Bull. Astr. Soc. India(1997)25, 533-540

On the triggering of quiet region flares without filament activation

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Received 16 June 1997; accepted 30 August 1997

Abstract. Using Kodaikanal observations we have analysed the cases of quiet region flares which are not associated with any filament activation. The rotations of the plages play a major role in triggering these spotless flares. The relative motions between the adjoining plages are calculated as a measure of shear. We are able to find considerable variation in the shear angle before the onset of a flare.

Key words : flares - sunspots - plages - filaments

1. Introduction

Solar flares generally occur in complex active regions which show fast changes in the magnetic field structure. Coronal levels are considered to be primary flare sites, but coronal magnetic field measurements are difficult to make. However, most of the results show that the magnetic field changes both in the photosphere and in the chromosphere are responsible for triggering flares at coronal levels. It is also believed that the main reservoir of stored energy may be hidden beneath the photosphere and the released energy is loosely related to the amount stored. But still the observations do not show clearly how and where the energy is accumulated for flare production. Yet, it is now established that flares derive their power from the stressed or non potential configuration of magnetic fields (Zirin and Tanaka 1973, Hagyard et al. 1984). The plasma motions of photospheric and choromospheric field structures being in shear which in turn give a non-potential character to the magnetic field. Therefore a flare must be a process associated with dynamics of solar active regions. A small percentage of flare also occurs in quiet regions with small or no spots (Dodson and Hedeman 1970). Švestka (1976) proposed the propagation of a slow-mode-wave from another active region as the cause for triggering a spotless flare. Generally, quiet region flares follow the activation and disappearance of dark H_α filaments (Moore et al.1979; Moore, and La Bonte 1980). The appearance of a newly emerging flux in the adjoining region is reported as the cause for setting this instability which disrupts the filament (Bruzek 1959, Rust et al. 1975). Rausaria et al. (1992) showed that the plage rotation creates the instability by changing the orientation of the H_α filament and subsequently disrupting it in the case of a spotless flare. The quiet region flares without filament activation are rare events. In such cases, it would be appropriate to look for the changes in the magnetic field structures to understand the flare triggering mechanisms. We report here the changes in the orientation of the plages as a measure of shear which sets the instability in the case of a few spotless flares that are not associated with any filament eruptions.

2. Observational data

Twisted or sheared magnetic loops are considered to be the primary condition for flare onset (Martens and Kuin 1989). Complexity in the magnetic field structure stresses the field which in turn induces magnetic shear in the form of changes in the magnetic field pattern. Also shear is induced by the relative motions of magnetic structures. These processes are likely to provide the available energy for flaring. Vector magnetic field measurement at the photosphere provide direct evidence for the twisted or sheared nature of magnetic loops. However, in the absence of vector magnetogram measurements, details concerning the dynamics of active regions and flares can be obtained from the spectroheliograms and white light pictures of the sun.

White light photoheliogram of the sun of diameter 8″ is recorded everyday at Kodaikanal using a 6″ refractor. H_α spectroheliograms in Littrow mount with a solar image diameter of 60 mm″ and Ca II K spectroheliograms of the same size using prisms are recorded daily. The data obtained at Kodaikanal are utilised in the present study.

3. Results and discussions

Plasma motions in the solar atmosphere contribute to an enhancement of magnetic energy over that contained in a potential field. These plasma motions can be inferred from the change observed in the orientations of magnetic field structures in the solar atmosphere. In the solar active regions evolutionary changes take place many hours or even days prior to the flare onset. These changes induce shear and a quantitative measure for magnetic shear at the photospheric level was proposed by Hagyard et al. (1984) from a detailed study of one active region. In the case of quiet region flares, the dynamic activity of the H_α filament is considered to be the best pre-flare indicator (Sundara Raman et al.1993). As the spotless flares reported here do not have any filament activity, the development of magnetic shear is inferred from the changes observed in the orientation of the active regions.

