J. Astrophys. Astr. (2000) **21,** 403–406

Exploring Coronal Structures with SOHO

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Abstract. We applied advanced image enhancement techniques to explore in detail the characteristics of the small-scale structures and/or the low contrast structures in several Coronal Mass Ejections (CMEs) observed by SOHO. We highlight here the results from our studies of the morphology and dynamical evolution of CME structures in the solar corona using two instruments on board SOHO: LASCO and EIT.

Key words. Corona—CME.

1. Introduction

The Solar and Heliospheric Observatory (SOHO) provides unprecedented views of CMEs to heliocentric distances of up to 32 solar radii. CMEs are spectacular phenomena in the solar corona which have a wide variety of morphologies. Their exact three-dimensional magnetic topology is not generally clear because it is hard to infer the three-dimensional structure of a CME from two-dimensional images.

The roughly circular cavity observed in many CMEs might be interpreted to be the top of a broad flux rope viewed face-on, where the flux rope is still connected with the Sun. We present here the results of our study of several events of this kind observed using the Ultraviolet Imaging Telescope (EIT) and the Large Angle Spectrometric Coronagraph (LASCO) instruments on SOHO.

2. Observations and data analysis

The EIT instrument images the disk of the Sun in one of four different bandpasses and its field of view reaches to heliocentric heights of about 1.4 $R_\odot$ (Delaboudinière *et al.* 1995). The wavelengths and the dominant emission lines in these bandpasses are 171Å (Fe IX and Fe X), 195 Å (Fe XII), 284 Å (Fe XV), and 304 Å (He II). LASCO was designed to observe the solar corona from 1.1 $R_\odot$ 32 $R_\odot$ (Brueckner *et al.* 1995). This instrument contains three individual coronagraphs, CI, C2, and C3, which produce overlapping views of the corona.

We selected three CMEs with circular rim structures which were observed on 1997 April 30th and February 23rd, and on 1999 August 28th. In spite of the morphological similarities these CMEs were quite different. The February 23rd and August 28th CMEs were accompanied by dramatic prominence eruptions and significant GOES

Xray flares, while the April 30th was accompanied by no apparent prominence eruption and only a weak Xray flare.

The images of these CMEs contain many complex components with different spatial scales and a wide range of contrast levels. The morphology and distribution of the small spatial scale structures cannot readily be extracted directly from these images, either because of limited resolution and noise in the images, or because of the low contrast of the small-scale structures when compared to the large-scale features. Spatial and temporal characterization of these structures is extremely important for understanding the origin and the early evolution of these dynamical phenomena.

We applied image enhancement techniques to explore in detail the characteristics of the small-scale structures within the CMEs, especially to find the locations of the leading edges, trailing edges and the centroids of the circular rims. These techniques include an image enhancement algorithm (IEA) (Karovska *et al.* 1994), and an average-differencing technique used to improve the visibility of various dynamical coronal structures against the largescale slowchanging background.

3. Results

The set of CMEs that we studied can be followed from their points of origin near the limb to large distances from the Sun in the LASCO C3 field of view. We studied the kinematics of these structures by measuring the motions of their leading and trailing edges, and of the centroids, using the enhanced images. As an example, Fig. 1 shows the enhanced LASCO C2 images of the 1997 April 30th CME. The CMEs velocity and acceleration curves were computed from the second order polynomial fits to the height measurements.

Our results show that for the three CMEs, the acceleration takes place below heights of about 4 $R_{\odot}$. These CMEs appear to have begun very close to the limb of the Sun, so it is unlikely that there is a substantial motion along the line of sight that we are not detecting. Thus, the velocities we are measuring should be close to the true velocities.

Despite being similar in appearance in the C2 and C3 fields of view, these CMEs have dramatically different velocities. For example, the leading edge of the April 30th and August 28th CMEs reach relatively slow velocities of few hundreds km s^{-1} which is slightly faster than the ambient solar wind. However, the leading edge of the February 23rd CME levels out at a much higher speed of almost 1000 km s^{-1}.

We used the observed CME structures motions to test a MHD model of an expanding flux rope (Chen *et al.* 1996). We interpret the circular structures seen in the studied set of CMEs as outlining the apex of a flux rope viewed face-on. In the flux rope model, the CME is initiated by an increase of the poloidal component of the helical magnetic field within the flux rope. In fact, in the enhanced C2 observations of the April 30th CME, we do see helical lines which suggest the presence of a helical magnetic field.

