The Relationship Between Solar Flares and Solar Sector Boundaries

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Phil H. Dittmer

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Abstract

A superposed epoch analysis of 1964-1970 solar flares shows a marked increase in flare occurrence within a day of (-+) solar sector boundaries as well as a local minimum in flare occurrence near (+-) sector boundaries. This preference for (-+) boundaries is more noticeable for northern hemisphere flares, where these polarities match the Hale polarity law, but is not reversed in the south. Plage regions do not show such a preference.

The Relationship Between Solar Flares and Solar Sector Boundaries

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Since the first magnetic observations of the sun were made by Hale in 1908 (Hale, 1908) the strong fields associated with sunspots have been a favorite object of study. Both the strong fields in the spots (Hale <u>et al</u>, 1919) and the weaker fields surrounding them (Babcock and Babcock, 1955) are characterized by differential rotation and by a reversal in polarity of preceding and following regions upon crossing the equator. The discovery of sectors in the interplanetary magnetic field (IMF), (Wilcox and Ness, 1965) has uncovered a different kind of large-scale, weak solar magnetism. Magnetic sector boundaries do not change polarity upon crossing the solar equator and do not show the effects of differential rotation. Flares have long been known to occur in the strong field regions near sunspots. Bumba and Obridko (1969) also found that they occur preferentially near sector boundaries. Because these findings provide a link between bipolar and sector magnetism, the present study was made to verify and extend the previous results.

The list of sector boundaries used was the list of well-observed boundaries as previously reported by Wilcox (for example, Wilcox and Colburn, 1972), well-observed meaning that the IMF was observed by spacecraft to be of one polarity for at least four days before the boundary, to reverse, and to be of the opposite polarity for at least four days after. A list of flares was assembled from confirmed flares of importance 1F or greater as reported in Solar-Geophysical Data (SGD) for 1968-1970. For 1964-1966 and 1967 the lists used were those given in Upper Atmospheric Geophysics Reports UAG-2 and UAG-19 which were assembled by Dodson, Hedeman, and [illegible] (1968 and 1972) and corrected by them for a diurnal dependence due t[illegible]onsistent reporting procedures. The corrections to SGD lists were made before publication from 1968 on. A superposed epoch analysis was made using these 112 boundaries and 2600 flares, with the boundaries displaced 4 1/2 days earlier in time to correct for the average 4 1/2 day solar wind transit time from sun to earth. Flares were listed in terms of time of central meridian passage (CMP), assuming a 27-day rotation period. It was found that flares prefer to occur within one day of boundaries as previously reported by Bumba and Obridko.

A routine check to determine if this result was the same for either type of boundary (away-toward (+-) and vice versa) led to the surprising result that a much sharper peak in the flare distribution was found to be present for (-+) boundaries and a local minimum was observed for (+-) boundaries. This result is shown in Figure 1. Such a difference in response for the two types of boundaries was not originally observed for many geomagnetic and IMF effects associated with sector boundaries, possibly due to a different dependence on solar latitude. Since observing this difference, however, the author has been made aware that a different response for each type of boundary has also been reported for the slowly varying component of solar radio emission (Scherrer and El-Raey, 1974), for daily average Kp (Shapiro, 1974) and for coronal green line intensity (Antonucci, 1974 and Antonucci and Duvall, 1974).

Since the coronal green line intensity near a boundary was also found to depend on latitude, the flares were next divided into two groups according to latitude to determine if the preference for (-+) boundaries was reversed in the less active southern hemisphere, as was reported for the green line emission. As Figure 2 shows, flares in the southern hemisphere also occur preferentially near (-+) boundaries, though the peak in the distribution near the boundary is less sharp. As observed by Antonucci, the more active (-+) boundaries in the north have the same polarity as bipolar regions obeying the Hale polarity law, which is why a reversal might be expected in the south. The absence of such a reversal is not strongly contradictory of the Antonucci finding since flares occur predominantly close to the equator (68 °/o of the list used are within $\pm 20^{\circ}$) and the reversal of "active boundaries" reported for the corona was not observed by Antonucci to occur until 17.5° south.

