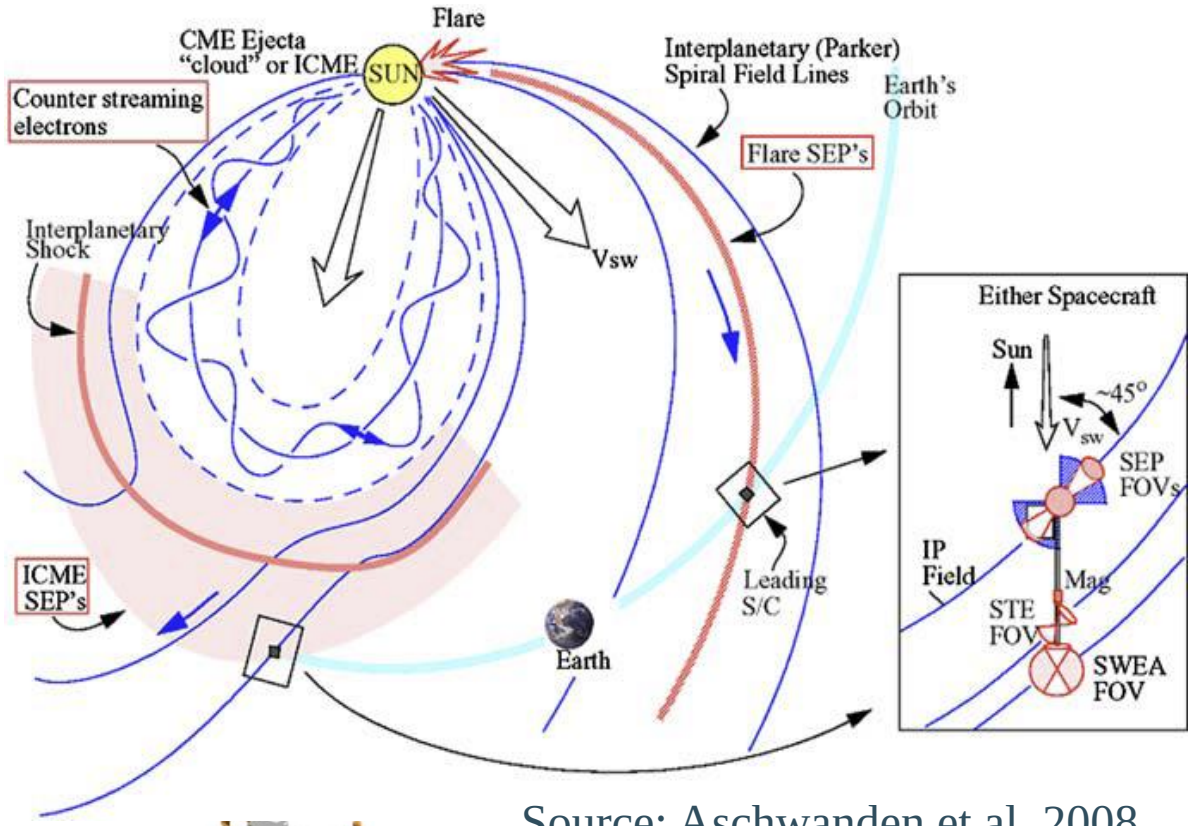
EUHFORIA 2.0 / EUHFORIA in PARADISE

EUHFORIA 2.0 + ESA HMT teams

Objective:

Project addresses geoeffectiveness, impacts and mitigation, including extreme events, related to solar eruptions, solar wind streams and Solar Energetic Particles, with particular emphasis on its application to forecast *Geomagnetically Induced Currents* (GICs) and *radiation on geospace*

The overall project goal is to develop a revolutionary space weather forecasting tool for forecasting geomagnetic disturbances and SEP events and their effects.



