetic storms, and investigate instead the average variations in terrestrial magnetism and sun-spot activity over several sun-spot cycles, it is found that the two agree very closely—*provided that the averages are taken over a sufficiently long interval of time.* While a year-to-year comparison shows a very high degree of correlation, the correlation from month to month is much less, and for the daily comparisons there is no correspondence at all.

It has been suggested that, instead of sun-spots, some other measure of solar activity should be used, such as the clouds of hydrogen and calcium that show on spectroheliograms. These phenomena are so closely correlated with sun-spots that no improvement is made by using them. Among other solar activities strongly suspected of producing magnetic storms are the bright hydrogen flares, several examples of which are shown in the illustration. Successive spectroheliograms taken at short intervals have shown that these outbursts spread over an area larger than the equatorial cross-section of the Earth in less than four minutes of time. After reaching maximum intensity they seem to remain nearly unchanged for several minutes or perhaps hours, then gradually fade away leaving the region



Spectroheliograms of the Sun made in the red light of the hydrogen chromosphere. No. 1 shows a brilliant eruption of hydrogen gas that occurred near a large spot-group on the central meridian of the Sun on June 5, 1924. This outburst may have caused the magnetic storm that started four days later. Nos. 2 and 3—taken on August 17, 1930—illustrate the transient character of these eruptions.

much the same as before. Up to this time it has been difficult to ascertain whether an individual flare started a magnetic storm, because solar observations at any one place seldom lasted longer than an hour, and no one knows how many other flares that we know nothing about may have occurred during the remainder of the day. However, such evidence as we have at present indicates an interval of the order of 26 hours between the time of the outburst and the beginning of the storm. Recently solar equipment has been installed at observatories circling the Earth and it is now possible to observe the Sun almost continuously and thus obtain a complete record of solar activity.

A peculiarity of magnetic disturbances which may be of great significance is the fact that they show a marked tendency to recur at intervals of 27 days, which is very close to the mean rotation period of most sun-spots. Sequences of ten or more disturbances at 27-day intervals have been noted. This tendency is displayed best by the small magnetic storms and disturbed days; the large storms are more likely to appear as isolated events. Sometimes a spot-group or calcium cloud is found to be at the same position on the Sun's disk on each of a sequence of disturbed days and thus might be supposed to have a connection with the magnetic disturbance. But just as often there is no correspondence among the markings. Hence, it has been simply assumed that there may exist on the Sun certain persistent, active areas which produce the magnetic disturbance, and which can not be observed by direct astrophysical methods. By making such an assumption the origin of any magnetic storm can naturally be explained; but actually, of course, we are no nearer to the solution of the problem than before.

Many theories ascribe the origin of the magnetic storm to something propagated from the Sun to the Earth, such as a stream of electrified particles expelled from a sunspot, or ultra-violet radiation, but so far no theory has been proposed which adequately explains all the observed facts. The theory of magnetic storms is thus found to be in a very unsatisfactory state—but this fact makes it an especially attractive field for investigation and it is possible that the answer may come directly from a study of solar activity. The astronomer's work is popularly regarded as being of little practical value, but from a purely scientific research of this kind may come discoveries of new methods for the transmission of energy over great distances which would be of immense practical importance in the future.