SOHO/EIT DATA ON GLOBAL CANALIZED DIMMINGS IN HALO CME EVENTS

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ABSTRACT

An analysis of SOHO/EIT difference images at 195 Å, particularly for the period of 2000–2001, revealed a new variety of dimmings, or transient coronal holes, observed on the solar disk after halo-type coronal mass ejections (CMEs). In large eruptive events, along with relatively compact dimmings adjoining to an eruptive center, we have found strongly anisotropic, somewhat less contrast *canalized dimmings*. They extend along several narrow, lengthy structures (channels) and span a considerable sector of the visible disk. We argue that these transient features are closely associated with a strong disturbance and restructuring of large-scale magnetic fields involved in the CME process. We also argue that the canalized character of the dimmings reflects a complex topology of the global solar magnetosphere near the maximum of the solar activity cycle.

Key words: solar corona, coronal mass ejections (CMEs), dimmings.

1. INTRODUCTION

CME-associated disturbances and restructuring of solar large-scale magnetic fields are known to be accompanied by coronal waves and dimmings (e.g., Thompson et al., 1998; Hudson and Cliver, 2001). The latter are observed in soft X-ray and EUV emissions as regions of reduced intensity. The deepest dimmings recorded with the EUV Imaging Telescope (EIT; Delaboudinière et al., 1995) aboard SOHO mission are simultaneously visible in at least three coronal lines of 171, 195 and 304 Å and therefore can be interpreted as evacuation of the coronal matter due to total or partial opening of the magnetic field lines (Thompson et al., 1998; Zarro et al., 1999).

EIT dimming events described so far in the literature have been dated mainly to the period of 1997–1998, i.e. to the ascending phase of the current solar cycle. When a single active region is present on the visible solar disk and therefore the structure of the global solar magnetosphere is relatively simple, the coronal waves and dimmings are quasi-isotropic and propagate in a wide angular sector more or less symmetrically relative to an eruptive center. Such disturbances took place particularly in the famous event of 12 May 1997 (e.g., Thompson et al., 1998; Plunkett et al., 1998; Gopalswamy and Thompson, 2000). Under more complex conditions, coronal waves can be reflected or refracted by interactions with strong magnetic fields of active regions (Ofman and Thompson, 2002), and dimmings can stretch along some large-scale loops (including those transequatorial) rooted in the region where the eruption occurs (Khan and Hudson, 2000; Pohjolainen et al., 2001; Wang et al., 2002). In a number of cases, so-called twin dimmings are observed when the deepest depletions occur in two regions adjoining to the eruptive center and are located symmetrically relative to the polarity inversion line and post-eruption arcade (Thompson et al., 1998; Zarro et al., 1999). Such twin dimmings appear to be footpoints of large-scale flux rope structures erupting in the CME process (see Sterling, 2000).

We analyzed the spatial structure of the EUV dimmings observed near the solar cycle maximum in 2000–2001 when the solar magnetosphere was complex (see Chertok and Grechnev, 2002). Our analysis shows that if several active regions, filaments and other features are present on the solar disk, many large CMEs are accompanied by pronounced anisotropic dimmings which we call *canalized dimmings*. They are developed along narrow, lengthy structures (channels) and stretch themselves out between remote active centers including those located on both sides of the helioequator.

In the present paper, this feature of the dimmings is illustrated by two analogous events occurred on 19 October 2001 at the interval of 15 hours and included the powerful 2B/X1.6 LDE flares in the active region AR 9661 and huge halo CMEs. To emphasize the dimming, we formed SOHO/EIT 195 Å *fixed difference images*, i.e., the same pre-event image was subtracted from all subsequent heliograms. To avoid the appearance of false bright or dark features, we rerotated all images before subtraction to the same pre-event time. We used *running difference images* as a helpful representation only, because they also produce false features. Additional images and movies for these and other dimming events can be found at the web site http://helios.izmiran.troitsk.ru/lars/Chertok/dimming/index.html.

