DISAPPEARING TRANSEQUATORIAL LOOPS AND CORONAL MASS EJECTIONS

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ABSTRACT

Large-scale dimmings in the form of disappearing transequatorial loops have been observed on several occasions in association with the onset of coronal mass ejections (CMEs). The opening of the CME magnetic field can be revealed by radio observations since the radio emission sources trace the propagation paths of electrons (along the large-scale loops in such cases). Some radio bursts are therefore signatures of energetic electrons produced in the rearranging magnetic fields, before the field opens up completely. We present one such event from February 8, 2000, and compare it with another similar event from May 2, 1998. We find that the start of the energy release does not seem to occur in the concentrated, sheared fields linked to the active region, but rather originates high in the corona when and where the large loops first get destabilized.

1. INTRODUCTION

Coronal mass ejections (CMEs), especially the "halo" type ones, have been found to be associated with EUV and soft X-ray dimmings, Hα (Moreton) and EIT waves, and sometimes with disappearing transequatorial loops, see e.g. Sterling & Hudson (1997), Zarro et al. (1999), Thompson et al. (2000), Khan & Hudson (2000). Dimmings usually represent depleted matter while Hα and EIT waves are mostly connected with flares, see e.g., Warmuth et al. (2001) and Hudson et al. (2003).

Flares and CMEs are often associated with decimetric-metric radio emission that originate at coronal heights: Type III radio bursts are produced by plasma emission processes when a stream of mildly relativistic electrons travels along open magnetic field lines (Vlahos & Raoult, 1995). The U- and J-subtypes of type III bursts result from energetic electrons streaming along long but closed loops.

Metric type II radio bursts result, ultimately, from plasma emission at MHD shock fronts (Wild & Smerd, 1972) and they can thus trace the propagation paths of both plasma ejecta and shock waves, see e.g., Klein et al. (1999) and Klein et al. (2003). Type IV radio emission most often occurs in conjunction with type II emission and has a close association with CMEs (Kahler, 1992).

Our interest is to study the onset of CME-related solar eruptions for which ample multiwavelength observations are available. The events on February 8, 2000 and May 2, 1998 were reported to include a fast 'halo' CME, a flare, EUV dimmings, and radio type II, III and IV emission. On closer inspection, they both included a transequatorial loop that dimmed during the event.

2. OBSERVATIONS

Multiwavelength analysis of structures related to a fast halo CME on February 8, 2000 (Pohjolainen et al., 2005) reveals similarites to another halo event that occurred on May 2, 1998 (Pohjolainen et al., 2001). Both events were observed by SOHO LASCO (Brueckner et al., 1995) that images the corona in white light, by SOHO EIT (Delaboudinière et al., 1995) that images the Sun at EUV wavelengths with 12 min image cadence, and by Yohkoh SXT (Tsuneta et al., 1991) that produced images in soft X-rays.

Radio observations were obtained from ARTEMIS-IV spectrograph which covers the spectral range 110–680 MHz (Caroubalos et al., 2000), and from Nançay Radioheliograph (Kerdraon & Delouis, 1997) which images the Sun at five separate decimetric–metric wavelengths.

2.1. February 8, 2000 halo-type CME

A halo type CME was first observed by LASCO C2 on February 8, 2000 at 09:30 UT at height 3.8 R_{sun}, with the main compact part proceeding towards the North-East (LASCO CME Catalogue, Catholic University of America). The estimated plane-of-the-sky speed of the CME was around 1300 km/s. An estimate of the time when the CME should have been over the flaring NOAA active region 8858 (N25 E26) is at 08:45 UT (obtained from a

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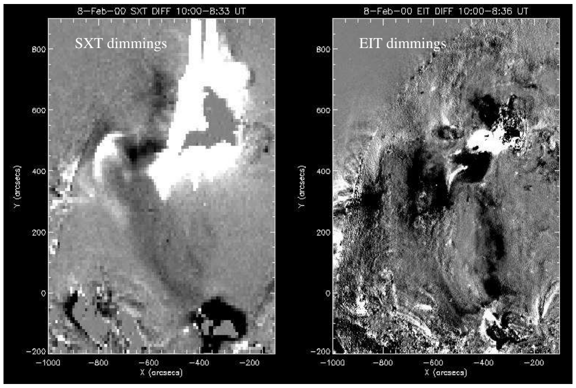


Figure 1. On the left: Yohkoh SXT 10:00–08:33 UT difference image that shows the large-scale loop-like dimming region in soft X-rays on February 8, 2000. On the right: SOHO EIT 10:00–08:36 UT difference image shows similar dimmed regions in EUV.

linear fit to the first three CME front locations). A polynomial fit to all CME front locations gives a slightly later start time, around 08:47 UT.

After the flare start and CME detection, difference images in soft X-rays and in EUV show dimmings that look like large-scale loops. The loop-like dimmings elongate towards an active region in the southern hemisphere, see Fig 1. The soft X-ray dimmings are not exactly cospatial with the EUV dimmings, but this is somewhat expected as they represent observations at different temperatures and consequently at different heights.

