Solar Activity and its Magnetic Origin
Proceedings IAU Symposium No. 233, 2006
V. Bothmer & A. A. Hady, eds.

doi:10.1017/S1743921306002183

Photometric study of EUV dimmings in powerful eruptive events observed with CORONAS-F/SPIRIT and SOHO/EIT

Vladimir A. Slemzin[1], **V. V. Grechnev**[2], **and S. V. Kuzin**[1]

[1]P.N. Lebedev Physical Institute, Lenisky pr., 53, Moscow, 119991, Russia
email: slem@lebedev.ru

[2]Institute of Solar-Terrestrial Physics SB RAS, Lermontov St. 126, Irkutsk 664033, Russia
email: grechnev@iszf.irk.ru

Abstract. We analyzed brightness variations in widespread dimming regions occurred in several major eruptive events in 2003 and 2005 resulted in fast halo CMEs. In all cases brightness of remote dimming regions show some pre-eruptive growth, then gradual and fast decrease to minimum. The time interval of maximal decrease overlaps with X-flare peak and LASCO CME onset. Brightness variations in some dimmed regions are highly correlated before the CME onset and much less – after. It suggests a break of magnetic connectivity between previously linked coronal structures. Dimmings develop similar at 175 and 195 Å being shallower and sometimes delayed at 304 Å . In large-scale region (L>0.5 $R_\odot$) dimming propagates with a speed of $\sim$ 250 km/s which is typical for EIT-waves.

Keywords. Sun:corona, Sun: coronal mass ejections (CMEs)

---

1. Introduction

Dimmings are the earliest, well-defined signatures of CMEs in soft X-rays and EUV (Hudson & Webb 1997, Harra & Sterling 2001) often interpreted as footprints of an ejected flux rope (Sterling & Hudson 1997; Zarro *et al.* 1999). Spectroscopic studies of EUV dimmings by Harrison *et al.* (2003) showed the major mass depletion to occur at temperatures of 1–2 MK and to constitute at least 70% of the CME mass.

There is a controversy over the dimming onset and flare. Zarro et al. (1999) and Sterling & Moore (2004) found EUV dimming to start after the flare onset. Howard & Harrison (2004) reported some cases when EUV dimming started several hours before flares (but they treated EUV dimming as a secondary phenomenon to the main eruption process).

Many authors in studies of dimming development often addressed their morphology, or brightness variations within arbitrarily selected boxes either inside a dimmed region (Zarro *et al.* 1999), or enclosing it (Harrison *et al.* 2003, Howard & Harrison 2004). However, their location and size could affect the results. Such boxes might incorporate regions irrelevant to the considered event or disturbed by some secondary process.

Our study is based on analyses of light curves for widespread regions of EUV dimming in the halo CME events. It is aimed, in particular, at: (a) proper identification of dimmed regions associated with a particular eruptive event, (b) studying interrelation of widespread dimmings and their association with flares and CME launch, (c) analysis of the dimming development in time and space in coronal and transition-region bands. Using the developed methods, we have studied several powerful events associated with halo CMEs occurred in periods of extremely high solar activity on Oct. 28, Nov. 17–18, 2003, and Sep. 13, 2005.

2. Observations and data processing

We used data of two EUV telescopes: SPIRIT (Zhitnik *et al.* 2002, Slemzin *et al.* 2005), which operated on the CORONAS-F satellite from Aug. 2001 till Dec. 2005, and EIT on SOHO. During Oct.-Nov. 2003, both telescopes observed in similar EUV bands (Grechnev et al. 2005). Only SPIRIT observed in Sep. 2005 (CCD blackout of EIT).

