

On a probable relationship between the Solar Prominences and Corona. By William J. S. Lockyer, M.A. (Camb.), Ph.D. (Gött.), F.R.A.S., Chief Assistant, Solar Physics Observatory.

Introduction

In a recent communication * to the Royal Society, Sir Norman Lockyer and I gave the results which had been deduced from a minute investigation of the percentage frequency of prominences as determined from observations made by Secchi and Tacchini at Rome, and Ricco and Mascari at Catania and Palermo.

It was there shown that the chief centres of prominence action indicated movements in heliographic latitudes, the general tendency of these being in a direction towards the solar poles, and not towards the equator as is the case with the spots. Attention was also drawn to the fact that these centres of prominence activity were not restricted to narrow zones like the spots, which only occur between the latitudes $\pm 5^\circ$ and $\pm 35^\circ$, but that at times they were numerous in such high latitudes as $\pm 80^\circ$ and even higher.

The object of the present communication is to give an account of the results of a general survey regarding the connection between the changes of position of these centres of prominence action and the various forms of the corona as observed during total eclipses.

It has been suggested, and the idea is generally accepted, that the various forms of the solar corona are intimately connected with the variation in the spotted area of the Sun's surface. Thus, generally speaking, at about the epochs of Sun-spot maxima, the corona is apparently very irregular in shape, there being little or none of the exquisite tracery at the Sun's poles which is so evident at the epochs of Sun-spot minima, while the streamers are less confined to mid-solar latitudes and the region nearer the equator than they are at the minima.

The facts that Sun-spots do not appear nearer the poles than latitudes $\pm 35^\circ$, and that large coronal streamers and prominent rays are sometimes situated in much higher latitudes than these, in fact at times very near the poles of the Sun, and consequently outside the regions of spot activity, suggested that the occurrence of prominences, very important factors in the mechanism of the solar atmosphere, might be closely connected with them.

Classification of Coronas.

For the present general inquiry the forms of the coronas that have been observed since the year 1857 have been divided into three main types, and this classification, which is not new,†

* *Roy. Soc. Proc.*, vol. 71, p. 446.

† *Solar Physics*, Lockyer (Macmillan & Co., 1874), p. 278 *et seq.*; also

is one into which most of the coronas, with the exception of two, namely 1865 and 1885, can be easily placed.

Since the forms of coronas are dependent chiefly on the positions of the coronal streamers, the three different types here adopted refer in the main to the positions of these streamers in relation to the solar equator and poles.

In the first or "polar" group, as it has here been called, since streamers are found near the solar poles, all those coronas are included which seem to have no regular form. The typical features of this group are that the polar rifts are absent, being replaced to a great extent by streamers at, or very close to, the poles, and the streamers are numerous in nearly all solar latitudes; also there is no definite equatorial extension.

To this class the following coronas belong: 1860, 1870, 1871, 1882, 1883, and 1893.

In the third or "equatorial" group, since the streamers are chiefly equatorial, the form of the corona is very regular. The polar rifts have a large spread in latitude and are well defined, while the large streamers are restricted to the regions near the equator; in fact, the great equatorial extensions are best seen in this type. This form generally takes the shape of a "wind vane," and is often referred to as such. The coronas which come into this category are those of 1867, 1868, 1878, 1889 Jan., 1889 Dec., 1900, and 1901.

The second group of this classification may be termed the "intermediate" type, as the streamers are about half-way or intermediate between the poles and the equator. In this group the polar rifts are present, but they are not so extensive in latitude as in the "equatorial" class. The coronal streamers also approach nearer the polar regions than in the "equatorial" class, but not so close as in the "polar" group, while the equatorial extensions are not in such great evidence. Generally speaking this form of corona is due to a large streamer in each quadrant, which gives the corona the appearance of a square, hence the name "square corona."*

The coronas which fall under this heading are 1858, 1869, 1874, 1875, 1886, 1887, 1896, and 1898. It may be stated that the "polar" and "equatorial" coronas are always followed by an "intermediate" type, the order being polar, intermediate, equatorial, intermediate, polar, &c.†

The "intermediate" type may sometimes approach in form a "polar" or an "equatorial" type, according as the epoch of the

Bull. de l'Académie Impériale des Sciences de St. Pétersbourg, 5e. Série, vol. vi. 1897, Hanksy.

