MAGNETIC SOURCES OF FLARES AND CMES FROM MULTI-WAVELENGTH FLARE STUDIES

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ABSTRACT

We will present the data analysis of an observing campaign on October 2003 with the objective of understanding the onset of Coronal Mass Ejections (CME) and solar flares. The magnetic field was observed with THEMIS and MDI, the chromosphere with the MSDP operating on THEMIS, the EUV images with SOHO/EIT and TRACE, the X-rays with RHESSI. We will show how important is the magnetic configuration of the active region to produce CMEs. Two examples of flares will be presented: the 28 Oct 2003 X17 flare and the 20 October 2003 M1.9 flare. The magnetic field analysis of the active region is done using a linear-force-free field code. The X17 flare gave a halo CME while the M1.9 flare has no corresponding CME. Before the X17 flare there was a pre-flare event which allowed to change the connectivities in a first phase and to relax the stressed field in a second phase producing the X17 flare. A compact twisted emerging flux was responsible of the M1.9 flare, which remains a compact flare due to very tied overlying loops. RHESSI showed that even during the M1.9 flare both components thermal and non thermal component are present.

Key words: sun; flares; coronal mass ejections.

1. INTRODUCTION

After October 19, 2003, and for about two weeks, the Sun displayed an extraordinary level of activity. Twelve X-class (X-ray GOES classification) flares and many smaller ones (lower class) were observed. Other phenomena were associated with these flares, including coronal mass ejections (CMEs) and strong fluxes of accelerated particles (electrons, protons and neutrons). The extremely high level of activity resulted from the formation of three \(\beta-\gamma-\delta\) sunspot groups (NOAA 10484, 10486, 10488). Eight of the X-flares started in active region (AR) 10486. Various aspects of this activity period have been investigated in special issues of the Journal of Geophysical Research, Geophysical Research Let-

\[\text{ters} \quad \text{and Space Weather published in 2004 and 2005 (see: http://www.agu.org/journals/ss/VIOLOCON1/).} \]

Most models for the initiation of flares and/or CMEs share the assumption that the stored magnetic energy lies in a low lying magnetic flux system (sheared or twisted). In general, models differ in the way the flare and/or CME is initiated and, also, in the precise role played by the overlying field.

We present two cases of flares, an explosive event on October 28, 2003 in region AR 10486 and a confined flare on October 20, 2003 in region AR 10484.

2. X17 FLARE OF OCTOBER 28, 2003

A major two-ribbon X17 flare occurred on 28 October 2003 in the active region NOAA 10486. The time evolution of the magnetic field in this region is presented in
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Figure 2. High-resolution THEMIS/MSDP magnetic field map obtained at 15:15–16:30 UT (upper panel) and detailed SOHO/MDI magnetic field map with four main polarities 1 – 4 (lower panel).

Fig. 1 (Schmieder et al. 2006).

This active region was also observed with THEMIS/MSDP instrument (Fig. 2 - upper panel). In the lower panel of this Figure we present the areas of four main polarities playing an important role in the flare origin. This flare was accompanied by the eruption of a filament in the central part of the region (Fig. 3 - left panel) and a fast halo Coronal Mass Ejection (Fig. 4).

We focused on the analysis of magnetic field (SoHO/MDI) and the brightenings observed in TRACE 1600 Å before the X17 flare (Fig. 3 - right panel). This pre-event involves a large scale quadrupolar reconnection processes that contributes to decrease the magnetic field tension in the overlying field configuration. It is a similar process that is proposed in the breakout model (Antiochos et al. 1999) but in our case the topological study does not exhibit the existence of a null point (Fig. 5). We proposed that magnetic reconnection occurs at Quasi-Separatrix layers (Mandrini et al. 2006).

3. M1.9 FLARE OF OCTOBER 20, 2003

The flare observed on October 20, 2003 occurred in a complex active region NOAA 10484 with a δ configuration (Fig. 6). The magnetic field observed by THEMIS in the Na D1 line was compared with the MDI map and a good correlation was found (Fig. 7). We used the EUV observational data from SOHO/EIT obtained with a cadence of 12 minutes.

Figure 4. Coronal Mass Ejection observed with SOHO/LASCO on October 28, 2003 at 11:30 UT.
Figure 5. Coronal magnetic field model of AR 10486. The lines show the original magnetic connectivity and the connectivity after reconnection.

Figure 6. Magnetogram at 07:59 UT (b) and intensity image at 06:46 UT (c) observed by SOHO/MDI (NOAA 10484). Magnetogram and intensity image (d, e) observed by THEMIS in the MSDP mode at Na I line 5896 ± 0.1Å.

Figure 7. Scatter plots of the longitudinal magnetic field $B_{\text{THEMIS}}$ at 0.3Å vs. $B_{\text{MDI}}$, plotted only for the area covering the sunspots (left panel) and for the area covering the solar network (right panel). Dashed line represents the equal-value line while continuous line shows the linear fit obtained for these two sets (THEMIS and MDI) of data. X and Y are the parameters of linear fit (Berlicki et al. 2006).

Figure 8. SOHO/EIT images of NOAA 10484 at 304 and 195Å on October 20, 2003.

The flare showed two ribbons R1 and R2 in 304Å wavelength, which underwent different changes in area and intensity versus time, and later on (30 minutes) a third one R3 with a "J shape" (Fig. 8). The ribbon R1 overlays the negative polarity, and the ribbons R2 and R3 the positive polarity. The 195Å image shows the high temperature loop connecting R1 and R2. The presence of the three ribbons observed in Hα and 304Å was interpreted by analysing the magnetic topology. We extrapolated the photospheric magnetic field obtained by THEMIS/MSDP with the assumption of a current–free field configuration and using the code developed by Démoulin et al. (1997) (code base of FROMAGE).

The ribbons are located in regions where the field changes of connectivity (Fig. 9). This suggests that these regions are corresponding to places where quasi-separatrix layers intersect the chromosphere (Démoulin et al. 1997). The successive appearance of ribbons is explained by multiple reconnections. This scenario is confirmed by the RHESSI spectral analysis (Li et al. 2005).
4. CONCLUSIONS

We presented two different cases of flares: an eruptive flare accompanied with CME and a confined flare without CME.

- For strong flares when the magnetic stress in the region is very large, it is particularly interesting to understand what happens long before the eruption, how the eruptive instability was built-up and how the magnetic energy is released. In the case of X17 flare on October 28, 2003 there was a quadrupolar reconnection before the main flare, but no null point was found during the magnetic topology analysis. It seems that the reconnection occurs with quasi-separatrices configuration. The main stored energy is not released during the pre-event but the release can occur when the overlying magnetic field is open. This ejection leads to a large halo CME.

- On October 20, 2003 the energy is released progressively as the field lines change of connectivity, with no sudden reconnection. Multiple reconnections are identified. That explains why the region produced only a relatively small flare and why the flare stayed confined and did not produce a CME.

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REFERENCES


Figure 9. Extrapolated magnetic field lines using the longitudinal magnetic field observed by THEMIS at 09:13:15 UT (background images) for the active region NOAA 10484. Thick lines indicate the lines where the change of connectivity is significant.