

CME evolution and 3D reconstruction with STEREO Data

A. Orlando^{1,2}, F. Zuccarello¹, P. Romano², F.P. Zuccarello³,
M. Mierla^{4,5,6}, D. Spadaro² and R. Ventura²

¹Dipartimento di Fisica e Astronomia, Sezione Astrofisica, Via S. Sofia 78, 95123 Catania, Italy

²INAF Osservatorio Astrofisico di Catania, Italy

³Centre for Plasma Astrophysics, K.U. Leuven, Belgium

⁴Royal Observatory of Belgium, Brussels, Belgium

⁵Institute of Geodynamics of the Romanian Academy, Bucharest, Romania

⁶Research Center for Atomic Physics and Astrophysics, University of Bucharest, Romania

Abstract. We describe a CME event, occurred in NOAA 11059 on April 3 2010, using STEREO and MDI/SOHO data. We analyze the CME evolution using data provided by SECCHI-EUVI and COR1 onboard STEREO satellites, and we perform a 3D reconstruction of the CME using the LCT-TP method. Using MDI/SOHO line-of-sight magnetograms we analyze the magnetic configuration of NOAA 11059 and we determine the magnetic helicity trend.

Keywords. Sun: coronal mass ejections (CMEs), Sun: magnetic fields

1. Introduction

Coronal mass ejections (CMEs) are eruptions of large amounts of mass (10^{16} g) and embedded magnetic fields from the Sun. Using data provided by the SECCHI coronagraphs onboard the STEREO mission (Kaiser *et al.*, 2008), we can infer the propagation direction and the 3-D structure of such events.

The SECCHI experiment (Howard *et al.*, 2008) on the STEREO mission is a suite of remote sensing instruments consisting of an extreme UV imager (EUVI), two white light coronagraphs (COR1, observing from 1.4 to 4 R_{\odot} , and COR2, characterized by a field of view from 2.5 to 15 R_{\odot}), and two Heliospheric Imager (HI1 and HI2) observing the heliosphere from 15 to 318 R_{\odot} .

We have analyzed a CME occurred on April 3 2010 at 09:05 UT in NOAA 11059 (S25 W03). The GOES 14 satellite (Stern *et al.*, 2004) recorded a B7.4 flare, beginning at 09:04 UT, with peak at 09:54 UT and ending at 10:58 UT, occurring in the same active region. In Fig. 1 (a) - (b) we report STEREO EUVI-A and B 195 Å images of the event.

2. CME observation and reconstruction

To obtain the images of the CME event with SECCHI COR1, a minimum intensity background over the images of the day when the CME was observed is subtracted from each frame containing the CME; the images are co-aligned in STEREO mission plane. Fig. 1 (c) - (d) show the CME observed by COR1 A and B, respectively.

Using the LCT (local correlation tracking) method we identify the same feature in COR1-A and COR1-B images (this technique is described in Mierla *et al.*, 2009). Once the association is found, making use of the position of the two spacecrafts, we obtain the 3D coordinates of our feature by a triangulation technique (sometimes referred as tie-pointing (TP), see Inhester, 2006).

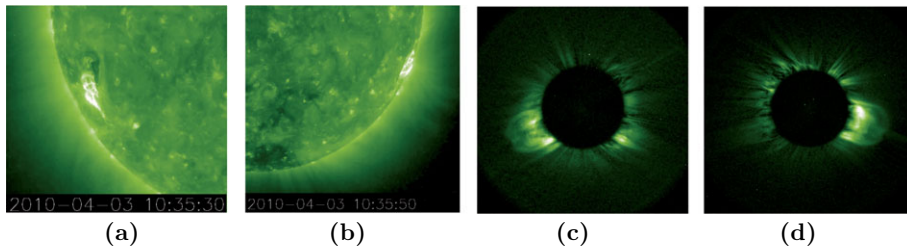


Figure 1. (a) STEREO-EUVI A image of NOAA 11059 acquired at 10:35 UT: a system of post-flare loops is visible at the flaring site; (b) STEREO-EUVI B image, showing the same event at the west-southern limb; (c) STEREO-COR1 A image, showing the CME at 09:45 UT; (d) COR1 B image of the CME at the same time. The separation angle between STEREO A and B on 3 April 2010 was 138.6 degrees.

Fig. 2 shows the LCT-TP reconstruction from three different points of view. The coordinate system is HEEQ (Heliocentric Earth Equatorial), with the origin in the Sun center, X pointing towards Earth and Z towards the solar north. The greyscale colors indicate the distance from the Sun center: black closest to the Sun and grey-white closest to the Earth.

3. Magnetic Configuration

To analyze the magnetic configuration of NOAA 11059 we used MDI/SOHO line-of-sight magnetograms acquired between 00:00 UT on April 1 to 04:00 UT on April 5 2010. We found that the magnetic flux has values within $4.2 - 6.0 \times 10^{21}$ Mx, and is characterized by an initial decreasing trend, followed by a modest increase in the hours preceding the CME. After the CME, the magnetic flux shows an abrupt decrease and later on it remains almost constant.

