Study of September 4, 2010 CME using ENLIL and EUHFORIA

M. Mierla[1,2], C. Scolini[3], L. Mays[4], J. Pomoell[5], L. Rodriguez[1]

1. Royal Observatory of Belgium, Brussels, Belgium
2. Institute of Geodynamics of the Romanian Academy, Bucharest, Romania
3. Center for mathematical Plasma Astrophysics, KU Leuven, Belgium
4. NASA/GSFC, USA
5. University of Helsinki, Department of Physics, Finland

Introduction

AIM:

- Validation of observation through MHD models
- Compare the in situ values of the CME arriving at STEREO-A on September 7, 2010 with the parameters derived using:
  - ENLIL (Odstrcil et al. 1999, Odstrcil 2003) and
  - EUHFORIA (Pomoell et al., 2017) models.

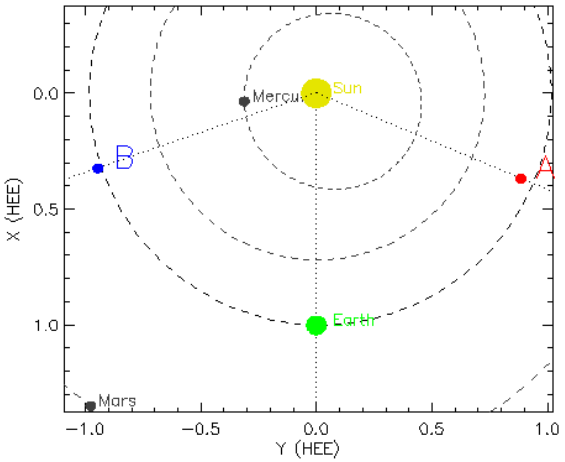
- Use ENLIL (version 2.8): request runs at CCMC:

http://ccmc.gsfc.nasa.gov/requests/SH/ENLIL-28/enlil_choices.php

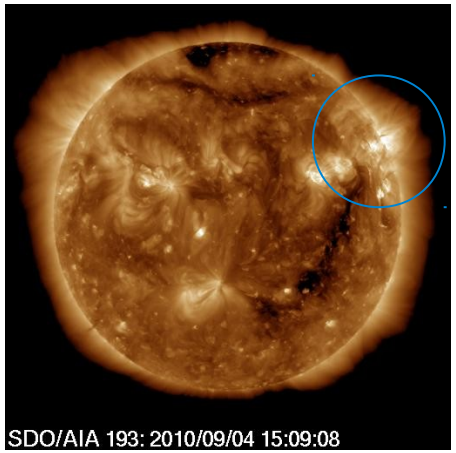
- Use EUHFORIA (version 0.9): run it at CmPA, Leuven

Event description

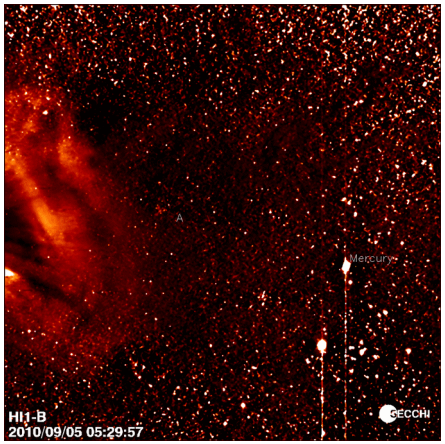
CME on September 4, 2010 arriving to STEREO-A on September 7, 2010.



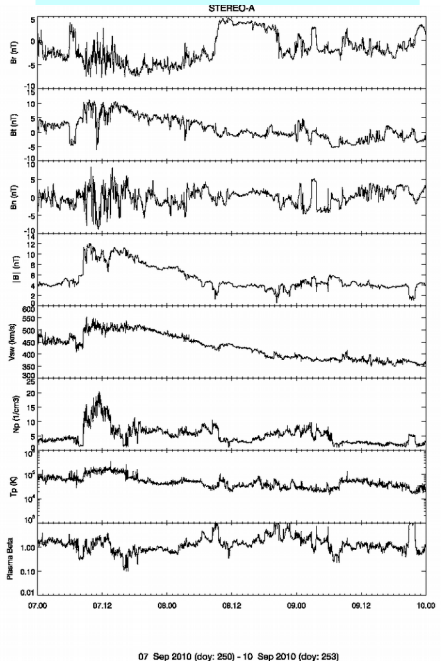
Source region:
EUV data from
- SDO/AIA
- PROBA2/SWAP
- STEREO/EUVI



