INTERPRETATION OF THE ACTIVITY DUE TO FLUX EMERGENCE IN AN AR

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ABSTRACT

The short-lived active region (AR) NOAA 7968 was thoroughly observed all along its disk transit (June 3 to 10, 1996) from the space and from the ground. During its early stage (June 6), it presented a very dynamical behaviour. Flux emerged in between the two main polarities, while arch filament systems (AFS) were observed in Hα. After this continuous and fast photospheric changes, the total positive and negative flux increased at a slower rate. Some new bipoles were observed at the South of the main positive polarity on June 9. The AR presented a very low level of activity during its life, only small X-ray (class B) flares and surge-like ejections were seen. Using a magnetohydrostatic approach, we have modelled the magnetic configuration of AR 7968 and have analyzed in particular its topology in relation to a surge observed on June 9. We have found that magnetic field lines related to the event have dips that touch tangentially the photosphere (the so called “bald patches”, BPs). Two interacting BPs, defining a separator, have been identified at the South of the new emerging flux region. We propose that magnetic field reconnection occurring at the separator is the origin of the observed surge. This result shows that current sheets can be formed and efficiently dissipated at a very low level in the atmosphere.

Key words: chromosphere; surges; flux emergence; magnetic fields

INTRODUCTION

AR NOAA 7968 was the target of a special coordinated observing campaign involving the instruments aboard the Solar and Heliospheric Observatory (SOHO), Yohkoh, and ground-based observatories. This AR was relatively short-lived and, thus, it was observed continuously from its birth to its decay phase. In a recent work (Deng et al. 1999), we have analyzed the magnetic topology of the AR along its life-time. We have found that its global magnetic structure corresponds to a nearly potential-field configuration, even during its growth stage. Only small GOES (class B) X-ray flares and some surge ejections were observed during the AR disk transit. In particular, on June 9 at 6:36 UT, when the region was already decaying, a surge was well-observed at the South of the main positive polarity by Bialków Observatory (Poland). The base of the surge was located in between an emerging negative flux region, already observed six hours before the surge, and the main polarity. It extended over a positive flux concentration that had also appeared on that day at the South of the negative region. No flaring was observed at that time.

The physical mechanisms which are involved in chromospheric mass ejections, called surges, are not clearly understood. The surge may be driven by a high pressure gradient in a magnetic tube, as first proposed by Steinolfson et al. (1979) or it may be due to magnetic energy release through reconnection (Heyvaerts et al. 1977, Shibata et al. 1992) in a more complicated magnetic configuration. Kurokawa & Kawai (1993) showed that Hα surges are seen in the early stages of flux emergence, and concluded...
that they are produced by magnetic reconnection between the emerging flux region and the preexisting surrounding field (see also Schmieder et al. 1996). Canfield et al. (1996) followed the same ideas to propose a phenomenological model to explain surges and X-ray jets in an AR. In the case described here, the topological analysis of the magnetic configuration suggests that the surge is also driven by magnetic reconnection, but unlike the examples just mentioned energy release seems to be linked to the presence of a separator created by the interaction of two "bald patches" (BPs) (Seehafer 1986, Titov et al. 1993, Bungey et al. 1996). In Section 2 we described the data; while in Section 3, after summarizing the properties of BPs, we analyze the magnetic topology at the surge location. Finally, we conclude on the role of the topology of BPs as the driver of the surge event.

2. OBSERVATIONS

AR 7968 appeared on the disk on June 3 as a negative polarity spot in a bipolar facular region. The evolution of the magnetic field as observed by SOHO/MDI and Huairou magnetograph has been described in detail by Deng et al. (1999). On June 6 the region was mainly bipolar. Emergence of new magnetic flux was clearly seen between the main polarities, while AFS were observed at chromospheric level. After this fast flux emergence, the total positive and negative fluxes
continued to increase at a slower rate during June 7 and June 8. By June 9, the AR magnetic flux started to decrease. Figure 1a shows the line of sight magnetic field as observed on June 8, while Figures 1b, c and d depict the evolution of the field during June 9. Notice the new negative flux at the South of the main positive polarity, this region was accompanied by a positive zone of lower magnetic field intensity.

The AR was thoroughly observed at chromospheric level. Hα filtergrams were obtained at Białków Observatory with a field of view of $\approx 5.83' \times 3.67'$ and a spatial resolution of less than $1'$. Velocity and intensity images were also obtained with the Multi-Channel Subtractive Double Pass (MSDP) spectrograph (Mein 1991). This instrument provides simultaneous data at nine spectral positions covering the Hα profile, with a field of view of up to $30'' \times 240''$. The Hα profiles are reconstructed for each pixel of the region. By locating the bisector position of the line profile and the minimum intensity, maps of Doppler shifts and intensity fluctuations can be obtained.

