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Sun-spots and Magnetism—A Retrospect.

Having in former years given my impressions on various matters astronomical with which I had become acquainted in the course of my work at the Royal Observatory, it has occurred to me, from the increased attention of late paid to the question of sun-spots, their periods, and relation with terrestrial magnetism, that this is also a subject on which it may be of interest to recall, so far as I am able, some particulars of its history.

I may premise that the Greenwich Magnetic and Meteorological Observatory, dating from the latter part of the year 1840, was one of a group of such establishments set up in various of our Colonies for the prosecution, for a period of three years, of continuous magnetical and meteorological work. After three years it was resolved to continue the observatories for a further similar period, and ultimately that at Greenwich was made permanent.

Much was looked for from these Observatories and interesting results were before long obtained. On September 25, 1841, there occurred at Greenwich a considerable magnetic storm, an account of which was at once printed by the Astronomer Royal and extensively circulated. Information in due time received (this was not the day of ocean telegraphs) from the Observatories at Toronto, St. Helena, the Cape of Good Hope, and Trevandrum in India, showed that at these places also there had been a magnetic storm, that at Toronto appearing "to have commenced nearly at the same absolute time as at Greenwich and to have been generally simultaneous at both stations." This simultaneity at places so widely separated created much interest, and the preliminary results when received were printed by General Sabine for immediate distribution to the directors of observatories in all parts of the world—an earnest of other important results that might be expected. The remarkable simultaneity in the commencement of

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magnetic disturbance over the whole Earth, in cases of great disturbance, was afterwards further investigated by me in a paper to be found in vol. 51 of the 'Proceedings of the Royal Society.'

In course of time the observations made at the various Colonial observatories, by officers of the Royal Artillery, came into the hands of General Sabine, who superintended the discussion thereof, communicating the results obtained from time to time in papers to the Royal Society. That "On Periodical Laws discoverable in the mean effects of the larger Magnetic Disturbances, No. II.," read before the Society on May 6, 1852, becomes of interest in the present day from the circumstance that at this early stage, and from comparatively insufficient data, Sabine could so certainly suggest unexpected concurrences between magnetic and solar phenomena that, in later times, and with a far greater wealth of material, have been abundantly confirmed. Indeed our knowledge in regard to the main facts has since scarcely been greatly enlarged, the progress consisting rather in the confirmation and development of the character and nature of the remarkable relation then brought to light: In the paper mentioned we find, Tables 13 to 17, that during the period 1843 to 1848, at two of the Colonial Observatories at which the observations had become discussed, Toronto and Hobarton (stations one in the northern and one in the southern hemisphere), there was found to be continuous increase in the frequency of magnetic disturbance, and also continuous increase in magnitude of the diurnal range of magnetic declination, and further that the increase in diurnal range was just as pronounced in the smaller winter values as in the larger summer values, which, as the winter values of one hemisphere correspond in time to the summer values of the opposite hemisphere, was suggestive of cosmical action. With this impression Sabine wrote: "In our present ignorance of the physical agency by which the periodical magnetic variations are produced, the possibility of the discovery of some cosmical connection which may throw light on a subject yet so obscure, should not be altogether overlooked"; and remarking that Schwabe's independent observation of solar spots showed, between 1843 and 1848, variations similar in character to the magnetic variations, he goes on to say: "As the physical agency by which the phenomena are produced is in both cases unknown to us, our only resource for distinguishing between accidental coincidence and causal connection seems to be perseverance in observation until either the inferences from a possibly too limited deduction are disproved, or until a more extensive induction has sufficed to establish the existence of a connection, although its precise nature may still be imperfectly understood," adding that for such continued observation we must look to those observatories that are permanent, "to those especially which combine astronomical and magnetical research," the Colonial observatories having ceased to exist on the accomplishment of the special objects for which they were established. In a postscript
to the same paper Sabine gives, in Table 26, an extended series of values of diurnal range of declination for Toronto and Hobarton, including the years 1841 to 1851, adding thereto values for Munich. These numbers show a minimum of diurnal range about 1843, and a maximum in 1848, in close agreement with the corresponding sun-spot minimum and maximum of 1843 and 1848. The results obtained for other of the Colonial observatories confirmed, apparently in a lesser degree, those found for Toronto and Hobarton.

