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

16th European Solar Physics Meeting, 6-10 September 2021

Team Members:

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Bemporad Alessandro, Frassati Federica, Mancuso Salvatore, Susino Roberto, INAF/OATo, Italy
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Feng Li, Ying Beili, Purple Mountain Observatory, China
Franci Luca, Queen Mary Univ., London, UK
Habbal Shadia, Institute for Astronomy, Univ. Hawaii, USA
Laming John, Ko Yuan-Kuen, Strachan Leonard, NRL, Washington DC, USA
Long David, MSSL, UCL UK
Magdalenic Jasmina, ROB, Bruxelles, Belgium
Naletto Giampiero, Univ. Padova, Italy
Nisticò Giuseppe, Perri Silvia, Zimbardo Gaetano, Univ. Calabria, Italy
Rodriguez-Garcia Laura, Rodriguez-Pacheco Javier, Gomez-Herrero Raul, Univ. of Alcalà, Spain
Stangalini Marco, Agenzia Spaziale Italiana, Italy
Vainio Rami, Univ. of Turku, Finland
Velli Marco, UCLA, USA

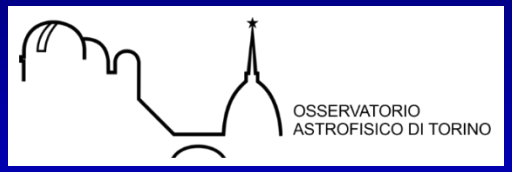
Past meetings (online only):

- Kick-off meeting: 24 June 2020; speakers: Stangalini, Romoli, Spadaro
- Second meeting: 30 September 2020; speakers: Zimbardo, Bemporad, Feng
- Third meeting: 24 November 2020; speakers: Rodriguez-Garcia, Magdalenic
- Fourth meeting: 9 March 2021; speakers: Vainio, Banerjee, Long, Ying

Here, we give an overview of the scientific presentations delivered so far, with the cover slide and a single slide for each talk.

Determination of plasma physical properties across CME-driven shocks with remote sensing data

A. Bemporad
INAF-Turin Astrophysical Observatory, Italy



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 ($\beta << 1$, $\gamma = 5/3$)

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

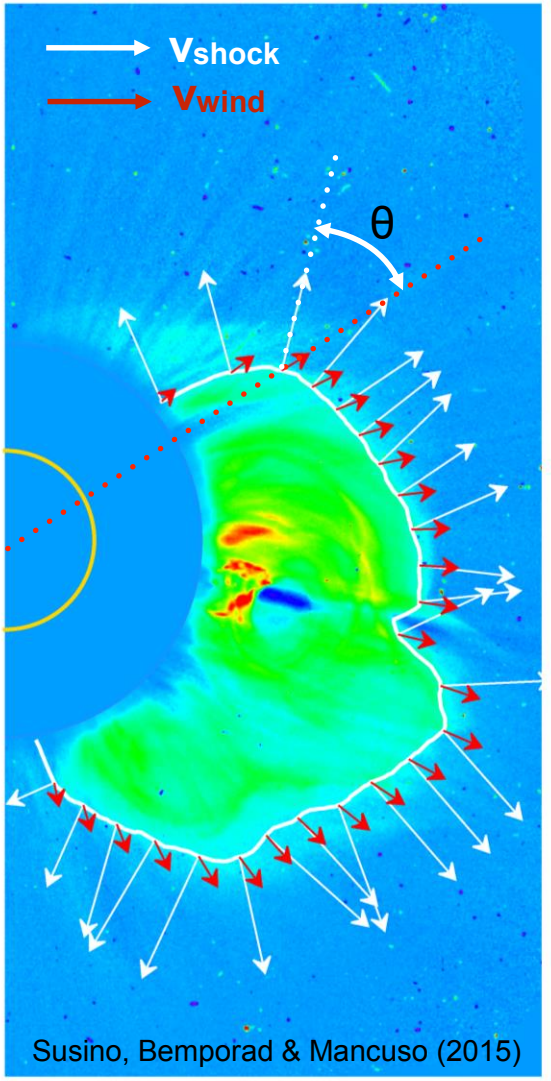
→ M_A maximizes at shock nose, M_A decreasing with shock altitude.

- **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.

