

Heliospheric Simulations of the SHINE Campaign Events

Dusan Odstrcil^{1,2}

¹University of Colorado/CIRES, ²NOAA/Space Environment Center

SHINE Workshop, Big Sky, MT, June 27 – July 2, 2004

Collaborators

- Nick Arge – AFRL, Hanscom, MA
- Chris Hood – University of Colorado, Boulder, CO
- Jon Linker – SAIC, San Diego, CA
- Rob Markel – University of Colorado, Boulder, CO
- Leslie Mayer – University of Colorado, Boulder, CO
- Vic Pizzo – NOAA/SEC, Boulder, CO
- Pete Riley – SAIC, San Diego, CA
- Marek Vandas – Astronomical Institute, Prague, Czech Republic
- Xuepu Zhao – Stanford University, Stanford, CA

Supported by AFOSR/MURI and NSF/CISM projects

Outline

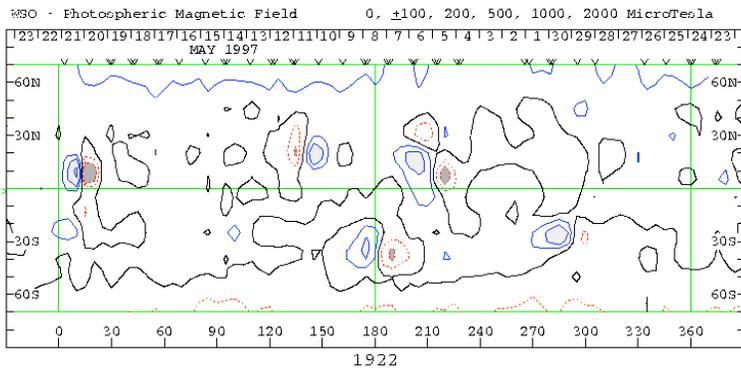
- (A) Numerical Modeling
- (B) 21 April 2002 and 24 August 2002 Event
- (C) 12 May 1997 Event

A.

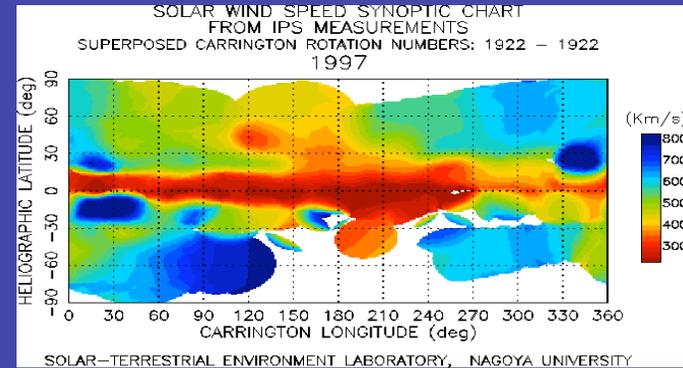
Numerical Modeling

Observations – 1997 May 12 Event

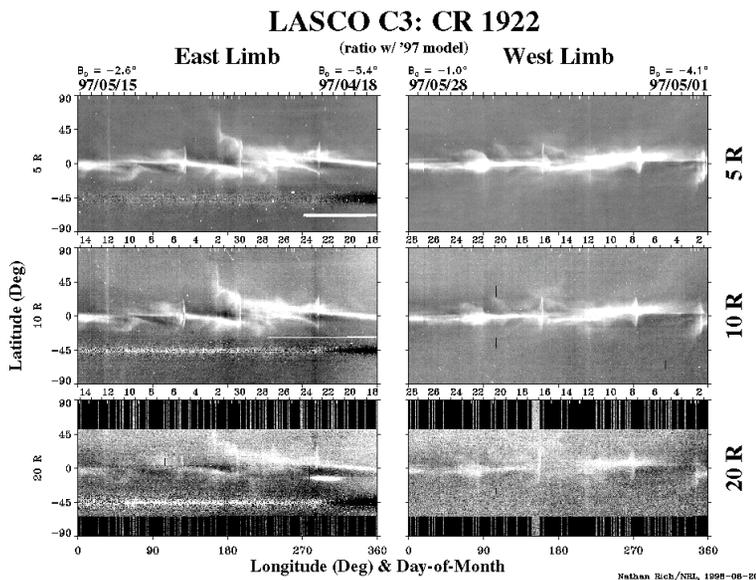
Photospheric magnetic field



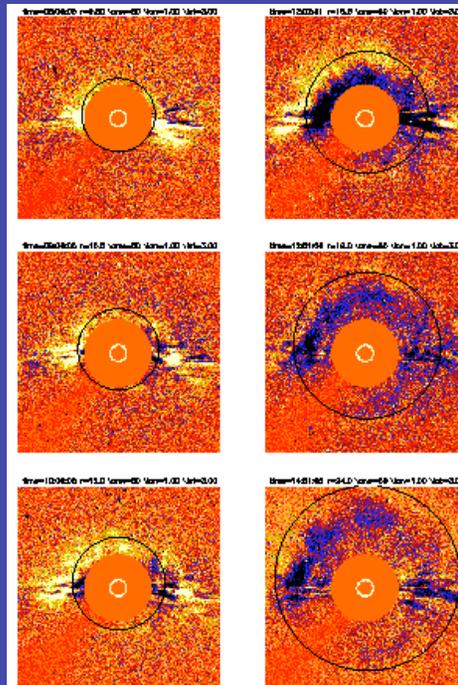
IPS Observations



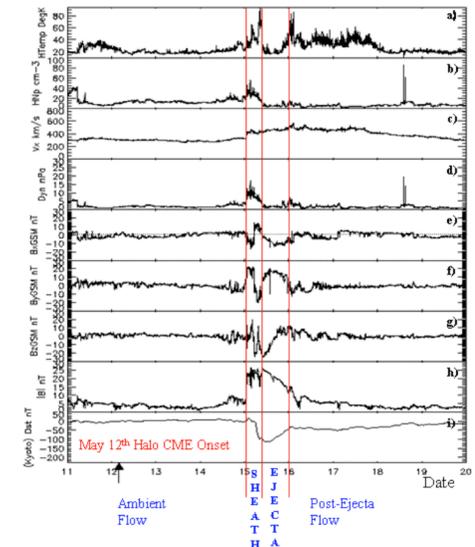
Coronal density at limbs



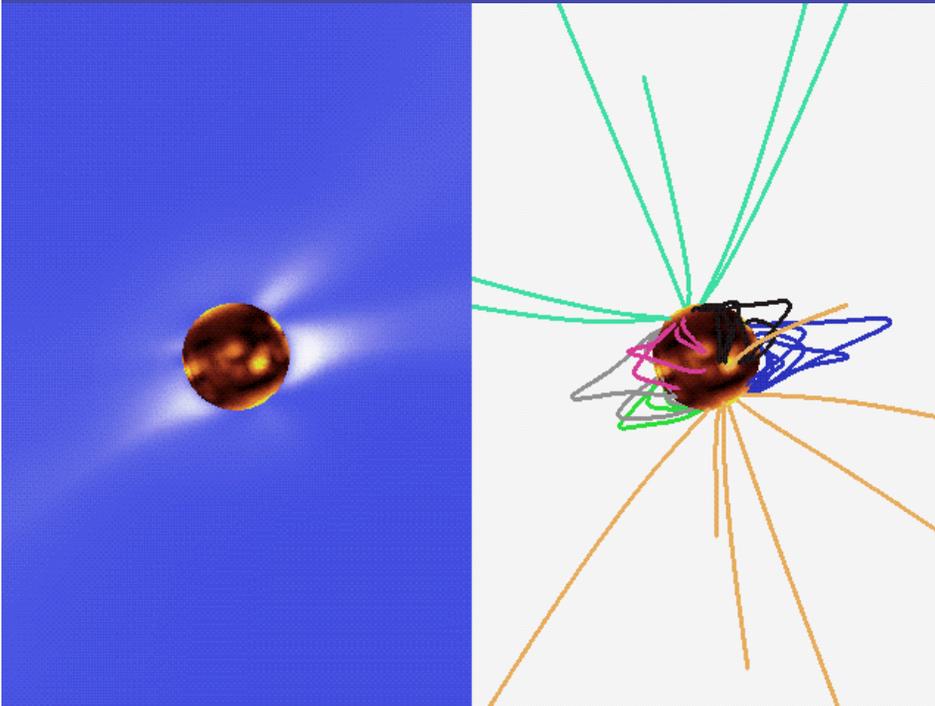
Halo-CME



Parameters at Earth

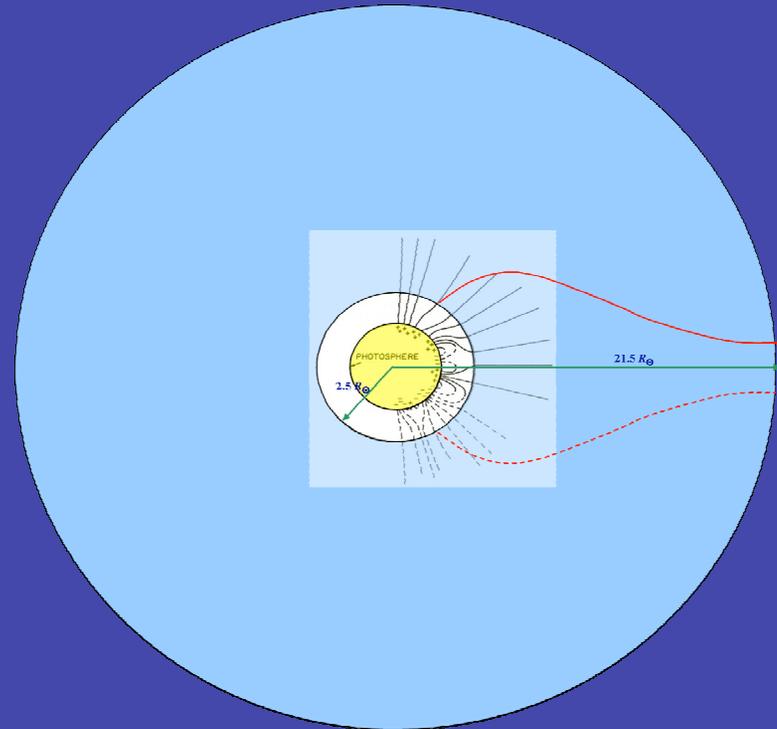


Ambient Solar Wind Models



SAIC 3-D MHD steady state coronal model based on photospheric field maps

[SAIC maps – Pete Riley]



CU/CIRES-NOAA/SEC 3-D solar wind model based on potential and current-sheet source surface empirical models

[WSA maps – Nick Arge]

