Activities of the topical team on Coronal Shocks and Particle Acceleration for Solar Orbiter coronagraph METIS

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On behalf of METIS topical team TT9

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2.3 How and where do shocks form in the corona?

2.3.1 (a) Identify coronal shocks and characterize their spatial distribution and outward propagation velocity;
(b) study interaction with coronal plasma;
(c) characterize the longitudinal distribution of coronal shocks during high latitude orbits.

2.3.2 What are the properties and distribution of heliospheric shocks?

2.3.3 Resolve the interplanetary shock field and plasma structure down to the spatial and temporal scales comparable and smaller than the typical ion scales.

2.3.4 Shock-surfing acceleration mechanism.

2.3.5 Understand the radio emissions from the ICME driven shocks.

2.3.6 Identify shock accelerated particles

3.1 How and where are energetic particles accelerated at the Sun?

3.1.0 Explore in depth the SEP properties:
Gradual SEP events, Impulsive SEP events

3.1.1 CME and shock associated SEP sources

3.1.1.1 Where and when are shocks most efficient in accelerating particles?
3.1.1.2 Why are gradual SEP events so variable?
3.1.1.3 How are energetic particles accelerated continuously in the corona and solar wind?
3.1.1.4 How can SEPs be accelerated to high energies so rapidly?
3.1.1.5 Do proton-amplified Alfvén waves play a role in accelerating particles at shocks?
3.1.1.6 What causes SEPs' spectral breaks?
3.1.1.7 Are there favorable environments for particle acceleration?

3.1.2 SEPs associated with flares, coronal loops and reconnection regions

Physics of Shock from VL: upstream magnetic fields

- **Pre-shock densities** derived with latest pre-CME LASCO pB image.

- **Compression ratios *X*** derived all along the shock front by:

→ *X* maximizes at shock nose, *X* decreasing with shock altitude.

- **Mach numbers M_A** derived all along the shock front by:

1. measuring from VL images the inclination θ of shock surface with respect to the radial,
2. applying the empirical formula (tested in Bemporad, Susino & Lapenta 2014; Bacchini et al. 2015) for M_A in oblique shock ($\beta \ll 1$, $\gamma = 5/3$)

$$M_{A\angle} = \sqrt{(M_{A\perp}\sin\theta)^2 + (M_{A\parallel}\cos\theta)^2}$$

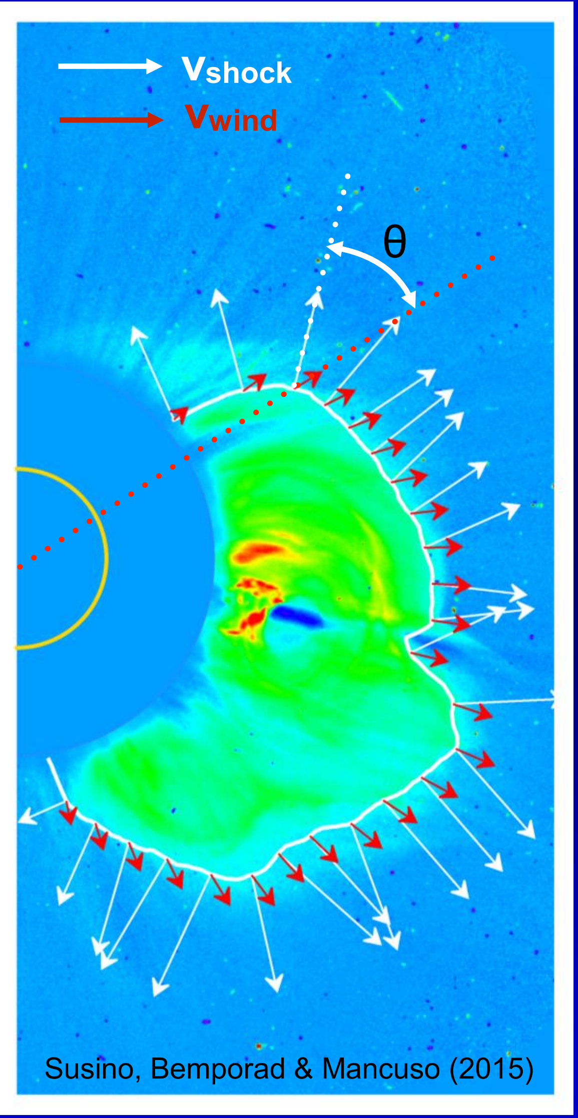
→ M_A maximizes at shock nose, M_A decreasing with shock altitude.