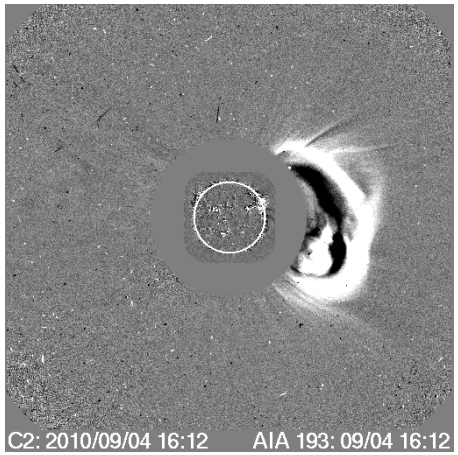
Interplanetary
STEREO/HI



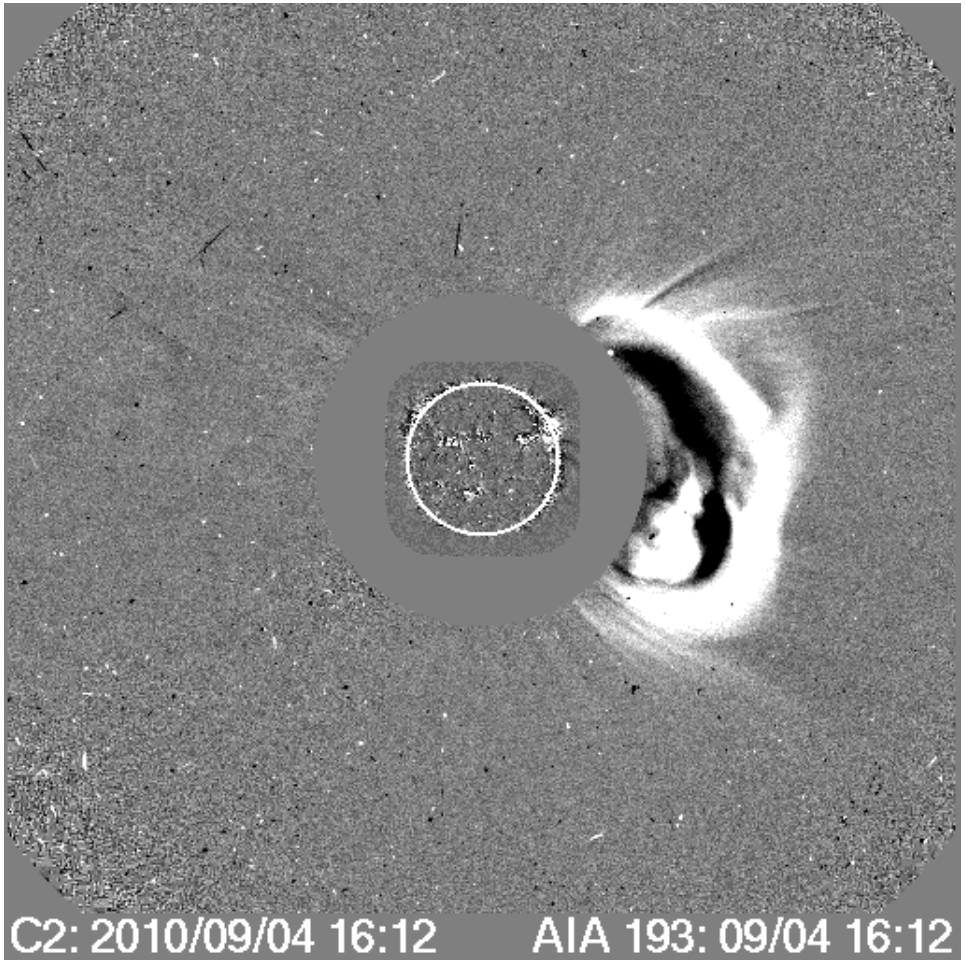
In situ
STEREO-A

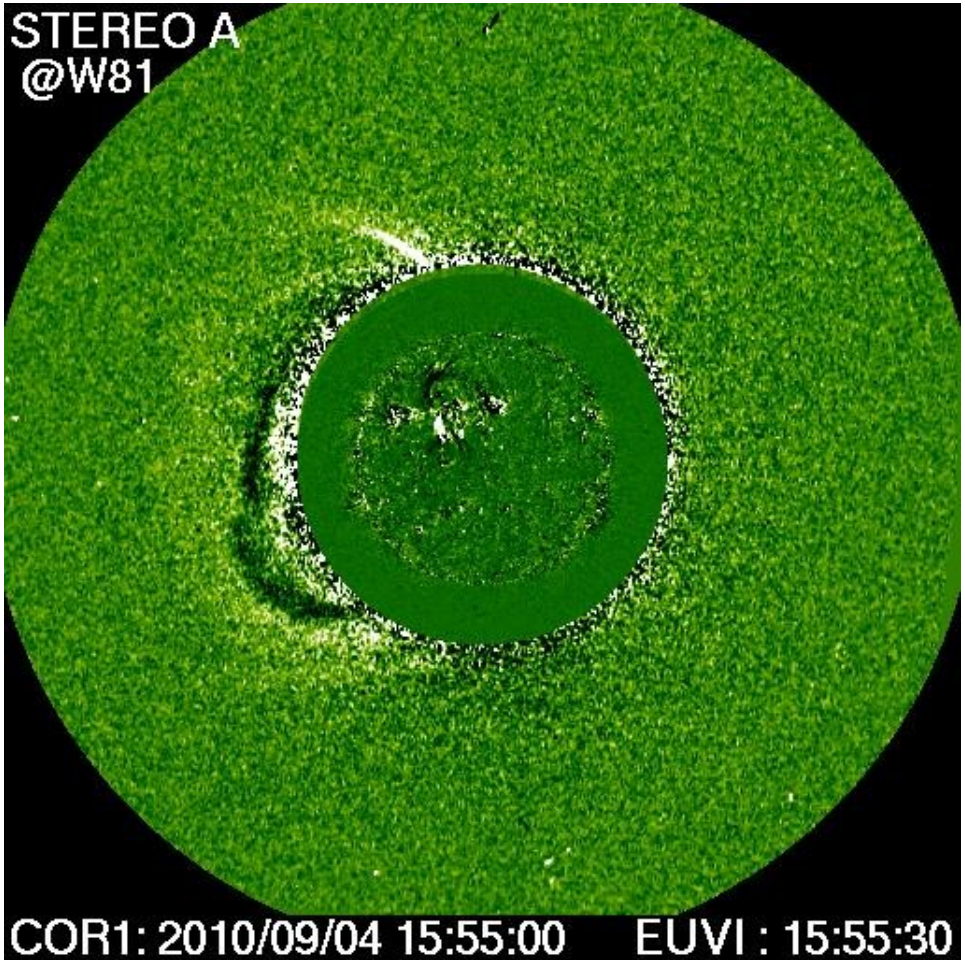


WL coronagraph images:
- SOHO/LASCO
- STEREO/COR

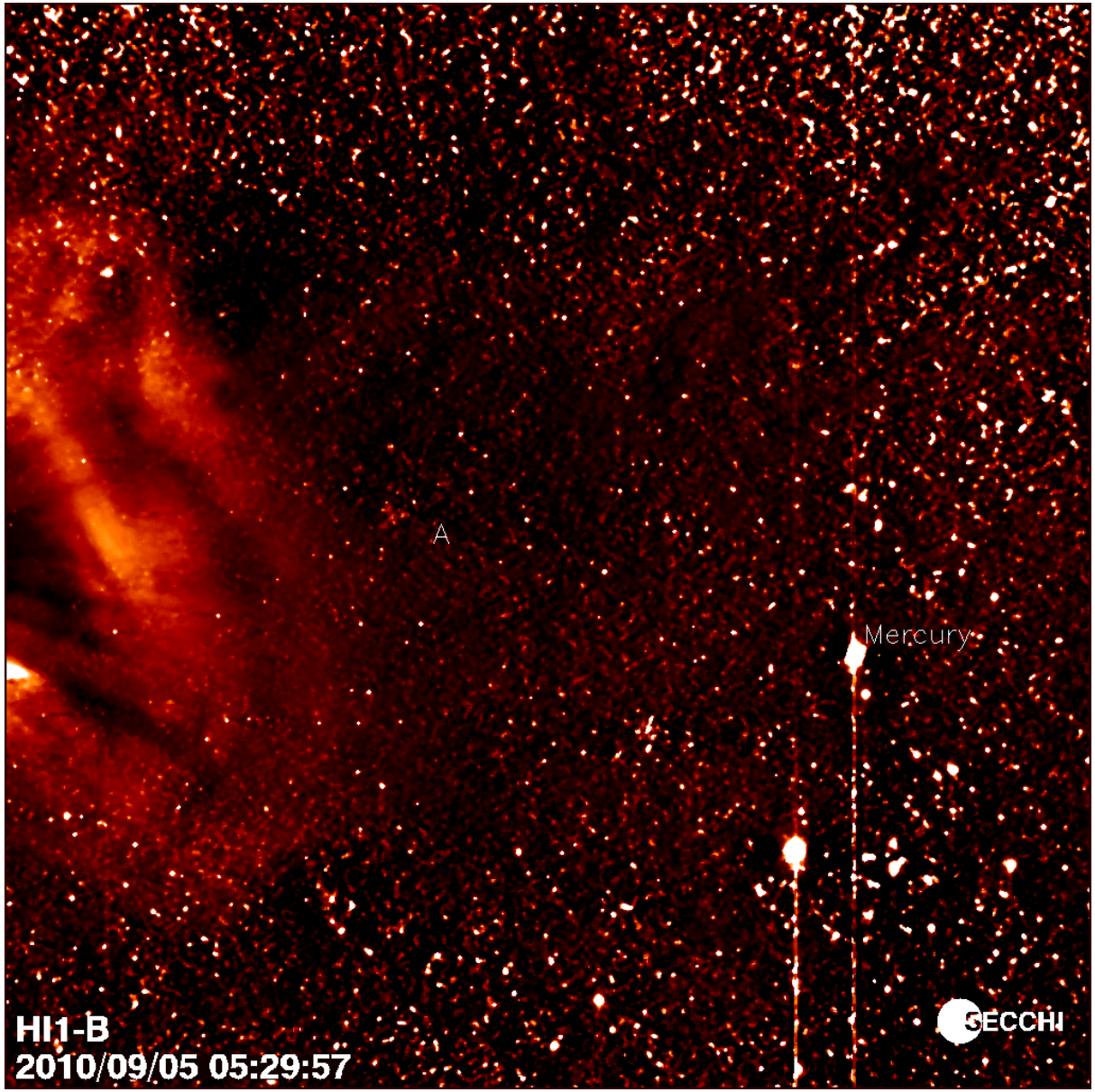


Observations - CME





Observations – CME, heliosphere