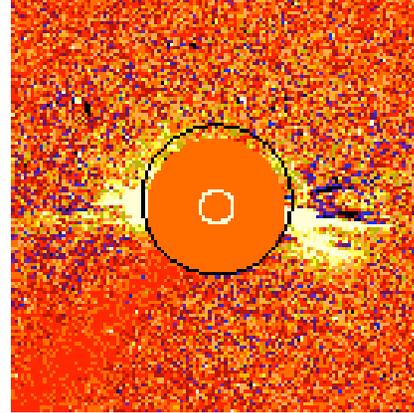
CME Cone Model

Best fitting for May 12, 1997 halo CME

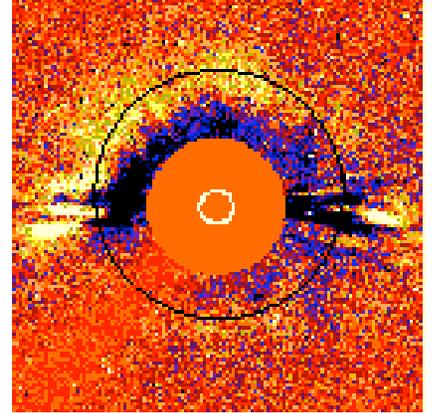
- latitude: N3.0
- longitude: W1.0
- angular width: 50 deg
- velocity: 650 km/s at 24 R_S
(14:15 UT)
- acceleration: 18.5 m/s²

[Zhao et al., 2001]

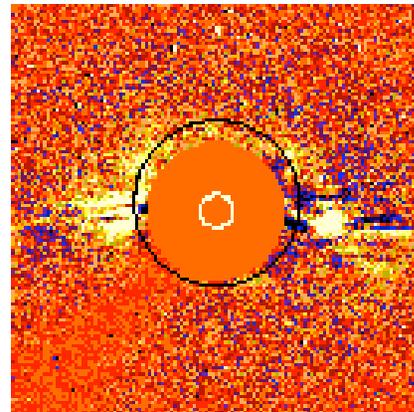
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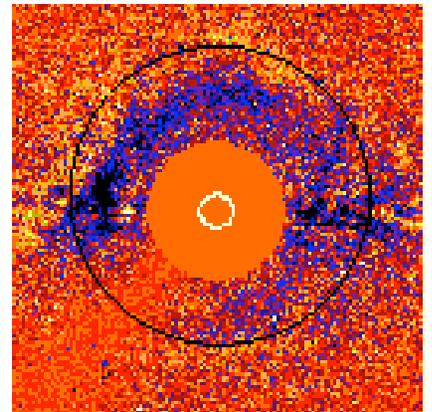
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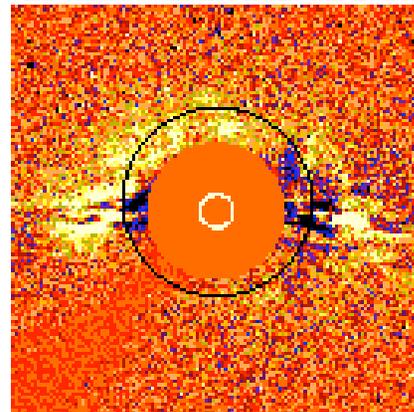
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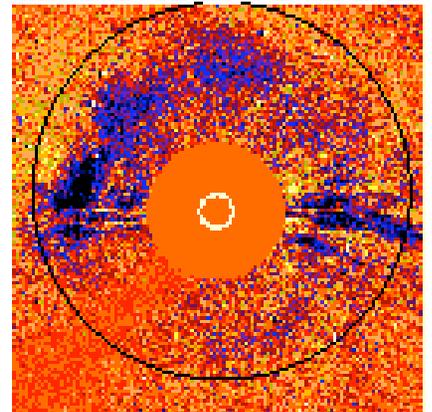
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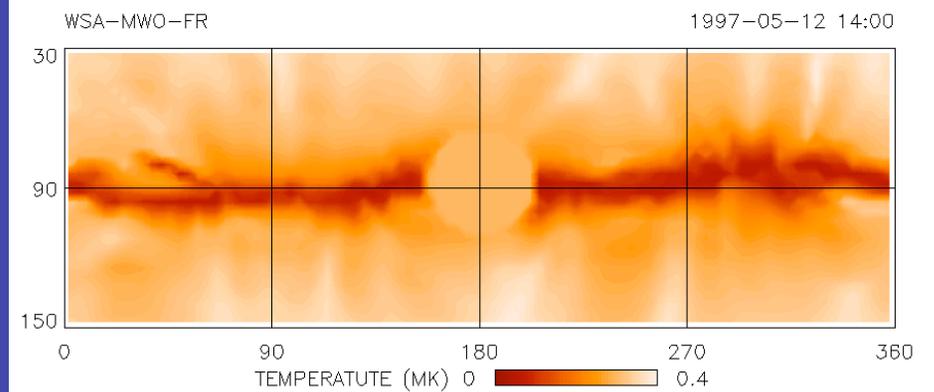
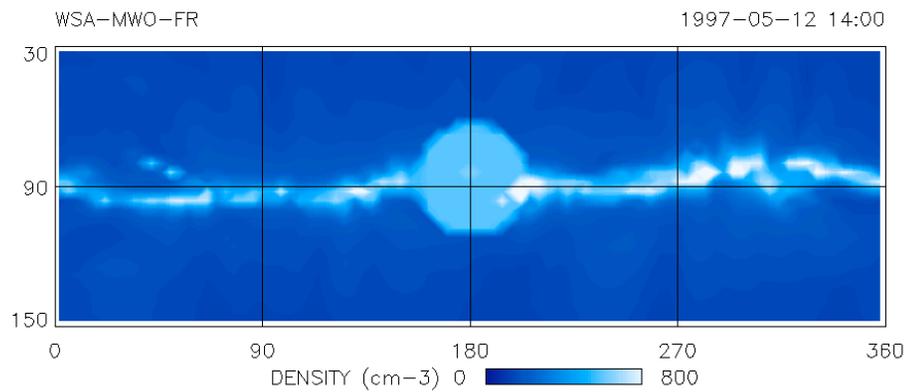
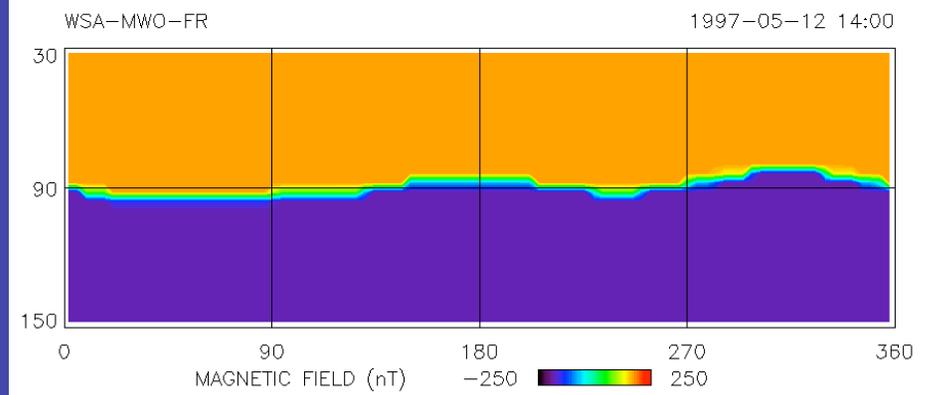
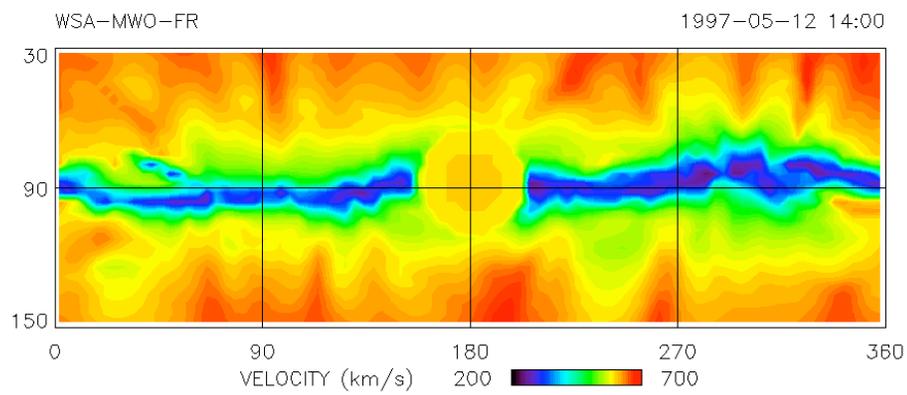
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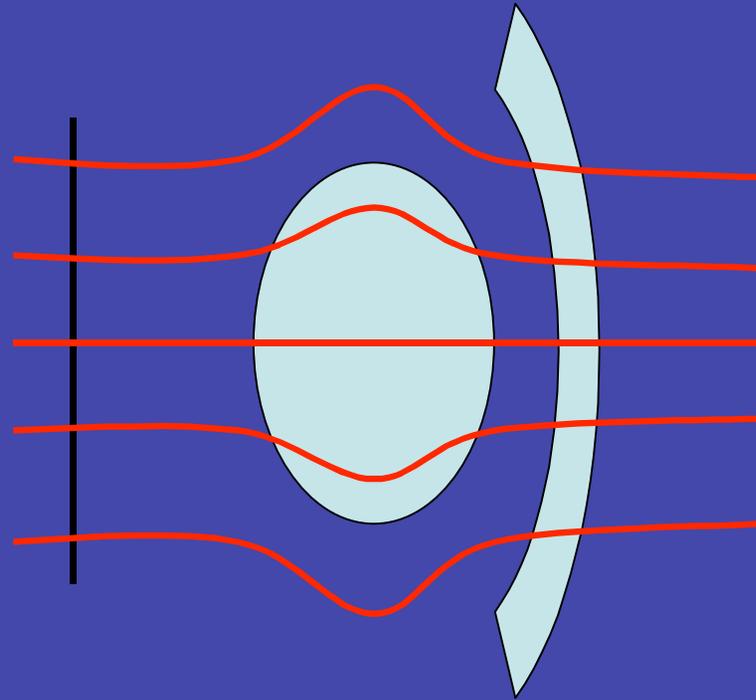
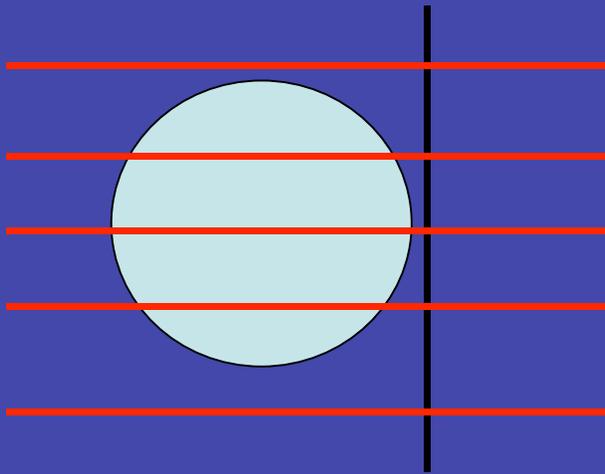
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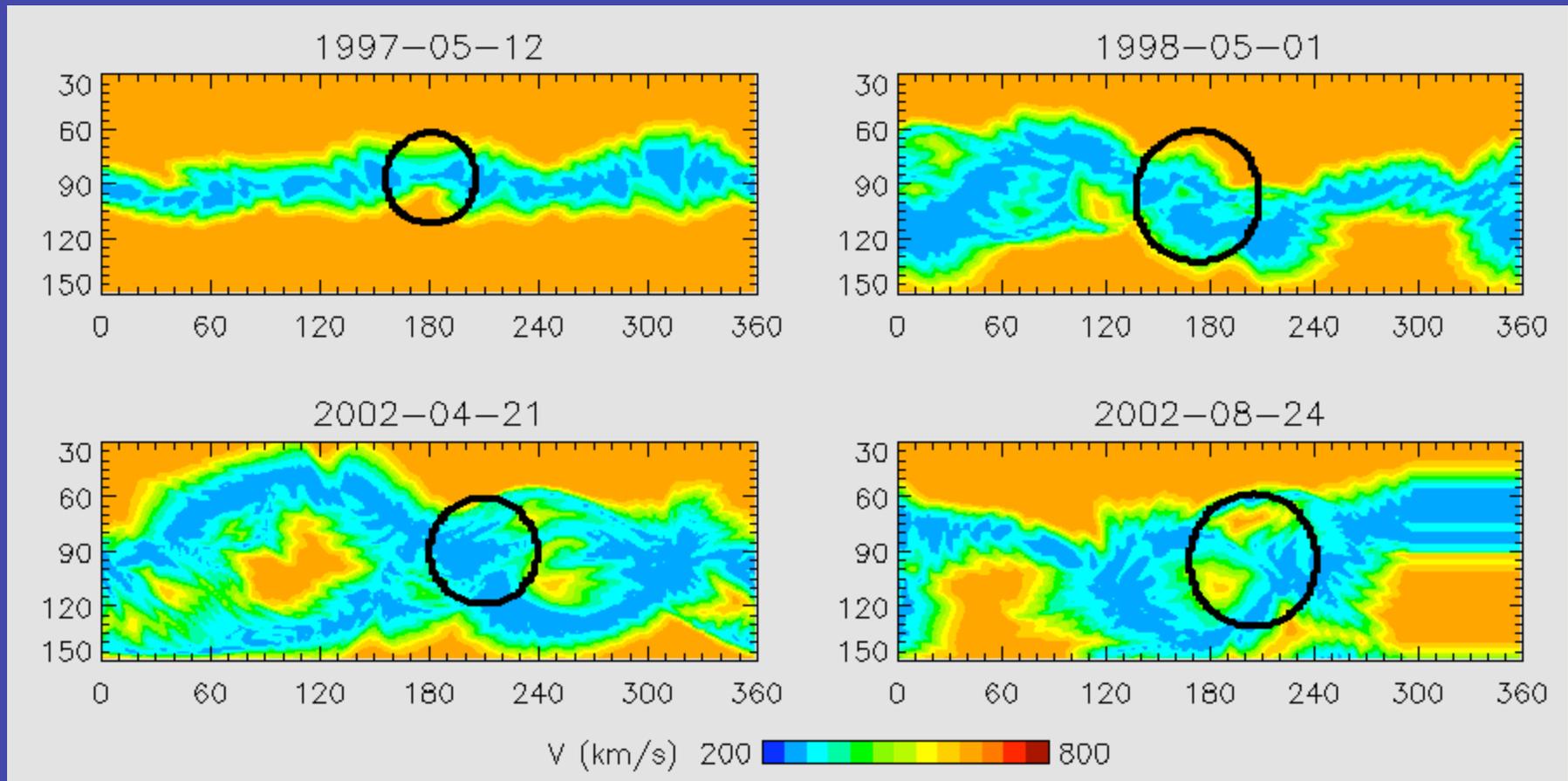
Time-Dependent Boundary Conditions