Source: Aschwanden et al. 2008

VSWMC

Horizon 2020 esa euhforia

Centre for mathematical Plasma Astrophysics

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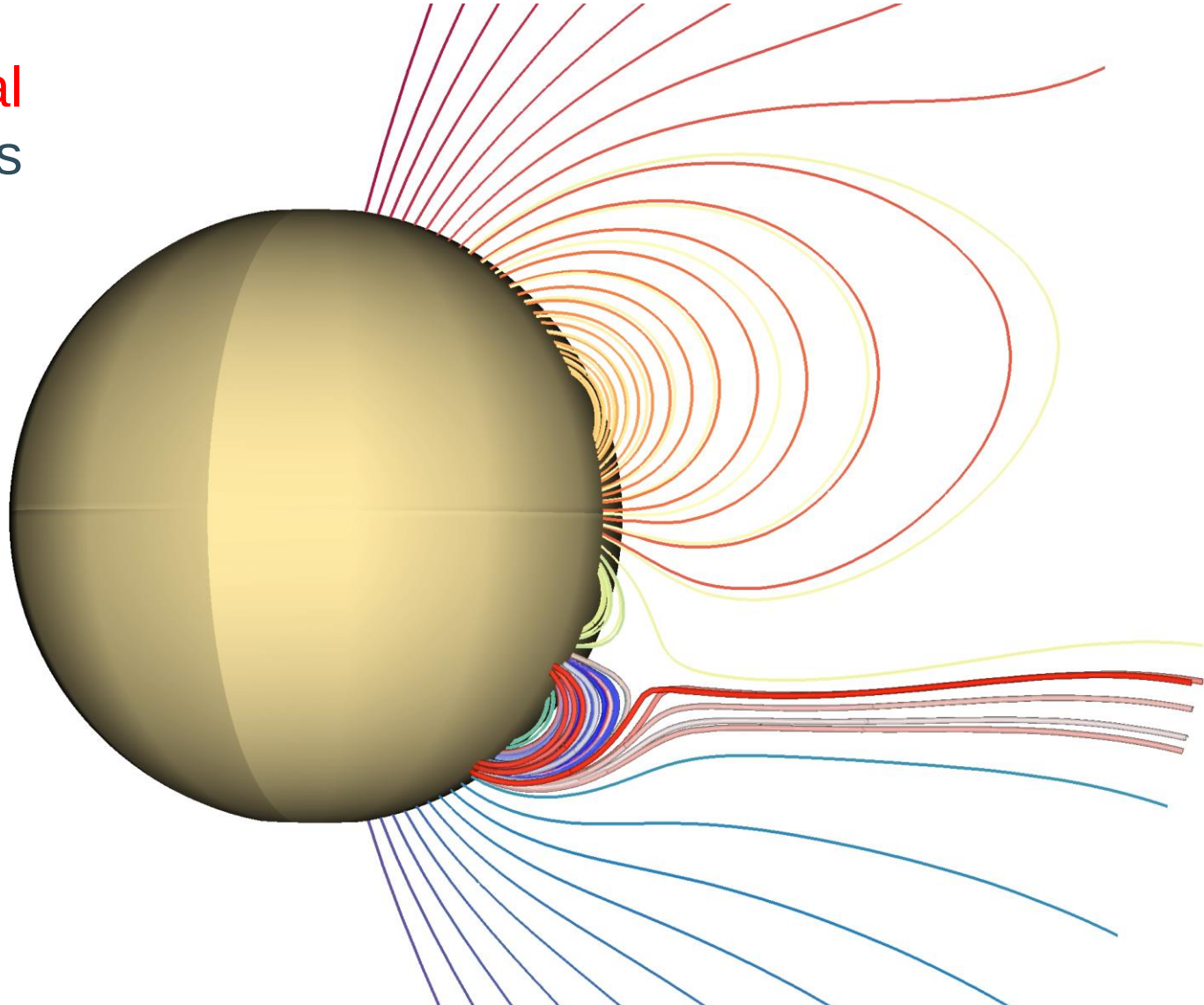
Global non-potential model coronal model

Development of a global non-potential model of the coronal magnetic field as an alternative to the current PFSS + Schatten current sheet model in EUHFORIA