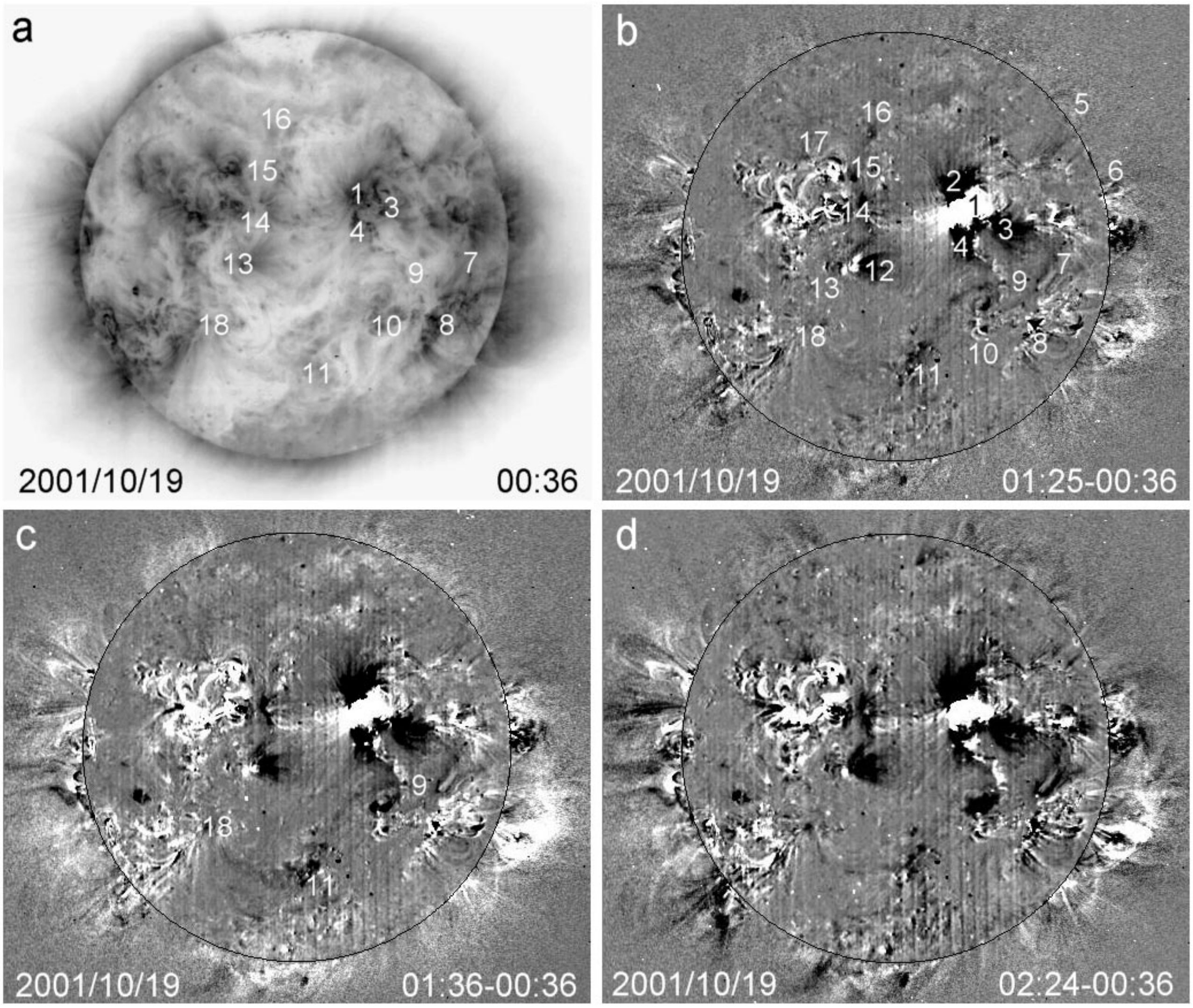

Figure 1. SOHO/EIT 195 Å images of the event of 19 October 2001, 01:00 UT: (a)–Inverted (negative) pre-event heliogram; (b-d)–Rerotated fixed difference images illustrating development and canalized structure of the dimmings.

2. THE EVENT OF 19 OCTOBER 2001, 01:00 UT

Figure 1a shows a pre-event situation at 195 Å. One can see a complex structure of the corona with several active regions including AR 9661 (hereafter referred as point 1) which is a source of the flare and center of the halo CME eruption. Fixed difference image at 01:25 UT (Figure 1b) displays three dimming areas 2, 3, 4 joined to a flare brightening 1 and several narrow dimming branches (channels) emanating from them. At least two faint branches 2-5 and 3-6 come to the western limb. More pronounced transequatorial dimming channels 3-7-8 and 4-9-10 extend to two southwestern active regions. Perhaps there is a faint dimming bridge 8-10 between them. One more dimming branch 9-11, going southward, attracts attention (see below). Moreover, a remote dimming patch 12 and vertical channel 13-14-15-16 with an eastward branch 15-17 are located approximately along the central meridian nearby the northeastern active center. There are some emission and absorption bridges connecting the eruptive center 1 with remote vertical dimming 13-14-15-16 mentioned above. Some stationary high-latitude brightenings and darkenings occur northward from line 2-16 and southward from line 11-18, respectively. However, a coronal wave in its usual sense is not distinguishable in this event.