Transient Disturbances

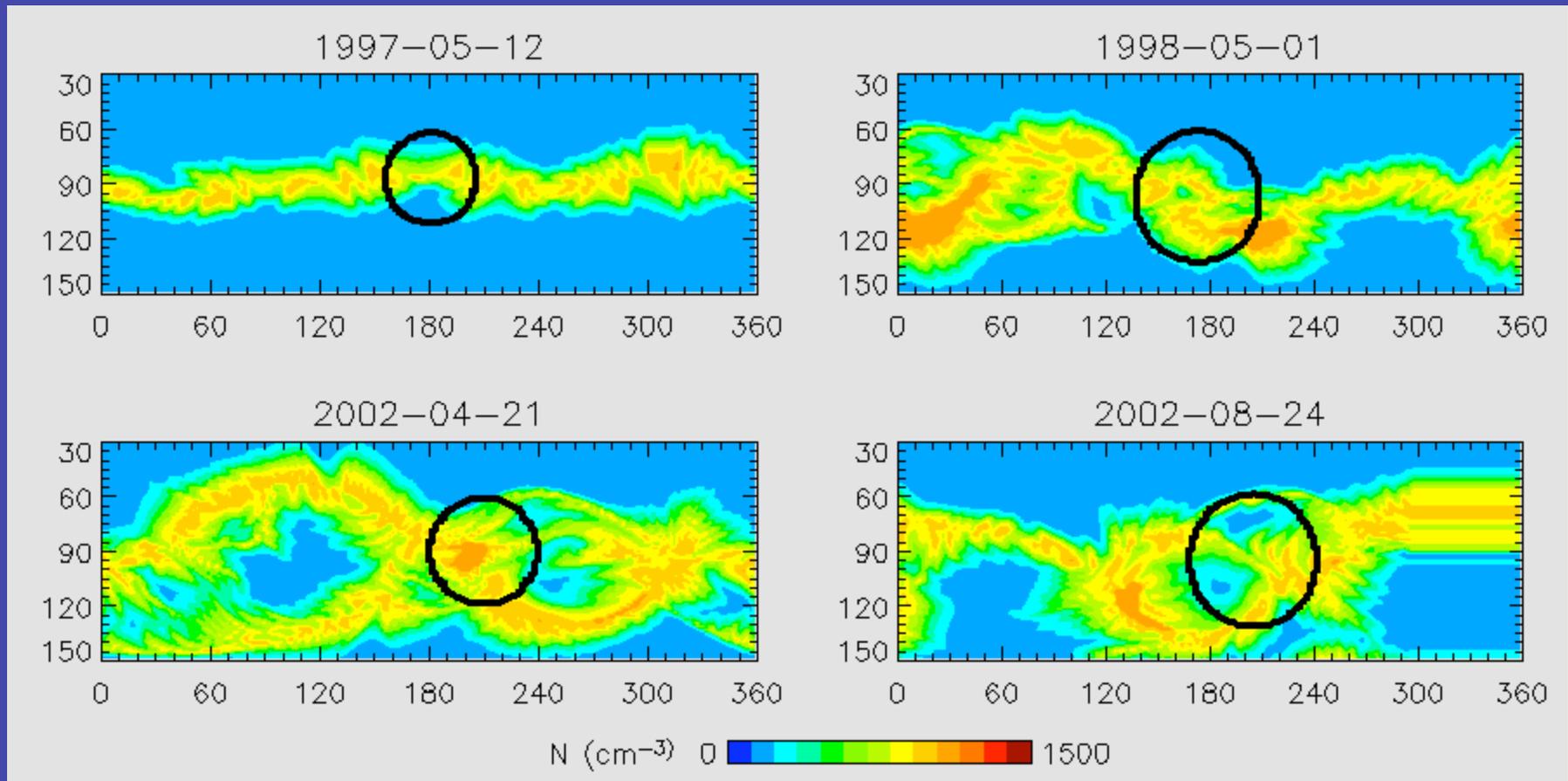


Outflow Boundary Conditions



ICME is launched at the streamer belt

Outflow Boundary Conditions



ICME is launched at the streamer belt

B.

21 April 2002 and 24 August 2002 Events

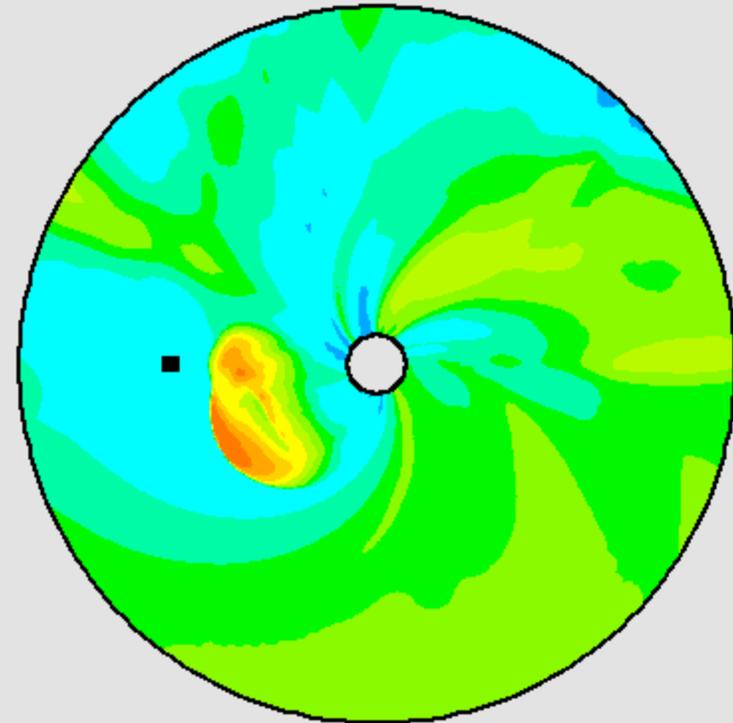
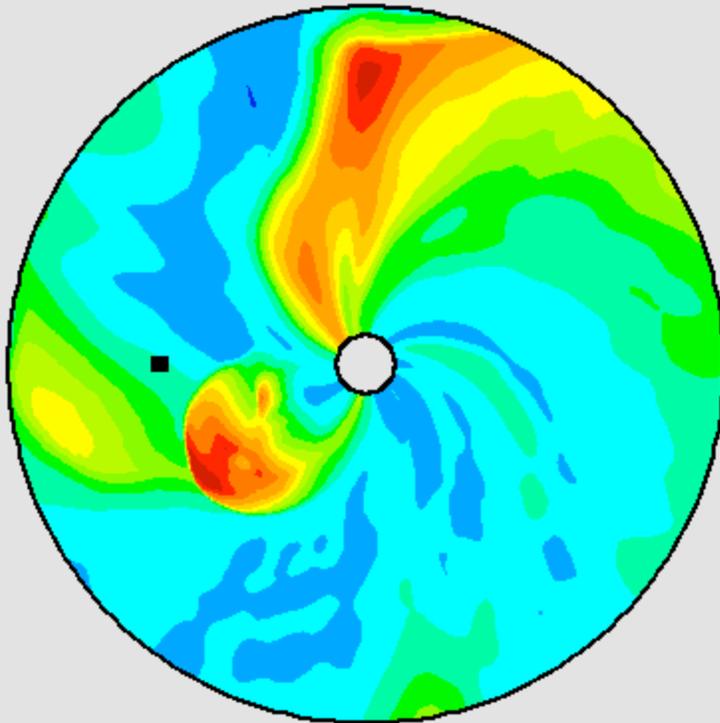
2002 April 21 and 2002 August 24 Events

