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Two candidate homologous CMEs on 2002 May 22

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Abstract

Two coronal mass ejections (CMEs) occurred on 2002 May 22, originating from the same active region, AR 9948. Multi-wavelength data are collected in order to clarify the relationship between the CMEs, the associated flares and filament eruptions, and some other magnetic activities, which is of great importance to understand the mechanism of each phenomenon. It is tentatively suggested that the two CMEs are probably homologous.

Keywords: Filaments; Flares; Coronal mass ejections

1. Introduction

Coronal mass ejections (CMEs) are the largest eruptive events in the solar atmosphere. A typical CME can be described as three parts: a front loop, a cavity, and a core, the latter of which is theoretically modeled as a flux rope, and in about one-third of all CMEs events. It carries about 10^{14}–10^{16} g of magnetized material into the interplanetary space. CMEs are believed to be the causes of many geoeffective activities such as geomagnetic storms, interplanetary shocks, and so on.

CMEs, filament eruptions and solar flares are often associated, although the exact causal relationship is not yet well known. In order to understand their mechanisms, it is very important to find out their temporal and spatial relationship. Zhang et al. (2001) analysed four events in 1997 and 1998, and found that the CMEs can be described in a three-phase scenario: the initiation phase, impulsive acceleration phase, and propagation phase. The initiation phase is characterized by a low ascension with a speed less than 80 km s^{-1}, with a period of tens of minutes. The initiation phase of a CME sometimes corresponds to a small bump of soft X-ray flux in the preflare phase. The acceleration phase corresponds to the impulsive phase of the associated flares. The acceleration of CMEs ceases near the peak time of the soft X-ray flare. Thereafter, CMEs undergo a propagation phase. Besides, they found that CMEs are generally initiated at a height of 1.3–1.5$R_\odot$ and accelerated until 3.7–4.7$R_\odot$. The three-phase scenario was also illustrated by Chen and Shibata (2000), who proposed an emerging flux trigger mechanism for CMEs on the basis of the strong correlation between reconnection-favored emerging flux and CMEs found by Feynman and Martin (1995).

On 2002 May 22, two CMEs appear in the field of view of the LASCO C2 coronagraph successively within 3 h, indicative of their sympathetic nature. Both of them are associated with two-ribbon flares and filament eruptions. Therefore, the two events present an excellent opportunity to investigate the relations between CMEs, solar flares and/or filament eruptions. Observations are described in Section 2, our analysis and the results are given in Section 3, followed by a discussion in Section 4.

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2. Observation

Two CMEs occur in the active region AR9948 (S25W64) within 3 h on 2002 May 22, which are observed by the Large Angle and Spectrometric Coronagraph (LASCO) telescope (Brueckner et al., 1995) on board the Solar and Heliospheric Observatory (SOHO) (Domingo et al., 1995).

Two solar flares classified as C9.7 and C5.0 occur during the events which are associated with the two CMEs, respectively. Both flares possess two-ribbon structures in the Hα images, which are observed by the Huairou Solar Observing Station (HSOS) of the National Astronomical Observatories of China (NAOC).

3. Analysis and results

As shown in Fig. 1, the first CME is first seen at 00:06:06 UT in the white light with the LASCO C2 coronagraph. In the SW direction, we can see a bright front loop with a cavity. From 00:06:06 to 00:26:06 UT, the bright front loop shifts from $3.23R_\odot$ to $4.85R_\odot$. Thereafter, it disappears from the C2 field of view, and becomes visible in C3, where its front loop propagates with a nearly constant speed before it goes out from the C3 field of view at $26.27R_\odot$. EIT running difference images, which shows the propagation of an EIT wave as studied by Zhukov and Auchére (2004), indicate that a filament erupts before 23:24:11 UT on 2002 May 21, before a C9.7 flare occurs. According to the GOES soft X-ray observation, the flare undergoes its preflare phase from 23:30 UT, and the soft X-ray flux peaks at about 00:25 UT.

The second CME first appears in C2 at 03:50 UT with a height of $4R_\odot$ as seen in the lower panels of Fig. 1. At 04:06:05 UT, the CME propagates to $5.95R_\odot$. Thereafter, it goes out of the C2 field of view, and undergoes a steady evolution in C3. It travels with a nearly constant speed until it goes out of the field of view at 06:42:05 UT. At 02:50 UT, a dark filament begins to be active. Between 03:12 and 03:24 UT, the filament erupts rapidly as shown in Fig. 2. At about 03:25 UT, the flare undergoes its rise phase, and its soft X-ray flux peaks at about 03:45 UT.

