STEREO/WAVES Science Nugget
November 01, 2012
Juan Carlos Martinez Oliveros, Hazel Bain, Claire Raftery

A CME--CME Interaction and its radio and white-light manifestations

During periods of increased solar activity, several coronal mass ejections (CMEs) can be launched by the same or nearby active regions (Gopalswamy et al. 2005). During these times of high activity, these CMEs may interact with one another while propagating through the interplanetary medium. The first CME-CME interactions were observed, at long wavelengths and in white-light coronagraphic images, by Gopalswamy et al. (2001, 2002) and Gopalswamy (2004). Based on the observational characteristics of these CMEs from white-light coronagraph and radio observations, Gopalswamy (2004) concluded that type II radio emission is enhanced and modified during the interaction between two CMEs. Gopalswamy et al. (2001) suggested that the observed radio enhancement results from an increased in density in the upstream medium, which reduces the Alfvén speed and thereby increases the Mach number of the shock. This is in agreement with results from numerical simulations, confirming that the radio enhancement was likely to be produced at the interaction region shock (e.g., Vandas and Odstrcil 2004). Gopalswamy et al. (2001) also mentioned additional possibilities for electron acceleration, such as reconnection between the two CMEs (see also Gopalswamy 2004).

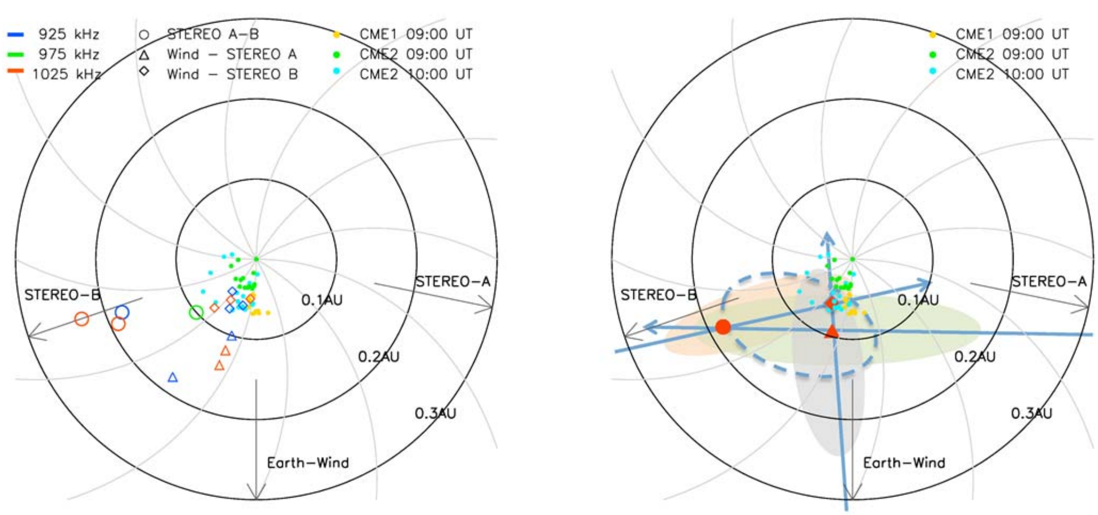

Figure 1. Left: Locations of the geometrically triangulated positions of the radio sources in interplanetary space for all operational frequencies as seen from above. The Parker spiral is plotted in gray for context. Right: Radio emission scenario, showing the possible emission region as an extended source propagating between STEREO -B and Wind. The dots represent positions of the two associated coronal mass ejections at different times. The red symbols show the intersection between line-of-sight vectors from the spacecraft represented by the arrows. These are results projected on the ecliptic plane. The color-shaded areas represent the overall regions where the direction-finding positions are located. The dashed ellipse shows the area covering all direction results.

The stereoscopic observations of the STEREO mission allow us to determine the location of different CME features in three dimensions (e.g., Frazin et al. 2009; Aschwanden and

Wülser 2011; Liu et al. 2009, 2010; Moran et al. 2010). Several direction-finding techniques have been implemented using observations made either by spinning spacecraft like Wind (e.g., Fainberg et al. 1972; Reiner et al. 1998) or three-axis stabilized spacecraft such as STEREO or Cassini (e.g., Cecconi et al. 2008; Santolík et al. 2003). The stereoscopic capability of STEREO /WAVES (Bougeret et al. 2008) can be used to triangulate the three dimensional position of a radio source at a particular frequency, provided both spacecraft observe the same source quasi-simultaneously. This technique has been applied with great success in the past in the study of type III emission (Gurnett et al. 1978; Reiner et al. 2009) but rarely in the study of type II bursts.