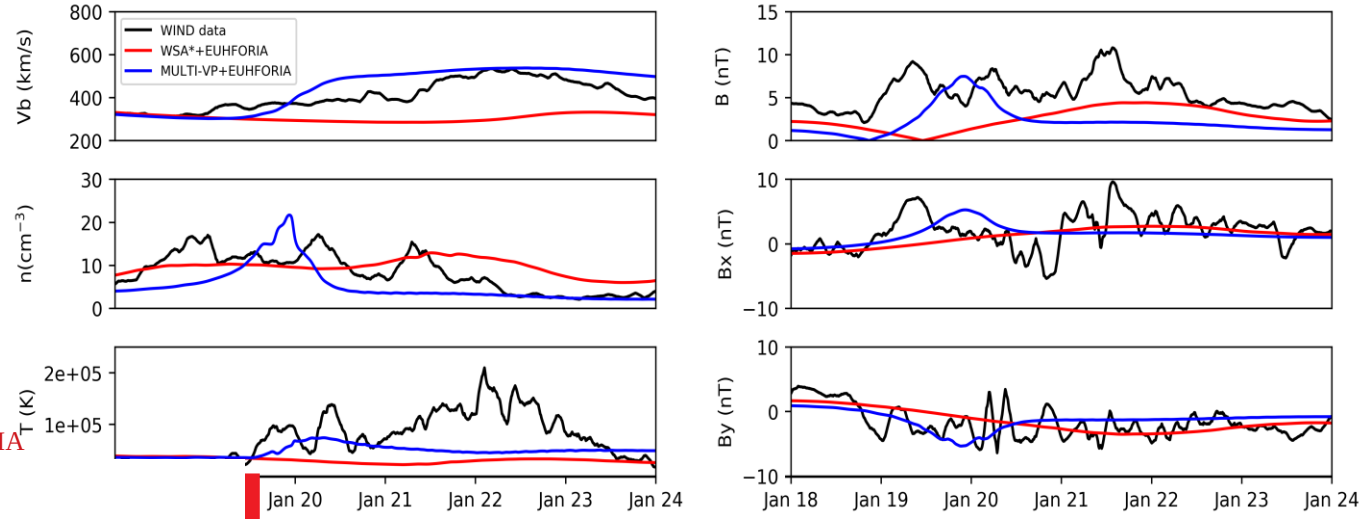


Formation of a sheared arcade structure in a multipolar magnetic field structure. The evolution of the Coronal field is efficiently computed using the Magneto-frictional relaxation model developed at University of Helsinki.

Source: Jens Pomoell

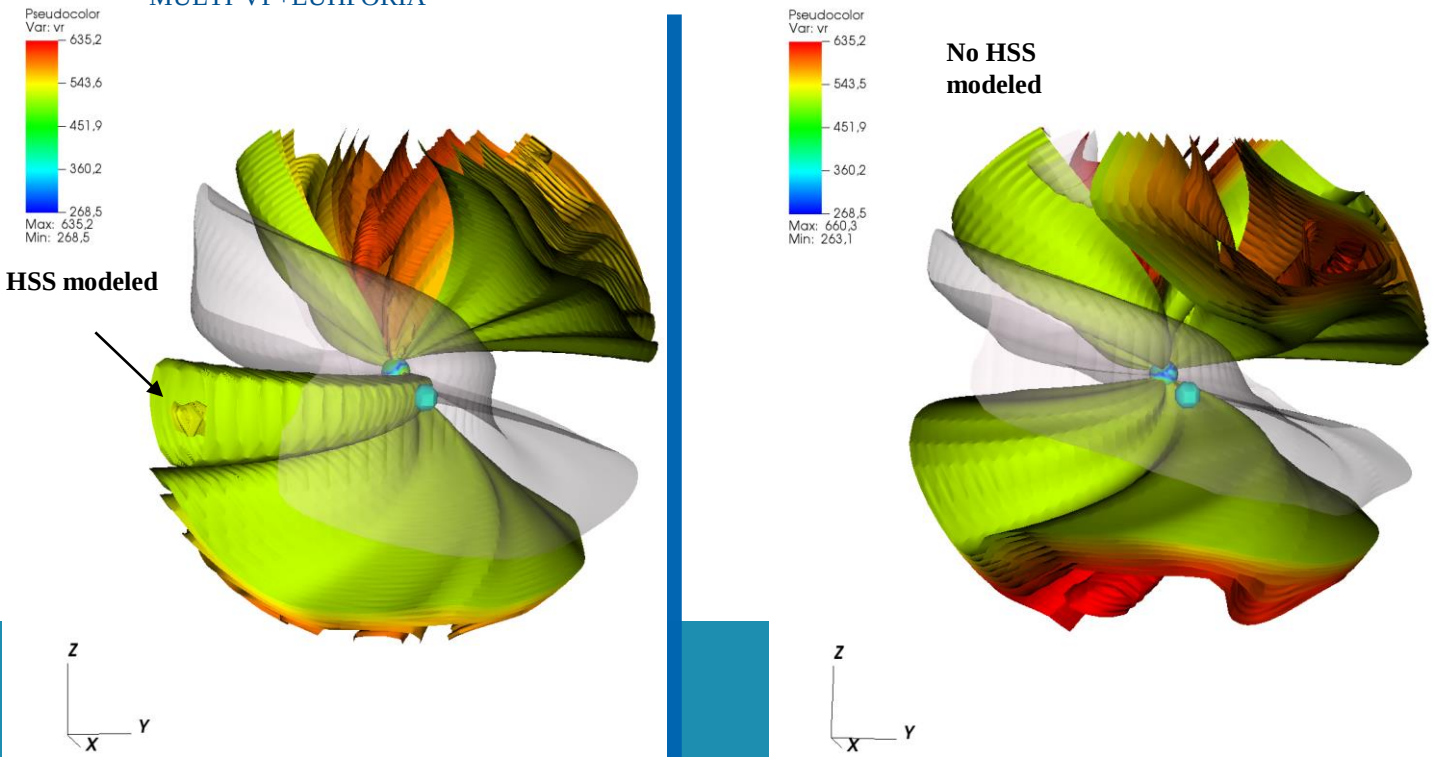
MULTI-VP coupled to EUHFORIA heliosphere

HSS bulk speed at Earth as modeled by WSA+EUHFORIA (red) and MULTI-VP+EUHFORIA (blue) for 6 days of forecasting. Both runs have been conducted with the GONG synoptic magnetogram taken on 2018-01-17T23:14. The MULTI-VP+EUHFORIA output captures the real HSS while this is not the case for the WSA+EUHFORIA.



