This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

EGU General Assembly 2022

Modelling the mispredicted September 2014 storm with EUHFORIA

Anwesha Maharana[1]

Camilla Scolini[2,3], Brigitte Schmieder[1,4], Stefaan Poedts[1,5]

[1]KU Leuven, Leuven, Belgium
[2]University of New Hampshire, Durham, NH, USA
[3]University Corporation for Atmospheric Research, Boulder, CO, USA
[4]Observatoire Paris, LESIA, Meudon, France
[5]Institute of Physics, University of Maria Curie-Skłodowska, Lublin, Poland

EGU22-5935

Background

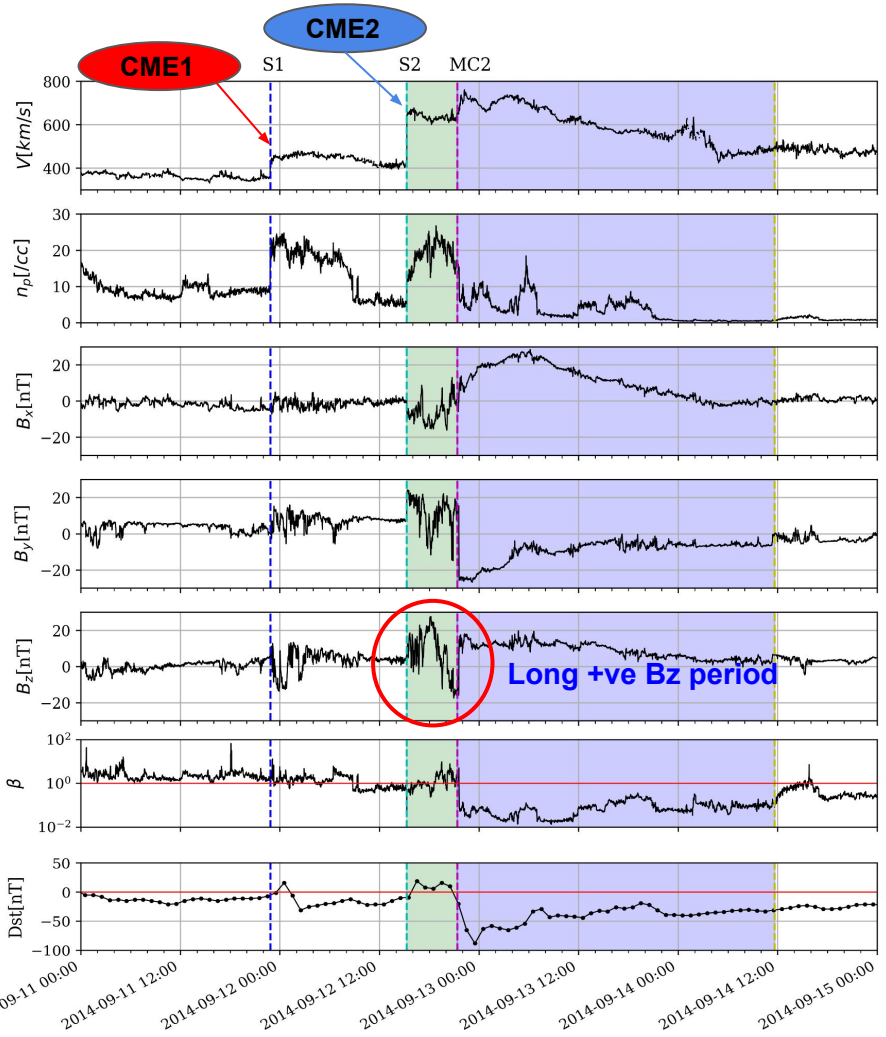
Preceding event (CME1) - **[September 8, 2014]**
Shock is recorded at Earth. Event not recorded in ICME catalogs.

Main event (CME2) - **[September 10, 2014]**
Well-recorded in ICME catalogs and previously studied [*Cho+2017, Kilpua+2021, An+2019*].

Initial predictions (ISEST, VarSITI program)
CME2 was predicted to be a direct hit and to produce a major storm (Dst < -100nT).

From in-situ observations
Positive Bz was encountered in its magnetic cloud.
Negative Bz (Dst ~ -73nT) was measured in the sheath.

Geo-effectiveness of different sub-structures of the storm mis-predicted.

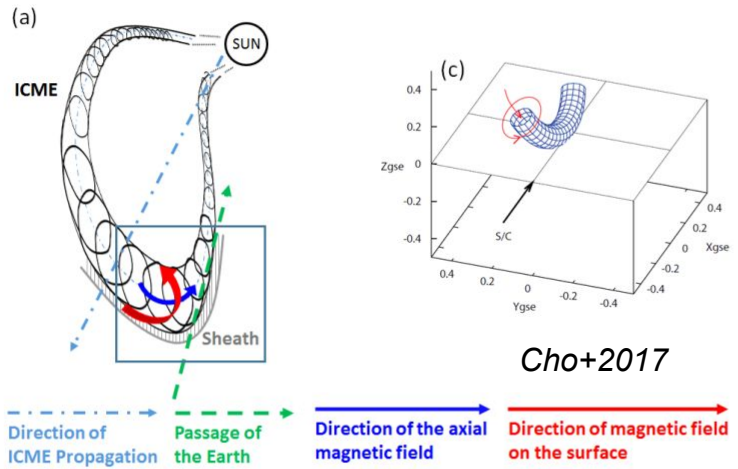


Objectives

Main event (CME2) - Well recorded in ICME catalogs and previously studied [*Cho+2017, Kilpua+2021, An+2019*].

1. **To understand the change in orientation** of CME2
   a. Rotation/deformation
      OR/AND
   b. Flank encounter

CME2



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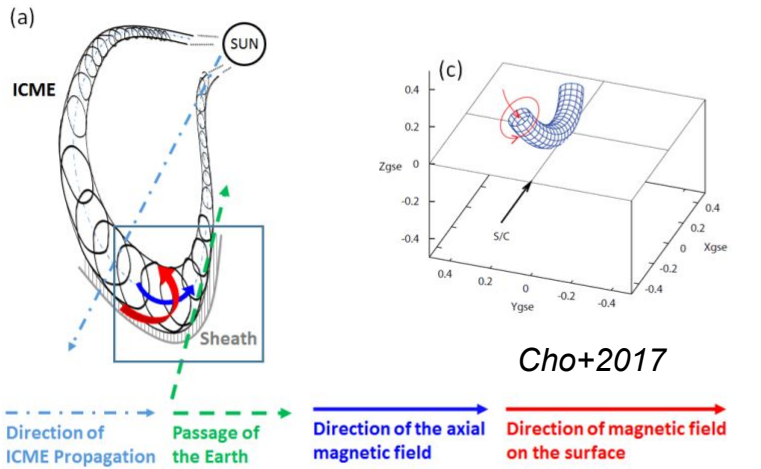
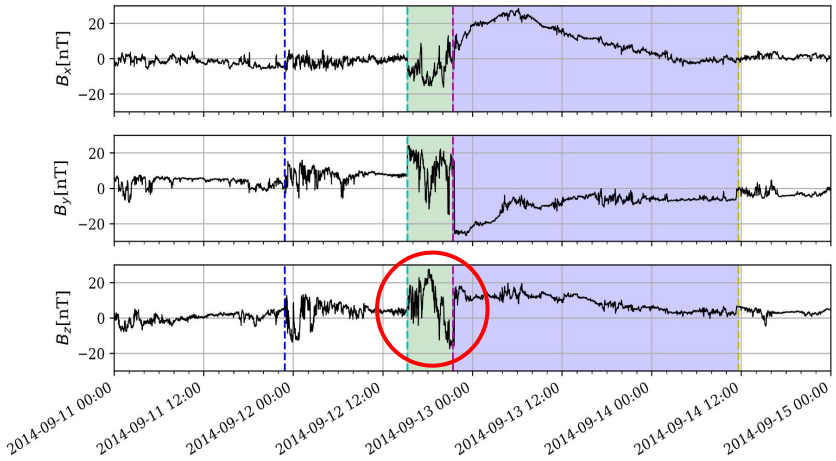
Main event (CME2) - Well recorded in ICME catalogs and previously studied [*Cho+2017, Kilpua+2021, An+2019*].

