FLARE ACTIVITY AND SPOTGROUP DEVELOPMENT

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ABSTRACT

The flare activity of all active regions having ten or more flares from August 1959 until December 1961 was investigated. We constructed flare-activity curves drawn with the aid of Kleczek's q-index. The characteristic magnetic situation on the Mt. Wilson synoptic charts of photospheric magnetic fields in which the flare-rich active regions developed is described. A flare activity rate 'quantization' was found. From the CSSAR magnetic observational material we studied the reorganization of the magnetic fields of active regions which correlated with sudden changes in the rate of flare activity.

1. Introduction

During recent years more and more effort has been spent in the investigation of solar flares. But usually the extremely large flares in extremely complicated magnetic situation of complex active regions are studied. We think that the systematic study of small, common flares and their relation to the normal common sunspot groups with relatively simple magnetic fields may have even greater importance.

Therefore we started to investigate flare activity and its changes in dependence on the development of the magnetic situation in all active regions covering a time interval of about two and half years. Our communication summarizes the first preliminary results obtained.

2. Method of Study and Observational Material

To visualize the frequency of flares of various importance we constructed curves of flare activity for each single active region from August 1959 till December 1961, which has the number of flares $n \geqslant 10$. For this period of time the Mt. Wilson synoptic charts of photospheric magnetic fields are available. For each of these active regions the curves of the development of the area of the sunspots were also drawn.

For the construction of flare activity curves we use the method of summation of q-indices defined by Kleczek (1952). This q $(q = i \cdot \bar{t})$-index characterizes each flare by its importance i and the mean duration $\bar{t}$ estimated for that importance, which means that the q-index may be in a certain degree proportional to the energy emitted by the flare. The flare-activity curve therefore can show the rate of flare-energy production given by the slope of the curve (Figure 1). The value proportional to the total flare-

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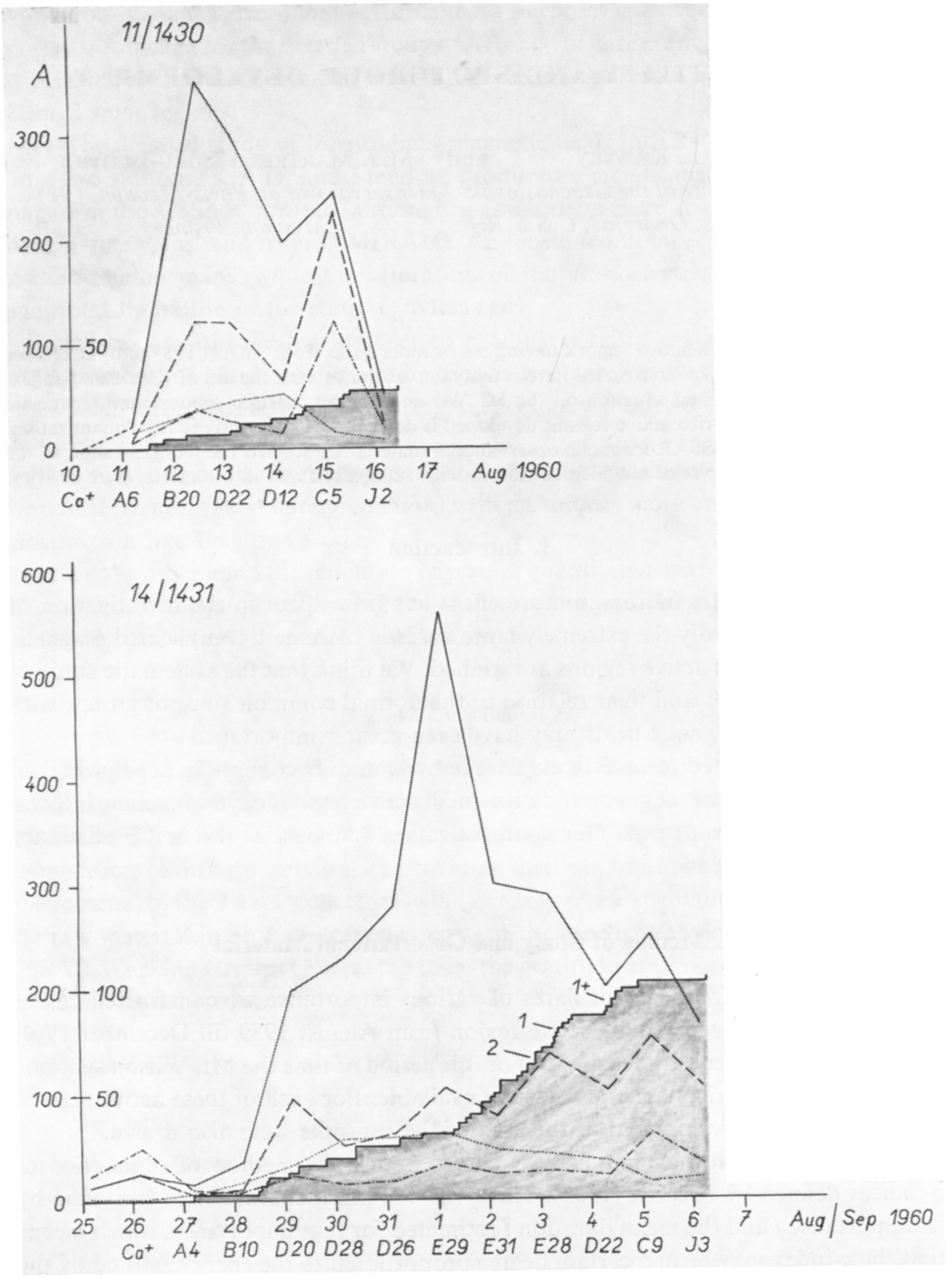