2.2. May 2, 1998 halo-type CME

A halo type CME was first observed on May 2, 1998 at 14:06 UT at height 3.5 R_{sun} by LASCO C2 (LASCO CME Catalogue). The main compact part was visible towards the West. The plane-of-the-sky speed of the CME front was around 1200 km/s. This event was associated with a major flare in NOAA AR 8210 (S15 W15). An estimate of the time when the CME should have been located over the active region, around 13:35 UT, can be obtained from a polynomial fit to the height–time data points.

Large scale loop-like dimmings were observed in soft X-rays and in EUV, and this time they elongated towards an active region in the northern hemisphere. Fig. 2 shows the first small dimmed region that was observed at the same time as the EIT wave. The dimming later enlarged into a loop form, as shown in Fig. 2.

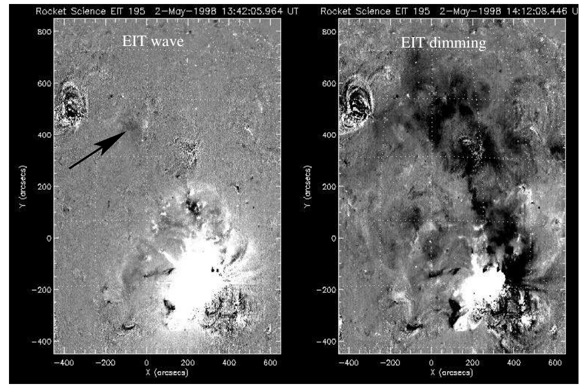


Figure 2. On the left: EIT-wave around the flaring active region and the first dimmed region along the transequatorial loop (indicated by black arrow) shown in the 13:41–13:19 UT difference image on May 2, 1998. On the right: EUV dimming spreads into a large loop-like formation between the two solar hemispheres (14:10–13:41 UT difference image).

2.3. Radio observations

Dynamic radio spectra from the two events show similar features, see Figs. 3 and 4. Before the shock signatures (i.e. type II bursts) and upwards moving structures (indicated by type IV bursts) they both show a similar sequence of events: First a few (reverse slope) type III bursts (interpreted as electron beams moving (down) in the solar atmosphere), then a sequence of J-bursts (electron beams moving along large scale loops, with starting point high in the corona), followed by pulsating structures that are widely spread spatially (indicating electron acceleration along a large number of different field lines).

Fig. 5 shows one radio emission path of a J-burst on February 8, 2000, imaged by the Nancay Radioheliograph. The J-burst starts from a region North-East of the active region and travels southwards along the later-dimmed transequatorial loop. The first sign of dimming along this loop is observed near the southern end (indicated by black arrow). Fig 5. also shows the spatial distribution of the narrowband fluctuations that followed the J-bursts, at one frequency.

In the May 2, 1998 event J-bursts also traced the transequatorial loop system before the large-scale eruption started (Fig. 6). Very soon after the last U-burst, illuminated loop-like structures were observed at several locations around the active region (see more details in Pohjolainen et al. 2001).

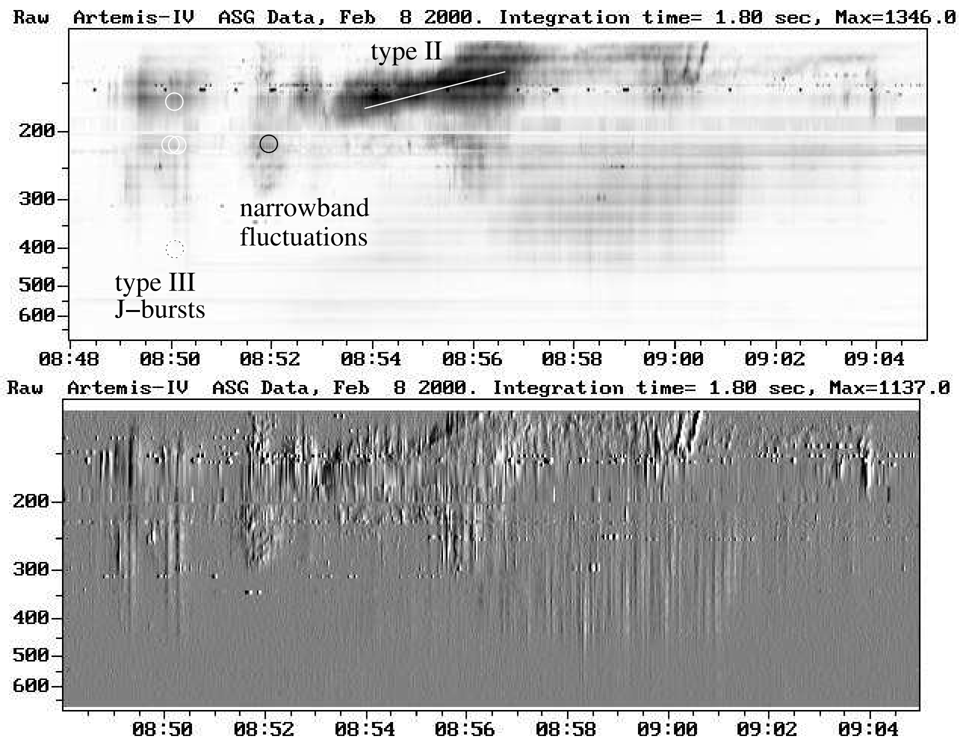


Figure 3. Dynamic radio spectrum (Artemis IV, Greece) on February 8, 2000, showing J-bursts, narrowband fluctuations, and the 2nd harmonic lane of the type II burst. Two separate reverse slope (RS) bursts were observed before the J-bursts at 08:44:20 UT and 08:46:05 UT (not shown in this spectral plot). Black and white circles indicate the radio sources that are imaged in Fig. 5.

