PREFLARE ACTIVITY OF SOLAR PROMINENCES

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Abstract. The preflare activity of a plage filament is analysed from Hα observations made with the Multichannel Subtractive Double Pass Spectrograph (MSDP) of the Meudon Solar Tower. The June 22, 1980 event is studied and interpreted in terms of preflare heating of a filament, connected to the rise of emerging flux, and the relative approach of pores of different magnetic polarity, prior to the onset of a two-ribbon flare.

The region with enhanced magnetic field, around the filament, begins to brighten slowly 20 min before the triggering of the flare, in the center of Hα. Filament dark material begins to rise rapidly while the brightest point on one side drifts towards it, 6 min before the onset of the two-ribbon flare. Simultaneously the absorbing material separates from the remaining part of the filament.

In the discussion, we suggest that most of the observed features may be the consequence of emergence of new magnetic flux and the related reconnection processes.

1. Introduction

The preflare activity of active regions filaments has been extensively described by Martin (1980). From her review paper, we note especially features as “the complete or partial disappearance of the filament”, “the increased absorption in the blue wing, the red wing and the line center of Hα as seen with filters of 0.5 Å bandwidth”, and the “visible ejecta of filament fragments”. She notices that the preflare activity begins on average 30 min before the Hα flare start by a Doppler-shifted phase.

The activity of filaments is closely related to the stability of the magnetic configuration and the main question is “what are the conditions for filament instability”? Mouradian et al. (1980) have shown that the Disparition Brusque of filaments may be inferred by heating (with no change in the magnetic field) or by dynamical processes (with filament eruption). This latter class of events has been studied by Malherbe et al. (1983b).

The role of the eruptive filament in the flare process has been discussed by Pneumann (1980), Švestka (1980), Martin (1979), and Švestka et al. (1979). They do not give any conclusions concerning its passive or active role in relation to the magnetic field changes.

We report here the activity in Hale active region No. 16918 (Boulder 2517) on June 22, 1980, which preceded a two-ribbon flare at 13:05 UT (Imp. 2). It was located at S07 W13.

This region has been studied during the Flare Build-up period from 16 to 23 June, 1980 (Martin et al., 1983). It is a decaying region which gave numerous major flares,
most of them related to emerging flux. A well defined complex of filaments is observed along the neutral line. Martin et al. identified by ‘O’ this region.

Preliminary results on the preflare heating have been reported by Malherbe et al. (1983).

We give a description of the events as observed in the $\text{H}_\alpha$ line with the Multichannel Subtractive Double Pass Spectrograph (MSDP) of the Meudon Solar Tower and discuss our observation with theoretical emerging flux models developed by several authors (Tur and Priest, 1976, 1978; Heyvaerts et al., 1977).

2. Observations and Data Processing

On June 22, 1980 a filament eruption was observed by the MSDP operating at the Solar Tower at Meudon Observatory. The instrument is designed to observe simultaneously 9 channels in the $\text{H}_\alpha$ line, covering 2.4 Å (Mein, 1977). The field of view is 1′ × 8′. Time resolution is 1 min and spatial resolution ~ 1 arc sec.

For each pixel, the line profile is reconstituted from the 9 channels, and the line parameters are deduced. Calibration and photometric corrections are described in a previous paper (Mein, 1977).

Data processing is performed to provide standard intensity maps at ± 0.3 Å from the center of the line and the related velocity maps (i.e., the measure of the Doppler-shift with respect to the mean position of the line center). The line profiles are used to analyse the evolution of the chromospheric features.

MSDP data are completed with filtergrams from Meudon Observatory, Debrecen Observatory and Tel Aviv Observatory of Caltech, and with white-light photographs from Debrecen.

In radiowavelength, the Harvard Radio Astronomy Station reported type I bursts from 12:56 to 13:14 UT and a type III burst at 13:02–13:03 UT in the 30–300 MHz band, but they do not give any location on the Sun.

