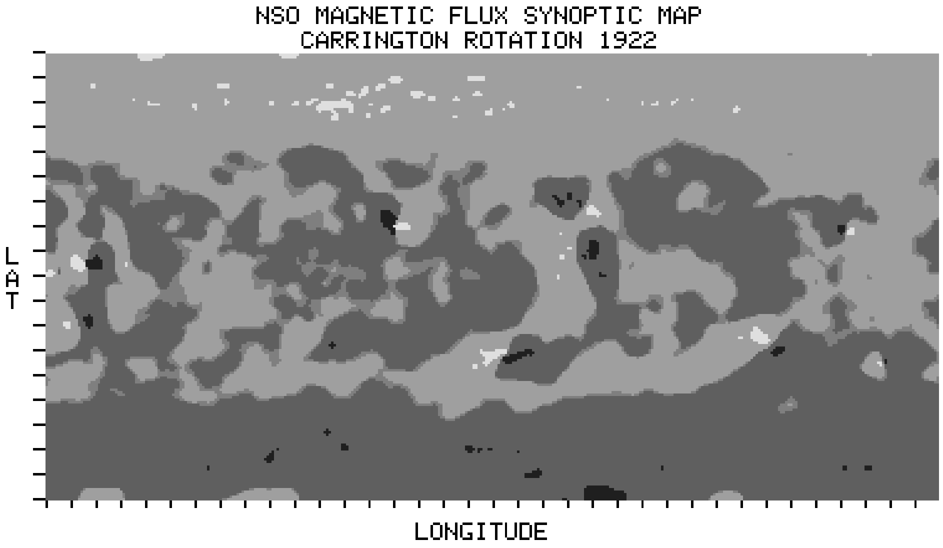
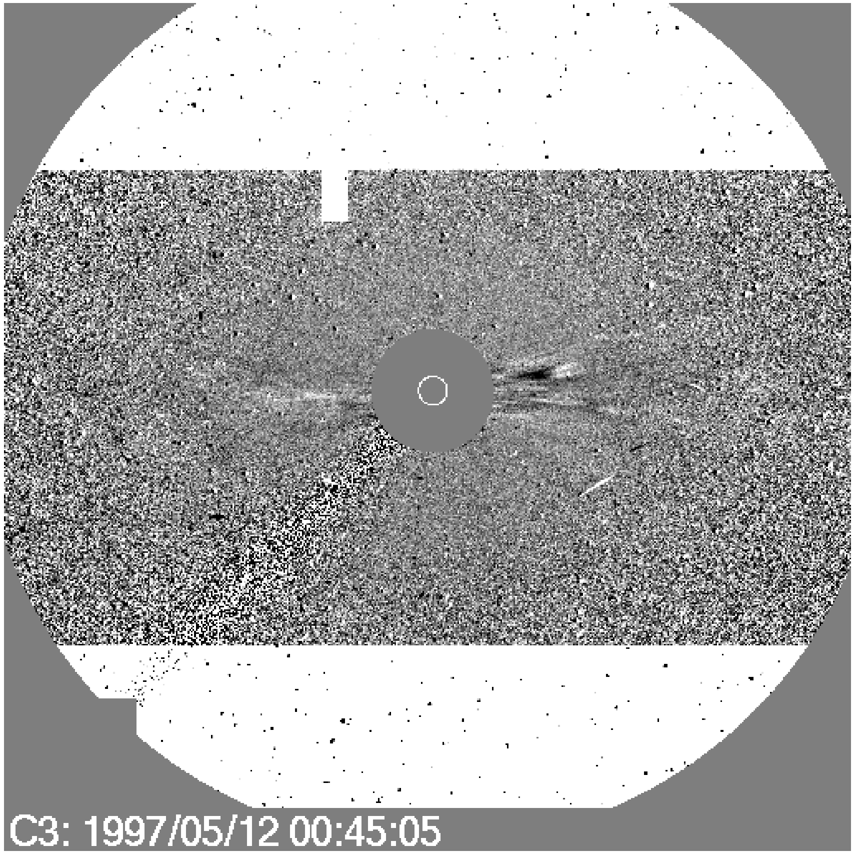
# Initialization of Numerical Models




Remote solar observations of the photospheric magnetic field

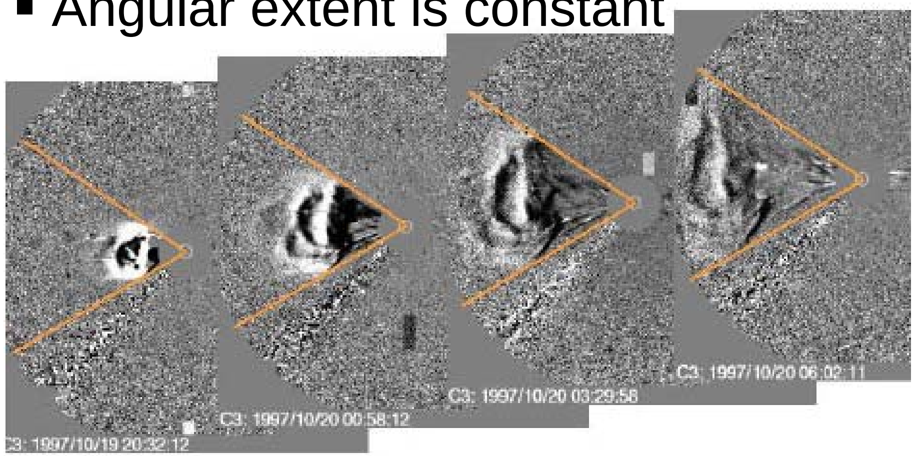



Remote coronal observations of the white-light scattered on density structures

# CME Cone Model

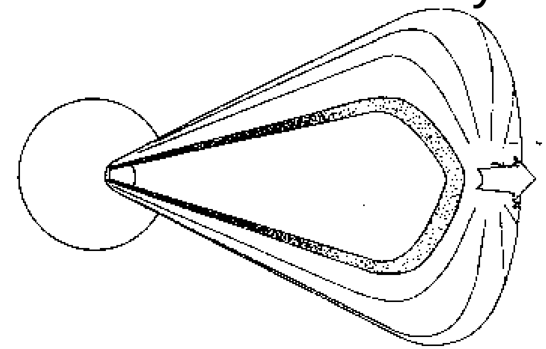
<u>Observational evidence:</u>

- CME expands self-similarly
- Angular extent is constant

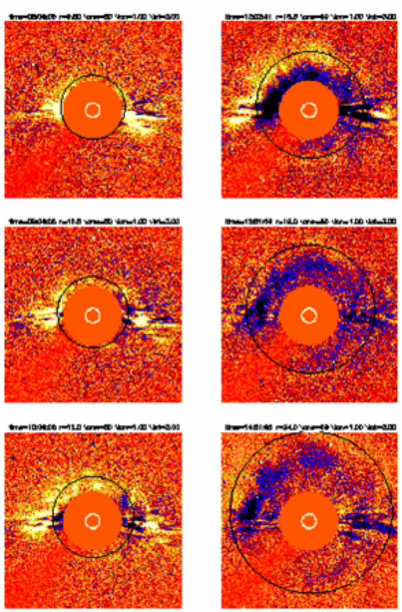


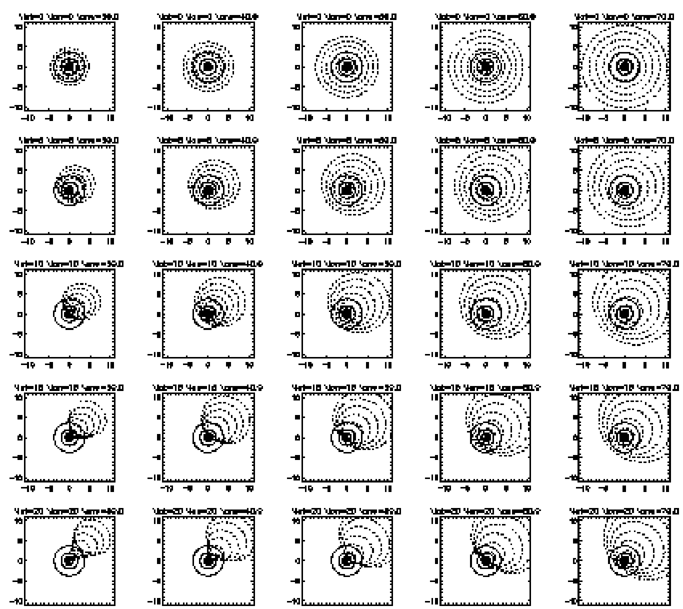

<u>Conceptual model:</u>

- CME as a shell-like region of enhanced density



[ *Howard et al*, 1982; *Fisher & Munro*, 1984 ]



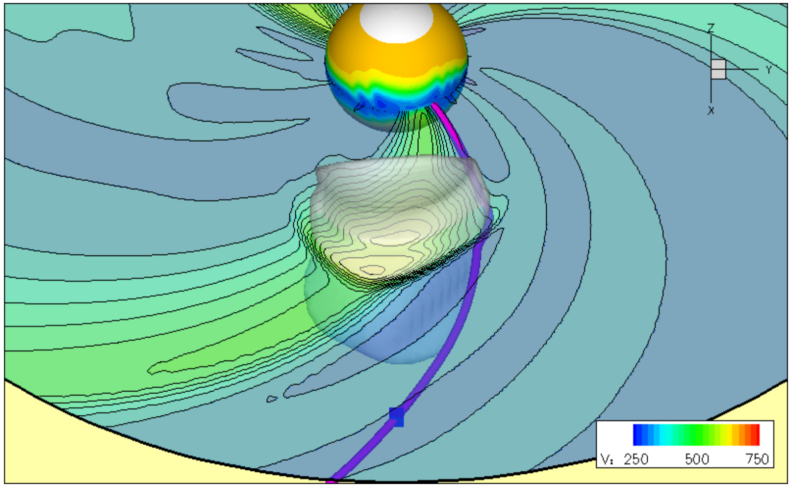


<u>Fitting of halo CMEs:</u>

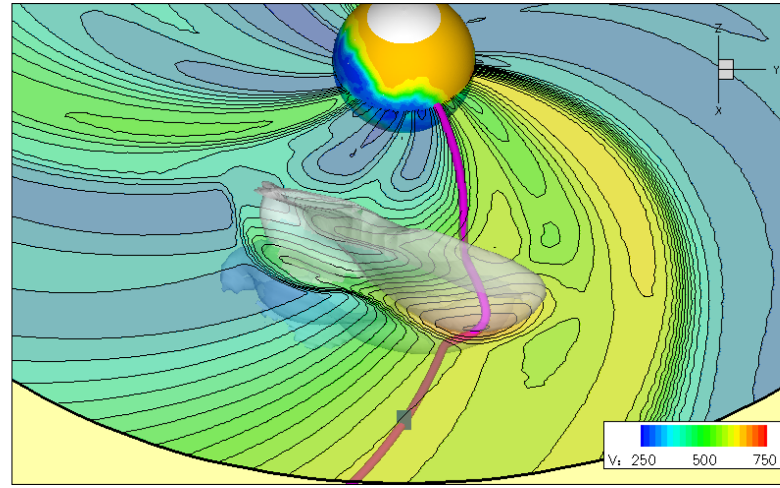
- Various authors [*Zhao, Liu, Michalek, Xie, etc*]
- Weak and fuzzy images
- Cannot see "beyond"
- STEREO will significantly improve accuracy