1. **To understand the change in orientation** of CME2
   a. Rotation/deformation
   OR/AND
   b. Flank encounter

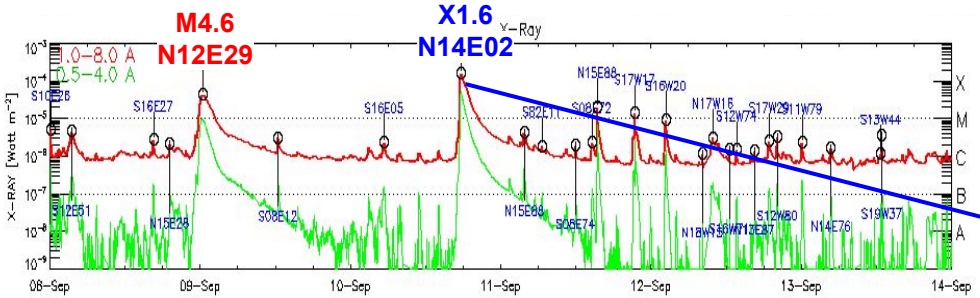
2. **To investigate the role of CME1-CME2 interaction**
   a. The geo-effectiveness occurs due to the -ve Bz in the sheath

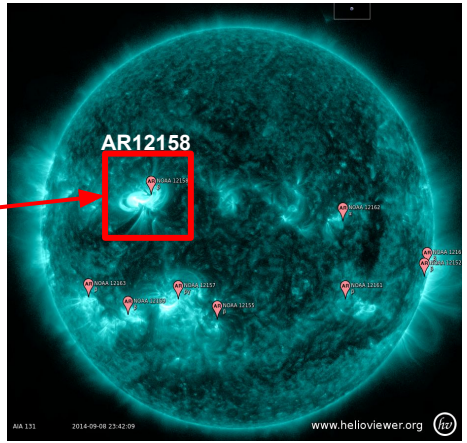
CME2

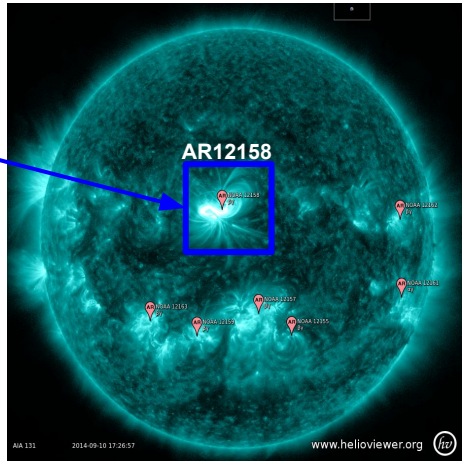




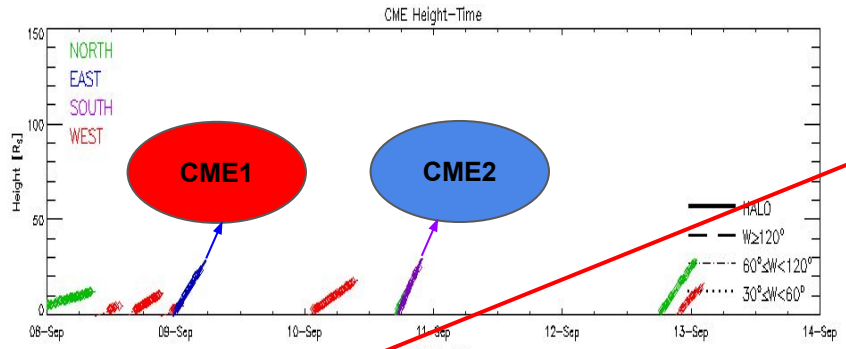
Flare-CME association

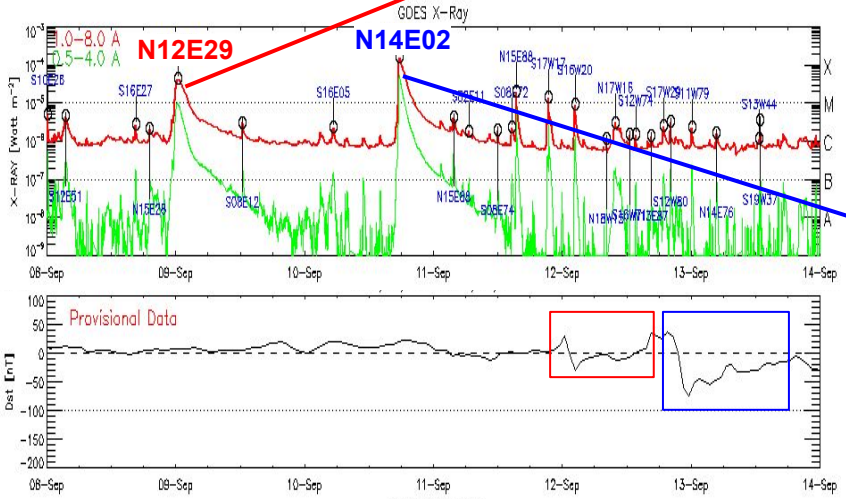


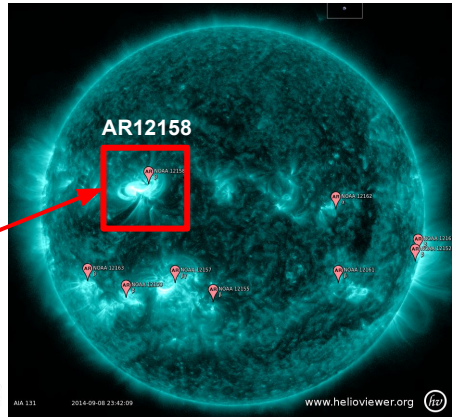


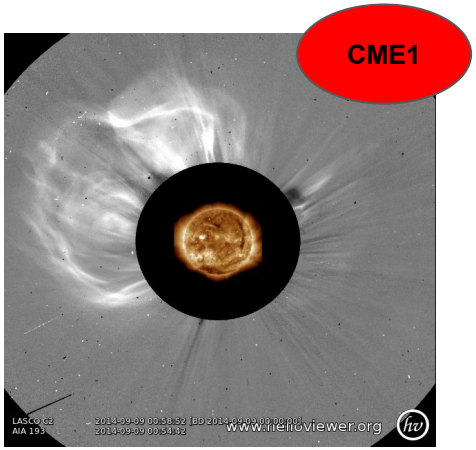


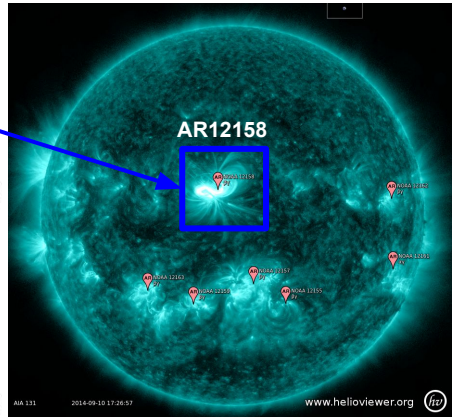
Flare-CME association

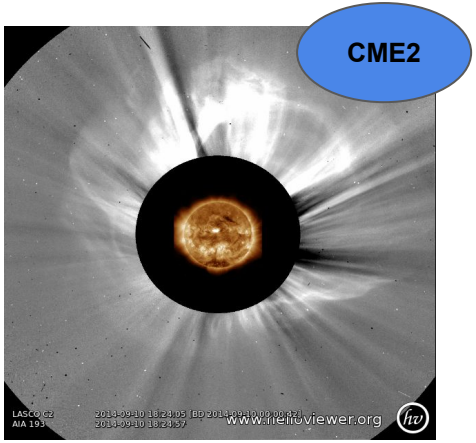






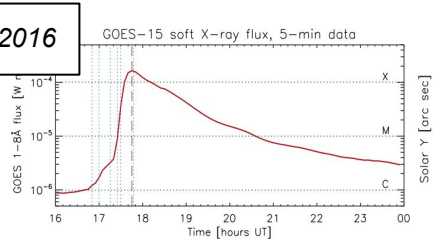