- **Magnetic fields** derived along the coronal region crossed by shock:

1. combining M_A values with measured shock speeds
2. assuming possible distributions of pre-shock solar wind speeds

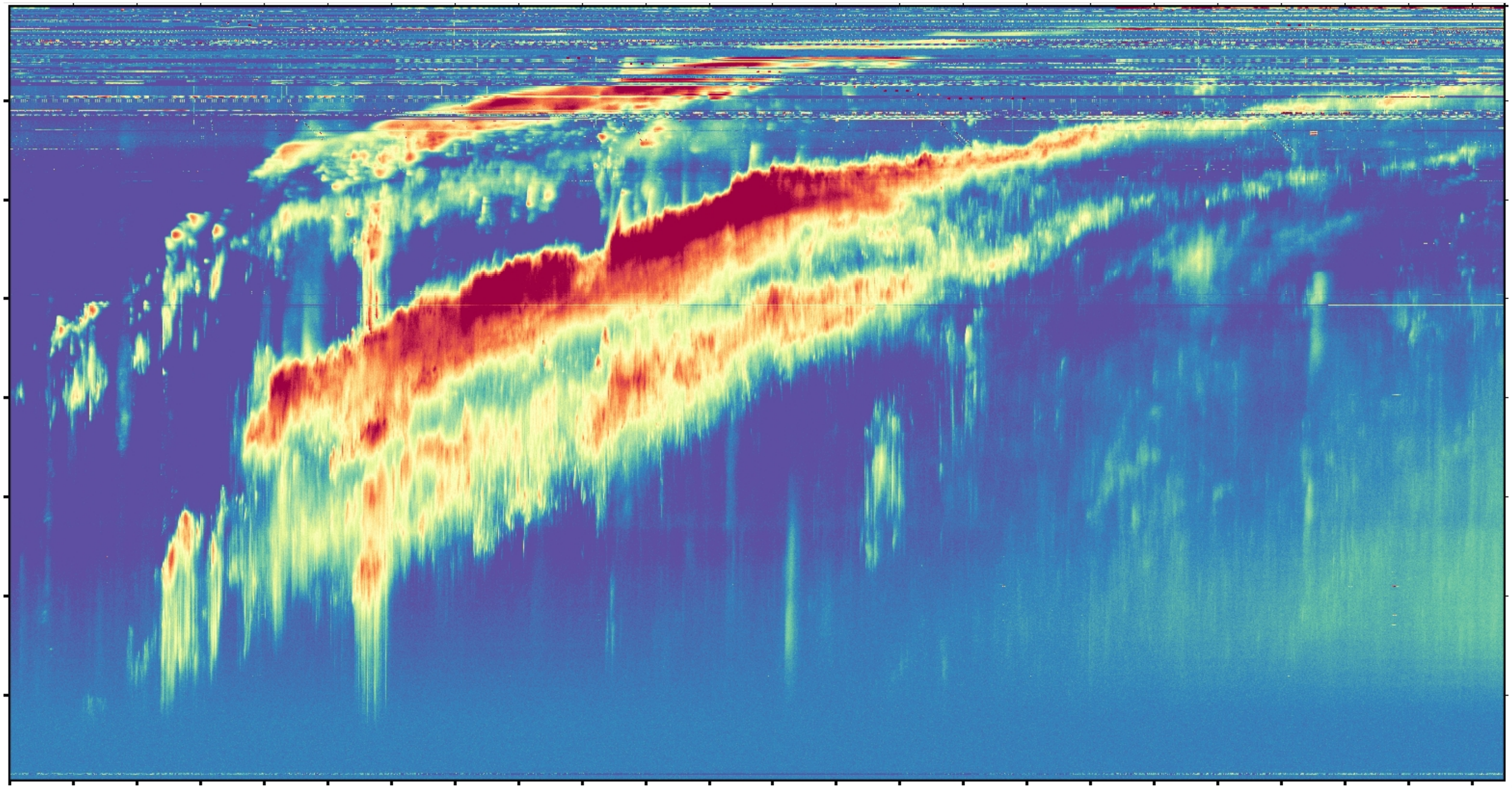
$$B_u = v_A\sqrt{\mu_0 m_p n_e}$$

→ output radial field profiles s in good agreement with previous estimates.



Susino, Bemporad & Mancuso (2015)

The type II burst observed by LOFAR



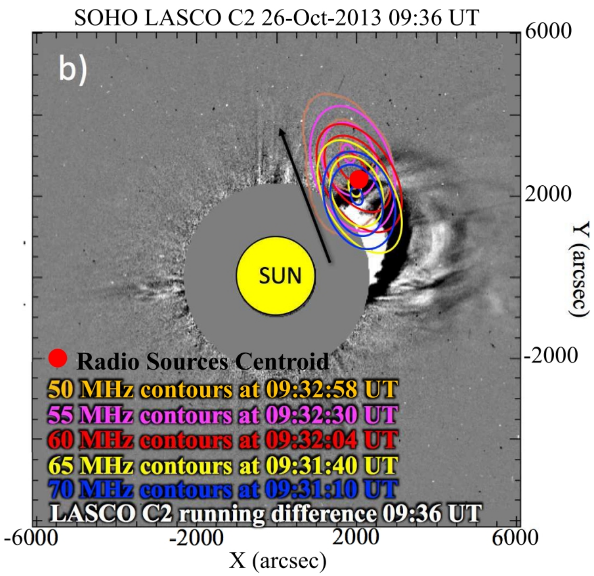
- LOFAR dynamic spectrum (observed with high time/frequency resolution of 10 ms &12.3 kHz) shows, for the first time, such a strong fragmentation of the shock associated radio emission.

