

Interplanetary coronal mass ejections during the descending cycle 23: Sheath and ejecta properties comparison

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Abstract

We have used Omniweb data in order to identify the sheath and the ejecta boundaries of 67 shock-driving interplanetary coronal mass ejections during the time period 2003–2006. We examine and compare their statistical properties (speed, magnetic field strength, proton density and temperature, proton plasma beta), with those of the typical solar wind. We also calculate their passage time and radial width. We study the correlation between the ejecta and sheath characteristics.

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1. Introduction

Coronal mass ejections (CMEs) are dramatic explosions on the solar atmosphere which lead to massive releases of mass and energy into the interplanetary space, that can range from 10^{13} g to 10^{16} g and from 10^{27} erg to 10^{33} erg, respectively (Vourlidas et al., 2002; Gopalswamy, 2004, 2006a). The occurrence CME rate depends on the phase of the solar cycle and can differ from 3.5 per day during solar maximum, to 0.2 per day during solar minimum (Gosling, 1990). The CMEs speed can be higher or lower than the ambient solar wind speed and can range from a few km/s to 3000 km/s (Howard et al., 1985; St Cyr et al., 2000; Gopalswamy, 2004, 2006a).

CMEs which occur close to the sun center and appear to surround the solar disk like a bright halo are called halo CMEs (Howard et al., 1982). Halo CMEs can be Earth directed (front-sided) or back-sided. Earth directed halo CMEs often have great consequences on the Earth's geomagnetism (Tsurutani et al., 1988; Gonzalez et al., 1999; Huttunen et al., 2005).

The manifestations of the CMEs in the interplanetary medium are called interplanetary coronal mass ejections (ICMEs), ejecta, clouds or plasma clouds. In this study they will be referred to as ejecta or ICMEs. They are recognized by in situ spacecraft observations of plasma and magnetic field data and most of them can be clearly associated with a CME on the sun (Lindsay et al., 1999). The signatures of ICMEs can include low plasma temperature (Gosling, 1990), strong and smooth magnetic field (Burlaga et al., 1981), enhanced helium abundance (Borrini et al., 1982; Galvin et al., 1987) and low plasma beta and density (Burlaga et al., 1981), when compared to the ambient solar wind. CMEs with supersonic speeds can drive shocks into the interplanetary medium, which accelerate particles. The shock can usually be identified by a sudden rise of the plasma speed, magnetic field strength, density and temperature. The area between the shock and the ICME is called sheath.

2. Data selection and boundaries Identification

We have identified 67 shock-driving ICMEs, through their interplanetary signatures using Omniweb data for the time period 2003–2006. The data include magnetic field strength, solar wind speed, proton density and tempera-

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ture. All of our events had a halo CME as a solar source possible candidate and were accompanied by a well defined shock. We excluded from our study interacting ICMEs and took into consideration only events with rather clear boundaries of the shock, sheath and ejecta region.

For each ICME the boundaries of the shock, the sheath and the ejecta have been identified, although that remains a subjective matter, since no unambiguous and universal signature has been found yet (Richardson and Cane, 1993; Goldstein et al., 1998; Wei et al., 2003). Of course, the shock arrival is very clear, but the identification of the ejecta is often pretty difficult. The front boundary of the ejecta is determined through the interplanetary signatures mentioned above, while the rear boundary can be placed at the time of an increase in temperature, plasma or magnetic field strength, after the ICME passage. An important subsection of ICMEs (almost one third of them) are magnetic clouds (Burlaga et al., 1981), which are easier to identify. They exhibit a smooth rotation of the magnetic field

vector, in addition to low plasma beta. However, we have included all types of ICMEs in our study, not just the magnetic clouds.

3. Comparison between the sheath and ejecta properties

For each of the 67 identified ICME we calculate its mean characteristic quantities, such as magnetic field strength, speed, density, temperature and plasma beta both of the sheath and the ejecta. We also estimate the mean passage time t and radial width, also known as length scale (ICME size in the radial direction).

