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Observations of radio CMEs using spectroscopic imaging with the Murchison Widefield Array

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Coronal Mass Ejections are the most violent explosions on the Sun and are the major drivers of 'space weather'. Considerable effort has hence been devoted to studying their initiation and evolution. Our primary source of knowledge about CMEs have been ground- and space-based coronagraphs. Numerous CMEs have been detected and studied in detail using these optical observations, providing detailed information about parameters like the shape, structure, speed, direction of motion etc. of the CME. Counterparts of CMEs at other wavebands have remained elusive, though their studies are essential to build a more complete picture of CME physics. Here we focus on the low radio frequency counterpart of the white light CME.

Most studies on CMEs using radio data were done using dynamic spectra and have concentrated on the intense type II plasma emission arising due to electron acceleration at the shock fronts. This limits their utility for studying the CME plasma itself and the regions of CME away from the shock front. Radio emission from the electrons accelerated during the CME initiation process trapped in the magnetised CME plasma has long been expected, but has remained hard to observe. This emission is expected to arise due to gyrosynchrotron mechanism and the metre wavebands are expected to be the optimal frequencies for their observations. Bastian et al. (2001) was the first to image the radio counterpart of a white light CME. They convincingly demonstrated the observed emission to be consistent with the expectations from gyrosynchrotron, and quantified the CME magnetic field as well as the non-thermal electron population responsible for this emission. Similar radio imaging studies were also carried out by Maia et al. (2007) and Démoulin et al. (2012). By modeling the CME spectra, these studies demonstrated the ability of radio observations to measure CME magnetic field, non-thermal electron population etc.. Not only are these parameters inaccessible by any other means, they also play a very important role from a space weather perspective. Despite their well established utility and sincere efforts, these few examples are the only direct radio detections of CME plasma. This even lead some researchers to suggest that, for reasons not yet understood, CMEs with radio emission from the flux rope (also referred to as radio CMEs) must be rare.

Here we present the radio detection of the white light CME which entered the LASCO C2 field of view at 02:12:04 UT on 04/11/2015. The radio data were obtained from the Murchison Widefield Array (MWA). Imaging was done at nine spectral bands, each 2 MHz wide, spanning 108 MHz to 240 MHz, using a tool designed for achieving high imaging dynamic range at low radio frequencies for arrays with a significant central cluster of antennas - the Automated Imaging Routine for Compact Arrays for Radio Sun (Mondal et al. 2018a, in press). Unlike earlier studies, we find a clear structural correspondence between the observed radio structure and the white light CME. We are also able to detect the flux rope for a longer duration and out to a larger distance, as compared to earlier studies. We model the CME spectra as gyrosynchrotron emission, using code from Fleishman and Kuznetsov (2010). Using the best fit model, we are able to constrain the magnetic field and energy distribution of the non-thermal electrons in a spatially resolved manner. We also find that the non-thermal electron energy distribution steepens with time. Finally, we present a comprehensive comparative analysis of all the earlier studies where similar measurements were made. We comment on why, we believe, that the MWA with its high imaging dynamic range and wide bandwidth can make a significant impact in advancing our understanding of CMEs.

References

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