In situ data

Shock: 7 September 2010, 08:29 UT

ICME start: 7 September 2010, 16:30 UT

ICME end: 8 September 2010, 09:04 UT

Br

Bt

Bn

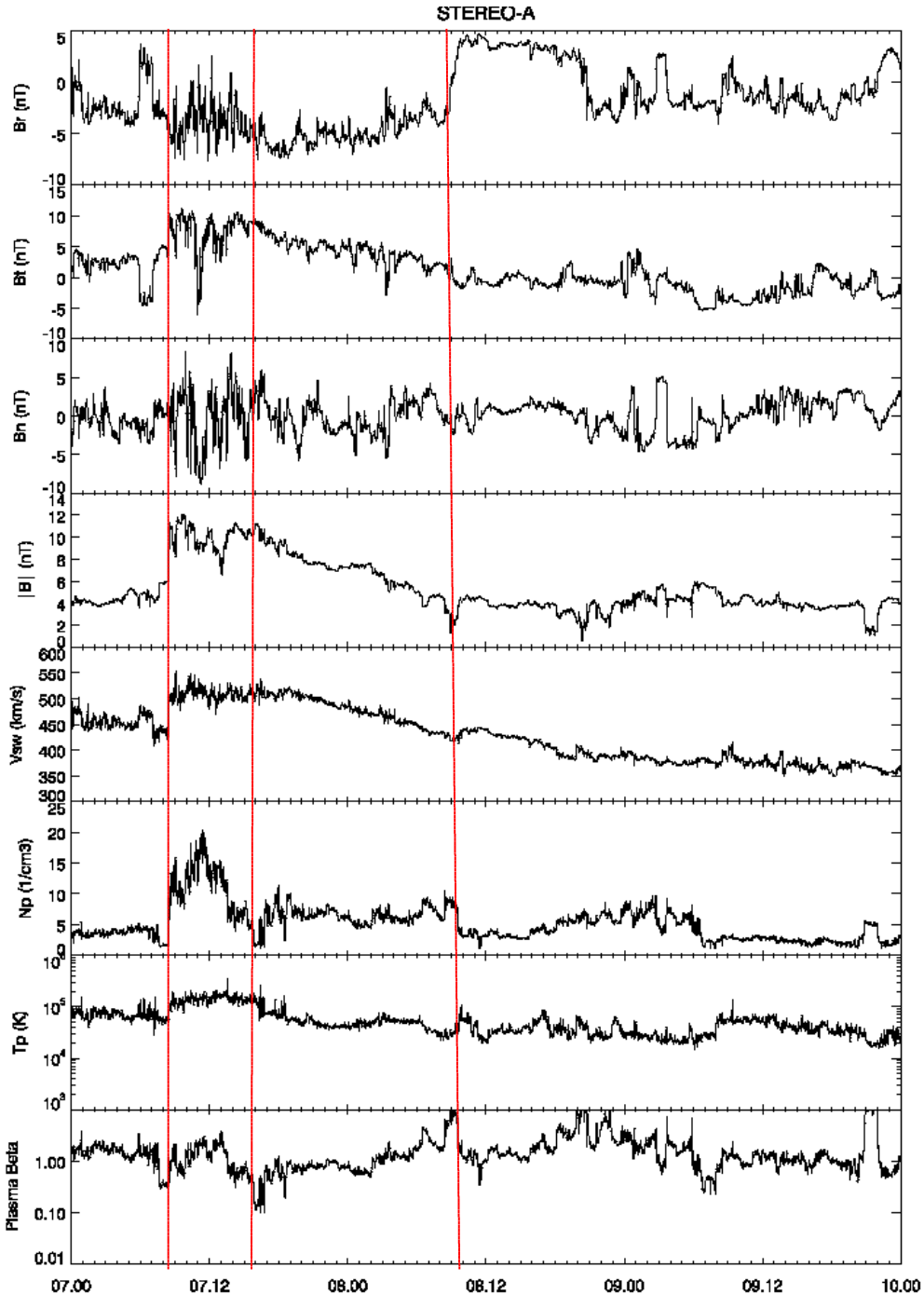
B

speed

density

temperature

Plasma β



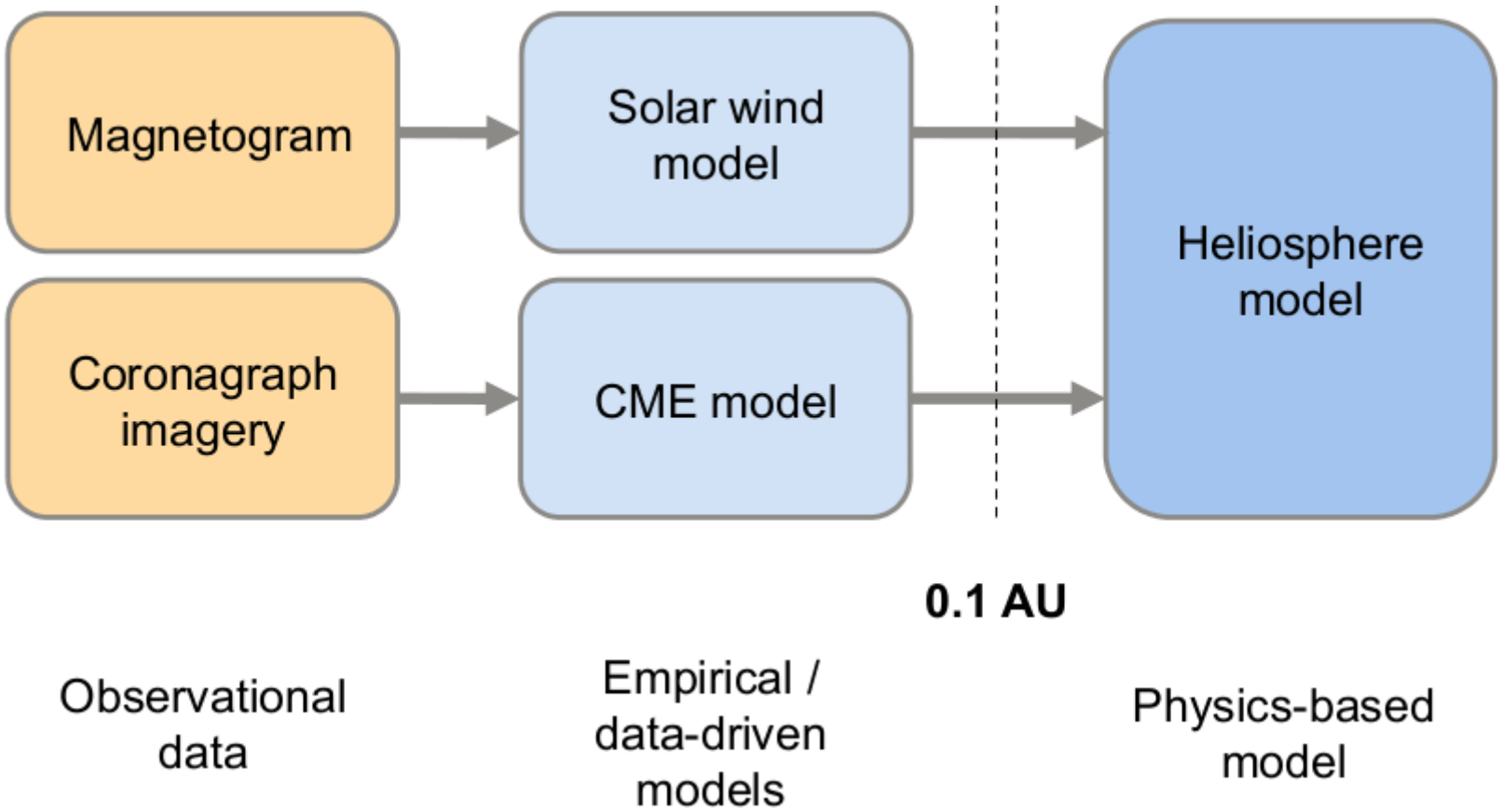
Models description (ENLIL and EUHFORIA)

