LFM-helio

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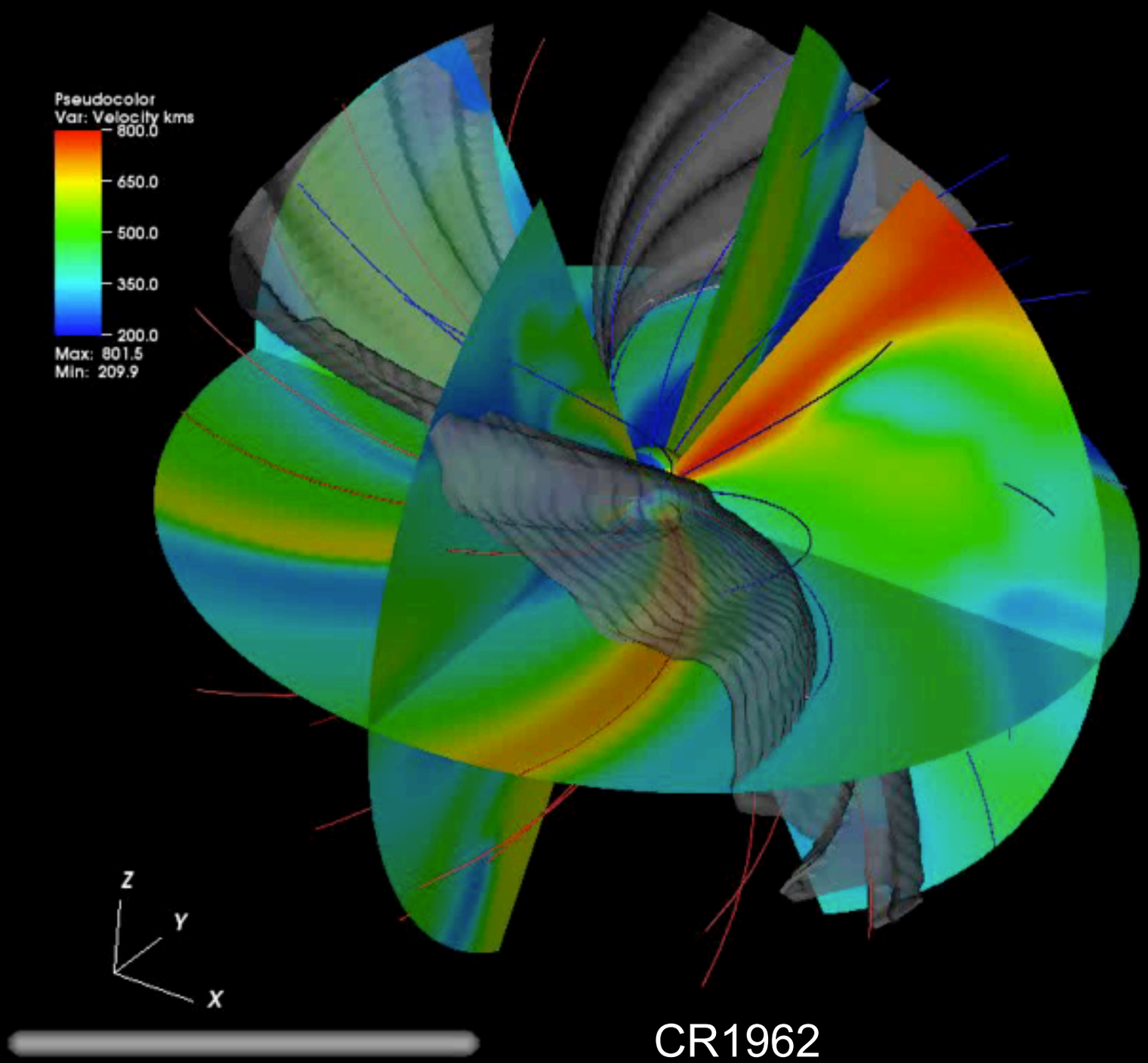
Outline

- LFM-helio 1.0
  - History
  - Highlights
- LFM-helio 2.0
  - Motivation, improvements
  - Recent work
  - Future directions

