WP2: CMEs, shock waves, and their radio diagnostics (A. Nindos, B. Vrsnak)

Monday, June 13

Coronal Mass Ejections, Associated Shocks and their Interactions with the Ambient Medium
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Tuesday, June 14

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Studying the Characteristics of Shock Waves Associated with CMEs Using Solar Radio Bursts (POSTER)
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WG2 Conclusions

ABSTRACTS

Coronal Mass Ejections, Associated Shocks and their Interactions with the Ambient Medium

Monique Pick_1
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Abstract
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This presentation is a contribution to the understanding of the role of the coronal environment in the development of CMEs and of the associated shocks. This study has bene_ted from multi-wavelength imaging observations and radio spectral data over a large frequency range. We selected events launched far from the local vertical direction and we followed step by step their progression from the low corona into higher altitudes, detected in white light. The availability of images from a combination of EUV imagers in quadrature combined with radio imaging observations allowed us to identify the successive complex interactions (e.g., compression, reconnection) between the CMEs and the ambient medium. For one event, the CME resulted from the interaction of an eruptive jet with the surrounding medium; the progression of this CME was closely associated with the occurrence of two successive type II bursts from distinct origins. Two other events originating from their source in the north hemisphere, underwent a large deection in the low corona and _nally emerged in the southern hemisphere following with a radial direction. We shall briey discuss the potential implication of this results for space weather purposes.

Triangulation of the continuum-like radio emission in a CME-CME interaction event

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Abstract
We present a study of the radio emission associated with the complex interaction of two coronal mass ejections (CMEs), successively launched from the same active region (NOAA AR 11158), on February 14 and February 15, 2011.
Although this CME-CME interaction event was widely studied (e.g. Temmer et al., 2014, Maricic et al., 2014, Mishra & Srivastava, 2014) none of the analyses determined the origin of the associated continuum-like radio emission observed in the decameter-to-hectometer frequency range. The continuum-like emission patch has a particular morphology and might be considered either as a continuation of the decametric type II radio emission associated with the second CME, either as a continuation of the type III radio bursts associated with a are from NOAA AR 11158. This ambiguity additionally complicates the question on the possible origin of the continuum-like emission. The association of this type of continuum-like radio emission and the CME-CME interaction was up to now established only by their temporal coincidence (Gopalswamy et al., 2001), which is not applicable in this event due to a complex and long-lasting interaction of the CMEs.
The radio triangulation study (see also Magdalenic et al., 2014) provided us with the 3D source positions of the continuum-like emission and the associated type II burst, which were compared with the positions of the interacting CMEs. First results indicated that the continuum-like radio emission is not the continuation of the type III radio bursts, but it is also not the radio signature of the CME-CME interaction.

A special solar type II radio burst observed with LOFAR

Frank Breitling_1, Richard Fallows2, Gottfried Mann3, Christian Vocks4, Mario Bisi5, Peter Gallagher6, Alain Kerdraon7, Jasmina Magdalenic8, Alec Mackinnon9, Helmut Rucker10, Alexandr Konovalenko11, Christophe Marque12, Eduard Kontar9, Bartosz Dabrowski13, Andrzej Krankowski13, Hamish Reid9, and Bo Thide14

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Abstract

On March 16, 2016, a special type II radio burst was observed in the frequency range 20-80 MHz with LOFAR. The type II burst shows the typical fundamental-harmonic structure. Because of the high sensitivity of LOFAR, the 3rd harmonic was measured. Additionally, a lot of herringbones were observed in both the fundamental and harmonic band. A preliminary evaluation of the burst is presented.

First observation of a solar type II radio burst below 50 MHz with the tied array beam mode of LOFAR

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Abstract

Type II radio bursts are evidence of shocks in the solar atmosphere emitting radio waves ranging from metric to kilometric lengths. These shocks may be associated with coronal mass ejections (CMEs) reaching super-Alfvenic speeds. Radio imaging of the decameter

wavelengths is now possible with the Low Frequency Array (LOFAR), opening a new radio window to study coronal radio shocks leaving the inner solar corona and entering the interplanetary medium and understand their association with CMEs.
Here, we study a coronal shock associated with a CME and type II radio burst to determine the locations that shocks are excited in relation to the propagating CME and the ambient medium Alfven speed. The type II shock imaging 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).
The radio emission associated with the type II shock was found to be located at the ank of the CME in a region where the Alfven speed reaches a local minimum. Using the tied array beam observing mode of LOFAR we were able to locate the type II radio shock position between 45 and 65 MHz and relate it to the expanding ank of a CME and a second CME leaving the inner corona.

