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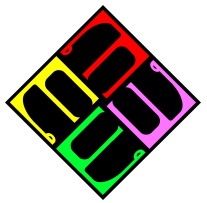
European Heliospheric Forecasting Information Asset

S. Poedts, J. Pomoell
F. Verstringe, J. Andries, D. Berghmans

Royal
Observatory
of Belgium



EUI

SWT-12

Theory & modeling support/preparatory science: What do we need? How do we implement it?

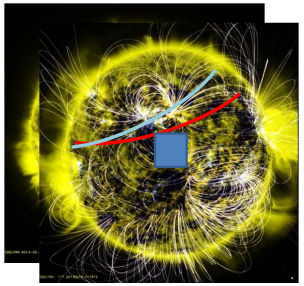
Susanna Parenti
Royal Observatory of Belgium

with inputs from F. Auchère, G. Aulanier, D. Berghmans, T. Dudok de Wit, L. Harra, B. Lavraud, L. Rodriguez, A. Zhukov

A possible process for planning

RS windows precursor observations

Prediction of connectivity for wind



Theory/modeling for B and wind paths

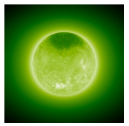
Prediction of possible connectivity for SEP/CMEs

Decision making for the targets:

- Identify possible targets
- Forecast activity

Evaluate the quality of the prediction with respect to:
- orbit main science goal
- potential quiescent /erupting targets
- mission constraints

Needs for target decision



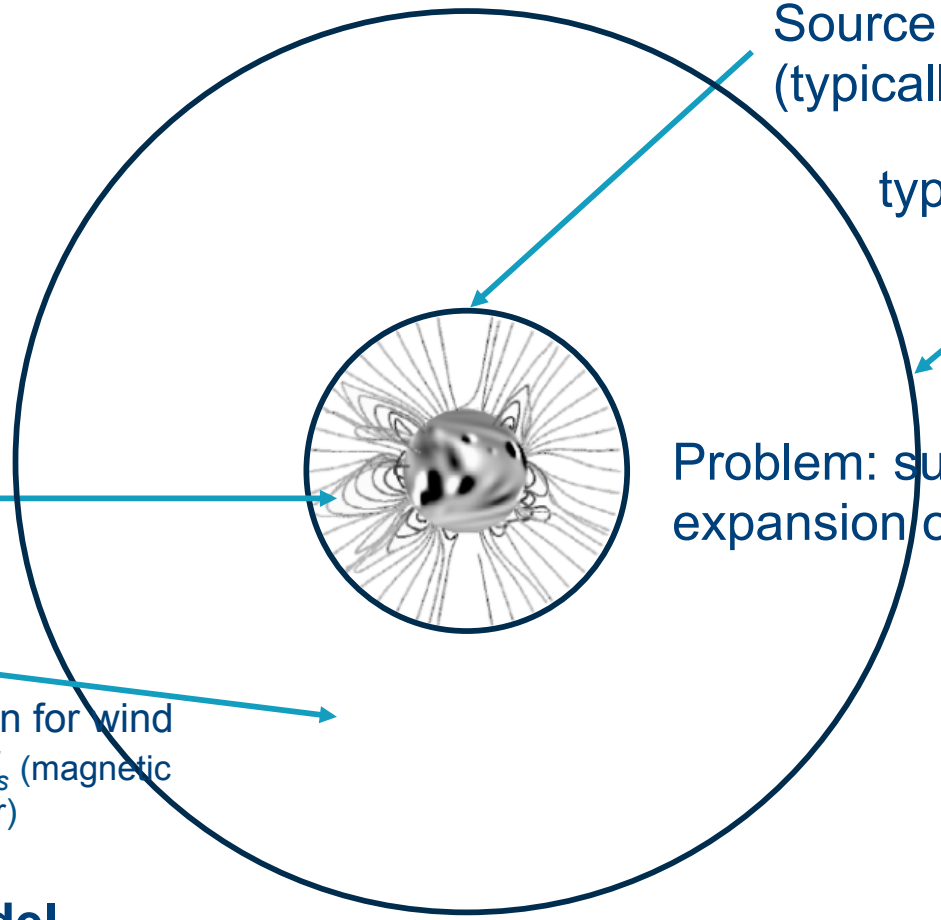
- Preparatory observations:
  - Precursors observations to identify targets of opportunity.
  - Forecasting work
- Theory and modeling support:
  - Verify the magnetic connectivity
  - Test instability conditions using the observational constraints
- Decision making for the targets:
  - Evaluate the 'quality' of the source region, the quality of the link with the in-situ, with respect to science goals and mission constraints.
    - Ex: transit trough boundary regions is good, too small CH is bad, telemetry constraints, etc…

