TRIANGULATION OF CME SOURCE REGION LOCATIONS ON THE SUN AND DEPENDENCE ON SPACECRAFT OBSERVATION ANGLES

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Abstract. STEREO-A, STEREO-B, and LASCO/SOHO observe coronal mass ejections (CMEs) from three different vantage points. On the basis of the radial plane-of-sky (POS) measurements of a CME in these three projection planes, the CME source region (SR) location was determined using the triangulation method of Temmer et al. (2009). As this triangulation method needs distance-time measurements in one POS as reference input, the determined SR varies with the change of the reference system. In the present study we vary the reference system, which shows the dependence of the resulting SR location of a CME on the spacecraft observation angles, and also reveals the limitation of the radial POS measurements.

Key words: coronal mass ejections - projection effects - triangulation method

1. Introduction

In white-light, coronal mass ejections (CMEs) are directly observed with coronagraphs, and therefore are subject to projection effects (Burkepile et al., 2004). CMEs are three-dimensional (3D) features which are projected onto a flat image, the plane-of-sky (POS). The appearance, width and kinematics of CMEs in a coronagraph are dependent on the CME’s source region (SR) location and the true 3D morphology (see Vršnak et al., 2007, and references therein). Consequently, the propagation direction and ”true” speed of CMEs cannot be derived directly. While the projection effect for limb CMEs can be neglected, it becomes increasingly important as a CME moves farther from the POS. Thus, Earth-directed CMEs, moving in line-of-sight of our observations, are mostly affected, and their measured POS velocities are much lower than their ”true” propagation speeds. With the coronagraphs (COR1/COR2; Howard et al., 2008) aboard the recently launched Solar TErrestrial RElations Observatory (STEREO) mission (Kaiser et al.,
2008), the observation of a CME in two different projection planes is possible. That allows us to calculate the true propagation vector in 3D space. Together with the Large Angle Spectrometric COronagraph (LASCO) experiment (Brueckner et al., 1995) on the Solar and Heliospheric Observatory (SOHO; Domingo et al., 1995), the propagation of a CME through the solar corona can be tracked in three projection planes. Studies using STEREO data (partially combined with LASCO data) are in progress and first results, determining the CME's SR, are derived by Thernisien et al. (2007); Mierla et al. (2008); Howard and Tappin (2008); Temmer et al. (2009). In this paper, we discuss the resulting SR locations of a set of selected CMEs using a modification of the triangulation method which is described in Temmer et al. (2009).

2. Method and Results

The analysis is based on the POS height-time measurements from three projection planes: STEREO-B (POS-B), LASCO (POS-L), and STEREO-A (POS-A) observations. A distinct CME feature, located along the leading edge close to the centre of the propagation direction (traditional CME measurements), is tracked in time. Using a geometrical triangulation method applying the separation angles between the three spacecrafts, the CME SR can be determined from the distance-time and position angle measurements of the CME (Temmer et al., 2009). Briefly explained, the triangulation method transforms, by varying the SR coordinates (latitude and longitude in Carrington coordinates), the distance-time measurements of the reference system to the view of the other two spacecrafts, which can be compared to the actual observations. The "true" SR is obtained, where the measured and calculated data curves have the smallest deviation. The study by Temmer et al. (2009) used LASCO data as reference system which are separately compared to STEREO-A and STEREO-B data. From the two spacecraft pairs (LASCO/STEREO-A and LASCO/STEREO-B) two source regions were obtained. The present study uses spacecraft triples and different reference systems, for which three source regions are obtained. Comparing the different outcomes, the quality of determining the SR location is obtained to be dependent on the vantage point of the used reference spacecraft.

On the example of the CME occurred on December 4, 2007, we demonstrate the determination of the SR (for the according distance-time mea-
measurements we refer to Temmer et al., 2009). Figure 1 shows the deviation minimum plot for the three different reference systems. From this we find the SR longitude in the solar west at 67° (STEREO-B), 64° (LASCO), and 71° (STEREO-A). On December 4, 2007, the spacecraft triple STEREO-A, STEREO-B and SOHO-LASCO, is positioned in such a way that STEREO-B observes the CME closest to its POS. The angle between STEREO-B line-of-sight and the CME source region on the Sun is \( \sim 68.6° \). From this we can assume that, using STEREO-B as reference system, the most reliable result is obtained for the CME kinematics, and thus, for the determination of the SR.

Table I lists the obtained SR longitudes (\( \varphi \)), derived from different authors (and methods). For the present study, the results from the reference system which observes the CME closest to its POS are marked in boldface. For comparison, \( \varphi_T \) are the values of the SR longitude determined from STEREO observations by Thernisien et al. (2007), who calculated the SR of a quite large set of CMEs using 3D flux rope modelling.

3. Conclusion

Applying a geometrical triangulation method, the SR longitude of a CME is estimated. These results can be used to correct for projection effects in the CME propagation direction. The best match between SR locations derived from different methods is obtained from data which observe the CME closest

Table I: Determined CME SR longitudes derived from 1) different reference systems as presented in this study, namely $\varphi_A$ for STEREO-A, $\varphi_B$ for STEREO-B, and $\varphi_L$ for SOHO-LASCO; 2) flux rope modelling $\varphi_T$ by Thernisien et al. (2007); 3) LASCO as reference system separately compared to STEREO-A $\varphi_{LA}$ and STEREO-B $\varphi_{LB}$. The source region which observes the CME closest to the POS, is marked in boldface.

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<th>CME date</th>
<th>$\varphi_B$ [°]</th>
<th>$\varphi_L$ [°]</th>
<th>$\varphi_A$ [°]</th>
<th>$\varphi_T$ [°]</th>
<th>$\varphi_{LA}$ [°]</th>
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to the POS, i.e. under an angle of 90° (limb CMEs). The deviations between the different results increase for larger angles between the POS and the propagation direction of the CME, indicating the limitations of traditional CME measurements. As an example, the January 22, 2008 CME reveals a "bad" quality of measurements, which results in an inaccurate SR location. The same holds for LASCO measurements of the June 22, 2007 CME.

It could be shown that the usage of different reference systems affects the applied triangulation method and thus, shows the meaningful application of a separate comparison between two spacecraft pairs, as outlined in Temmer et al. (2009). This also confirms that especially for CMEs propagating close to the line-of-sight, it is difficult to track certain features, which still poses problems, even in the STEREO era.

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References