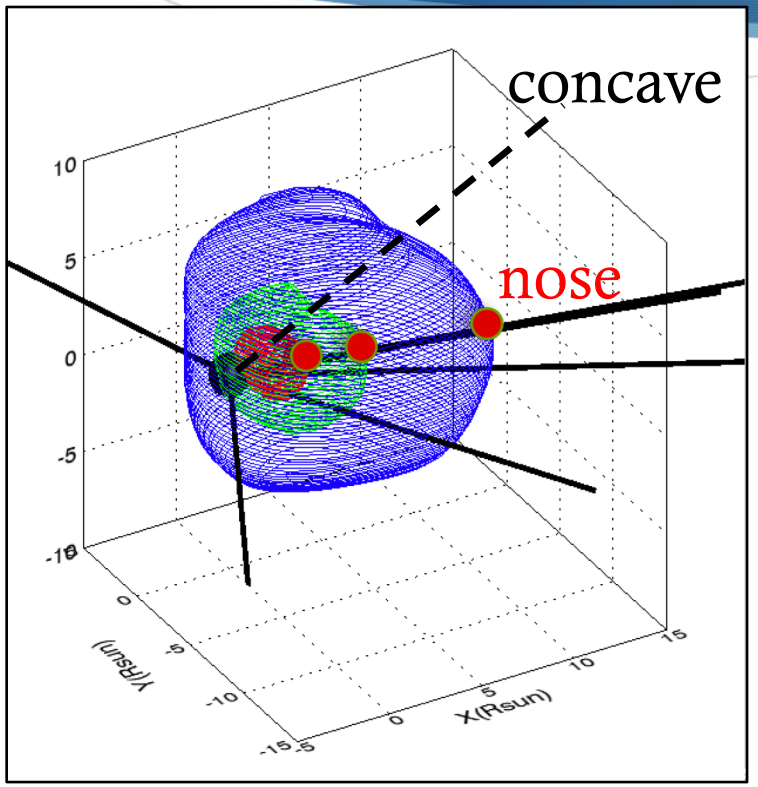


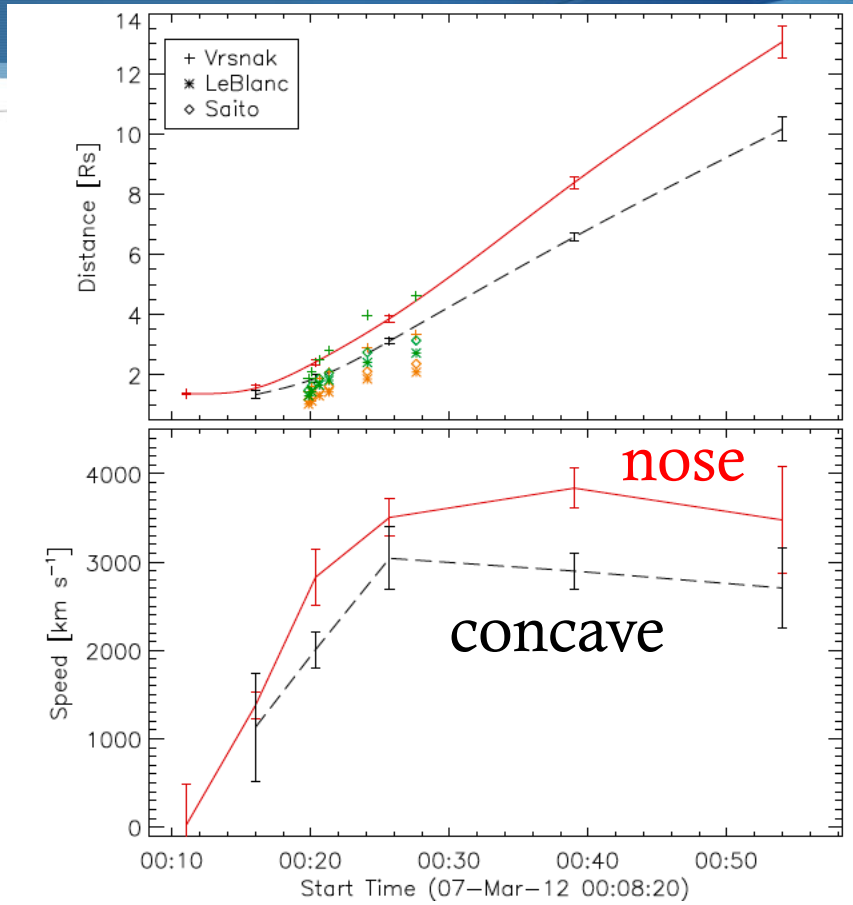
Susino, Bemporad & Mancuso (2015)

3D reconstructions of a coronal shock with the mask-fitting method

Li Feng, Lei Lu, Beili Ying (ASO-S team)
Purple Mountain Observatory, CAS, China
B. Inhester, J. Plowman, M. Mierla, M. West,
F. Shen, Y. Wei, J. Guo

