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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

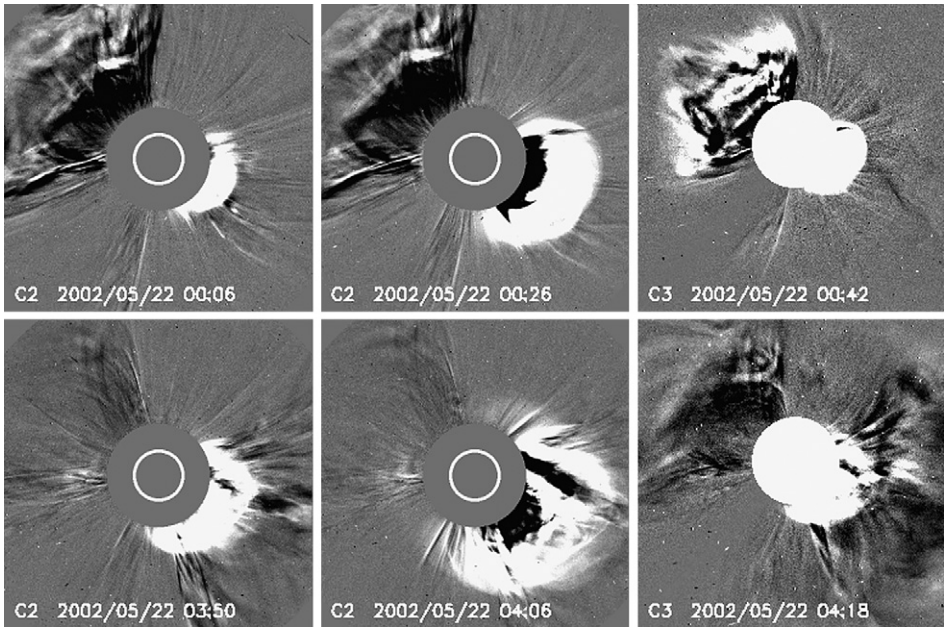

Fig. 1. Evolution of the first CME (upper panels) and the second CME (lower panels).