Insights into Coronal Mass Ejection Shocks with the Irish Low Frequency Array (I-LOFAR)

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The Sun can produce large-scale energetic events such as solar flares and coronal mass ejections (CMEs) which can excite shock waves that propagate through the corona. To date, the shock kinematics responsible for particle acceleration and emission at radio wavelengths are not well understood. Here, we investigate these phenomena using radio observations of the 2017 September 2, C7.7 solar flare at 10-240 MHz from Irish Low Frequency Array (I-LOFAR). We investigate the relationship between the features in I-LOFAR's dynamics spectra and the shock kinematics as derived from imaging observations using the AIA, SUVI and SOHO/LASCO. In future work we will calculate shock Mach number from both shock geometry in SUVI and modelling of coronal Alfvén speed. The relationship between shock characteristics from SUVI and data driven modelling will be compared to shock characteristics from radio in order to determine the plausibility of shock accelerated electron release into the solar corona.

1. Flare and CME in X-rays, EUV and Radio

- A C7.7 flare occurred on 2017 September 2 in NOAA 12672.
- The flare was followed by a CME, first seen by SOHO/LASCO at 16:00 UT. The leading edge of the CME had average velocity of ~717 km/s [1].

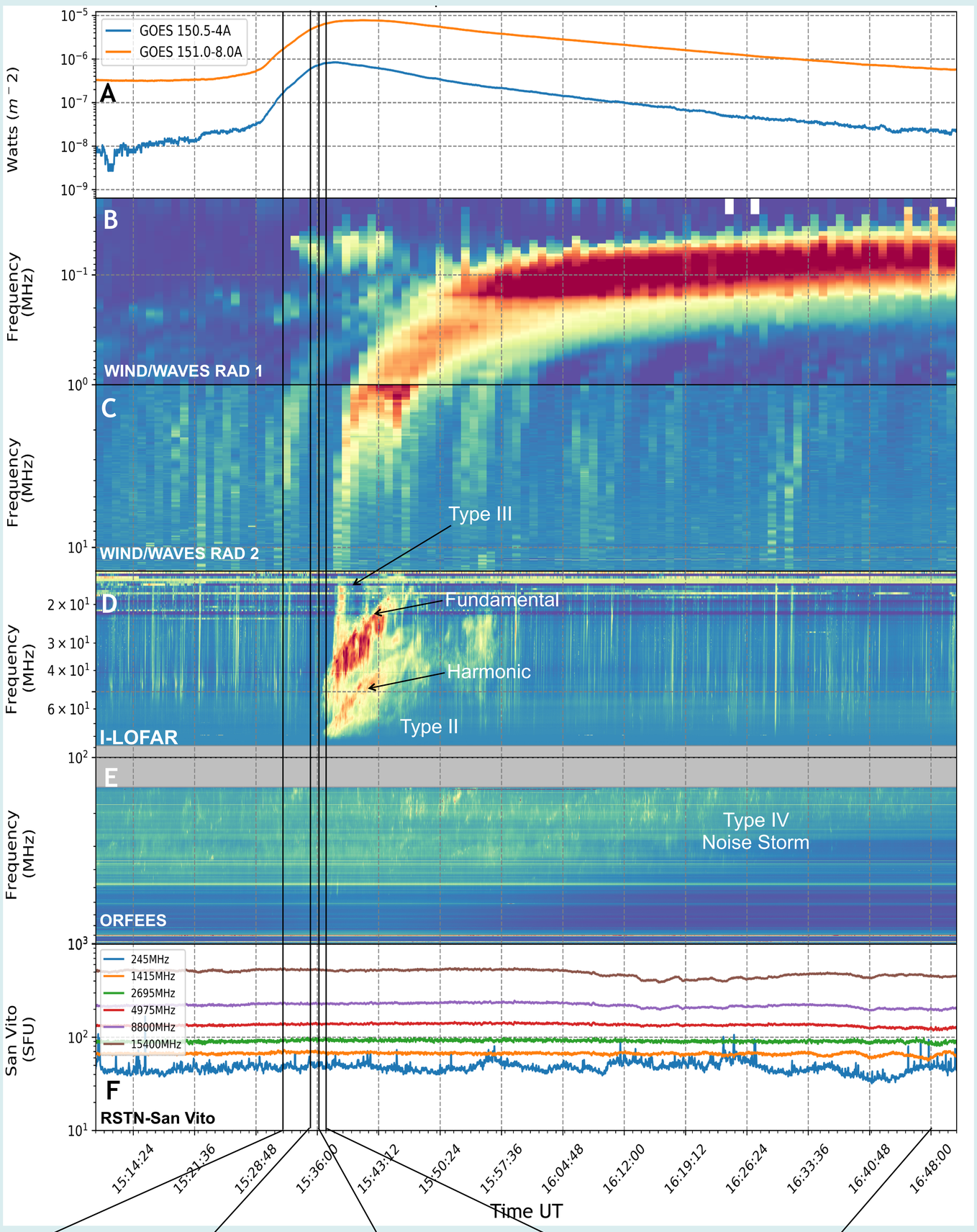

Figure 1. **A.** GOES X-ray time profile showing the 2017 September 2 C-class flare.
B. WIND/WAVES RAD 1 showing 0.02-1 MHz.
C. WIND/WAVES RAD 2 showing 1-14 MHz.
D. I-LOFAR showing 14-88 MHz.
E. ORFEES showing 144-1005 MHz.
F. Flux densities at 245, 1415, 2695, 4975, 8800 & 15400 MHz from San Vito.
