Spatial Correlation of Solar Flares and Coronal Mass Ejections

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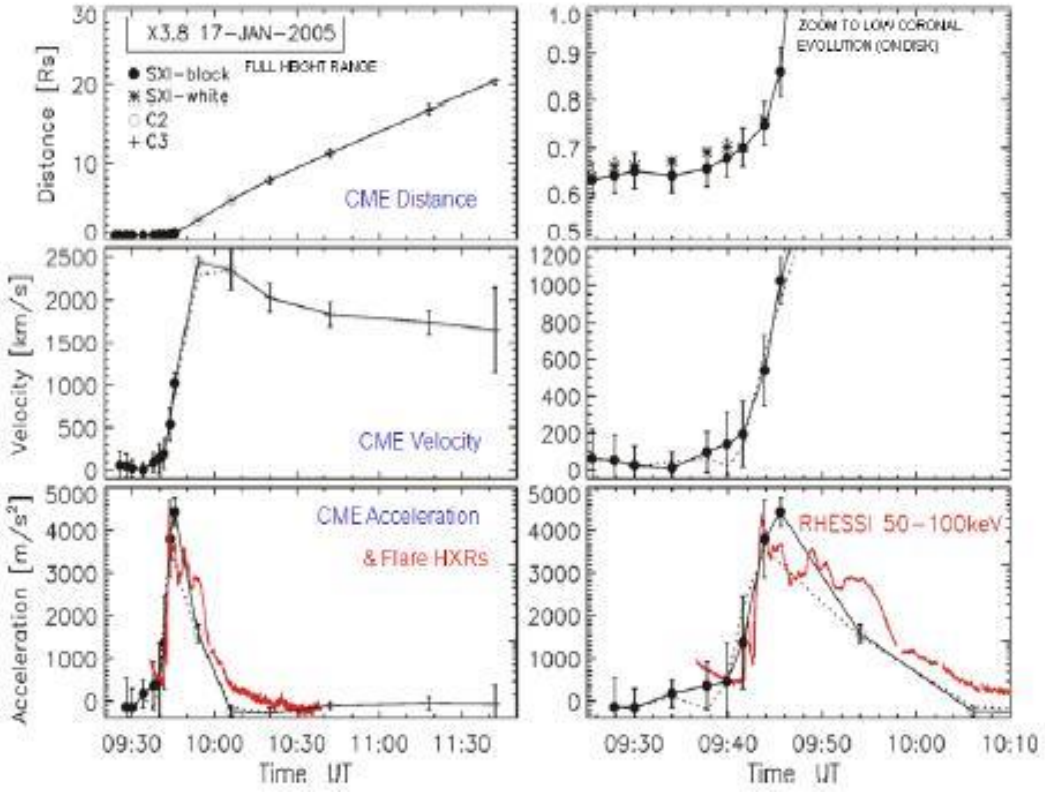
Outline

- Introduction
- Data base description
- Data Analysis
- Results
- Discussion - Conclusions

Introduction

Flare – CME Relationship



Temmer et al. (2008)

Temporal Relationship: There is a good synchronization between the eruptive phase of the flare and the accelerating phase of the CME.

[Zhang, Dere, Howard, Kundu, White (2001); Zhang, Dere, Howard, Vourlidas (2004); Gallagher, Lawrence, Dennis (2003); Vrsnak, Maricic, Stanger, Veronig (2004); Maricic et al. (2007); Temmer et al. (2008); Temmer, Veronig, Kontar, Vrsnak (2010)]

The spatial relationship between solar flares and coronal mass ejections is still an open subject.

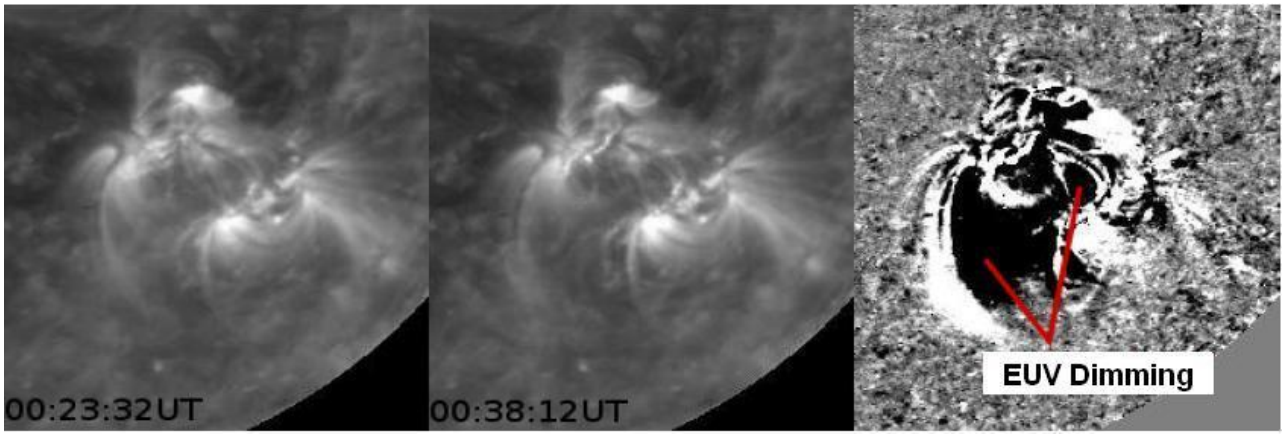
• Until now, ONLY data from coronagraphs have been used in order to determine the spatial relationship between solar flares and coronal mass ejections, Harrison et al. (1986); Kahler et al. (1989); Yashiro et al. (2008).

