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Sun to Earth environment with the MHD models: COCONUT, Icarus, EUHFORIA

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COCONUT (COolfluid COroNa UnsTructured)

Overview

COCONUT (COolfluid COroNa UnsTructured)
COOLFluiD platform *(Lani et al. 2005, 2006)*

- Radial domain: ***1 $R_\odot$*** ⇨ ***21.5 $R_\odot$***
- ***180°*** in latitudinal direction
- ***360°*** in longitudinal direction

Unstructured Grid ⇩

Implicit Solver ⇩

No singularities at the poles; CFL values up to 100,000. ***Efficient and fast*** simulations for forecasting purposes.

Physics

Source terms (coronal heating, radiative losses, thermal conduction) are added to **the energy equation**

$$S = Q_H + Q_R + Q_C$$

Heating profile

Described in Mikic et al. 1999, Downs et al. 2010

$$Q_H^B = H_0 |\mathbf{B}|$$

$$Q_H^{exponential} = H_0 e^{-\frac{r-R_\odot}{\lambda}}$$

$$\Rightarrow Q_H^{combined} = H_0 |\mathbf{B}| e^{-\frac{r-R_\odot}{\lambda}}$$

Radiative losses

$$Q_R = -n^2 P(T)$$

Described in Mikic et al. 1999, Rosner et al. 1978

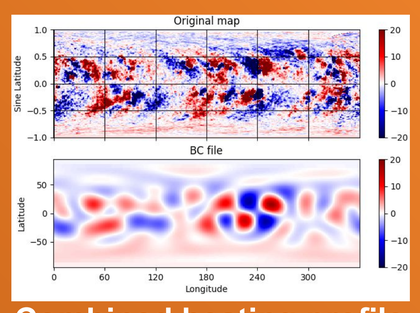
$$P(T) \approx \begin{cases} 10^{-21.85} & (10^{4.3} < T < 10^{4.6}\ \mathrm{K}) \\ 10^{-31} T^2 & (10^{4.6} < T < 10^{4.9}\ \mathrm{K}) \\ 10^{-21.2} & (10^{4.9} < T < 10^{5.4}\ \mathrm{K}) \\ 10^{-10.4} T^{-2} & (10^{5.4} < T < 10^{5.75}\ \mathrm{K}) \\ 10^{-21.94} & (10^{5.75} < T < 10^{6.3}\ \mathrm{K}) \\ 10^{-17.73} T^{-2/3} & (10^{6.3} < T < 10^{7}\ \mathrm{K}) \end{cases}$$

Thermal conduction

$$Q_C = -\nabla \cdot \mathbf{q}$$

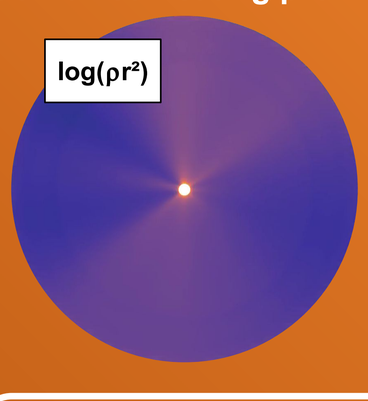
$$\begin{cases} \mathbf{q} = -\kappa_{||} \hat{\mathbf{b}}\hat{\mathbf{b}} \cdot \nabla T & \text{Collisional} \\ \mathbf{q} = \alpha n_e k T \mathbf{v} & \text{Collisionless} \end{cases}$$

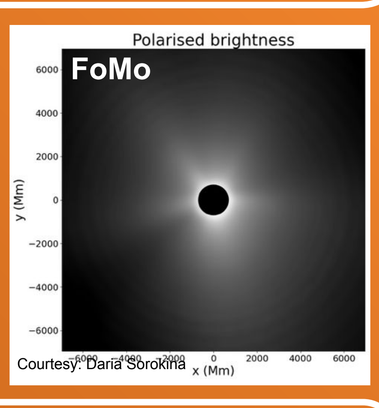
Modelled Corona



Combined heating profile

GONG zero-corrected product was chosen for the input magnetogram. The case corresponds to the **total solar eclipse 08.04.2024**.

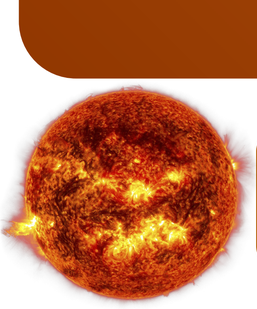




Courtesy: Daria Sorokina

Conclusion

The bi-modal wind was obtained with the **combined heating profile**. The data at 0.1 AU is coupled to Icarus or EUHFORIA.