To identify the plasma motions in the solar atmosphere, the photospheric and chromospheric features are sketched on a sun chart. The sun chart is a rectangular plot of heliographic coordinates with corrections for Bo (solar latitude of disk centre). The photoheliogram and its spectroheliogram mates are enlarged to the same size and the position of the sunspots, calcium

K-line plages and H_α filaments are sketched on the same sun chart by carefully noting the pole markings. In this way daily synoptic charts are prepared at Kodailkanal which show the daily solar activity. These charts are used in this study to look for the dynamics of active regions. Quiet region flares are usually connected with adjoining plages. We feel that the changes in the orientation of the neighouring plages from one day to the next exhibit the relative motion of the plages and can be given as a representative of shear. The rotation axis of the sun is taken as a reference for measurement of angles, as there is no filament present in between the plages participating in the flare activity. The following method is adopted to identify the rotation or relative motion of the plages. Figure 1 shows the direction of the plages with respect to the centre of the sun. AC and BC are the lines drawn on the sun chart connecting the centres of gravity A and B of the plages P1 and P2 with the centre of the sun C on its rotation axis NS. It is fairly easy to locate the centres of gravity of the plages that are chosen. The direction of the plages P1 and P2 with respect to the centre of the sun on a particular day of observation is given by angle 'θ' measured from north towards east direction after applying corrections for foreshortening effects. Any variation in this angle θ on the next day represents the rotation or relative motion of the plages and indicates the twist or shear developed in the plages P1 and P2. In this way the shear developed due to the changes in the orientation of adjoining plages is calculated directly from the sun charts of successive days and the values thus obtained are listed in table 1. We are able to find a considerable variation in the shear angle prior to the flare onset. Since too many sun charts are involved in this study, the sequences of photospheric and chromospheric events that are responsible for the flare development are sketched from respective days of the sun charts and are outlined from Figure 2 to 4. Flare regions are marked by arrows in these Figures. These sketches provide simultaneous view of the conditions prevailing at different atmospheric levels of the sun prior to the flare. Figure 5 shows the H_α pictures of the flares. Four cases of quiet region flares observed at Kodaikanal are morphologically studied and the details are discussed below.

3.1 IN flare observed on 19 February, 1973

Figure 2 shows the activity from 14 to 24 February, 1973. Two pores S1 which appear on 14 February evolves as a single spot with multiple nuclei on 16 February. It has decayed into two pores on 17 February and finally disappeared on 18 February. The plage P1 is covering this spot during its evolution. A 1N flare has resulted on 19 February, one day after the disappearance of S1. On 19 February the plage P1 splits, the sizes of P1 and P2 have changed, and in addition a rotation of 9° is seen in P1 and P2 compared to the previous day. The rotation of the plages P1 and P2 sets the instability resulting in a flare in the region covered by the plage P1. The flare region is well above the location of the filament.

The plage P3 does not have any resolvable size from 16 to 18 February and reappeared along with a group of small plages P4 on 19 February. The emergence of P3 on 19 February has caused a change in the direction of the filament F2 pointing towards the plages P2 and P3.

3.2 1N Flare observed an 24 February, 1973

A group of pores S2 appeared on 20 February, 1973 in the region covered by the plage P3

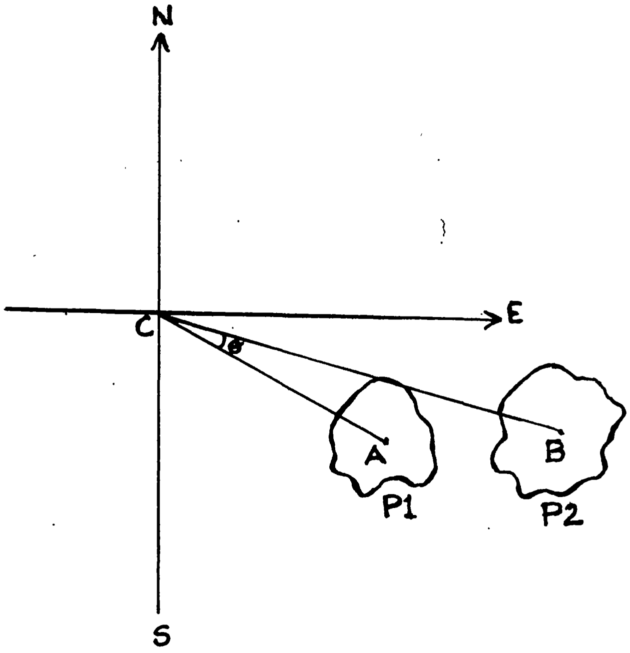

Figure 1. Angle ‘θ’ gives the direction of the plages P1 and P2 involved in the flare activity with respect to the centre of the Sun. Any variation in this angle represents the twist or shear developed in the active region. This line NS represents the solar rotation axis.