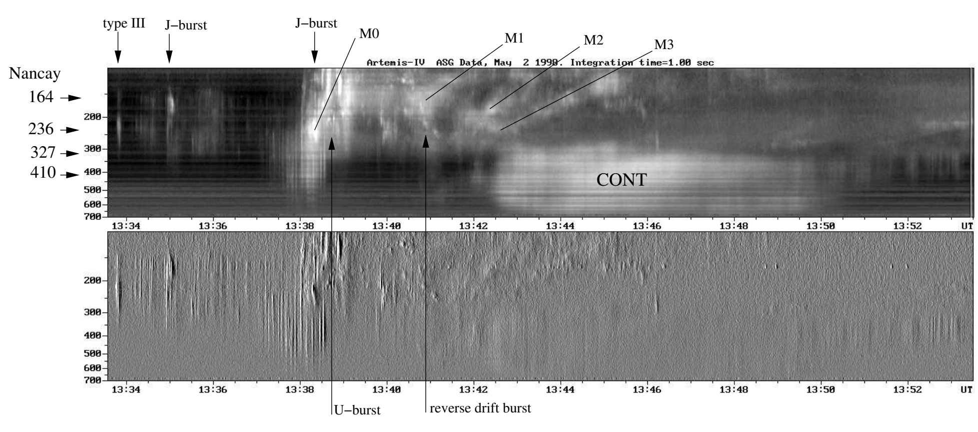


Figure 4. Dynamic radio spectrum (Artemis IV, Greece) on the May 2, 1998 event, showing a type III burst, J- and U-bursts, fluctuations with reverse slopes, and 4 different lanes of type II-like bursts (M0-M3). Type III activity was also observed at 13:28 UT, before the start time of this plot.

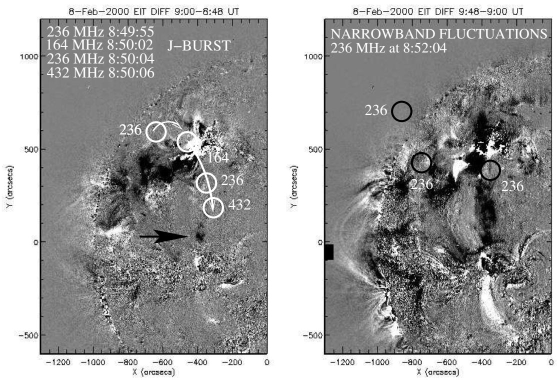
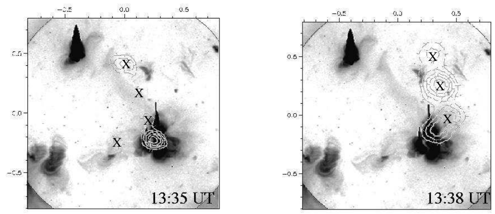


Figure 5. On the left: Burst trajectory of one of the J-bursts (white circles and arrow), imaged by the Nancay Radioheliograph on February 8, 2000. The J-burst traces the location of a dimmed transequatorial loop system in EUV. Black arrow points to the location of the first dimming along the large-scale loop. On the right: Narrowband fluctuations show wide-spread emission at one single frequency, observed after the J-burst group.

3. DISCUSSION

The halo CME events on February 8, 2000 and on May 2, 1998 both show large-scale loop-like dimmings in soft X-rays and in EUV, along which radio sources are seen before the impulsive phase of the associated flare. The radio burst sources indicate electron acceleration and electron beams travelling along these loops. We can pinpoint the time and the location of the first large-scale field-line opening by tracing the electron propagation paths above the active regions and along the transequatorial loop systems, where large-scale mass depletion later takes place. In both cases the radio type IV emission confirmed CME lift-off.

Large scale field line opening preceding the lift-off of material is an essential part of the 'breakout' model by Antiochos et al. (1999). They claim that the opening of fields starts at a neutral point high above the core region. The initial condition is to have a multipolar complex field with coronal null points where magnetic reconnection can occur. Our observations of propagating electron beams high in the corona, over large-scale multipolar fields, at very early stages of the events are signatures that give support to the 'breakout' model.



May 2, 1998 J–bursts

Figure 6. Yohkoh SXT images on May 2, 1998 show the transequatorial interconnecting loop system that later disappears (dims) partly. Superposed on the SXT images are the Nancay radio source positions of two of the J-bursts (source centroids marked with 'X'). J-bursts trace the later-dimmed EUV and SXT transequatorial loop systems.

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