Applications: 3D kinematics





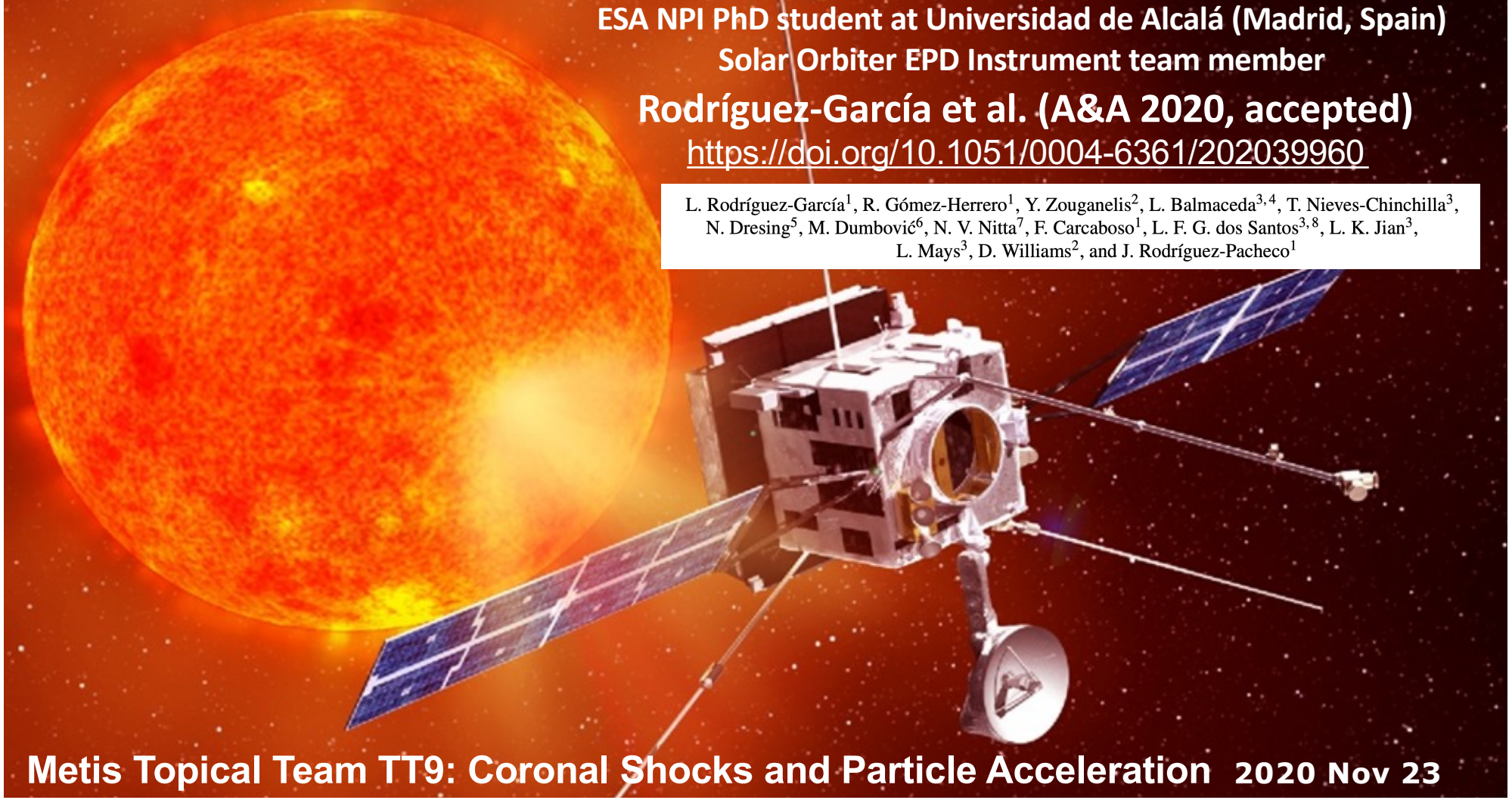
The Unusual Widespread Solar Energetic Particle Event on 2013 August 19

Solar origin and particles longitudinal distribution

Laura Rodríguez-García
ESA NPI PhD student at Universidad de Alcalá (Madrid, Spain)
Solar Orbiter EPD Instrument team member

Rodríguez-García et al. (A&A 2020, accepted)
https://doi.org/10.1051/0004-6361/202039960

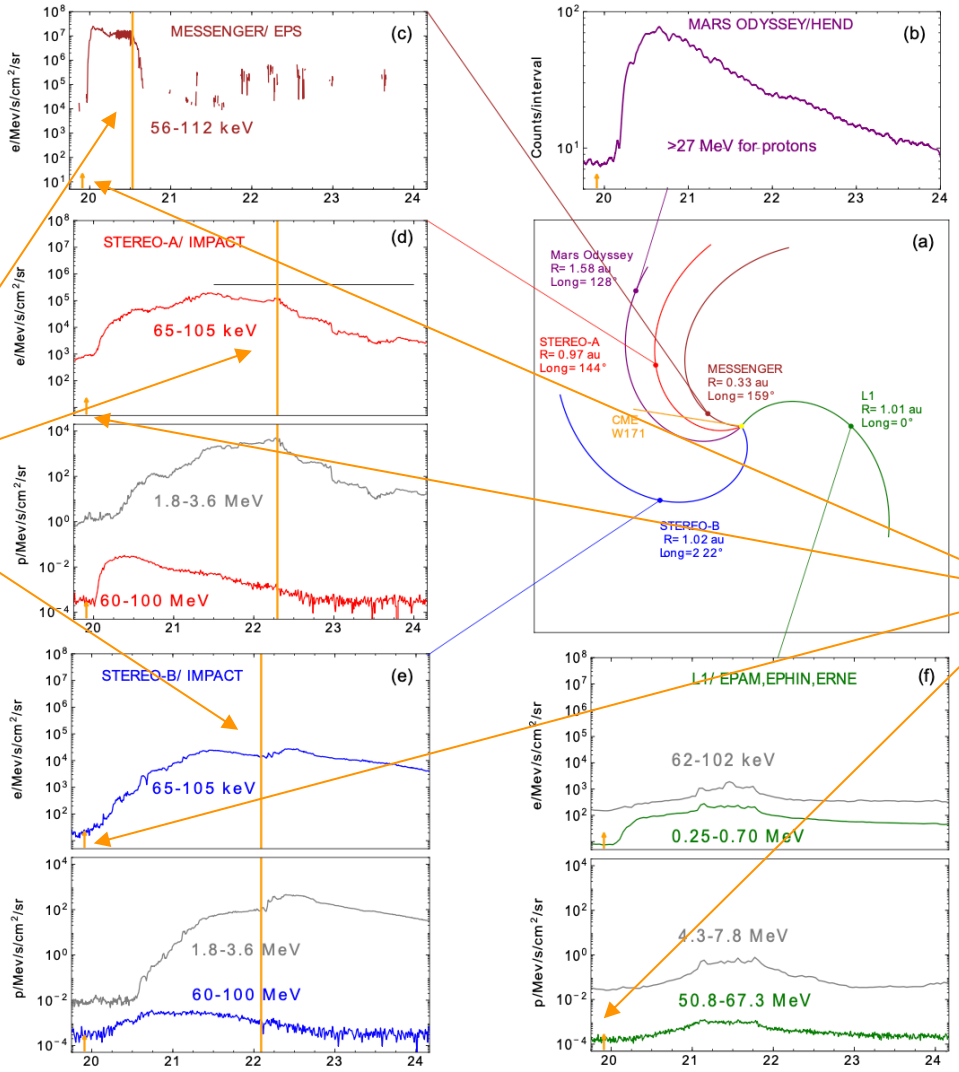
L. Rodríguez-García[1], R. Gómez-Herrero[1], Y. Zouganelis[2], L. Balmaceda[3,4], T. Nieves-Chinchilla[3], N. Dresing[5], M. Dumbović[6], N. V. Nitta[7], F. Carcaboso[1], L. F. G. dos Santos[3,8], L. K. Jian[3], L. Mays[3], D. Williams[2], and J. Rodríguez-Pacheco[1]