• What has already been studied is the preferential appearance of flares compared to CME's angular width, which gives approximate results, since no solar disk data have been used.

• The most popular view of that subject comes through the Standard Model

EUV Dimmings

EUV Dimmings are a powerful diagnostic of the early phase of CMEs and represent a mass deficit after the launch of a CME.



Data Base Description

Criteria

- We used only C-class flares and a subflare, no M-class and X-class flares were used in order to avoid saturation.

- We used data in the EUV at 174 Å taken from the SWAP instrument aboard the PROBA-2 satellite.

- Flare locations were close to the disk center (E25-W25), as viewed from Earth, whereas there were observed as limb events by the SECCHI/ EUVI instruments.

Description of events

A/A	Date	Flare Maximum (UT)	Flare Classification	Flare Position	Active Region
1	04/08/2010	03:25	B3.7	N24E17	11060
2	14/02/2011	06:58	C6.6	S20W01	11158
3	14/02/2011	12:53	C9.4	S20W02	11158
4	14/02/2011	19:30	C6.6	S20W05	11158
5	15/02/2011	14:44	C4.8	S20W16	11158
6	02/06/2011	06:36	C1.4	S19E20	11227
7	02/06/2011	07:46	C3.7	S19E25	11227
8	21/06/2011	03:25	C7.7	N16W08	11236
9	11/07/2011*	10:52	C1.4	S18E19	-
10	11/07/2011	11:03	C2.6	S17E06	11249
11	27/09/2011	20:58	C6.4	N10E09	11302
12	29/09/2011	12:47	C2.7	N10W11	11302
13	30/09/2011	04:00	C7.7	N10E10	11305
14	10/10/2011	14:35	C4.5	S13E03	11313
15	22/12/2011	02:08	C5.4	S19W18	11381
16	25/12/2011	08:55	C5.5	S21W20	11387
17	26/12/2011	11:50	C5.7	N18W02	11384
18	23/04/2012	17:51	C2.0	N14W17	11461
19	25/09/2012	04:35	C3.6	N09E20	11577

Data Analysis

SWAP/ PROBA-2

- Correction of differential rotation
- Movies with plain and base difference images
- Identification of the dimming area
- Identification of the dimmings' centroid
- Identification of the flare brightenings' and their centroids
- Distance calculation between the two centroids
- Calculation of the dimming area and study of its evolution

EUVI/ SECCHI (EUVI A and EUVI B)

- Movies with plain and base difference images
- Identification of the CME initiation time

Magnetograms (HMI and MDI)

- We used date for almost 5 days before the initiation of each event
- Correction of differential rotation
- Movies

Method Analysis

We used a modified version of the method presented by Podladchikova & Berghmans (2005) in order to indentify the dimming area.

Two groups of pixels were used in each frame, a maximal and a minimal pixel map.

• The maximal pixel map contains all pixels in the base difference image, below a weak threshold.

• The minimal pixel map is constructed by selecting the 200-1000 darkest pixels of each base difference image. All of those pixels belong by assumption to the dimming area (leaving aside the noise for the time being).

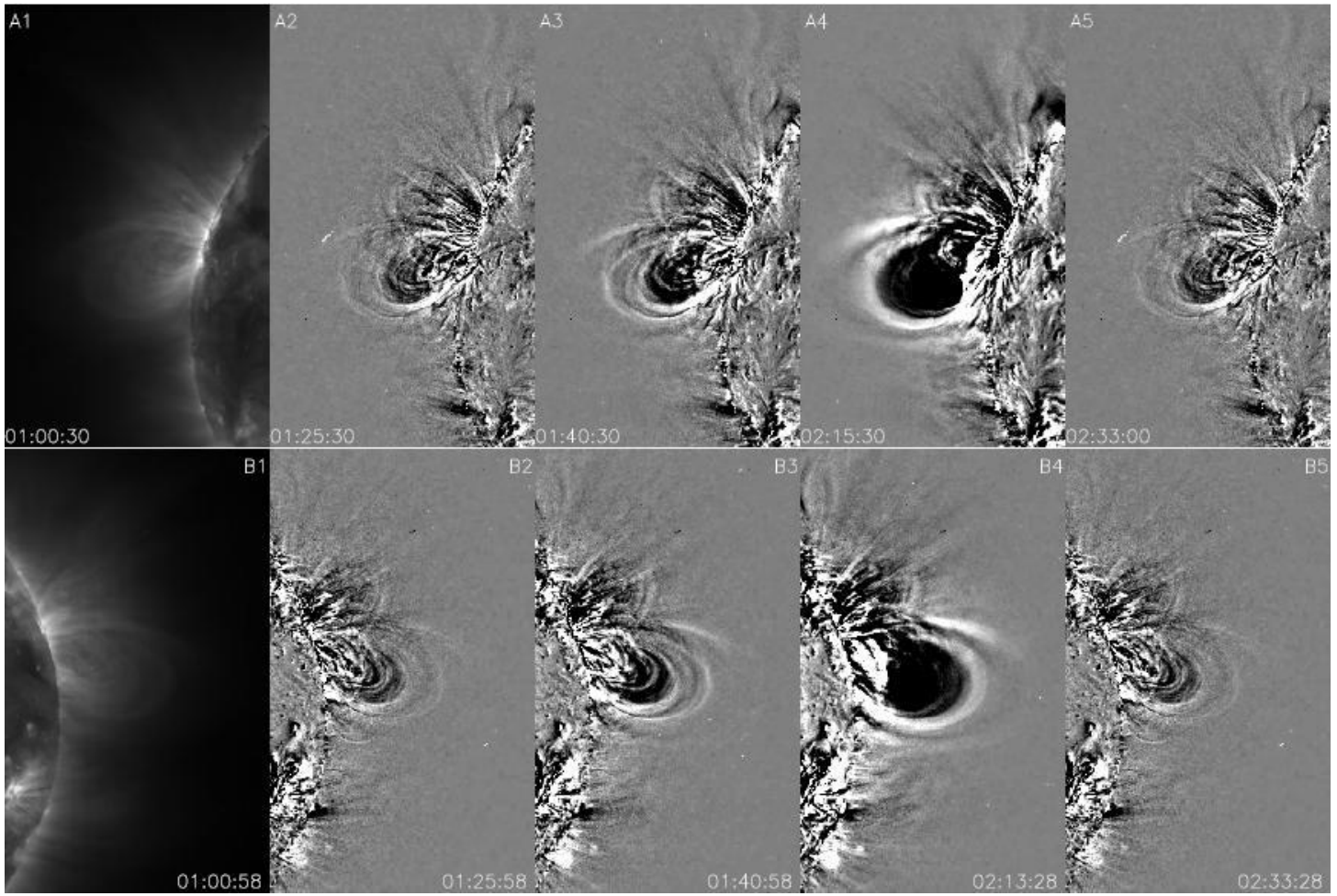
• The final dimming area is formed by using the pixels in the minimal pixel map as seeds for a region-growing method.