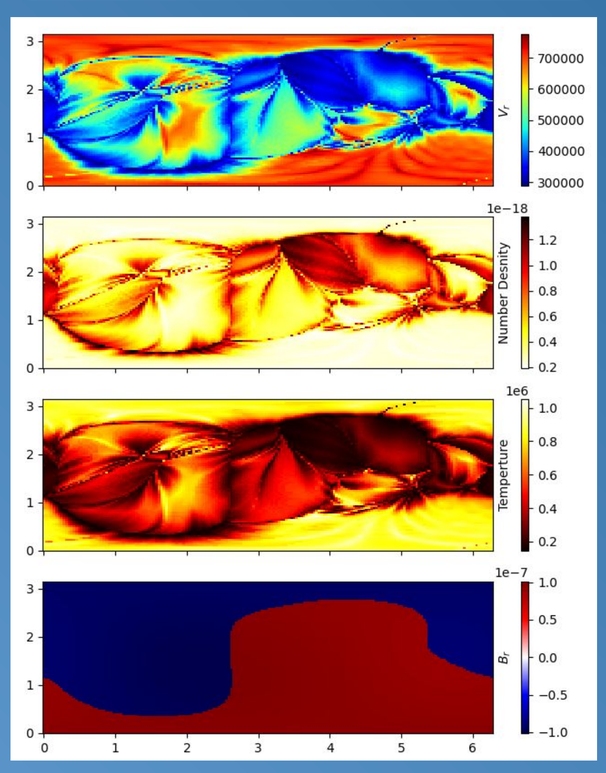


COCONUT | 0.1 AU | **ICARUS/EUHFORIA**

Heliosphere

Input file at 21.5 $R_\odot$

The input boundary file for Icarus was generated from WSA or a COCONUT solution at 21.5 $R_\odot$.



Heliosphere Models

ICARUS

Domain

- Radial domain: ***21.5 $R_\odot$*** ⇨ ***432 $R_\odot$***
- ***120° (-60°, 60°)*** in latitudinal direction
- ***360°*** in longitudinal direction

Output

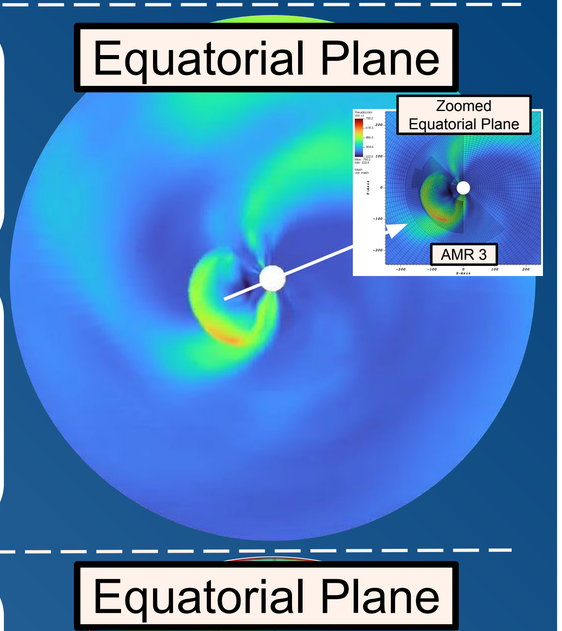
- 3D global heliosphere with the chosen frequency
- Time-series at various satellites/planets in the heliosphere

Radial Grid Stretching

Adaptive Mesh Refinement

Time dependent/ Steady boundary driving

CME models: **Cone model Spheromak**

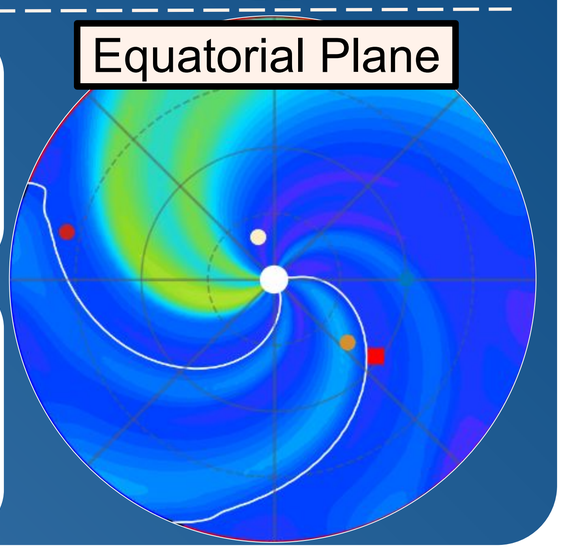


Uniform Grid

HEEQ Coordinates

Steady boundary driving

CME models: **Cone model Spheromak Fri3D**



EUHFORIA

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