MULTI-VP+EUHFORIA

WSA+EUHFORIA



3D visualizations of the structures produced by WSA+EUHFORIA and MULTI-VP+EUHFORIA throughout the inner heliospheric domain. The heliospheric current sheet is indicated in grey while the colorful isosurfaces represent solar wind speeds between 520 and 600 km/s. Earth is shown in light blue color.

Source: Samara et al. 2021

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Improved coronal models: polytropic MHD model

Cf. Barbara Perri at 16:55 today in Plenary 6

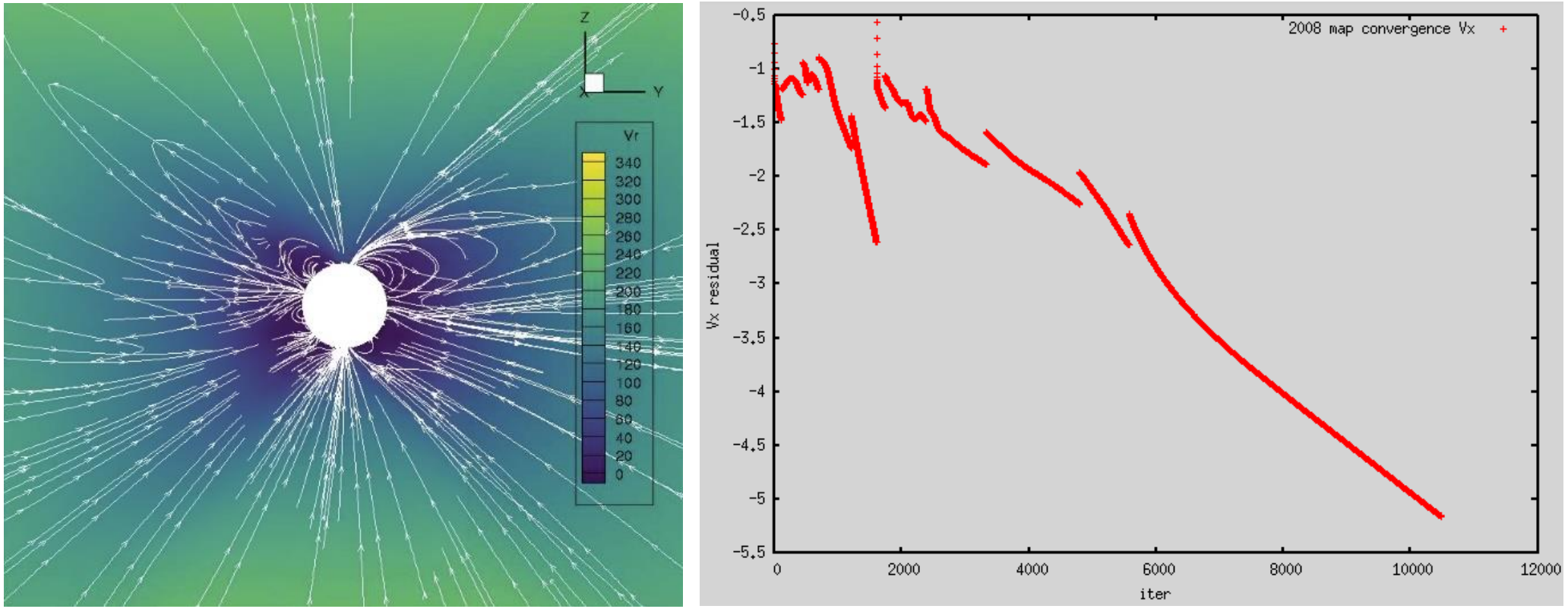


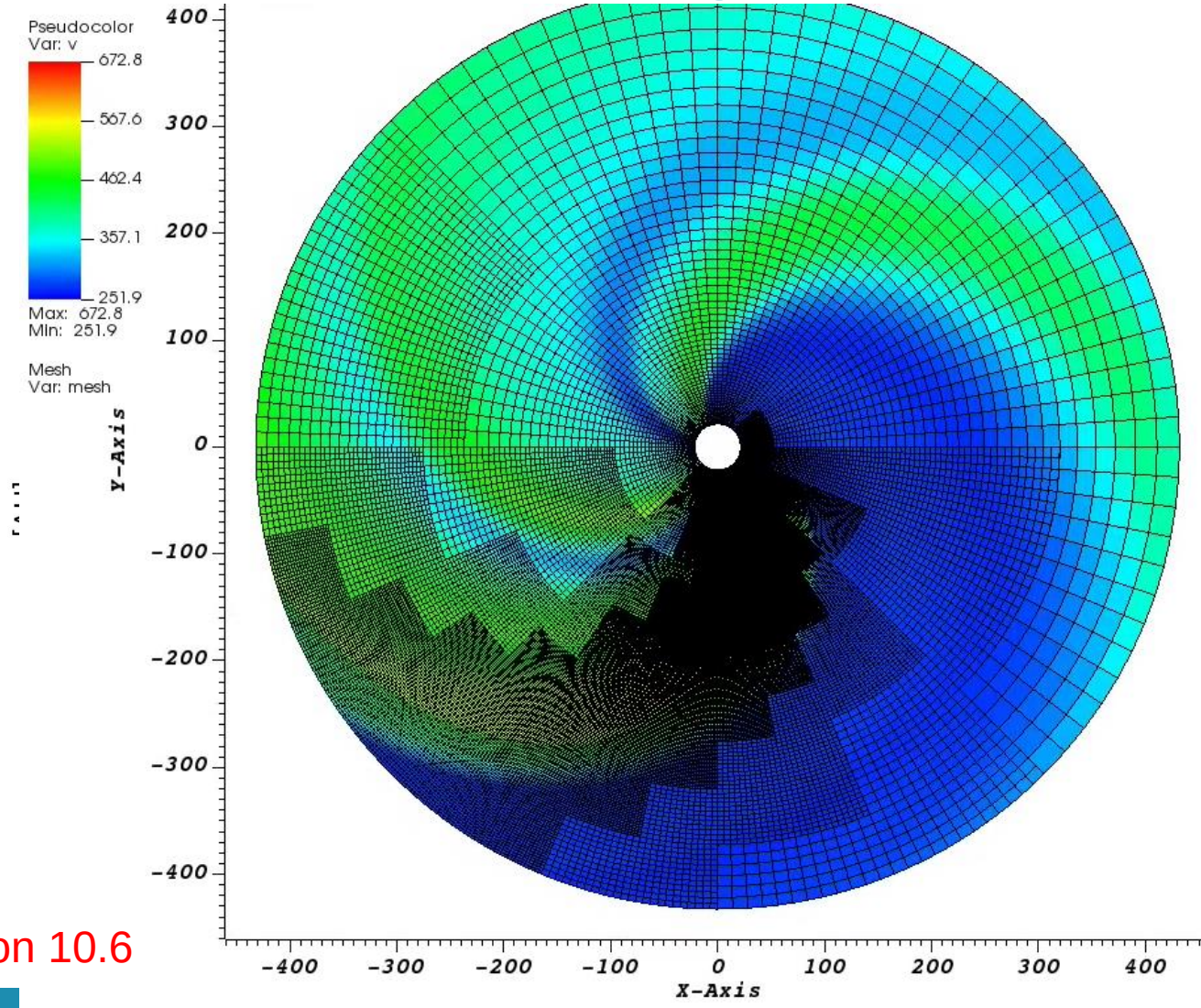
Fig. 1: *Example 2D cut of a converged coronal model based on a magnetogram of 2008 using unstructured grid code with implicit solver*. Left: *Magnetic field lines are superposed on coloured contours of the radial component of velocity. Right: convergence history. The final CFL number was 64 for this particular case.*

Source: Leitner et al. 2021

Advanced solar wind and CME modelling

AMR refinement criterion depending on application:

- CME erosion/deformation ⇒ tracing function (ex.: 3 refinement levels)
- CIR shocks ⇒ $\nabla.\mathbf{v}_{SW}$ (normalised)
  - Expanding Solar wind ⇒ deceleration
  - Compression / shock waves ⇒ acceleration
- CME shocks ⇒ $\nabla\rho$ and/or $\nabla.\mathbf{v}_{CME}$ (normalised)