What we have: modeling/theory

- What kind of models exist
  - Which physics/complexity they have
    - e.g. time dependence; PFSS vs NLFFF
  - Which quantities they predict
    - e.g. B and/or v
  - With which precision
    - Global models miss small scales
    - Errors on the hypotheses/boundary conditions
  - How fast they are:
    - extrapolation vs. iterative model (NLFFF)
    - rapidity vs. resolution

Solar wind modeling

Taking coronal model as lower boundary condition



Source surface: $B_\varphi = B_\theta = 0$
(typically at 2.5 Rs)

typ. at about 21.5 Rs (0.1 AU)

Coronal model
with PF or NLFFF

Problem: super-radial expansion of flux tubes

WSA model
Semi-empirical relation for wind speed as function of f_s (magnetic flux tube expansion factor)

MHD wind model
ENLIL, SWMF, **Euhforia**, etc.

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Coronal model

AIM: Produce plasma condition at r = 0.1 AU as input to MHD model

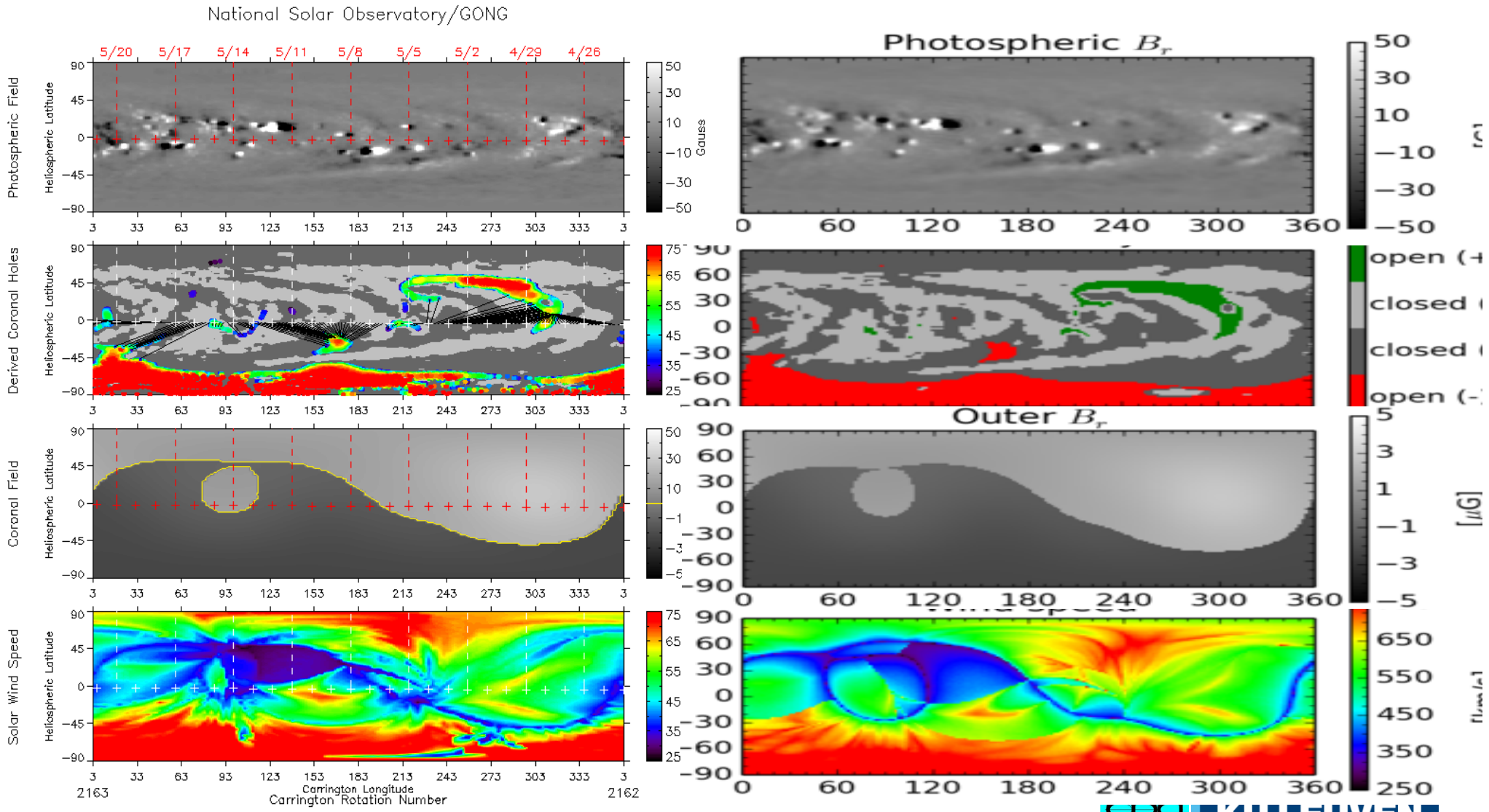
INPUT: GONG synoptic LOS magnetograms (updated every hour)