# Application of the CME Cone Model

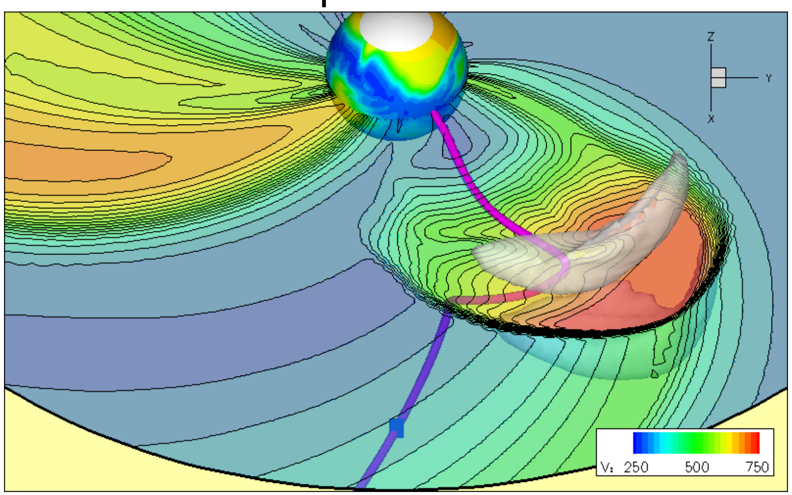
12 May 1997



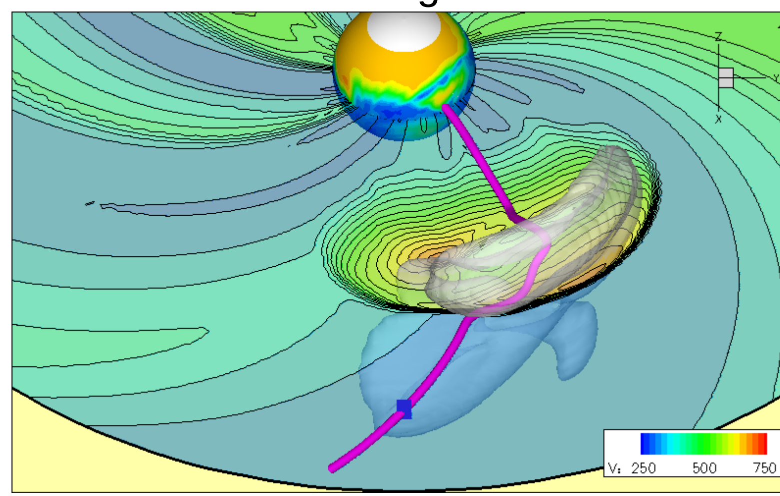

1 May 1998




21 April 2002

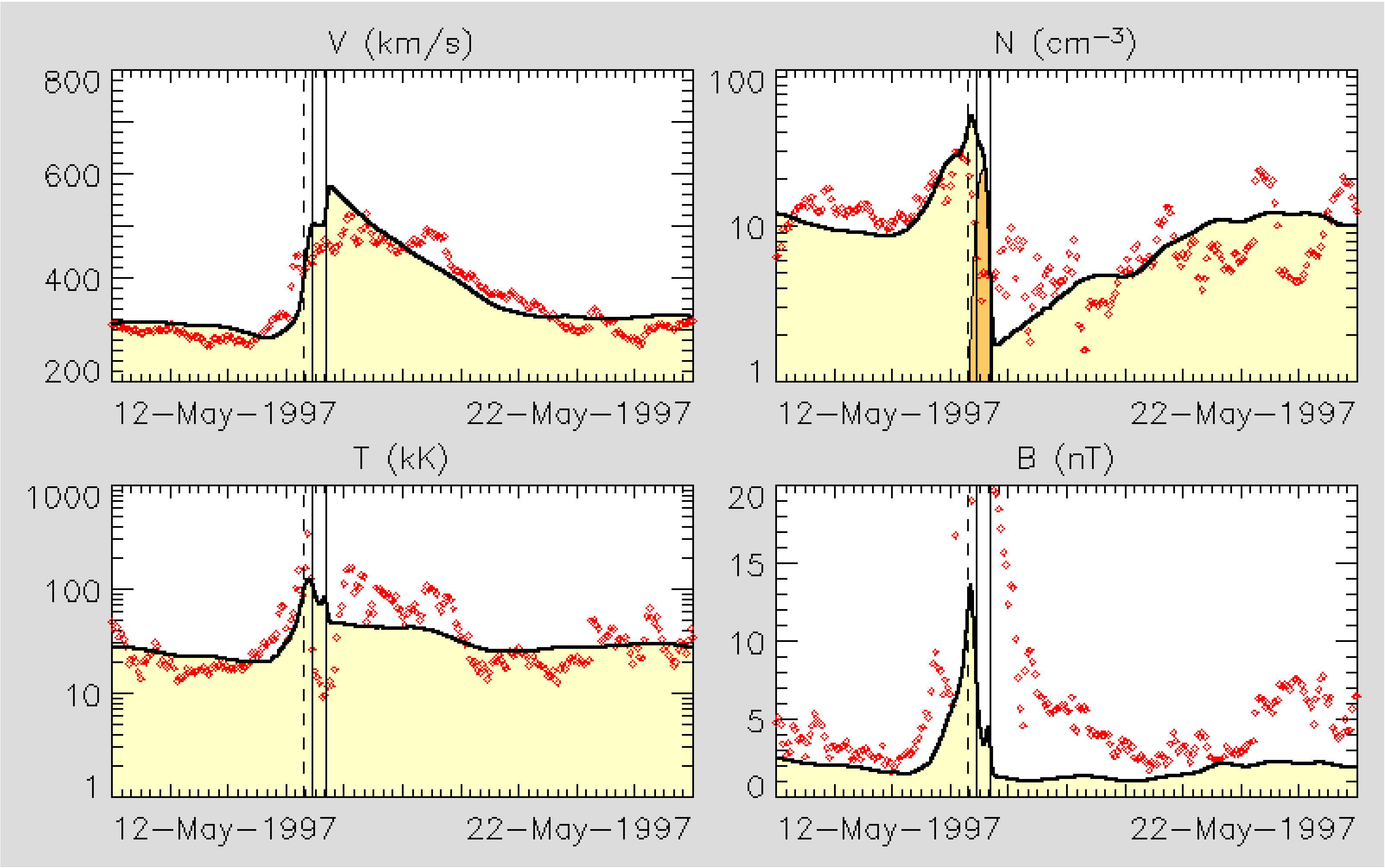



24 August 2002



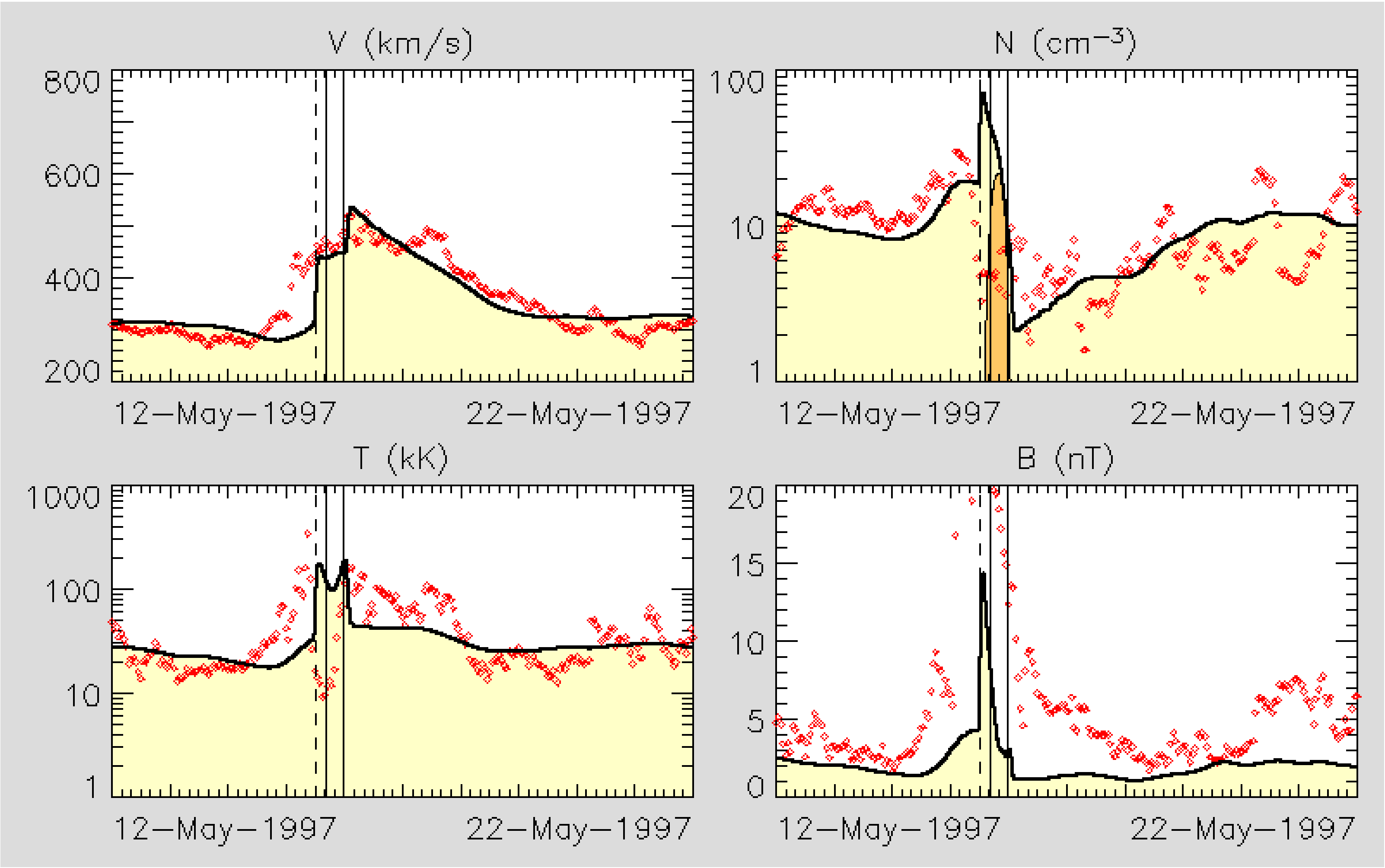

The heliospheric simulations may provide a global context of transient disturbances within a co-rotating, structured solar wind and they can serve as an intermediate solution until more sophisticated CME models become available.