Cf. Tinatin Baratashvili today at 11:26AM in Poster session 10.6

Source: Verbeke et al. 2021

CME models integrated in EUHFORIA

Cone-like model (unmagnetised) Pomoell & Poedts, 2018

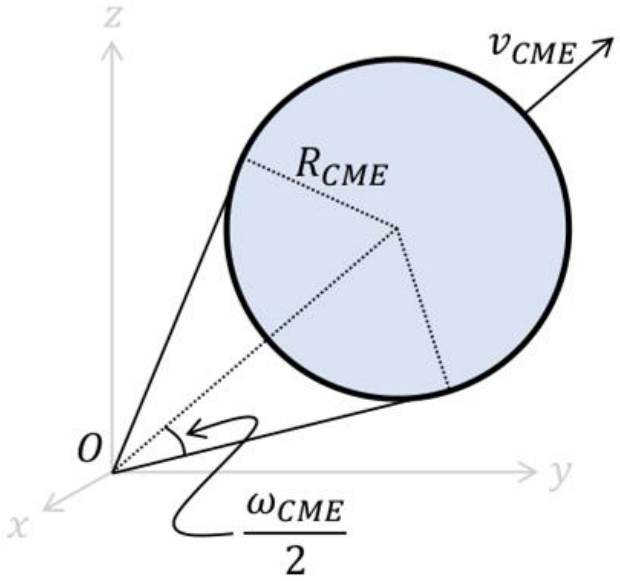


Image courtesy: Camilla Scolini

Spheromak CME (flux rope - spherical geometry) Verbeke et al, 2019

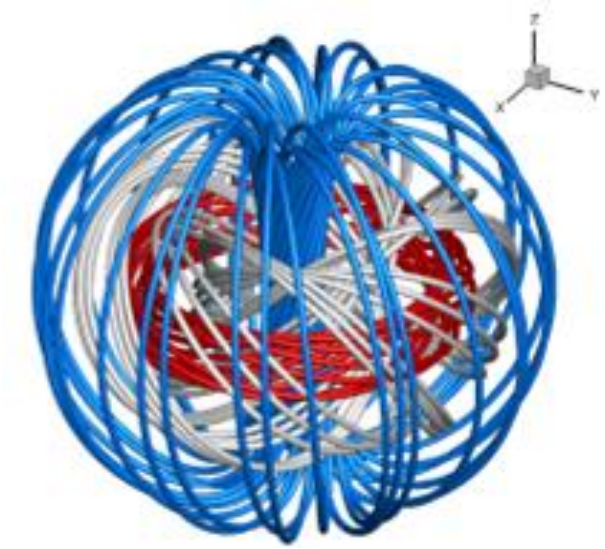
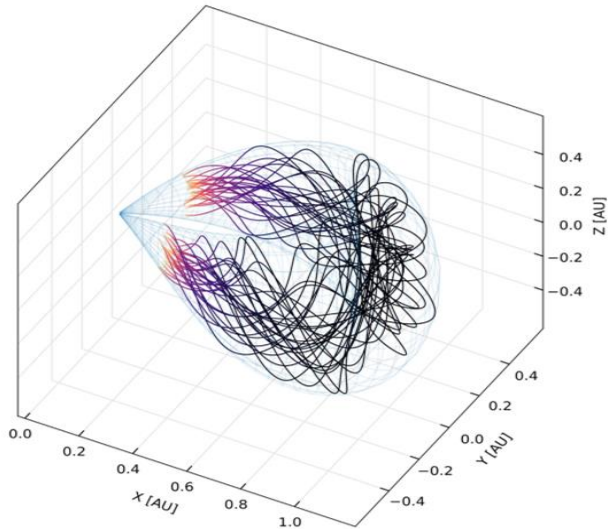