The SEP Event: 2013 August 19: Disentangling the time profiles

STA and MESSENGER are magnetically connected to the shock ~3Rs

CME-driven shock arrival



CME eruption

STB is not magnetically connected to the shock until ~0.6 au

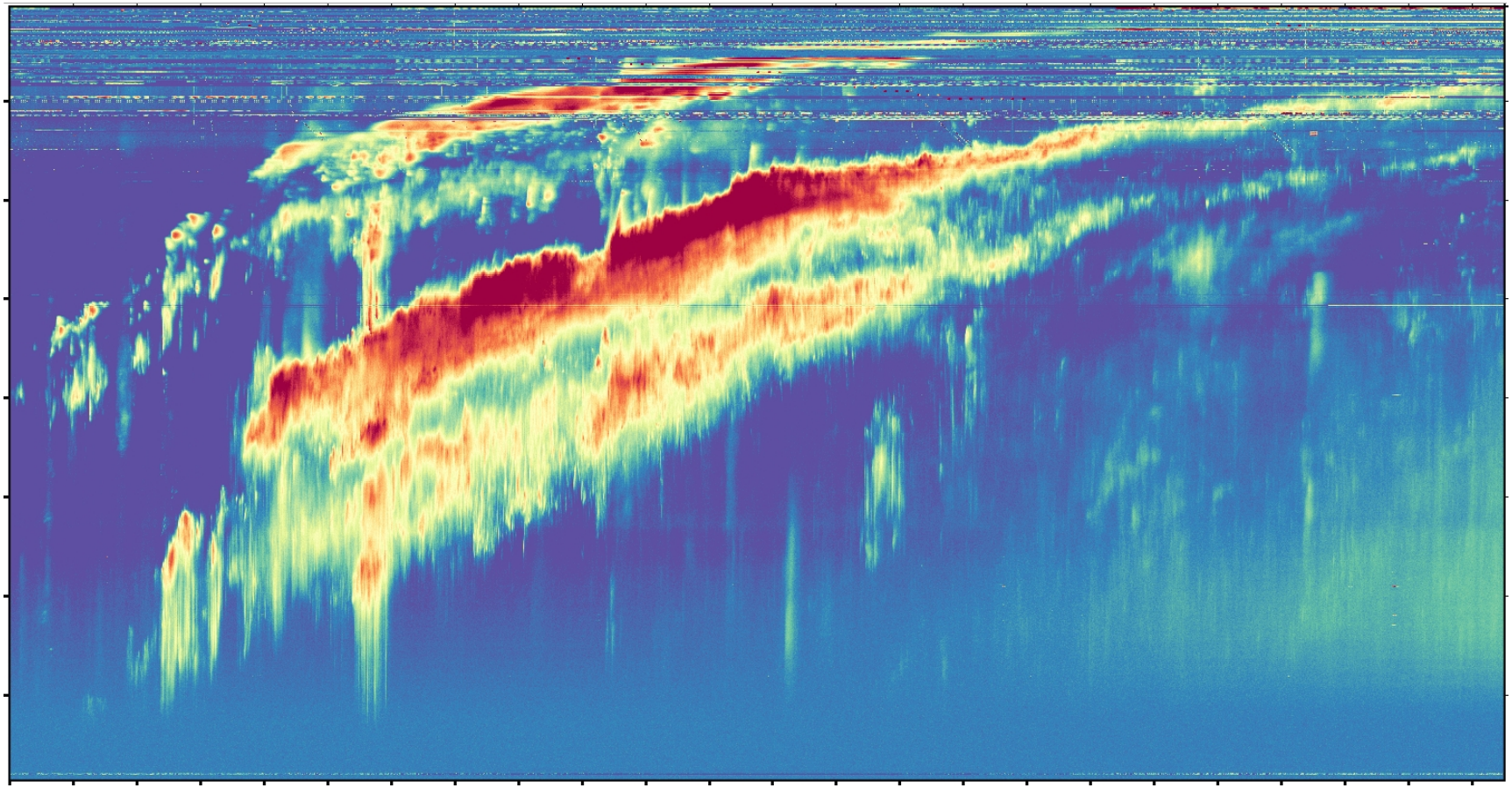
L1 is not ever connected to the CME-driven shock

What can we learn from solar radio observations with LOFAR?

Jasmina Magdalenić

Royal Observatory of Belgium

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.