# Evolution of Parameters at Earth – Case A




Poorly defined shock and its stand-off distance from the ejecta

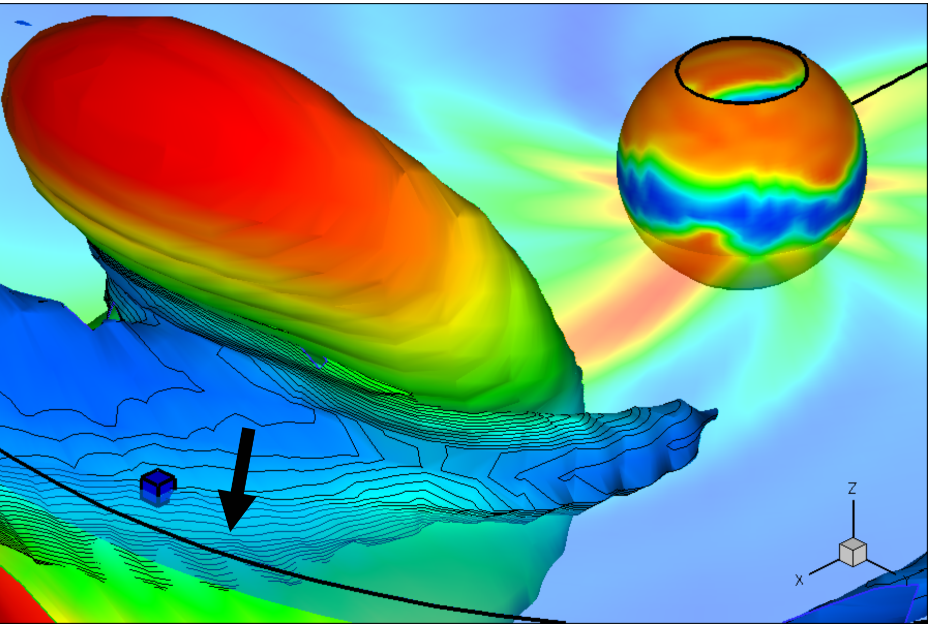
# Evolution of Parameters at Earth – Case B



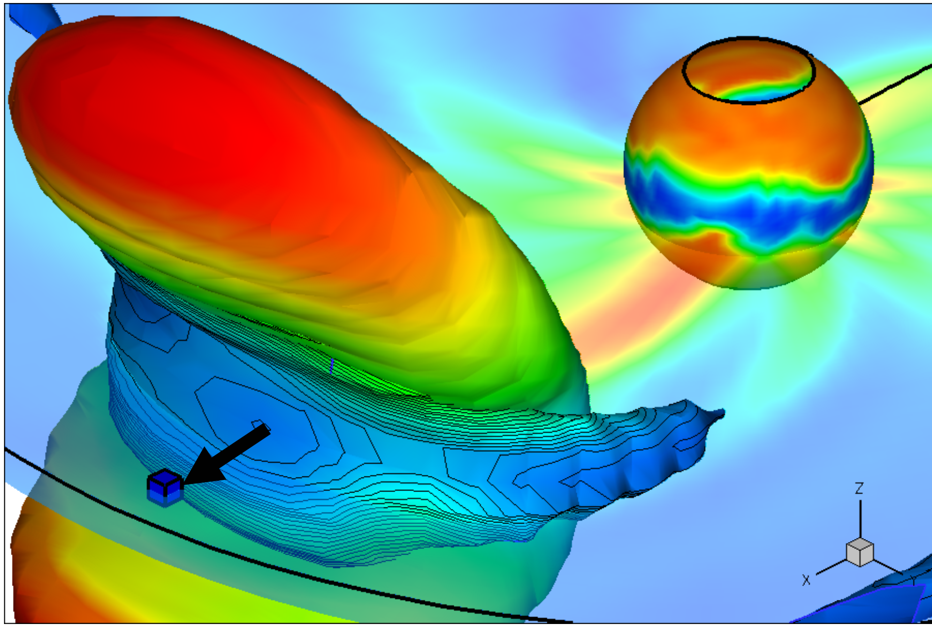

Accurate locations of stream boundaries and their rapid displacements are important for ICME properties at Earth

# Effect of Fast-Stream Evolution

Case A




Case B



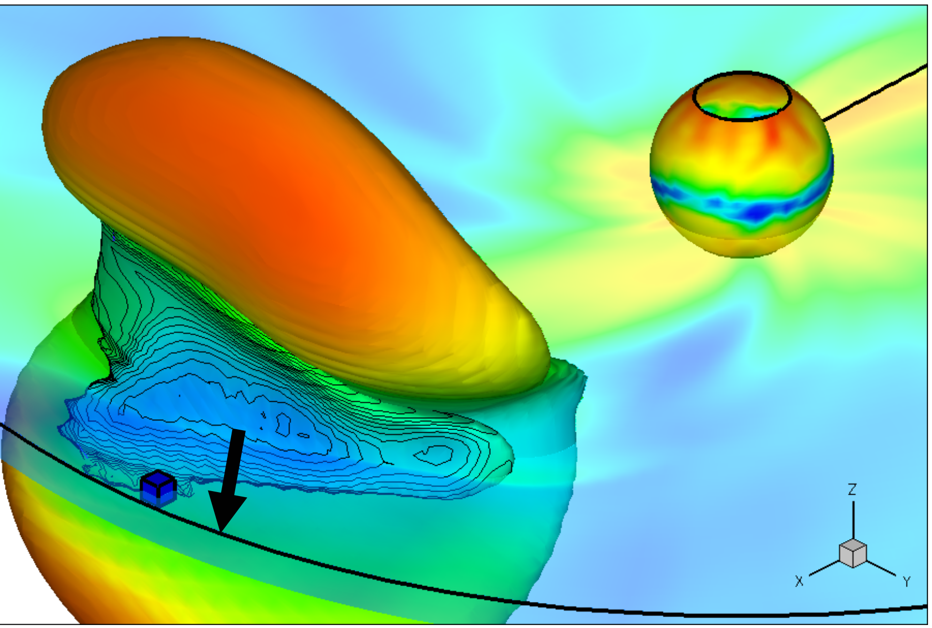

Earth : Interaction region followed by shock and CME (*not observed*)

Earth : Shock and CME (*observed but shock front is radial*)

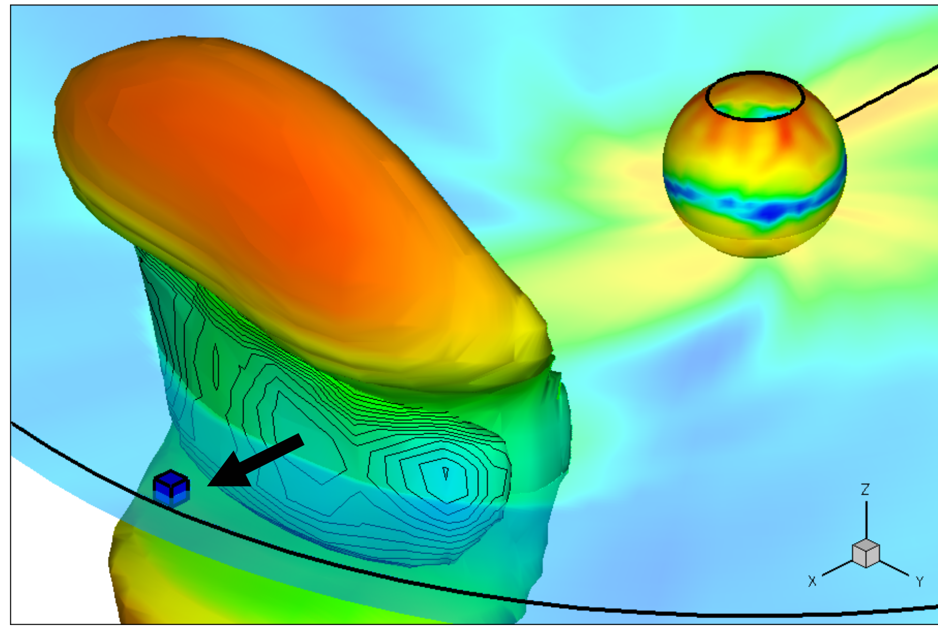
# Effect of Fast-Stream Evolution

[ *WSA maps – Nick Arge* ]

Case A




Case B




Earth : Interaction region followed by shock and CME (*not observed*)

Earth : Shock and CME (*observed but shock front is radial*)

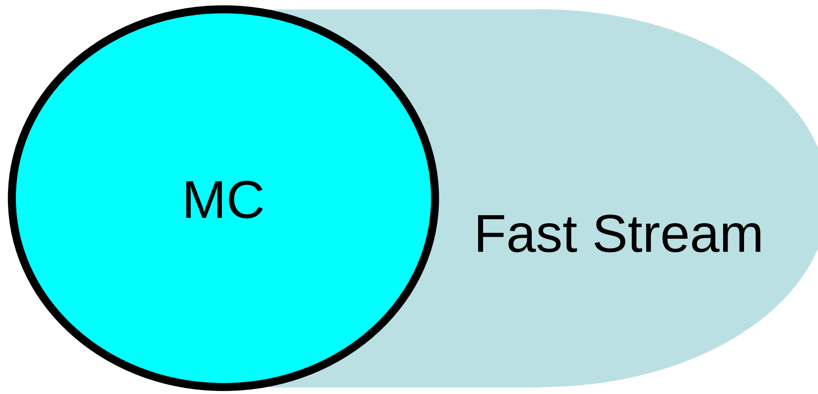
# CMEs Cone Model Parameters

| | Date | Time | Lat (deg) | Lon (deg) | Width (deg) | Speed (km/s) |
|---|---|---|---|---|---|---|
| CME-1 | 1998-04-29 | 21:25 | N09 | E04 | 52<br>111 | 953<br>1134<br>1374 |
| CME-2 | 1998-05-01 | 07:36 | S05 | E04 | 54<br>40 | 847<br>1427<br>585 |
| CME-3 | 1998-05-02 | 14:09 | N02 | W06 | 57<br>39 | 484<br>1612<br>542 |
| CME-4 | 1998-05-02 | 19:55 | N16 | E15 | 53<br>sym | 698<br>sym<br>938 |

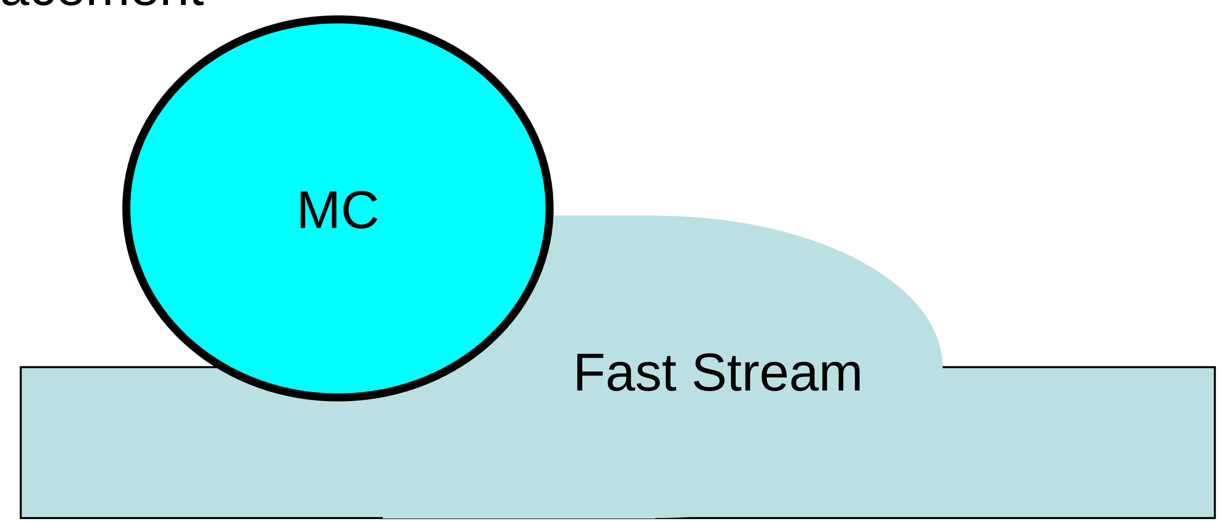
CMEs fitted by: Liu (2005), Michalek (2003) and linear POS fit (CME list)