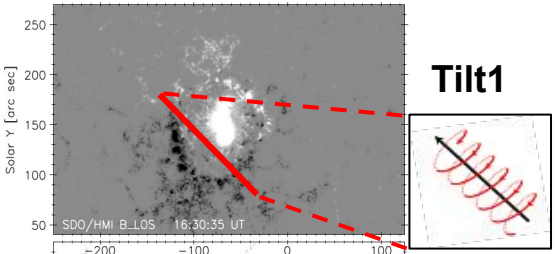




CME2: Eruption at the Sun

Dudik et. al 2016

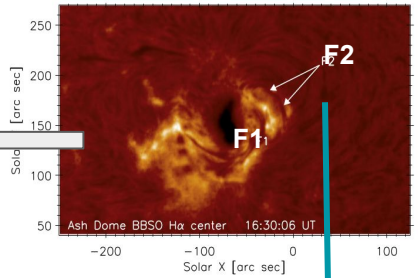


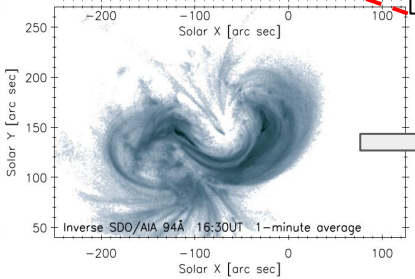


Tilt1

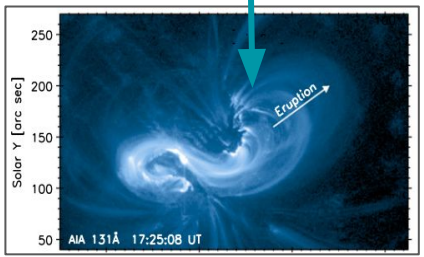
If F1 erupted

Two flare ribbons:
→ F1 stays unperturbed
→ **F2 erupts** in the NW direction





Inverse-S sigmoid
Left-handed chirality

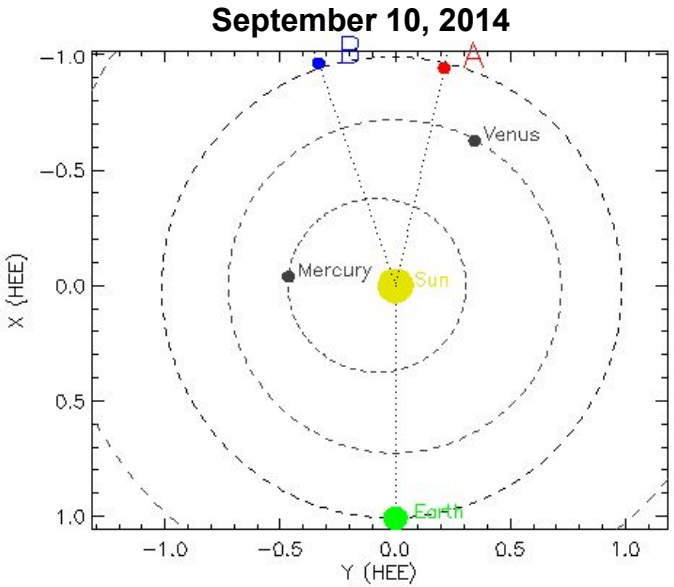


Tilt2

If F2 erupted

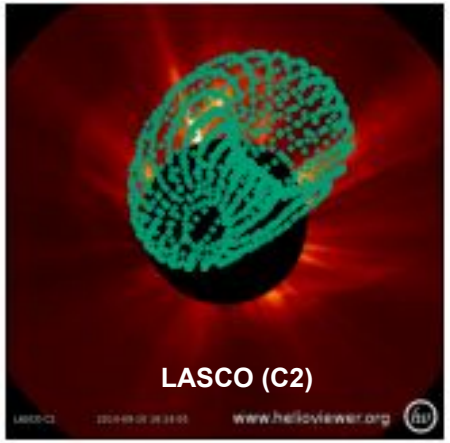
Northward eruption

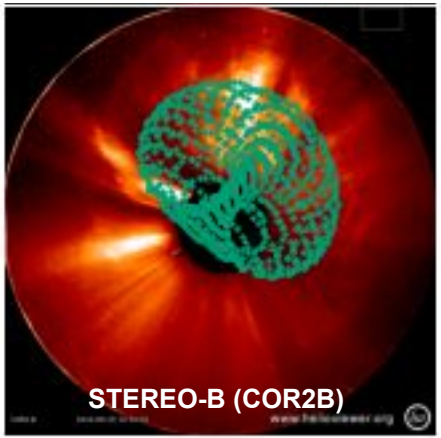
CME2: 3D Reconstruction within 0.1 AU

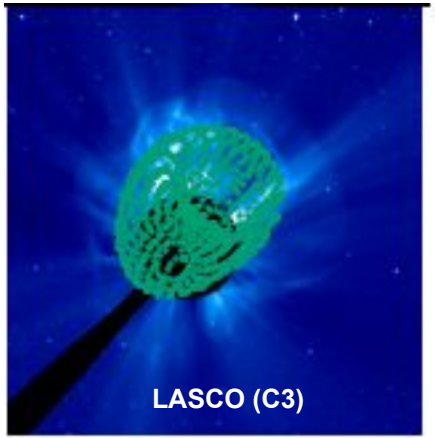


- **Availability of coronagraph data** from **LASCO** and **STEREO-B**
- **CME2**: Observed as a ‘halo’ CME from both LASCO and STEREO-B.