Image courtesy: Camilla Scolini

Cf. Anwesha Maharana Poster session 1.6

FRi3D model (flux rope - extended geometry) Isavnin et al, 2016



- Stretched flux rope
- Lundquist magnetic field

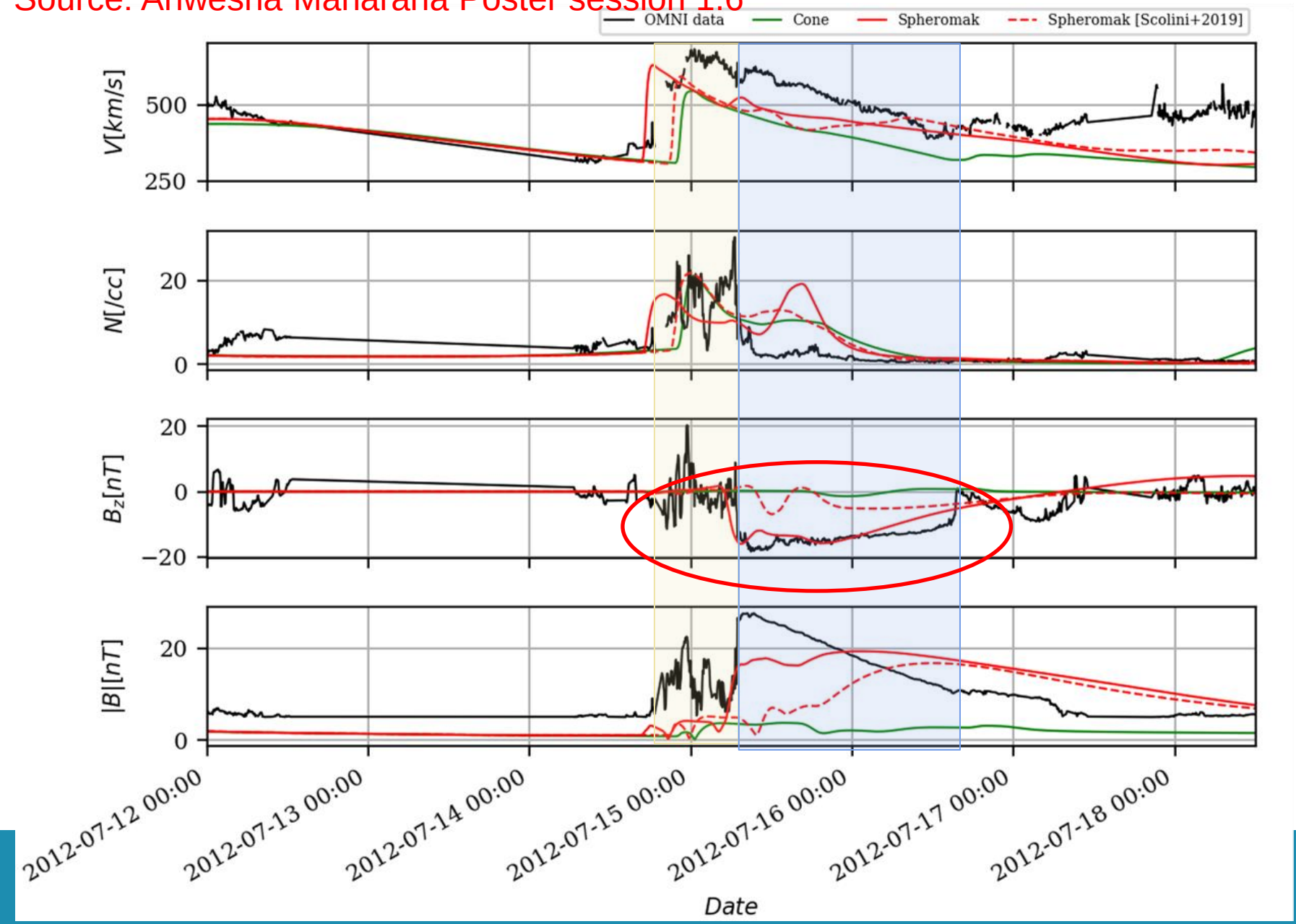
$$\mathrm{B}_\rho = 0$$