LFM-helio 1.0: History

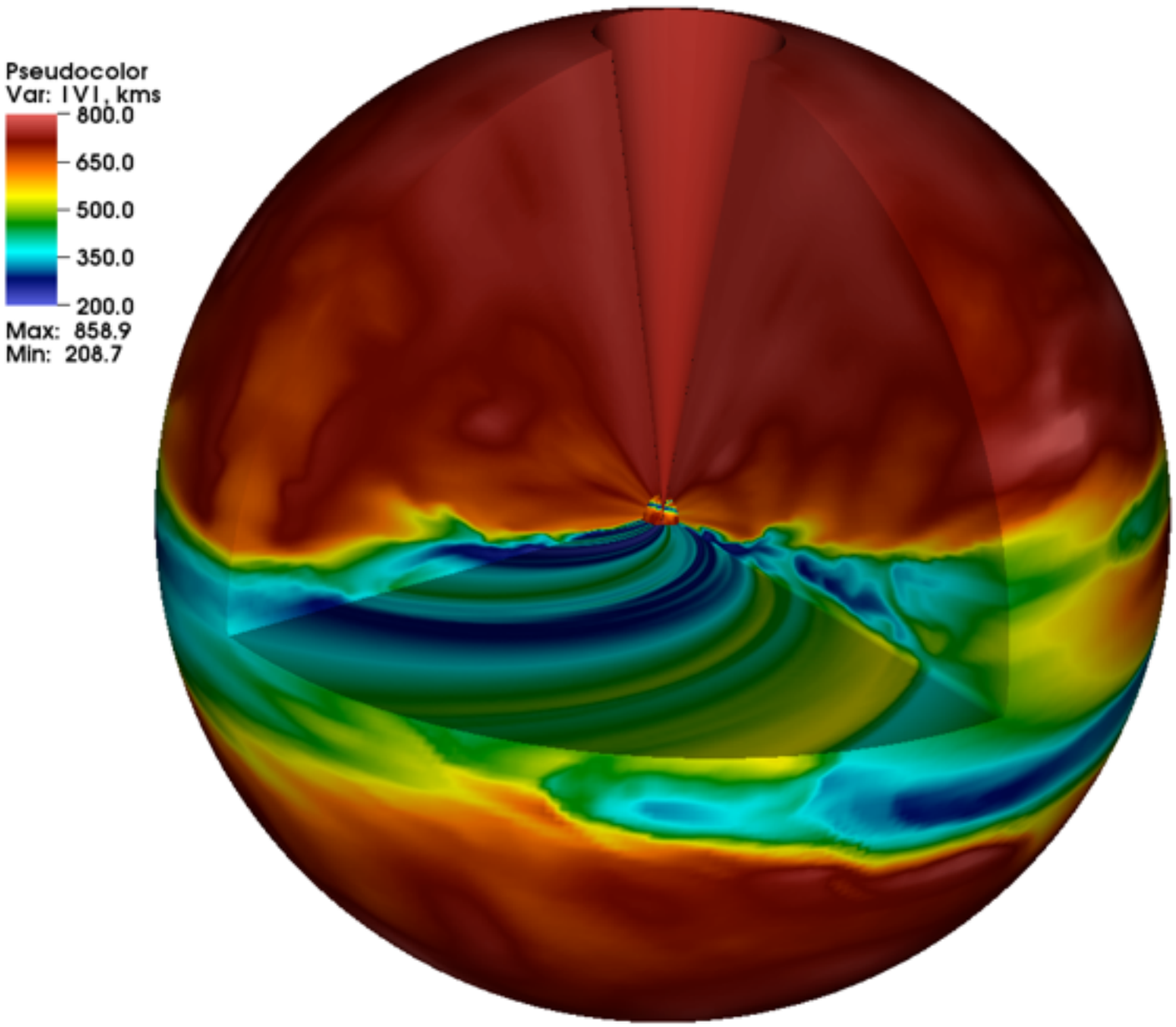


CR1962

From 0.1 to 1 AU

- LFM uses finite volume technique with arbitrary (static) hexahedral mesh.
- Can be adapted to an arbitrary problem geometry.
- High resolving power numerics can be leveraged for heliospheric problems, e.g., CIR and CME-driven shocks, particle acceleration, magnetic structure, instabilities, etc.
- These factors motivated the initial development of LFM-helio.

LFM-helio 1.0: history cont'd

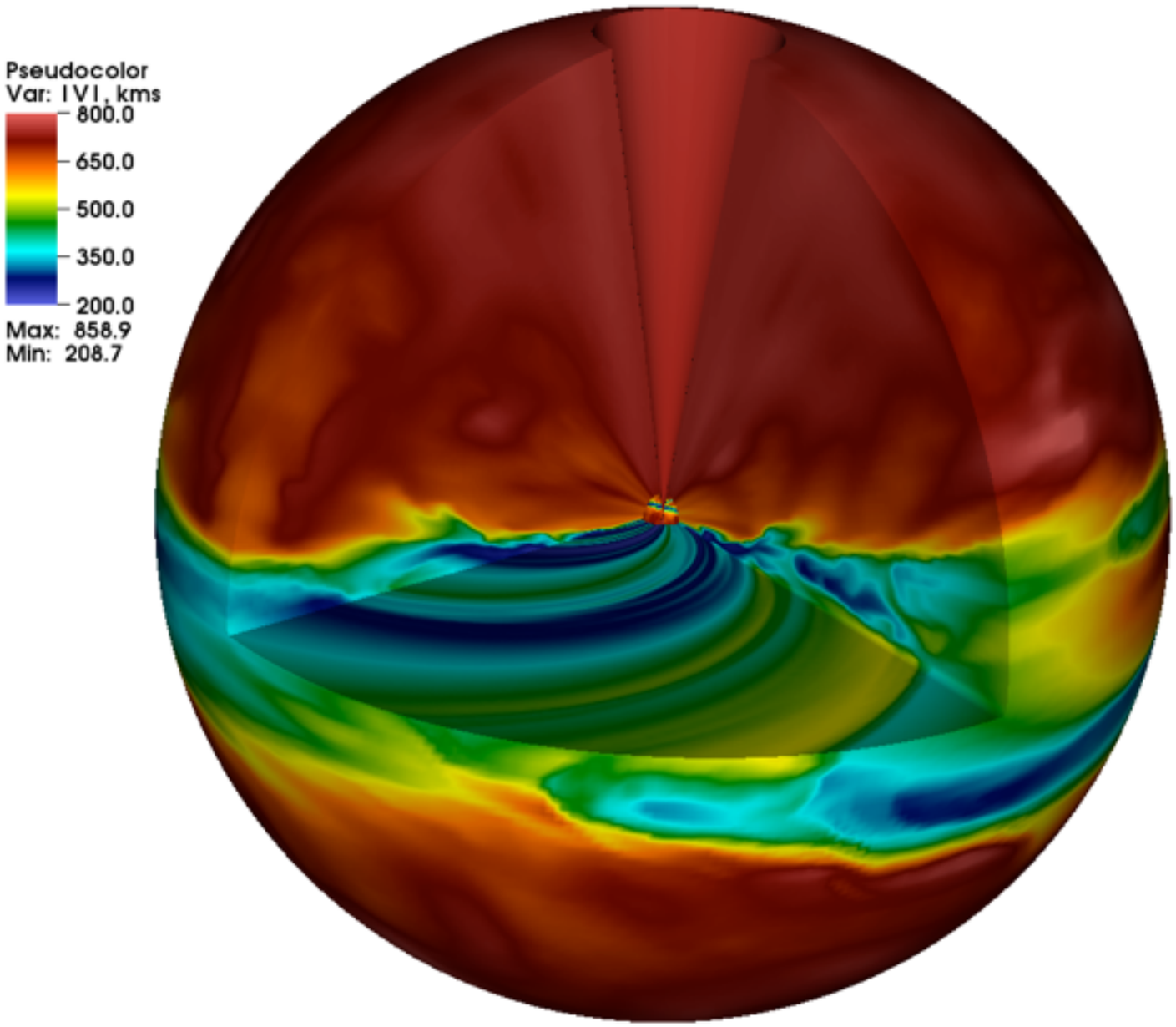


CR1892

From 0.1 to 2 AU

- LFM — MHD code developed by John Lyon, Joel Fedder and Clark Mobarry at NRL in the 80's.
- Mainly applied to terrestrial magnetosphere.
- Very low-diffusion numerical scheme (8th order TVD).
- Adapted static mesh (Arbitrary hexahedral).
- Magnetic field divergence-less to roundoff ($\nabla \cdot \mathbf{B}=0$).
- Axis cut out, but not a fundamental limitation (see LFM-helio 2.0).