Modeling solar wind and CMEs into heliosphere

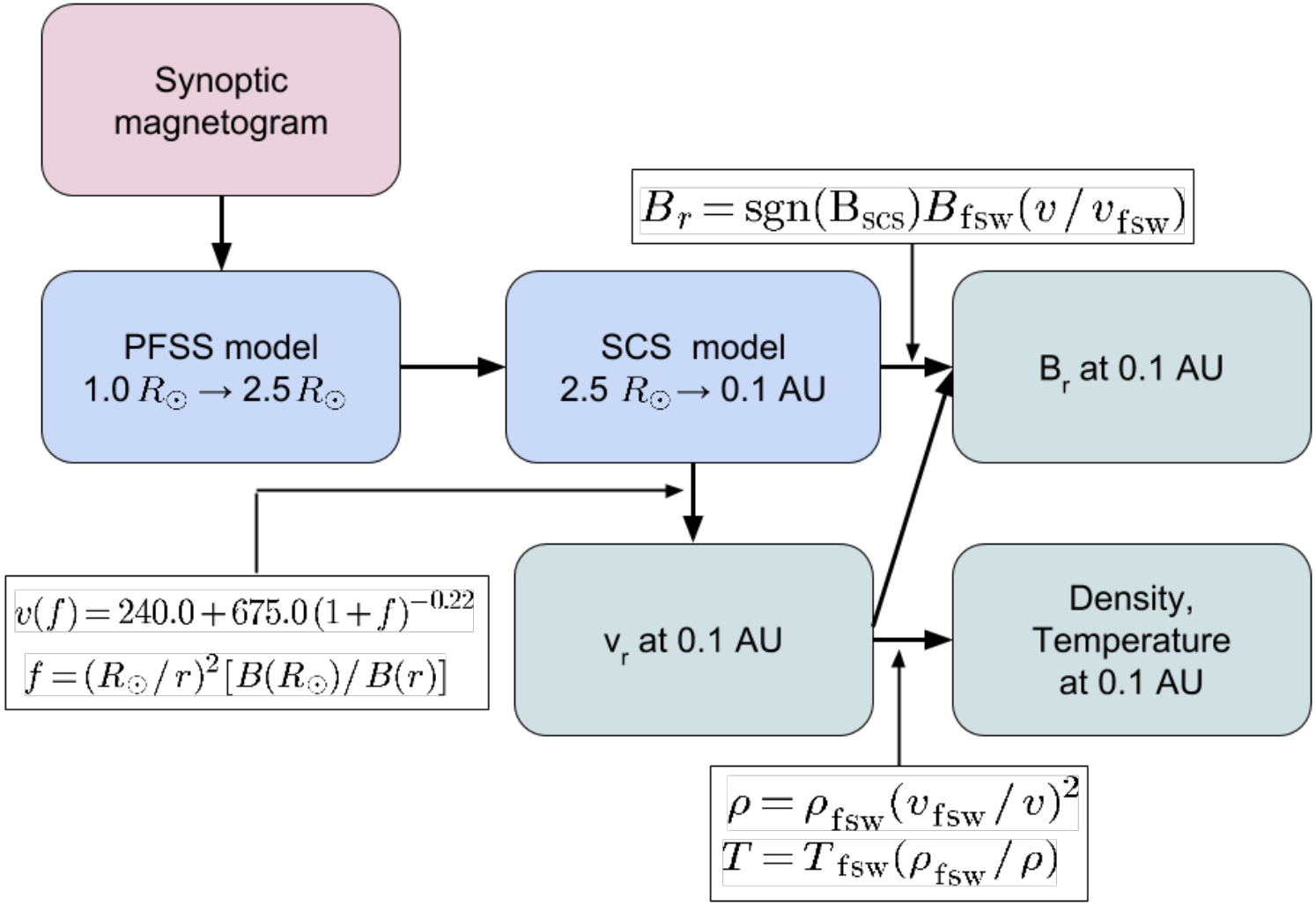
Domains:

➔ corona (from 1 Rs to 0.1 AU): empirical

➔ heliosphere (from 0.1 to 2.1 AU): Time-dependent MHD: evolves n, B, v, T in 3D+t



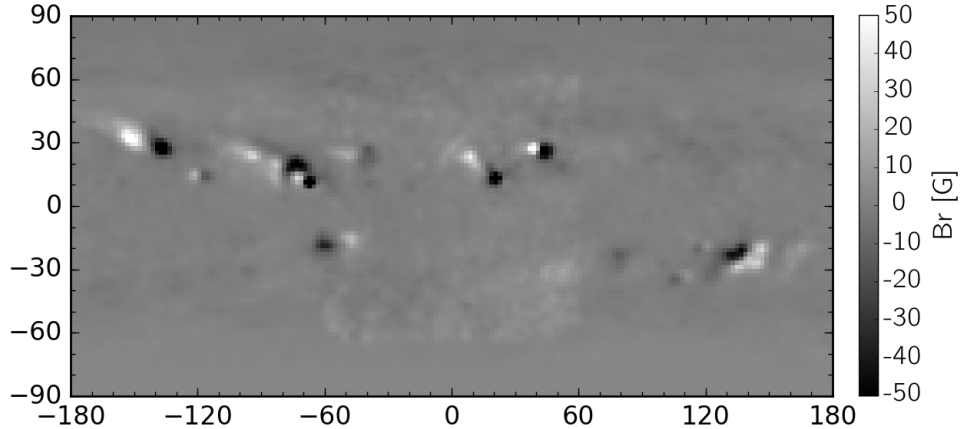
Semi-empirical solar wind model - WSA (EUHFORIA)