On June, 9 at $\approx 06:36$ UT, a surge was observed close to the new negative polarity (Figure 2a), extending towards the S. From almost the beginning of the event and until $\approx 06:47$ UT both blue- and red-shifts could be identified. The red-shifts were seen until 07:27 UT. Figures 2b, c and d show the
evolution of the Hα velocity field during the surge, notice the location of the change between blue- and red-shifts.

Figure 3. Magnetic field model of AR 7968. The model corresponds to June 9, 08:40 UT, magnetogram. The locations of two BPs (BP1 and BP2) are shown in thick light grey, together with intersection of their associated separatrices with the photosphere drawn in continuous dark grey lines. The figure corresponds to the local frame ((x,y) on the photospheric plane, z normal to it). The convention for the magnetic field drawing is the same as in Fig. 1

3. MAGNETIC FIELD TOPOLOGY

Apart from the case in which magnetic nulls are present in the corona, separatrices can only appear in a magnetic volume when some field lines are tangentially touching the boundary (i.e. the photosphere). This can happen along portions of the inversion line, for the component of the field normal to the boundary. These portions are the so-called BPs. Above a BP the field lines are curved up, and the horizontal component of the magnetic field (the one on the photospheric plane) crosses the inversion line from the negative to the positive polarity, i.e. in the opposite way as compared to the normal portions of this line. The criterion for the existence of BPs was first given by Seehafer (1986) and in more detail by Titov et al. (1993).

BPs are interesting topological features for several reasons. They define separatrices where current sheets can develop (see e.g. Low and Wolfson 1988, Vekstein et al. 1991, Aly & Amary 1997). The separatrices starting at two distinct BPs may intersect defining a topologically special field line, called separator, where magnetic reconnection is quite plausible (Bungey et al. 1996). In this aspect BPs are important since, contrary to the traditional definition, this separator does not connect two null points. Besides during the evolution of some magnetic configurations, BPs may be precursors of the emergence of a null point in the coronal field (Bungey et al. 1996), being again associated with reconnection processes. Finally, BPs are thought to be the locations where chromospheric material can be lifted up and so they can be also linked to processes occurring in prominences (Titov et al. 1993, Aulanier & Démoulin 1998a). There are some evidences of the role of BPs in flares, the first examples were given implicitly by Seehafer & Staude (1980) and Seehafer (1985). More recently, Aulanier et al. (1998b) found a close correspondence between the BP separatrices and the Hα and X-ray emissions in a small flare. Furthermore, Mandrini et al. (1999) have found that the evolution of chromospheric fibrils, observed during June 6 in AR 7968, could be linked to magnetic reconnection occurring at BPs.

In order to investigate the origin of the observed surge, we have modelled the field of AR 7968 as observed on June 9. We have extrapolated the observed line of sight component using the linear magnetohydrostatic approach developed by Low (1992). This method takes into account the effects of the plasma

Figure 4. Idem Fig. 3. A set of field lines, issued from the BPs, matching the shape of the observed surge has been added. The figure corresponds to the observer's point of view. The convention for the magnetic field drawing is the same as in Fig. 1

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Figure 5. Separatrix surface associated to BP2. We have drawn only the portion of the surface which may be associated to the surge (for aesthetics the vertical height (z) has been modified by the function 15√z). The convention for the magnetic field is the same as in Fig. 1 and the region is seen from an arbitrary northern point of view.

Figure 6. Separatrix surface associated to BP1 (for aesthetics the vertical height (z) has been modified as in Fig. 5). The convention for the magnetic field is the same as in Fig. 1 and the point of view is rotated by 180° with respect to that of Fig. 5.

region and the preexisting magnetic field. For the surge observed in AR 7968 on June 9, 1996, we have found that the topological analysis of the magnetic configuration suggests that the event may be driven by magnetic reconnection occurring at the separator created by the interaction of two BPs.

The evolution of the photospheric field, mainly the changes in the magnetic field intensity and the displacements of the positive polarity at the South of the new negative flux (see Figures 1), might have induced the energy release by magnetic reconnection at the separator region. Dense chromospheric plasma would be compressed at the reconnection region and pushed into the reconnecting field lines forming the observed surge. This dense plasma would flow along the magnetic field lines, in such a way that we would see red-shifts towards the northern portion of the surge and blue-shifts towards its southern portion as energy release proceeded (see Figures 2); finally, we would observe red-shifts all along the reconnected loops as the plasma flowed back to the chromosphere from the highest portion of the field lines (to the South-West of BP2). The size and shape of the field lines associated to BP1 and BP2 support this picture (see Figures 5 and 6).

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4. DISCUSSION AND CONCLUSION

The origin of surges has been in general associated to magnetic reconnection between a new emerging flux
Figure 7. The separator. The line of intersection between the two separatrix surfaces is drawn with a thick continuous line. Examples of field lines outside the separatrices and corresponding to the surge are also shown. The convention for the magnetic field is the same as in Fig. 1 and the point of view is the same as in Fig. 5 (for aesthetics the vertical height has been modified as in Fig. 5).

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