Flux Rope in 3D (FRi3D)
(Isavnin+2016)

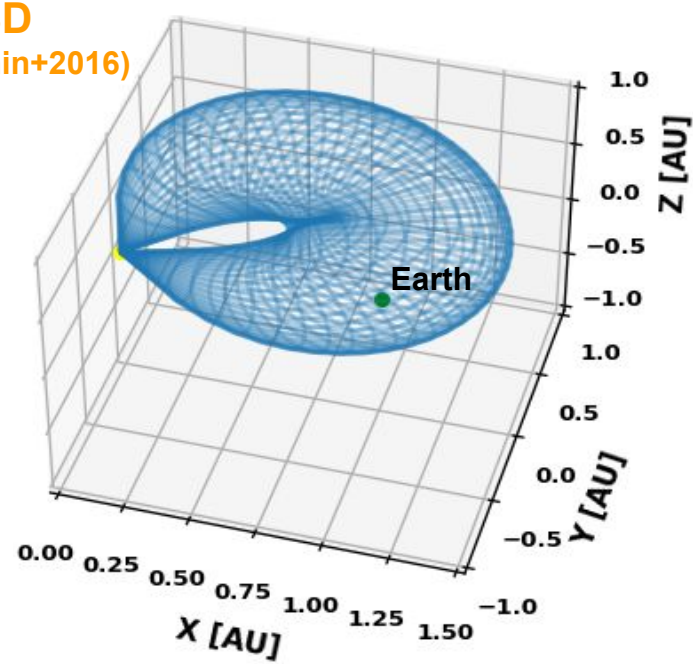






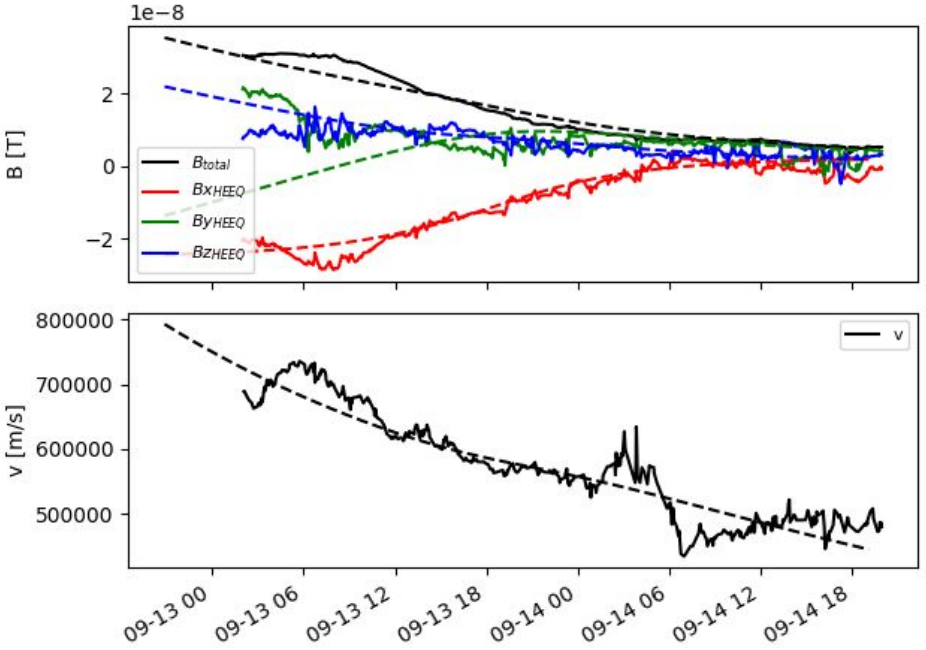
CME2: Extrapolation to 1 AU

FRi3D
(Isavnin+2016)



➢ FRi3D flux rope when self-similarly expanded till Earth, suggest **flank encounter.**

CME2 at 1 AU



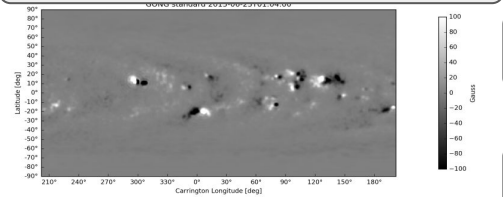
➢ **Numerical fitting of the FRi3D model** to in-situ measurements at Earth using a **differential evolution algorithm**
  - Matches the orientation at 0.1 AU

EUropean **H**eliospheric **FOR**ecasting **I**nformation **A**sset (EUHFORIA)

Pomoell & Poedts, 2018

Corona:
Semi-Empirical WSA model

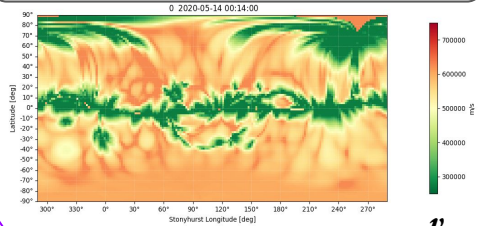
Synoptic Magnetogram (1 R_{sun})



PFSS model
(1 - 2.3 R_{sun})

SCS model
(2.6 R_{sun} - 0.1 AU)

MHD parameters (0.1 AU) using empirical relations



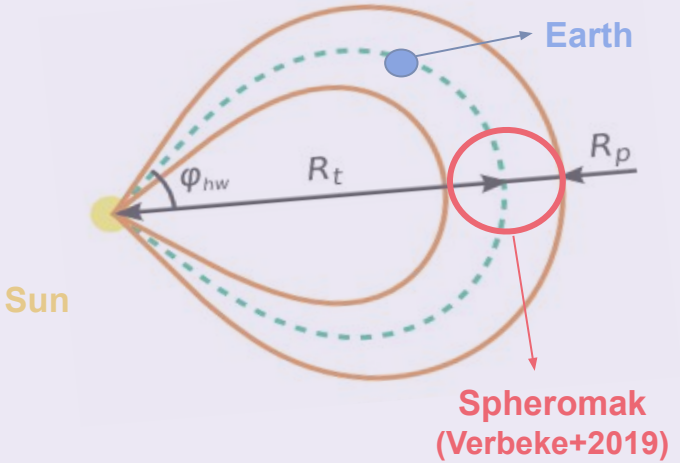
v_r

$$v = v(f,d)$$

B_r, n, T are also empirically derived.

FRi3D
(Isavnin+2016)

To model the flank encounter by CME2



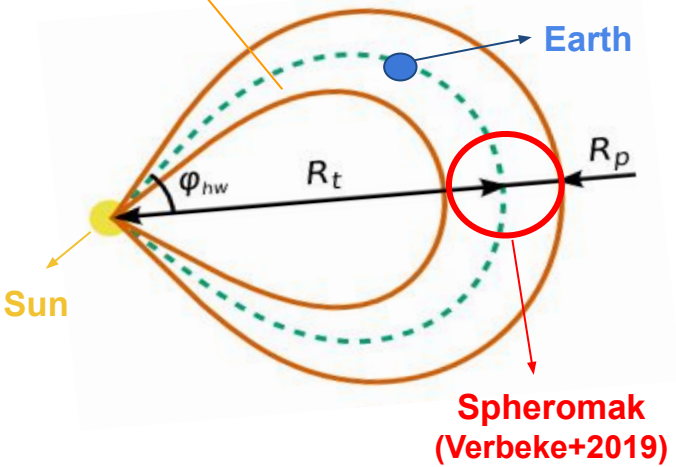
Solar wind relaxation → CME insertion @0.1 AU

