STUDY OF A SMALL-SCALE ERUPTIVE EVENT OBSERVED BY SOHO/SUMER

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ABSTRACT

We report on theoretical modeling of an eruptive event observed by SoHO/SUMER in H I Lyβ 1025.72 Å, C II 1037.00 Å and O VI 1037.64 Å emission of the quiet solar atmosphere. We are using two different theoretical approaches. The first one is based on the application of the cloud model to a loop hanging in the solar atmosphere and being irradiated by incident photospheric and chromospheric emissions. This model gives spectral profiles of the hydrogen Lyβ line that are in good quantitative agreement with the observations. The second approach is based on potential-field extrapolation of the photospheric magnetic field as from SoHO/MDI line-of-sight magnetograms into the upper layers of the solar atmosphere. Here, the aim was to find evidence for a possible magnetic reconnection process responsible for the energy release during the observed event. We found that the event is located closely to a separator field line intersecting two separatrix surfaces which evidence the possible magnetic reconnection process. The typical height of the loop systems derived from magnetic field extrapolation is in good agreement with the top height of the eruptive event structure computed from the cloud model. Finally, two possible scenarios of the eruptive event are proposed.

Key words: Sun: transition region; Sun: magnetic field; Sun: UV radiation.

1. INTRODUCTION

There is still unsolved enigma of solar corona heating. An observations of the solar atmosphere by instruments on SoHO (*Solar and Heliospheric Observatory*) allow a deeper insight into this problem. Two kinds of controversial small-scale events are often observed by SoHO in the transition region (hereafter TR) emission lines, namely blinkers (e.g. Harrison, 1997; Bewsher et al., 2003) and explosive events (e.g. Brueckner & Bartoe, 1983; Innes et al., 1997). Blinkers are small intensity enhancements lasting ∼13 minutes as observed in the TR emission lines by CDS (*Coronal Diagnostic Spectrometer*; Harrison et al., 1995) instrument. They mostly appear above regions of strong single polarity magnetic field. Plasma velocities associated with blinkers are up to 30 km/s in the quiet Sun and up to 40 km/s in active regions, and blinkers profiles are mostly redshifted. Explosive events are transient brightenings usually observed by SUMER (Solar Ultraviolet Measurements of Emitted Radiation; Wilhelm et al., 1997; Lemaire et al., 1997) spectrometer and they are accompanied by strong non-Gaussian profiles witnessing velocities up to 300 km/s and cancellation of the photospheric magnetic field. The mean lifetime of an explosive event is ∼4 minutes. After almost a decade of comparisons of blinkers and explosive events it is still not clear whether or not there is a relationship. Peter & Brković (2003), Brković & Peter (2004) and Bewsher et al. (2005) studied variability of the quiet Sun spectra of the explosive events and blinkers. They concluded that blinkers and explosive events are not physically connected to each other although there are some correlations between them. It seems that the investigation of such small-scale eruptive events could play an important role in understanding the energy transfer processes, because high velocities could well be directly related to reconnection as it has been suggested by Innes et al. (1997).

2. OBSERVATIONS

We present a re-analysis of the eruptive event that has been observed on May 5, 1999 in the TR C II 1037.02 Å and O VI 1037.62 Å lines. Also chromospheric response associated with the event was detected in the Lyβ 1025.72 Å line. The observations were performed using the SUMER spectrometer in the frame of the SoHO JOP078 (Kučera et al., 1999). The main geometrical and physical parameters of the eruptive event were derived (Tomasz et al., 2003; Tomasz et al., 2004). The event was composed of three brightenings, it had an extent of 7200 km corresponding to 9 pixels along the SUMER slit (Fig. 1) and it lasted during 7.5 min. A single Gaussian fitting of the O VI line revealed small values of χ^2 and of the line width within the first and second burst.