FIG. 1. *Two examples of curves of flare activity: On the top for AR No. 11/1430. On the bottom for AR No. 14/1431 (Quarterly Bulletin). – For each AR the daily values of the total spotgroup corrected area A (solid lines) and umbral area (dashed lines) daily number of spots in the group n (dotted lines) and the 'mean area of one spot' n/A (dash-dot lines) are given. The pattern of development from Fraunhofer Institute daily data is presented below each graph. For better visualisation of the flare-activity curves, the areas between them and the horizontal axis are shaded. The values of the q-index for importance 1, 1^+, and 2 are indicated.*

energy output of the active region is represented by the final coordinate of the curve on the q-axis.

3. Results

From the investigation of our observational material which includes about 115 active regions the following preliminary results were made:

(1) All active regions with the number of flares $n \geq 10$ develop in a very characteristic magnetic situation: they are usually bound to the places where the new developed magnetic field of the following polarity is strongly compressed between the large-scale patterns of the magnetic field of the leading polarity (Figure 2). Because the new formations as a rule are a part of a complex of activity (Bumba and Howard, 1965) and because only rarely is one active region apart from the main body of the background field observed, usually two or more flare-active regions are combined with one of such inclusions of following magnetic field mostly surrounded by the large body of the leading field. This magnetic situation is as a rule followed by a large maximum of green-line coronal emission and radio emission (1420 Mc/s) sitting above the inclusion (Bumba *et al.*, 1968*b*).

(2) Looking at the curves of flare activity we may see that their parts may be approximated by straight lines with certain value of inclination. If we plot the frequency curve of the slopes of these straight lines, we obtain several maxima in their distribution. This fact may be visualized by the help of the overlapping of individual flare-activity curves in the same way the curves of growth or the photographic characteristic curves are constructed (Figure 3). By this method we are able to divide all our active regions in 6 (7) groups with different values of flare-production rate. The first group of active regions has the slope of the main part of its flare-activity curves corresponding closely to the production of one flare of importance 1 per 24 hours, the second one to the rate of flare production of one flare of importance 1^+ per 24 hours, and so on. (The maximum for 1^-/24 hours is visible from the other observational material CSSAR.)

Very often one curve of flare activity for a single active region may be approximated by several straight lines, the inclination of which usually agrees with one of the main directions.