Table 1. Change in the orientation of the plages as a measure of shear.

Event	Date	Plage direction in degrees	Magnitude of shear angle in degrees
1	14 Feb. 1973	4	-----
	15 Feb. 1973	-----	-----
	16 Feb. 1973	9	-----
	17 Feb. 1973	10	1
	18 Feb. 1973	10	0
	19 Feb. 1973	19	9
2	22 Feb. 1973	12	-----
	23 Feb. 1973	9	3
	24 Feb. 1973	17	8
3	14 Feb. 1981 (03.24.44)	16	-----
	14 Feb. 1981 (08.04.50)	2	14
4	2 Mar. 1983	25	-----
	3 Mar. 1983	23	2
	4 Mar. 1983	5	18
	5 Mar. 1983	7	2

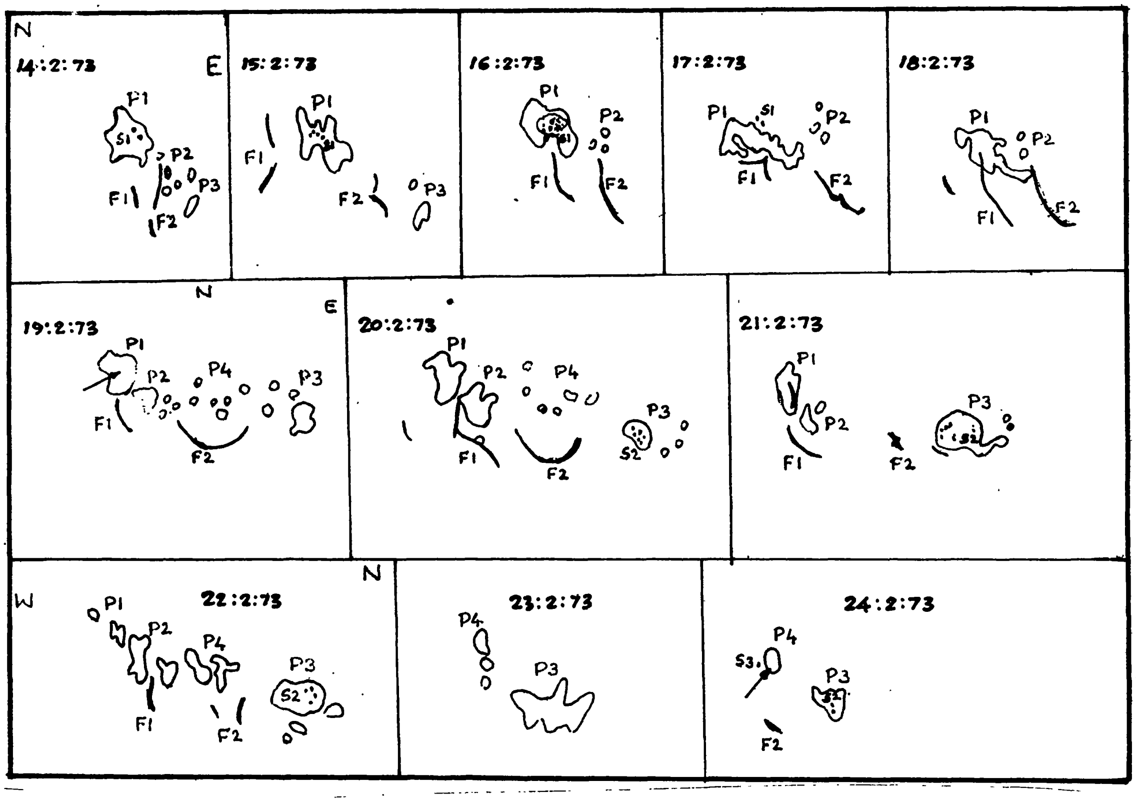

Figure 2-4. Sketches made from the sun charts showing the sequences of events leading to quiet region flares. The positions of sunspots, plages, and H_α filaments are draw from the respective photoheliograms and spectroheliograms over the sun charts.