Results

June 21, 2011

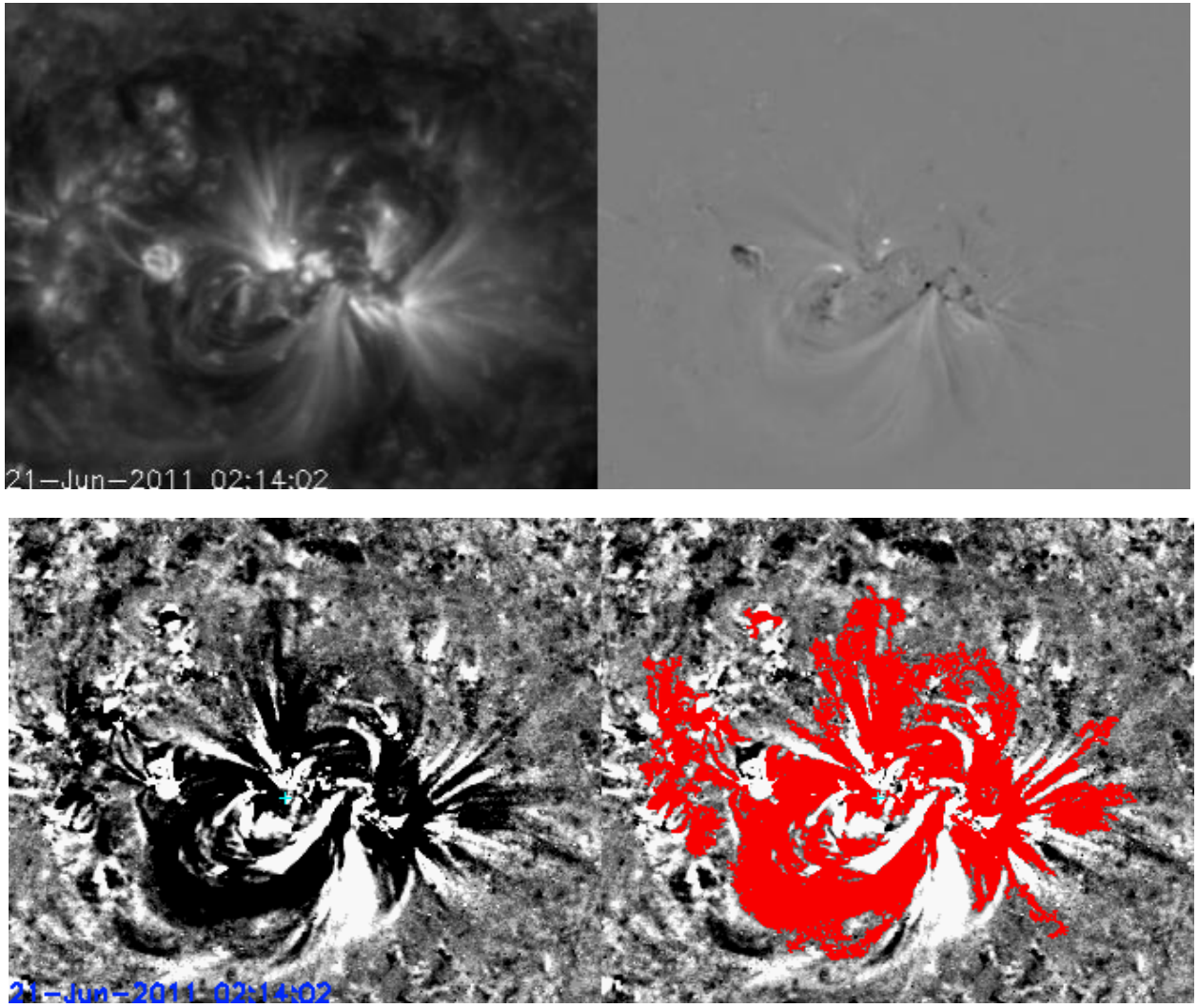
Base difference images taken from EUVI A (left) and EUVI B (right)

June 21, 2011



Screenshots of the evolution of the event by EUVI A (top row) and EUVI B (bottom row)

