SOME CHARACTERISTICS OF SUNSPOT ACTIVITY WITHIN A CYCLE

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During a study of the longitudinal distribution of sunspot activity for the period 1889–1954, a detailed examination[1] of the migration in latitude and longitude of the individual sunspot groups of cycle 17 was made, the results of which are reported here.

The longitude (as given in the Greenwich photoheliographic results) of every spot group occurring during the cycle was corrected for differential rotation after taking into account the exact average latitude at which the group had appeared. All spots were referred to a rigid longitude system pertaining to solar rotation 1035 beginning in January 1931, *i.e.* three years before the commencement of the cycle under study. This reference date was chosen to correspond to the commencement of the cycle from the magnetic point of view when, one may assume with Babcock[2], that the Sun has an axisymmetric dipole with lines of force lying in meridional planes. For every spot group, data regarding latitude, the rotation number in which it has occurred and its corrected longitude, referred to a system of longitudes pertaining to the commencement of rotation 1035, were thus assembled. The recurrent groups were considered only once, and that appearance of the group was considered in which it had the maximum area. The spots occurring in the northern and southern hemispheres were separated. The spots were then grouped according to their corrected longitudes and allotted to 12 longitudinal zones each of width 30°. Thus, spots having corrected longitudes between 0° and 29° will belong to zone 1 and those in longitudes 30° to 59° to zone 2. Then, for each longitudinal zone a diagram was prepared with rotation number as abscissa and latitude as ordinate, showing the position of the spot groups during the course of the cycle. The groups were represented with filled circles at their appropriate rotation number and latitude and the diameters of the circles act as measures of their area. Two of these diagrams are given in Fig. 1 (*a*) and Fig. 1 (*b*) for illustration.

An examination of the diagrams revealed certain interesting features. In each hemisphere the regions of high spot activity aligned themselves into two distinct series, both of them having the general shape of Spörer's curve. In some zones the series were clear-cut and distinct whereas in some other cases they were close to each other. In a very few cases the existence of three series was perceptible. Again, whereas in some zones there was a gradual movement in latitude of the activity consistent with Spörer's law, in other zones, the activity sometimes persisted at the same latitude for several rotations, irrespective of the phase of the cycle. The latter was the case in six consecutive zones particularly in the northern hemisphere. This goes to show that there were certain regions on the Sun in a longitude belt of 180° showing persistent activity throughout the major part of the cycle. Incidentally it may be mentioned that this belt exhibiting regions of persistent activity took the major share of the total activity in the cycle when one considers the distribution of the total spot activity in longitude during the cycle.

An examination of the magnetic characteristics of the spots in the two series in each hemisphere did not reveal any distinguishing feature. However, the two series revealed different commencement times; the series at higher latitudes commenced about $1\frac{1}{2}$ to 2 years later than the one at lower latitudes. This time delay exhibited by one of the series may very well mean that the

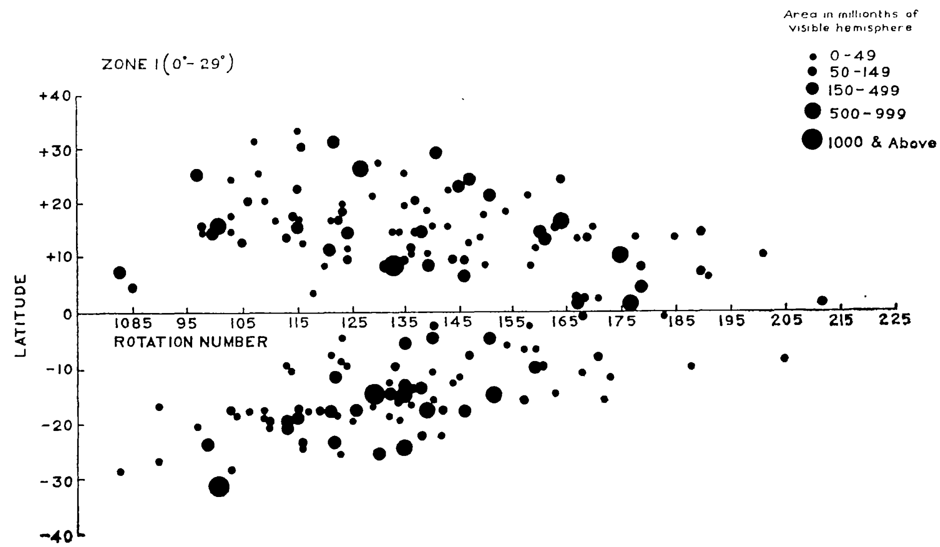

FIG. 1 (*a*)