The next question considered was, how significant is this result-- could it be the result of chance? Two qualitative tests were made to confirm that the preference of flares for (-+) boundaries was significant. First the superposed epoch analysis was repeated one year at a time (with 1964 and 1965 grouped together since few flares occurred in these years). Though statistics were poor and noise levels high, in no case was the result contradictory.

Another check was made by removing flares occurring on those CMP days when 20 or more flares crossed central meridian to determine if the peak in the superposed epoch was due entirely to the 12 CMP days with 20 or more flares. As Figure 3 shows, the peak is reduced but still well above the noise level which may be estimated by following the superposed epoch curve beyond the 4 day limit where polarities are well determined.

Finally, a semi-quantitative approach was used to examine how likely it was that such a peak might be due to chance. The boundary list was used to generate 112 random boundaries with the intervals between boundaries and the number per year kept the same as in the original list but with the order of the intervals scrambled. Ten such random boundary lists were generated and used to run a superposed epoch analysis of the flare data using 100 day wide windows. Thus 1000 random values were obtained for each type of boundary, or 2000 in all. Only 1 value in 2000 was greater than the peak obtained for northern hemisphere flares in the day preceding (-+) boundaries so the probability of such a result occurring by chance is estimated conservatively to be about 2/2000. There were 30 values less than the value obtained for the northern hemisphere flares in the day preceding (+-) boundaries, and 10 more equal, so the probability of chance occurrence indicated is about 40/2000. These estimates are very conservative since the day on either side of the (-+) maximum is also well above the noise level, and the (+-) minimum is 3 days wide.

Conclusion

Although obscured by the lack of a reversal in the south, the pattern that emerges is one of flares preferring to occur near sector boundaries whose polarity agrees with that of bipolar active regions as given by the Hale polarity law. Since a similar analysis of active regions (calcium plage regions), as reported in SGD, showed no preference for the vicinity of boundaries, it would appear that the creation of active regions is unrelated to sector boundaries. However, if they are created near a boundary of the same polarity, flare production is encouraged, and if the polarities disagree, flare production is reduced.

A physical mechanism immediately suggested for this difference is the random-walk dispersion of active region magnetic fields as discussed by Leighton (1964). It would seem that this dispersion would proceed more slowly if the active region fields agree in polarity with the large scale solar fields indicated by the sector polarity. Similarly, one might expect more rapid dispersion if the polarities disagree. An analysis of plage regions weighted by age in solar rotations did not confirm this suggested mechanism since longer lived plages showed no preference for sector boundaries of like polarity. A weighting of plages by area did show a slight preference of larger plages for the favorable boundary.

Acknowledgements

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Figure Captions

Figure 1. Superposed epoch of solar flares 1964-1970, using well-defined sector boundaries as measured by spacecraft. Figure 1(a) uses (-+) boundaries, and Figure 1(b) uses (+-) boundaries. The vertical line represents the position of the boundary corrected for 4 1/2 day solar wind transit time. Each tick mark on the horizontal axis is 1 day, and on the vertical axis is 10 flares.

Figure 2. Same format as above. Figures 2(a) and (b) use only northern hemisphere flares, and (c) and (d) use only southern hemisphere flares. Figures 2(a) and (c) use only (-+) boundaries, (b) and (d) use only (+-) boundaries.

Figure 3. Same format as above. Northern hemisphere flares only are used, with all flares removed which occur on CMP days with 20 or more flares. Only (-+) boundaries are used on 3(a), and (+-) boundaries are used on 3(b).