Throughout the mentioned characteristic quantities, such as magnetic field strength, speed, density, temperature, plasma beta ($=p_{\text{gas}}/p_{\text{mag}}$), passage time and radial width, are symbolized as $j = B, V, d, T, \text{beta}, t, w$, respectively.

We plot the statistical distributions of each j and deal further with its mean value in the sheath and the ejecta,

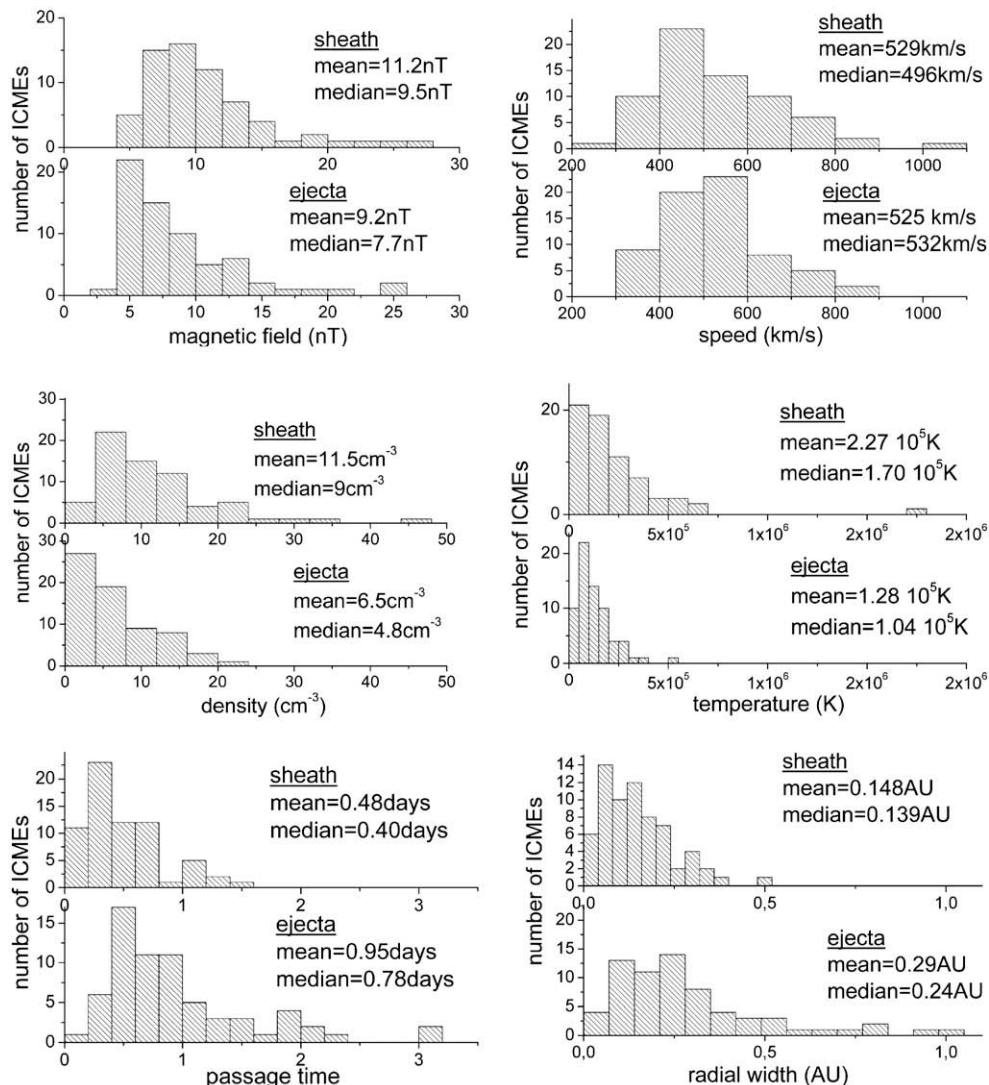


Fig. 1. Statistical distribution of the magnetic field strength, speed, proton density, proton temperature, passage time and radial width of both the sheath and the ejecta. The mean and median values are indicated.

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