# Magnetic Cloud and Fast Stream

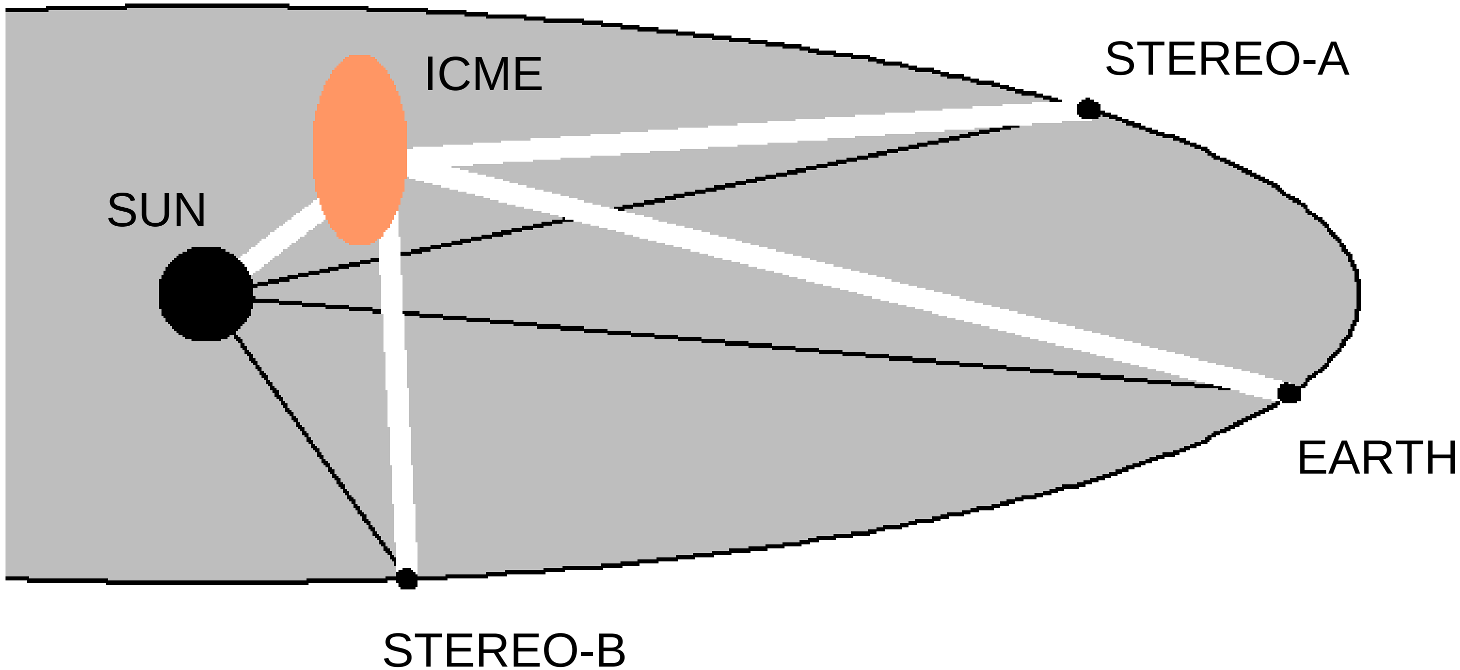
Post-Eruptive Flow



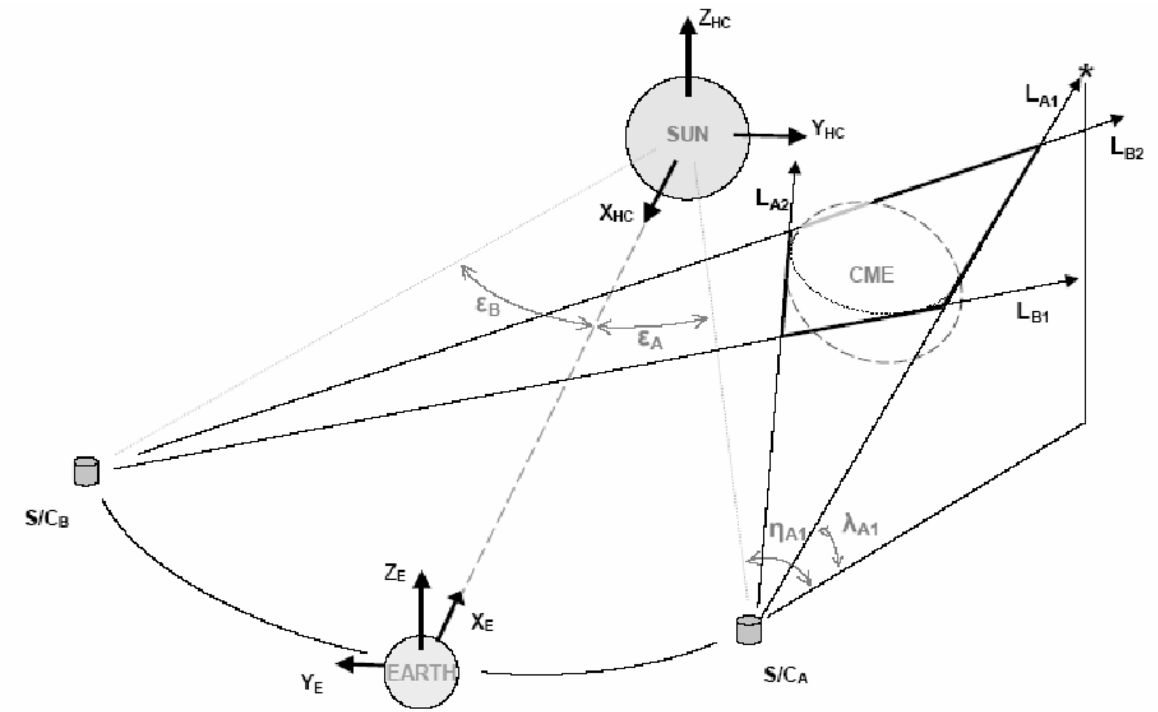

Sudden Stream Displacement

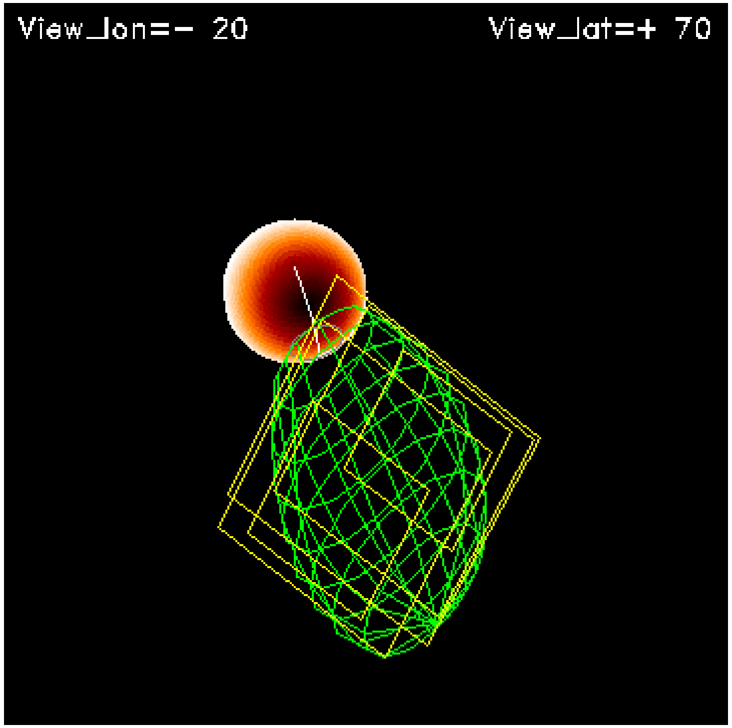


# Increasing Accuracy of Cone Model Specification



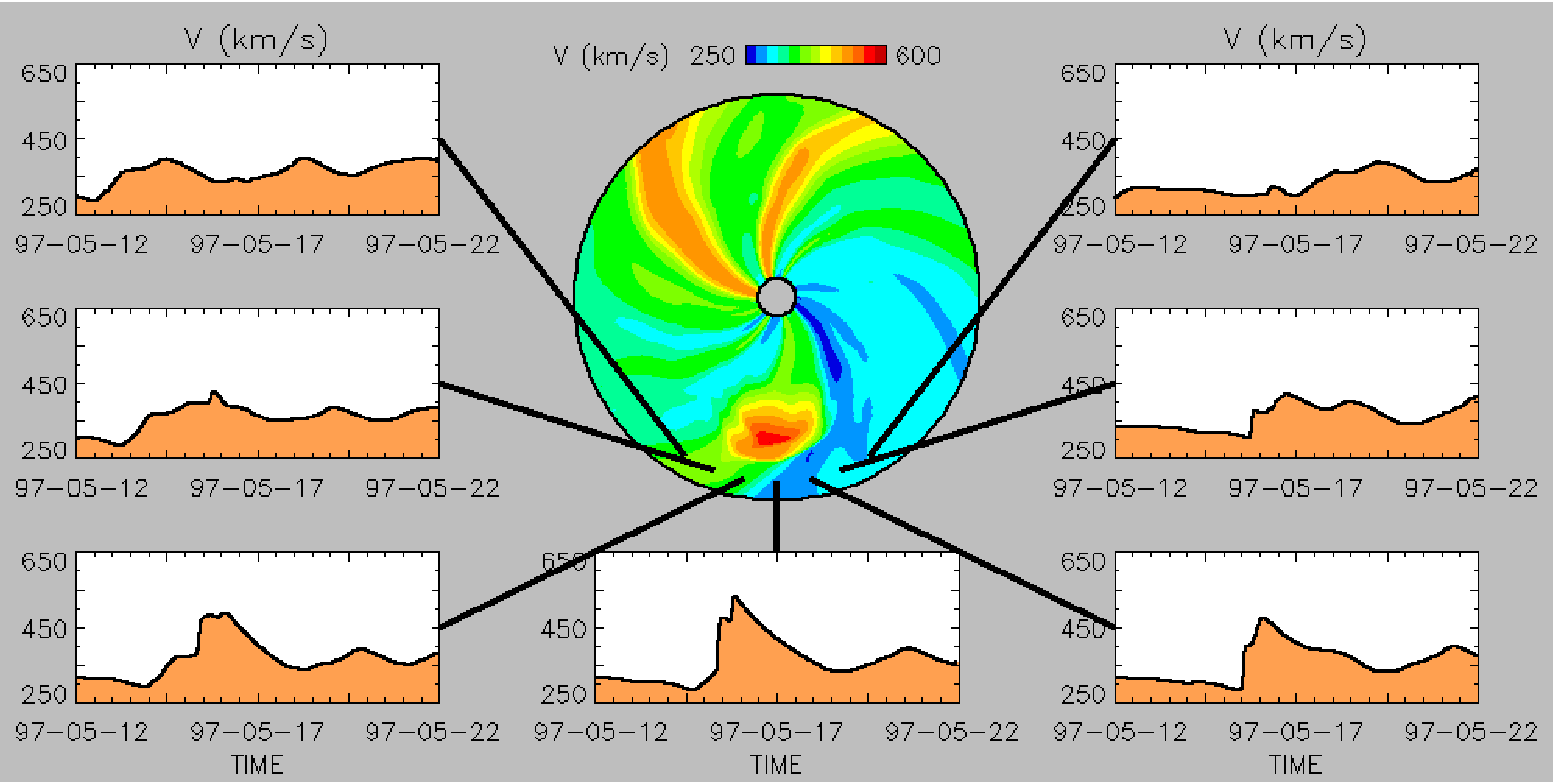
