Evaluations of Numerical ~~Flux Schemes~~ Implementations of a Coronal MHD Model – ***COCONUT***

– *Why do we need to model the real world?*
– *Are we able to model it?*
– *What should we do better?*

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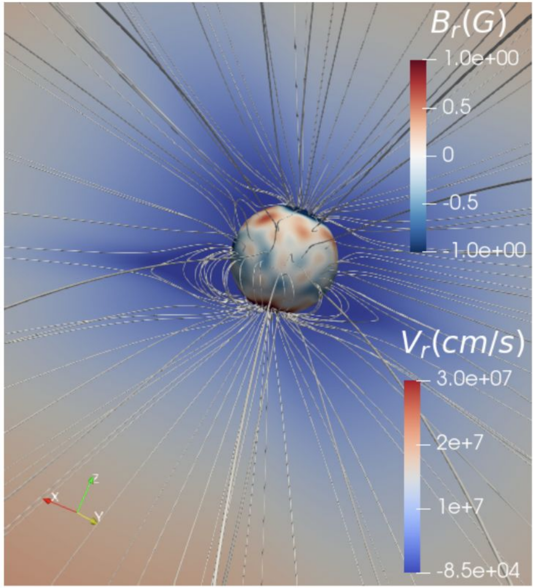
Presented at EGU General Assembly 2022

A *real* solar eclipse. Credit: Jay M. Pasachoff (Williams College) Antarctic Eclipse Expedition

What can COCONUT (COolfluid COroNa UnsTructured) do?

Currently:

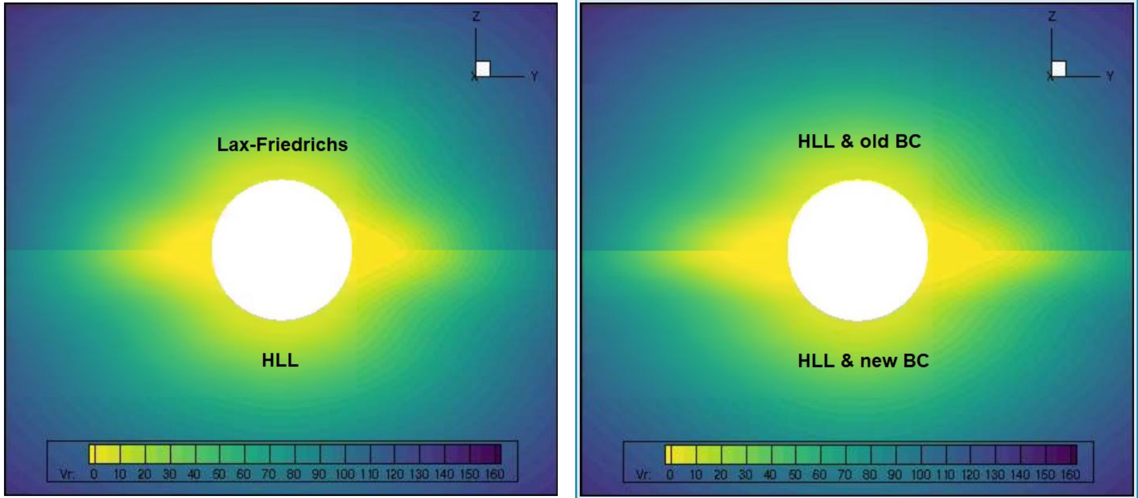
- A **data-driven MHD model** covering from the surface of the Sun to 0.1AU
- Providing **inner boundary condition for EUHFORIA** heliospheric model, replacing the empirical WSA model
- Using **fully implicit time-stepping** methods to significantly speed up the simulations
- Validated with the explicit **Wind Predict** model *Perri et al. JPlPh. 2018*



Comparison for the 1st of August 2008 GONG corrected synoptic map case between a white-light composite eclipse picture (left), the **COCONUT** solution (right). *Perri, et al. Accepted by ApJ.*

What are we doing to make COCONUT better?

– Numerical implementations: numerical flux schemes, boundary conditions, high-order methods, etc.



Different numerical schemes

Different boundary conditions

Differences found in a simple magnetic dipole case.
Perri, et al. Submitted to ApJ. Brchnelova, et al. Submitted to ApJ.

Basics of the inner BC:

- Magnetic field:

  PFSS solutions

- Velocity field:

  Parker's wind profile

- The modified/new BC:

$$\vec{V}_b \times \vec{B}_b = \vec{0}$$

The influences of the inner boundary condition

Ideal MHD equations → **E** = **V** x **B**

$$\frac{d\rho}{dt} + \nabla \cdot (\rho \vec{V}) = 0,$$

$$\frac{d(\rho\vec{V})}{dt} + \nabla \cdot \left(\rho\vec{V} \otimes \vec{V} + \mathbf{I}\left(P + \frac{\vec{B}^2}{8\pi}\right) - \frac{\vec{B} \otimes \vec{B}}{4\pi}\right) = \rho\vec{g},$$