FRi3D CME model in EUHFORIA

Pomoell & Poedts, 2018

FRi3D
(Isavnin+2016)

To model the flank encounter by CME2

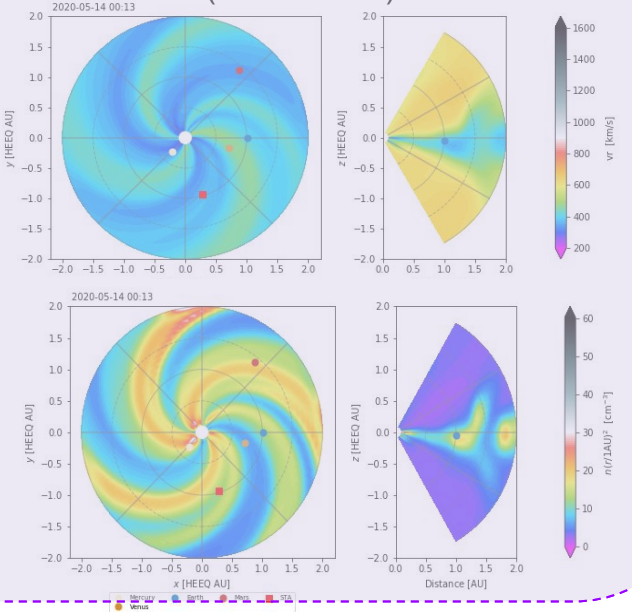


Heliosphere:
time dependent ideal MHD model

Evolves MHD parameters $\boldsymbol{v}, n, \boldsymbol{B}, T$
(0.1 - 2.0 AU)

v_r

$n.r^2$



CME insertion @0.1 AU

⇨

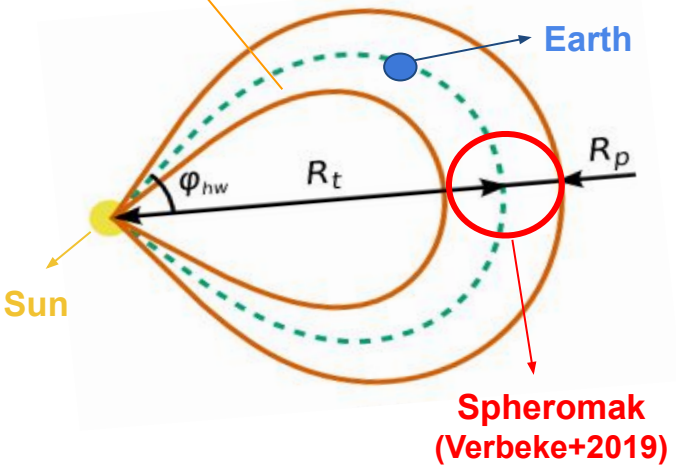
Forecasting

FRi3D CME model in EUHFORIA

Pomoell & Poedts, 2018

FRi3D
(Isavnin+2016)

To model the flank encounter by CME2



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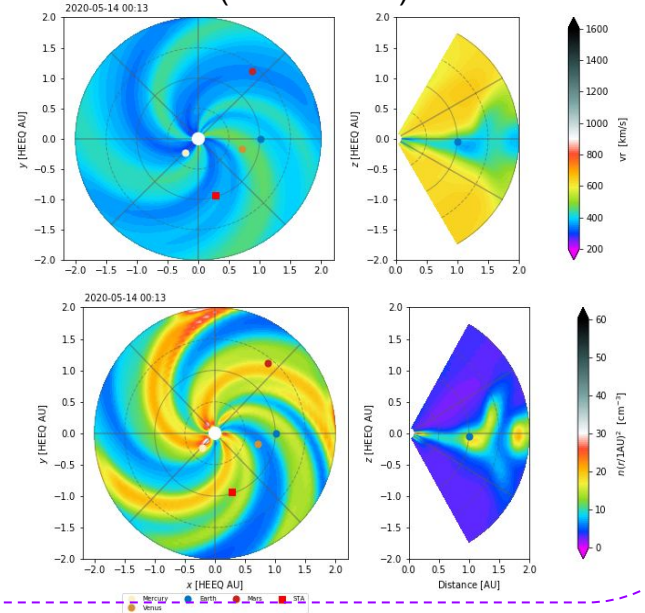
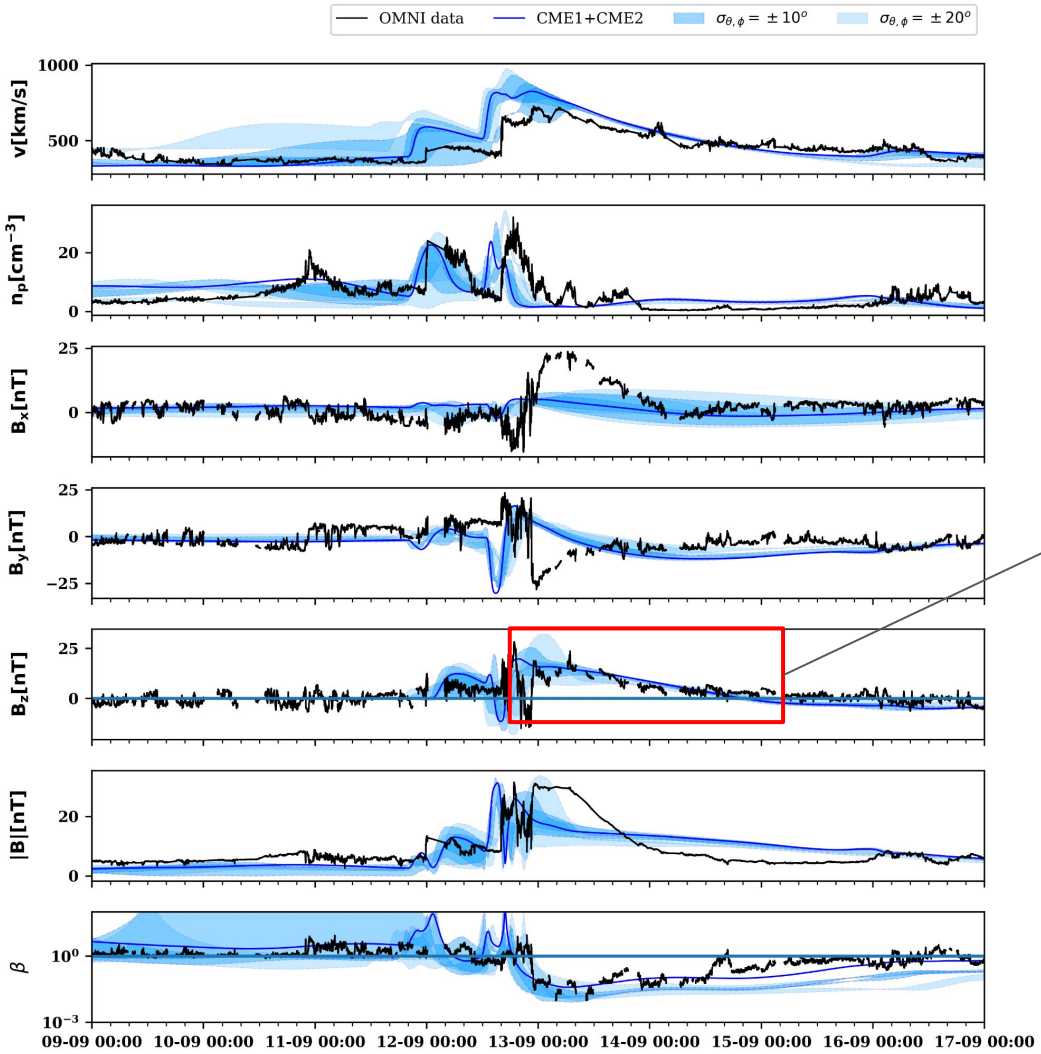