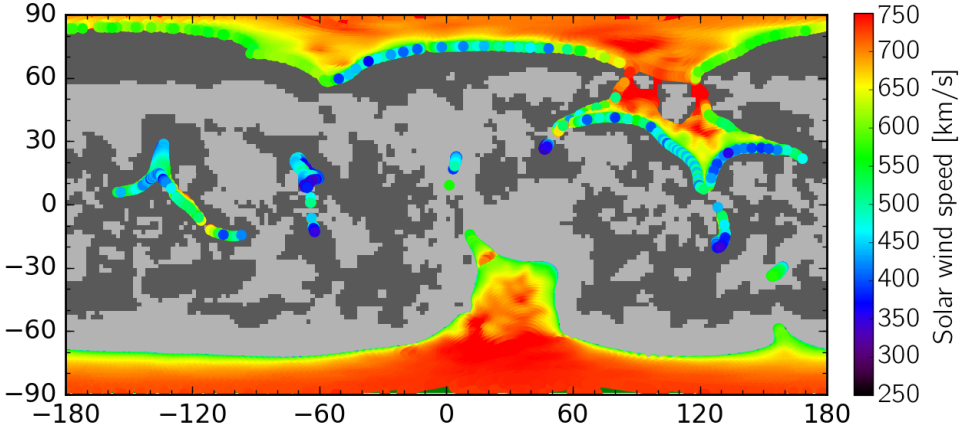
ENLIL is using a different relation between v and f, **and possible between ρ and v, T and v and B and v.**

Semi-empirical solar wind model - EUHFORIA

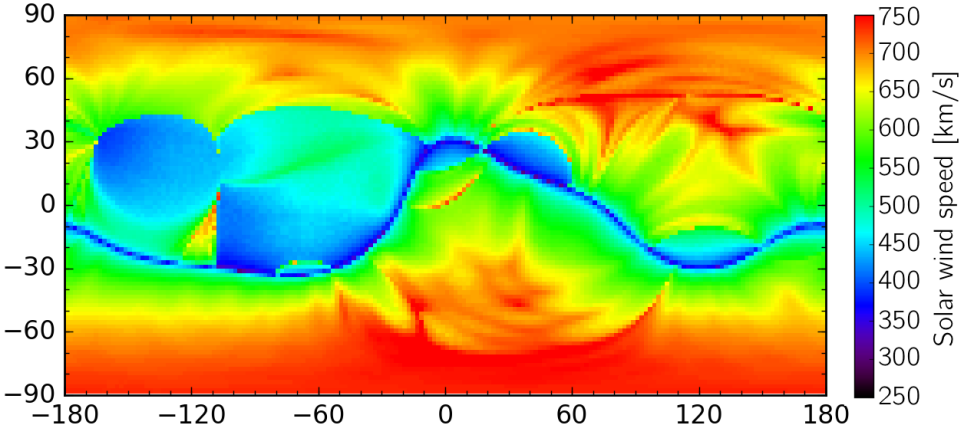
Input magnetogram.



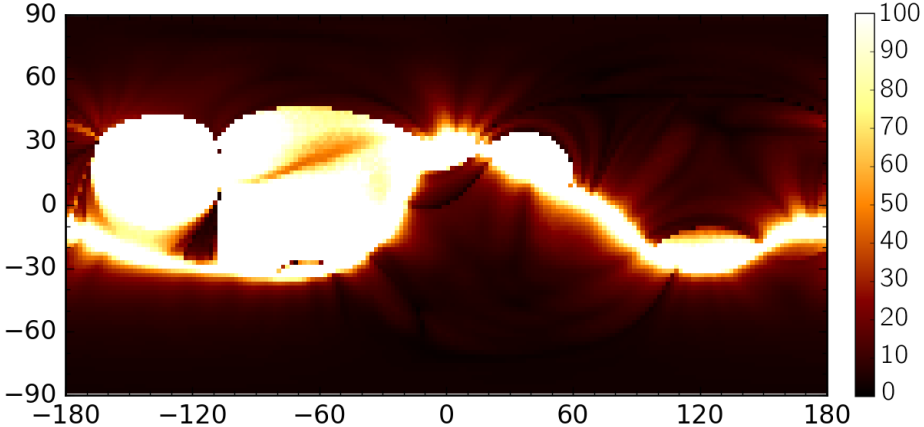
Coronal topology.



Solar wind speed at 0.1 AU.



Flux tube expansion factor at 0.1 AU.



ENLIL: different magnetogram + different relation between v and f

CME models

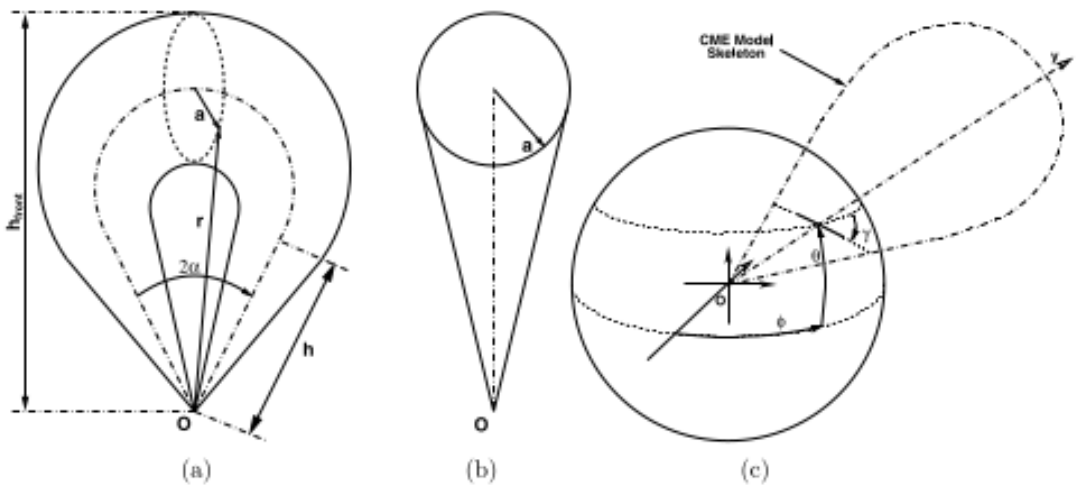
Primary CME model: hydrodynamic, uniformly filled spheroid

Inserted as time-dependent boundary condition at 0.1 AU

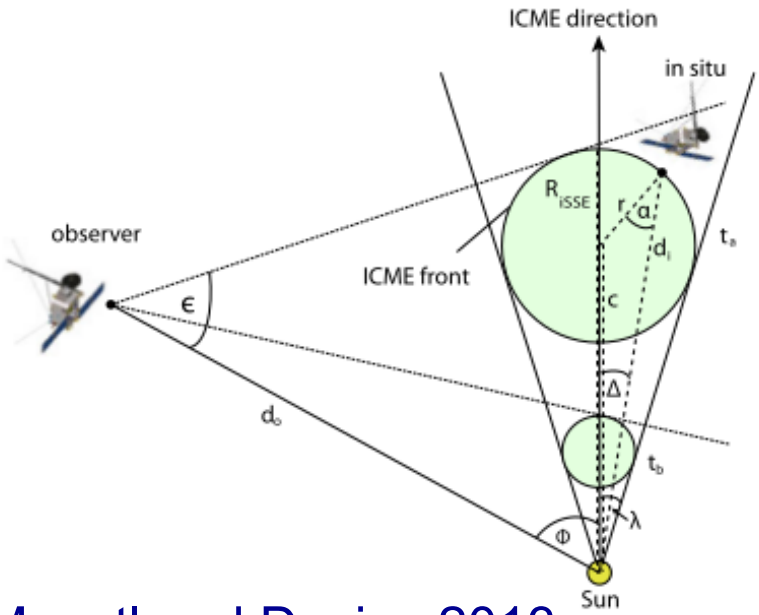
Deriving the input parameters for CME

From FM - coronagraphs:
Height: < 15 Rs

From SSE – HI
Height: > 15 Rs



Thernisien et al. 2009



Moestl and Davies 2013,
Davies et al. 2012

Differences in applying ENLIL and EUHFORIA on the CME of September 4, 2010

1) Different magnetograms (CR 2100):