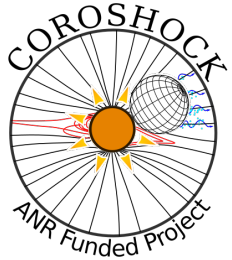
Magdalenić et al., ApJL, 2020

Particle acceleration in coronal shocks: some recent findings from simulations and data-analysis

Rami Vainio

Department of Physics and Astronomy, University of Turku (UTU)

Main collaborators: Alexandr Afanasiev (UTU), Athanasios Kouloumvakos (IRAP) & Alexis Rouillard (IRAP)



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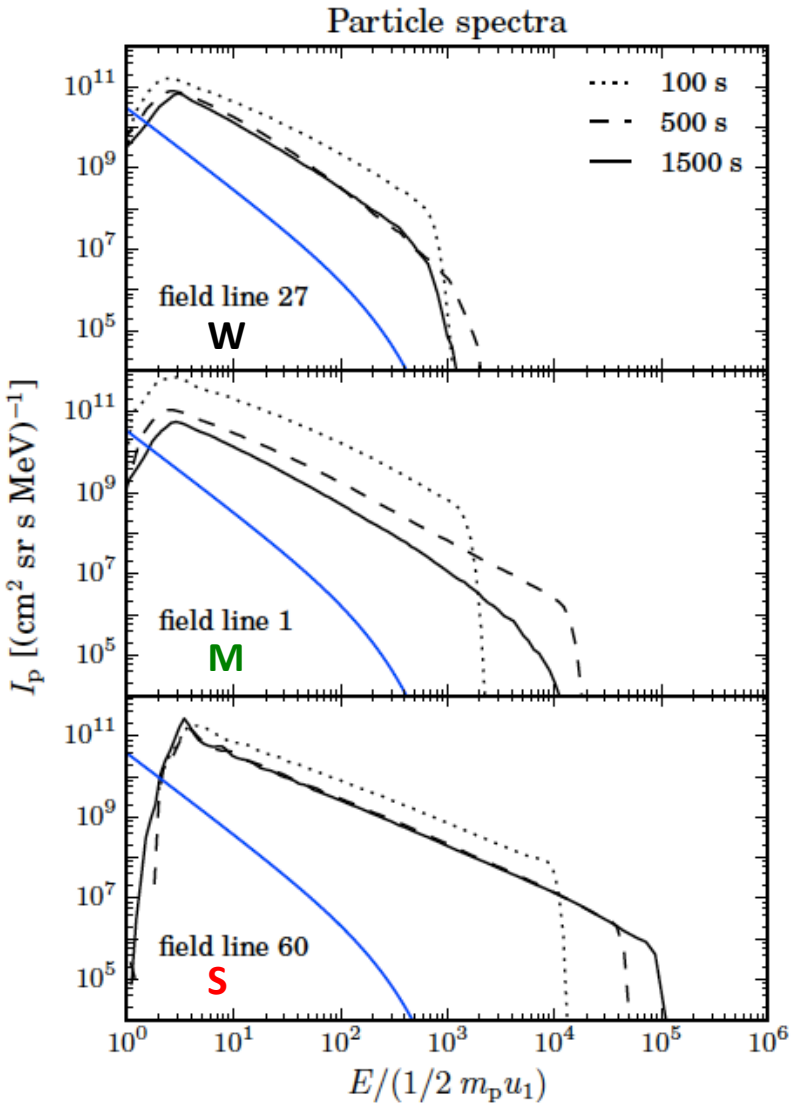
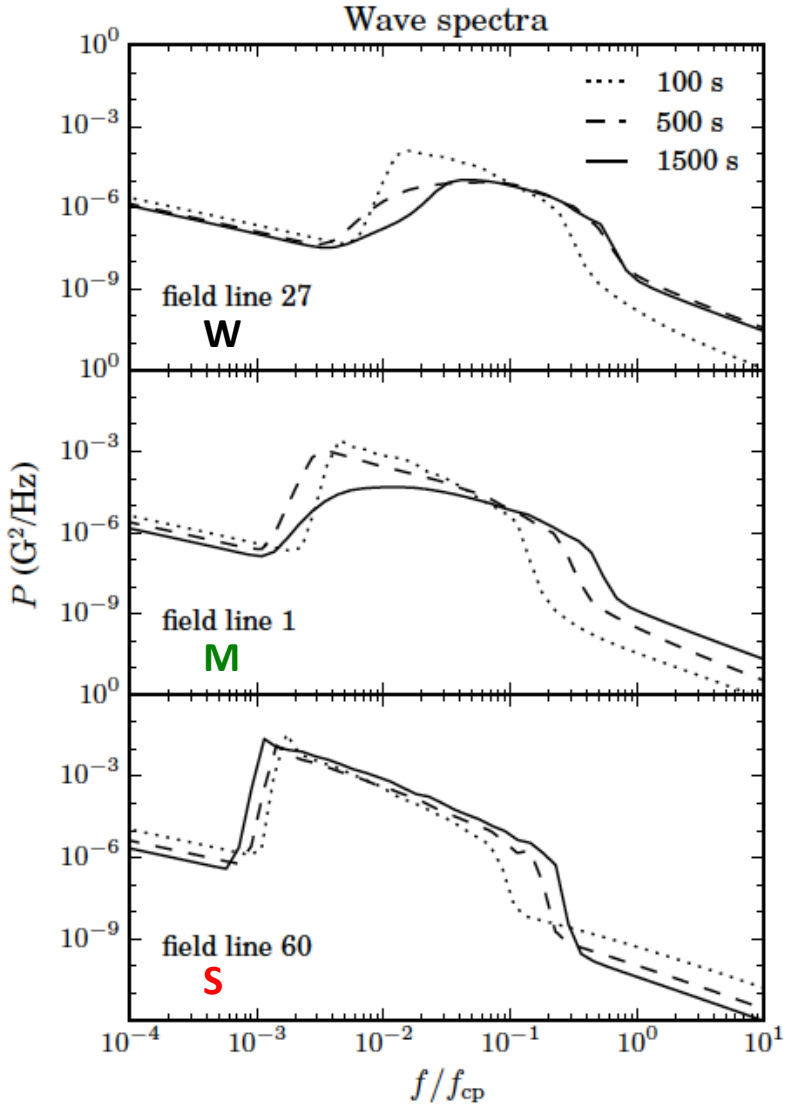
Simulated spectra at the shock





A kappa-distribution with $\kappa = 2$ and an exponential cutoff at 1 MeV is used as the upstream distribution function.