We first pre-process SPIRIT and EIT images and then create fixed-base difference images, in which the same reference pre-event image is subtracted from all others with preparatory compensation of the solar rotation (Chertok *et al.* 2004). We take a fixed-base image ∼1 hr before the event onset ($t_{0\,\mathrm{CME}}$ or the flare peak time from GOES 1–8 Å flux) and map dimming from a difference image at ∼1 hr after. Then we filter dimming regions using minimal and maximal pixel maps (Podladchikova & Bergmans 2005) and sort them according to their contribution to the total depth of the dimming (regions with a contribution $< 1\%$ are discarded). After such filtering some regions still can be incidental.

To identify regions related to particular eruption event we compute light curves for pre-selected regions. We integrate brightness in difference images over the area of each region and then calculate the Pearson correlation coefficients C_P between each curve and the curve for the main region (with largest contribution to the total dimming intensity). We regard regions with $C_\mathrm{P} > 0.5$ as belonging to the same primary eruption (the Student's t-test: a confidence level for correlation is more than 0.95 if the number of points >15). Finally, we normalize light curves of identified regions to their values at the time of reference image and compute the total dimming profile as the ratio of the difference integrals over whole dimmed area to the total flux in the reference image, to show a contribution of emission from dimmed coronal structures to the total EUV solar flux.

3. Light curves of dimming in coronal EUV lines

The event of Oct. 28, 2003 (Grechnev *et al.* 2005) was related to an X17.2 flare at ∼11:00 (hereafter UT) in AR 10486 and a halo CME with $V = 2460$ km/s, $t_{0\,\mathrm{CME}}$ =11:02 (http://vso.nso.edu). Fig. 1a shows a dimming map in SPIRIT 175 Å difference image (11:59–10:26). Before the eruption (02:00–11:26) six of 10 regions (white numbers 1–4, 8–10) highly correlated with the main region 1 (together ∼ 81% of the total dimmed area in 175 Å), unlike three others (black numbers 5–7). However, the correlation for the first regions disappeared after the eruption (11:26-20:00), suggesting that the magnetic connectivity between structures, previously linked with long loops, was destroyed.

Fig. 1b shows relative dimming plots for the major region 1, a high-correlating region 2, and a low-correlating region 6. In region 4 located 990 Mm apart from region 1, the delay of the brightness decrease is less than 15 min, the time resolution of SPIRIT. The total dimming plots for both 175 and 195 Å are very similar: the brightening from 08:00 on, maximum at ∼09:30, and then slow decrease to the initial level by the flare onset at 10:00. The deepest dimming occurs at ∼12:00. The brightening in the dimming area 2 hr before the event may reflect pre-eruptive processes in coronal structures (cf. Howard & Harrison 2004). The time interval of fast darkening overlaps with $t_{0\,\mathrm{CME}}$ and the flare peak. In all dimming regions brightness decrease started one hour before the Moreton wave was firstly observed in Hα(11:04, Pick *et al.* 2005). It suggests that surface wave cannot be a trigger of the dimming.

The evolution of dimming on Sep. 13, 2005 (fig. 2) was similar. There was the only active region 10808 on the disk, and all dimmed regions well correlate before the eruption. The fast darkening at 175 Å (19:48) within temporal resolution agrees with the flare peak