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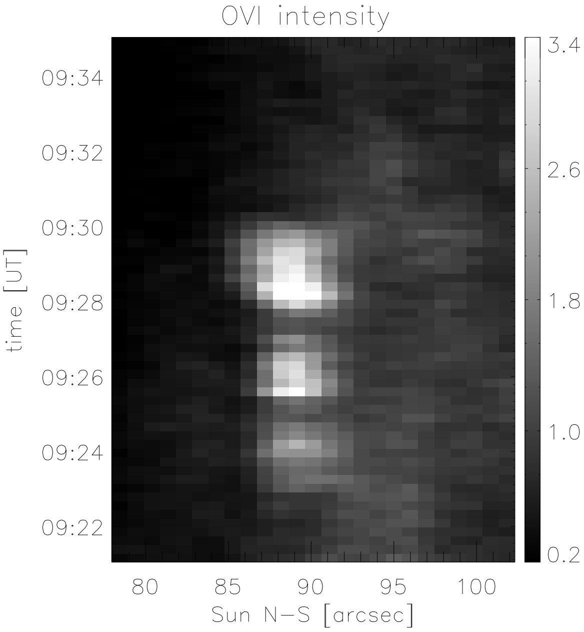

Figure 1. An eruptive event was detected as an increase of the intensity in the TR O VI *line. The event had a substructure of three distinct, repetitive bursts. Intensity is expressed in W/sr/m^2/Å.*

The rapid increase of these parameters during the third burst suggests that the O VI line profile is non-Gaussian in shape and consists of multiple Gaussian components. Decomposition of the O VI profile into two Gaussians revealed the bi-directional nature of the third burst (Fig. 2). Velocities of both signs were simultaneously observed spanning the range from -35 km/s to +50 km/s. The eruptive event was also detected in C II, a line formed in the lower TR. Single Gaussian fitting of the C II line was found to be adequate and the intensity variations of C II and O VI were co-spatial and co-temporal.

The chromospheric response of the eruptive event in integrated intensity of the Lyβ line has shown temporal and spatial shifts relative to the intensity of the O VI line. The response in the Lyβ line occurred $\sim$90 s after the beginning of eruptive event in the O VI line. Moreover, the maximum of the Lyβ line was spatially shifted by 2 arcsec as well as temporally shifted by 60 sec relative to the peak emission in O VI line.

The task of the coalignment of SUMER and MDI data was accomplished in two steps. The coalignment of the specially selected Lyβ SUMER data and Lyα TRACE data was done first. Secondly, TRACE white-light and MDI white-light data were used to coalign data of these two instruments. Using both transformations we were able to convert SUMER coordinates into MDI coordinates. The resulting coalignment uncertainty was estimated to be less than 3 arcsec.

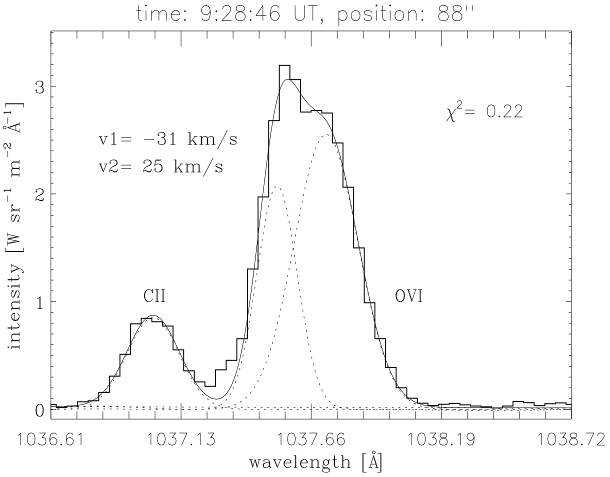

Figure 2. Decomposition of the individual O VI *line profile from the third burst where single Gaussian fitting was insufficient. Two Gaussian components with the Doppler shifts of both signs are present after applying double Gaussian fitting. These components point to a bi-directional nature of the event likely caused by magnetic reconnection.*

3. CLOUD MODEL

A cloud model (Heinzel et al., 1997) was used to compute the vertical structure of the observed eruptive event. This model assumes an isolated structure (usually a loop or a system of loops) hanging in the solar atmosphere at the height of h and with geometrical thickness of D, being illuminated only from below. The outgoing intensity depends on the geometrical parameters of the structure.