G. Base ratio images from SUVI shows the evolution of shock and the flux rope [2].
H. CME as seen LASCO C2.

2. Type II and Type III Radio Bursts

- Electrons accelerated by shockwaves result in emission at the local plasma frequency, which manifests as a type II radio burst seen in I-LOFAR observations in figure 1 D.
- Both the fundamental and harmonic components are observed in the type II [3].
- A type III radio burst which is associated with electrons propagating along open magnetic field lines is superimposed on the type II.

3. CME Kinematics

Comparing kinematics from SUVI and Alfvén modelling will allow us to determine how the type III was generated.

Is it related to the shock or accelerated by CME-driven reconnection?

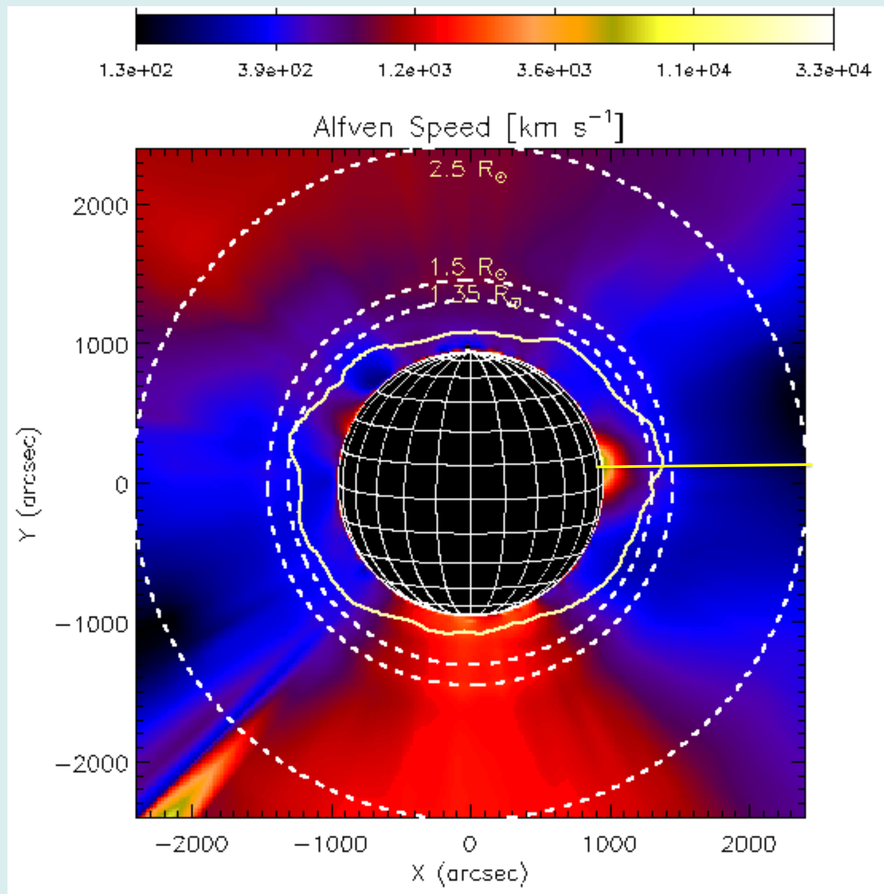

Figure 2. Alfvén map [Zucca model; 4]. The white contour is the electron density corresponding to the starting frequency of the observed type III.

- Taking the Alfvén speed along the yellow line in figure 2 and speeds from AIA/SDO gives Mach numbers ranging from 0.75-1.5 over 1.2 to 1.5 R_S.

4. Future Works

- Shock velocities will be derived using [5] to determine Mach numbers. We will then investigate the nature of mach number at electron release time and relate this to the shock kinematic variability as observed in EUV and white-light.
- The coronal magnetic field will be measured using the shock standoff distance and the radius of curvature of the flux rope.

[1] Schenk, K. M., private communication
[2] Seaton D., private communication
[3] McLean, D. J., & Labrum, N. R., Solar Radiophysics, 1985
[4] Zucca, P et al., A&A, 2014
[5] Gallagher, P. T. et al, ApJ, 2003

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