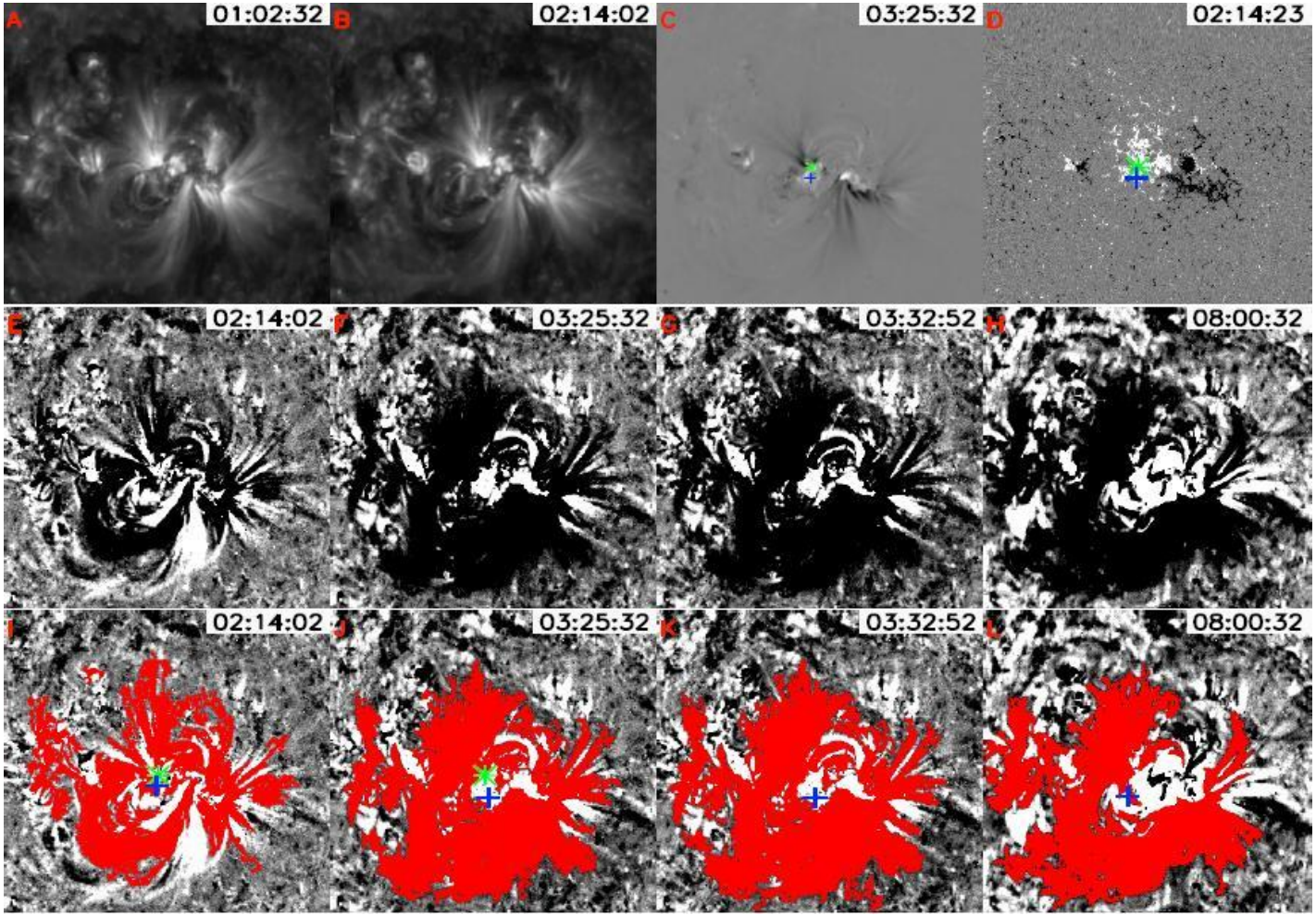
June 21, 2011



Evolution of the event using SWAP data and identification of the dimming area.

[Red pixels represent the dimming area, while the + symbol, refers to their centroid]