# Geometric Localization of STEREO CMEs



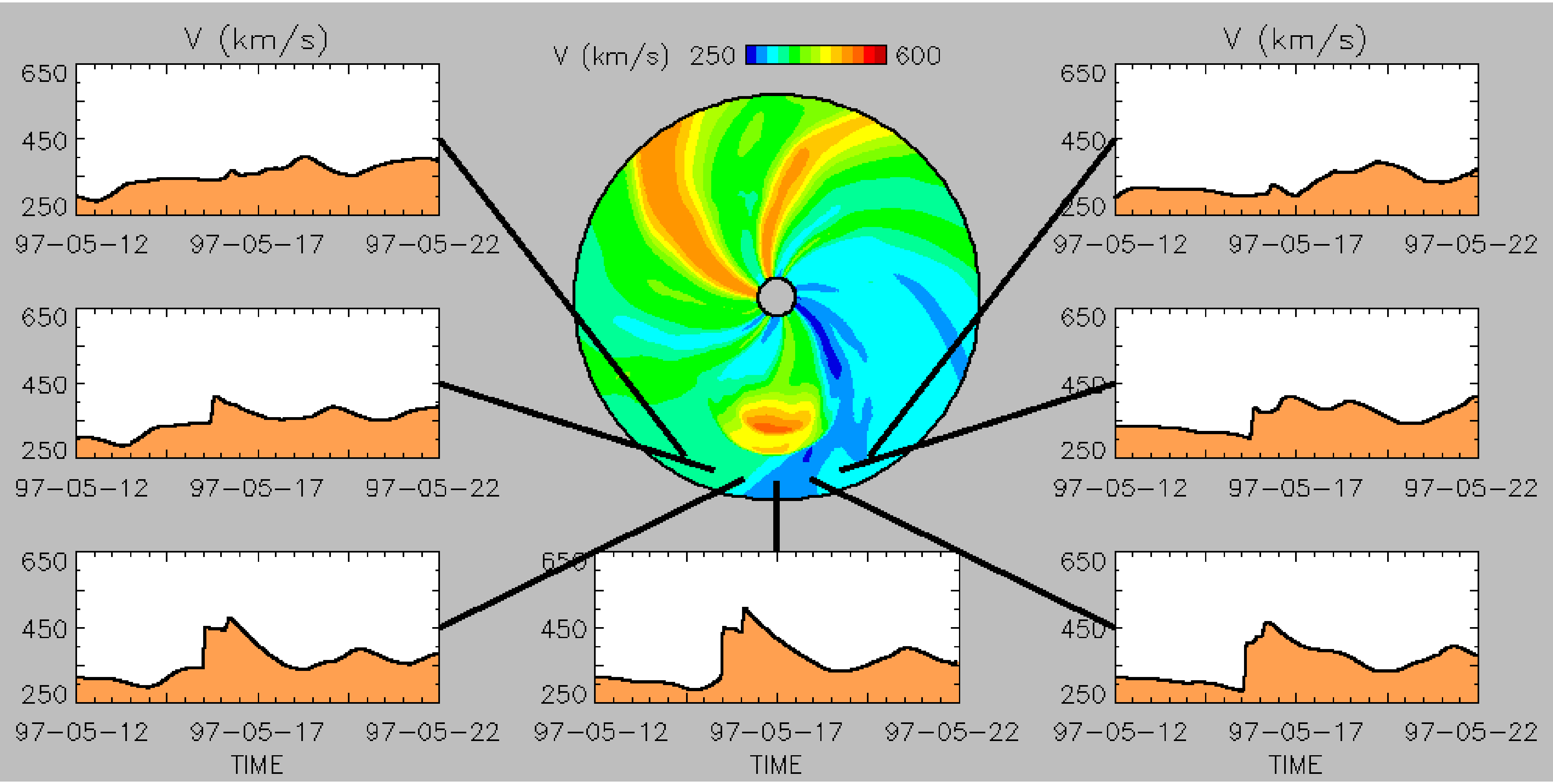




[ *Pizzo and Biesecker*, 2005 ]

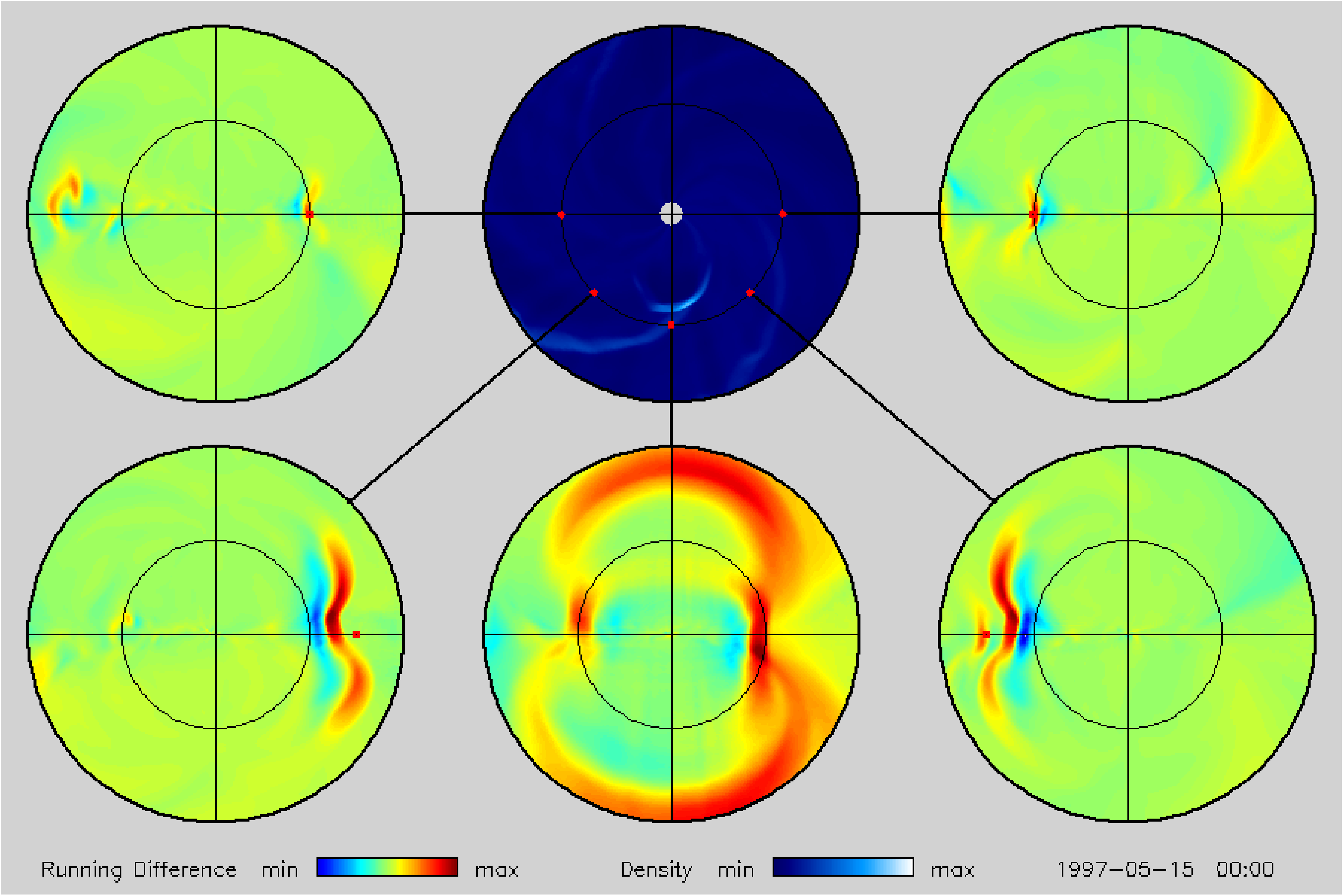
# Improving Validation of Cone Models – A



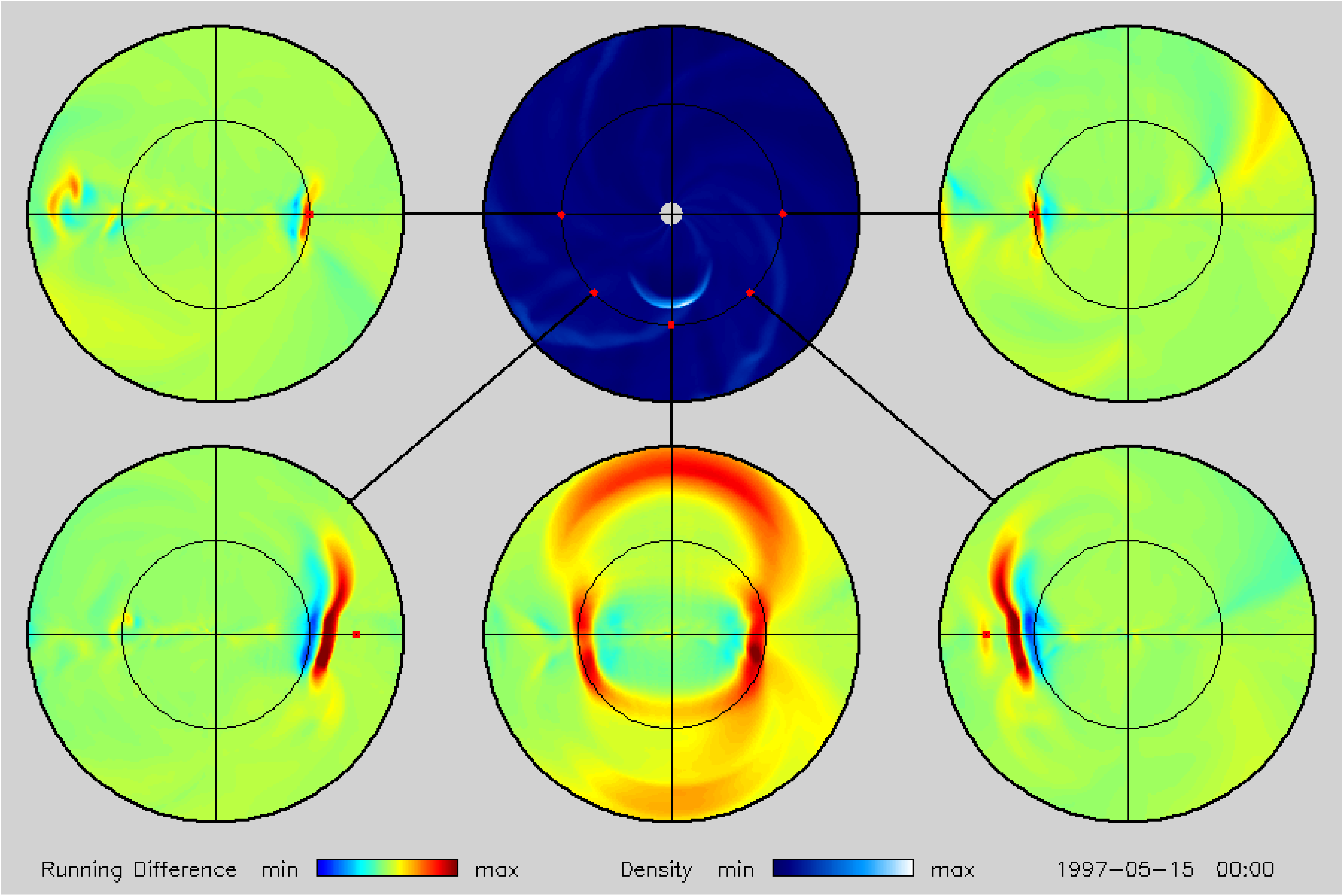
# Improving Validation of Cone Models – B