LFM-helio 1.0: history cont'd

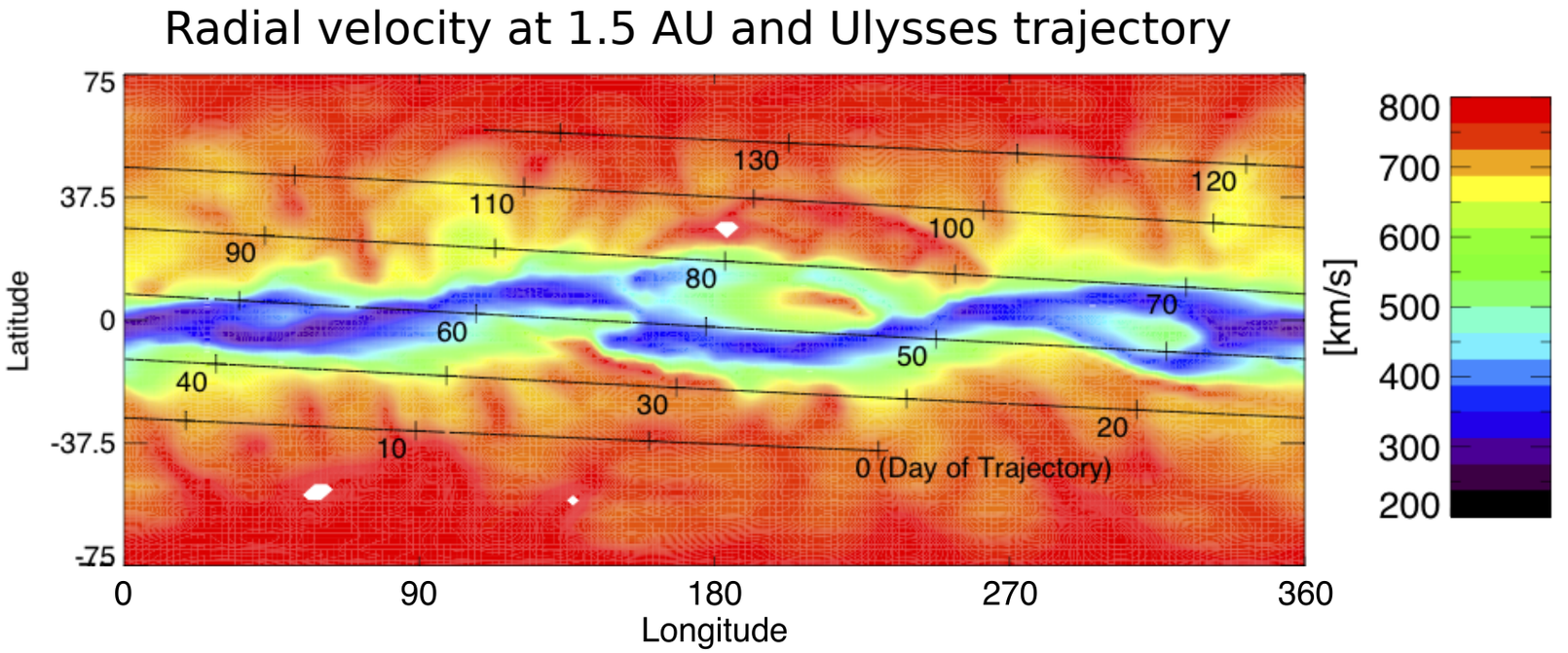


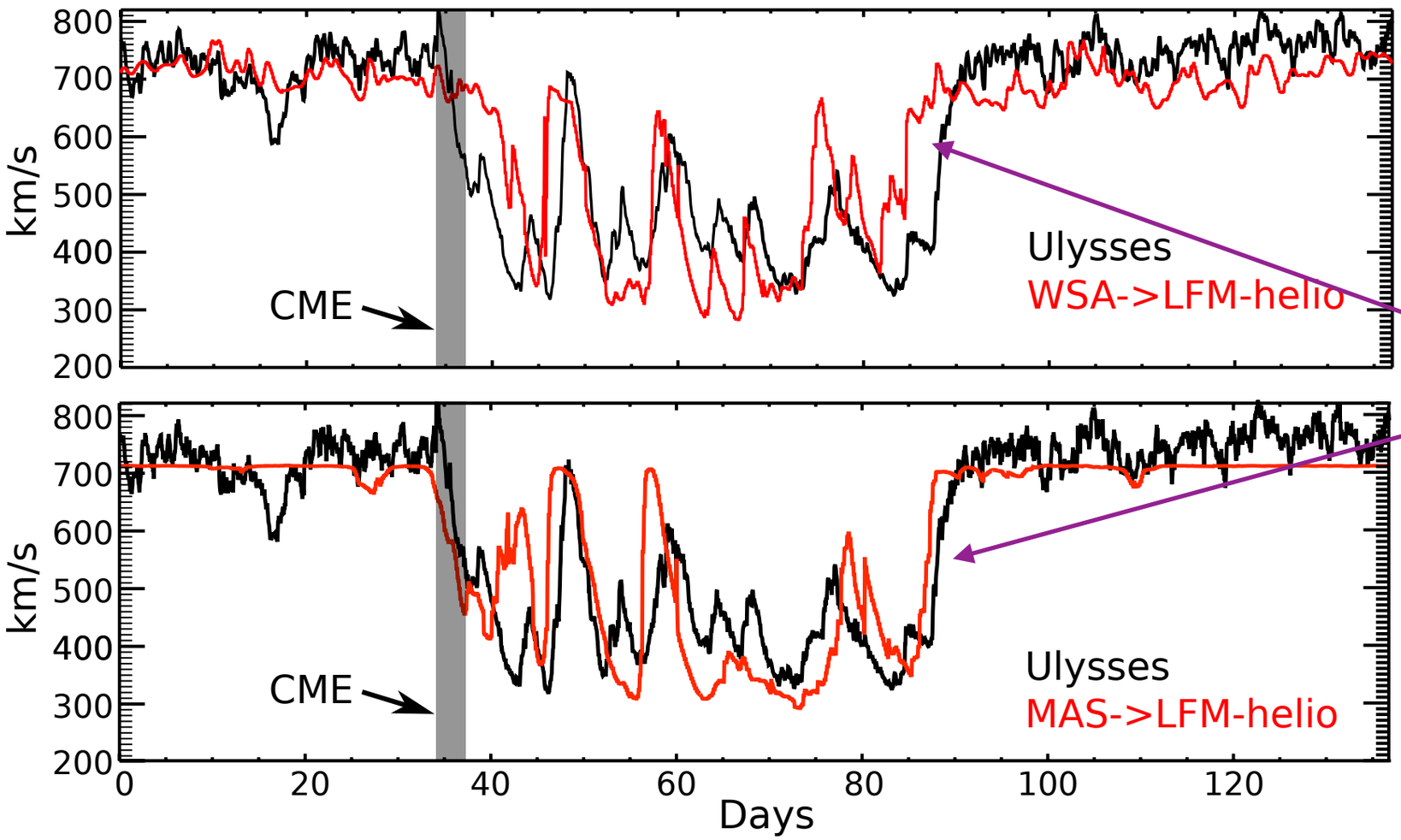
CR1892

From 0.1 to 2 AU

- At the time LFM was 2D decomposed. LFM-helio 1.0 introduced 3D decomposition.
- Axis averaging did not work for 3D decomposition.
- Axis was removed for speed up.
- Some additional tweaks in communication were used to achieve further speed improvement.
- Scaled well up to ~1000 cores (did not try to go much further).