The Nançay Radioheliograph which was operating did not observe the type III burst but only series of preflare type I bursts at 169 MHz (Vilmer, 1983).

The GOES data show a ‘plateau’ both in 1.8 Å and in 0.5–4 Å channels starting around 11:45 UT and a steep rise a few minutes after 13:00 with a maximum at 13:30 UT.

The microwave data (Schmahl, 1983) present a 25% enhancement of the trailing part of the active region. As a flare occurred in that region (26 S–18 E) at the same time as the one observed with MSDP, we cannot determine from what region the type III burst and the X-ray flux originated.

Figure 1 shows the region under study 30 min before the flare. The filamentary structure lies along the main axis of our field of view. This filament is rather faint and overlies the bright region which is identified as the new emerging flux region ‘O’ (Martin et al., 1983). It stays at the same location during our observation.
Fig. 1. (i) Hα intensity map (± 0.3 Å) at 12:50:50 UT on June 22, 1980 from MSDP data. Isocontours are white (or black) for intensities brighter (or respectively darker) than the mean chromosphere (arbitrary units). The filament is indicated by the dashed line. Regions (a), (b), and (c) and point D refer to different studied areas. (ii) Hα velocity map (± 0.3 Å) at 12:50:50 UT. Contour levels are −2 and −1 km s⁻¹ (black), 2 and 1 km s⁻¹ (white). (iii) Magnetic field map at 09:36 UT from Meudon magnetograph. Contour levels are −50, −30, and −10 G (black), 10, 30, and 50 G (white). The box corresponds to the MSDP field of view and the dashed line to the filament location.

3. Description of the Observations

3.1. PHOTOSPHERIC DATA

The Debrecen white-light observations show that two pores are present in that region, noted O₈ and O₉ in the paper by Martin et al. (1983). They are located on each side of the filament with opposite magnetic polarities. They have relative velocities of approach higher than 0.2 km s⁻¹. This observation is crucial to understand the mechanism of both the filament eruption and the flare.

3.2. INTENSITIES IN THE FILAMENT AND IN THE NEIGHBOURHOOD

Figure 2(i) shows the filament mean intensity along its long axis at different times. We can distinguish 3 parts with different behaviour:
(a) strongest absorbing part of the filament;
(b) faint part of the filament;
(c) part of the filament crossing the Emerging Flux Region (EFR) which presents a discontinuity in D.
Fig. 2.  (i) Hα intensity (arbitrary units) along the filament for several times. Note the stability of emission before the flare, except through the EFR (region (c)) where intensity is enhanced. (ii) Doppler velocity (km s⁻¹) along the filament for the same times. Significant upward velocities are observed through the EFR a few minutes before the flare. A strong downflow appears in the western region at flare onset. The regions (a), (b), and (c) are defined on Figure 1. Note the discontinuity of intensity and velocity in D.
The time evolution of each part is shown in Figure 3. Regions (a) and (b) remain stable until flare onset when the filament becomes bright in the center of the line. Intensity in region (c) is presented for each side of the discontinuity $D$: $c_1$ that joins the quiet part of the filament to the EFR shows an enhancement from 12:58 UT while the part $c_2$ (crossed curve) is always bright with enhanced intensity from 12:52 UT. For the 3 regions, the intensity decreases after the flare onset, but the filament has not yet been relaxed to its previous state at 13:50 UT.

Some important results can be emphasized from the observation of the region surrounding the filament.

The whole region of enhanced magnetic field is bright. Hα kernels of the flare lie on the south side of the filament part (a), (b), and (c) and on the north one of region (c) (see Figure 1), which indicates a highly sheared magnetic configuration.

