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Rapid Acceleration of a Coronal Mass Ejection in the Low Corona and Implications for Propagation

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ABSTRACT

A high-velocity Coronal Mass Ejection (CME) associated with the 2002 April 21 X1.5 flare is studied using a unique set of observations from the *Transition Region and Coronal Explorer* (TRACE), the Ultraviolet Coronagraph Spectrometer (UVCS), and the Large-Angle Spectrometric Coronagraph (LASCO). The event is first observed as a rapid rise in GOES X-rays, followed by simultaneous conjugate footpoint brightenings connected by an ascending loop or flux-rope feature. While expanding, the appearance of the feature remains remarkably constant as it passes through the TRACE 195 Å passband and LASCO fields-of-view, allowing its height-time behaviour to be acurately determined. An analytic function, having exponential and linear components, is found to represent the height-time evolution of the CME in the range 1.05–26 $R_\odot$. The CME acceleration rises exponentially to $\sim$900 km s^{-1} within approximately 20-min, peaking at $\sim$1400 m s^{-2} when the leading edge is at $\sim$1.7 $R_\odot$. The acceleration subsequently falls off as a slowly varying exponential for $\sim$90-min. At distances beyond $\sim$3.4 $R_\odot$, the height-time profile is approximately linear with a constant velocity of $\sim$2400 km s^{-1}. These results are briefly discussed in light of recent kinematic models of CMEs.

Subject headings: Sun: corona – Sun: coronal mass ejections (CMEs) – Sun: flares

1. Introduction

CMEs are among the largest energy releases in the solar system and can directly affect space weather in the near-Earth environment. Although of such practical importance, the physical mechanisms responsible for CME initiation, acceleration, and propagation remain unclear, despite their having been observed and studied for upwards of 20-years (Crooker et al. 1997; Song et al. 2001).

It is well known that CMEs are associated with both filament eruptions and solar flares (Zhang et al. 2002; Moon et al. 2002; Moon et al., in preparation), but the driver mechanisms remains elusive. Several possible drivers are described by Krall et al. (2000, 2001), within the context of the flux rope model of Chen (1989, 1996). These include: flux injection; footpoint twisting; magnetic energy release; and hot plasma injection. An alternative to this bipolar flux rope model is the so-called "magnetic break-out" model of Antiochos, DeVore, & Klimchuk (1999), where the CME eruption is triggered by reconnection between the overlying unsheared field and a neighbouring flux system. Another possibility is the Forbes & Priest (1995) model, in which a converging flow towards the neutral line results in reconnection between two footpoint sources beneath the flux rope. These, together with other directly driven and storage-release CME initiation models, are discussed in Klimchuk (2001).

Following initiation, the CME plasma and associated field are accelerated away from the solar surface, and both divisions of model can give rise to rapid acceleration of fast CMEs, which can reach velocities of $\sim$1000 km s^{-1} within $\lesssim$3 $R_\odot$ (St. Cyr et al. 1999; Zhang et al. 2001; Alexander, Metcalf, & Nitta 2002). For the event discussed here, the heights and times of the first two data points measured above 3 $R_\odot$ by the Large Angle Spectrometric Coronagraph (LASCO; Brueckner et al. 1995) imply a mean transit speed of 2296 km s^{-1} between them. Such high velocities are not inferred from low coronal data, nor is even the greatest acceleration inferred from LASCO data (107 m s^{-2}; Yashiro et al., in preparation) sufficient to accelerate a CME constantly to such a speed between 1 and 3 $R_\odot$. Once accelerated, most CMEs assume a near-linear height-time evolution as plasma density, magnetic field, and gravity drop off (Chen et al. 2000); this phase becomes important for heights greater than $\sim$5 $R_\odot$, and can be characterized by a constant velocity or ballistic motion.

In this paper, we present and analyse data from an event unusual in two regards: its speed and coverage. Its mean linear speed through LASCO is 2600 km s^{-1}; this is within the fastest 1% of CME speeds inferred from LASCO data (Yashiro et al., in preparation). Also, to

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