LFM-helio 1.0: highlights

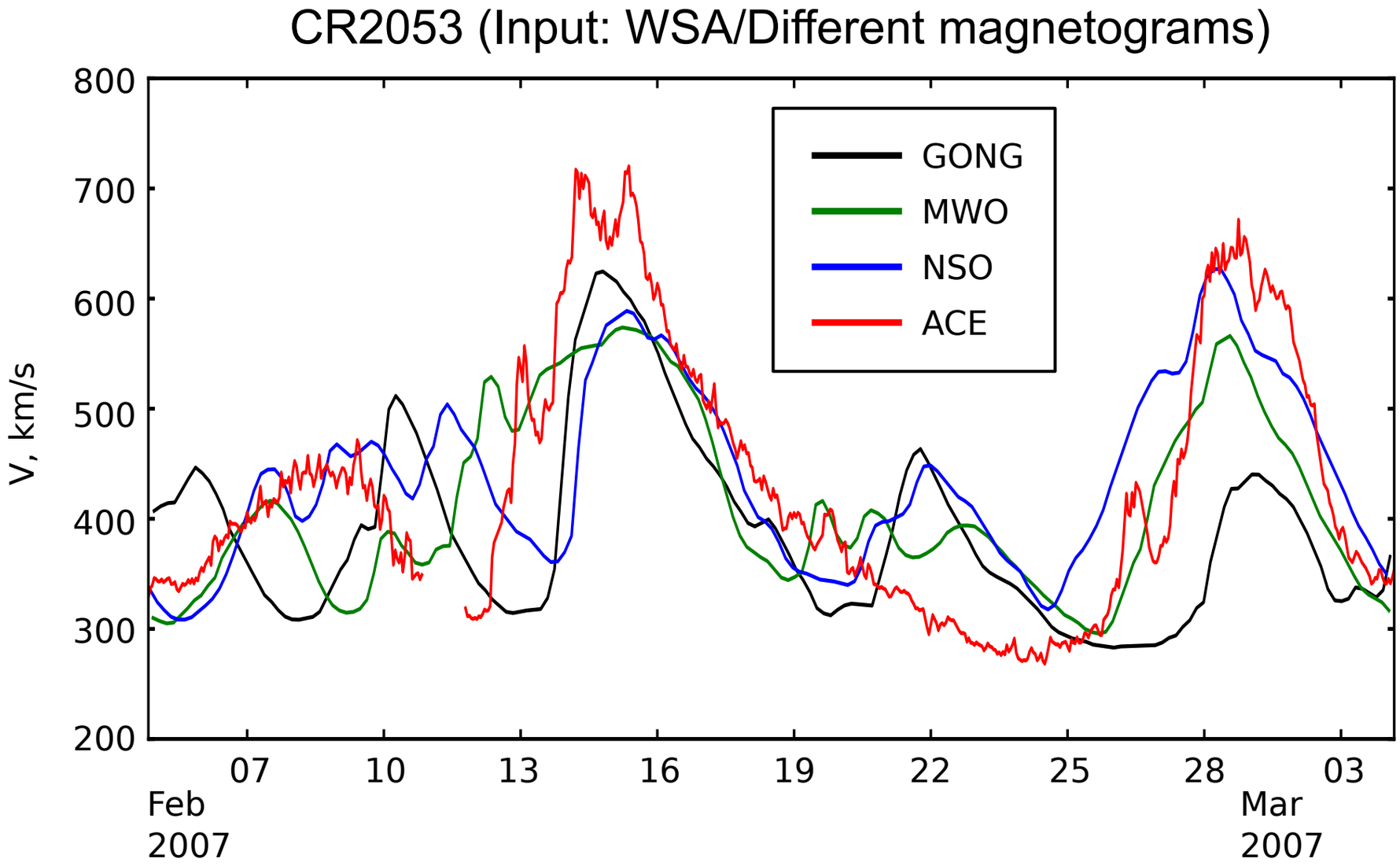




- Ulysses first Fast Latitude Scan (Jan — Apr 1995).
- WSA and MAS were driven by different magnetograms.
- Fast-slow wind transition is sensitive to the strength of polar fields.

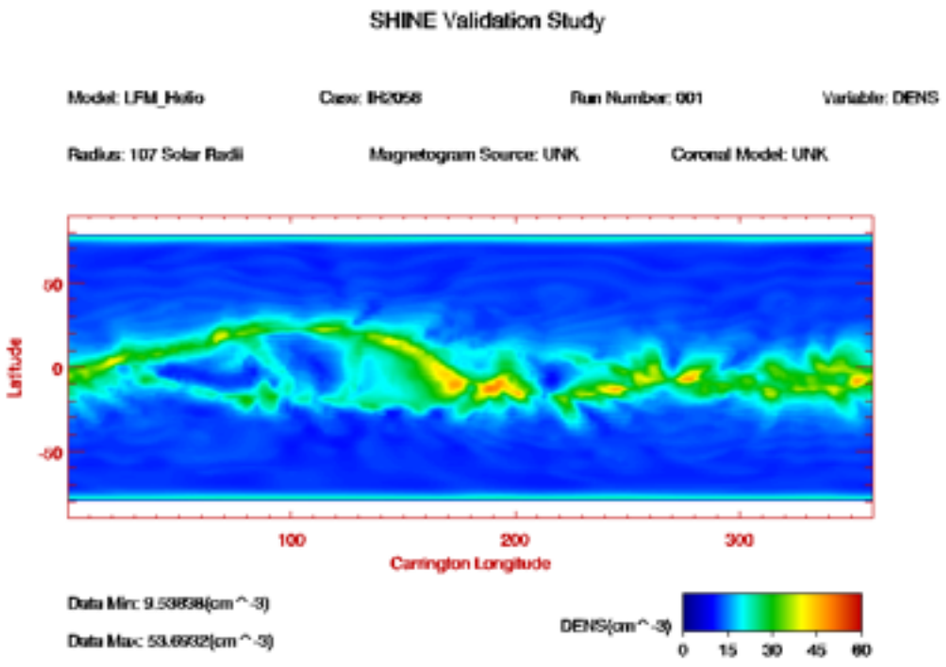
LFM-helio 1.0: highlights cont'd

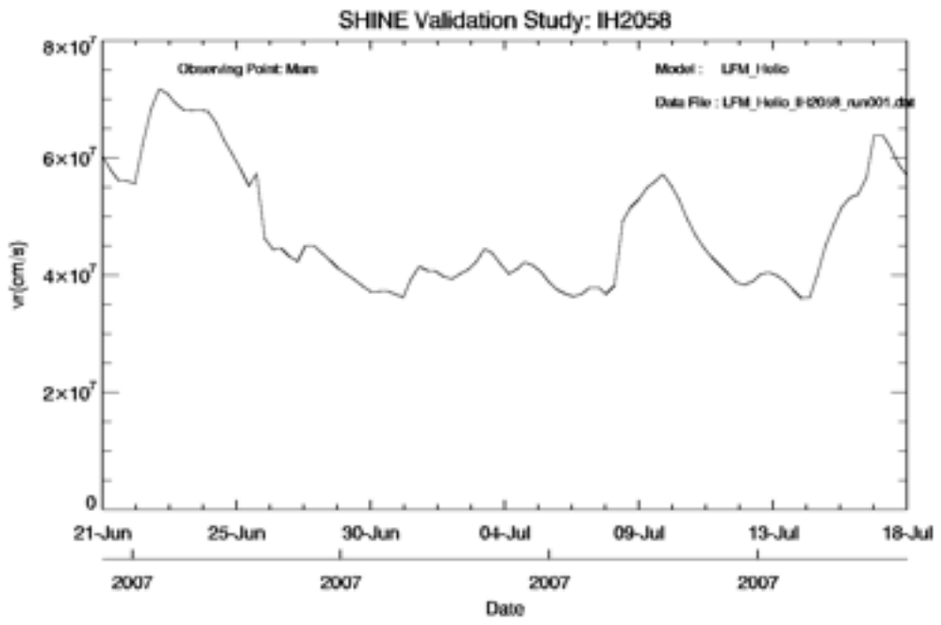
ACE comparisons



- Many CR simulations performed up to now.
- ACE/Messenger comparisons: Pahud et al., [2012]