Both events involve three solar phenomena: a CME, a filament eruption, and a flare, though the second eruption is more drastic than the first one. Their temporal relationship is synthesized in Fig. 3, which presents the estimated onset times of the filament eruptions (asterisks) and the height–time evolutions of the two CMEs (solid lines) superposed on the GOES soft X-ray (dashed line) light curve. Note that the occurrence times of the filament eruptions are determined by examining both EIT 195 Å and Hα images, and the crosses connected by solid lines in the figure correspond to the CME frontal loop heights measured from LASCO images. The earlier evolutions of the CMEs, which are missed due to the occultation of the coronagraph, are extrapolated backward to the solar limb with the uniform acceleration assumption. The first CME is thereby estimated to be triggered at about 23:14 UT on May 21, 2002, 10 min before the associated filament eruption, with an acceleration ~300 m s^{-2}, while the associated flare starts

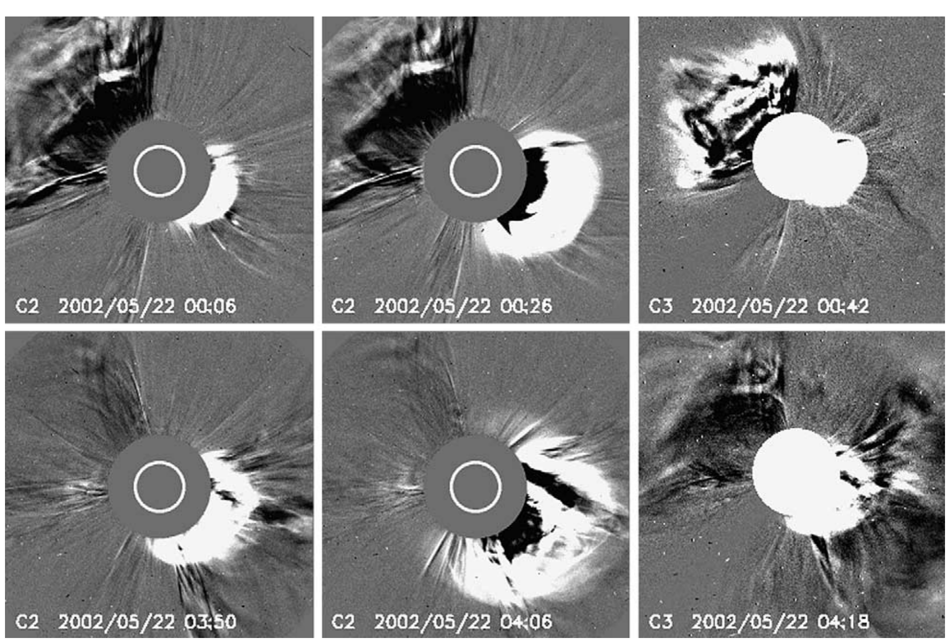
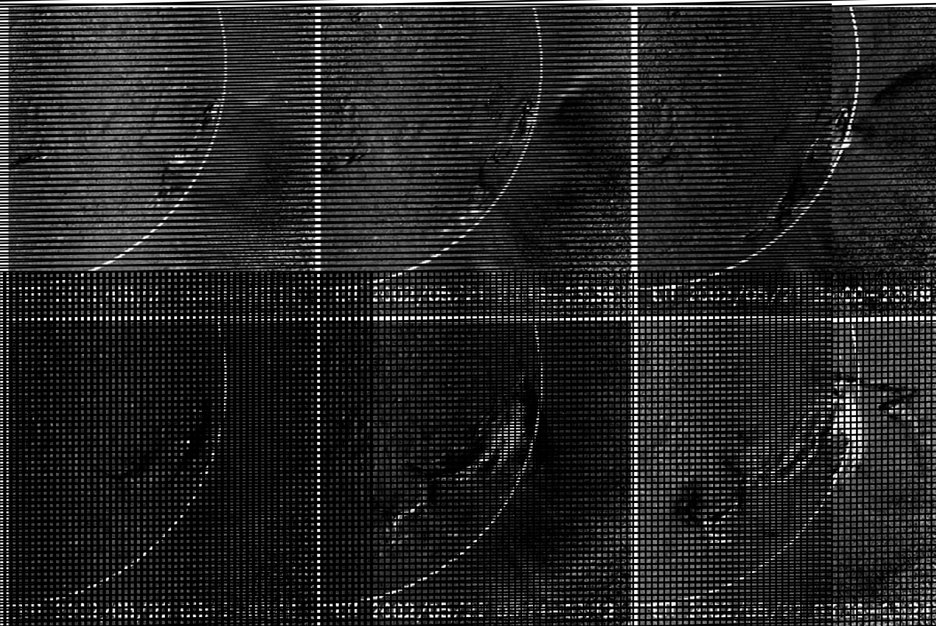
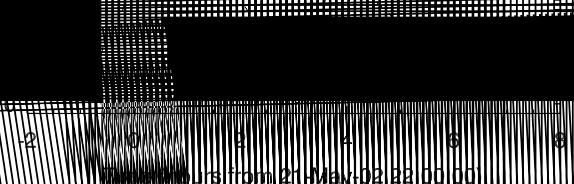


Fig. 1. Evolution of the first CME (upper panels) and the second CME (lower panels).