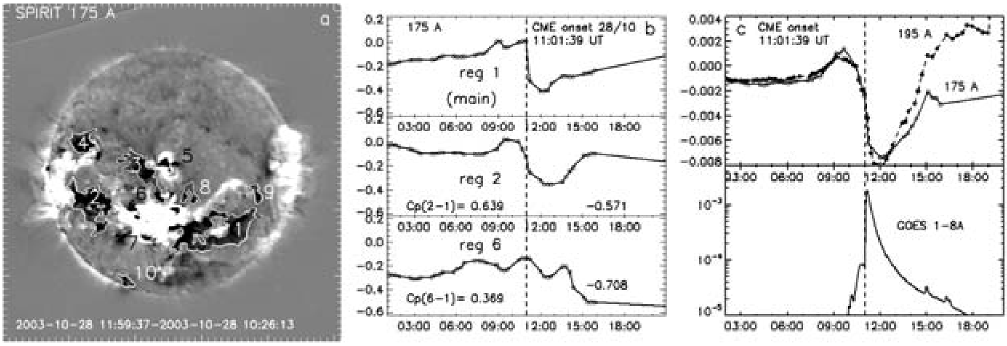

Figure 1. Oct. 28, 2003. a) Map of dimming in the SPIRIT 175 Å difference image, b) time profiles of relevant (1, 2) and irrelevant (6) dimmed regions, c) total intensity in the dimmed area in 175 Å (SPIRIT), 195 Å (EIT) and GOES 1–8 Å flux. Dashed lines: $t_{0\,\mathrm{CME}}$.

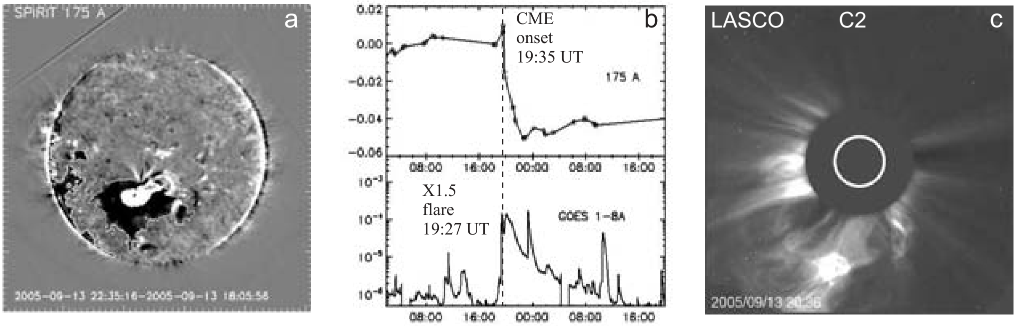

Figure 2. a) The dimming map for Sep. 13, 2005 event in SPIRIT 175 Å image; b) total intensity in the dimmed area in 175 Å and GOES 1–8 Å flux; c) CME in LASCO C2.

(19:27) and the CME onset (19:35). The CME was associated with eruption of a filament giving a bright core in the LASCO C2 image (fig. 2c).

4. Dimming in coronal and transition-region bands

Both SPIRIT and EIT operated on Nov. 17–18, 2003. Two CMEs originated from AR 10501 within one-day interval: 09:03 on Nov. 17 and 08:06 on Nov. 18. One large and several minor dimmings spread over the SE quarter of the solar disk after the first CME. The second event produced lesser and shallower dimmings at close positions. Fig. 3a shows an overlapped map of dimmings at 195, 175, and 304 Å. All light curves integrated over this area (fig. 3b) are similar: brightening started at 03:00, fast decrease at ~09:00, close to CME onset and the flare peak (fig. 3c). For the second CME, the 304 Å dimming reached its minimum 2 hr later than in coronal lines.

5. Spatial development of a large-scale dimming

The longest dimming on Nov. 17 exceeded $0.5R_{\odot}$ (fig. 4a). The derivatives of light curves for 30×30 Mm boxes along 195 Å dimming show its propagation rate (beginning of raises at fig. 4b). A linear-fit speed of dimming measured from a plot of distances between boxes 2–4 and 1 vs. the onset of decrease (fig. 4c) is ~258 km/s, which is a typical speed for EIT waves (but no wave was observed in this event).