CME insertion @0.1 AU

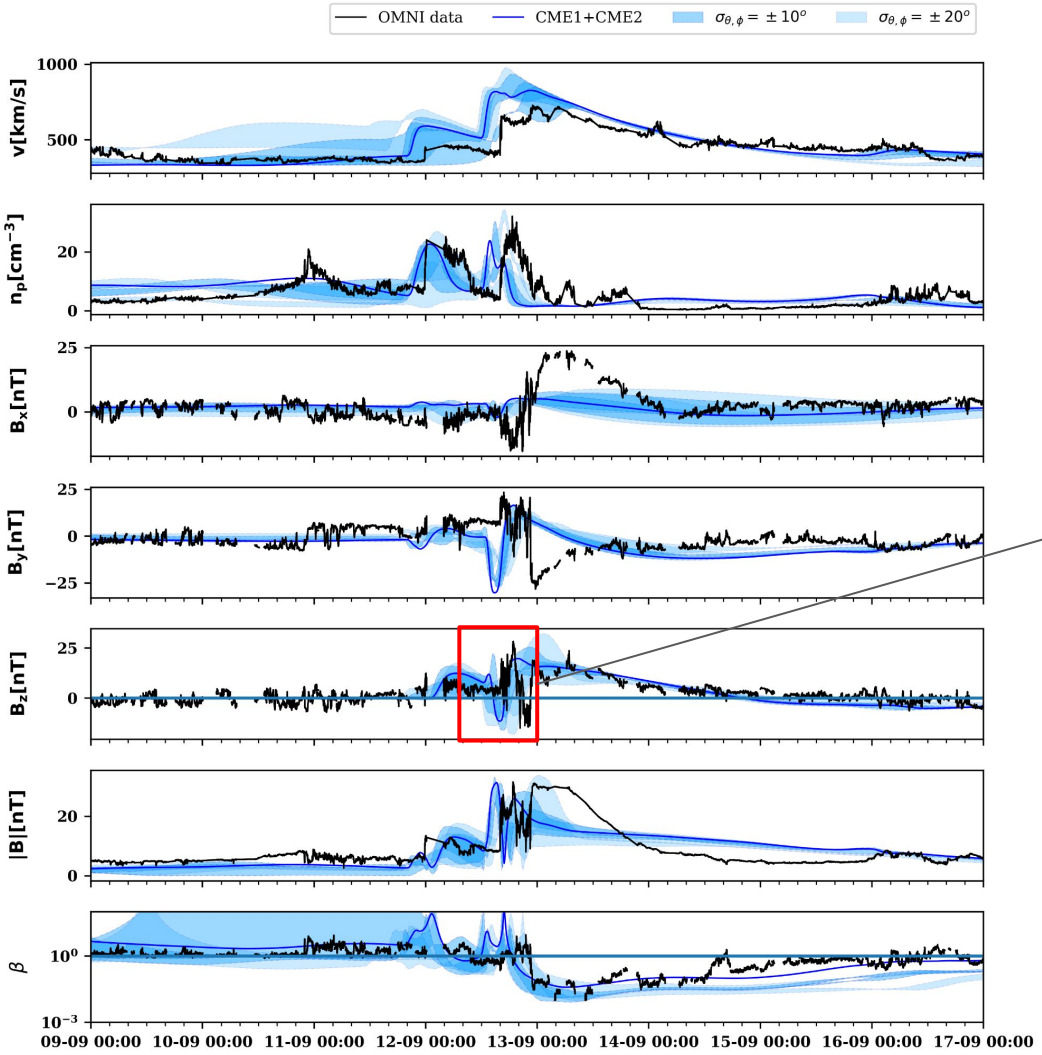
Forecasting



Results

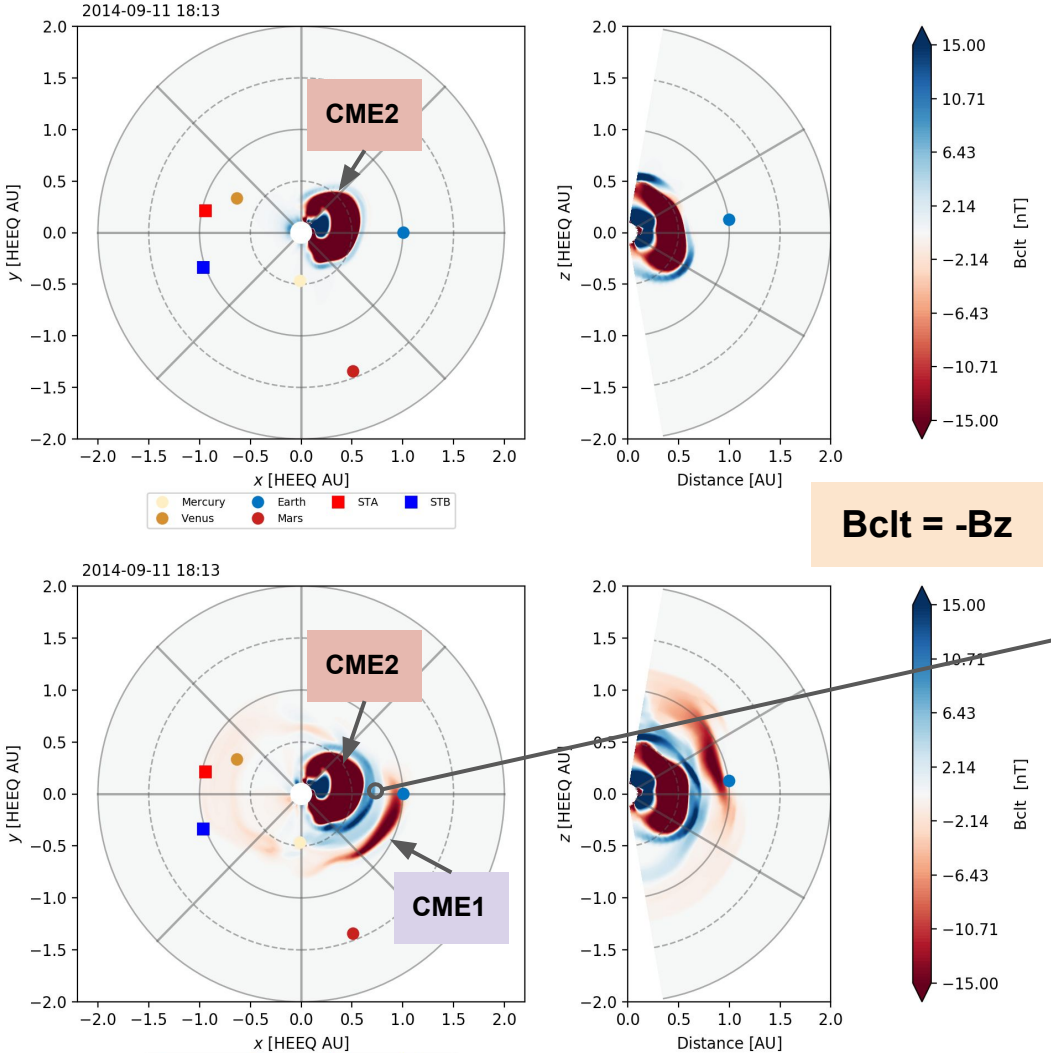
CME1 and CME2 are modelled with spheromak and FRi3D respectively.