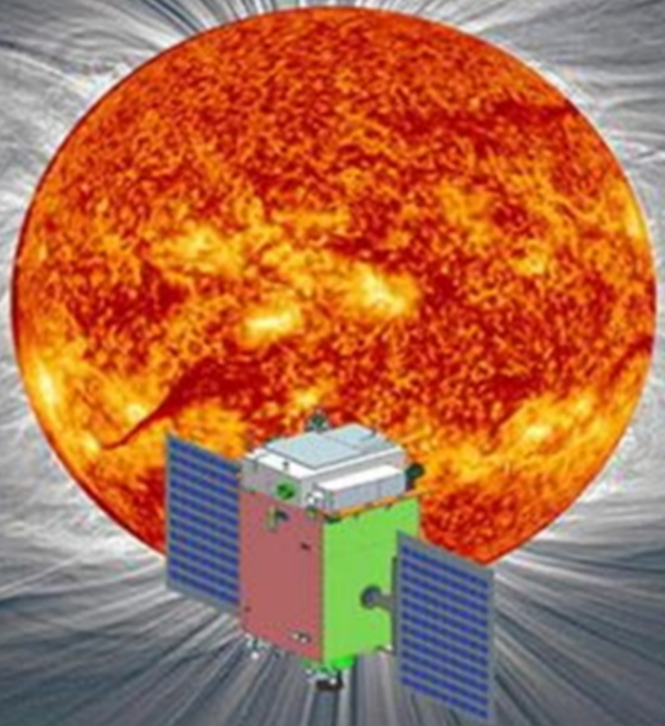
A function to fit particle spectra:

$$I_{\mathrm{p}}(E) = CE^{-\beta}\mathrm{e}^{-\left(\frac{E}{E_{\mathrm{c}}}\right)^{\delta}}$$

C, β, E_{c} and δ are fitting parameters

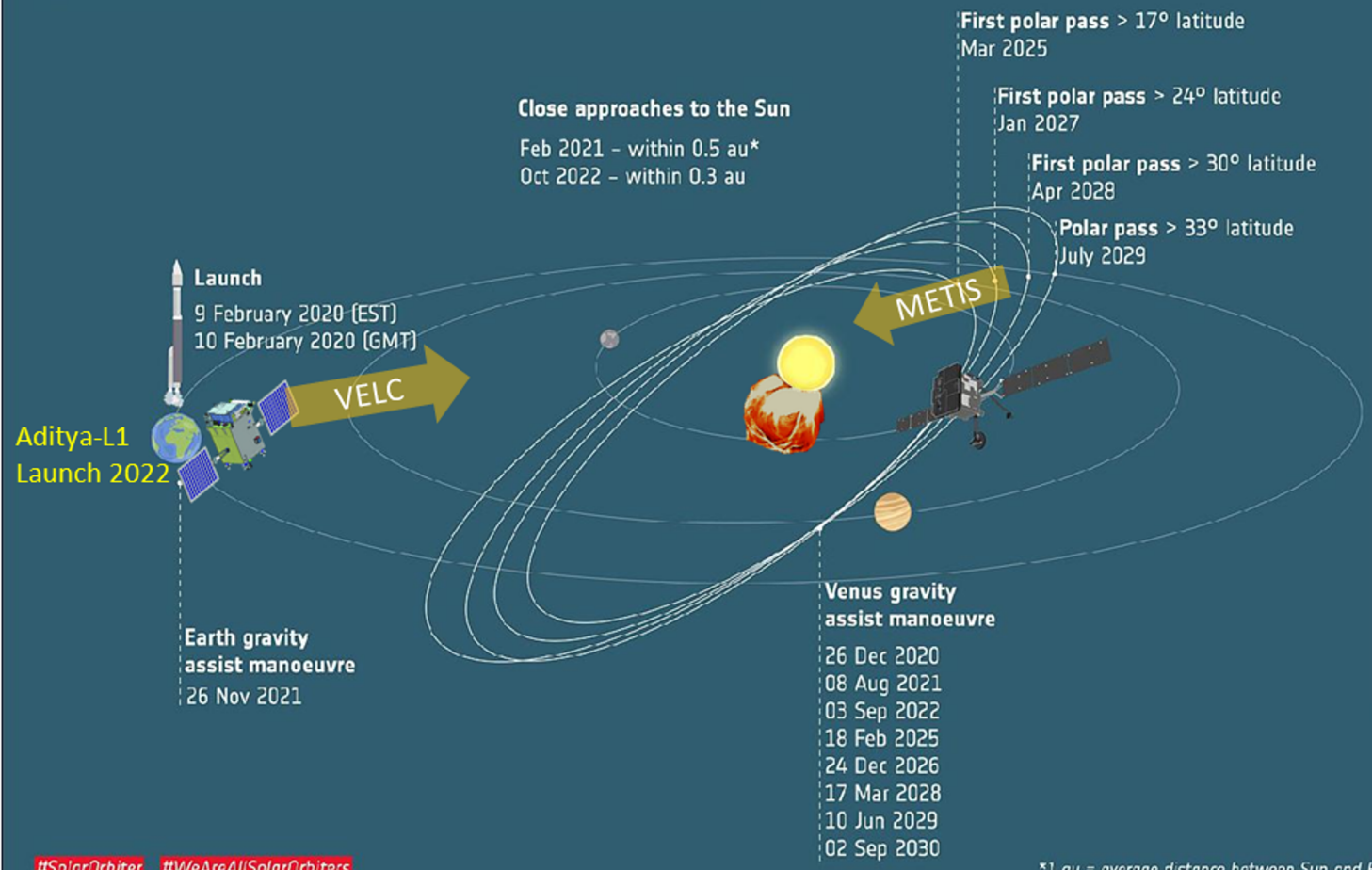
Afanasiev et al. (2018)

