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Association of solar flares with twisting of magnetic neutral lines

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Abstract. Assuming that the flares tend to occur in highly sheared magnetic fields which also lead to a twisting of magnetic neutral line in complex active regions, we have defined a 'twisting index'. The correlation of this twisting index with flares of various importance classes has been investigated. For cases where at least one bright flare has occurred in the complex active region the number of flare events seems to increase with the twisting index. For the cases of at least one normal flare or all faint flares, a similar but weaker dependence has been noticed.

Key words : neutral line—twisting index—H-alpha flare

1. Introduction

Tanaka & Nakagawa (1973) have shown that the flares of 1972 August can be explained in terms of the energy stored in force-free magnetic field built up by proper motions of sunspots associated with the region of flares, and their later relaxation. The proper motions of sunspots lead to a shearing of potential fields manifested through the twisting magnetic neutral line. Following up this work, Guo-xiang & Fan-xi (1983) have also shown that the twisting of neutral lines may be a potential tool for forecasting proton flares. It is interesting to note that the magnetic energy stored in the sheared force-free fields increases with the increase in magnetic field strength ($\propto B^2$) and increase in shear angle. Thus in an active region where small magnetic field strengths prevail, larger shear would perhaps be needed for the storage of the same amount of magnetic energy for production of strong flares.

In the light of the above, we undertook a study of all H-alpha flares of 1980 July, August and 1981 June (taken from the Solar Geophysical Data and magnetograms from Mt Wilson observatory) with the following aims :

(i) to define a generalized 'twisting index' in the magnetic neutral lines; and
(ii) to correlate the above index with the frequency of occurrence of flares for various importance classes.

The results of the investigation are reported here.

2. Analysis of data

From Mt Wilson magnetograms we have drawn neutral lines between the regions of positive and negative polarities. Since the scale at which the neutral lines are available with us is very small, we plotted them graphically on a much larger scale. Since in general the neutral line is quite twisted and variously curved, we first defined an average neutral line in each case by drawing such a line for which deviations on either side approximately become equal in area. Then, in each case an 'average twisting index' was obtained as follows:

$$I_T = \frac{N}{L} + C + \sqrt{\Sigma(C - C_i)^2},$$

where N represents the number of deviation peaks; L the overall length of the neutral line; C the overall curvature of neutral line irrespective of the direction of the neutral line; and $\sqrt{\Sigma(C - C_i)^2}$ is the sum of i deviations from the mean curvature of neutral line.

The data were first organized on day to day basis and the number of active Hale regions available on that day was considered. The twisting index was then estimated in each casé. From this the number of flares of all kinds, that is, bright (B), normal (N) and faint (F) for the corresponding region were counted. The number of flares of all kinds against the index has been plotted in figure 1. The open circles (○) represent the case when at least one bright flare has occurred; filled triangles (▲) represent cases where at least one normal flare (N) has occurred; and filled circles (●) represent all faint flares. Though the scatter is large it does seem that there is an increase in the number of such flares with the twisting index. This is shown clearly in figure 2 where only such flare events have been used where at least one bright flare has occurred in the region. A similar but weaker dependence on twisting index is noted for such events where at least one normal

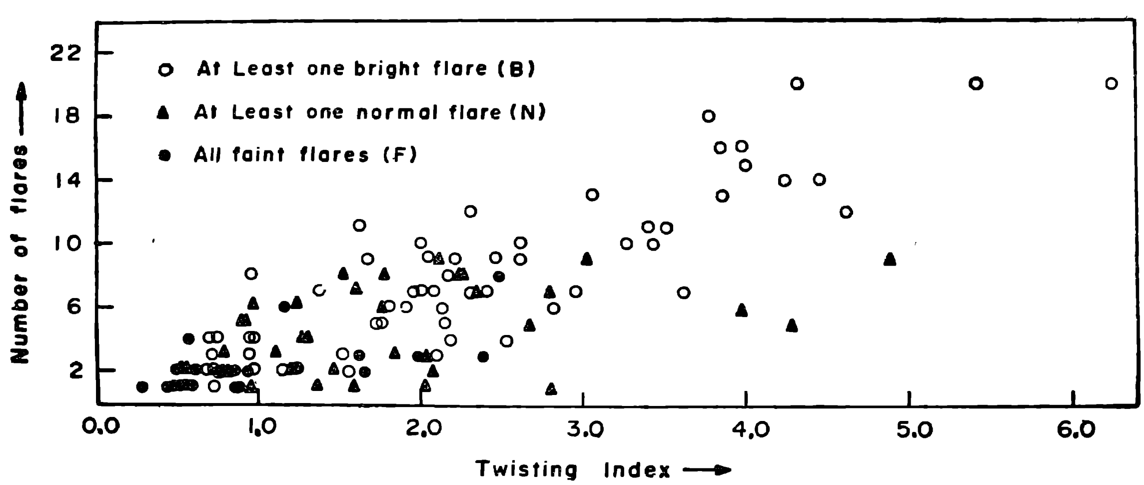

Figure 1. Number of flares versus twisting index. Here open circles (○) denote cases with at least one bright (B) flare, filled triangles (▲) denote cases with at least one normal (N) flare; and filled circles (●) include only all faint (F) flares, for flares of 1980 July, August and 1981 June.

(N) flare and fainter (F) events have occurred. However, for such cases where only faint flares have occurred (*cf.* figure 1) it is hard to distinguish them from the case with at least one normal flare. Figure 3 shows the evolution of magnetic neutral line in the Hale region 16992.