- **CME2** modelled with FRi3D uses the **orientation** obtained from 3D reconstruction **at 0.1 AU**.
- The positive Bz in the magnetic cloud is reproduced.



Results

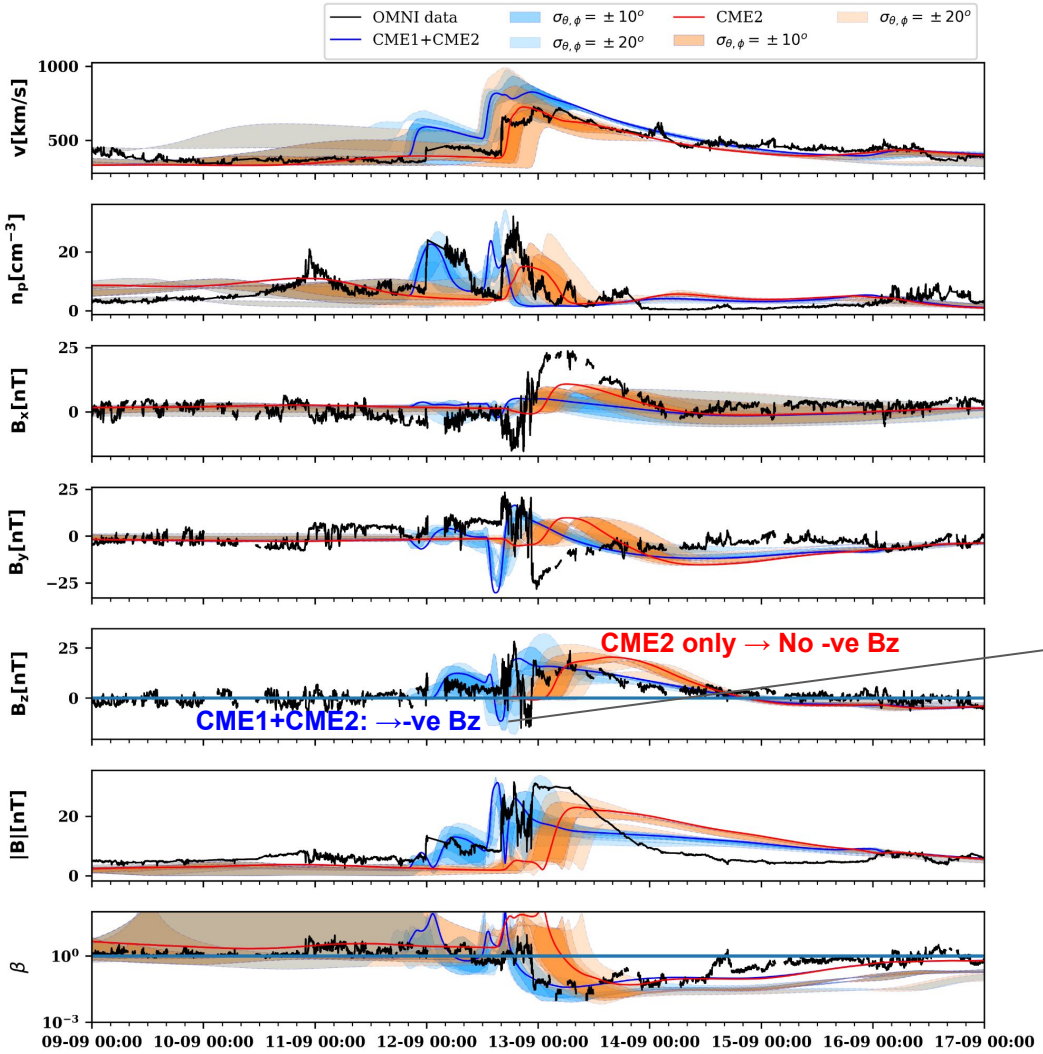
- **CME2** modelled with FRi3D uses the **orientation** obtained from 3D reconstruction **at 0.1 AU**.
- The **positive Bz** in the magnetic cloud is reproduced.
- The **rotation of Bz** in the sheath region has been modelled.



BcIt = -Bz

Results

- **CME2** modelled with FRi3D uses the **orientation** obtained from 3D reconstruction **at 0.1 AU**.
- The **positive Bz** in the magnetic cloud is reproduced.
- The **rotation of Bz** in the sheath region has been modelled.
- The **negative Bz in the sheath** is formed due to the interaction between CME1 and CME2.



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- The **rotation of Bz** in the sheath region has been modelled.
- The **negative Bz in the sheath** is formed due to the interaction between CME1 and CME2.

Maharana et. al, in preparation

Conclusion

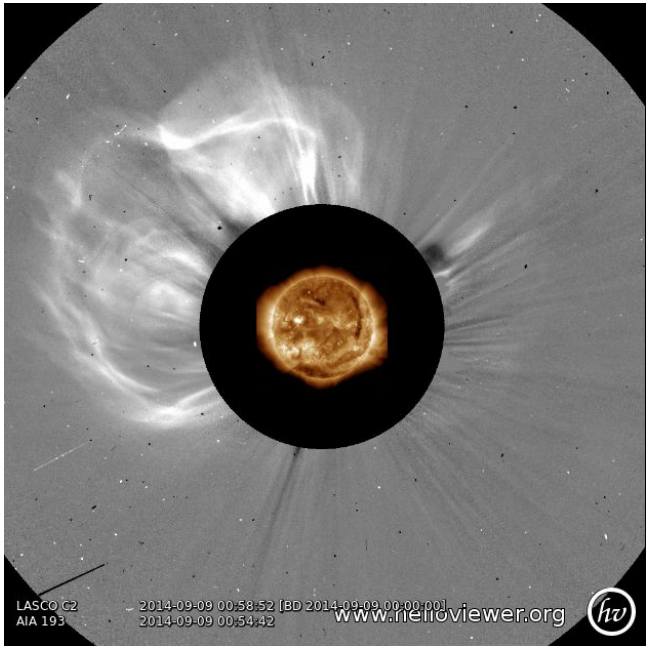
- We simulated successfully the magnetic field components at Earth for the September 2014 event with **CME1 (spheromak)** and **CME2 (FRi3D)**.
- We identified the **correct orientation** of the **erupting flux rope at the source region**.
- With **Flux Rope in 3D (FRi3D)**, we could model the **flank encounter** of CME2 at Earth.
- **Interaction between CME1 and CME2** is important to produce the **geo-effectiveness in the sheath** ahead of CME2.
- **3D MHD CME evolution model**, EUHFORIA is crucial in understanding geo-effectiveness due to different sub-structures in the case of CME-CME interaction.