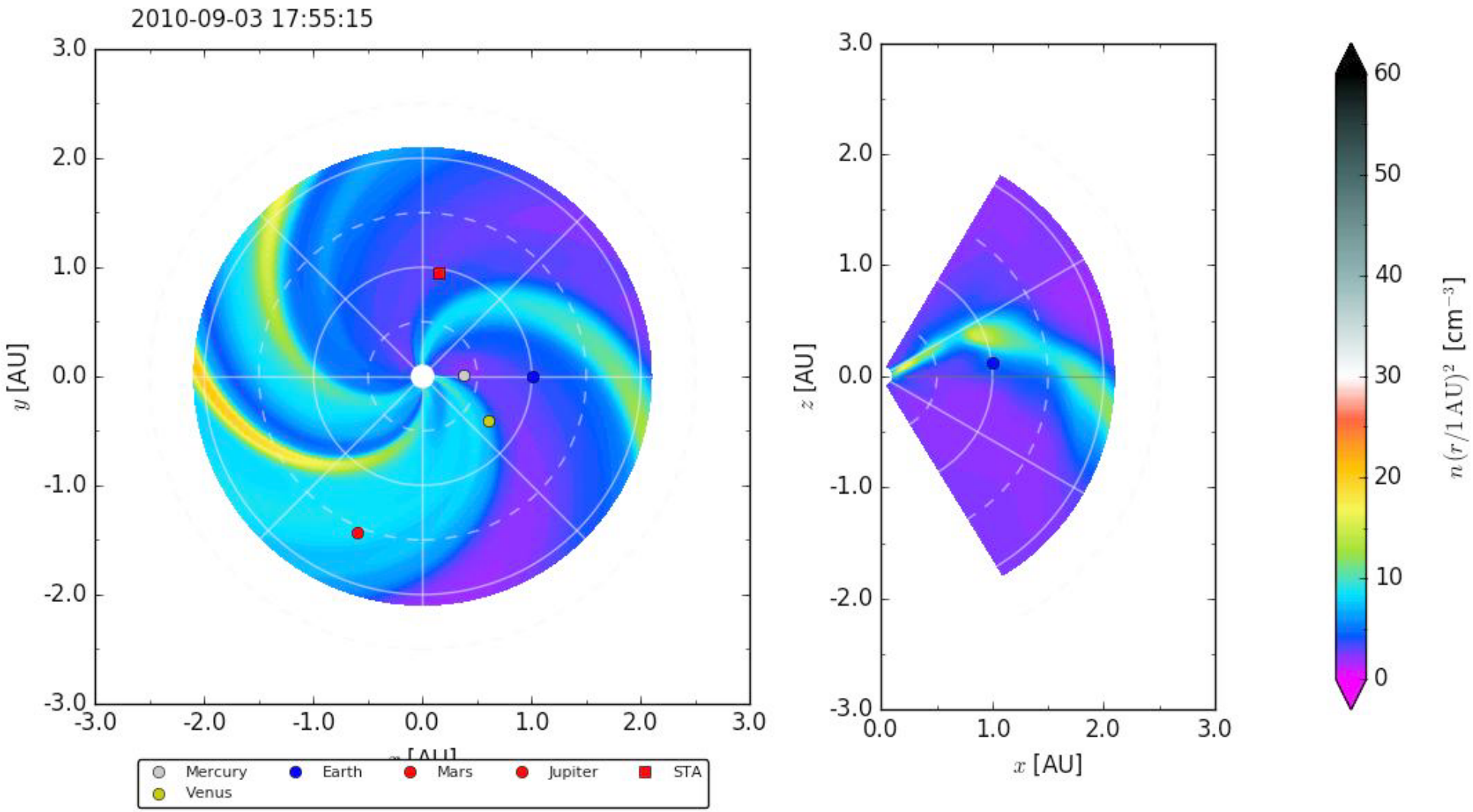
- ENLIL: GONG integral CR map;
- EUHFORIA: GONG Janus magnetogram synoptic map.

2) When deriving WSA wind model:

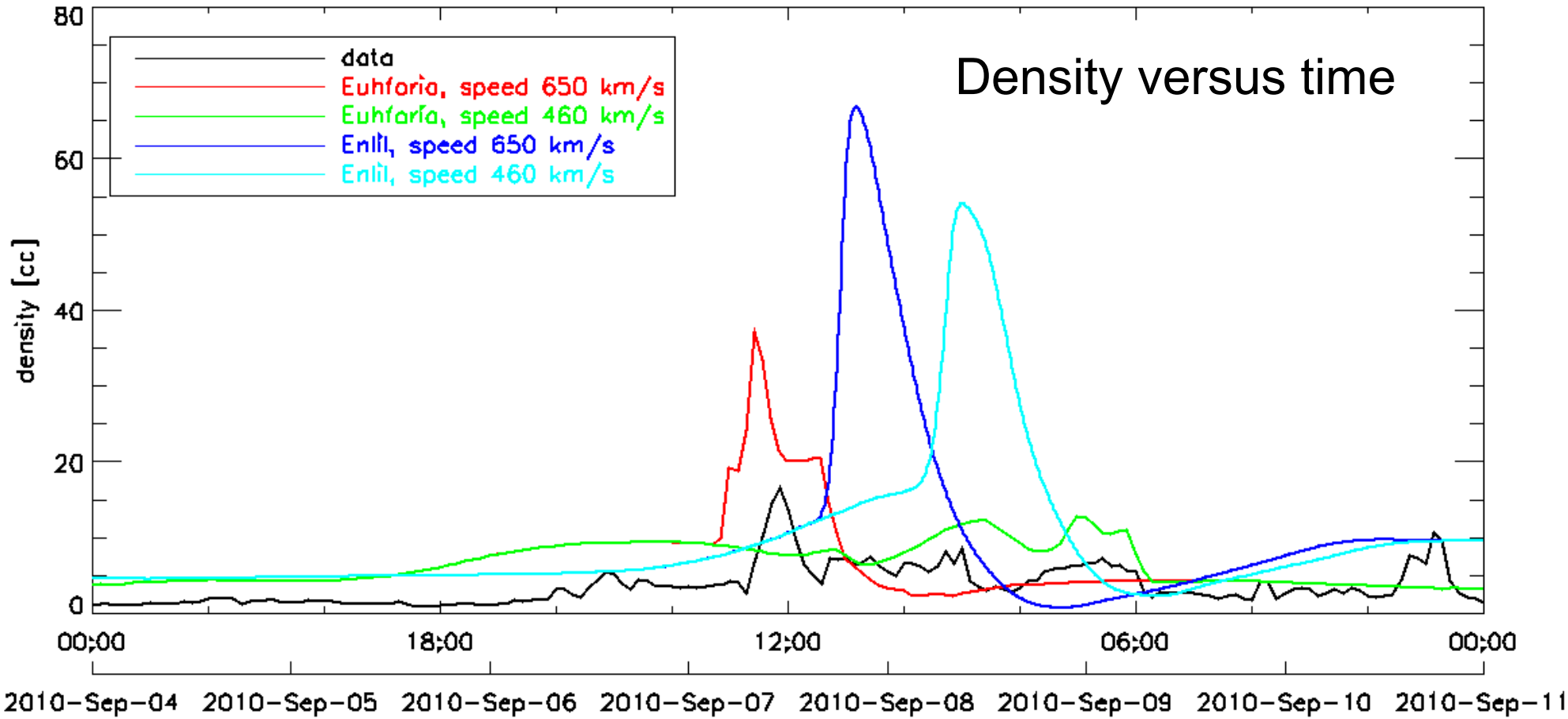
- different relations between the speed and expansion factor are used
- different methods to account for the acceleration of the solar wind.