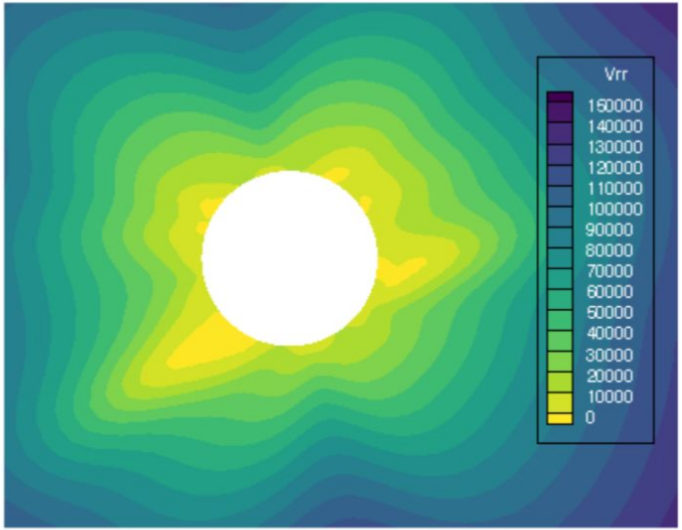
$$\frac{1}{c}\frac{d\vec{B}}{dt} + \nabla \times \left(-\frac{\vec{V} \times \vec{B}}{c}\right) = \vec{0},$$

$$\frac{d}{dt}\left(\rho\frac{\vec{V}^2}{2} + \rho\mathcal{E} + \frac{\vec{B}^2}{8\pi}\right) + \nabla \cdot \left[\left(\rho\frac{\vec{V}^2}{2} + \rho\mathcal{E} + P\right)\vec{V} - \frac{1}{4\pi}(\vec{V} \times \vec{B}) \times \vec{B}\right] = \rho\vec{g} \cdot \vec{V}.$$

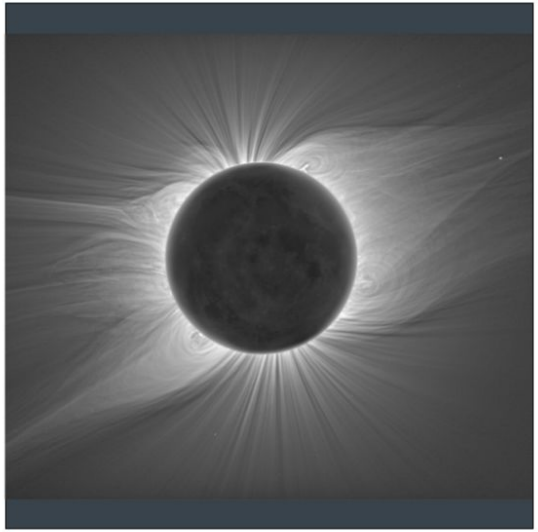
B	magnetic field
V	velocity
rho	density
t	time
eps.	internal energy
g	gravity
P	pressure

More about the effects of the (inner) boundary condition

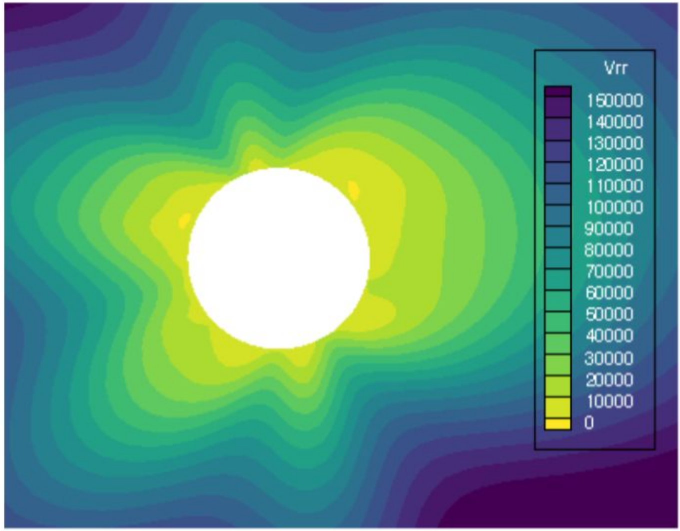
Radial velocity - low E field



Observation



Radial velocity - large E



Comparisons with the 2008 solar eclipse observed by M. Druckmüll, et al.
Simulations are introduced in *M. Brchnelova, et al. Submitted to ApJ*

For more details:

- Perri B., et al. 2022 “COCONUT, a novel fast-converging MHD model for solar corona simulations: I. Benchmarking and optimization of polytropic solutions”, *accepted by ApJ*, doi: 10.48550/arXiv.2205.03341
- Perri B., et al. 2022 “COCONUT, a novel fast-converging MHD model for solar corona simulations: II. Assessing the impact of the input magnetic map on space-weather forecasting at minimum of activity”, *submitted to ApJ*
- Brchnelova M., et al. 2022 “Effects of Mesh Topology on MHD Solution Features in Coronal Simulations”, *JPP* 88(2), doi: 10.1017/S0022377822000241
- Brchnelova M., et al. 2022 “To E or not to E: Numerical Nuances of Global Coronal Models”, *submitted to ApJ*