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Shock location and CME 3-D reconstruction of a solar type II radio burst with LOFAR.

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Type II radio bursts are evidence of shocks in the solar atmosphere and inner heliosphere emitting radio waves ranging from sub-meter to kilometre lengths. These shocks may be associated with coronal mass ejections (CMEs) reaching speeds higher than the local magneto-sonic speed. Radio imaging of decametre wavelengths (20-90 MHz) is now possible with the Low Frequency Array (LOFAR), opening a new radio window to study coronal shocks which leave the inner solar corona and enter the interplanetary medium and to understand their association with CMEs.
To this end we study a coronal shock associated with a CME and type II radio burst to determine the locations where the radio emission is generated and investigate the origin of the band-splitting phenomenon.
The type II shock source-positions and spectra were obtained using 91 simultaneous tied-array beams of LOFAR while the CME was observed by the Large Angle and Spectrometric Coronagraph (LASCO) on board the Solar and Heliospheric Observatory (SOHO) and by the COR2A coronagraph of the SECCHI instruments onboard the Solar Terrestrial Relation Observatory (STEREO). The 3D structure was inferred using triangulation of the coronographic observations. Electron densities were calculated using the six filters of the Atmospheric Imaging Assembly (AIA) on the Solar Dynamic Observatory (SDO) and polarised brightness from LASCO [1]. Coronal magnetic fields were obtained from a 3-D MHD polytropic model using the photospheric fields measured by the heliospheric imager (HMI) on-board SDO as lower boundary [2].
The type II radio source of the coronal shock observed between 50 and 70 MHz was found to be located at the expanding flank of the CME, where the shock geometry is quasi-perpendicular with θ_{Bn}~70. The type II radio burst showed first and second harmonic emission, the second harmonic source was cospatial with the first harmonic source to within the observational uncertainty. This suggests that radio wave propagation does not alter the apparent location of the harmonic source. The sources of the two split bands were also found to be cospatial within the observational uncertainty, in agreement with the interpretation that split bands are simultaneous radio emission from upstream and downstream of the shock front. The fast magneto-sonic Mach number derived from this interpretation was found in the range 1.3-1.5. The fast magneto-sonic Mach numbers derived from the modelling of the CME and the coronal magnetic field around the type II source were found in the range 1.4-1.6.

1. P. Zucca, E. P. Carley, D. S. Bloomfield, P. T. Gallagher, "The formation heights of coronal shocks from 2D density and Alfvén speed maps", Astronomy & Astrophysics, 2014a, A&A, 564, A47

2. A. P. Rouillard, I. Plotnikov, R. F. Pinto, M. Tirole, M. Lavarra, P. Zucca, R. Vainio, "Deriving the properties of coronal pressure fronts in 3D: application to the 2012 May 17 ground level enhancement", The Astrophysical Journal 833 (1), 45