ENERGY RELEASE FROM A LARGE-SCALE MAGNETIC NULL POINT IN THE CORONA?

Henry Aurass¹, Axel Hofmann¹, and Bojan Vršnak²

¹ Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany
² Hvar Observatory, University of Zagreb, Faculty of Geodesy, Kačićeva 26, HR - 10000 Zagreb, Croatia

ABSTRACT

We observed how a flare disturbs a system of interconnecting loops between neighboring active regions. The disturbed loops brighten in SOHO/EIT images of the coronal magnetoplasma. They are part of a large scale structure embracing a weak field range in the photospheric and coronal magnetic field. Near the weak field site but away from active regions and from the EIT-detected loop heating, an initially narrowband nonthermal meter wave radio source is observed by the AIP spectrometer and the Nançay radio heliograph. The formation of this source and the EIT loop brightening can be consequences of current sheet activation and excessive coronal heating at a disturbed magnetic null point.

1. INTRODUCTION

The magnetic field of the active solar corona is formed by a varying number of magnetic flux sources. Model investigations of such complex fields reveal that even magnetically simple configurations (e.g. 3 sources, Priest et al. 1997) can form a complex field with 3D magnetic null points and separator field lines. Under such circumstances a source motion can "... drive current sheet formation and coronal heating at the network of separators and separatrices ..." (Inverarity and Priest 1999). We report on observational evidence of energy release at separator field lines in a weak field region of an interconnecting loop structure. We will demonstrate that a characteristic new nonthermal radio source and EIT-detected excessive heating of the coronal plasma appear at a suspect site.

On 29 March 2001 at about 10 UT, thermal and nonthermal energy release excited by a flare in AR 9393 (N16W12) is recorded by Astrophysical Institute Potsdam (AIP) radio spectral as well as Nançay radio heliograph (NRH) imaging instruments. Some complementary Solar Heliospheric Observatory Extreme Ultraviolet Telescope (SOHO/EIT) 195 Å flare images show transient hot coronal plasma structures.

Our interpretation of the observed facts is based on the good coincidence between the field line systems seen in a potential field extrapolation of Kitt Peak magnetogram data with the SOHO/EIT images, and with the source sites of a nonthermal metric radio burst with a very specific spectral appearance.

2. OBSERVATIONS

Aurass et al. (2001) described impulsive phase shock signatures during the March 29, 2001 1N, X1.7 flare observed in active region NOAA AR 9393 between 09:55 and 11:25 UT. The flare was associated with a halo CME. From SOHO/LASCO C2 and C3 data a mass ejection propagation speed of about 940 km s⁻¹ was estimated (CSFSW/NRL/NASA CME-Catalogue 2001 of Gopalswamy, Yashiro, and Michalek).

Figure 1. Dynamic radio spectrum of the 29 March 2001 event in the range 110-500 MHz. The arrow S shows the start of the slowly drifting narrowband source at 327 MHz, arrow M points at time of flux maximum. The arrows are derived from NRH imaging observations (courtesy A. Kerdraon and K.-L. Klein). The harmonic mode of the type II burst appears from 140-240 MHz around 10:04 UT.
In connection with the flare there are observed three radio sources distributed on the disc. In Figure 2 top we present the spatial arrangement of meter wave flare sources on the background of the 10:13 UT EIT image. Next to the flaring active region 3993 the main flare source "A" appears (Fig. 2, right). We have plotted brightness isolines during an instant in which source A is relatively faint and a more southward occuring source "B" is bright. This source B corresponds with the initially narrowband spectral feature in Figure 1. The relative strength of sources A and B over time is given in the source flux plots Fig. 2, bottom. In Fig. 2 top, left, we have drawn the 236 MHz type II burst source (compare with Fig. 1).

Figure 3 summarizes the flare evolution by selected SOHO/EIT images. The 09:47 UT image (left) only faintly reveals flare preheating. The two arrows point on the site of first flaring (top) and on the lateron disturbed interconnecting loops (bottom arrow). The middle and right frames are difference images and reveal almost all important features of this eruption. After flare loop ignition a large patch of moss-like emission (Berger et al. 2000) above comparatively strong active region fields is already bright in the 10:13 UT image (south of the top arrow). Further southward of the active region the 10:13 - 09:59 UT difference image reveals the brightening of loops which are disturbed but not disrupted. Westward of this brightening a stable dark pattern is visible in the EIT images all the time.