$$\mathrm{B}_\phi = B_0 J_1(\alpha r)$$
$$\mathrm{B}_z = B_0 J_0(\alpha r)$$

Credit: Anwesha Maharana

Toroidal CME model (Grad-Shafranov solution): validation ongoing

Event 2012-07-12 @Earth

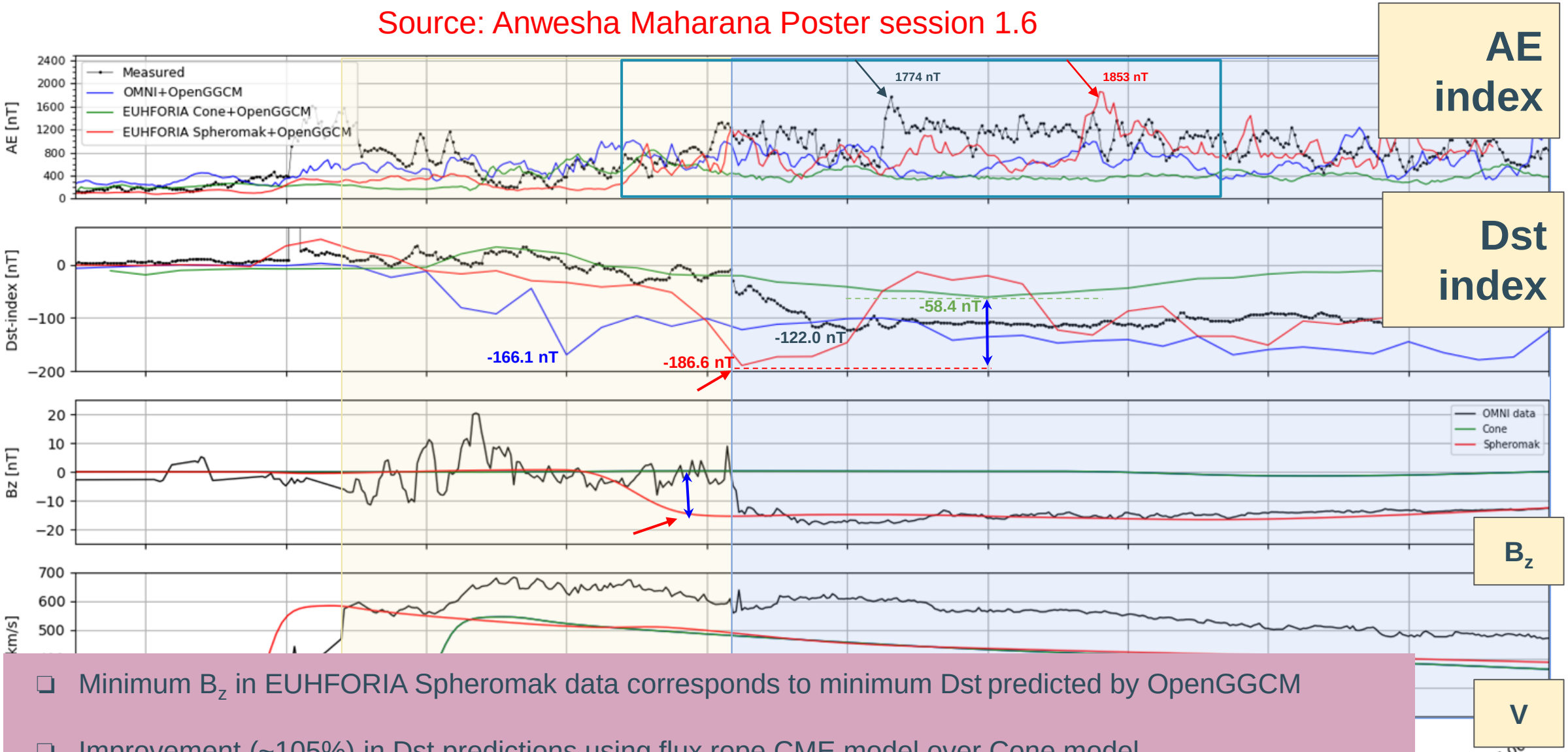
Source: Anwesha Maharana Poster session 1.6