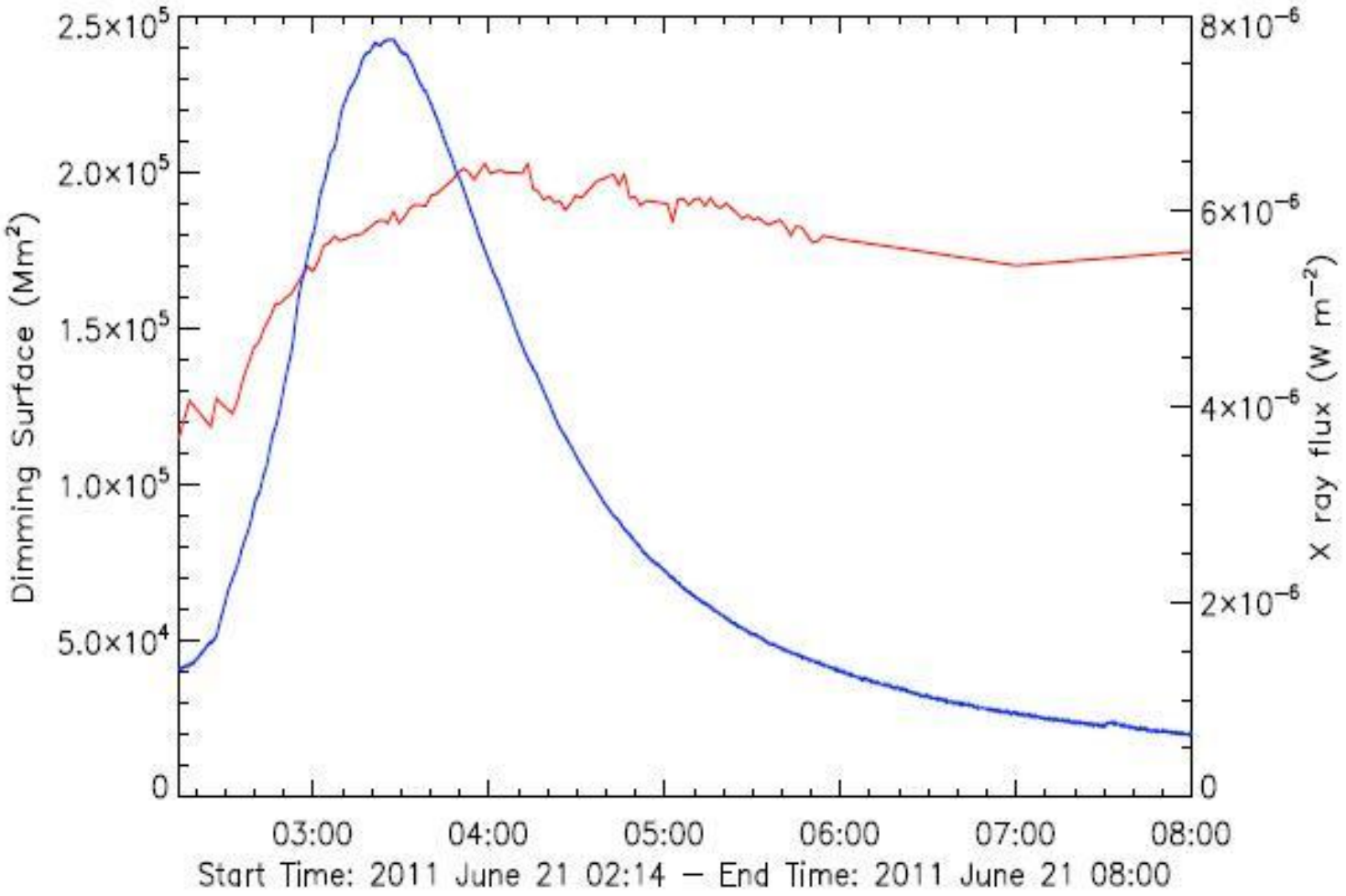
June 21, 2011



Screenshots of the evolution of the event using SWAP and HMI data.

[Red pixels represent the dimming area, while the + symbol, refers to their centroid. The * symbol refers to the centroid of the flare brightenings]