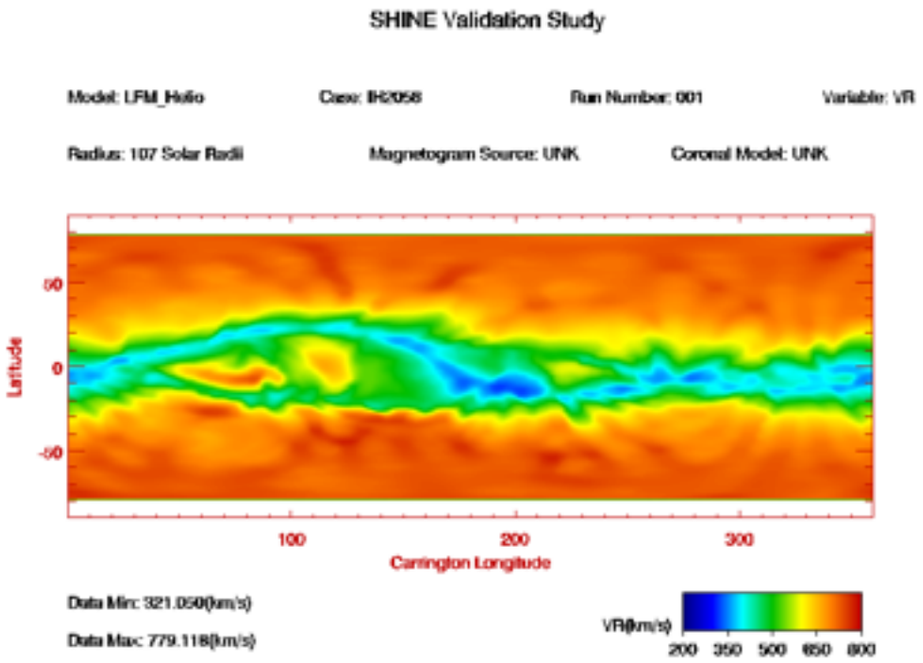
LFM-helio 1.0: highlights cont'd

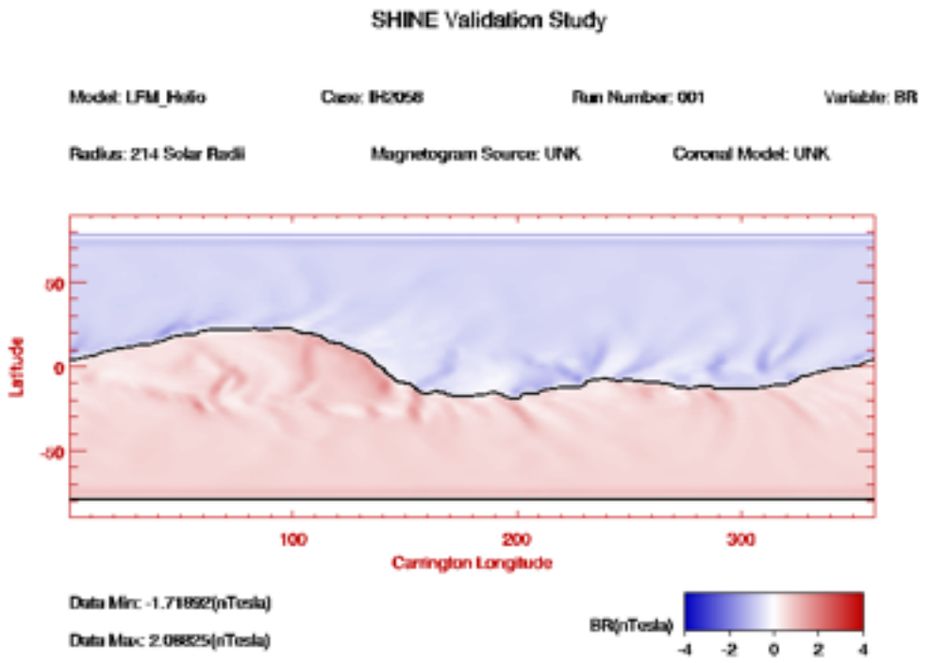




SHINE Validation Challenge

- Selected results available at CCMC.
- Plan to rerun those with LFM-helio 2.0 (see below).



