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The spatial relationship between coronal mass ejections and solar flares

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Abstract: Using 19 well-observed eruptions that were associated with both CMEs and flares we quantified their spatial relationship. The flare and CME source locations were identified using images obtained at 174 Å by the SWAP instrument aboard PROBA 2 satellite. The SWAP data are suitable for this study because flare emission does not saturate much. To reduce saturation even more, our database did not contain any M-class or X-class flare events. We selected eruptions that occurred close to the disk center, as viewed from Earth, whereas they appeared as limb events in images obtained by the EUV Imagers (EUVI) aboard the two STEREO spacecraft. The centroids of the CME-associated EUV dimmings in the SWAP images were used as proxies for the CME source locations. For each event, we compared the location of the flare brightenings centroid with the location of the dimmings centroid at the CME onset time, which was determined from the EUVI data. Furthermore we investigated the CME source locations with respect to the photospheric magnetic field distributions using data from HMI aboard SDO. We also examined the evolution of the dimmings surface over time.

1 Introduction

The relationship between CMEs and flares is of great importance, but until now only their temporal relationship was addressed. It is known, that the CME acceleration phase and the eruptive phase of the flare are closely synchronized (e.g. Zhang et al., 2001; Temmer et al., 2008). There are CME signatures on the solar disk, such as ascending loops, ascending cusps, eruptive prominences, ribbon separation in Hα and EUV, but the best diagnostic is the coronal dimming. A coronal dimming is the decrease of intensity observed on the solar disk across a large area in EUV or X-rays as a consequence of the mass depletion during a CME. Dimmings are used as signals of the source region of CME.

2 Data Analysis

After correcting the SWAP data for differential rotation, we produced movies for each event consisting of not only plain images, but also of base difference images by subtracting a base image before the event from the next ones, because they allow us to identify the dimming. Figure 1(A-D) gives four indicative events. Based on those base difference images we identified the dimming areas using a modified version of the method presented by Podladchikova and Berghmans (2005) and computed their centroids. The red regions in Figure 1(E-H) show the dimming area which was derived from these computations. We also computed the centroids of the flare brightenings. Those locations are illustrated in the same panels. Figure 1(I-L) displays the magnetograms for the events of Figure 1(A-D). Moreover, the evolution of the dimmings surface over time resulted from processing every frame of each event separately. The results are displayed in Figure 2.

3 Results

In six cases the CME location was cospatial with the flare brightenings, like in Figure 1G while in the remaining cases the distance between each pair of flare-CME locations varied from 4 to 191 arcsecs with a median value of 71 arcsecs. Five cases, like in Figure 1F exhibit large distance value, more than

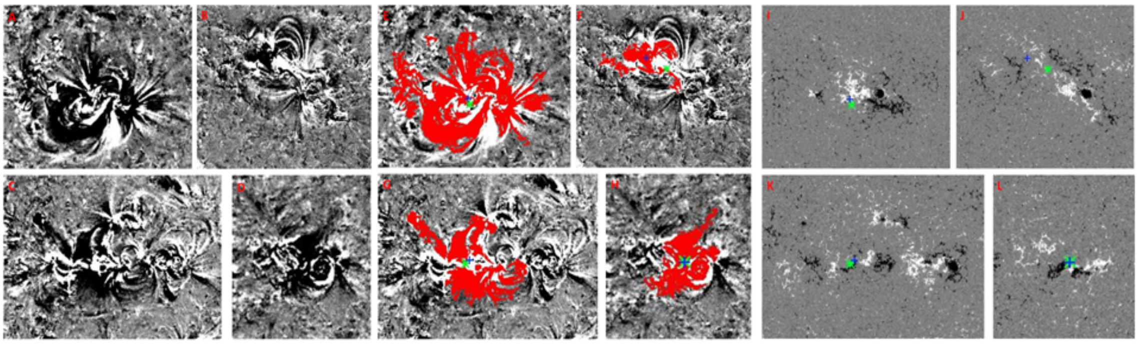

Figure 1: A-D: Base difference images of four active regions presenting the formation of dimmings in flare-CME events at the CME onset time. A: 2011 June 21, B: 2011 December 26, C:2012 September 25, D: 2011 July 11, E-H: With red we display the dimming area for the events presented in A-D figures. The dimming's centroid is illustrated by the + symbol and the * symbol presents the centroid of the flare brightenings, I-L: Magnetograms taken from HMI for the four events at the CME onset time. The + symbol corresponds to the dimmings centroid and the * symbol to the flare brightenings centroid.

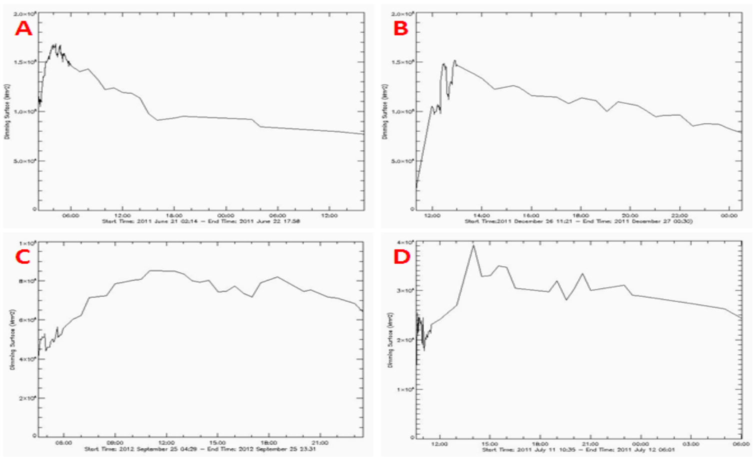

Figure 2: Evolution of the dimming area for the events of Figure 1(A-D).

95 arcsecs, and this is due to the morphology of those events. In these cases there are either two active regions involved which leads to the formation of interconnecting loops away from the location of the flare or the correlated loops are inclined with respect to the instrument's line of sight. If we ignore those events the mean value of the distances turns into 50 arcsecs. Regardless to those events, each event should be examined for projection effects. In terms of the underlying magnetic field structures we found out that in five cases the CME occurs above the neutral line like in Figures 1J and 1L. Finally, the gradual decrease of the dimmings surface over time was clear for all events.

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References

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