Multi-Wavelength Investigations of Solar Activity
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Multi-wavelength observations of CME-associated structures on the Sun with the CORONAS-F/SPIRIT EUV telescope

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Abstract. Multi-wavelength imaging of the solar corona is a powerful observational method to study CME-related dynamics of structures in spectral bands related to the solar corona and transition region. We analyze large-scale eruptive events caused by halo-type CMEs observed at the solar disk with the CORONAS-F/SPIRIT (175, 304, and 284 Å) and SOHO/EIT telescopes on November 4, 2001 and October–November, 2003. For most events, CME-associated dimmings coincide in different bands, but the 304 Å dimming in November 4, 2001 event was delayed by $> 1/2$ hours. In October–November events, coronal waves were observed in 195 Å and some in 175 Å channel. In a CME event associated with a filament eruption on November 18, the SPIRIT images display a propagating disturbance seen as a darkening in 304 Å channel only. This phenomenon was not described earlier.

1. Introduction

CME-related phenomena embrace significant areas of the Sun and involve solar plasmas over the corona and transition region in a wide temperature range from $2 \cdot 10^4$ K to several MK. Multi-wave imaging in spectral lines of different temperature and dynamic ranges promises the detection of CMEs' manifestations and yields important diagnostic information (e.g., Harrison et al. 2003).

The SPIRIT telescope aboard the CORONAS-F spacecraft launched in 2001 observes the whole Sun in several EUV bands, including 284 Å (FeXV) line and simultaneous imaging in 175 Å (FeIX–XI) and 304 Å (HeII) bands with intervals from several minutes to hours (Zhitnik et al. 2002). We overview the results of our studies of CME-associated structures using CORONAS-F/SPIRIT images along with SOHO/EIT images (if available) for several halo-type CME, which produced powerful geoeffective events. In our data analysis we use difference images. For studies of long-living dimmings, the most convenient are fixed-difference 'derotated' images. Our method involves subtraction of a reference pre-event heliogram from all others taken during several hours after the event, with a preparative compensation for the solar rotation in all of them.

2. Event of 4 November 2001

An eruptive event of November 4, 2001 (after 16:00 UT) is among the biggest and most geo-effective ($D_{st} \approx 300$ nT) ones, being comparable to the well-known "Bastille Day" event of July 14, 2000. It was observed by the SPIRIT in three EUV bands of 284, 175, and 304 Å (Chertok *et al.* 2004). SOHO/EIT data are absent for this event.

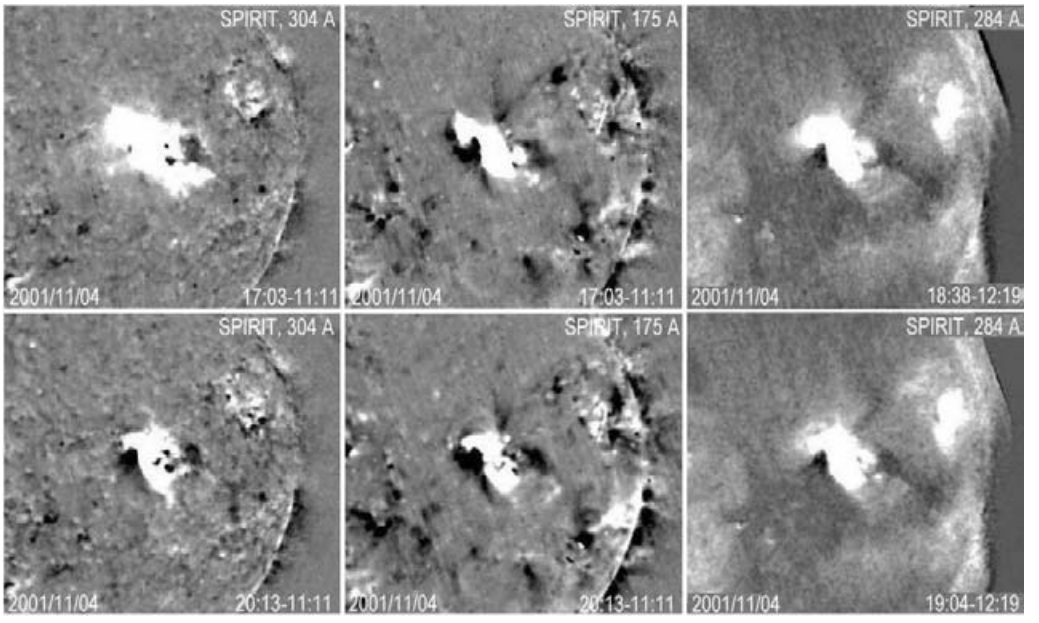

Figure 1. Fixed-difference derotated heliograms produced from the CORONAS-F/SPIRIT images illustrating large-scale coronal (175 & 284 Å) and transition region (304 Å) dimmings in the 4 November 2001 event. In each frame, first time is related to the current image, second–reference image. The brightness of the post-eruptive arcade exceeds the brightness threshold.