Figure 1c and, especially, a corresponding movie show that dimming 9-11 propagates farther to the southeastern active region 18. The 12-min cadence of the 195 Å images allows us to estimate roughly the propagation speed of this dimming of $V \geq 500-550$ km/s. As an additional analysis shows, main patches and channels of this global CME-associated dimmings persist several hours almost unchanged (see Figure 1d). The depth of the dimming ranges from 5–10 to 70%.

From comparison with the pre-event image (Figure 1a) one can see that the main canalized dimmings coincides with the corresponding emitting structures labeled with the same numbers. In particular, dimming channels 3-7-8, 4-9-10 and 9-11-18 are formed as a result of partial depletion of the interconnecting emitting structures. Meridional dimming 13-14-15-16 is located along a bright pre-

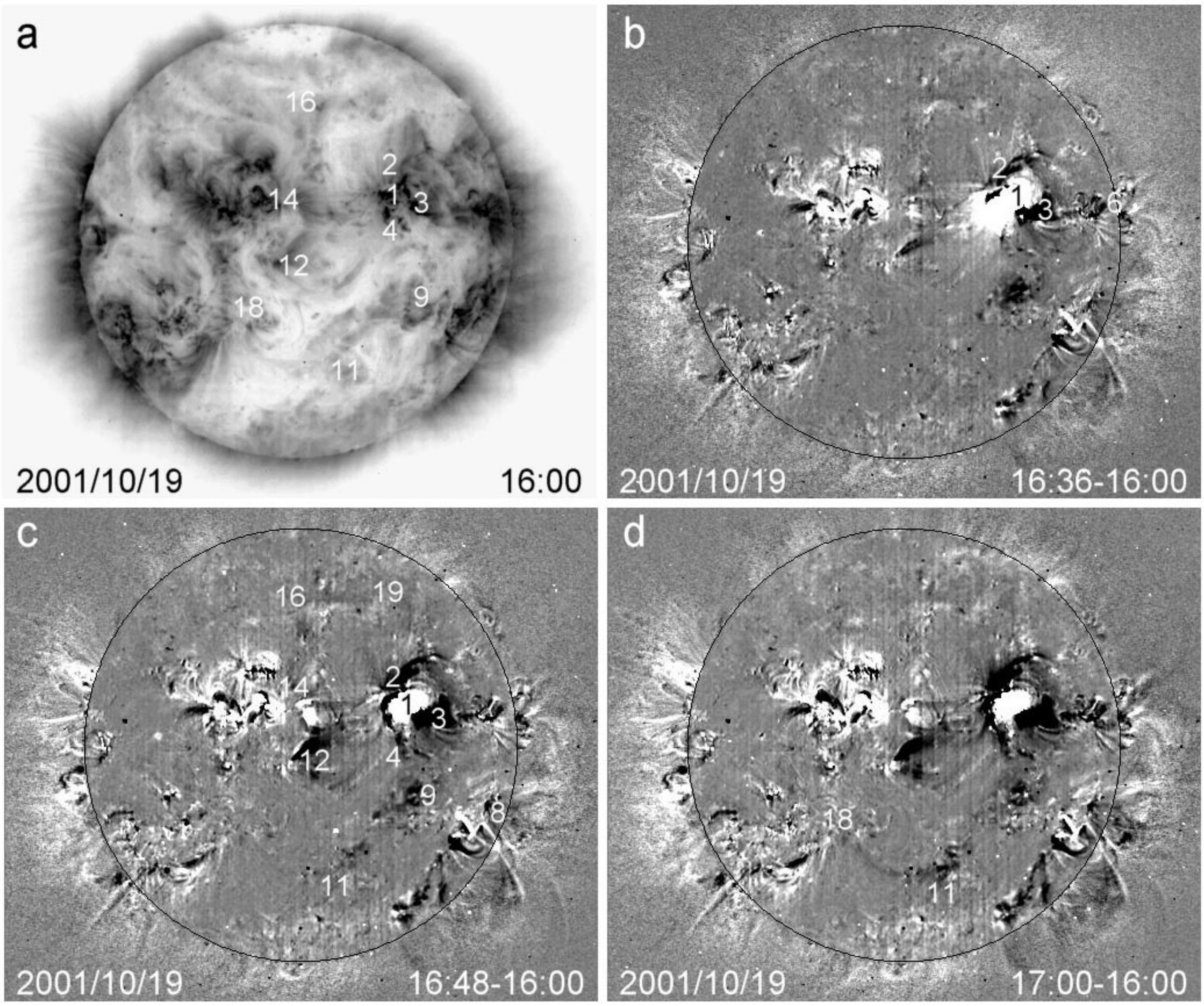

Figure 2. The same as Figure 1 but for the event of 19 October 2001, 16:30 UT.

existing large-scale chain (see Chertok, 2001), both being an eastern footpoint ribbon of the arcade stretching itself out to region 1 and its outskirts.