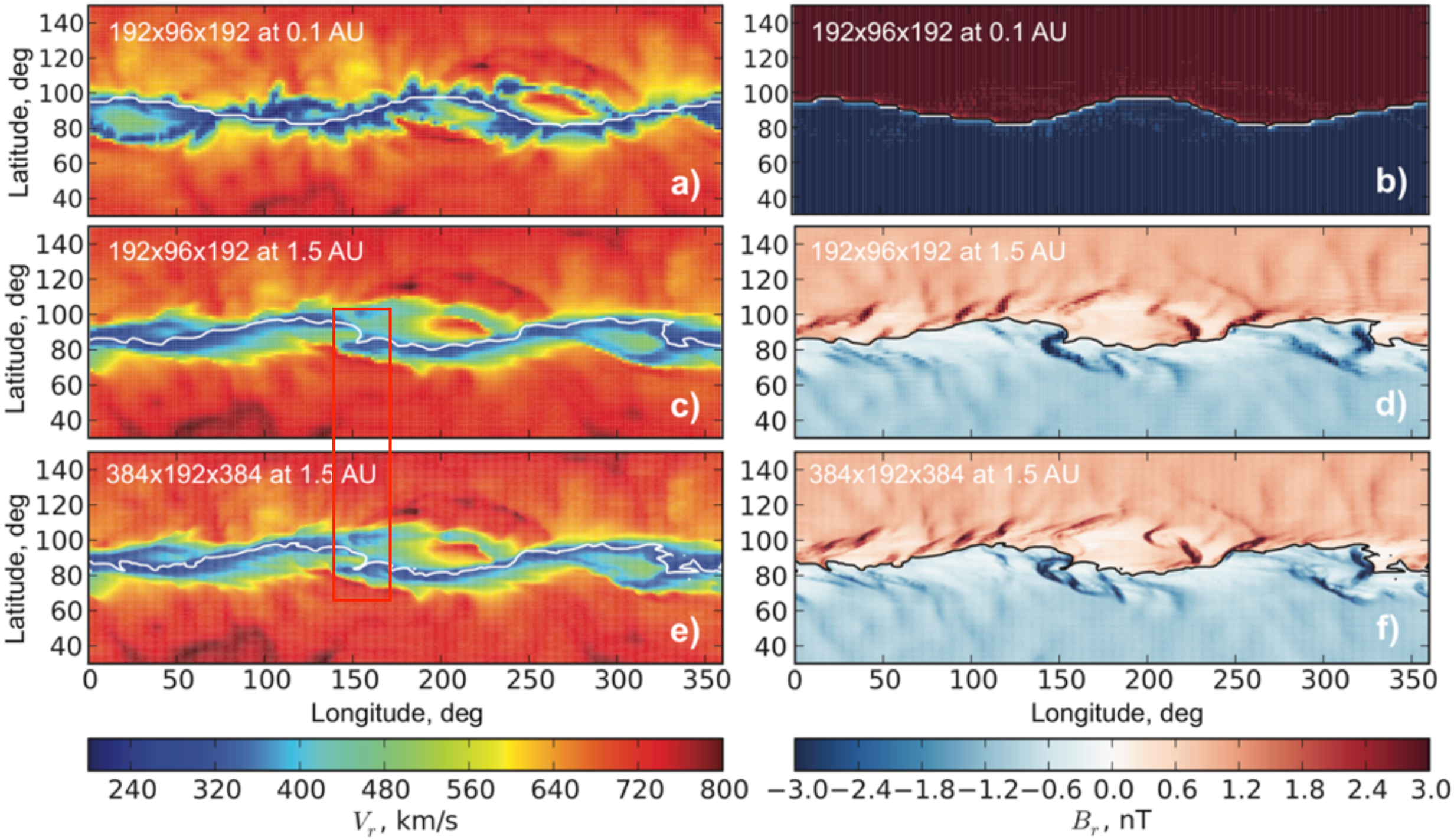


Plots: courtesy P. Macneice

http://ccmc.gsfc.nasa.gov/challenges/SHINE/

LFM-helio 1.0: highlights cont'd

High resolution simulations

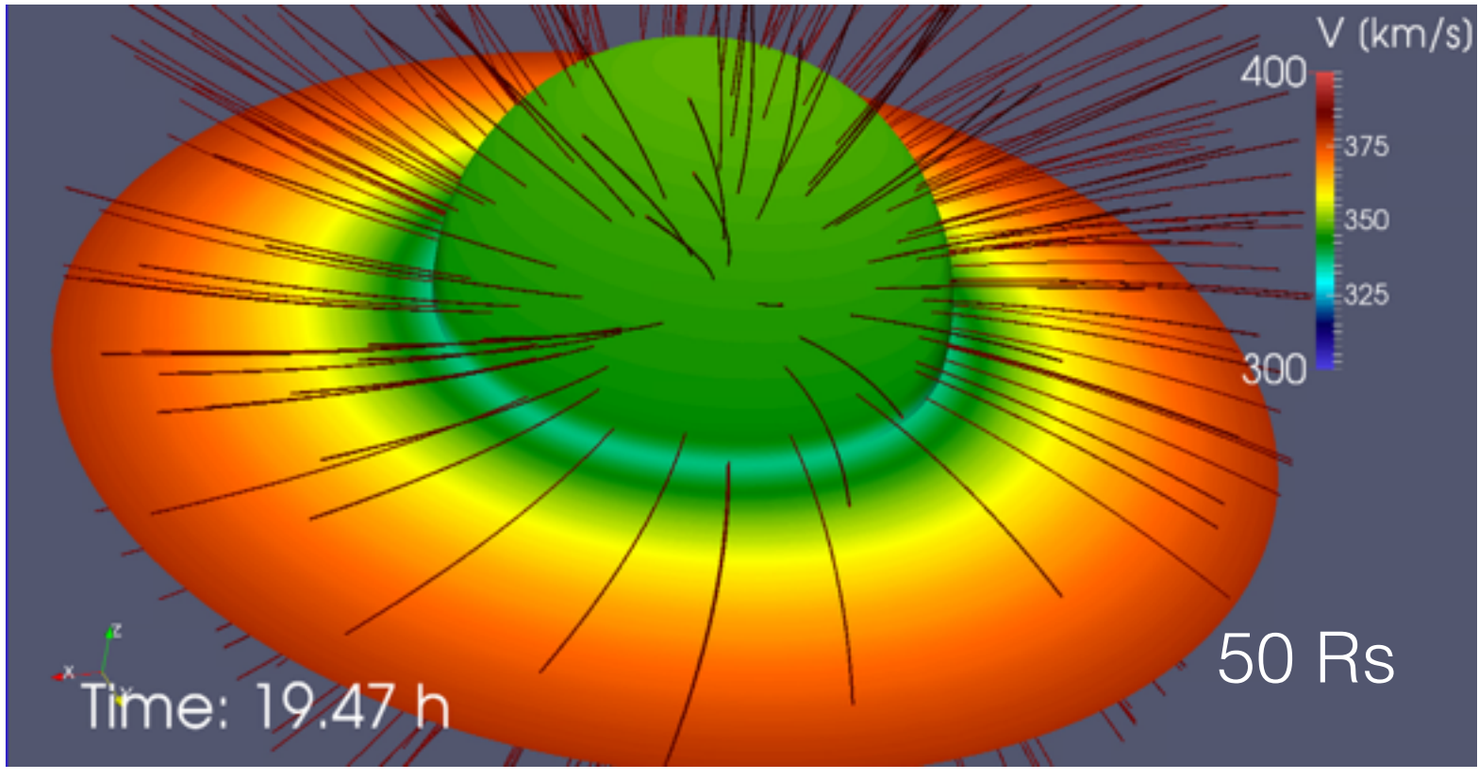


Smooth inner boundary: Structure develops as solar wind progresses away from the sun.