The event started with the disappearance of an Hα filament in AR 9684 and a 3B/X1.0 flare (16:03 UT). A halo-type CME was observed from 16:35 UT on as a bright, large-scale structure ascending above the western limb with a sky-plane velocity of 1800 km/s.

The SPIRIT images at 284, 175, and 304 Å obtained 4–5 hours before the event and 0.7–4.3 hours after the flare maximum allowed us analyzing long-term CME features, giant post-eruptive arcade and dimmings (Fig. 1).

The most prominent are compact dimmings adjoining to the posteruptive arcade at its eastern and western sides, accompanied by several narrow, extended channeled dimmings. Two other channeled dimmings extend to the north and northwest from the northern dimming node with a length being similar to the extent of the arcade. The channeled dimmings are somewhat shallower than the dimmings near the eruption center. The main dimmings observed at 175 Å at 17:03 and 20:13 UT showed almost no variability over three subsequent hours. In the highest-temperature band, 284 Å, the main dimming structures are similar to those of 175 Å. The eastern compact dimming visible in 284 Å passes into a large but relatively weak transient coronal hole.

The transition region 304 Å band shows two remarkable features: (1) most 304 Å dimmings coincide with the coronal-band dimmings with comparable depths of tens of percent, (2) the eastern 304 Å dimming lags behind the other dimmings by $> 1/2$ hours. Note that the depth of the coronal dimmings did not decrease herewith.

3. Events of October 26 and 28

During October–November 2003, several big events occurred, including X-class flares and CMEs, producing large particle fluxes and geomagnetic disturbances (e.g., Chertok & Grechnev 2004). In particular, the SPIRIT observed events of October 26, 28, and November 17, 18 in the same activity complex in two consecutive solar rotations.

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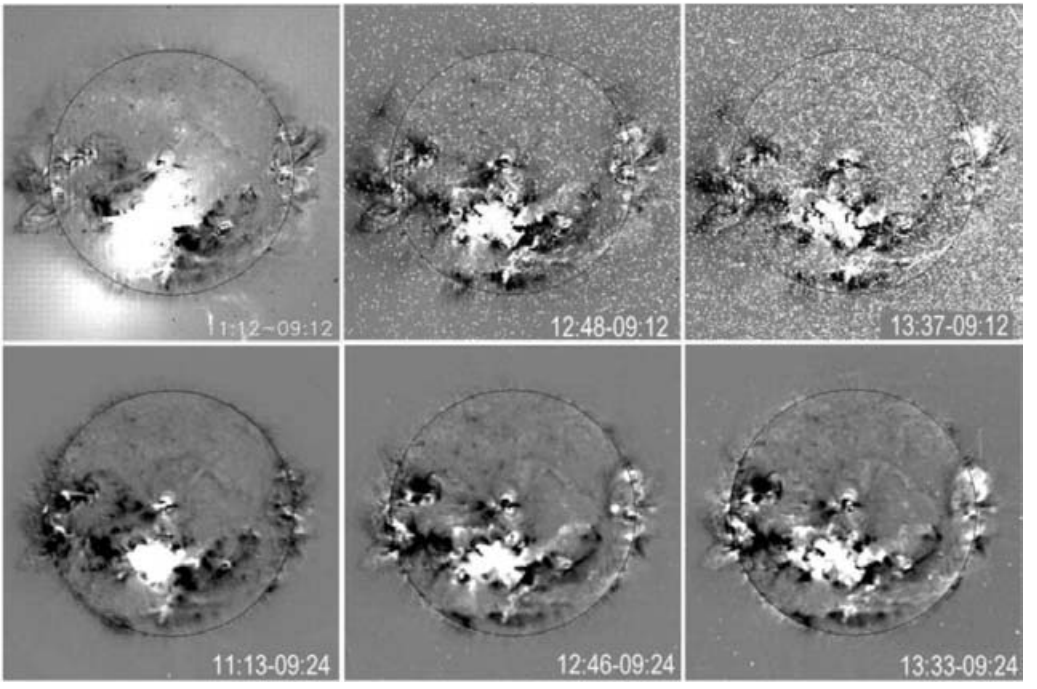

Figure 2. Fixed-difference images of the 28 October 2003 event by data of SOHO/EIT at 195 Å and CORONAS-F/SPIRIT at 175 Å.

