‘BARTELS’ ACTIVE LONGITUDES’, SECTOR BOUNDARIES AND FLARE ACTIVITY

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Abstract. The flare activity and especially the proton-flare activity is concentrated in the zones of ‘Bartels’ active longitudes’ and in the neighbourhood closest to the sector boundaries of the interplanetary magnetic field. This concentration seems to be greater if the importance of the event increases.

1. Introduction

Recently it was shown that the new solar activity regions develop in the patterns of the old magnetic background field (BUMBA and HOWARD, 1965). This mutual relationship of the old and new magnetic fields in the solar atmosphere together with the other characteristics of the solar magnetic field and activity distribution and the dynamics of the new activity regions development leads to the regular and persistent distribution of magnetic fields and to the formation of so-called rows and streams of the solar magnetic field with a constant ‘Bartels’ heliographic longitude’ (BUMBA and HOWARD, 1969a). This means that the rotational period of the main pattern of the solar magnetic field distribution is 27.0 days and therefore the magnetic rows and streams drawn in the Carrington system are inclined from 4 to 5° per rotation (shifted to the West every successive rotation), especially in the equatorial zones ($\pm 20°$).

It was also shown that the classical ‘active longitudes’ in the Carrington system of heliographic coordinates, studied by scores of authors during the past eighty years and whose reality is still not fully certain, are different from those in the Bartels’ system. The mutual relations of both types of longitudinal activity distribution, or in other words, of persistent features having various values of inclination in one system of heliographic coordinates, is still unknown. Meanwhile there are some indications of such possible relation, for example, through the periodical development of activity in the one or other type of ‘active longitudes’.

The close connection of solar magnetic fields with the interplanetary magnetic field structure was statistically shown by NESS and WILCOX (1966). Just recently the connection of ‘Bartels’ active longitudes’ with the same interplanetary field was demonstrated by BUMBA and HOWARD (1969b).

In a recent paper ŠVESTKA (1968) demonstrated that practically all proton-flare regions in the last ten years were concentrated in a few ‘complexes of proton-flare activity’ with a fairly constant heliographic longitude on the Northern solar hemisphere and with two rows of such complexes travelling in the heliographic longitude on the

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Southern hemisphere. Some indication of the solar activity longitudinal concentration by use of calcium flocculae was shown by DODSON-PRINCE and HEDEMAN (1968) for practically the same time interval. Therefore it seems to us that it may have some interest to study the relation of the flare activity and especially of the proton-flare activity longitudinal distribution to the newly demonstrated 'Bartels' active longitudes' and to the boundaries of sectors in the interplanetary magnetic field which are bounded to these active longitudes.

2. 'Bartels' Active Longitudes' and the Flare Activity

A. PROTON-FLARES

Two periods of time for which it was possible to estimate previously the position of the center of gravity of the 'Bartels' active longitude' visualized in the distribution of solar equatorial magnetic fields (BUMBA and HOWARD, 1969a) were taken for such a study: August 1959–October 1961 (rotations Nos 1417 to 1446) and July 1963–March 1967 (rotations Nos 1469 to 1521). During the first interval two longitudes about 16–17 days apart were found. At the beginning of the first observational period (rot. No. 1417) the approximate position of both longitudes in the Carrington system was 270° (the first longitude) and 60° respectively. During the last months of the year 1960 in the neighbourhood of the first longitude, a rich fine structure appeared disintegrating the stream and the estimation of the longitude position became uncertain.

In the second period only one main longitude existed throughout the whole time interval concerned. For the rotation No. 1469 the center of gravity position of this longitude was about 10° of the heliographic longitude in the Carrington system. At the beginning of the studied time interval from July 1963 till October 1964 (less certain till June 1965) two secondary active longitudes may be found with the position of their centers of gravity in the rotation No. 1469 at about 200° and 300° longitude in the Carrington system.

The data for the proton-flare event for the first time interval concerned were taken from the catalogue published by ŠVESTKA and OLMR (1966). During this period 30 proton-flare regions with a total number of 60 proton-flares were observed. In the second time period 18 proton-flare regions with total 26 proton-flares were observed (ŠVESTKA, 1968; KŘIVSKÝ, 1968).

The histogram of the frequency distribution of the time differences between the central meridian passage of the proton-flare region and the center of gravity of 'active longitude' expressed in days is shown on Figure 1. At first sight, there is a certain concentration of proton-flare regions around centers of 'active longitudes'. In the first period studied, about 73% of all proton-flare regions occurred at a distance not greater than ± 3 days from the mean position of 'active longitude' or 43% if we narrow the time interval between the central meridian passages to ± 2 days. The homogeneous distribution of proton-flare regions over all solar longitudes give us by chance the probability of 44% and 30% respectively for both central meridian passages intervals. A similar situation may be seen in the second period of time studied: about 61% of proton-flare regions occur not farther from the center of an 'active longitude' than ± 3 days and about 50% in the narrowed interval of ± 2 days. The distribution by chance, if we take into account the only temporary existence of the secondary 'active longitudes' gives 35 and 21% respectively.