The Lyβ line was used for the computation of the vertical structure of the eruptive event. As it was not possible to directly determine the incident intensity we used a mixture of the intensity of the internetwork before and after the event, of the intensity from the network elements in the vicinity of the event, and of the intensity of pure internetwork. We obtained synthetic profiles for the Lyβ line by varying the geometrical thickness D and the height h. Synthetic profiles were compared to the observed ones and characterized by a χ^2 parameter as in the example given in Fig. 3.

We found a thickness D of the eruptive event between 370 km and 590 km. The uncertainty of this parameter is $\sim$400 km thus, we can not detect changes of the thickness during the evolution of the event. For the average height above the solar surface we derived a value of h of $\sim$1600 km. Variations in height are not visible because of the uncertainty of $\sim$700 km. Therefore no temporal changes of the thickness and height due to evolution of the eruptive event were considered.

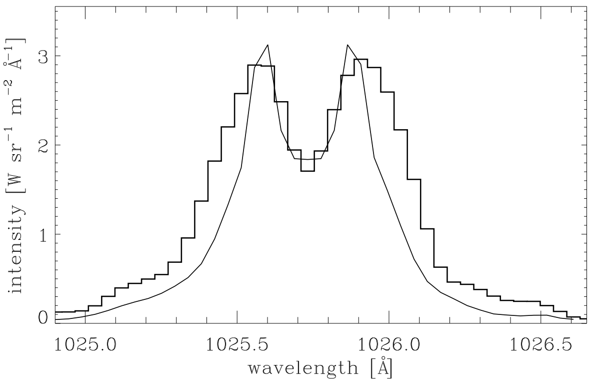

Figure 3. Comparison of the Lyβ observed and synthetic profiles. Observed profile (histogram) is in relatively good agreement with the synthetic profile (solid line) computed from the cloud model. This particular profile corresponds to the model parameters D=440 km and h=1650 km.

4. MAGNETIC FIELD EXTRAPOLATION

Bi-directional jets and transient bursts are typical features of explosive events, supposedly evidence of magnetic reconnection. Therefore we studied the localization of the magnetic field loops in the solar atmosphere as well as the magnetic field topology associated with this particular eruptive event. To complete the above mentioned study, we have extracted a small field of view of 400x400 arcsec^2 from full disc MDI line-of-sight magnetograms with a time cadence of 1 min and a spatial resolution of 1.97 arcsec.

In order to determine the configuration of the magnetic field in the vicinity of the eruptive event we extrapolated the SoHO/MDI photospheric magnetic field following the current-free (potential) field assumption. We used a computational box of 400x400x100 arcsec^3 with open boundary conditions to take into account the existence of open field lines and/or the large scale magnetic field. In Fig. 4, we plot characteristic field lines associated with a magnetic field strength of about 20G around the slit (white line). Two loops systems are identified originating in the negative polarity (South) in the internetwork and connected to two positive polarities (North) along the network boundaries in different place of origin along the network. The magnetic field distribution is equivalent to the topology of a broken fan as discussed by Longcope & Klapper (2002, see their Fig.2): two connectivity domains are divided by a separator field line intersecting two separatrix surfaces. The separator field line intersected the SUMER slit position exactly in the middle of the position of the eruptive event along the slit. There were only small changes of the magnetic configuration before and after the eruptive event. Therefore we can not conclude on the amount of released magnetic energy.

Two areas of 'north' footpoints of size 3×5 pixels and 4×4 pixels and one area of 'south' footpoint of size 4×3 pixels were used to see changes of the magnetic field strength. We found that these changes were below 20 G. This value is comparable to the uncertainty of the MDI measurements of the magnetic field strength.