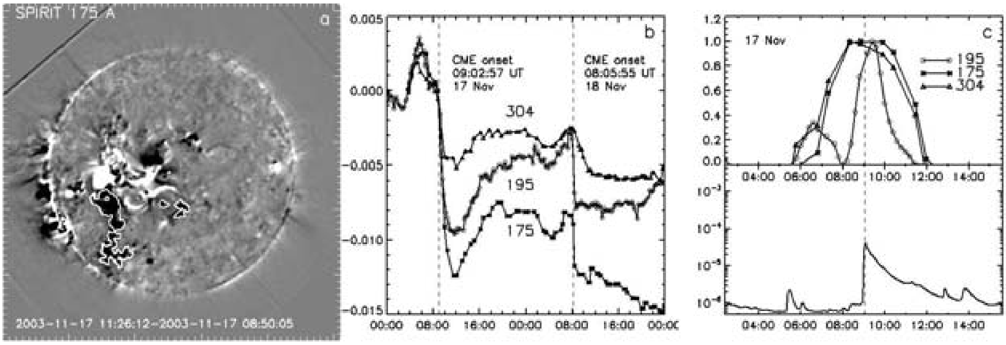

Figure 3. Nov. 17–18, 2003: a) Overlapping part of dimmings at 195, 175 and 304 Å; b) total intensity in the dimmed area in EUV bands and GOES 1–8 Å flux; c) normalized to 1 negative temporal derivatives of the EUV profiles for the first CME. Dashed lines: $t_{0\,\mathrm{CME}}$.

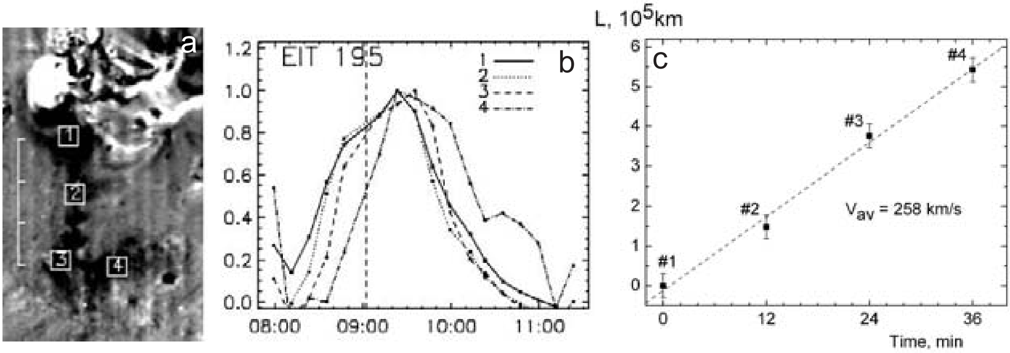

Figure 4. Nov. 17, 2003. a) Dimming and sampling boxes. b) Normalized negative derivatives of light curves for boxes 1–4. Dashed line: $t_{0\,\mathrm{CME}}$. c) Position-time plot of dimming propagation.

Acknowledgements

This study was partly supported by Russian Foundation for Basic Research (grant 05-02-17415). SOHO is a project of international cooperation between ESA and NASA.

References

Chertok, I.M. *et al.* 2004, *Astron. Rep.* 48, 407.
Grechnev, V.V. *et al.* 2005, *JGR* 110, A09S07.
Harra, L.K. & Sterling, A.C. 2000, *ApJ* 561, L215.
Harrison, R.A. *et al.* 2003, *Astron. Astrophys.* 400, 1071.
Howard, T.A. & Harrison, R.A. 2004, *Solar Phys.* 219, 315.
Hudson, H.S. & Webb, D.F. 1997, *in: N.Crooker, A. Joselyn, J.Feynman (eds.), Coronal Mass Ejections, Geophys. Monograph. Ser. 99,* 27.
Pick, M. *et al.* 2005, *ApJ* 631, L97.
Podladchikova,O. & Bergmans, D. 2005, *Solar Phys.* 228, 267.
Slemzin, V.A. *et al.* 2005, *Sol. Sys. Res.* 39, 489.
Sterling, A.C. & Hudson, H.S. 1997, *ApJ* 491, L55.
Sterling, A.C. & Moore, R.L. 2004, *ApJ* 602, 1024.
Zarro, D.M. *et al.* 1999, *ApJ* 520, L139.
Zhitnik, I. *et al.* 2002, *ESA* SP-506, 915.