* *Solar Physics*, p. 276.

† It may be here remarked that the "intermediate" type between an "equatorial" and "polar" type has only once (1869) been recorded during the period here under investigation, and this is due to the absence of eclipses during the two short available periods since that date—namely, 1879–1881 and 1890–1892.

occurrence of the eclipse occurs nearer or farther from the epochs of occurrence of polar prominences.

Further, the "intermediate" type preceding a "polar" type will differ to some extent from one immediately following a "polar" type, because the latitudes of the centres of prominence action in each case are different, as can be seen from the accompanying plate.

Two coronas which have not yet been classified are namely those of 1865 and 1885. The former of these is of a type between the "intermediate" and "equatorial," while the latter falls between the "polar" and "intermediate" groups.

The Method of Inquiry.

The first natural and crucial test to apply, in order to determine whether there was a connection between prominences and the different forms of the corona, was to inquire at what epochs the coronal streamers were situated nearest the solar poles, and whether these were coincident with those times when the prominences were most numerous in those regions.

If this relationship were found to hold good, the next step was to see if it were possible to connect the two other main types of coronas, with the other conspicuous prominence changes.

The comparison for the first test showed that the only five "polar" coronas recorded since the year 1869, when prominence observations were commenced, occurred at those epochs when the prominences attained their highest latitudes.

This satisfactory result indicated a very probable cause and effect between prominences and the coronal streamers, for the region considered was quite outside the zone of the spots, and therefore independent of them.

It was next found that the other two types of coronas were closely associated with the number and latitudes of the centres of prominence action. Thus the "equatorial" type only occurred when there was *one* definite centre of prominence action in each hemisphere, while the "intermediate" type has been recorded at those times when *two* centres of action in each hemisphere were in progress.

The accompanying illustration (Plate 17) shows the relationship between the Sun-spot curve for both hemispheres together, the latitudes of the centres of action of the solar prominences for each hemisphere, explained in detail in a previous communication,* and the times of occurrence of all the eclipses that have occurred since the year 1857. When two eclipses of the same type occur in the same, or two successive years, they have been inserted either one above the other or obliquely to avoid overcrowding. A curve is also drawn through the different types, showing their relation to the Sun-spot curve.

* *Roy. Soc. Proc.*, vol. 71, p. 447.

Since the systematic prominence observations only commenced in the year 1872, the dotted portions of the curves previous to that date are intended only to give a rough idea of the variations as based on a general repetition of the observations of 1872 to 1885.

Fortunately for the present inquiry Respighi* made some very valuable prominence observations during the years 1870, 1871, and 1872, which are sufficiently numerous to indicate the positions of the centres of prominence activity for these years. These showed that during the years 1870 and 1871 there were two well-marked prominence zones in each hemisphere, and that the latitude of one of the zones was very high. The positions of these zones are indicated in the accompanying plate by the small circles against these years, and they agree well with the dotted curves representing the probable conditions as might have been expected from subsequent observations.

The different types of corona are plotted in three different horizons in the order "polar," "intermediate," and "equatorial," and the symbols adopted for each—namely, small circles with eight rays for the first, four rays for the second, and two rays for the third—are inserted at the epochs of their occurrence, according to the general time-scale for all the curves.

The continuous and broken vertical lines denote the epochs of the Sun-spot maxima and minima, as determined from a discussion of spots recorded on both hemispheres of the Sun.

The Results of the Comparison.