- **Arrival time, speed** and **number density** peaks reproduced at Earth.
- Flux rope CME modelling upgraded as compared to Scolini et al., 2019
- IMF rotations in all magnetic field components of flux rope well-captured
- Flux rope model enhances the predictions of **B** and **B_z** by around 48% and 46% as compared to Cone CME

Geomagnetic indices from OpenGGCM

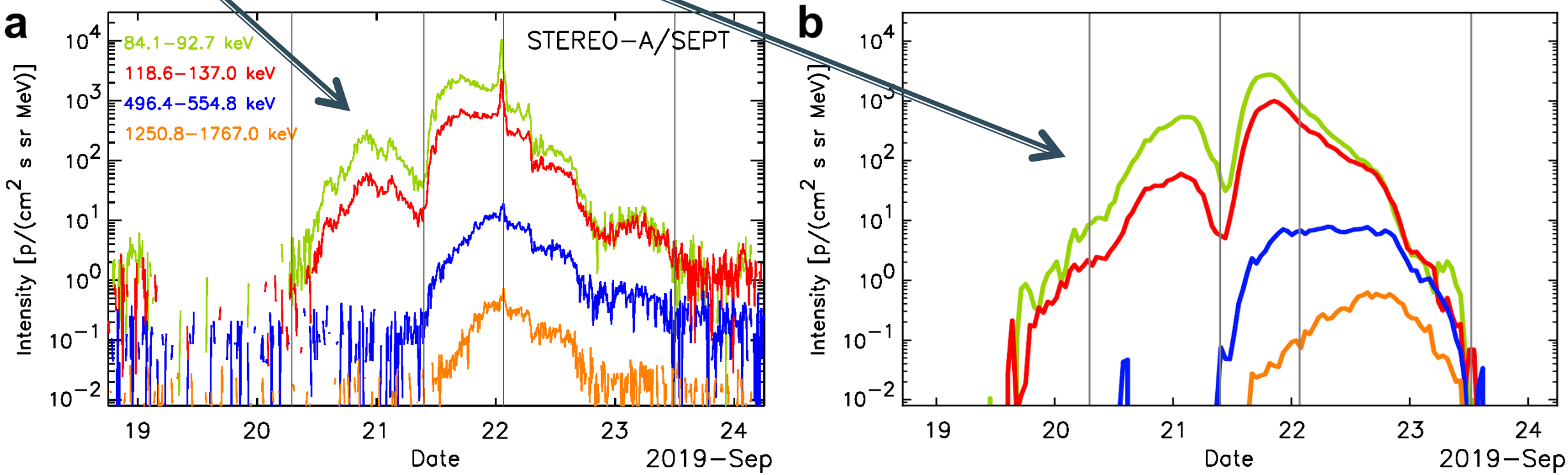
Source: Anwesha Maharana Poster session 1.6



- Minimum B_z in EUHFORIA Spheromak data corresponds to minimum Dst predicted by OpenGGCM
- Improvement (~105%) in Dst predictions using flux rope CME model over Cone model
- AE index corresponding to negative B_z region reproduced with flux rope CME (~57% better than Cone)

Coupling to PARADISE: PSP CASE study

Observed (left) and **simulated** (right) omni-directional ion intensities at STEREO-A. The vertical lines indicate the onset time of the SIR (stream interaction regions) event (Sep 20 09:00 UT), the stream interface (Sep 21 09:30 UT), the developing reverse shock (22 Sep 01:35 UT), and the stop time of the SIR event (23 Sep 12:00 UT).



Credit: N. Wijsen et al., 2021

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