June 21, 2011

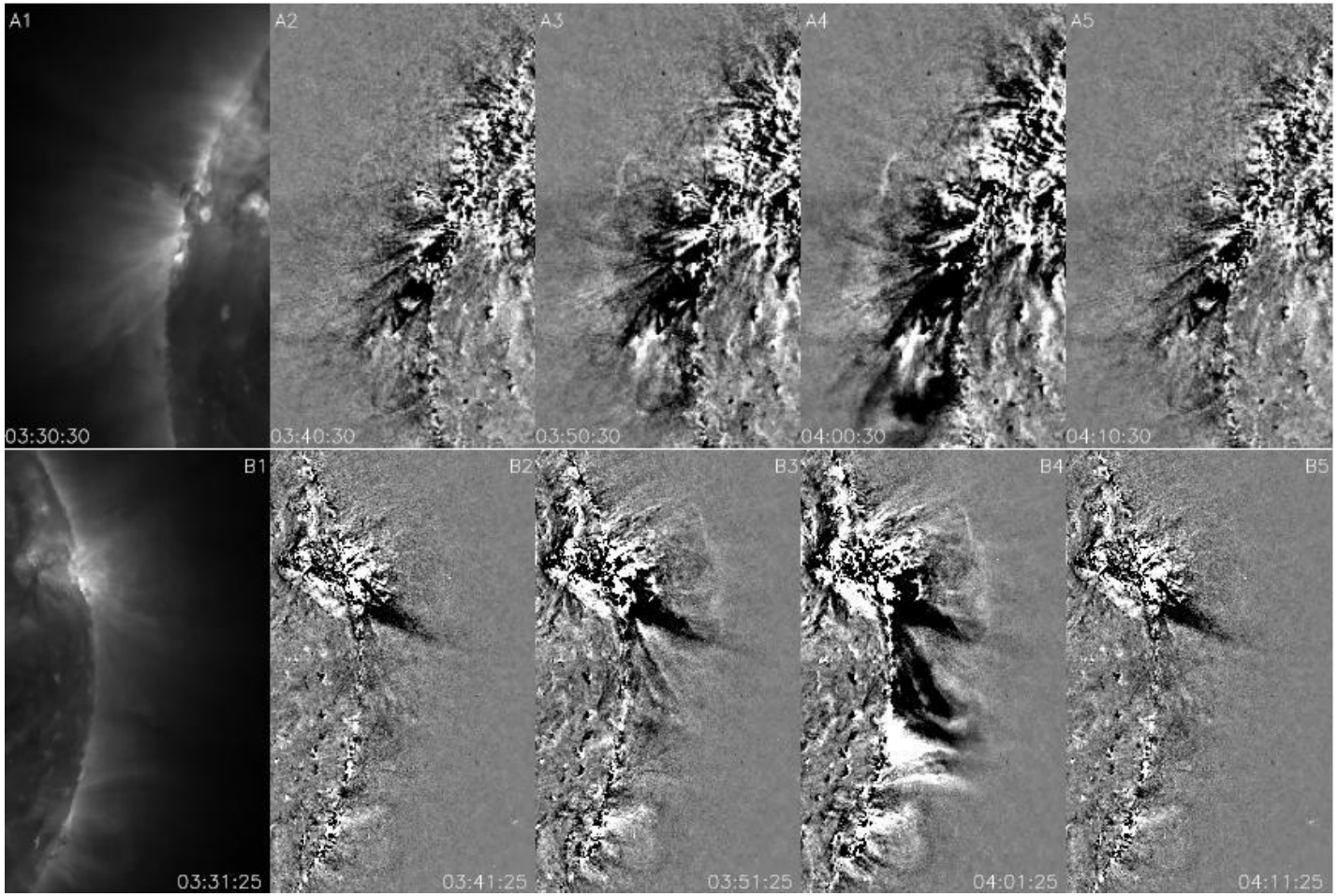


Evolution of the dimmings' surface over time (red curve) and X-ray flux from GOES (blue curve).

September 30, 2011

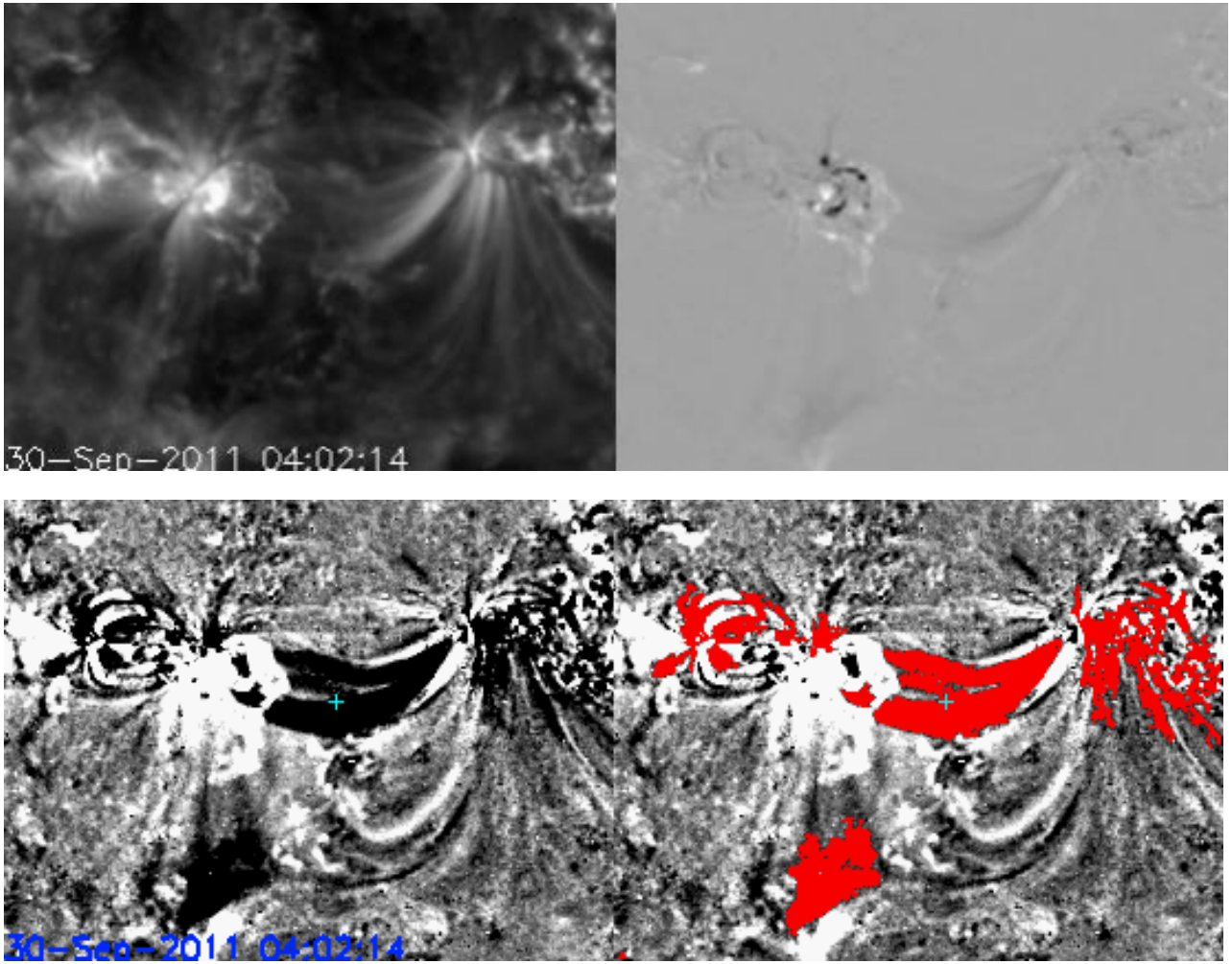
Base difference images taken from EUVI A (left) and EUVI B (right)

September 30, 2011



Screenshots of the evolution of the event by EUVI A (top row) and EUVI B (bottom row)