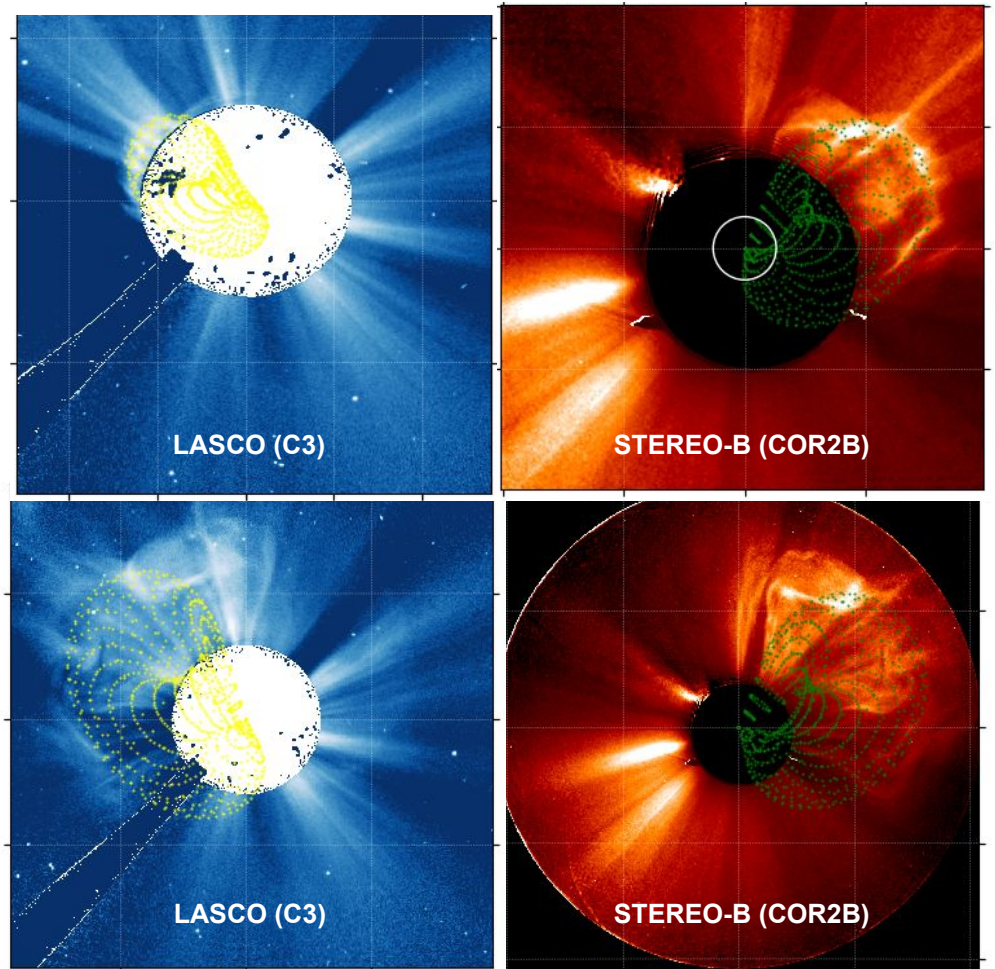
Thank you

anwesha.maharana@kuleuven.be

EXTRAS

CME1 reconstruction

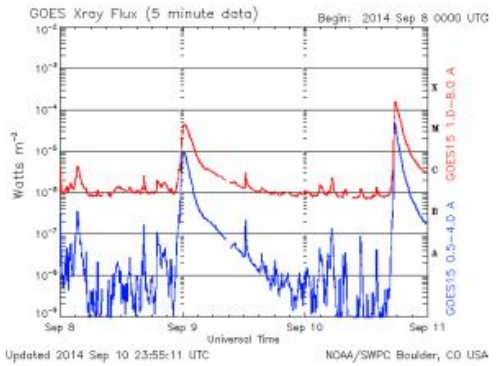




Event identification

Side event (CME1) - Shock is recorded at Earth. Not recorded in ICME catalogs.
Main event (CME2) - Well recorded in ICME catalogs and previously studied [*Cho+2017, Kilpua+2021, Ann+2019*]

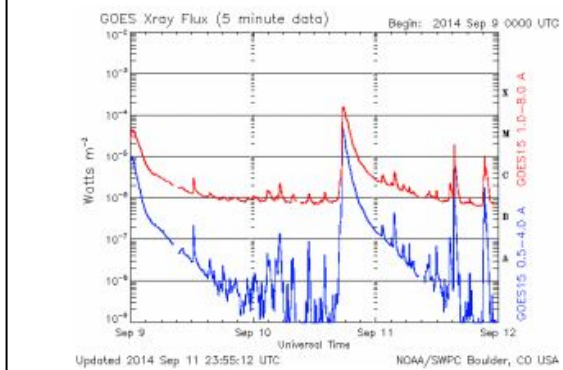
CME1: flare class M4.6
(start 08/23:12 - peak 09/00:28 - end 09/01:30)



Reconnected flux from statistical relations:

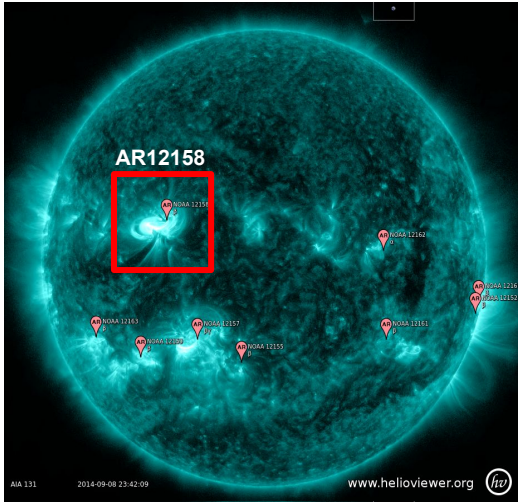
φ_{RC} = 4.94 × 10^{21} Mx (Tschernitz+2018, ribbons)
φ_{RC} = 4.41 × 10^{21} Mx (Kazachenko+2017, ribbons)
φ_{RC} = 2.74 × 10^{21} Mx (Dissauer+2018, dimmings)

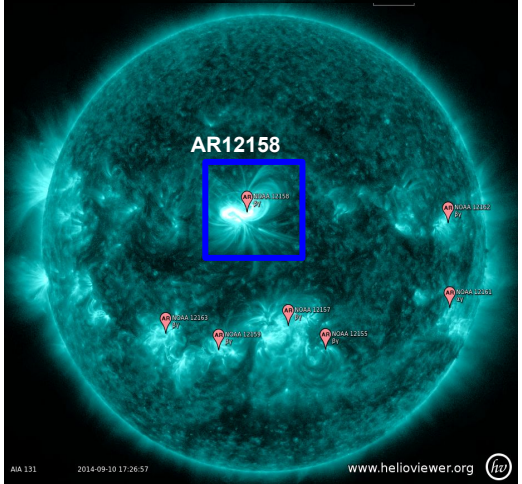
CME2: flare class X1.6
(start 10/17:21 - peak 10/17:45 - end 10/17:45)



Reconnected flux from statistical relations:

φ_{RC} = 1.02 × 10^{22} Mx (Tschernitz+2018, ribbons)
φ_{RC} = 9.79 × 10^{21} Mx (Kazachenko+2017, ribbons)
φ_{RC} = 4.63 × 10^{21} Mx (Dissauer+2018, dimmings)





Reconnected flux computed as **input** for flux rope while injection into EUHFORIA.