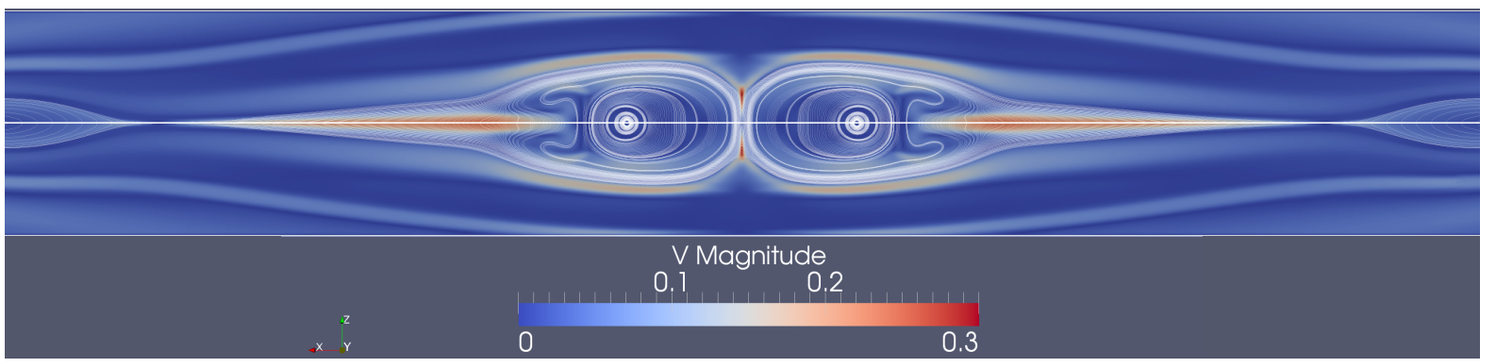
Merkin et al., GRL, 2011

LFM-helio 2.0: motivation, improvements

MAS-driven relaxed state



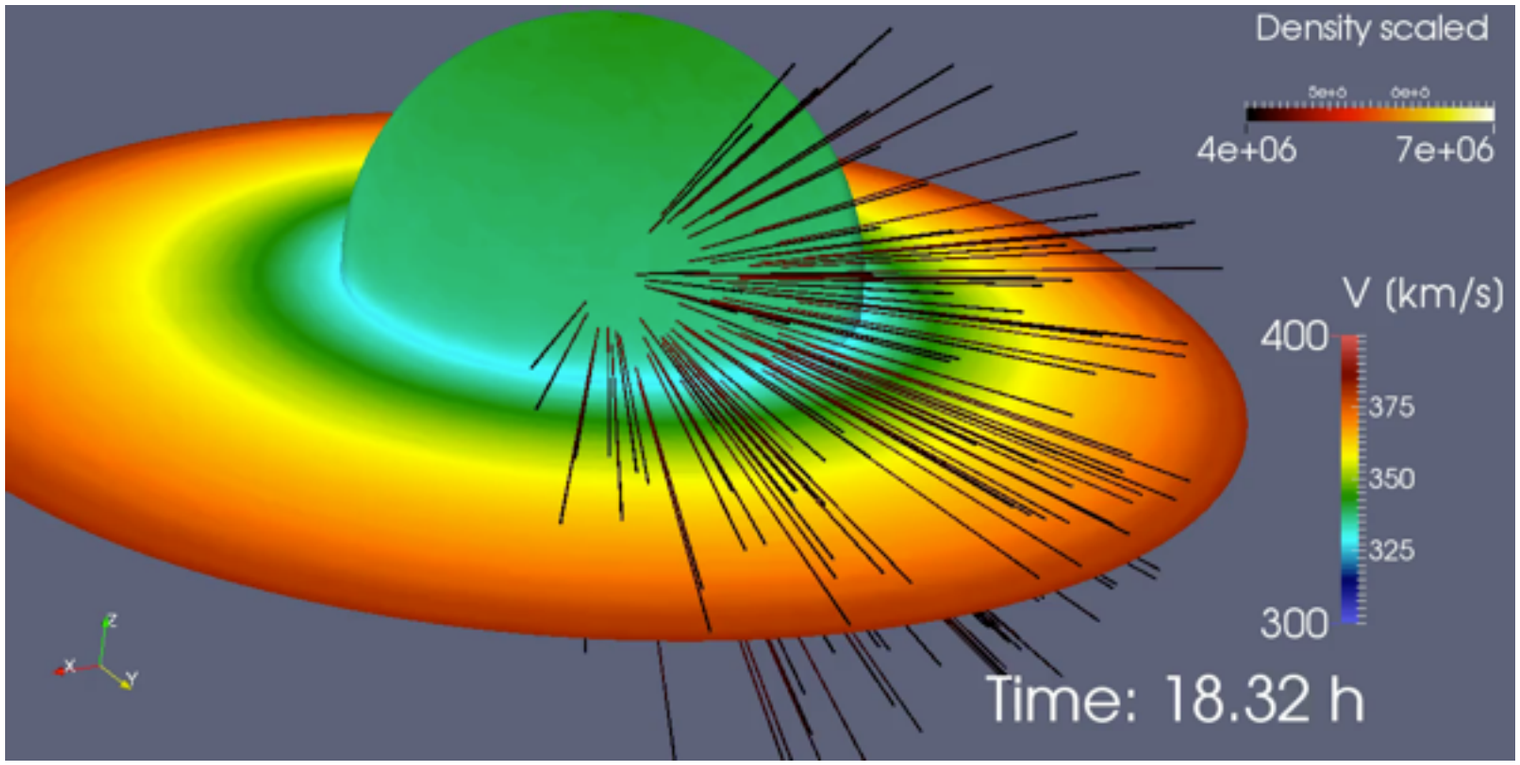
Basic reconnection problems with resistive LFMBOX