In Figure 4 we give selected field lines of a potential field extrapolation of the flaring active region and its surroundings. For the extrapolation, the Kitt Peak magnetogram (observed 5 hours after the flare/CME) was resampled to a mesh width of 8 arcsec. We used the extrapolation according to Seehafer (1978). Despite the large width of the extrapolation area and the plane geometry approach, the field line pattern shows a good coincidence with the hot coronal loop structures seen in EIT images. The

Here we continue the analysis of this event by presenting EIT and type II burst data revealing large amplitude wave propagation. The wave hits a system of interconnecting loops. Simultaneously, we observe in this system a new radio source characterized by a very specific long duration and narrowband, slowly drifting spectral signature. This signature is shown in the dynamic radio spectrum Fig. 1. Its slow frequency drift corresponds with an exciter speed toward lower densities of about 200 km s$^{-1}$. For comparison, the somewhat earlier at lower frequencies observed type II burst yields an exciter speed estimate of about 1080 km s$^{-1}$. The "emission line" feature reminds initially to the sawtooth pattern discovered by Klassen et al. (2001), and to a type II burst. But we do not see the typical gaps and jumps like in the sawtooth bursts, nor we find harmonically related features or herringbone fine structure emission.

Figure 3. SOHO/EIT 195 Å images of 29 March 2001, the same part of the disc like in Fig. 2 top, right. Left: 09:47 UT. Middle and right: Difference frames 09:59 - 09:47 and 10:13 - 09:59 UT. The upper arrow points to the site of flare onset. The lower arrow points on the site of transient brightening of interconnecting loops. Compare also Fig. 4.
dark zone in the EIT image near to which we found the narrowband radio source B (Fig. 2 top, right) is well figured out in the potential field extrapolation as a weak field region (symbol N in Fig. 4). The NE branch of the surrounding field line bunches is directly hit by the large amplitude flare wave—it is in projection on the disc next to the radio type II burst source. The transient brightening in EIT loops (Fig. 3 right, bottom arrow) is situated within the stippled circle in the field map. For orientation we wrote into the image the NOAA AR numbers and (as "X") the corrected NRH source centroid sites for the three radio sources shown in Fig. 2.

In Figure 5 we have plotted a perspective view on the extrapolated coronal field lines with a turning height between 100 and 350 Mm. We have selected for this plot only those field lines which are rooted in the cross-hatched active regions 9400 (middle right in Fig. 5) and 9405 (left in Fig. 5). The field lines coming from these two regions are closed partly toward active regions 9395/97, and partly toward active region 9390. In other words, at the site N (see Fig. 4) two separator surfaces are crossing and divide the corona into four magnetically distinct regions. If such a region is disturbed reconnection can occur in the large scale three dimensional null point structure. Related model calculations and TRACE observations were reported e.g. by Priest and Schrijver (1999). We argue that the transient EIT loop brightening and the radio source "B" with the specific, initially narrowband spectrum shown in Figure 1 are signatures of this reconnection process.

3. CONCLUSION

We identified for the first time - stimulated by the detection of a strange spectral feature in the dynamic radio flare spectrum - a spatially distinct flare/CME-associated nonthermal radio source next to a large
Figure 5. A perspective view on selected field lines around point N in Fig. 4; seen from North–West. Maximum height is about 0.5 $R_\odot$. In the foreground there is AR 9390, right AR 9400, in the background ARs 9395/9397.

scale magnetic 3D-null point. The weak field configuration is formed above a photospheric weak field range between at least seven active regions. We have demonstrated that there four magnetically distinct regions contact each other. The 3D-null point is activated due to the flare and related transient wave propagation, or due to coronal reconfiguration following the associated coronal mass ejection release. Transient EIT loop heating, and an unusual radio source formed away of the flare site are observed as corresponding energy release features.

ACKNOWLEDGEMENTS

We are grateful to Dr. B.J. Thompson for support in SOHO/EIT data access and processing. SOHO is a common project of ESA and NASA. Further we acknowledge the advice of A. Kerdraon and K.-L. Klein concerning the correction of Nançay radio heliograph data and the access to these data.

REFERENCES


© European Space Agency • Provided by the NASA Astrophysics Data System