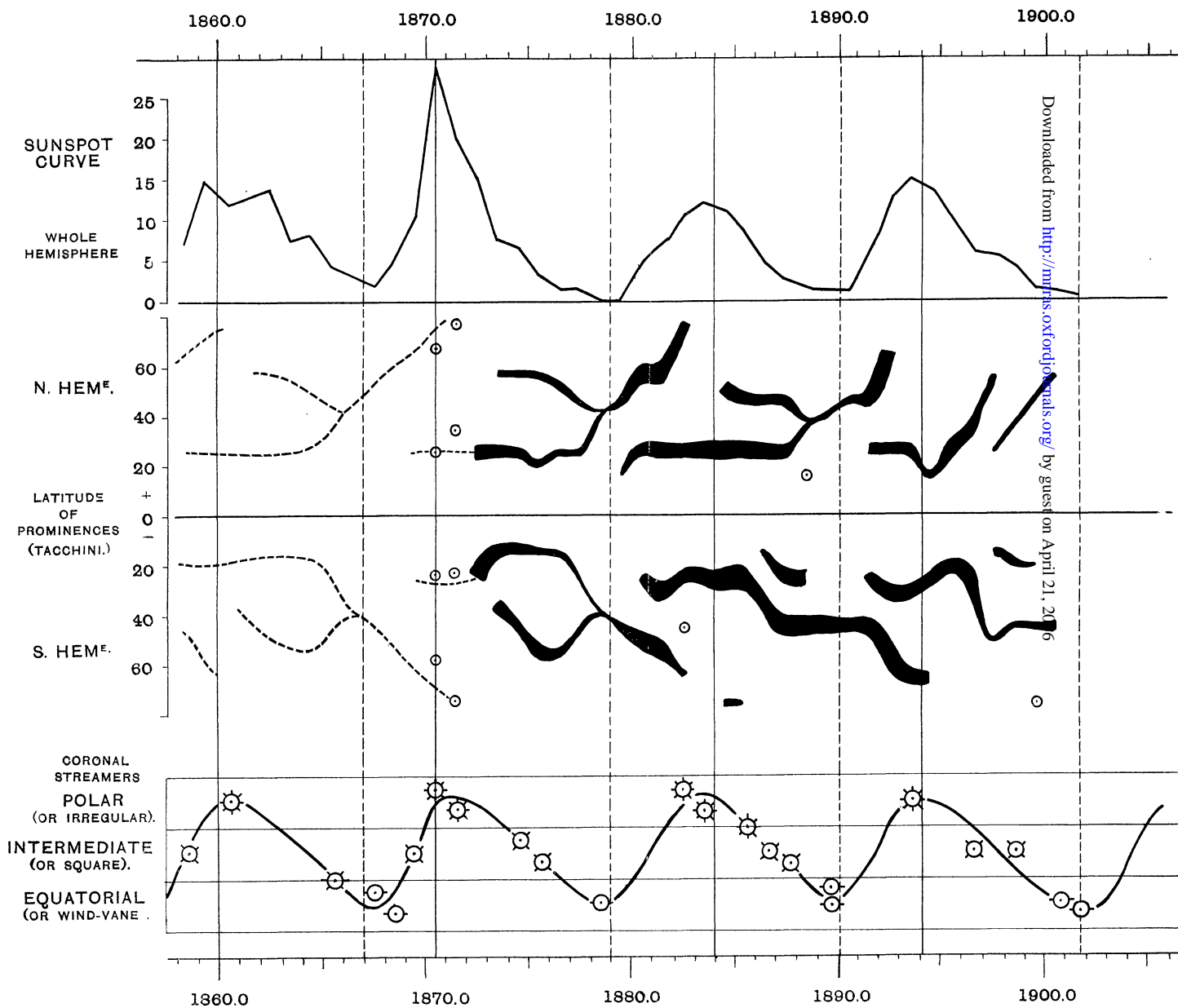
At the first glance it will be observed that the three types of the corona, as seen from the curve drawn through them, follow the Sun-spot curve very closely—that is, that at about the times of the maxima of Sun-spots, the "polar" type is present; at the minima, the "equatorial" type; and at the intervals between these, the "intermediate" type.

Although the Sun-spot curve thus affords a means of predicting in a general manner the epochs about which any of these types will occur, such a small restricted zone which the spots occupy excludes the idea of their presence being responsible for such widely distributed coronal phenomena.

The prominence curve, on the other hand, not only provides us with a more accurate method of forecast, but such phenomena can account for the changes of position and form of the coronal streamers.

By examining the prominence curves in relation to the three different types of coronas from the year 1869, this connection is seen to be very close. Thus, during the years 1870 and 1871, there were two centres of prominence action in each hemisphere, one of which was in high latitudes, and the coronas for that period

* *Solar Physics*, Appendix II. p. 654.



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The vertical continuous & broken lines represent the epochs of maxima & minima of sunspot activity from a reduction of the observations of both hemispheres.