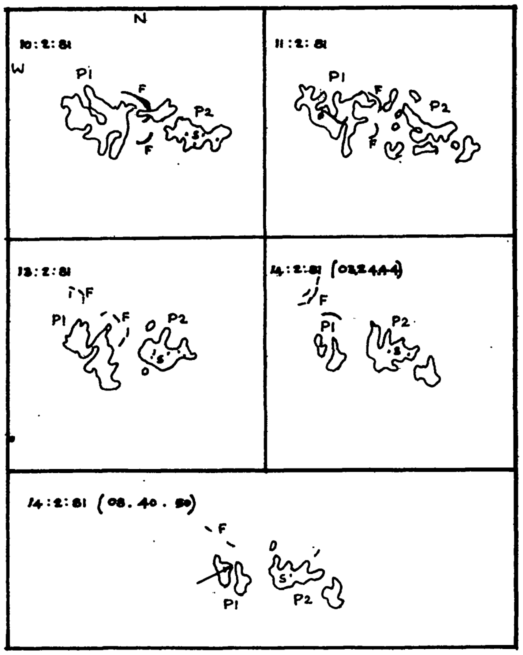

Figure 3.

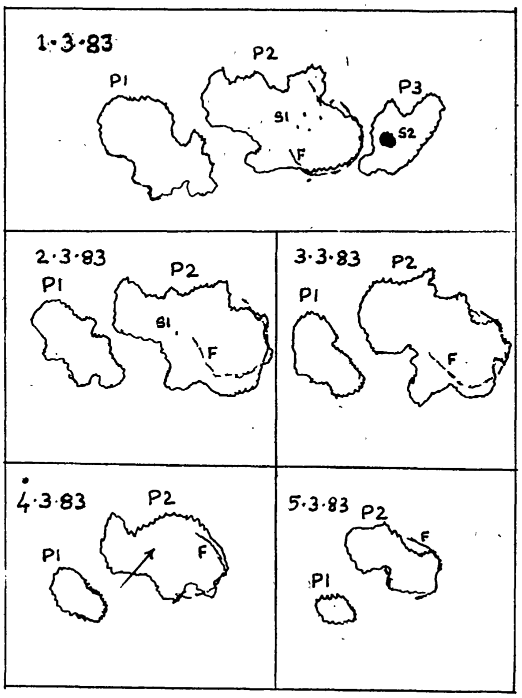

Figure 4.

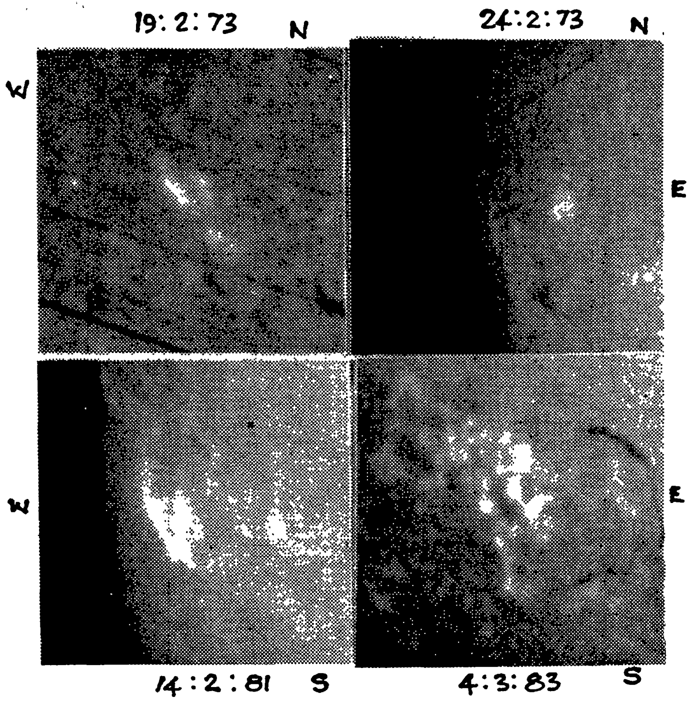

Figure 5. H_α pictures of the quiet region flares.