Sabine was not alone in pointing out the relation of terrestrial magnetism to sun-spots. Dr. Wolf of Zürich and Alfred Gautier both shortly afterwards, independently of each other, found a similar relation with variations of declination range as observed by Lamont at Munich. On which Schwabe enthusiastically wrote, on August 30, 1852, in a letter to Wolf: “Es ist gewiss sehr merkwürdig wie Ihre, Sabine’s, Gautier’s und Lamont’s Beobachtungen übereinstimmen, was bald einigen Aufschluss über die rätselhafte Natur der Sonne geben wird.” The question was now for future confirmation or otherwise, but still so far suggestive as distinctly to merit further attention. Dr. Wolf continued to make observations of sun-spots during the remainder of his life, publishing the results in his well-known ‘Mittheilungen,’ and the general table of sun-spot values which he eventually formed, founded on ancient and modern observations, including his own, acquires its value from the long period of time through which it extends. Prof. Wolf, his successor at Zürich, continued the work on the same plan, rendering Dr. Wolf’s work and his own throughout comparative, the general table having been also revised as other older observations came to light. It was interesting to me to see, when at Zürich some ten years ago, the telescope with which Dr. Wolf made his observations.

If the presumed relation did not at first receive that attention generally that might have been expected, it is to be remembered that the concurrent progression for a few years only of two distinct phenomena, so different in character, might reasonably have been thought to be fortuitous. A curious example of chance agreement, during sixteen years, between the variations of sun-spots and a certain meteorological element with which there could be no distinct relation, is pictorially illustrated in the ‘Observatory’ for the month of June 1889. On the other hand, the significance of the sun-spot variation, as indicating the existence of far-reaching cosmical action, was scarcely apprehended. The degree of attention given to sun-spot observation in those days, as compared with the rigorous scrutiny which the Sun in our time daily undergoes in all parts of the world, and at all times of total eclipse, in a sense measures the fuller knowledge of the constitution of the Sun that through the agency of photography and the spectroscope has been revealed to us.

We turn now to two papers by Sir George Airy read before the 2 x 2
1906 Royal Society—one "On the Diurnal Inequalities of Terrestrial Magnetism," on April 23, 1863, the other, continuing the subject, on December 10, 1868, in which will be found vector diagrams (combination of diurnal inequalities of magnetic declination and horizontal force in the horizontal plane) for each of the years 1841 to 1863. These diagrams show marked increase in magnitude from 1841 to 1848, very considerable decrease from 1848 to 1857, and again increase from 1857 to 1860, which Airy refers in a general way to changes in the magnetic energy of the Sun (pages 315 and 417 of the two papers respectively), apparently overlooking the circumstance that the vectors, representing the diurnal ranges of magnetic declination and horizontal force, show variations in magnitude in close correspondence with those of sun-spots, the vector maximum of 1848 and minimum of 1857 corresponding to the sun-spot maximum of 1848 and minimum of 1856 quite confirming what Sabine suggested. The question was not, however, lost sight of, for a table given in the first paper is extended in the second paper to include the days of unusual magnetic disturbance at Greenwich in each year from 1841 to 1863, on which it is remarked (page 313 of first paper): "These numbers, as I believe, give a very fair measure of great magnetic disturbance in each year. There is no appearance of decennial cycle in their recurrence"; and at page 414 of second paper: "If they point to any cycle at all, it is one of 6 or 6½ years." In the first paper, page 313, it is further said: "Nor does the number of disturbed days appear to have any distinct relation to the magnitude of diurnal range." The conclusion that magnetic disturbance did not show decennial cycle is not surprising, it is quite a fair inference from the numbers given. For although magnetic disturbance becomes grouped about epochs of sun-spot maxima, it is subject to irregularities (see my chart of magnetic disturbance 1848 to 1897 in the 'Monthly Notices of the Royal Astronomical Society' for December 1899), showing at times in the approach to sun-spot minimum renewed activity, as was the case previous to the minimum of 1856, a period included in that dealt with by Airy, so giving the appearance of a 6-year cycle having, as he remarked, no distinct relation with diurnal range. Had he proceeded one step further and made direct comparison of the variation in magnitude of his vector diagrams with the variation of sun-spots, the accordance between the phenomena, as above pointed out, might have been at once perceived. The observations of sun-spots of Schwabe and Wolf would have provided a continuous record, which could have been employed, although a certain amount of work might have been necessary to put the observations into shape for making the requisite comparison. But there was the discordant result already found from the consideration of frequency of disturbance, offering little inducement to pursue the subject further. It was not at that time known that whilst variation of diurnal range is closely synchronous with variation of
sun-spots, which a comparatively short interval of time will show, magnetic disturbance is erratic, as above mentioned, requiring a long period to bring out completely its character, one feature of which is that disturbance in our latitude always dies down at the actual epochs of sun-spot minimum. In the absence of this information it thus happened that the contradictory conclusion arrived at from consideration of disturbance was apparently taken as valid, in which case the character of the result that might have been deduced from consideration of diurnal range would appear comparatively unimportant. And so, by a kind of accident, the Greenwich magnetic results were thought not to confirm relation with sun-spots.