	2002-04-21 Event	2002-08-24 Event
Flare Characteristics		
Flare Location (deg)	S15, W84	S02, W81
Flare Size	X1.5/1F	X3.1/1F
Cone Model		
CME Location (deg)	N00, W30	N05, W25
CME Diameter (deg)	59	73
CME Speed (km/s)	2700	1500
CME Timing (UT)	03:30 – 04:30	04:00 -- 07:30

Interplanetary Disturbances

2002-04-23 00:00

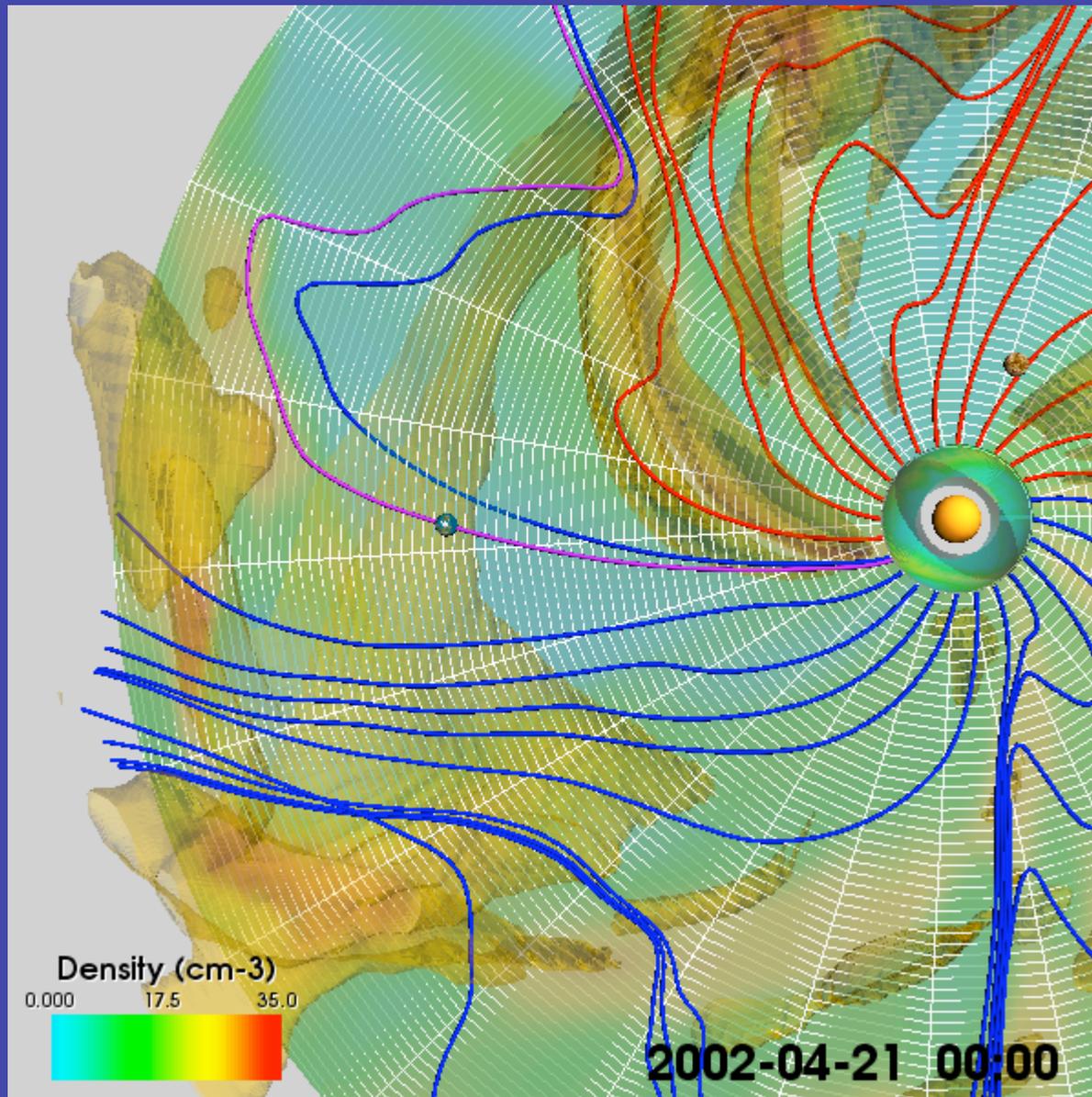
2002-04-23 00:00



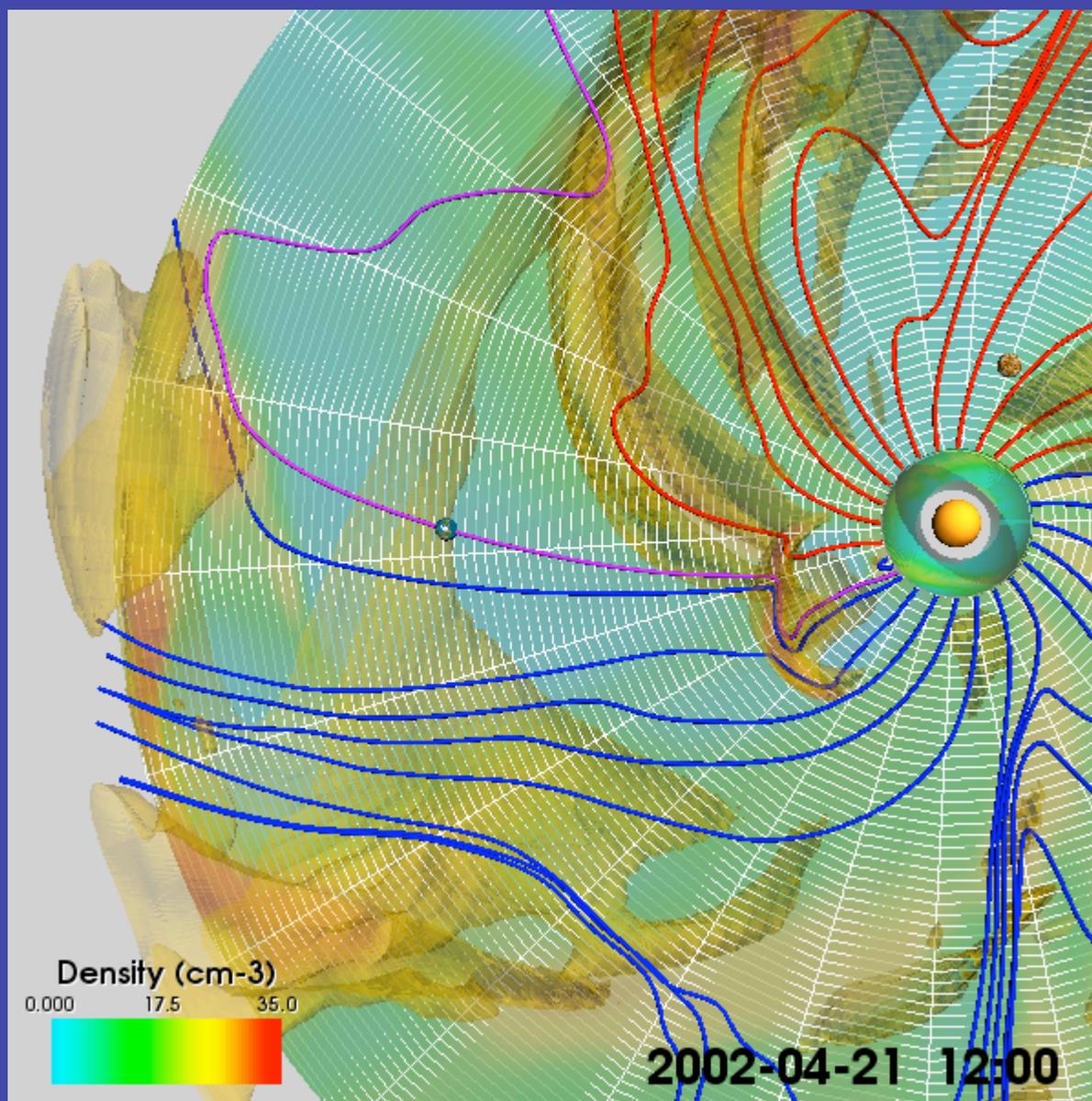
V (km/s) 200  800

- Similar – Transient disturbances are centered east of the Sun-Earth line
- Different – Ambient solar wind with and without an equatorial fast stream