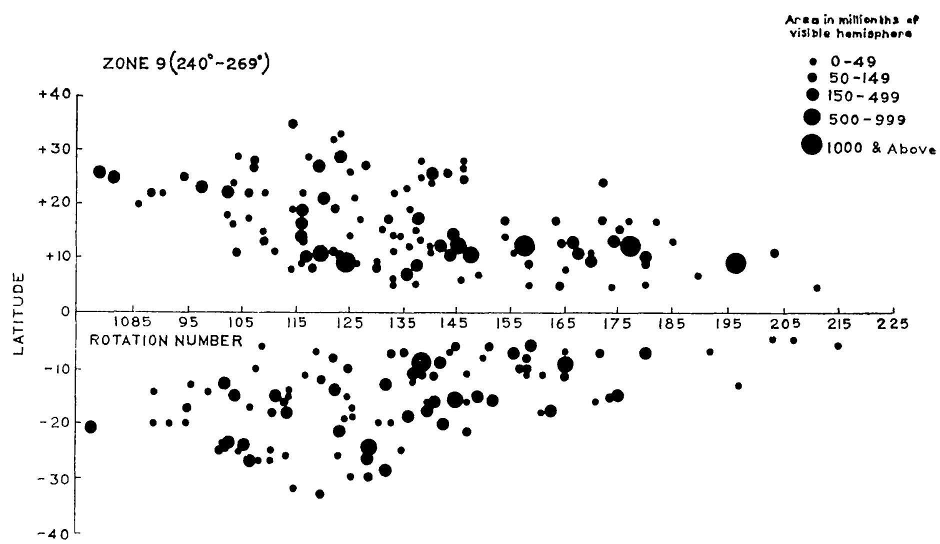

FIG. 1 (*b*)

process of spiral winding of the lines of force continued for a long time for the series at higher latitudes ($m \geqslant 4$, Kopecky[3]). Kopecky's modification of Babcock's expression for Spörer's law requires that in each hemisphere, after the minimum, two regions of activity should be formed in two heliographic latitudes, situated symmetrically to 45°, and that one region should get shifted towards the poles and another towards the equator. In our diagrams no poleward motion of the regions of activity in the higher latitude series was visible and therefore it is difficult to establish a connection between our series and the two series required by Kopecky's expression. Our principal finding is the persistence of activity in particular latitudes in some zones during the major part of the cycle.

It will now be worth while to see whether the present results lend support to the view that sunspots are formed in the close proximity of the photosphere. Trotter and Billings[4] have examined the distribution of general activity on the Sun during cycle 18 and have come to the conclusion that the internal cause of sunspots has a meridional structure not affected by differential rotation, though the effect of differential rotation was apparent. However, they have only studied the activity integrated over approximately the first half of the cycle and have compared it with the activity in the later half of the same cycle, and as such no detailed study of the movement of individual regions of high activity was made. On the other hand Tuominen[5], improving on the results of Becker[6], used the Greenwich photoheliographic data for the period 1874–1954 and made a study of the regions of formation of new sunspot groups. He came to the conclusion that sunspots are produced in close proximity of the photosphere and take part in the large-scale motion at the photospheric level. Both Becker and Tuominen have handled voluminous data statistically. We chose the regions which showed persistent spot activity to examine whether the spots are formed at a level having a rotation period different from what is observed on the surface. It was in these regions that sunspots appeared persistently one after the other, for several rotations. Since differential rotation has already been allowed for, any movement in longitude exhibited by the spots during their successive formation will throw light on the layer in which they are formed. Such regions in zones having regions of persistent activity were examined and an occasional random movement of individual groups in longitude was found. Some of these were recurrent groups which did not show any change of latitude during successive appearances. It was found that in almost all cases, the shift did not exceed one degree per rotation. Also the movement was not always in the same direction, there being certain cases of movement towards higher longitudes and certain other cases of movement towards decreasing longitudes. This seems to show that the regions of persistent spot activity do not show any systematic drift in longitude that could prove that the spots are formed in a layer rotating faster or slower than the surface. We therefore conclude that sunspots originate in the immediate vicinity of the photosphere.

References

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