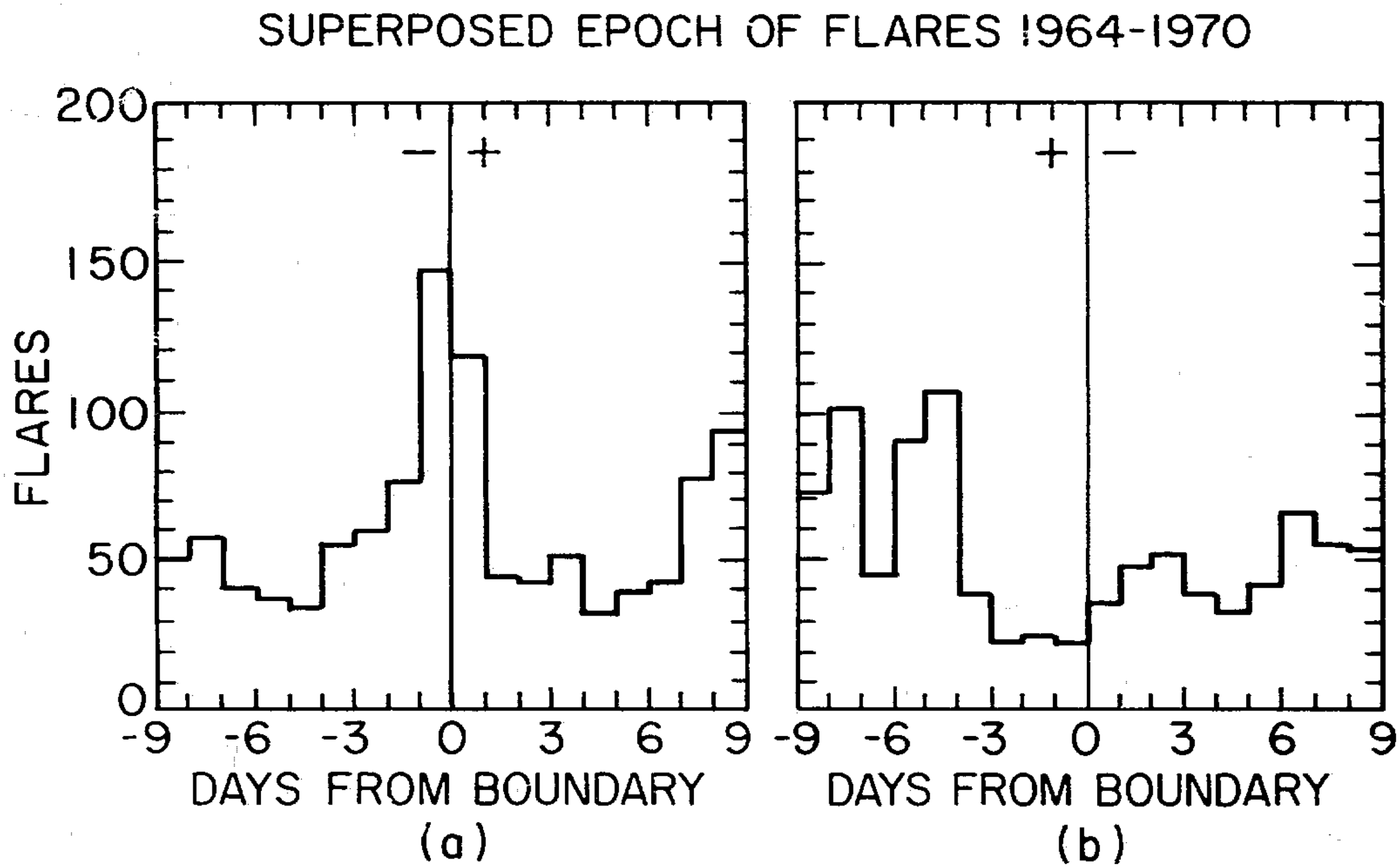
SUPERPOSED EPOCH OF FLARES 1964-1970
FLARES
200
150
100
50
0
-9
-6
-3
0
3
6
9
DAYS FROM BOUNDARY
(a)
(b)
−
+