The duration of flare activity with high values of the rate of flare production is usually much shorter (1–3 days) (with the exception of the largest regions) than that of the small rate (5–10 days), so that the sum of q-indexes for each of the active regions does not differ very substantially from the mean. In the other hand the time of flare activity may differ within a much larger interval.

(3) As was found earlier from the observational material concerning the CSSAR-Period, the quality and methods of magnetic field measurement do not yet allow us to search for magnetic-field configuration changes connected with the occurrence of individual small flares. But the sudden changes of the rate of flare activity, as shown

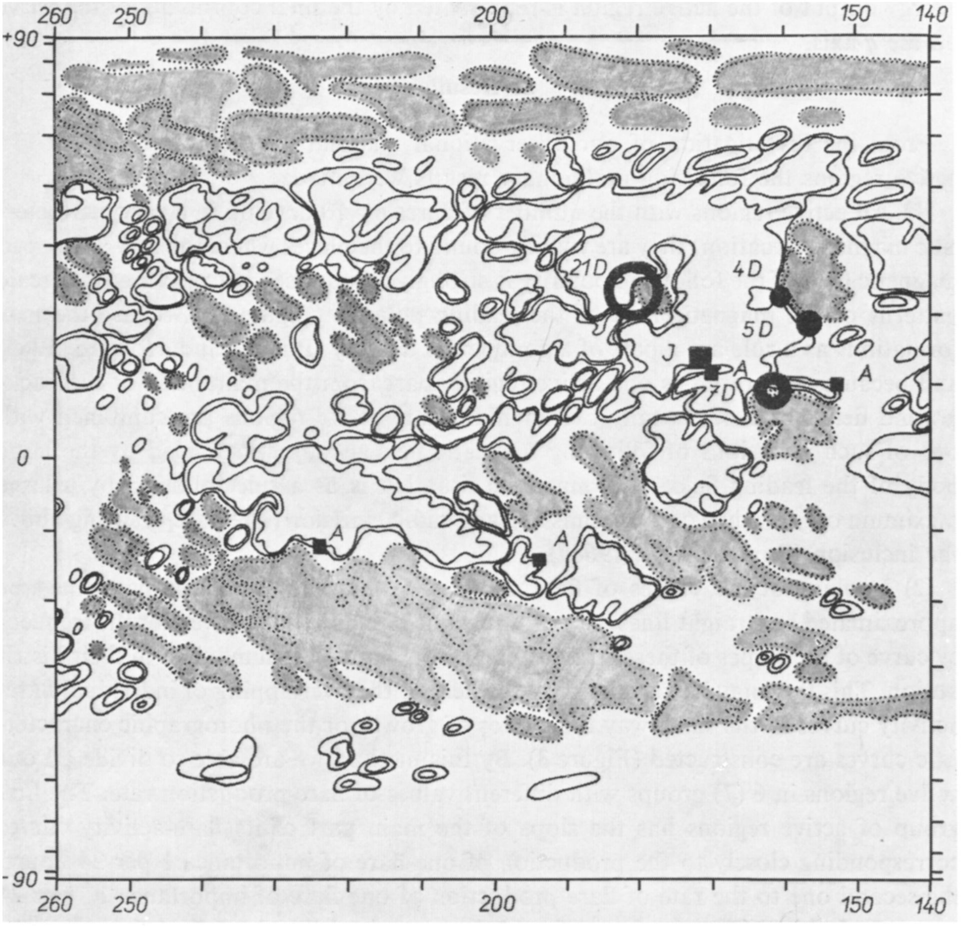

FIG. 2. *Example of the magnetic situation in which flare-active centra develop. A part of the Mt. Wilson synoptic chart representing photospheric magnetic fields from November 1960 is given. Solid lines represent isogauss for the positive (leading in the Northern hemisphere) polarity, dotted lines for the negative polarity. Active regions with flare activity are represented by circles and the Waldmeier type of the maximum phase of evolution together with the total number of flares. The regions represented by squares did not have flares observed. The situation in the left part of the figure represents the old magnetic-field areas, the appearance of which is in strong contrast to the inclusions of following polarity of new formed ARs in the right upper part of the figure.*

by the changes of flare-activity curve slopes at the beginning of the main flare-activity phase, may be correlated very well with the reorganization of the magnetic field of the active region: as soon as the magnetic situation (as a rule in the centre of the group at the boundary of polarities) becomes more complicated the rate of flare activity becomes greater, and vice versa. The greater magnetic activity is a characteristic process taking part during the phase of growth or renewal of activity in the