Magdalenić et al., ApJL, 2020

Synergy with Solar Orbiter & Metis

Origin and early propagation of CMEs

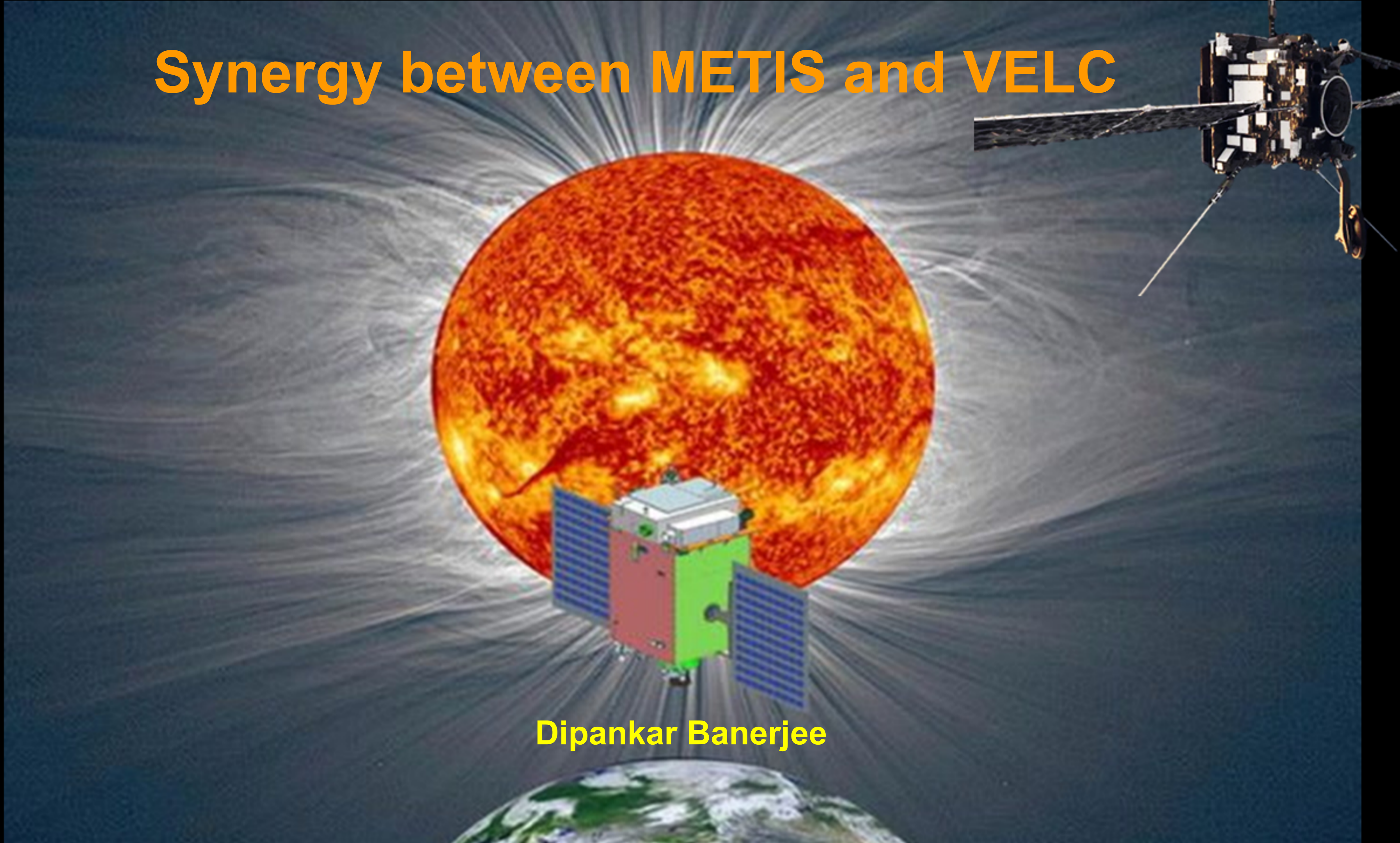
- Are some of the coronal type II bursts observed with LOFAR, and in particular in LOFAR HBA, generated by flares?
- What is the formation height of shock waves and how it relates with the type II radio emission?
- With what coronal structures are related noise storms, S-bursts and other very structured solar radio bursts.



Presently the radio sources observed in HBA, and high frequency part of the LBA are situated in the coronagraph data gap.

It's important to map well the CME acceleration phase (Metis) and combine it with the high resolution observations of the CME initiation and flares (EUI).

Synergy between METIS and VELC



Dipankar Banerjee

3D Reconstruction of CMEs with VELC & METIS