… during … EUV dimming associated with the two CMEs. Dimming occurred during the first event in … the second event … Extended EUV dimmings in both two events are very similar with each other.

It was established that reconnection-favored emerging flux often proceeds the onset of CMEs (e.g., Feynman and Martin, 1995), which is later explained as an emerging flux trigger process proposed by Chen and Shibata (2000). MDI magnetograms before the two CME events are checked in Fig. 4. It is identified that flux emergence did appear inside the filament channel two days before the eruptions, as indicated by the ellipses. According to the … given by Feynman and



10 min later than the filament eruption. The speed of the first CME continues to increase with an acceleration of $\sim$300 m s^{-2} until C3. Thereafter, it runs with a nearly constant speed of $\sim$1240 km s^{-1}. The second CME is estimated to be initiated at about 03:02 UT, 13 m… fore the associated filament eruption, with an … tion about 500 m s^{-2} while the associated … 10 min later than the filament eruption … the second CME continues to increase … tion of $\sim$470 m s^{-2} until C3. Then … constant speed of $\sim$1740 km s^{-1}.

4. Discussion

CMEs erupte… AR9948 on 2… an unique… cesses, … flares… ou…

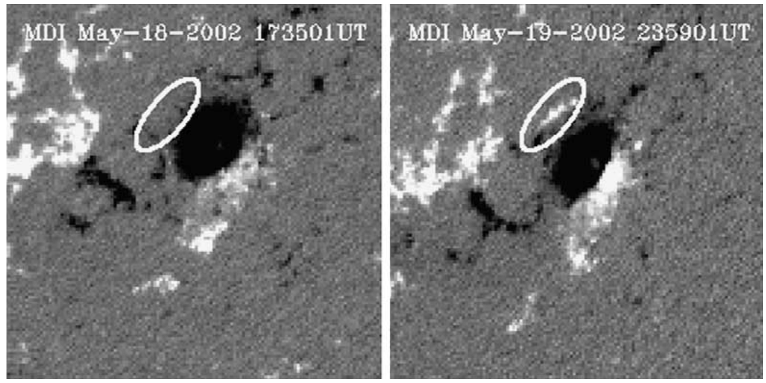


Fig. 4. Magnetic field evolution of the active region AR9948 seen in the SOHO/MDI magnetogram. The ellipsed regions show the places where new flux emerged.

among the CMEs, filament eruptions, and solar flares are roughly consistent with the results obtained by Simnett (2000) and Zhang et al. (2001), i.e., the coronal swelling (or CME onset) starts before the onset of the filament eruption, which is followed by a solar flare.

Recently, Zhang and Wang (2002) proposed the concept "homologous CMEs" to describe the consecutive CME events that originate from the same source region and resemble each other in appearance. According to their definition, the two CMEs should satisfy the following conditions if they are considered as homologous CMEs: (1) each member of homologous CMEs must associate with a member of homologous flares; (2) extended EUV dimming must be similar among homologous CMEs and flares; (3) the coronagraph appearance of the homologous CMEs and flares must resemble each other, where the definition of homologous flares states that members of a series must have the same main footpoints as defined by Hα or EUV kernels, and share the same general shape in the main phase as defined Hα ribbons or EUV images (Woodgate et al., 1984). According to our data analysis in Section 3, the CMEs occurring consecutively within $\sim$3 h on 2002 May 22 resemble each other in the LASCO coronagraph appearance, although the second event has a little larger angular span near the south limb of the sun as revealed in Fig. 1. Besides, the running difference images of SOHO/EIT indicate that the low-lying EIT dimming regions of the two CMEs are also similar, though the EIT dimming of the second CME is somewhat extended to the south limb, compared to that of the first event. Therefore, the two CMEs satisfy the last two conditions for homologous CMEs proposed by Zhang and Wang (2002), and violate the first condition since the associated flares in our events occurred in different locations, though within the same active region. Here, we tentatively extend slightly the definition of homologous CMEs given by Zhang and Wang (2002) not to include their first condition. The reason is explained as follows. Flares are small-scale phenomena with a size typically smaller than 2.3′, while CMEs are large-scale eruptions with an average angular width of 72°, which correspond to the global magnetic restructuring. The CME shape is determined by the large-scale background magnetic field, and the associated flares could be at any position within the angular span of the CME. Therefore, it is plausible that two CMEs with associated flares at different locations could resemble each other in appearance and hence are classified to be homologous CMEs when the CMEs propagate to a certain distance, say $2R_{\odot}$, if there are interconnecting magnetic loops covering over both the flares. Note that in the early phase when the CMEs are still developing in the low corona, they are confined around the associated flares, therefore, are different in appearance. In this sense, these two CMEs can be regarded as homologous CMEs.

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