In these two events, EIT observed coronal ('EIT') waves. On October 26, a fainter wave was also observed in the SPIRIT 175 Å images. On October 28 (Fig. 2), EIT 195 Å images show an extended narrow front going southward of the eruptive center, then eastward, which was not observed in 175 Å images.

The EIT observations are contaminated with saturation and stray light during the flare, and then by the 'snowstorm' due to energetic particles generated in the event. The SPIRIT 175 Å images do not show those effects, because (1) the detector does not reach saturation, (2) the CORONAS-F is shielded from protons by the magnetosphere.

Dimmings are global to embrace the whole southern hemisphere and consist of some elongated structures expanding from the eruptive center towards other active regions, some of which being located near the limb. A separate high-latitude dimming structure envelopes the south polar coronal hole. There are almost no well-pronounced dimming manifestations in the northern hemisphere. The dimming structures observed in the 175 Å and EIT 195 Å bands mainly coincide and persist almost unchanged for several hours. SPIRIT and EIT data can be combined for better time coverage of the events.

4. Events of November 17 and 18

A series of geo-effective CME events occurred during the two days in the AR 501. On November 17, an M3.9 flare occurred at 08:31 and a halo CME at 09:02 UT. At 09:53, the 175 & 304 Å SPIRIT and 195 Å EIT images show a deep long dimming in the SE direction originating from the left side of the AR, which was stable throughout the day.

On November 18, several M-class flares occurred, in particular, at 07:52 and 08:31 UT in the same active region. The corresponding CMEs also had several components including halo-type at 08:06 and 09:36, one of them being very similar to the CME of November

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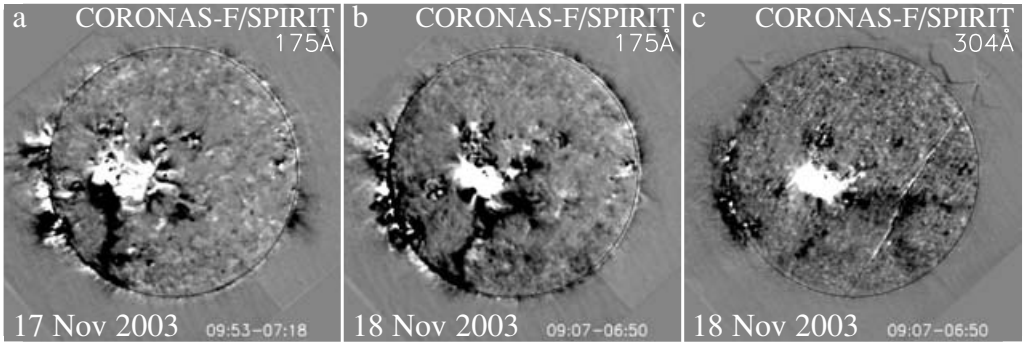

Figure 3. Fixed-difference SPIRIT images of the November 17 and 18, 2003 events.

17. Hα images show disappearance of a filament between 07:39 and 09:20 UT. The CME of 08:06 produced a deep elongated dimming seen in all SPIRIT and EIT channels in the SSE direction practically at the same place as one day before (Fig. 3). However, it originated from the right side of the AR.

A coronal wave propagating from the eruptive center in the south direction is seen at 08:36–08:48 in the EIT 195 Å the SPIRIT 175 Å band, and faintly visible in the SPIRIT 304 Å band due to the hot SiXI component.

The most remarkable feature was detected on November 18 after the flare and CME of 08 UT (Fig. 3c). This phenomenon was not observed earlier. The SPIRIT 304 Å heliograms from 08:23 to 09:54 UT clearly show a dimming-like disturbance propagating from the eruption region toward the southwest limb. It appeared 17 minutes after the eruption, when the leading edge of the CME reached the distance of $3R_{\odot}$. The sky-plane velocity of this dark feature is ~ 200 km/s. At 10:43 UT, it disappeared at the disk, and no manifestation of anything related to this feature was seen above the limb in either EIT, SPIRIT, or LASCO images. This feature is seen as a darkening of about 30% in the HeII 304 Å band only. In the coronal 195 and 175 Å bands it is not pronounced. The darkening is probably due to absorption in the remnants of the erupted filament.

Acknowledgements

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