Synergy between METIS and VELC



Dipankar Banerjee

3D Reconstruction of CMEs with VELC & METIS



300 million km
Maximum distance between Earth and Solar Orbiter

16.5 min
Maximum time for a radio signal to travel one way between Earth and Solar Orbiter

22 orbits
around the Sun

Nov 2021
Start of main mission

Dec 2026
Expected start of extended mission

#SolarOrbiter #WeAreAllSolarOrbiters

*1 au = average distance between Sun and Earth (149 597 870 700 m)

Localised acceleration of energetic particles by a weak shock in the solar corona

David M. Long, Hamish A. S. Reid, Gherardo Valori, Jennifer o'Kane

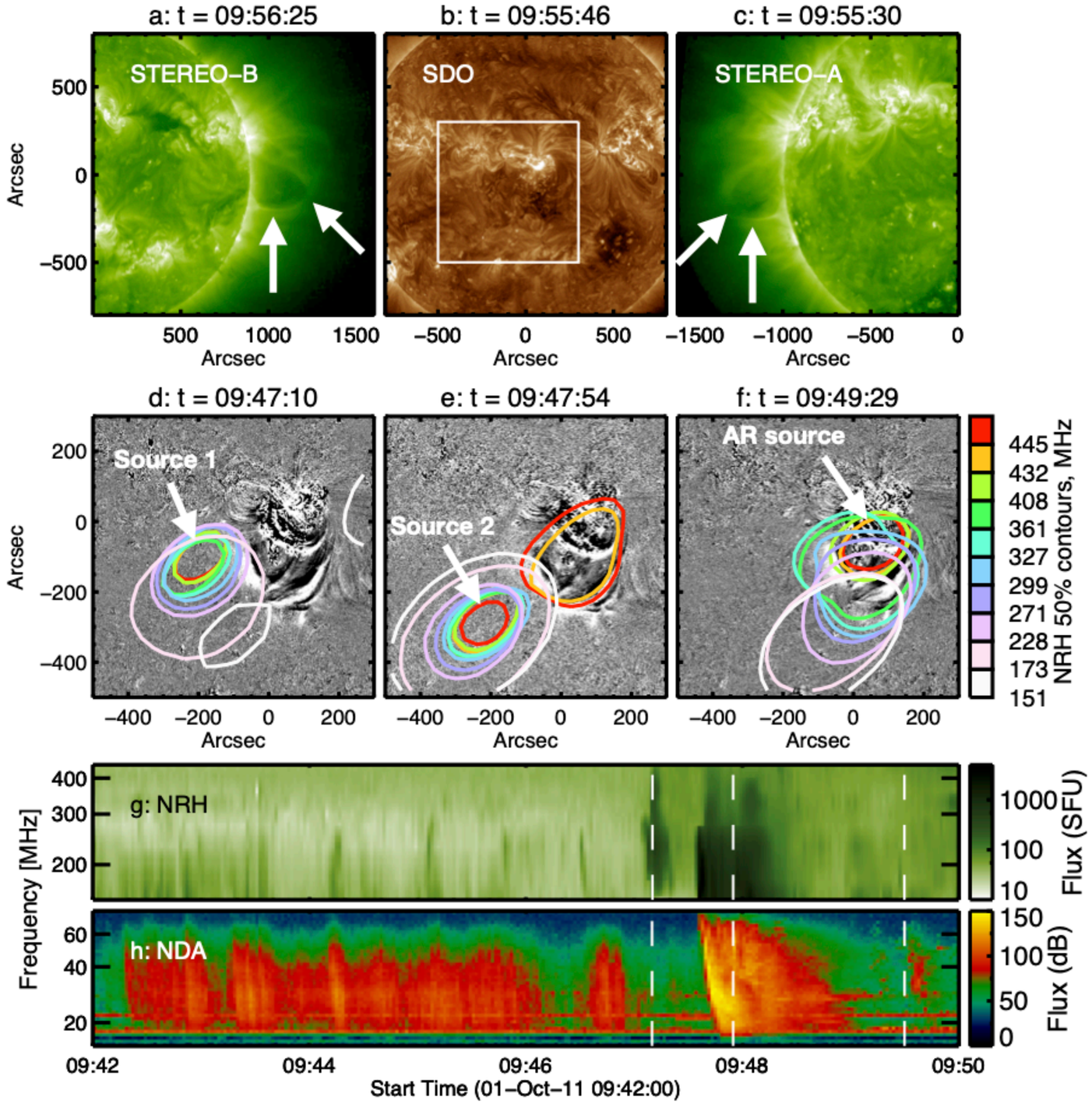
Mullard Space Science Laboratory, University College London