Figure 1

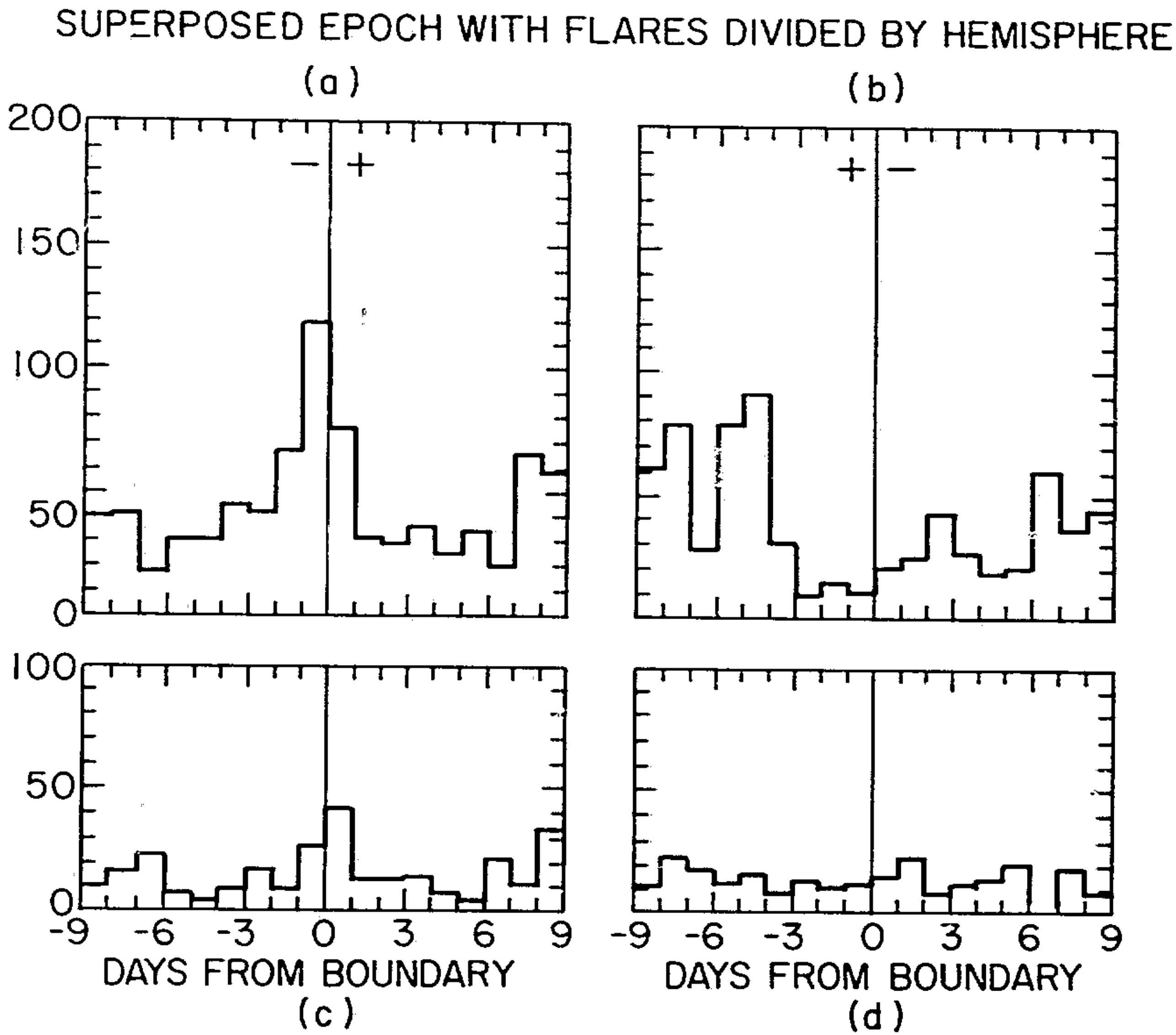
SUPERPOSED EPOCH WITH FLARES DIVIDED BY HEMISPHERE
(a)
(b)
200
150
100
50
0
100
50
0
− +
+ −
-9 -6 -3 0 3 6 9
-9 -6 -3 0 3 6 9
DAYS FROM BOUNDARY
DAYS FROM BOUNDARY
(c)
(d)