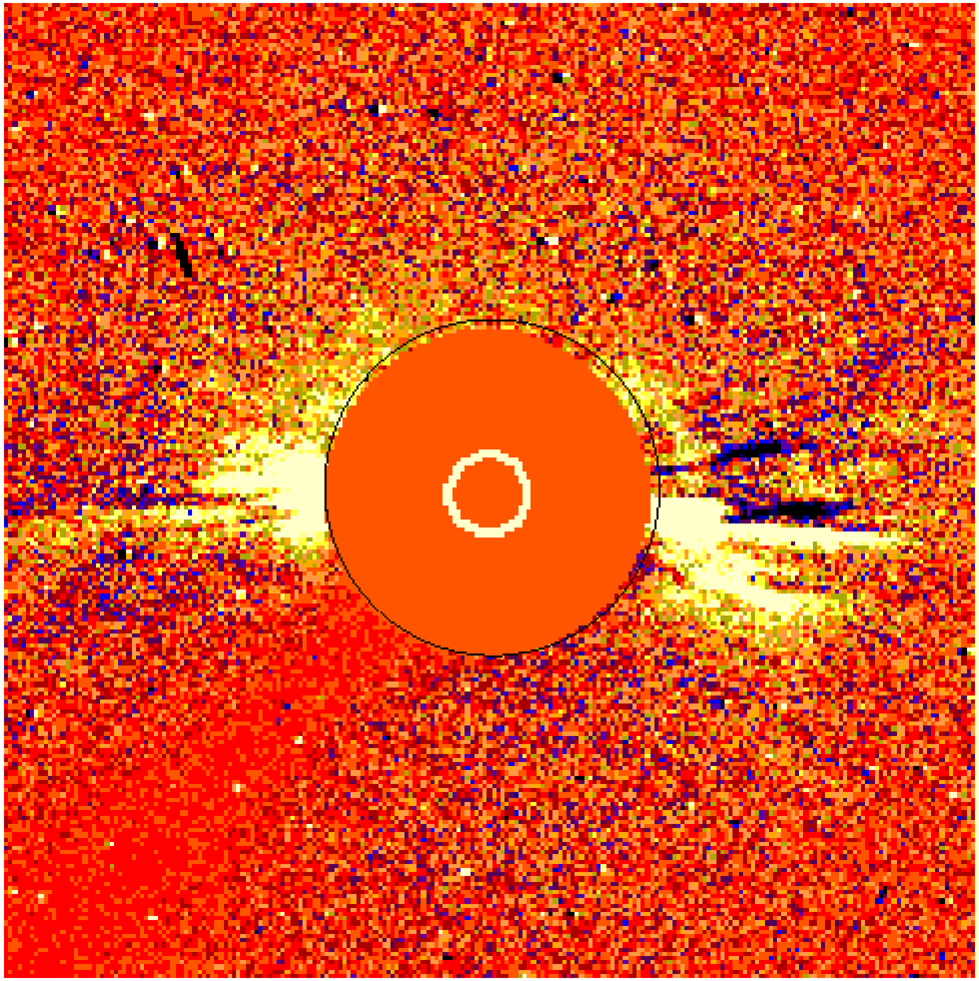
# Multi-Perspective Remote Observations – A



# Multi-Perspective Remote Observations – B

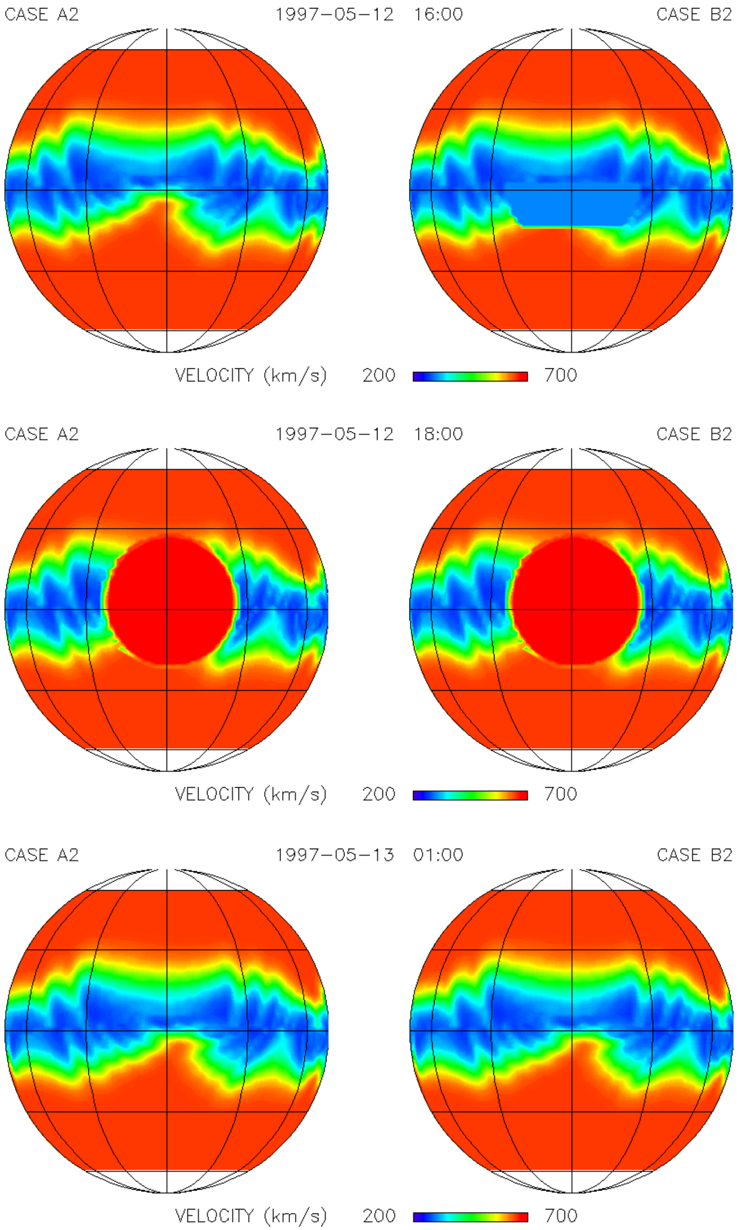


# May 12, 1997 Halo CME



# Fast-Stream Evolution

Case A Case B




Ambient state before the CME launch

Disturbed state during the CME launch

Ambient state after the CME launch

# Cone Model Features

| | Feature |
|---|---|
| Plus | ▪ observationally based (main causal geo-effectivity link)<br>▪ simple specification (with direct control of consequences)<br>▪ numerically robust (beyond supercritical point)<br>▪ slightly more accurate than empirical formulae (realistic solar wind)<br>▪ global context (transient and background structures)<br>▪ interplanetary shocks and IMF line connectivity (shock-observer) |
| Minus | ▪ absence of internal magnetic structure<br>▪ initial effect on surrounding solar wind<br>▪ reverse shock<br>▪ shock stand-off distance<br>▪ internal profile of parameters |

<u>Cone models</u> – Intermediate solution until more realistic coronal models will enable routine application

# Specification of Parameters

| | Observation-Based Parameters | Free Parameters |
|---|---|---|
| Cone Model | ▪ latitude of cone axis<br>▪ longitude of cone axis<br>▪ radius of cone<br>▪ cone speed<br>▪ time when cone at the inner heliospheric boundary | ▪ cone mass density<br>▪ cone temperature<br>▪ (profile of parameters) |
| Flux Rope | ▪ (orientation of flux rope axis) | ▪ separation of legs<br>▪ width of legs<br>▪ winding angle<br>▪ field strength<br>▪ (profile of parameters)<br>▪ (blending with external field) |

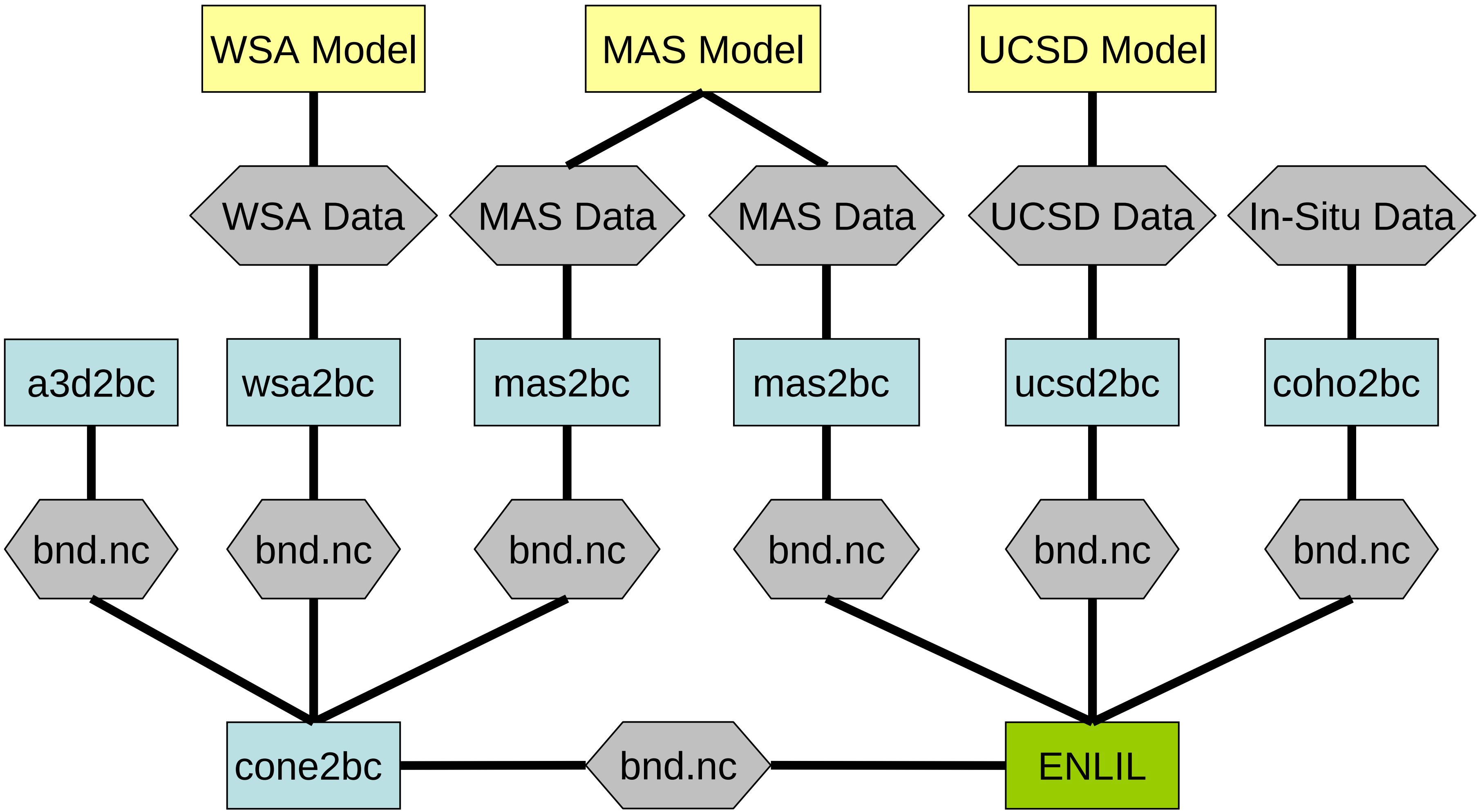
<u>Too many free parameters</u> – while observed events may be reconstructed from case to case, their initialization cannot be automatized