September 30, 2011



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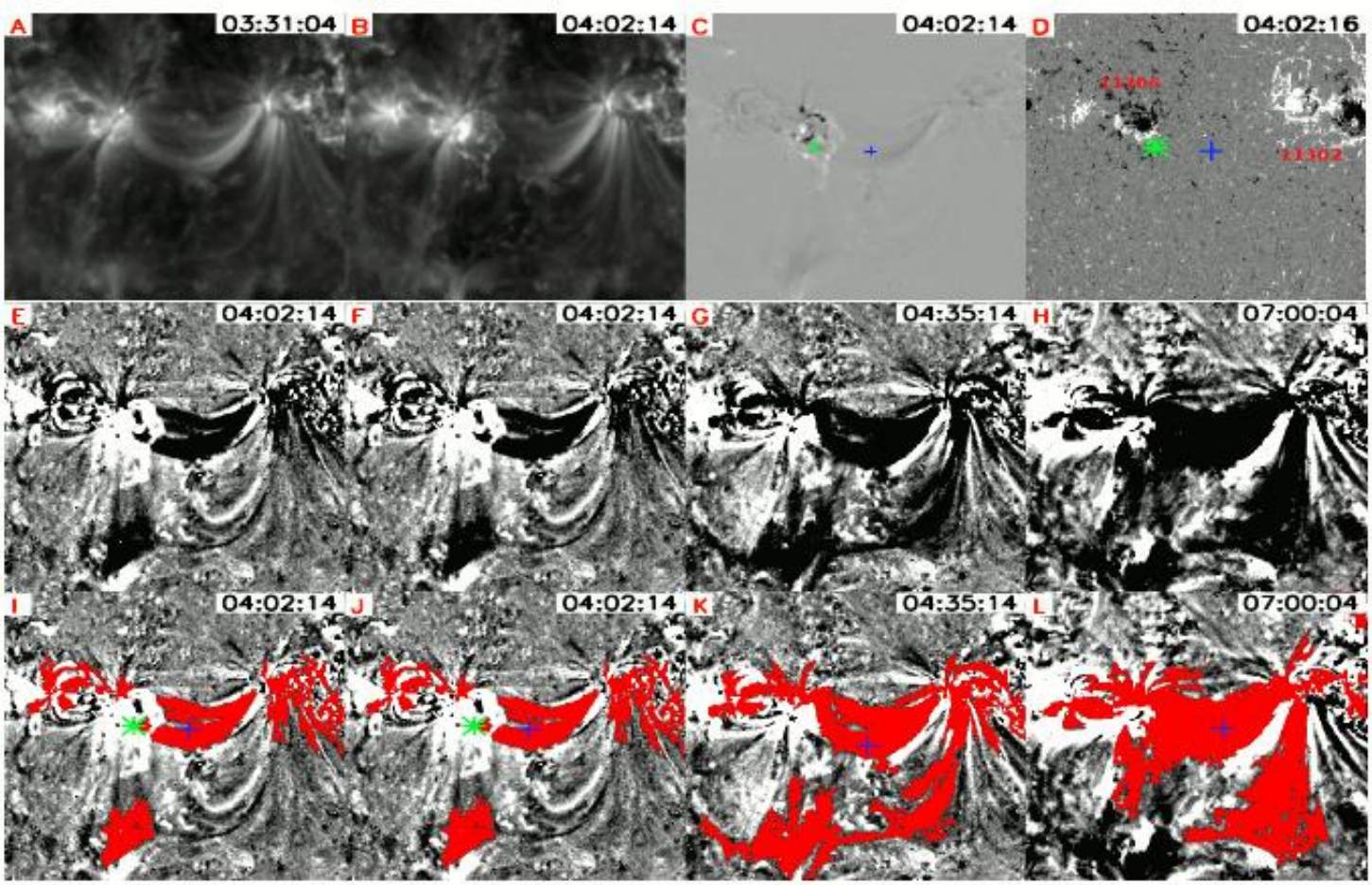
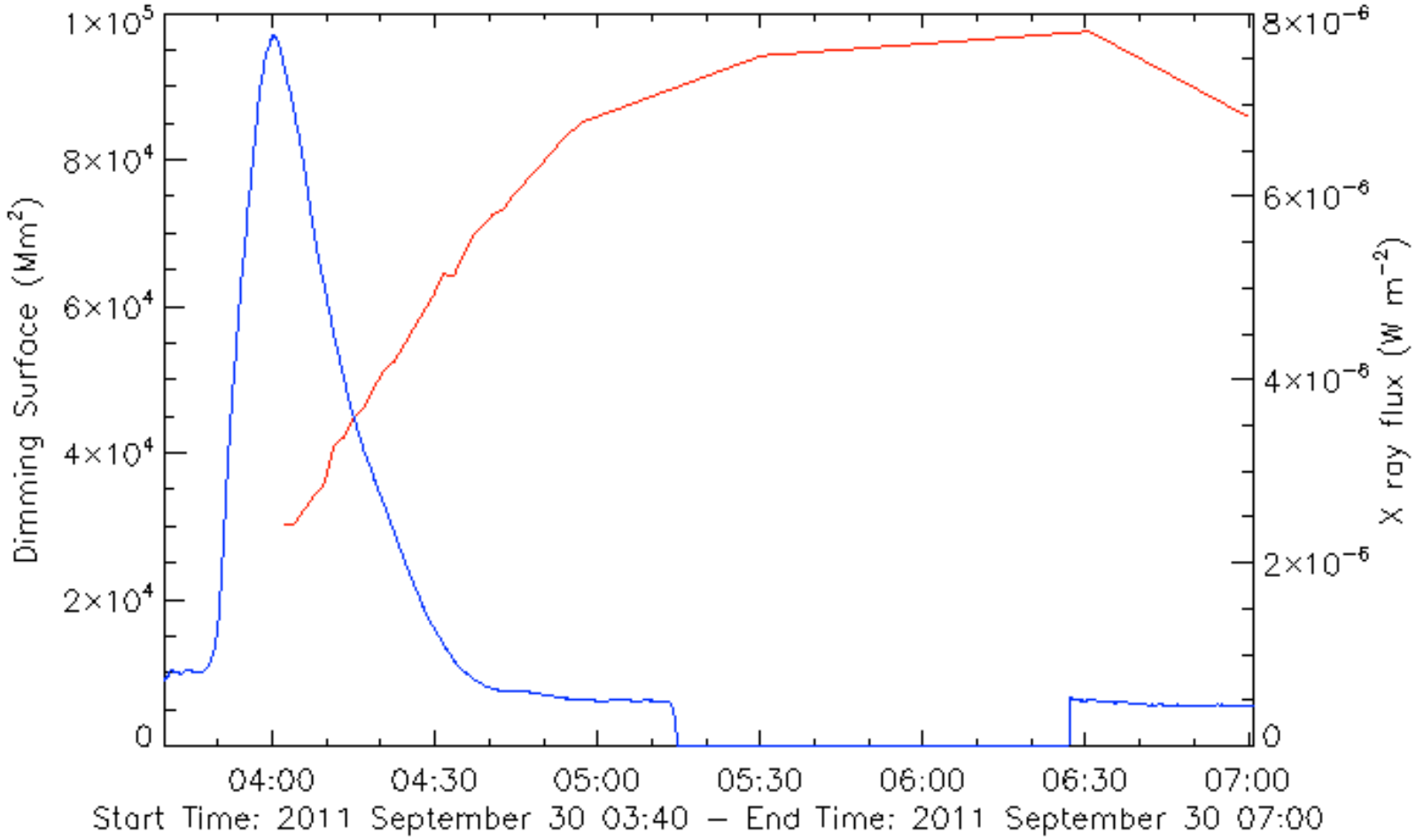