The position of the maxima of intensity for each time are drawn in Figure 4, with the filament location. The north side maxima $B$ and $C$ do not move significantly; on the contrary, the brightest point $A$ on the south side begins to drift toward the filament at 12:59 UT with a horizontal velocity of 20 km s$^{-1}$. This important observation will be a main feature for the discussion of the physical process of triggering the flare.
3.3. **Velocities in the Filament and in the Neighbourhood**

The Doppler velocities along the filament are presented in Figure 2(ii). They are generally upward and rather small ($\leq 2$ km s$^{-1}$). Region (c) shows a strong discontinuity in point D as observed from the intensity. Velocity in $c_1$ is generally downward while in $c_2$ it is rather upward with an increase from 12:59 to 13:02 UT (Figure 3).

In region (a) a red doppelshift is observed when the flare is triggered. The profiles show dark material falling down into the chromosphere.

Well defined velocity cells are present near the filament, especially on the side affected by the flare. They remain during the observations and new cells appear as the flare is triggered.
3.4. ABSORBING MATERIAL EVOLUTION

The points where high velocities are observed have been carefully studied, using the whole profiles. One of them is illustrated in Figure 5.

Profile 1 characterizes a bright pixel near the filament and 2, the same pixel, two minutes later. It is clear that the profile 2 is disturbed in the blue wing. We interpret such a profile by the absorption of the chromospheric light by a cloud of dark material rising from the filament into the corona between 12:59 and 13:04 UT. Such asymmetric profiles have been observed with the MSDP in filaments (Malherbe et al., 1983) or in surges (Schmieder et al., 1983). Velocities greater than 50 km s\(^{-1}\) are inferred for the absorbing cloud.

Always connected to the filament during that early phase, the cloud presents a sharp edge at the discontinuity \(D\), while the whole eastern end of the filament is affected by the rise of the material.

The Debrecen filtergrams at 13:02, 13:03, and 13:04 UT (Figure 6) show that this dark material is no more connected to the filament after 13:03 UT. This means that the eruption stops when the flare is triggered, although the cloud is still rising into the corona.

4. Discussion

The two-ribbon flare phenomenon has been discussed theoretically by several authors.
Fig. 6. Hα (−0.5 Å) filtergrams from Debrecen Observatory at 13:02, 13:03, and 13:04 UT. The rising dark material is no more connected to the filament after 13:03 UT, as the flare is triggered.
Sturrock (1968) proposes a streamer-like magnetic configuration. The flare is initiated by the occurrence of a tearing-mode instability in the open current sheet.

Heyvaerts et al. (1977) develop an emerging flux model in which the instability is initiated by turbulence onset as the current sheet formed between the new and old flux rises into the chromosphere. This model may explain some observed characteristics of most of the two-ribbon flare phenomena: the preflare heating and the eruption of the filament, the related coronal events and the onset of the flare. The authors follow the Kopp and Pneuman (1976) model (developed by Cargill and Priest, 1982; and by Forbes and Priest, 1982) for the production of an open magnetic structure by the filament eruption: heat is conducted from a region which produces magnetohydrodynamic shock waves down to the chromosphere to produce H\(\alpha\) ribbons. An alternative explanation is given by Priest (1976) that requires a closed cylindrical domelike structure: successively higher sheets are destabilized to infer the observed outward moving ribbons.

The current sheet formation has been studied by many authors (see the review from Priest, 1981). Models involving magnetic evolution forced by a decrease of the distance between dipoles (Priest and Raadu, 1975) or by the relative change of the magnetic moments of dipoles (Tur and Priest, 1976) have been developed. The Tur and Priest analysis shows that a curved current sheet is formed when a small dipolar flux system emerges against a larger dipolar field. The location and shape of the sheet change with the increase of the new flux, as shown on Figure 7, and the lower end point moves towards the larger dipole.

Our observations show clearly the influence of the emerging flux on the filament behaviour. Only the part crossing the EFR is associated with the preflare heating and with the slow preflare rise of the filament material (before 12:59 UT), while enhanced chromospheric heating coincides with the bipolar photospheric magnetic field structure.