# Observed Ejecta Signatures and Shock Stand-off Interval

| Signature | Duration (h) | Stand-off (h) | Reference |
|---|---|---|---|
| MC fit | 15 | 8:45 | *Webb et al. (2000)* |
| MC fit | 16 | 7:45 | *Watari et al. (2001)* |
| MC fit | 14 | 8:36 | *Ivanov et al. (2003)* |
| MC fit | 17 | 7:45 | *Lepping et al. (2003)* |
| Plasma | -- | 8:35 | *Webb et al. (2002)* |
| Field rotation | 15 | 7:45 | *Berdichevsky et al. (2002)* |
| Strong field | 19 | 3:45 | *Berdichevsky et al. (2002)* |
| Low T_p | 17 | 5:45 | *Berdichevsky et al. (2002)* |
| Low beta | 14 | 8:45 | *Berdichevsky et al. (2002)* |
| N_alpha/N_p | 22 | 3:45 | *Berdichevsky et al. (2002)* |

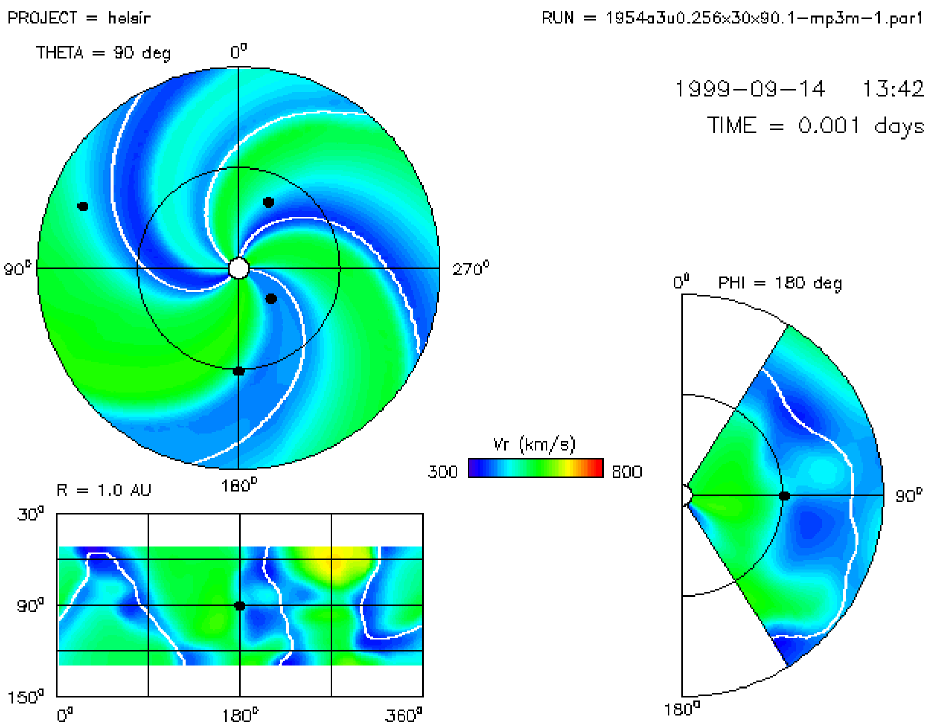
Various interpretations of single-point, in-situ observations

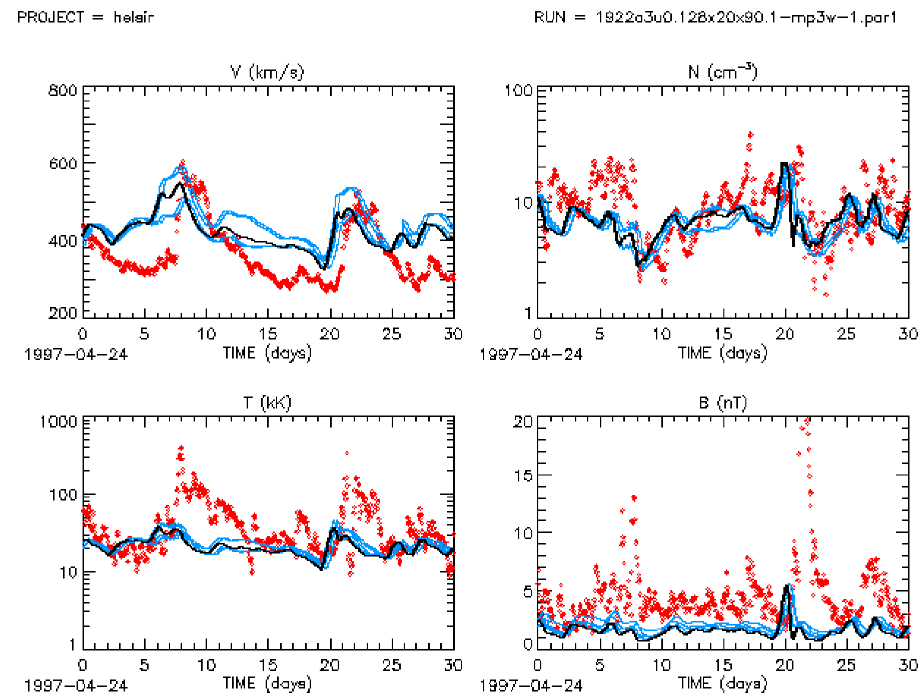
# Driving Heliospheric Computations at CCMC




- Currently, there are three models (yellow) that can be used to drive ENLIL (green)
- Computational system shares data sets (grey) and uses couplers (blue)