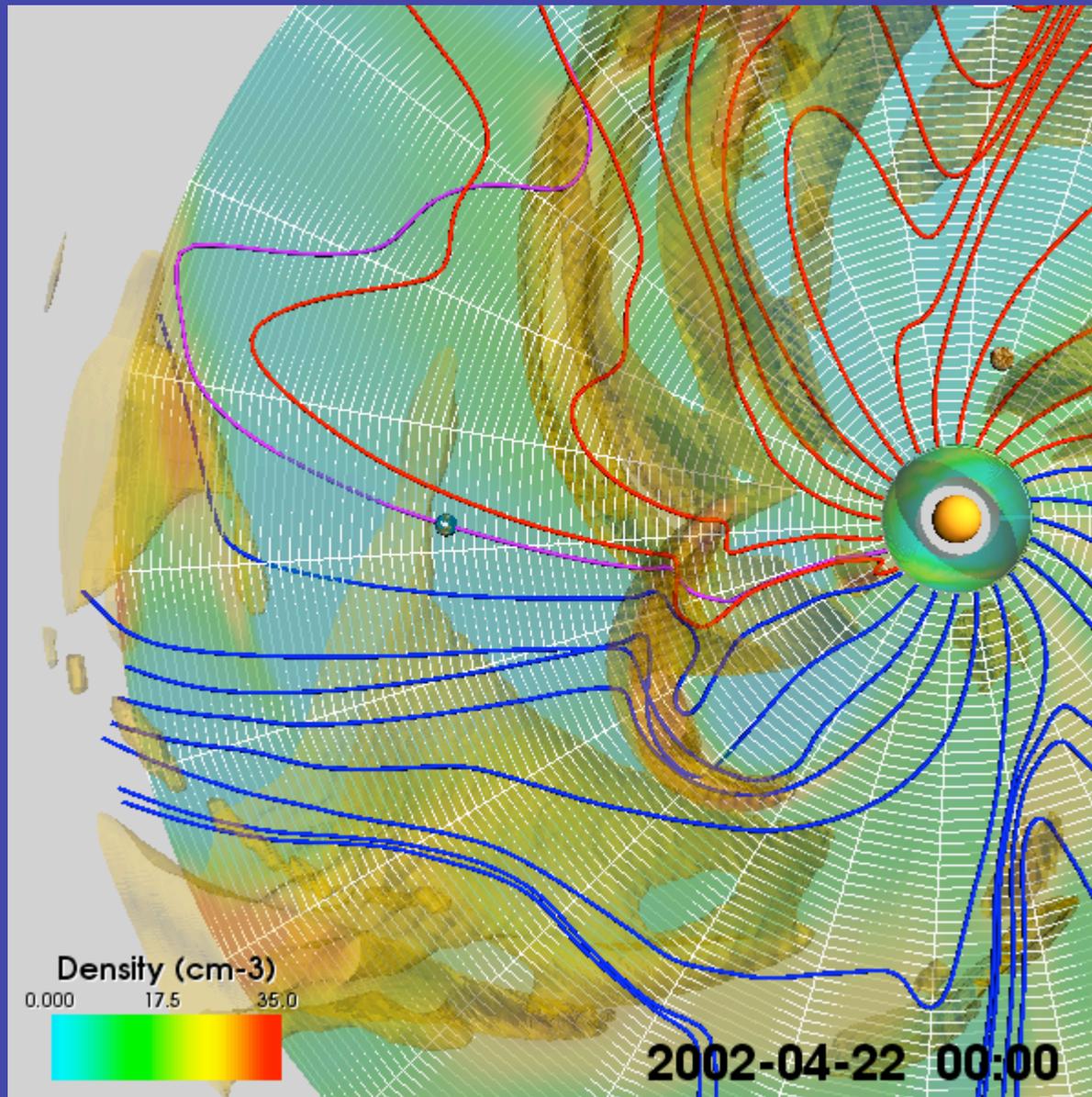
21 April 2002 – IMF Lines



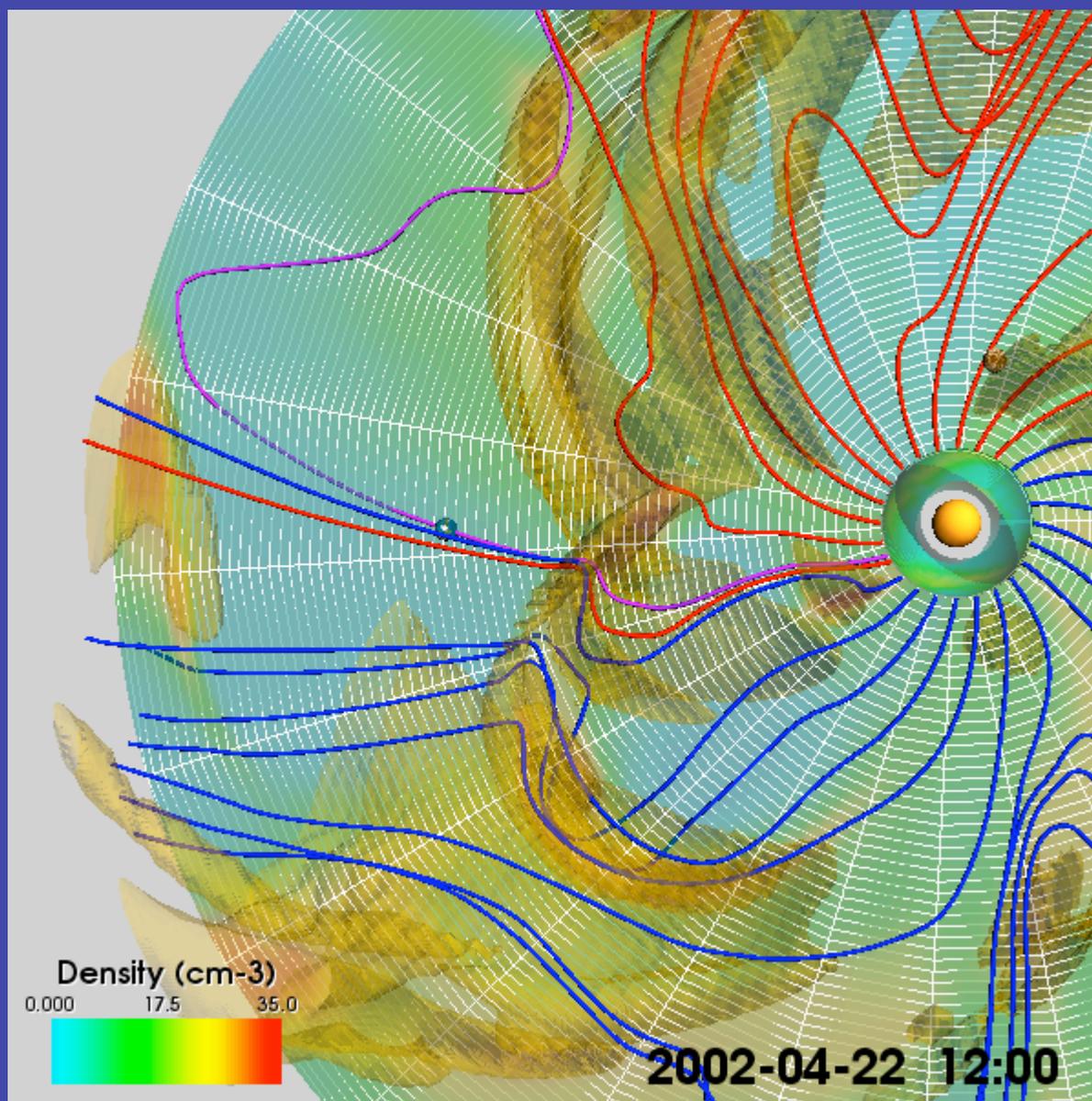
21 April 2002 – IMF Lines



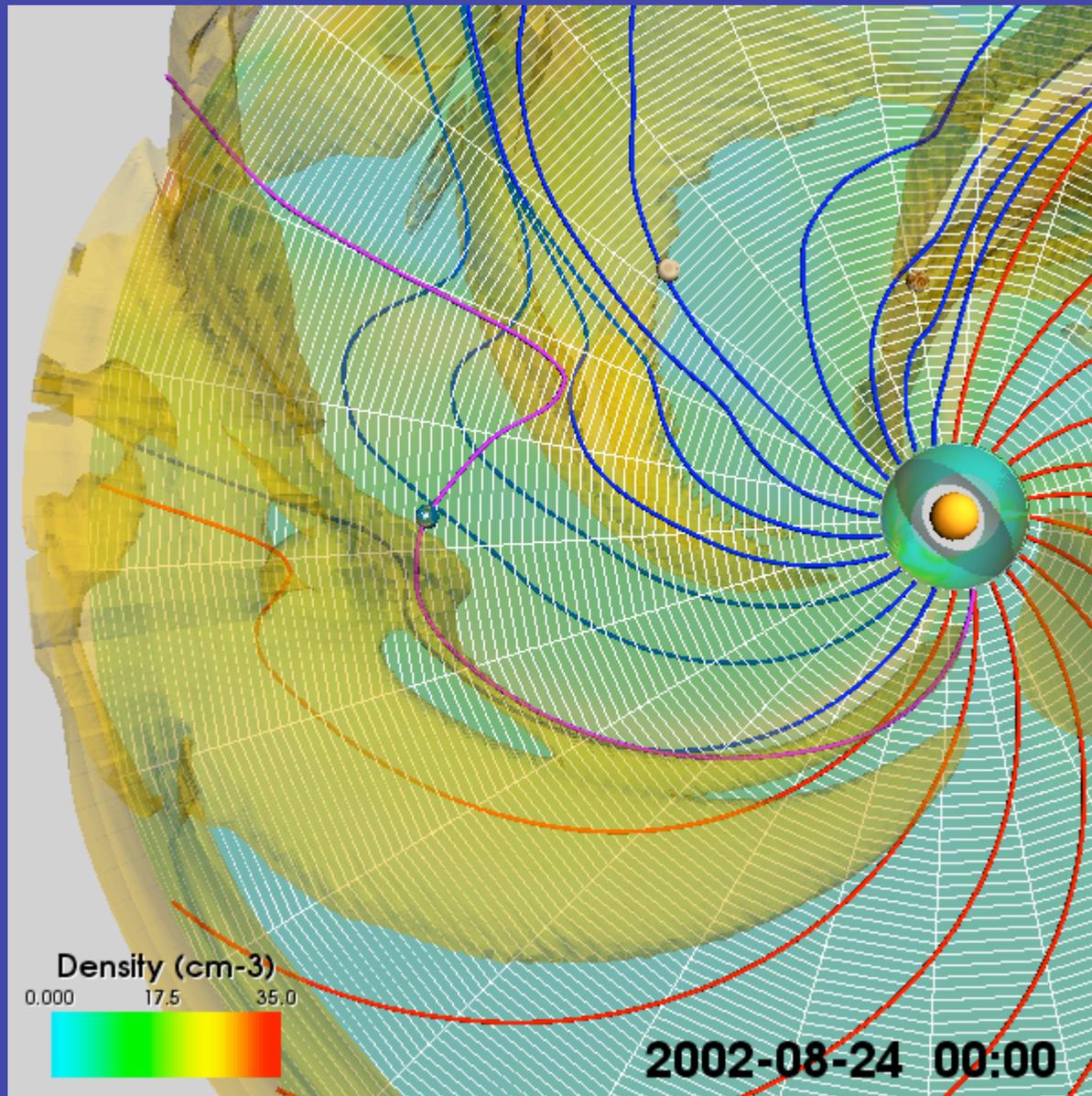
21 April 2002 – IMF Lines



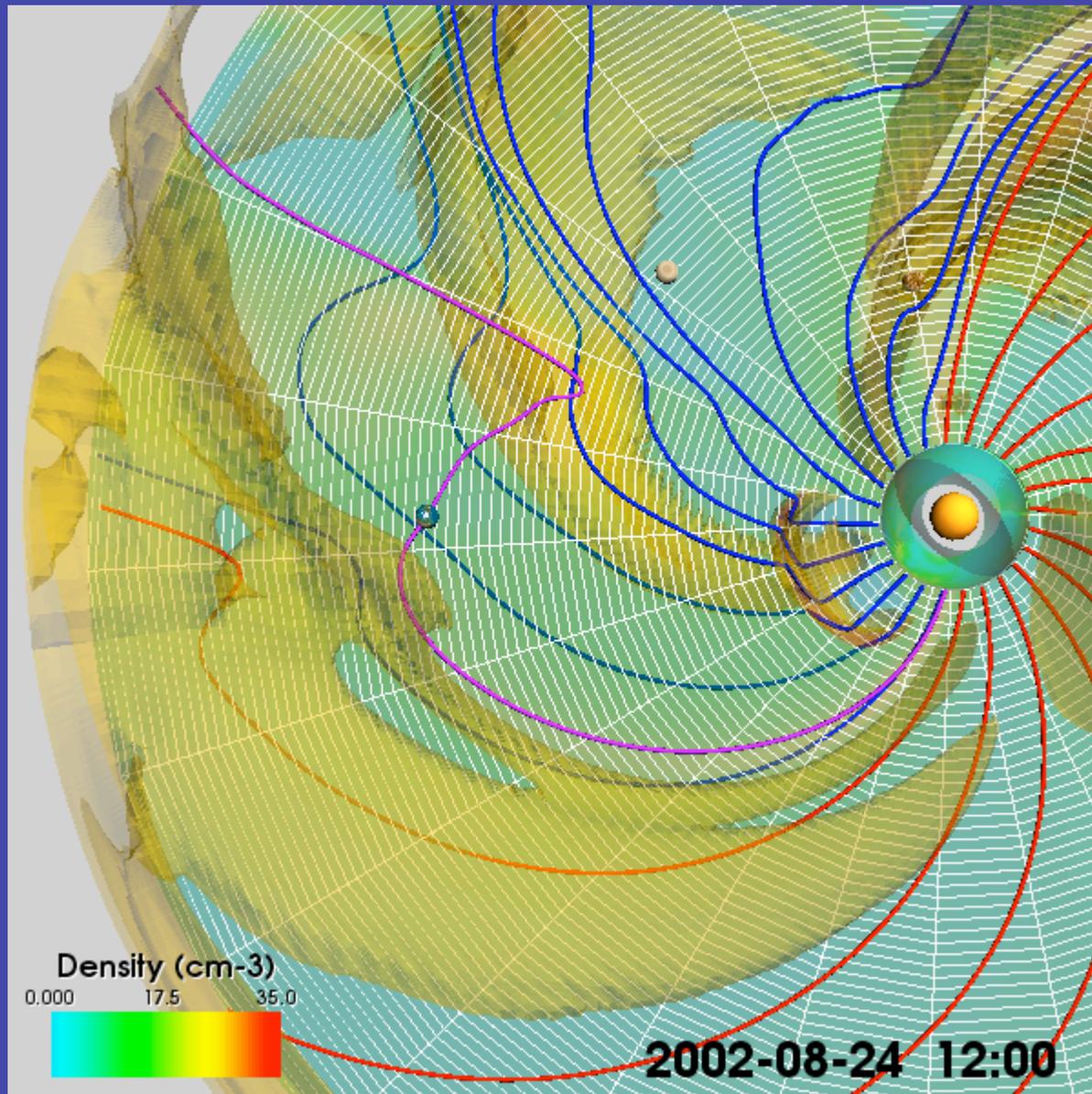
21 April 2002 – IMF Lines