METHOD:

- PFSS field extrapolation using hybrid FFT (in azimuthal direction) and second order finite differences (in meridional plane)
- Determination of CHs, distance to nearest CH, FT expansion factor etc., from the PFSS+CS model, i.e. various applications of field line tracing
- Current sheet model (Schatten) beyond the source surface
- Based on parameters determined from the PFSS+CS model, use semi-empirical formulas for the solar wind speed at r = 5 R_{Sun}
- Translate the speed at r = 5 R_{sun} to 0.1 AU, other plasma variables set according to semi-empirical considerations

Comparison with WSA

Plot in WSA style (http://legacy-www.swpc.noaa.gov/ws/gong_all1.html



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Heliosphere model with CMEs

AIM: Compute time dependent evolution of MHD variables from 0.1 AU to 1 AU and beyond (up to a few AU)

INPUT: Plasma properties at 0.1 AU from coronal model, cone model CME parameters from fits to observations

METHOD:

- Second order finite volume MHD scheme
- Python matplotlib / VisIt for visualization

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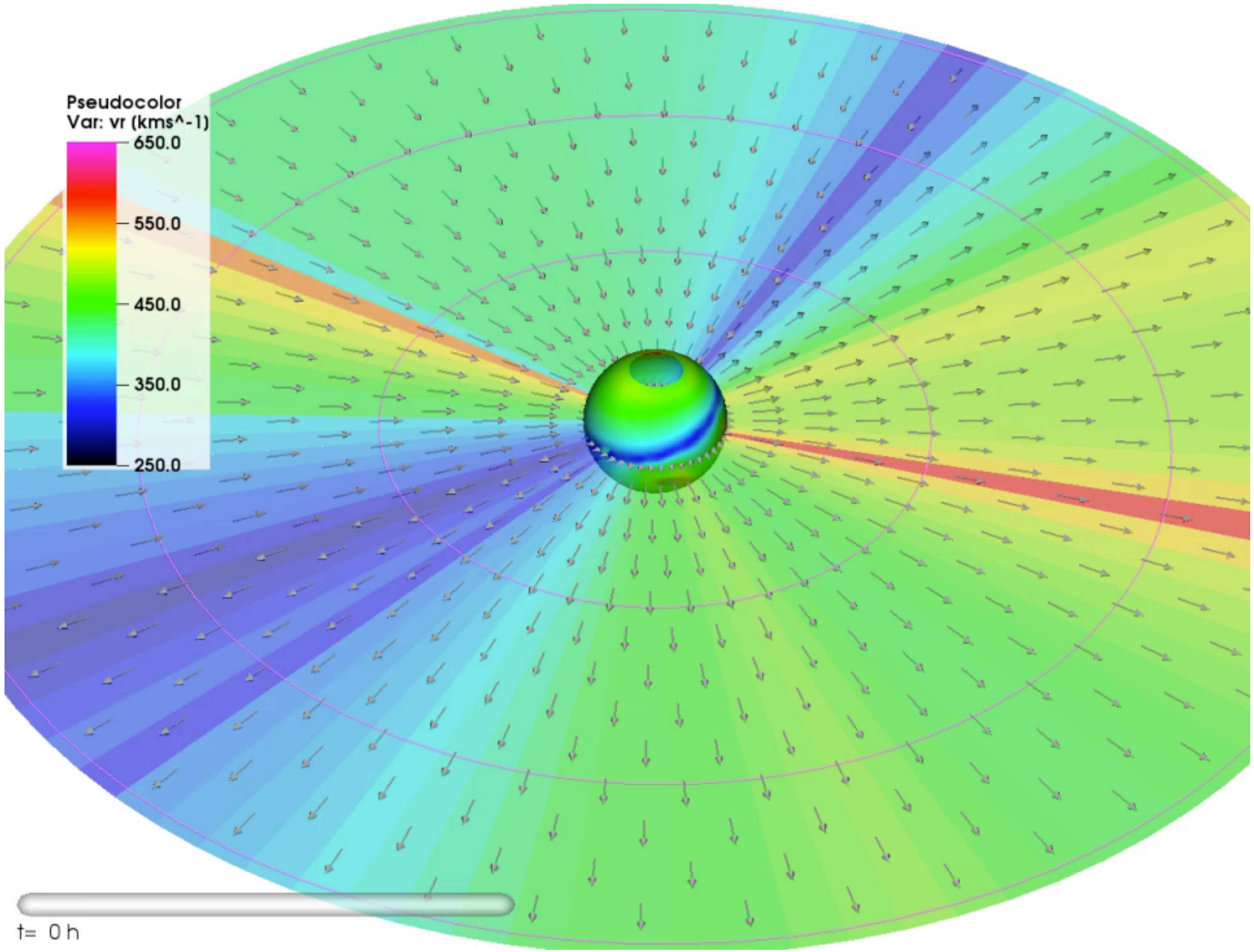
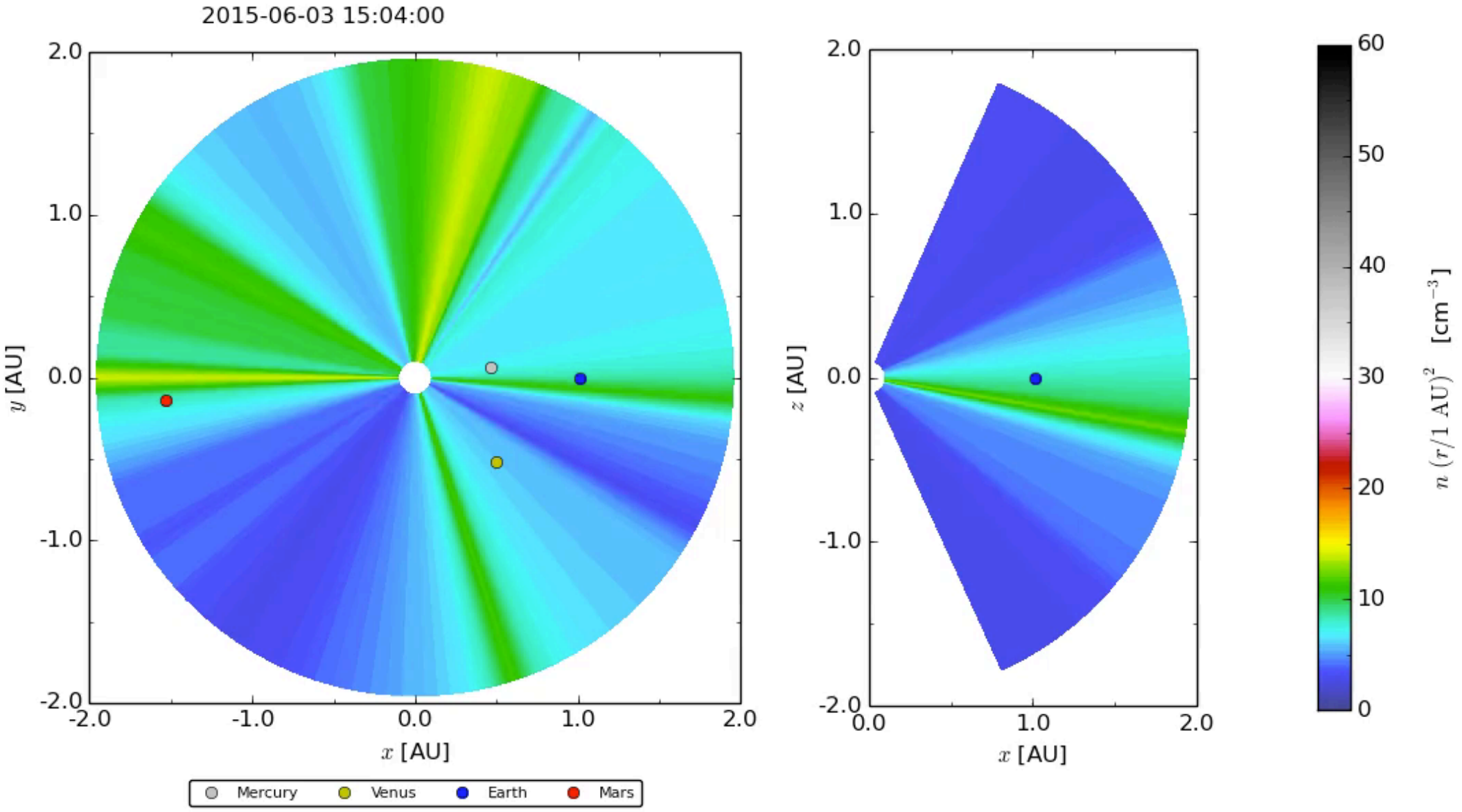


3D visualization of **MHD relaxation** in low resolution (same as ENLIL) 0.1 AU - 1 AU

Color = radial velocity (initially extended)
Arrows = magnetic field (initially radial)


2015-06-03 15:04:00
2.0
1.0
0.0
-1.0
-2.0
y [AU]
-2.0
-1.0
0.0
1.0
2.0
x [AU]
Mercury
Venus
Earth
Mars
z [AU]
x [AU]
60
50
40
30
20
10
0
n (r/1 AU)^2 [cm^-3]

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Upcoming next

- Further model improvements (update coronal model to MPI-AMRVAC) and reproduction at ROB
- improve CME insertion (cone model, CACTus, etc)
- validation (comparison with ENLIL, ACE)
- daily, semi real-time operations at ROB, integration with space weather forecasting activities
- visualisation improvements, integration with Helioviewer TBD