Science & Technology Facilities Council | UK Research and Innovation

UCL

Event evolution

- Possible to identify two distinct radio sources at leading edge of global wave
  - Also radio emission from source active region
- Correspond to Type III radio emission
  - Source 1 at higher frequencies
  - Source 2 at high -> low frequencies



3D reconstruction of a CME-driven bow shock & H I Lyα intensity calculation

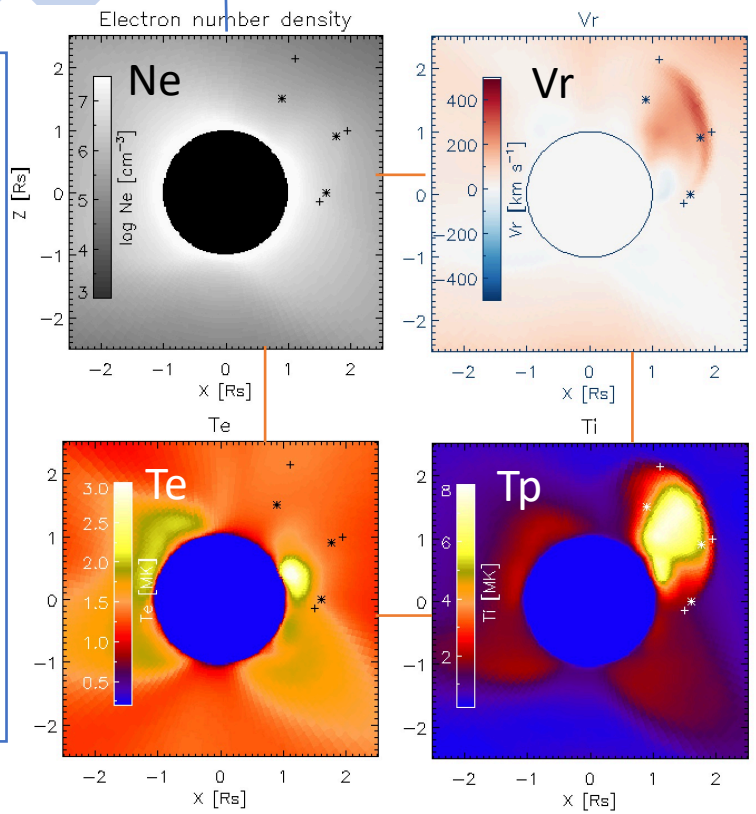
Beili Ying

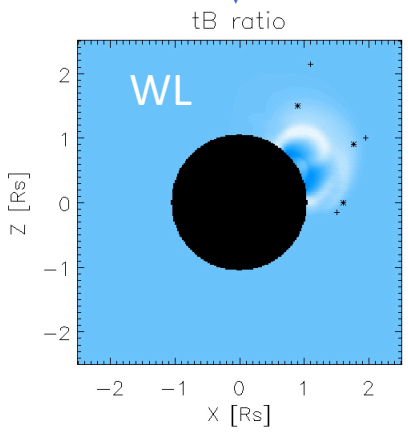
Li Feng et al.

Purple Mountain Observatory, Nanjing, China

Calculation of H I Lyα intensity based on the 2-fluid MHD simulation

MHD parameters on the POS

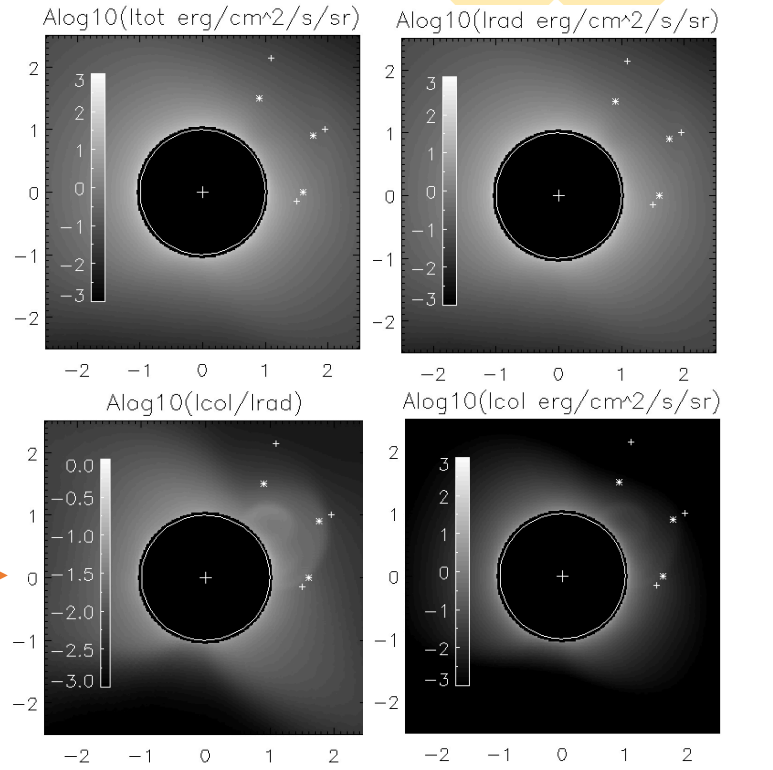




Considering **(Irad1)**

1. nonuniform disc intensity
2. scattering angle
3. $T_p \neq T_e$

Lyα intensity by integrating along the LOS



Differences with **Irad1** conditions:
Irad2: uniform disc
Irad3: doesn't consider scattering angle
Irad4: $T_p = T_e$

Relative comparison