as shown in Figure 2 and starts disintegrating during 21 to 24 February. The plage groups P1 and P2 disappear on 23 February and a pore S3 has emerged in the region close to the plage P4 on 24 February. There is no photoheliogram observation on 23 February. A rotation of 8° observed in the plages P3 and P4 between 23 and 24 March is responsible for triggering a 1N flare in the plage region P4. It is interesting to note that the flare region does not have any filament activity.

3.3 1B Flare observed on 14 February 1981

The activities from 10 to 14 February 1981 are shown in Figure 3. No spot activity is observed in the plage region P1. A group of pores S appears on 10 February and decays into a single pore on 14 February in the location of plage P2. A filament F is formed between the plages on 10 February. The filament structure and position has changed from 10 to 14 February due to the interaction of the active regions at P1 and P2. The plage P1 is split at 03 24 44 hours on 14 February. A rotation of 14° is observed in the split plages of P1 between 03 24 44 hours and 08 40 50 hours on 14 February but there is no appreciable rotation between the plages P1 and P2. A 1B flare results in the spotless region on the leading part of the plage P1 at 08 40 50 hours on 14 February and is shown by the arrow mark. We feel that splitting of the plage P1 and its rotation has caused the flare. Figure 5 gives the flare in H_α and there is no filament activity seen in the flaring region.

3.4. 1B Flare observed on 4 March, 1983

The activities from 1 to 5 March, 1983 are shown in Figure 4. A new group of pores S1 has emerged on 1 March in the region covered by plage P2. An H_α filament F is present in the region between the sunspots S1 and S2. Since the flare activity takes place in between the plages P1 and P2, the following plage P3 covering the spot S2 is not shown from 2 March onwards in Figure 4. A slight variation in the filament direction from 1 to 5 March is due to the interaction of the active regions P2 and P3. The spot S1 is reduced to a single pore on 2 March and subsequently disappeared on the next day. There is no appreciable rotation of the plages P1 and P2 from 1 to 3 March but a change in the orientation of 18° is observed in the plages P1 and P2 between 3 and 4 March. We believed that the large shear developed on 4 March is responsible for triggering a 1B flare. The flares is in the spotless region covered by the plage P2 and is shown by the arrow mark in Figure 4. The position of the filament is away from the flare region and it is not involved in the flare activity.

4. Summary

The cases of quiet region flares associated with plages have been discussed in this study. The plage corridors or dark lanes which delineates the magnetic neutral line show the opposite polarity plages (Gibson 1973). The flare cases reported here do not have any H_α filament present in the region between the opposite polarity plages where interaction is taking place. The flares on 19 February, 1973 and also on 4 March, 1983 were in a spot free region but pores were present one day earlier in the same locations whereas the flare on 14 February, 1981 is evolved totally in a spotless region. The changes in the orientation of the adjoining plages play an important role for the development of magnetic shear, and storage of energy. We have calculated the relative motion between the plages as a measure of shear. It can be seen from the table 1 and also from Figures 2 to 4 that the same active regions have no flares when the shear value is minimum. Once the shear attains a sufficient value, the instability sets in for the release of stored energy as a flare. For example a 2° shear on 3 March, 1983 has not yielded a flare whereas a shear of 18° observed on the next day 4 March, 1983 has resulted in a flare. Since the changes in the orientation of the plages on a particular day is responsible for triggering these spotless flares, table 1 gives only the magnitude of the shear angle. It suggests that two oppositely directed fields in the form of plages are pushed together in a steady motion, as a result the lines of force reconnect in a neutral plane and the flare is triggered. We conclude that it is possible to predict the flare occurrences by continuously monitoring the changes that are taking place in the active region. In the cases reported here, small pertubations due to the relative motion of the neighbouring plages in an active region play a crucial role in triggering these quiet region flares.

Acknowledgements

We thank Mr. P. Paramasivam for making the photographic prints. We sincerely thank the unknown referee for giving valuable suggestions to improve the paper.

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