The most important point for the discussion is the evolution during the last 5 min before the flare onset: (i) The filament erupts while the brightest (hottest) point in the chromosphere moves toward the neutral line and the photospheric pores \(O_8\) and \(O_9\) approach each other (the velocity of \(O_9\), associated to the H\(\alpha\) moving bright point, is the most important); (ii) the rising material separates from the remaining part when the flare is triggered. Observation (i) may be understood with the Tur and Priest (1976) model if we consider that the moving point is related to the lower end point of the current sheet. The filament eruption may be produced by enhanced pressure at the base of the filament which causes the height of the filament to exceed the critical value for the eruptive instability (Hood, 1980).

The observation (ii) shows that the filament eruption stops when the flare begins. That means that reconnection processes have isolated the rising part of the filament which continues its travel through the corona as a dark cloud while the underlying magnetic configuration closes again. The filament reforms a few minutes later as shown on H\(\alpha\) line center filtergrams from Debrecen Observatory.

The dark cloud seems to be channelled by some wide magnetic arcade, which implies that the magnetic configuration over the filament is not open. The absence of type III burst clearly related to this event prevents us to deduce the magnetic configuration from
Fig. 7. Schematic representation of the magnetic field configuration in the plane perpendicular to two line dipoles at \( x = \pm a \), (a) for a purely potential situation, with a neutral point at \( Z_N \); (b) after an increase in moment of the smaller dipole resulting in the formation of a current sheet between \( Z_1 \) and \( Z_2 \); (c) the locus (dashed) of the end points of the current sheet as the moment of a dipole at \( x = -a \) increases from 0.01\( D_A \) to \( D_A \), where \( D_A \) is the moment of a constant dipole at \( x = +a \). Several examples of the sheet, showing its shape, are superimposed (after Tur and Priest, 1976). The plane of this representation may be the vertical plane which contains \( A \) and \( C \) (see Figure 4). The filament is represented in the hatched area. The moving point \( A \) is, in the chromosphere, connected to the lower point \( Z_1 \) of the current sheet.
coronal manifestations. Nevertheless, the observations of preflare type I with the Nançay Radioheliograph may give some evidence for the existence of a large overlying arcade connecting neighbouring active regions.

We give however great importance to the Hα observation to conclude that the Priest's closed model (1976) is more likely than the open structure model developed by Kopp and Pneuman (1976) to explain this particular event. This idea is reinforced by the dynamic behaviour of the filament. It has been shown in Section 3 that the velocities were rather small. No plasmoid with high velocity was seen such as Malherbe et al. (1983b) observed for the 22 June, 1981 when a filament clearly erupted. The reformation of the filament during the flare shows that the magnetic configuration supporting the filament has not been destroyed during the flash phase.

5. Conclusion

The events described show the various stages of the onset of a two-ribbon flare. We have been able to investigate important features such as preflare heating and filament eruption with a good temporal and spatial resolution. Furthermore, our observations in the Hα line indicate that the instability happens in a rather tiny region close to the filament, which would be the signature of a current sheet formed by emerging magnetic flux. The emergence of flux manifested itself through the pores. The relative motion of the pores did serve for the crucial triggering of both the filament eruption and the flare.

Following a slow rise period, the filament eruption is simultaneous with the drift of the Hα brightest point in the enhanced flux region toward the neutral line, during 5 min before the flare. The filament eruption and the flare onset appear to be two consecutive phenomena induced by different phases of the emergence of the flux and the reconnection processes. We find no evidence of the opening of the overlying magnetic structure. On the contrary, from the trajectory of the cool material that has been blown up from the filament, we may suppose that the magnetic topology remains closed.

To obtain more conclusive information on the phenomena which trigger the filament eruption, flare onset and evolution of the magnetic structure, it would be necessary to get high spectral, spatial and time resolution coordinated observations at all levels in the solar atmosphere.

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