We successfully applied three radio direction-finding techniques (Fainberg et al. 1972; Santolík et al. 2003; Martinez-Oliveros et al. 2012) to the 2010 August 1 type II radio burst and determined the direction of arrival of the radio emission (Figure 1). Our analysis shows that the radio source locations are spread over a large area covering about 4º, suggesting that the radio source has an extended and complex structure in nature, perhaps composed of multiple radio emitting regions which may have a common origin. We found good consistency between the triangulated white-light positions and the Wind--STEREO-B triangulated positions. This event, in particular, was characterized by the interaction between two CMEs. The first CME erupted at 02:00UT and the faster second CME erupted at 07:00UT. The interaction with each other, resulting in a low frequency type II radio burst was observed on 1 August 2010 at about 09:00 UT. While a weak type II radio burst was produced by the fast CME at the start of the event, this radio emission was enhanced in regions where the two CME interacted. We found that the regions of enhanced emission are located near or in the front of the fast expanding CME, as suggested by Gopalswamy (2004) (See Figure 2).

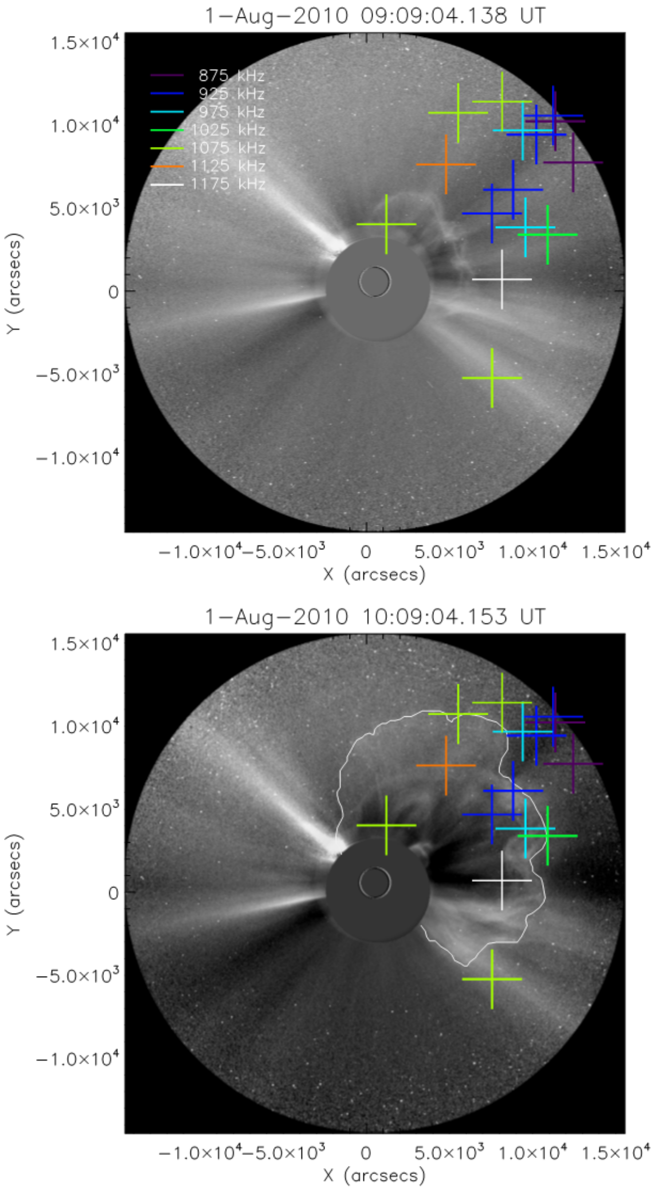

Figure 2. STEREO -B observation of the 2010 August 1 CME from Cor2 at two representative times of type II radio burst, 09:09 UT and 10:09 UT, with line-of-sight direction-finding results from STEREO -B /WAVES overplotted in color, where color represents different frequencies. The solid white line in lower panel shows the contour of the expanding CME.

Bibliography

Aschwanden, M. J. and J.-P. Wülser (2011, June). 3-D reconstruction of active regions with STEREO. Journal of Atmospheric and Solar-Terrestrial Physics 73, 1082–1095.