3) The heliospheric models, even if based on the same equation system, are computed differently

Some results – propagation in heliosphere



Some results – in situ comparison

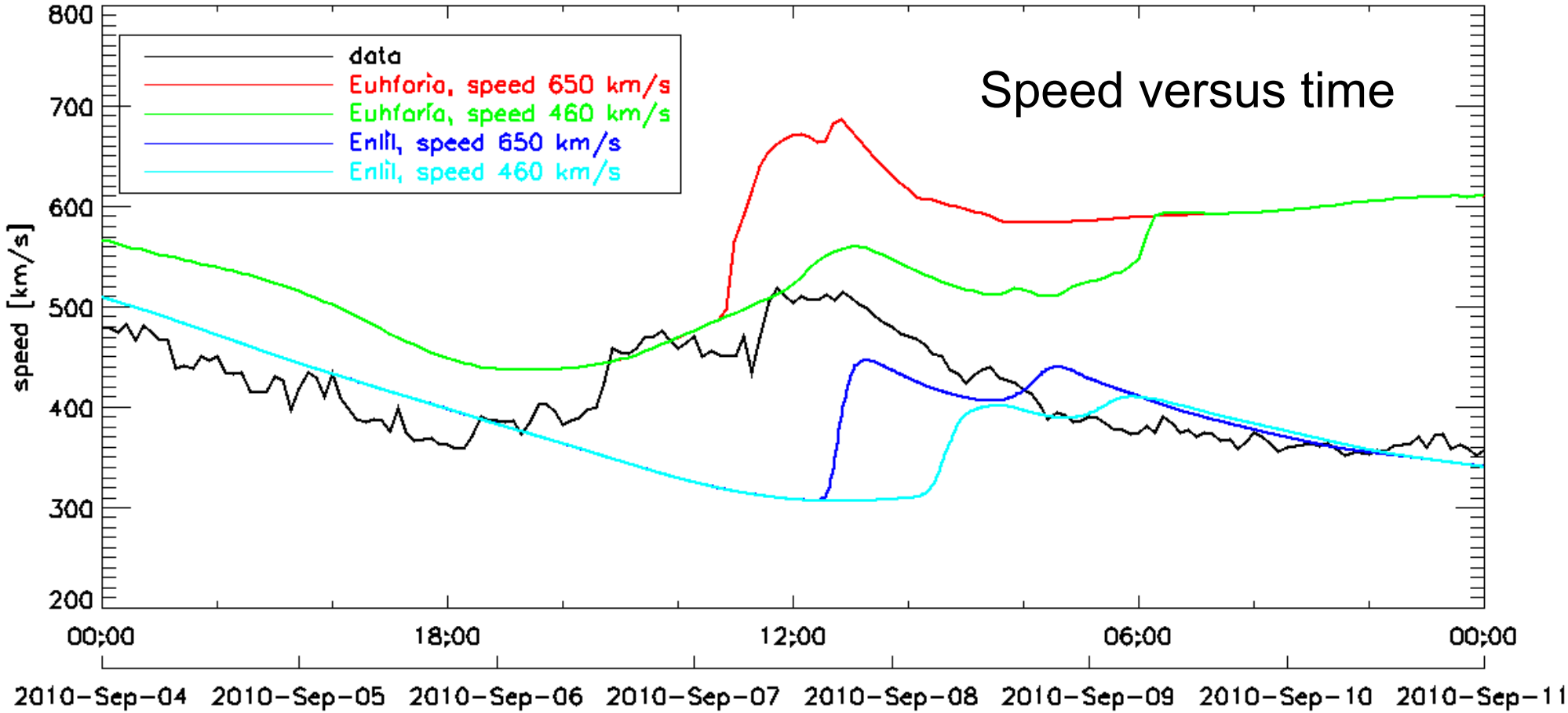


Max density (Enlil 650): 7-Sep-2010 **20:11 UT**

Max density (Euhforia 650): 7-Sep-2010 **7:54 UT**

Shock arrival (Data): 7-Sep-2010 **08:29 UT**

Some results – in situ comparison

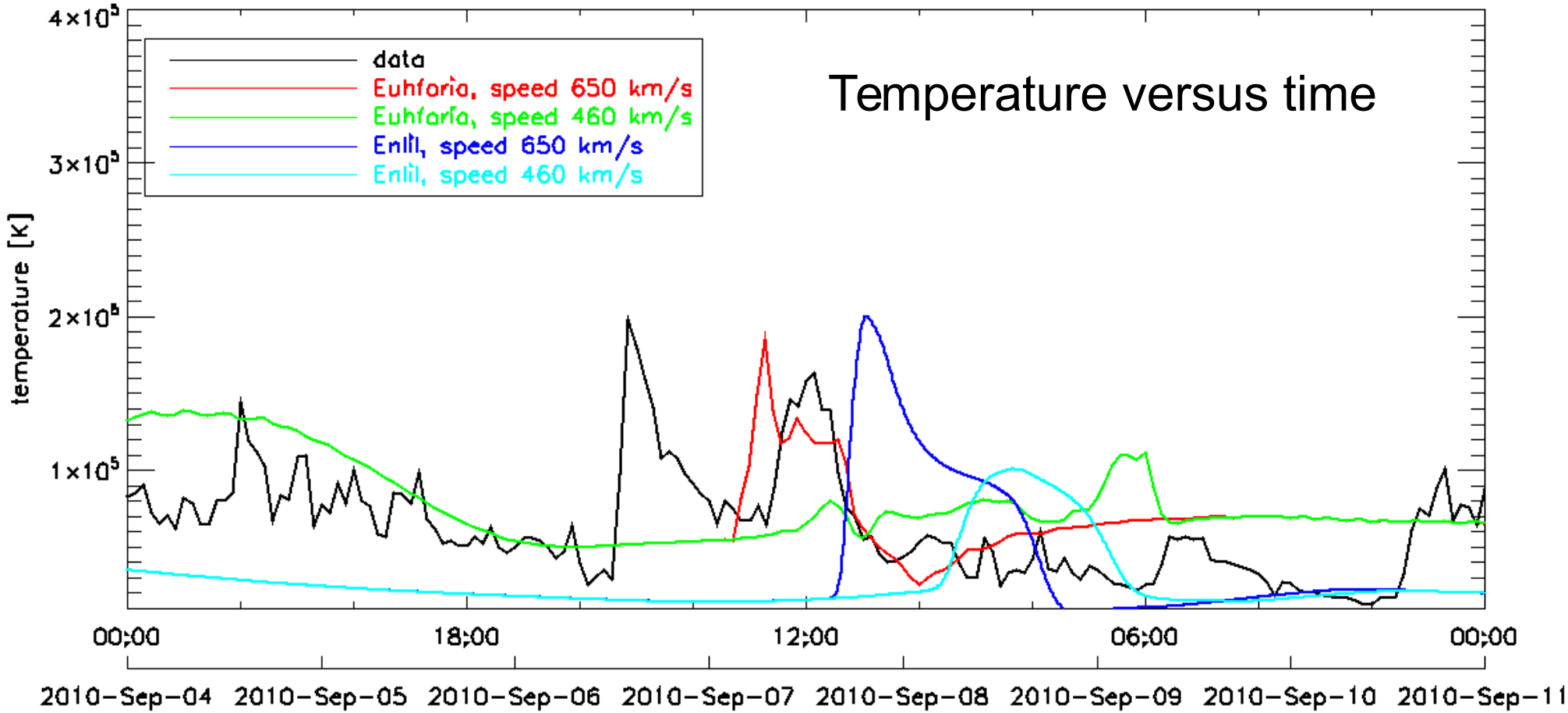


Max speed (Enlil 650): 7-Sep-2010 **20:47 UT**

Max speed (Euhforia 650): 7-Sep-2010 **~12:00 UT**

Shock arrival (Data): 7-Sep-2010 **08:29 UT**

Some results – in situ comparison

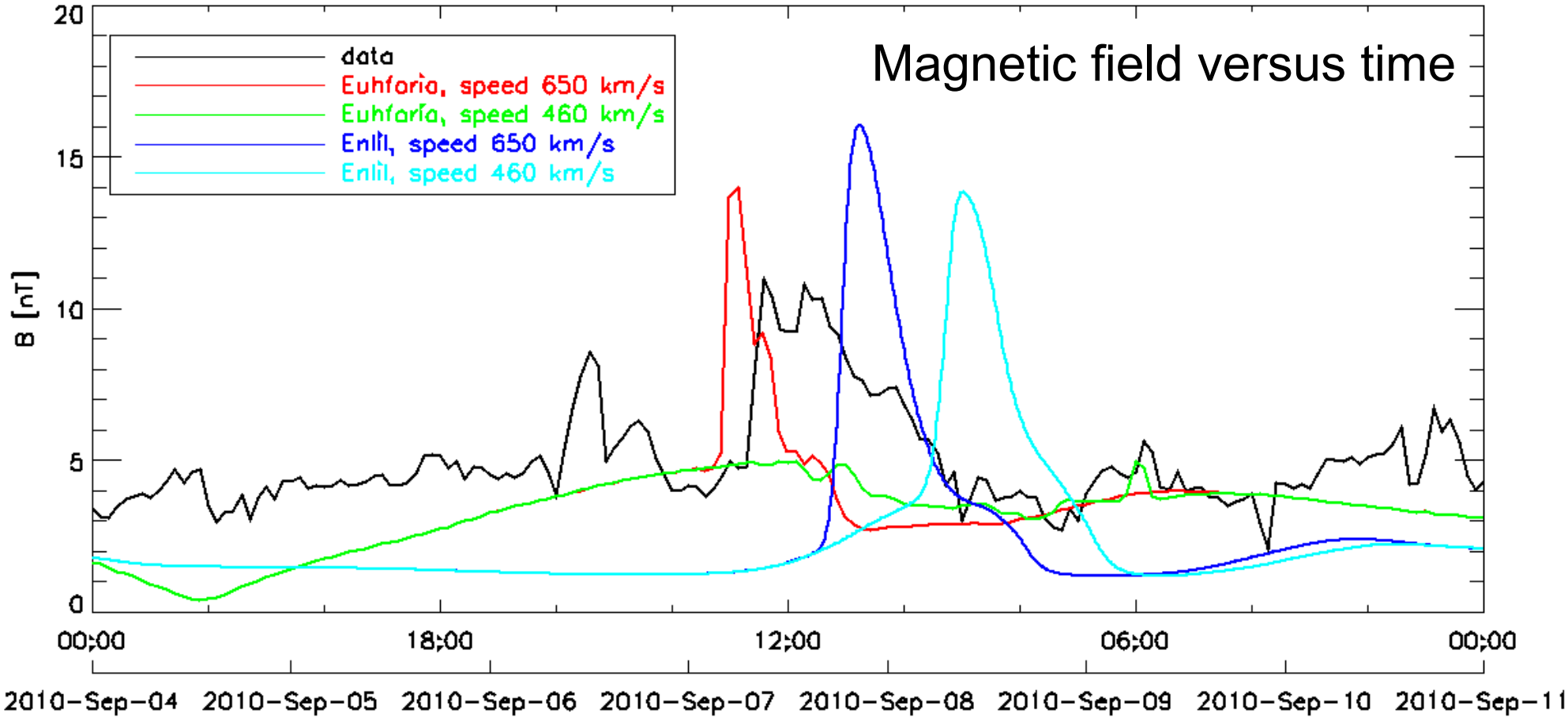


Max temperature (Enlil 650): 7-Sep-2010 **19:26 UT**

Max temperature (Euhforia 650): 7-Sep-2010 **6:54 UT**

Shock arrival (Data): 7-Sep-2010 **08:29 UT**

Some results – in situ comparison



Max B (Enlil 650): 7-Sep-2010 **20:33 UT**

Max B (Euhforia 650): 7-Sep-2010 **5:54 UT**

Shock arrival (Data): 7-Sep-2010 **08:29 UT**

Summary

- The best fit is for the density, EUHFORIA's run with 650 km/s – though the in situ values are overestimated
- The worst fit, for both models, is for the speed.
- EUHFORIA run anticipates the arrival of the CME at ST-A (up to 3h), while ENLIL delays it (up to 12h).