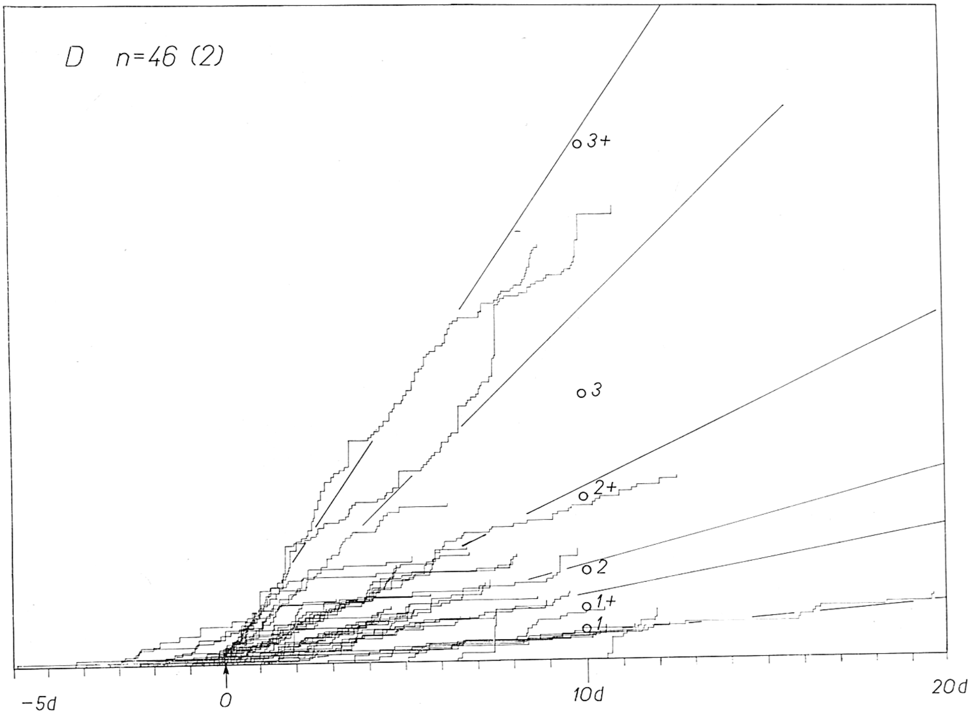

Fig. 3. *Overlapped flare-activity curves for ARs developed during the studied time interval on the visible disk. The concentration of curves around certain values of slopes is seen. The theoretical values of slopes for frequencies one flare of importance 1 per 24 hours and so on are given.*

centre of the active region, where one observes the formation of a gulf on the boundary between both polarity regions or islands of opposite polarity connected with the appearance of new spots (Figure 4) (Bumba *et al.*, 1968*a*). The flare activity reaches its maximum rate in most groups 2–3 days before the maxima of their sunspot areas. The decay of the magnetic activity in the centre of the group is followed by a decrease of the flare activity after a certain interval of time.

It seems that in some active regions there may exist a secondary increase of flare activity connected, for example, with magnetic changes during the dissipation of sunspots in the group, but this process needs more observational material.