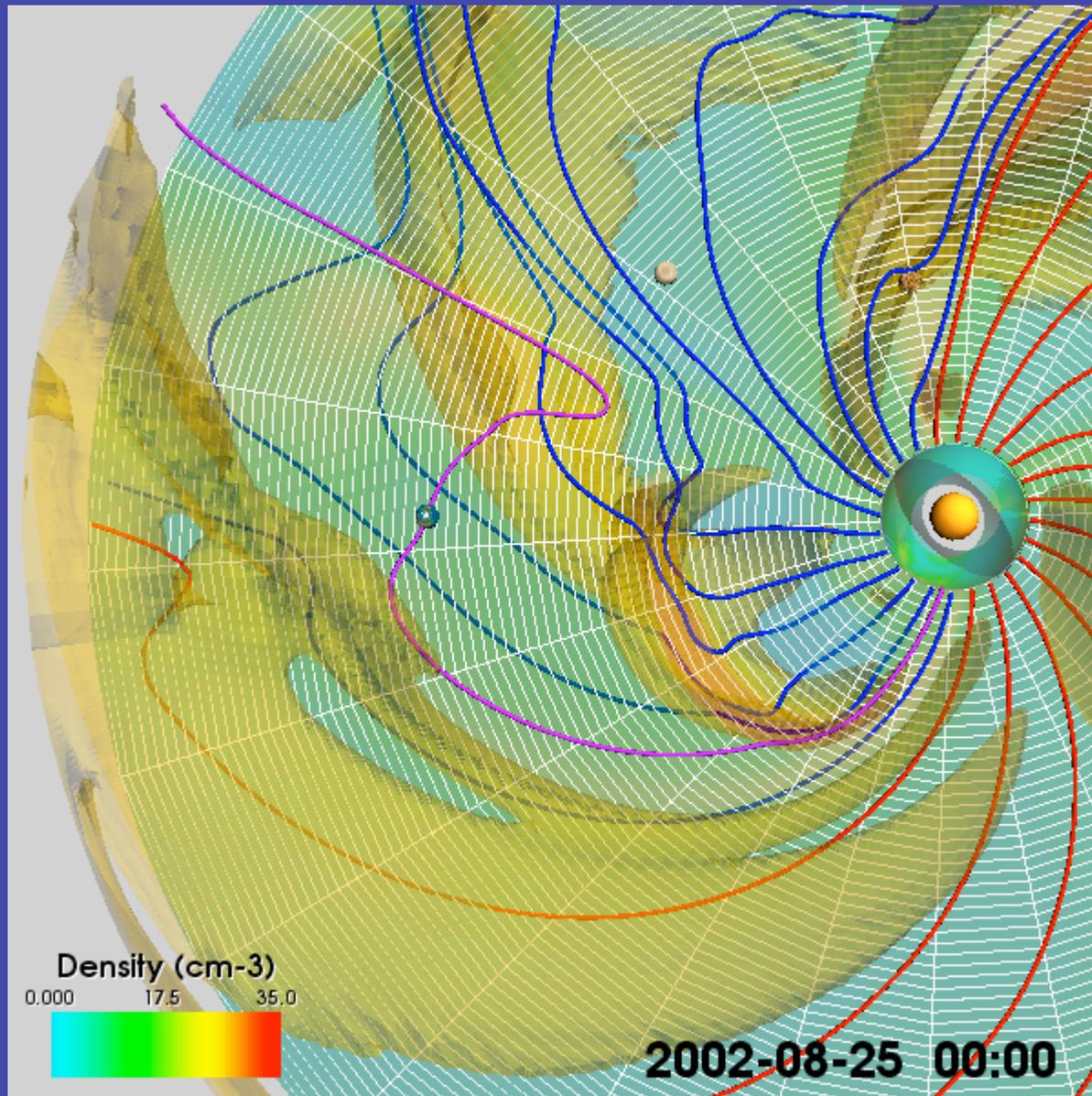
24 August 2002 – IMF Lines



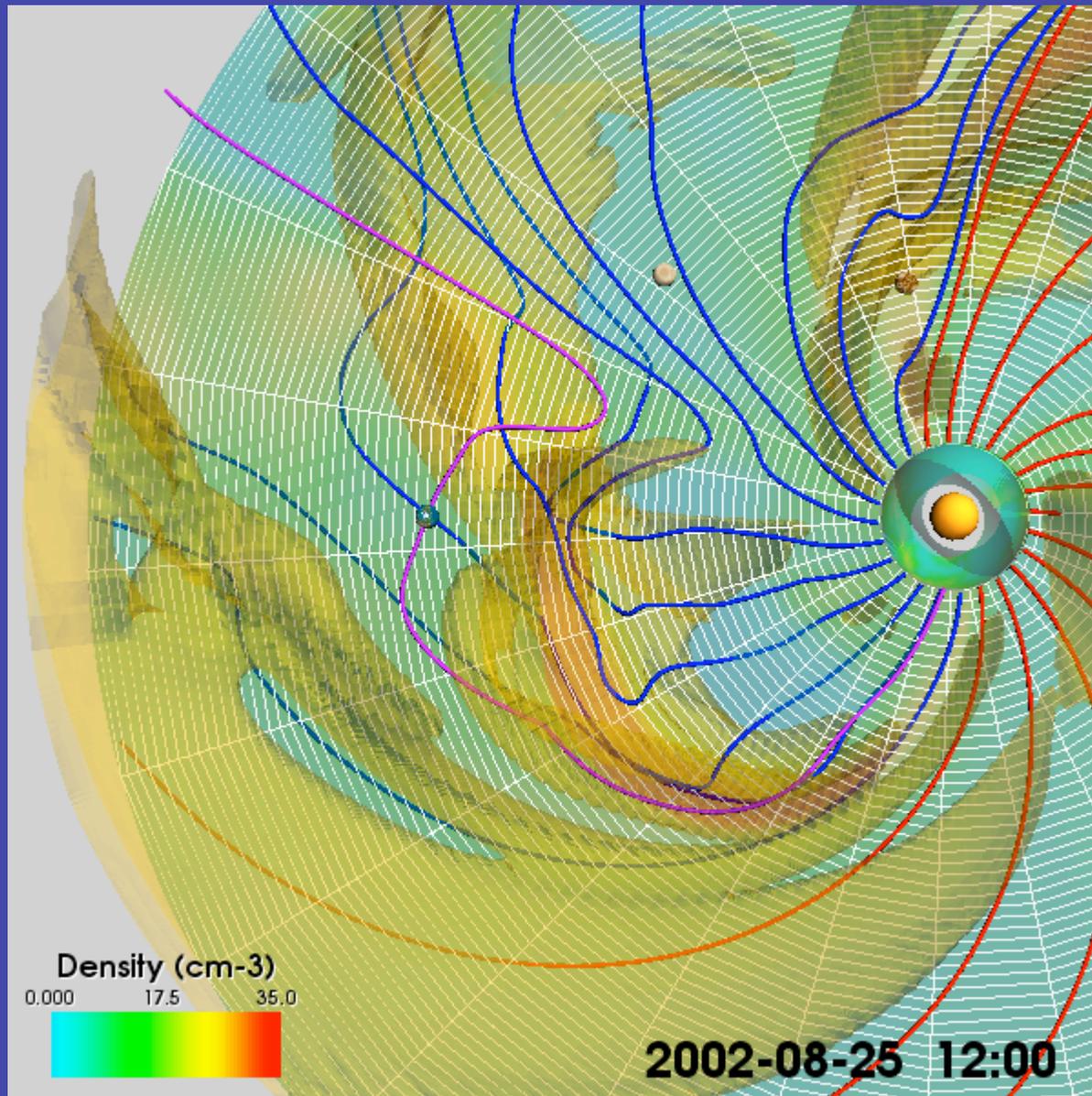
24 August 2002 – IMF Lines



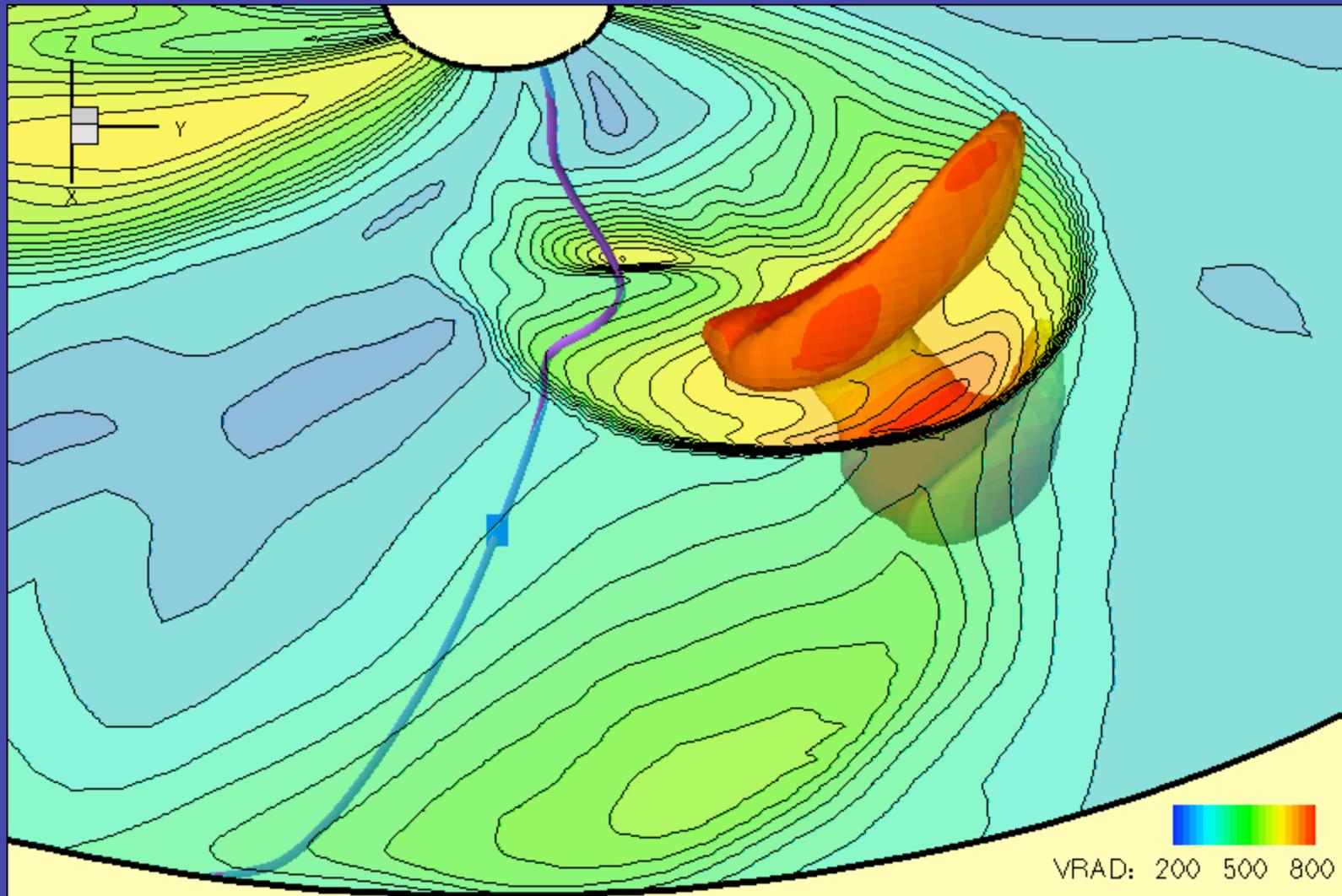
24 August 2002 – IMF Lines



24 August 2002 – IMF Lines