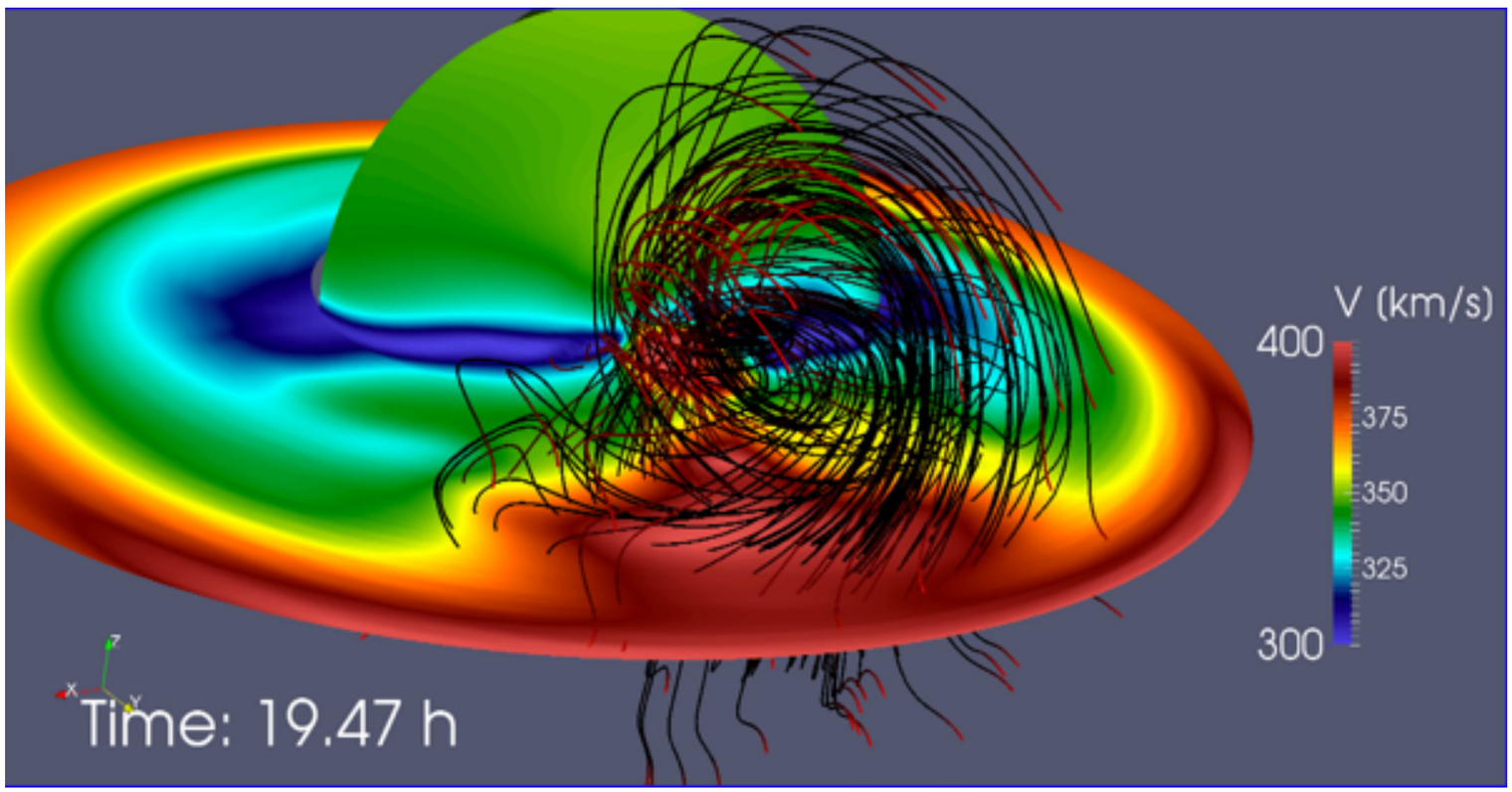


- During the lifetime of LFM-helio 1.0, the LFM code base has significantly evolved.
- 3D decomposition, significant improvements in performance and scaling are part of the current LFM code base — higher resolution.
- Generalized grid geometries and boundary conditions are easier to implement.
- LFM-helio 2.0 is the version of the heliospheric code developed from the most recent LFM code base.
- Axis is included back into the simulation domain.
- Other applications include LFMBOX — a Cartesian version of the code for basic MHD problems (includes resistivity).
- See John Lyon's presentation this afternoon for more details on the common LFM code base.

LFM-helio 2.0: recent work

Coupling with MAS for CME propagation





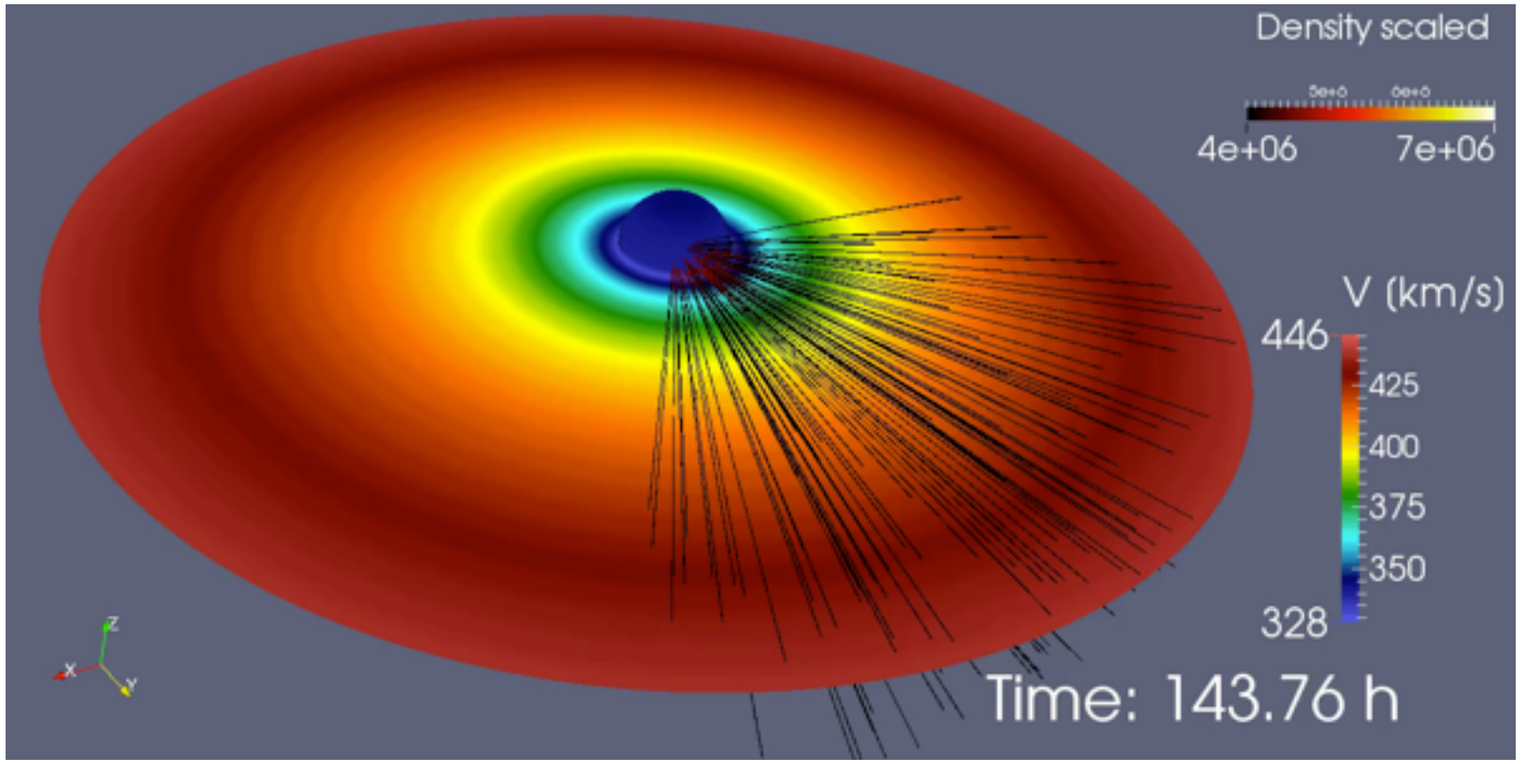
LFM/MAS
identical grids

- Grids staggered differently. Even for identical LFM and MAS grids, interpolation is necessary.
- LFM ghost region overlaps with the MAS coronal grid in volume.

LFM on own
grid + rotation

LFM-helio 2.0: recent work cont'd

Coupling with MAS for CME propagation



- Same setup, but LFM grid runs out to Earth.
- Interpolation, time dependent (rotating) boundary implemented for MAS coupling.
- Standing ready to try a realistic event simulation.

- In parallel, reworking and cleaning up the inner boundary code.
- Getting ready for high-resolution runs.

LFM-helio 2.0: future directions

- High resolution (significantly sub-degree angular, sub-Rs radial) — instabilities, velocity shear effects, current sheet distortion.
- Time-dependent magnetograms (ADAPT).
- Generalized time-dependent inputs (CMEs, instabilities).
- Ensemble modeling.

- Cleaning up the code base, boundary interfaces, user interface — ultimate goal — transition to CCMC — requires resources.
- Streamline common LFM code base between different applications — useful for developers, internal users, external users (CCMC), therefore, the community.