We performed a force-free field extrapolation on the MDI magnetogram acquired at 07:59 UT using the method introduced by Alissandrakis (1981) and the value for the force-free field parameter $\alpha = 0.02$. The results show several systems or bundles of field lines. These bundle of field lines have the same shape of the loops observed by TRACE at 195 Å and some of them outline the magnetic arcades supporting and confining some filaments observed in H α images. These field lines most probably correspond to the post-flare loop system observed in STEREO A images (Fig. 1 (a)).

To determine the magnetic helicity in the active region we determined the horizontal motions of the field line footpoints using the differential affine velocity estimator (DAVE) method (Schuck, 2005), with a window size of 20 arcsec and a time interval between two successive frames of 96 min. Subsequently we estimated the magnetic helicity rate and helicity accumulation using the method described by Pariat *et al.*, (2005). The results indicate that the rate of magnetic helicity is extremely variable, with an initial predominance of negative values, followed by positive values after about one day from the initial time (00:00 UT on April 1 2010). Concerning the accumulated magnetic helicity, the maximum negative value is reached at about 00:00 UT on April 2, and later the helicity increases almost continuously. However, immediately after the CME occurrence, there is an abrupt change in the accumulated magnetic helicity.

4. Discussion and Conclusion

Using STEREO-EUVI data we could visualize a system of post-flare loops developing after more than one hour from the beginning of a B7.4 flare associated to the CME.

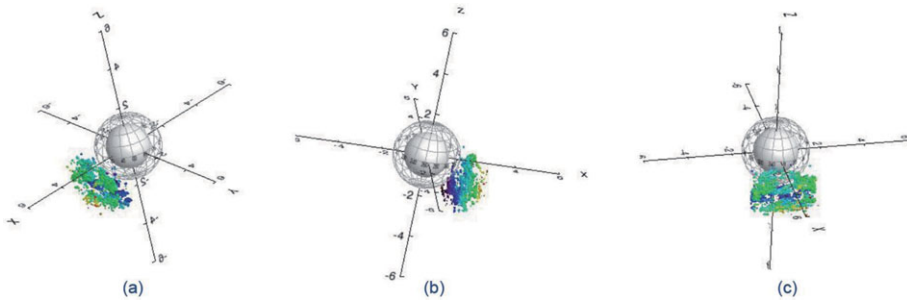


Figure 2. (a) 3D reconstruction from STEREO A view point at 09:45 UT, as seen edge-on; (b) CME 3D reconstruction as seen by STEREO B; (c) CME 3D reconstruction as seen by the Earth.

The analysis of H α images showed the presence of some filaments along the magnetic neutral line: we believe that the activation of parts of these filaments gave rise to the B7.4 flare and to the CME. This hypothesis is corroborated by the results obtained from the force-free field extrapolation, showing the presence of several systems or bundles of field lines, characterized by different heights and connectivity domains, some of which clearly resembles the post-flare loops system seen by EUVI on STEREO A.

Using the LCT-TP method to COR1 data acquired at 09:45 UT, we carried out the 3D reconstruction of the CME: due to the optically thin properties of the CME plasma, it is not possible to get a full 3D geometry of the CME, but an estimate of the direction of propagation can be accurately determined (from Fig. 2 (c) it is clear that the CME is directed towards the Earth, and indeed, the CME hit the Earth on 5 April).

The analysis of the MDI magnetograms indicates that the magnetic flux showed a small increase in the hours preceding the CME and an abrupt decrease immediately after it. The helicity accumulation changed abruptly after the CME, indicating a torque unbalance between the subphotospheric and the coronal domain of the magnetic field (see, e.g., Smyrli *et al.*, 2010).

Acknowledgements

This work was supported by the European Commission through the SOLAIRE Network (MTRN-CT-2006-035484), by the Istituto Nazionale di Astrofisica (INAF), by the Catania University, by the Agenzia Spaziale Italiana (contract I/015/07/0).

References

- Alissandrakis, C. E. 1981, *A & A*, 100, 197
 Howard R. A., Moses J. D., Vourlidis A. *et al.* 2008, *Space Sci. Rev.*, 136, 67
 Kaiser M. L., Kucera T. A., Davila J. M., *et al.*, 2008, *Space Sci. Rev.*, 136, 5
 Inhester B. 2006, *arXiv:astro-ph/0612649*
 Pariat E., Démoulin P., & Berger M. A. 2005, *A & A*, 439, 1191
 Mierla, M., Inhester, B., Marqu'è, C., Rodriguez, L., Gissot, S., Zhukov, A. N., Berghmans, D., & Davila, J. 2009, *Solar Phys.*, 259, 123
 Schuck P. W. 2005, *ApJ*, 632, L53
 Smyrli A., Zuccarello, F., Romano, P., Zuccarello, F. P., Guglielmino, S. L., Spadaro, D., Hood, A. W., & Mackay, D. 2010, *A & A*, in press
 Stern, R. A., *et al.* 2004, *Proc. SPIE*, 5171, 77