So matters for a time remained. When in the year 1875 I was transferred at the Royal Observatory from the Astronomical to the Magnetic and Meteorological Department, I had not had occasion to consider the question. But in the daily examination of the photographic registers it became in course of time apparent to me that magnetic disturbance was visibly becoming less frequent, in striking contrast to the prolific disturbance of the immediately preceding years 1869 to 1872, and also that the amplitude of diurnal range was similarly diminishing in magnitude, the contemporaneous observation of sun-spots, recently commenced at Greenwich, showing corresponding diminution of solar spot frequency. It was at about this time that Dr. Wolf communicated to the Royal Astronomical Society the paper that appears in Vol. 43 of the 'Memoirs,' containing his table of monthly sun-spot numbers from 1749 to 1876, so giving a favourable opportunity to test whether the Greenwich series of magnetic observations from 1841 onwards would really confirm the relation between magnetism and sun-spots pointed out by Sabine, and remarked in recent years to exist. The result altogether exceeded expectation, showing, both for declination and horizontal force, the variation in magnitude of diurnal range and that of frequency of sun-spots to be in close accord throughout. My paper giving the data employed and the discussion thereof for the period 1841 to 1877 was communicated by Sir George Airy to the Royal Society in 1879, and appears in Vol. 171 of the Phil. Trans. In a further paper contributed to Vol. 63 of the 'Proceedings of the Royal Society,' the inquiry was extended to include the period 1841 to 1896, in which it was further shown that, as found from quiet days alone (free from magnetic disturbance), there was a like relation between variations of diurnal range and sun-spots. In a third paper, that already spoken of as appearing in the 'Monthly Notices of the Royal Astronomical Society' for December 1899, the relation of magnetic disturbance to sun-spots was further considered.

I should further point out that the Astronomer Royal, Sir William Christie, in a communication to the 'Monthly Notices of the Royal Astronomical Society' for November 1889, gave a chart showing, for the years 1873 to 1888, curves not only of whole spots, but also of the
faculae and umbrae, together with curves of the variations of diurnal range of the magnetic elements of declination and of horizontal and vertical force, which, in a further paper communicated to the 'Monthly Notices' for June 1903, was extended to include the years 1873 to 1902. These charts confirm in the most striking manner the fact of concurrent variation between magnetic and sun-spot phenomena. And the relation is shown to be so close for the limited period in all treated, 1841 to 1902, that it seems not an unfair presumption to conclude that it always holds—that is to say, whatever may be (if we may so call them) the freaks of sun-spots, those of terrestrial magnetism are in harmony therewith. The object having been to show that this relation is a reality, which I believe to be sufficiently proved, the problem now is to discover the nature of the relation, whether direct or otherwise. It therefore gave me great pleasure to place any material I had gathered at the disposal of Mr. Maunder when he desired to make such further inquiry (see his papers in the 'Monthly Notices of the Royal Astronomical Society' for November 1904, and April and May 1905), although I do not propose to enter on that separate question here, except to remark that I had sometimes in the past noticed what seemed to be recurrence of disturbance at intervals of a month or so, but without giving further attention thereto.

Prof. Schuster in his paper in Vol. 206 of the Phil. Trans., "On the Periodicities of Sunspots," finds definite periods underlying the irregular sun-spot periods as observed. But the variations of diurnal range of magnetism at Greenwich so far as examined, 1841 to 1902, entirely synchronise with those of sun-spots, in the length of individual periods, relative intensity, and other points. It would therefore seem, by analogy, that underlying periods found generally to exist in the irregular sun-spot variations as observed should similarly exist in the synchronous irregular magnetic variations as observed.

The subject of the relation of terrestrial magnetism to sun-spots has been pursued by others, not only in this country but also abroad, but of the labours of others it is beyond the scope of this paper to speak. Indeed I am scarcely in a position adequately to describe what in other directions has been done, my narrative being simply some history of such part of the work as attaches to Greenwich.

W. Ellis.

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The Number of the Visible Stars.

The total number of the stars visible in the largest telescopes and on photographs is usually estimated at about 100 millions. To test the probable accuracy of this estimate I have made a number of counts of stars on the photographic prints given in the late