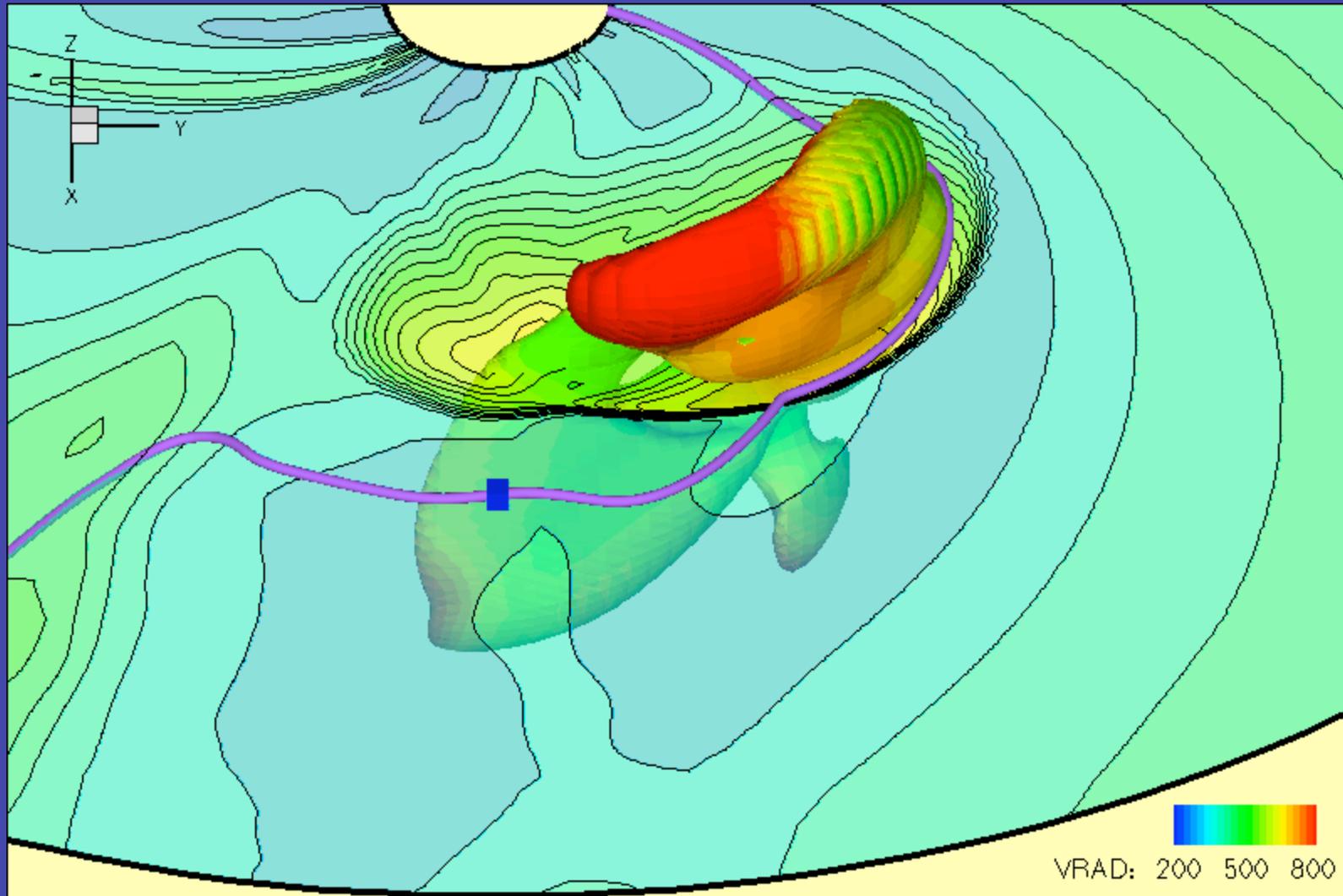


21 April 2002



Quasi-parallel shock

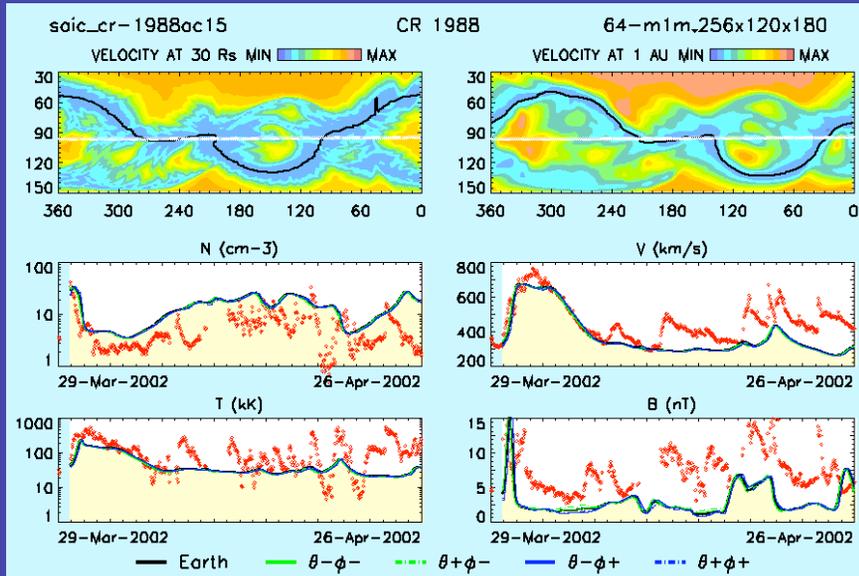
24 August 2002



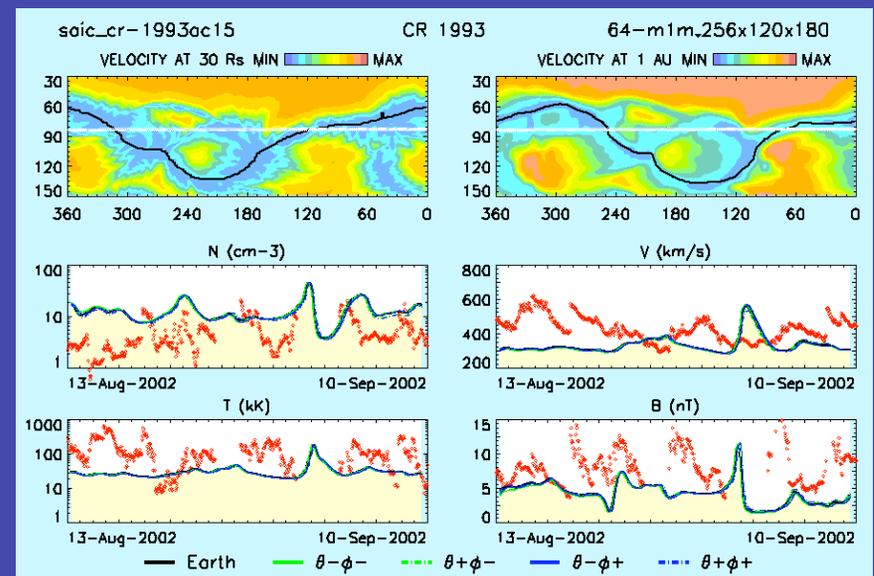
Quasi-perpendicular shock

Limitations

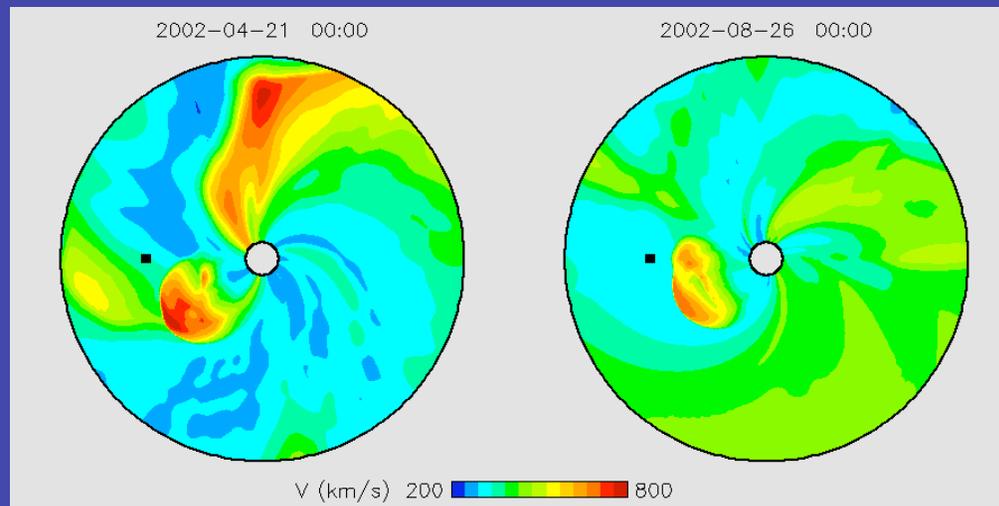
Ambient Solar Wind – CR1988