Studying the Characteristics of Shock waves associated with CMEs using solar radio bursts. **(POSTER)**

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Abstract
Fast CME/shocks propagating in the Corona and the interplanetary medium can generate metric and kilometric Type II radio emissions at the local plasma frequency and/or its harmonic, respectively. So these radio emissions provide a means of remotely tracking CME/shocks. We apply analysis technique, using the frequency drift of metric spectrum obtained by ground station e-Callisto (Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory) in Space Weather Monitoring Center (SWMC) { Helwan University, and estimated by using electron density model the propagation speed of CME/shocks in the corona, and the km-TII spectrum obtained by the WIND/WAVES experiment, to infer, at some adequate intervals, the propagation speed of CME/shocks in the interplanetary medium. We applied this technique on _ve CME/shocks. We combine these results with previously reported speeds from coronagraph white light and interplanetary scintillation observations, and in-situ measurements, to study the temporal speed evolution of the _ve events. The speed values obtained by the metric and km-TII analysis are in a reasonable agreement with the speed measurements obtained by other techniques at di_erent heliocentric distance ranges. The combination of all the speed measurements show a gradual deceleration of the CME/shocks as they propagate to 1 AU. This technique can be useful in studying the evolution and characteristics of fast CME/shocks when adequate intervals of km-TII emissions are available.

Observations of Near-Simultaneous Split-Band Solar Type-II Radio Bursts at Low Frequencies **(POSTER)**

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Abstract
We report ground-based radio spectral and polarimeter observations of two successive split-band Type-II bursts that occurred on 20 February 2014 at low frequencies (less than 100 MHz) in association with a solar coronal mass ejection (CME). The temporal interval between the onset of the two bursts was very small, _ one minute. Both of the bursts exhibited fundamental{harmonic structure. The coronal magnetic-_eld strength [B] in the upstream region of the associated magnetohydrodynamic (MHD) shock, estimated from the split-band observations, is in the range B _ 1.3{1.1 G over the radial distance [r] interval

r _ 1.49 { 1.58 R for the _rst Type-II burst, and B _ 1.3{1.0 G over r _ 1.49 { 1.64 R for the second Type-II burst. Based on the results obtained, we show that the _rst and the second Type-II bursts in the present case were likely due to MHD shocks generated by the near-simultaneous interaction of two di_erent regions of the aforementioned CME with a preceding CME and a pre-existing coronal streamer.

Interplanetary Type IV Bursts **(POSTER)**

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Abstract
We study the characteristics of moving type IV radio bursts which extend to the hectometric wavelengths (interplanetary type IV or type IVIP bursts) and their relationship with energetic phenomena on the Sun. Our dataset comprised 48 Interplanetary type IV bursts observed by the Wind/WAVES in the 13.825 MHz-20 KHz frequency range. The dynamic spectra of the RSTN, DAM, ARTEMIS-IV, Culgoora, Hiraiso and IZMIRAN radiospectrographs were used to track the evolution of the events in the low corona; these were supplemented with SXR ux recordings from GOES and CME data from LASCO. Positional information for the coronal bursts were obtained by the Nan_cay radioheliograph (NRH). We examined the relationship of the type IV events with coronal radio bursts, CMEs and SXR ares. The majority of the events (45) were characterized as compact; their duration was on average 106 min. This type of events were, mostly, associated with M and X class ares (40 out of 45) and fast CMEs; 32 of these events had CMEs faster than 1000 km/s. Furthermore, in 43 compact events the CME was, possibly, subject to reduced aerodynamic drag as it was propagating in the wake of a previous CME. A minority (3) of long lived type IVIP bursts was detected, with durations from 960 min to 115 hours. These events are referred to as extended or long duration events and appeared to replenish their energetic electron content, possibly from electrons escaping from the corresponding coronal type IV bursts. The latter were found to persist on the disk, for tens of hours to days. Prominent among them was the unusual Interplanetary Type IV Burst of 2002 May 18-23 which is the longest event in the Wind/WAVES catalog. The 3 extended events were, usually, accompanied by a number of ares, of GOES class C in their majority, and of CMEs, many of which were slow and narrow.