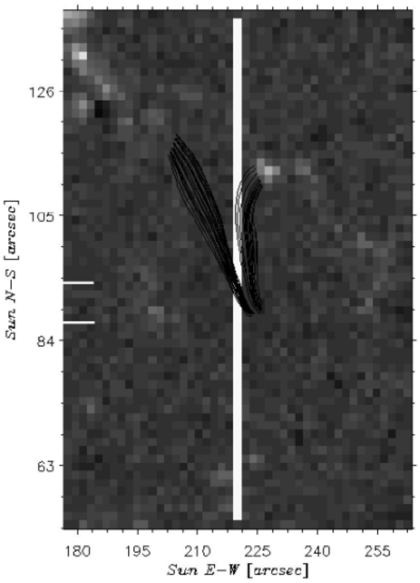

Figure 4. Configuration of the magnetic field in the vicinity of the SUMER slit just after the eruptive event vanishing. White horizontal lines on the edge of the figure mark the spatial interval where the eruptive event was observed along the SUMER slit (white thick vertical bar). This place is situated in an area of the separatrix surface, where magnetic reconnection often takes place.

The characteristic height of the extrapolated loops was found to be between 1200 km and 1900 km before and between 1150 km and 1600 km after the eruptive event. This is consistent with the results derived from the cloud model.

5. CONCLUSIONS

Spatial and temporal coincidence (within the coalignment error between SUMER and MDI data) of the eruptive event and the separatrix surface between two systems of loops allow us to conclude that the observed TR eruptive event and its chromospheric counterpart were caused by a magnetic reconnection at the separatrix surface where magnetic reconnection is very likely. We propose two alternative candidates as trigger for the observed eruptive event. First, we suppose downflow motions of the plasma along the loops. These motions are detectable when they cross the slit (during first two bursts). These motions trigger magnetic reconnection and bi-directional jet (the last burst). Secondly, magnetic reconnection plays a role during the whole eruptive event. But, only one jet is detected in the spectra of the first two bursts because of the spatial separation of jets. Displacements of the magnetic field configuration caused such motions in the atmosphere that both parts of the bi-directional jet appeared after some time at the area of the slit.

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REFERENCES

Bewsher, D., Parnell, C. E., Pike, D. C., Harrison, R. A.: 2003, Sol. Phys., 215, 217

Bewsher, D., Innes, D. E., Parnell, C. E., Brown, D. S.: 2005, A&A, 432, 307

Brković, A. and Peter, H. : 2004, A&A, 422, 709

Brueckner, E. G., Bartoe, J.-D., F.: 1983, ApJ, 272, 329

Harrison, R. A., Sawyer, E. C., Carter, M. K. and 36 coauthors: 1995, Sol. Phys., 162, 233

Harrison, R. A.: 1997, Sol. Phys., 175, 467

Heinzel, P., Schmieder, B., Vial, J.-C.: 1997, in Proceedings of *'Fifth SOHO Workshop, 'The Corona and Solar Wind Near Minimum Activity'*, ed. A. Wilson, ESA SP-404, p. 427

Innes, D. E., Inhester, B., Axford, W. I., Wilhelm, K.: 1997, Nature, 386, 811

Kučera, A., Curdt, W., Fludra, A., Rybák, J., Wöhl, H.: 1999, in 'JOSO Annual Report 1998', eds. A. Antalová, H. Balthasar, A. Kučera, Astronomical Institute, Slovak Academy of Sciences, Tatranská Lomnica, p. 149

Lemaire, P., Wilhelm, K., Curdt, W. and 13 coauthors: 1997, Sol. Phys., 170, 105

Longcope, D. W., Klapper, I.: 2002, ApJ, 579, 468

Peter, H. and Brković, A.: 2003, A&A, 403, 287

Tomasz, F., Rybák, J., Kučera, A., Curdt, W., Wöhl, H.: 2003, Hvar Observatory Bulletin, 27, 75

Tomasz, F., Rybák, J., Kučera, A., Curdt, W., Wöhl, H.: 2004, in Proceedings of *'SoHO 13 - Waves, Oscillations and Small-Scale Transient Events in the Solar Atmosphere: A Joint View from SOHO and TRACE'*, ed. H. Lacoste, ESA SP-547, p.307

Wilhelm, K., Curdt, W., Marsch, E. and 16 coauthors: 1995, Sol. Phys., 170, 75