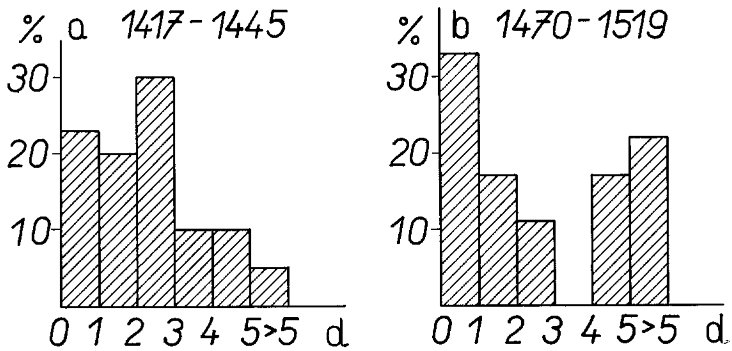

Fig. 1. The histogram of frequency distribution of the time differences between the central meridian passage of the proton-flare region and the center of gravity of an 'active longitude' expressed in days (horizontal axis): (a) for rotations number 1417 to 1445; (b) for rotations number 1470–1519.

It may be interesting to remember here that the estimated width of a magnetic stream or 'Bartels' active longitude' is about $\pm 30°$ or a little more (BUMBA and HOWARD, 1969a) which practically coincides with the above used time differences intervals.

B. NORMAL SOLAR FLARES

To investigate the relation of the normal flare activity with the 'Bartels' active longitudes' for the time interval from August 1963 till December 1966 all sunspot groups containing flares of an importance 1^+ or greater were written down from the *Quarterly Bulletin of the Solar Activity*. The total number 103 of such sunspot groups producing 188 solar flares of this importance was registered. From this material about 32% of all groups and 30% of solar flares occurred in the ± 3-day interval around the center of the 'active longitude' and about 27% of groups and 23% of flares took place in the ± 2-day interval. The number of groups and flares obtained by chance in the studied intervals would be 22 and 15% respectively. During the 16 rotations where the two secondary 'active longitudes' were seen about 80% of sunspot groups originated around them. This seems also to be a little higher than the normal degree of probability for the group development by pure chance which makes about 63%.

We can restrict the number of flare active regions using only the regions with the highest flare activity. Again from the *Quarterly Bulletin on the Solar Activity*, but this time only the spot groups with the greatest number of solar flares produced in the studied rotation were chosen. For the case when equal maximal number of solar flares for several groups was found or if there were during the one rotation more groups with the number of flares greater than ten, all such groups were taken into consideration. All in all 88 such sunspot groups were estimated from the material used. From these about 42% developed in the ±3-day and 33% in the ±2-day interval. Finally, it was shown that from the total number of flares 1763 observed during the total time interval considered, 36% took place in the ± 3-day interval and 26% in the ±2-day interval.

3. Sector Boundaries and Flare Activity

As the basis for the investigation of the relation of flare activity to the interplanetary magnetic field structure the data concerning this field distribution published by Ness and Wilcox (1967) were used. The main period of time having more or less exactly estimated position of sector boundaries starts in December 1964 and continues till November 1966. There are also some uncertain data obtained by the Mariner spacecraft during September and October 1962. During this whole time interval for which the sector boundary positions are at our disposal 14 proton-flare groups on the sun were indicated. In Table I the data are given of the central meridian passages of all proton-flare groups together with the central meridian passages of the sector boundary nearest in the longitude to the group and time difference between these two central meridian passages expressed in days.

TABLE I

CMP of proton-flare groups and sector boundaries.

No. of active region	CMP of the proton-flare group T_1	CMP of the sector boundary T_2	T_2–T_1	Note
1	1962 Sept. 9.5	(Sept. 7)	(−2.5)	
2	Sept. 17.4	(Sept. 22)	(4.6)	
3	Oct. 18.2	(Oct. 17)	(−1.2)	
4	1964 March 11.1	March 12	0.9	
5	1965 Feb. 3.8	Feb. 4	0.2	&
6	June 13.0	June 13	0.0	&
7	July 8.9	July 9	0.1	&
8	Oct. 1.8	Oct. 1	−0.8	& *
9	Dec. 24.9	Dec. 22	−2.9	
10	1966 Jan. 19.3	Jan. 19	−0.3	&
11	March 21.2	March 21	−0.2	&
12	July 3.5	July 4	0.5	&
13	Aug. 29.0	Aug. 29	0.0	
14	Sept. 19.5	Sept. 20	0.5	*

There exists some degree of uncertainty in the estimation of the sector boundary position. In the majority of cases the sign of the polarity changes on both sides of this boundary. But in some cases we may find a more or less elongated region with no field between two sectors of opposite polarity. In Table I the sector boundaries of the interplanetary field accompanied by the fast one- or two-day changes of the magnetic field polarity sign connected with the central meridian passage of an active region are indicated by &. In two cases indicated by an asterisk, the boundary between the one polarity area and zero field area was accepted as a sector boundary.