Figure 2

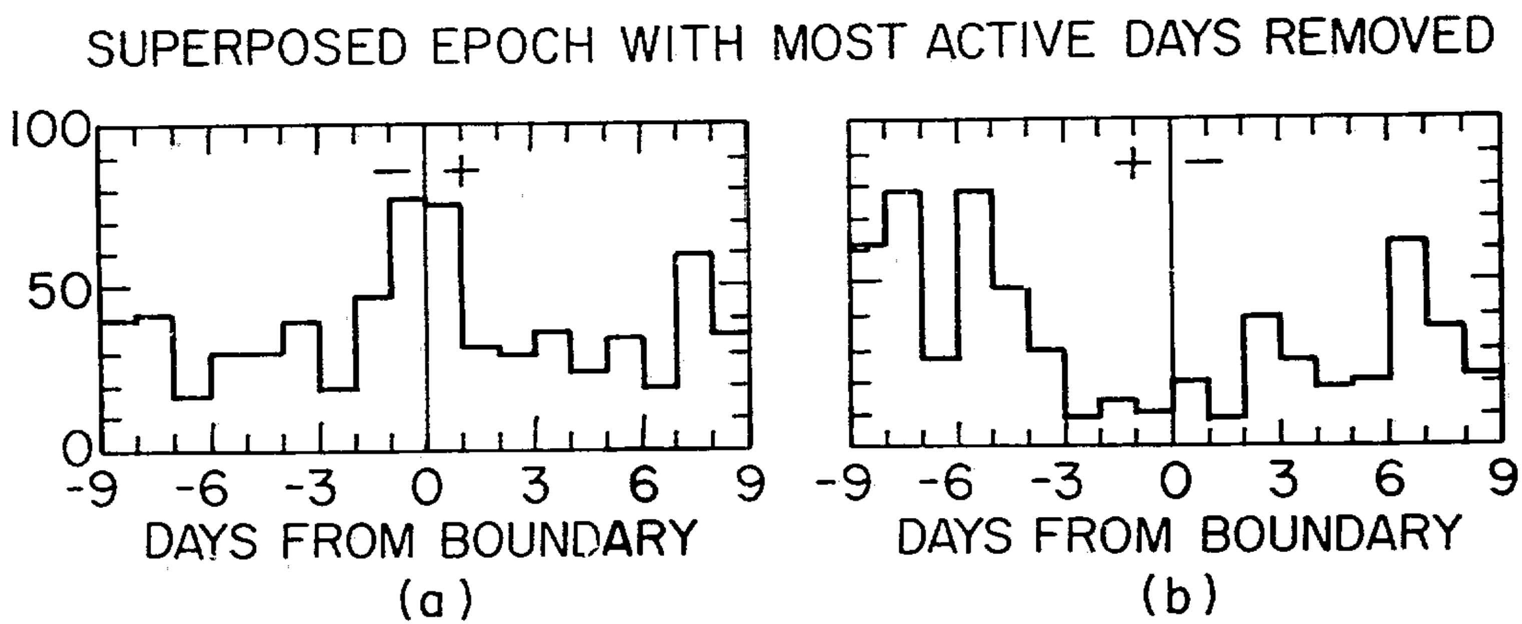
SUPERPOSED EPOCH WITH MOST ACTIVE DAYS REMOVED
100
50
0
-9 -6 -3 0 3 6 9
DAYS FROM BOUNDARY
(a)
-9 -6 -3 0 3 6 9
DAYS FROM BOUNDARY
(b)

Figure 3

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