4. Discussion of Results

The division of active regions into different classes depending upon their flare-activity rate certainly depends upon the method of classification of flares, and it may be influenced by the irregularity of geographic longitudinal distribution of observational stations. But a detailed study of flare activities shows that the most important

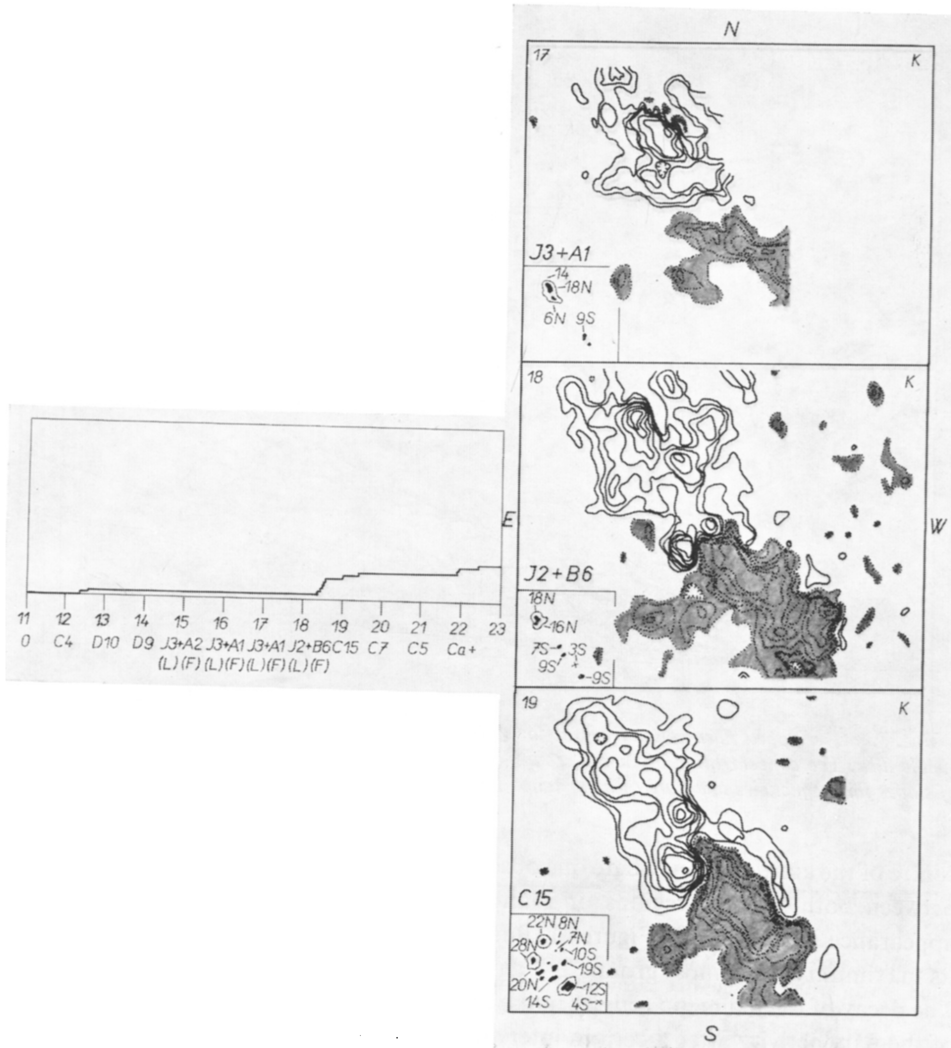

FIG. 4. *A series of Crimean magnetic maps for AR No 1/1492 during the days of larger flare activity is shown. On the left part the flare-activity curve for the group is given. The simple magnetic situation on March 17 with no flare activity, and the complication of the magnetic situation at the boundary of the polarities accompanied by increased flare activity on March 18 and 19 is evident.*

factor influencing the slope of the curves is for a given part of the curve the relatively regular frequency of small flares of importance 1 and 1^+.

If we try to give some explanation to the fact of the flare-activity rate 'quantization', we may point to the existing hierarchy in the sizes of the elements of the magnetic-field distribution in the solar atmosphere depending on the hierarchy of the dynamical elements of the atmosphere. This means that there exist tubes of magnetic lines of force with certain relatively constant values of their diameters given probably by the conditions of stability in individual atmospheric dynamical elements. Certainly the consumption of such magnetic fields by flare activity will be accompanied by the dissipation of whole tubes of lines of force involved.

The future study of magnetic changes in the centre of spotgroups which seem to be connected with the reorganisation of the supergranular pattern may give us more information about the physics of such processes.

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