Bougeret, J. L., K. Goetz, M. L. Kaiser, S. D. Bale, P. J. Kellogg, M. Maksimovic, N. Monge, S. J. Monson, P. L. Astier, S. Davy, M. Dekkali, J. J. Hinze, R. E. Manning, E. Aguilar-Rodriguez, X. Bonnin, C. Briand, I. H. Cairns, C. A. Cattell, B. Cecconi, J. Eastwood, R. E. Ergun, J. Fainberg, S. Hoang, K. E. J. Huttunen, S. Krucker, A. Lecacheux, R. J. MacDowall, W. Macher, A. Mangeney, C. A. Meetre, X. Moussas, Q. N. Nguyen, T. H. Oswald, M. Pulupa, M. J. Reiner, P. A. Robinson, H. Rucker, C. Salem, O. Santolik, J. M. Silvis, R. Ullrich, P. Zarka, and I. Zouganelis (2008, April). S/WAVES: The Radio and

Plasma Wave Investigation on the STEREO Mission. Space Sci. Rev. 136, 487–528.

Cecconi, B., X. Bonnin, S. Hoang, M. Maksimovic, S. D. Bale, J. Bougeret, K. Goetz, A. Lecacheux, M. J. Reiner, H. O.

Rucker, and P. Zarka (2008, April). STEREO/Waves Goniopolarimetry. Space Science Reviews 136, 549–563.

Fainberg, J., L. G. Evans, and R. G. Stone (1972, November). Radio Tracking of Solar Energetic Particles through Interplanetary Space. Science 178, 743–745.

Frazin, R. A., M. Jacob, W. B. Manchester, H. Morgan, and M. B. Wakin (2009, April). Toward Reconstruction of Coronal Mass Ejection Density from Only Three Points of View. ApJ 695, 636–641.

Gopalswamy, N. (2004, December). Recent advances in the long-wavelength radio physics of the Sun. Planet. Space Sci. 52, 1399–1413.

Gopalswamy, N., S. Yashiro, M. L. Kaiser, R. A. Howard, and J. Bougeret (2001, February). Radio Signatures of Coronal Mass Ejection Interaction: Coronal Mass Ejection Cannibalism? ApJ 548, L91–L94.

Gopalswamy, N., S. Yashiro, S. Krucker, and R. A. Howard (2005). CME Interaction and the Intensity of Solar Energetic Particle Events. In K. Dere, J. Wang, & Y. Yan (Ed.), Coronal and Stellar Mass Ejections, Volume 226 of IAU Symposium, pp. 367–373.

Gopalswamy, N., S. Yashiro, G. Micha□lek, M. L. Kaiser, R. A. Howard, D. V. Reames, R. Leske, and T. von Rosenvinge (2002, June). Interacting Coronal Mass Ejections and Solar Energetic Particles. ApJ 572, L103–L107.

Liu, Y., J. G. Luhmann, S. D. Bale, and R. P. Lin (2009, February). Relationship Between a Coronal Mass Ejection-Driven Shock and a Coronal Metric Type II Burst. ApJ 691, L151–L155.

Liu, Y., J. A. Davies, J. G. Luhmann, A. Vourlidas, S. D. Bale, and R. P. Lin (2010, February). Geometric Triangulation of Imaging Observations to Track Coronal Mass Ejections Continuously Out to 1 AU. ApJ 710, L82–L87.

Martinez-Oliveros, J. C., C. Lindsey, S. D. Bale, and S. Krucker (2012). Determination of Electromagnetic Source Direction and Polarization as an Eigenvalue Problem. Sol. Phys. 279, 153–171

Moran, T. G., J. M. Davila, and W. T. Thompson (2010, March). Three-Dimensional Polarimetric Coronal Mass Ejection Localization Tested Through Triangulation. ApJ 712, 453–458.

Reiner, M. J., M. L. Kaiser, and J.-L. Bougeret (2007, July). Coronal and Interplanetary Propagation of CME/Shocks from Radio, In Situ and White-Light Observations. ApJ 663, 1369–1385.

Santolík, O., M. Parrot, and F. Lefeuvre (2003, February). Singular value decomposition methods for wave propagation analysis. Radio Science 38 (1), 010000–1.

Vandas, M. and D. Odstrcil (2004, February). Acceleration of electrons by interacting CMEs. A&A 415, 755–761.