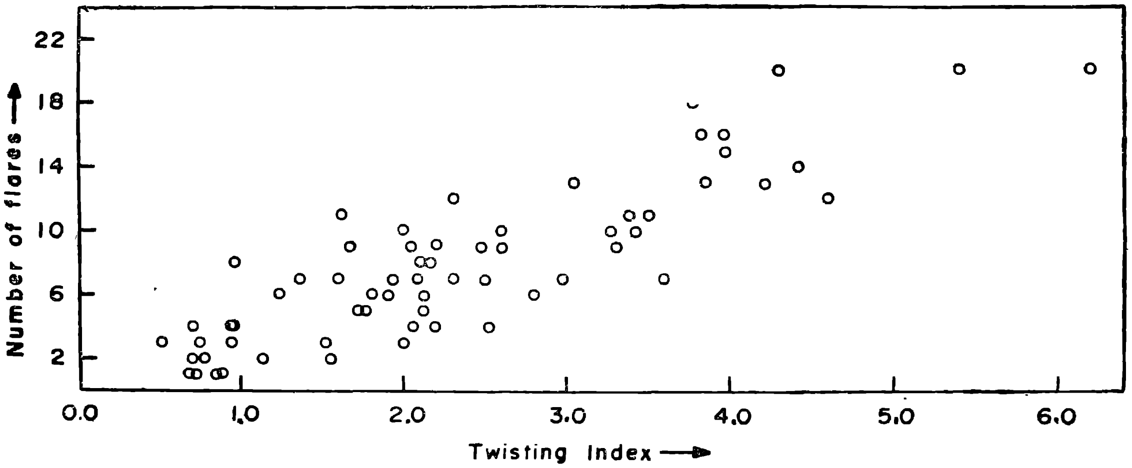

Figure 2. Number of flares versus twisting index for cases where at least one bright flare has occurred.

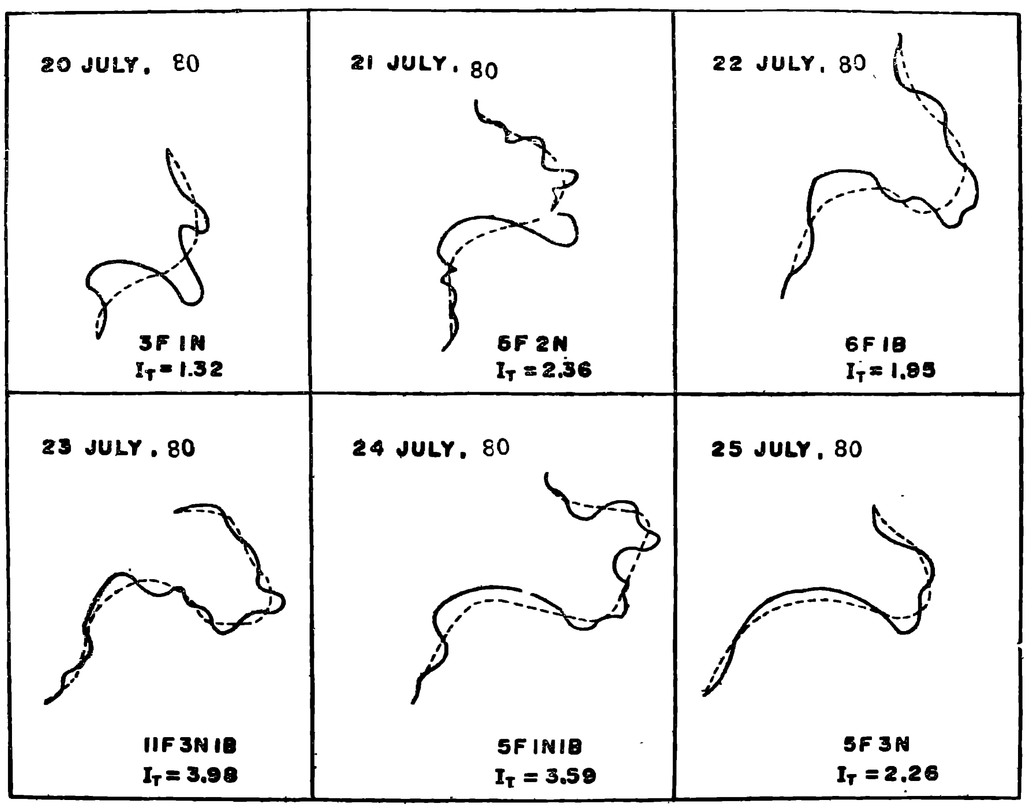

Figure 3. Evolution of magnetic neutral line in the Hale region 16992. Here I_T denotes twisting index (as defined in the text). Further, F, N, and B respectively denote faint, normal, and bright flares. For example, 11F 3N 1B means occurrence of 11 faint, 3 normal, and 1 bright flares in the region on that date.

3. Conclusions and discussions

We thus conclude :

(i) The number of flare events in a complex active region with at least one bright flare increases with the increasing 'twisting index'.

(ii) The number of flare events with either at least one normal flare and or all faint flares only also may have a weaker dependence on 'twisting index'.

It seems that one may have to make simultaneous magnetic field measurements along with the H-alpha observations with high spatial and temporal resolutions before, during, and after the flare events in order to examine the 'local twisting index' for 'bright', 'normal' and 'faint' flares separately. Such an approach will certainly facilitate investigation of flare build-up mechanisms.

References

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