We used only two free parameters to model the observed dynamics:

(1) the geometry of the initial flux rope, represented by the footpoint separation and (2) the profile of the poloidal flux injection (Chen *et al.* 1997; Wood *et al.* 1999).

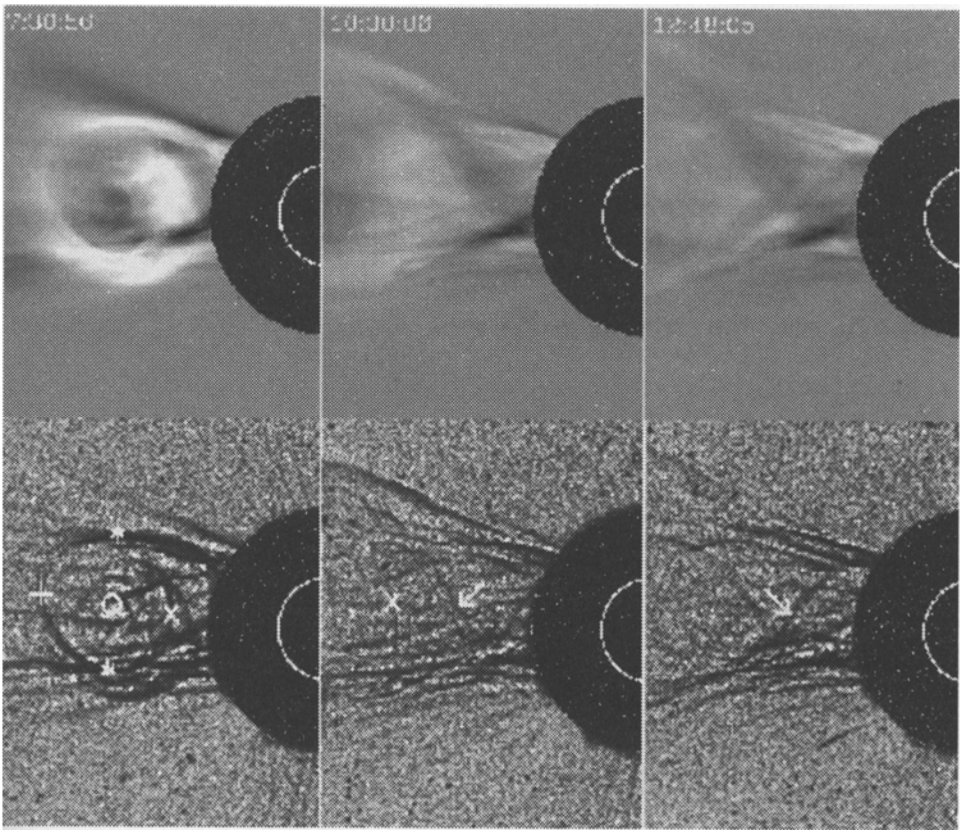

Figure 1. Average-differenced and edge-enhanced versions of three LASCO C2 images of the 1997 April 30 CME. These images were recorded at 7:00:56 UT, 10:30:06 UT, and at 12:40:05 UT, respectively. The locations of the leading edge (plus sign), trailing edge (X's), sides (asterisks), and centroid (circle) of the bright circular rim structure of the CME are indicated. Helical lines are seen below the rim which possibly trace the magnetic field. Two of these lines are identified with arrows.

For the April 30th CME, the initial position of the flux rope is observable in LASCO C1 Fe XIV λ5303 images as a bright semicircular region at the east limb, which starts to dim hours before the beginning of the CME. For the February 23rd CME, LASCO C1 images show a large loop in the northeast quadrant of the Sun which may mark the initial flux rope position.

We conclude that for 1997 February 23rd and April 30th CMEs, the trajectories are in good agreement with the flux rope model (Wood *et al.* 1999). We are currently testing the flux rope model using the measurements of the 1999 August 28th CME kinematics.

Acknowledgements

This project is supported by funding from the Naval Research Laboratory to the Harvard-Smithsonian Center for Astrophysics under contract N0014-97-1-G023.

M.K. is a member of the Chandra X-ray Observatory Center and is partially supported by NASA, Contract #NAS8-39073.

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