From Table I we may see that 11 from the 14 proton-flare regions occurred at the distance smaller or equal to 1 day from the boundary of the sector structure of the interplanetary magnetic field. Only in three cases this distance was greater than 2 days and it is important to emphasize that two of these extreme events were connected with

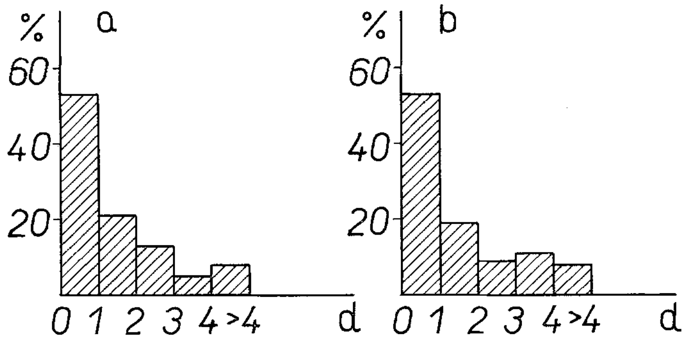

Fig. 2. The histogram of frequency distribution of the time differences between the central meridian passage of spot groups and that of the interplanetary magnetic field sector boundary for the groups: (a) with flares of importance 1 + or greater; (b) with the number of flares equal or greater than ten.

TABLE II

Distances between the CMP of sector boundaries and flare-active sunspot groups

		Distances between the CMP in days					Total number of cases
		1	1–2	2–3	3–4	4	
All Groups with flares of importance 1 +	*n*	46	18	11	4	7	86
	%	53	21	13	5	8	
Groups without proton-flare groups	*n*	38	18	10	4	7	77
	%	50	23	13	5	9	
Events indicated by an asterisk excluded	*n*	28	20	16	7	15	86
	%	33	23	19	8	17	
All Groups with great flare activity	*n*	40	14	7	8	6	75
	%	53	19	9	11	8	
Groups without proton-flare groups	*n*	31	14	5	8	6	64
	%	49	22	8	12	9	
Events indicated by an asterisk excluded	*n*	34	12	11	9	9	75
	%	45	16	15	12	12	

the uncertain data obtained by Mariner. The fast changes of the polarity at the sector boundary were observed seven times.

The connection of the normal flare activity with the sector structure was investigated in the same manner as during the previous study of the influence of the 'active longitudes' on the flare activity. Figure 2 demonstrates the results again for the groups with all flares having importance greater or equal to 1+ and for the groups with the maximal flare production. The high degree of concentration of the groups with flare activity to the sector boundary is clearly visible: about 56% of groups with flares having the considered importance and about 41% of all flares observed during the studied period took place not farther than 1 day from the sector boundary.

It is possible to see the results in Table II in a little more detail. Although if we exclude the active regions with proton-flare activity or the cases where the line between one polarity and zero field was taken as a boundary position, the concentration of groups with flares to the sector boundaries is conserved.

4. Conclusions

We may summarize the above-obtained results about the dependence of flare activity on the 'Bartels' active longitudes' and on the interplanetary magnetic field sector structure boundaries as follows:

(1) The flare activity and especially the proton-flare activity is concentrated in the zones of 'Bartels' active longitudes'.

(2) The flare activity and especially the proton-flare activity is concentrated in the neighbourhood closest to the sector boundaries.

(3) It seems that the concentration of flare activity around the 'active longitudes' as well as around the sector boundaries increases with the importance of the event. The highest degree of concentration may be seen for the proton-flare regions.

(4) Once more the high correlation of sector structure boundaries positions with that of 'Bartels' active longitudes' during the investigated interval is shown.

(5) The 'proton-flare activity complexes' found by Švestka (1968) coincide with the complexes constituting the 'Bartels' active longitudes'.

(6) About one half of proton-flare region developments is accompanied in the interplanetary magnetic field structure by the fast and short-lived changes of polarity around the boundary of sectors. This is probably due to the strong influence of the complicated fields of the newly formed proton-flare regions.

As yet it is very difficult to interpret fully the above summarized results. The more sensitive reaction of the flare activity concentration on the position of the sector boundary than on that of the active longitudes we may try to explain on one side by the relatively broad zones of 'active longitudes' for which it is not easy to estimate their center of gravity and on the other side by the fact that the resulting sector boundary represents an integral of the complicated magnetic field structure in the 'active longitude' zone. The simplification of magnetic field structure with height and therefore the better role of the sector boundary as the indicator of a general change in the integrated magnetic field polarity was already shown (BUMBA, 1964), just recently by KRÜGER *et al.* (1968).

The physical reason for the concentration of flare activity in the long-lived concentrations of magnetic field seems to be obvious. It is not only due to the fact that in the case of existence of an 'active longitude' the greatest part of magnetic fields is concentrated to these longitudes but also due to the still more and more recognized connection of the newly formed active regions with the remainders of the magnetic field of old active regions and to the more complicated field configuration resulting from this situation.

The presented conclusions may be used for the prediction of greater flare activity position on the sun. The fact that the life-time of 'active longitudes' is greater than one year is very favorable for such prediction. But to make the forecast more effective it is necessary to have more information about the development of solar activity in these longitudes with time and to learn better the reason for development of the field configurations leading to greater flare activity.

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