# 3-D Values at Time Level – tim.****.nc

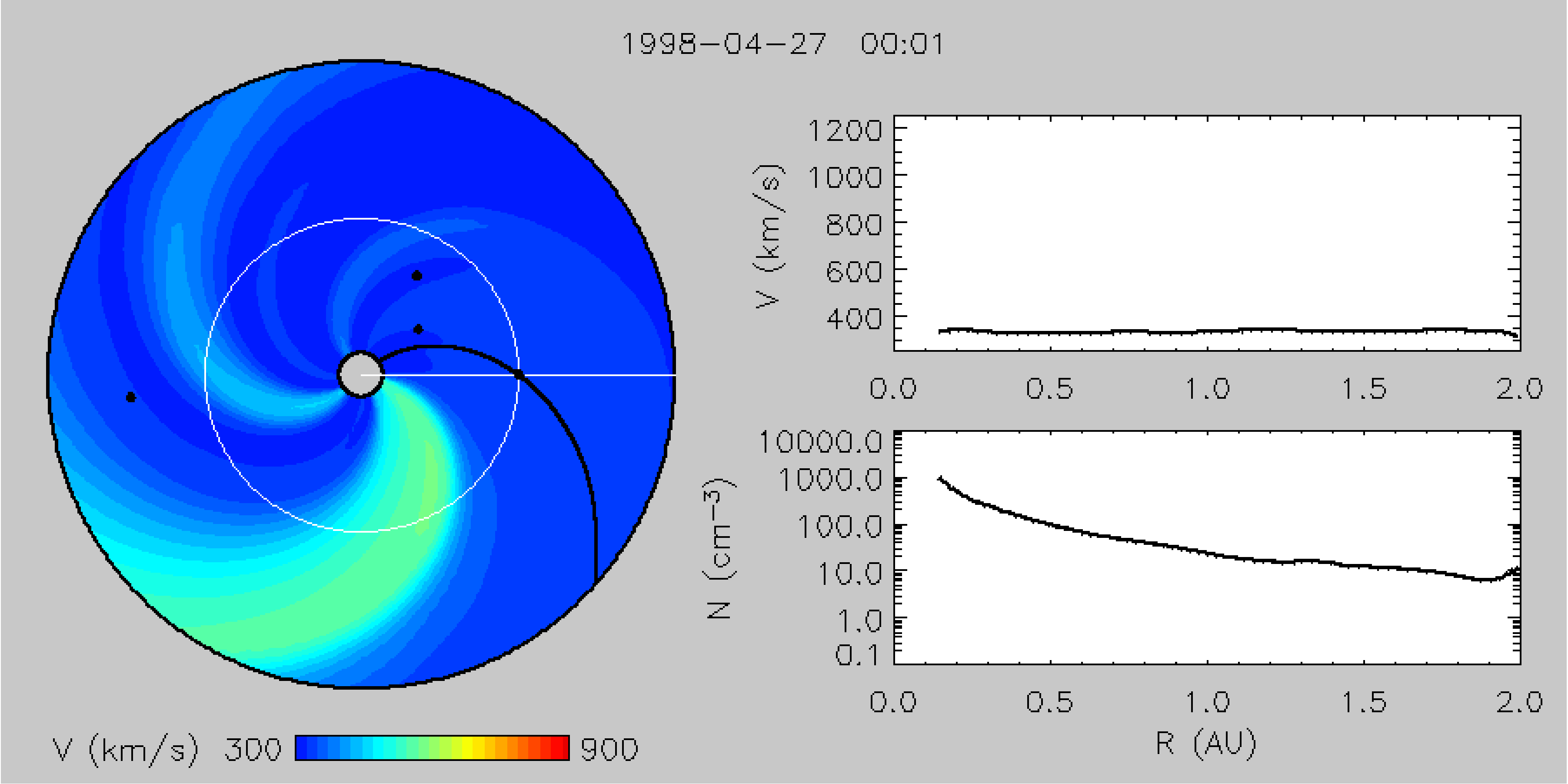


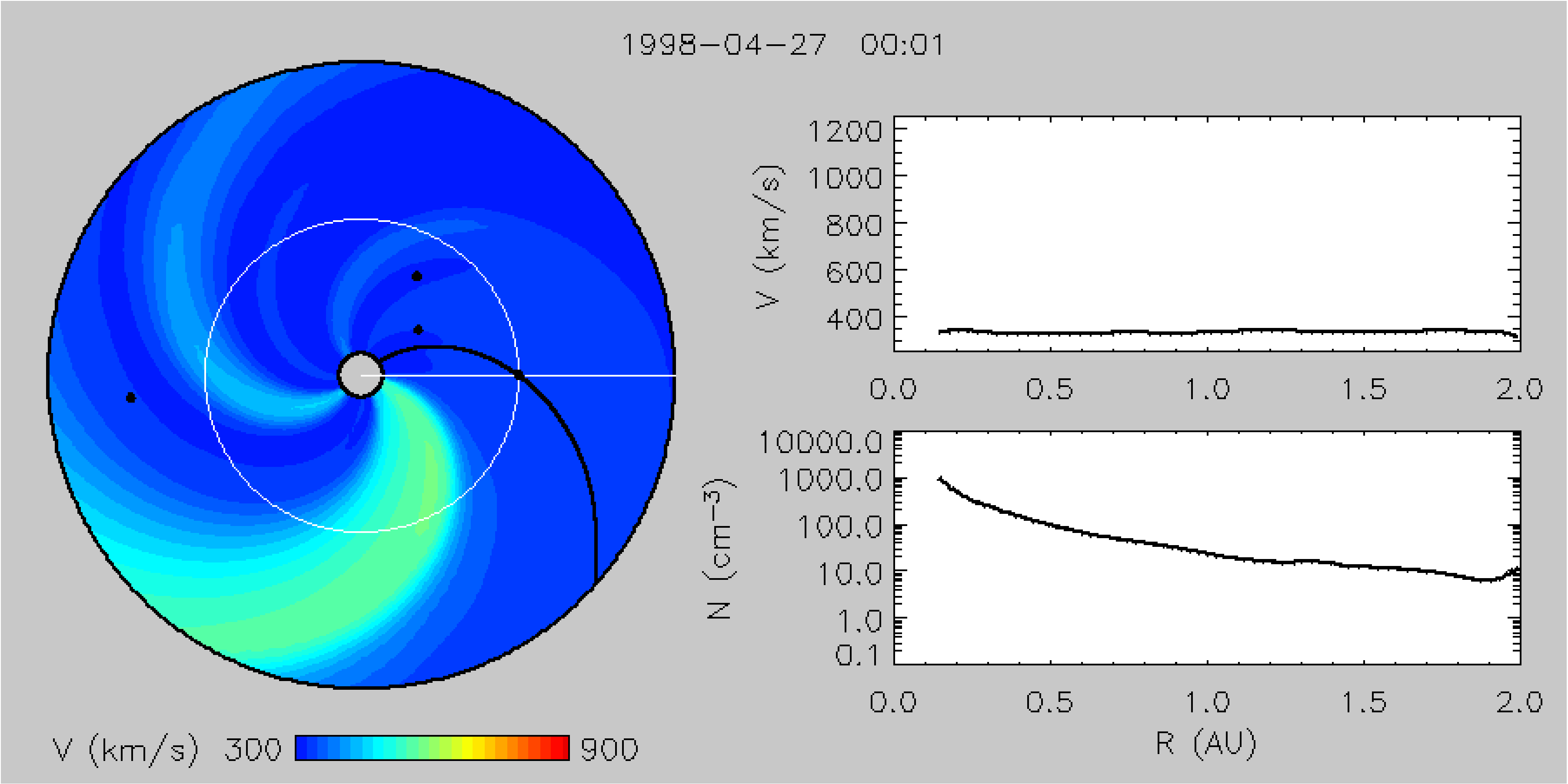

- Values are shown on various slices passing through Earth
- Current sheet is shown by white line
- Planet positions are shown by black spheres
- Calendar data and physical time correspond to file record number (****)

- Values are shown at Earth position (thick black line) and nearby grid points (light blue lines).
- Observations from NASA-OMNIweb are shown by red dots.
- Viewing evolution at nearby points can reveal effect of numerical resolution and can provide inclination of structures for geospace models

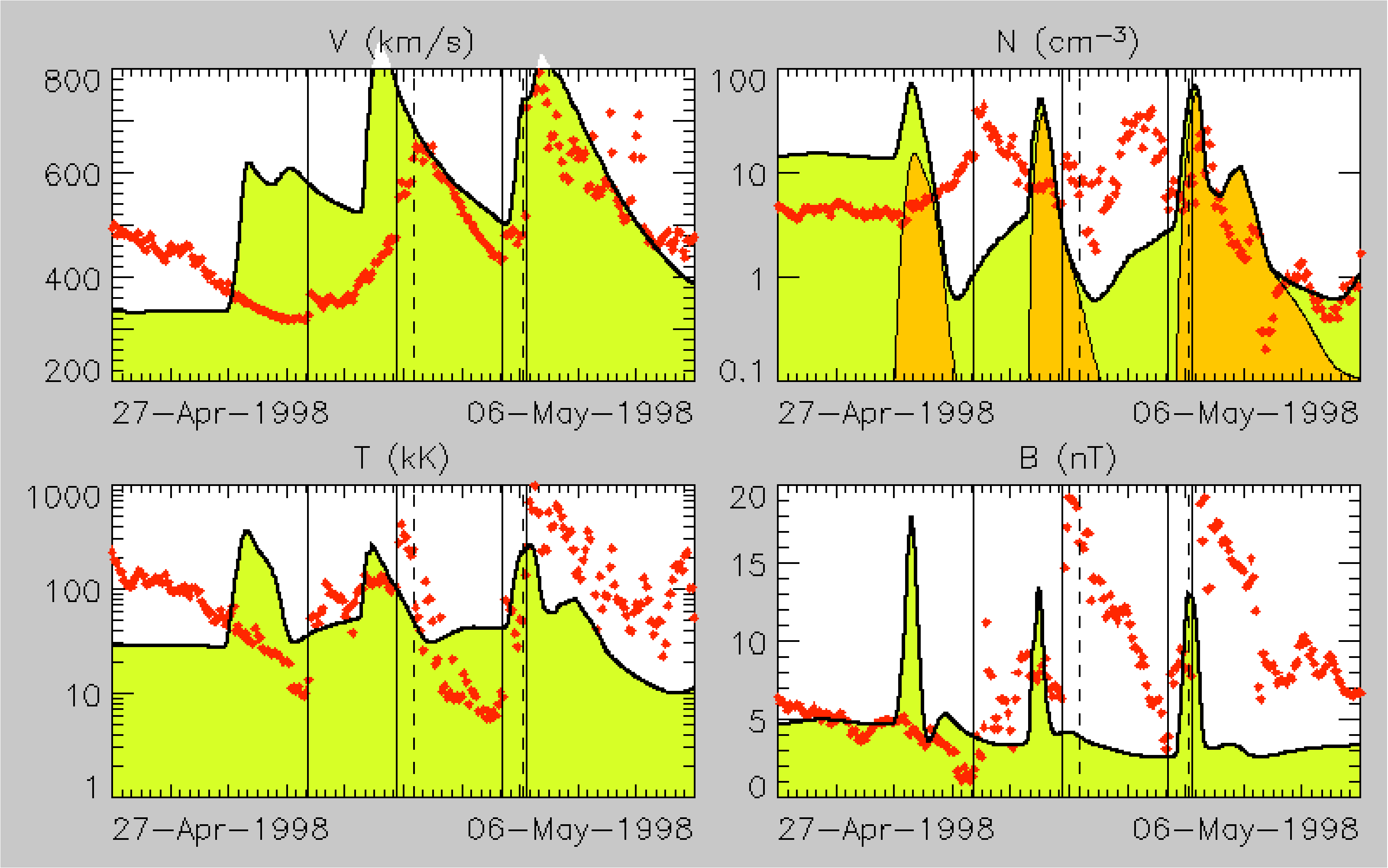
# Initial Ambient State



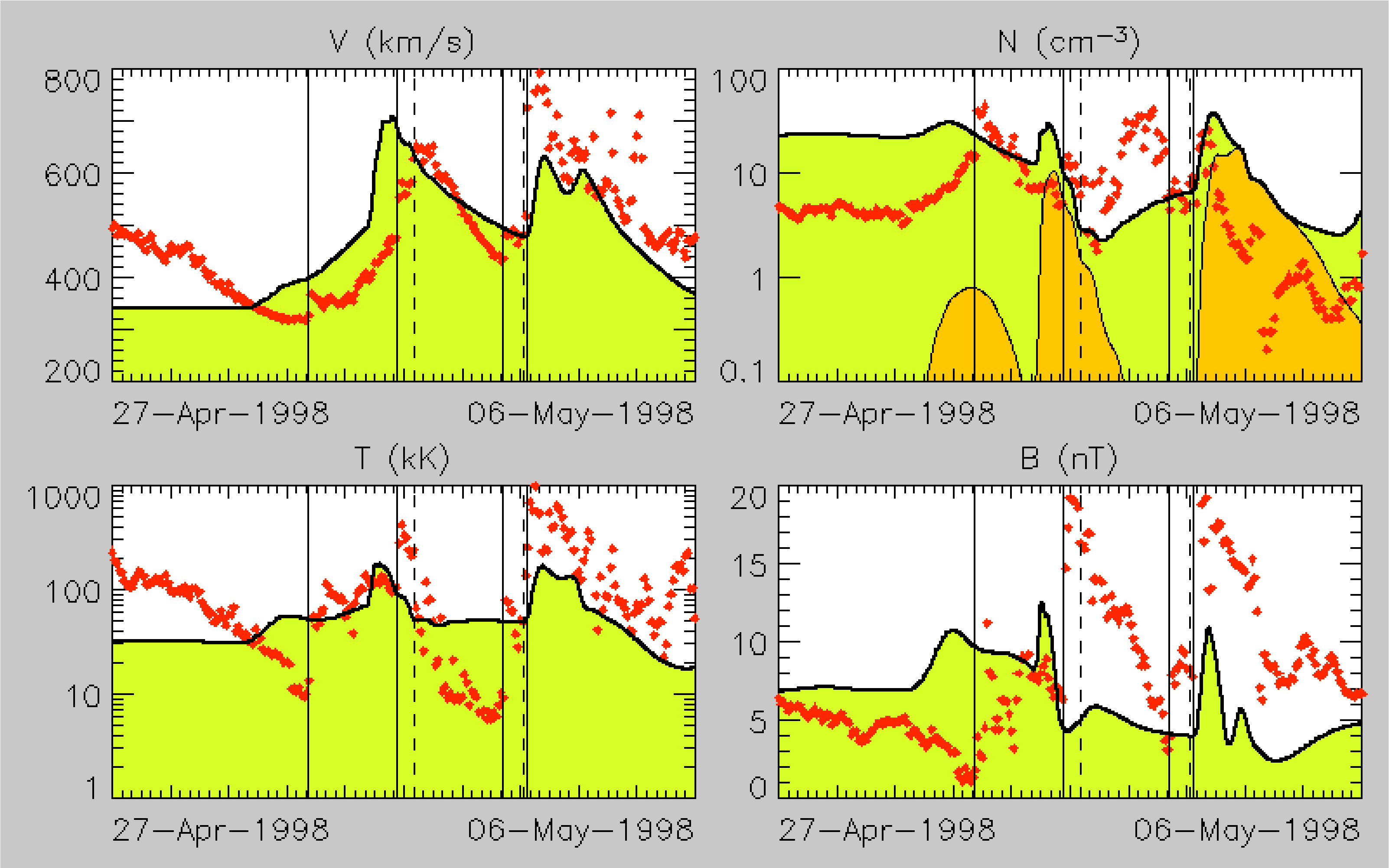
# Evolution of Interplanetary Disturbances



# May 1998 – CMEs fitted by Liu & al.



# May 1998 – CMEs fitted by Liu & al. – 1/2



# May 1998 – CMEs fitted by Michalek & al.