3. THE EVENT OF 19 OCTOBER 2001, 16:30 UT

To the onset of this second event (Figure 2a), all major large-scale structures exposed to the dimmings during the previous event of 01:00 UT restore their emitting intensity at 195 Å. Basically, the second event is very similar to the first one not only in its location, associated flare and halo CME, but also in the accompanied dimmings. However, there are some differences (Figures 2b-d). Nearby the flare brightening 1, only dimming 3 maintains its patchy character, while dimmings 2 and 4 take a channel shape. Among outgoing canalized dimmings, channel 3-6 extending to the western limb becomes more pronounced, but there is no transequatorial branch stretching to the southwest region 8.

The homology of these two events is emphasized particularly by the development of a similar transequatorial canalized dimming which propagates again southward from the source region 1 along the same large-scale bowed structures. From Figures 2c and d one can see that at 16:48 UT this dimming comes through point 9 to region 11 and then turns to southeastern region 18. The estimated propagation speed of the dimming in this case is similar to that in the first event, i.e. several hundred km/s.

The remote meridional dimming structures are fainter, except for a patchy dimming 12. Some dimming manifestations are present along line 12-14-16 (with a longitudinal branch 16-19), but they adjoin to diffuse brightenings. The latter gradually become predominant, connected with the eruptive center 1 extending northward and perhaps revealing signatures of an anisotropic coronal wave. Between the eruptive center and segment 12-14 of the meridional structure, a number of dimming loops can be seen in this case. General characteristics of the dimming such as formation and life time, its large spatial extension and global character, are also similar to those of the first event.

4. DISCUSSION AND CONCLUSION

The described events illustrate features of CME-associated dimmings typical for the maximum of the solar cycle. In contrast to some quasi-isotropic dimmings which occurred at the ascending phase of the cycle, dimmings at the maximum stage manifest a pronounced anisotropy. Besides the dimming patches joined to an eruptive center, there are many dimmings that look like narrow, lengthy structures (channels). Such dimmings stretch themselves between remote active centers, can be transequatorial, and often extend throughout almost the entire visible disk, i.e. have a character of global disturbances.

The intensity depletions of the EUV emission in the canalized dimmings are comparable to or somewhat less than that in isotropic and patchy dimmings and can amount to tens percent. Similar to patchy elements around eruptive centers, canalized dimmings develop during tens of minutes and exist during several hours. In some cases, propagation of the dimmings along the channels is observed. According to rough estimations which can be done using available data, the propagation speed is several hundred km/s, i.e. similar to that of quasi-isotropic coronal waves (e.g., Thompson et al., 1998; Klassen et al., 2000; Warmuth et al., 2001; Biesecker et al., 2002).

In the canalized dimming events, the emitting coronal waves either are not observed at all or they are also anisotropic and propagate in a confined sector of the disk. Sometimes instead of the bright coronal wave, something like a dark “dimming wave” is visible.

Appearance of either isotropic or canalized dimmings is caused by degree of the complexity of the global solar magnetosphere. Quasi-isotropic dimmings and coronal waves are observed when large-scale magnetic fields have relatively simple structure, e.g., when single active center is on the disk. On the contrary, canalized dimmings and sometimes anisotropic coronal waves are typical for the complex global solar magnetosphere, when several active regions, filaments, coronal holes etc. are present on the solar disk.

Canalized dimmings outline or surround substantial pre-event coronal structures. In particular, some dimming channels appear to coincide with interconnecting loop-like structures (see Khan and Hudson, 2000), footpoints of big arcades, and large-scale emitting chains (Chertok, 2001). In the last case, canalized dimmings may be treated as transient chains observed in absorption. As a whole, the dimmings outline global coronal structures involved in a CME process.

The deepest dimmings appear to occur in those structures which are sources of enhanced emission, i.e., possess sufficiently large emission measure. The dimmings and dimming channels demonstrate that in complex solar magnetosphere there are distinct coronal elements and lengthy structures in which the most significant depletions of the emission intensity take place. These decreases can be a consequence of a partial or entire opening of the magnetic field and evacuation of the matter during the CME process (e.g., Delannée, 2001). Another possibility is an influence of MHD disturbances on these structures. Perhaps, in concrete events or some region of the global solar magnetosphere these two factors, opening of field lines and MHD disturbance, can dominate or act jointly. Clearer ideas on the canalized dimmings and their role in the CME process should be obtained in further studies.

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