Screenshots of the evolution of the event using SWAP and HMI data.

[Red pixels represent the dimming area, while the + symbol, refers to their centroid. The * symbol refers to the centroid of the flare brightenings]

September 30, 2011



Evolution of the dimmings' surface over time (red curve) and X-ray flux from GOES (blue curve).

Distances between the centroids

A/A	Date	CME Onset (UT)	Distance (Mm)
1	04/08/2010	02:50	31.9
2	14/02/2011	07:02	49.7
3	14/02/2011	13:00	42.1
4	14/02/2011	19:41	53.6
5	15/02/2011	14:57	74.1
6	02/06/2011	06:37	15.7
7	02/06/2011	07:45	59.9
8	21/06/2011	02:14	22.8
9	11/07/2011	10:30	31.2
10	11/07/2011	10:35	12.5
11	27/09/2011	20:53	60.8
12	29/09/2011	12:45	71.4
13	30/09/2011	04:02	103.9
14	10/10/2011	14:40	24.8
15	22/12/2011	02:29	80.3
16	25/12/2011	08:56	86.1
17	26/12/2011	11:21	137.2
18	23/04/2012	17:41	40.6
19	25/09/2012	04:29	31.1

Discussion - Conclusions

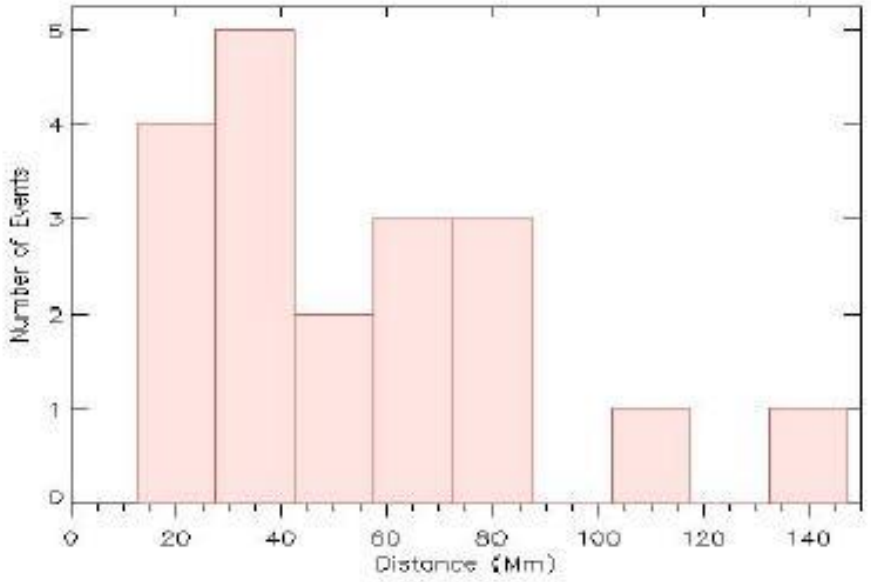
Of the events studied, we had

- 14 events with complete spatial separation
- 5 events where the CME was observed above the flare brightenings

→ 12.5 Mm – 31.2 Mm

Distances
12.5 Mm - 137.2 Mm

Mean Value: 54.2 Mm
Median Value: 49.7 Mm



Of the events studied, we had

- 7 events in which the distance between the centroids was greater than 60 Mm

  → escaping inclined loops

  → interconnecting loops between two neighboring active regions

  → CME deflection in low altitude

- 12 events in which the distance between the centroids was less than 60 Mm

  → CME process involved only a single active region

Dimmings' area evolution with time

- We calculated the dimmings' surface after we transformed the images into the heliographic coordinate system

→ the dimming area decreases more gradually than the X-ray flux

→ in 17 of the events, the dimmings' area was increased and then was gradually decreased

Of the events studied, we had

- 8 events in which the dimmings' centroid is located above the neutral line of the magnetic field
- 5 events in which the dimmings' centroid is located out of the active region
- 6 events in which the dimmings' centroid is not located above the neutral line of the magnetic field

Future Plans

- Study more events
  (probably by using other instruments)

- Automation of our method

Thank you for your attention