Links to ENLIL runs:

Speed 650 km/s:

https://ccmc.gsfc.nasa.gov/database_SH/Camilla_Scolini_021317_SH_9.php

Speed 460 km/s:

https://ccmc.gsfc.nasa.gov/database_SH/Camilla_Scolini_022217_SH_1.php

Future work

- Find a more quantitative way to compare the results in situ
- Use different input parameters to see which one improves the forecast
- Test it on many CMEs.

Within the framework of the **Brain-be project (J. Magdalenic)** **EUHFORIA** will be improved, validated/tasted, and then run routinely at ROB for scientific and space weather forecasting purposes.

Project title: CCSOM – Constraining CMEs and Shocks by Observations and Modeling through the inner heliosphere.

Acknowledgements

ENLIL simulation results have been provided by the Community Coordinated Modeling Center at Goddard Space Flight Center through their public Runs on Request system (http://ccmc.gsfc.nasa.gov). The CCMC is a multi-agency partnership between NASA, AFMC, AFOSR, AFRL, AFWA, NOAA, NSF, and ONR. The ENLIL model was developed by D. Odstrčil at the University of Colorado at Boulder.

EUHFORIA is developed as a joint effort between University of Helsinki (lead: J. Pomoell) and KU Leuven (lead: S. Poedts).