Ambient Solar Wind – CR1993



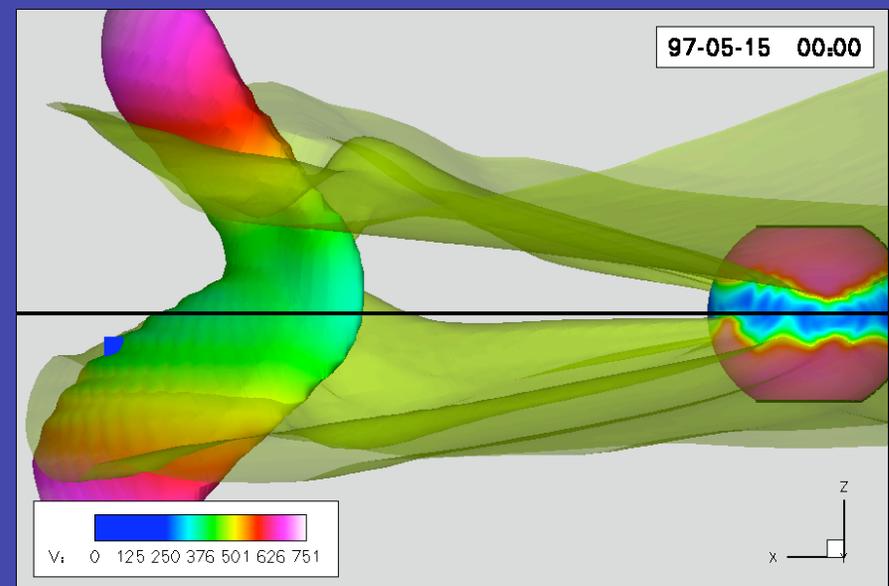
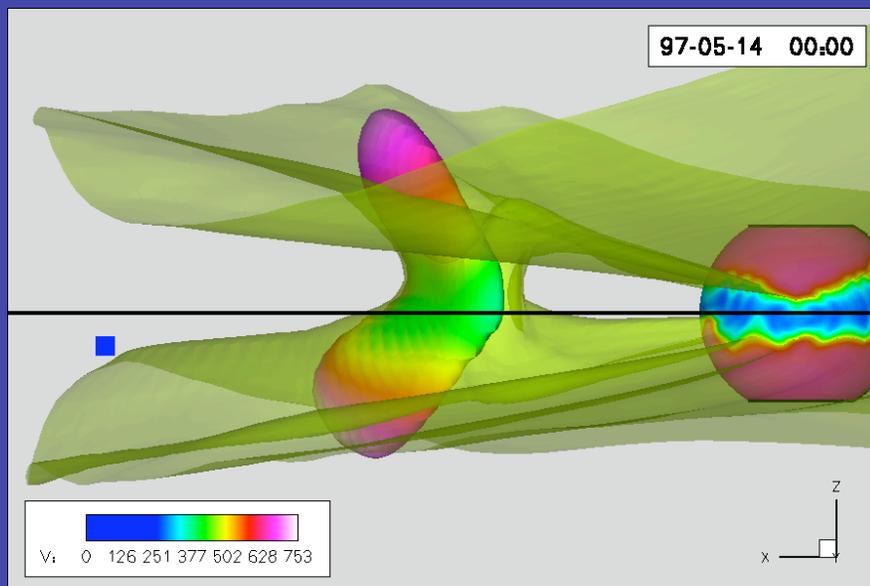
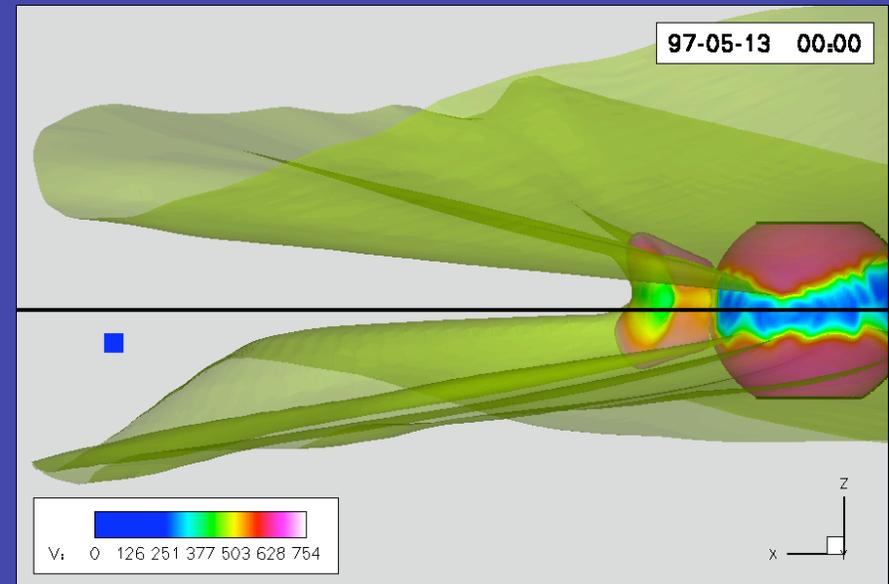
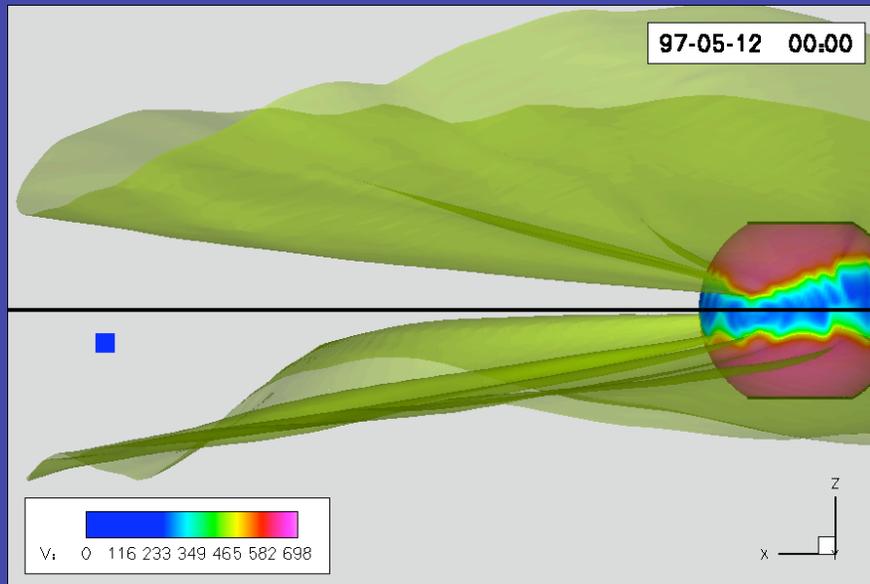
Transient Disturbances



C.

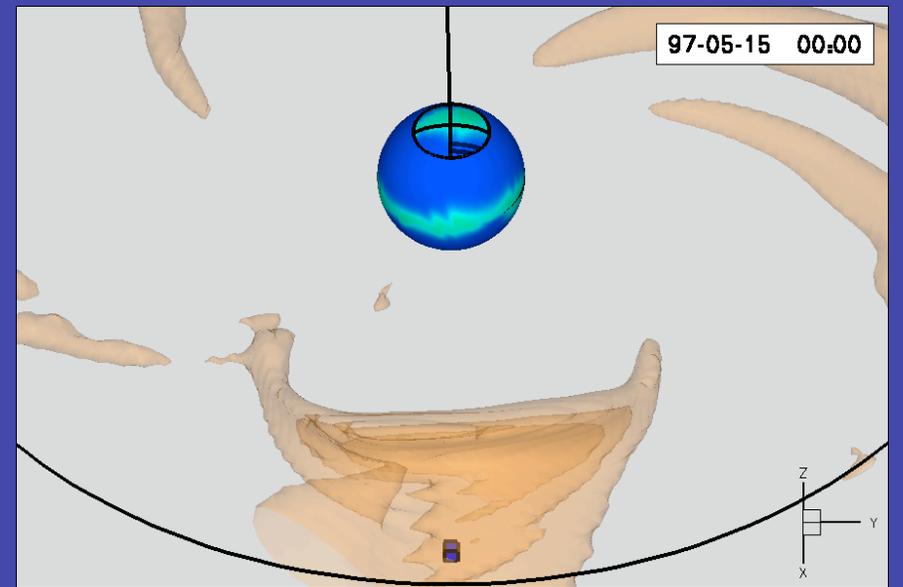
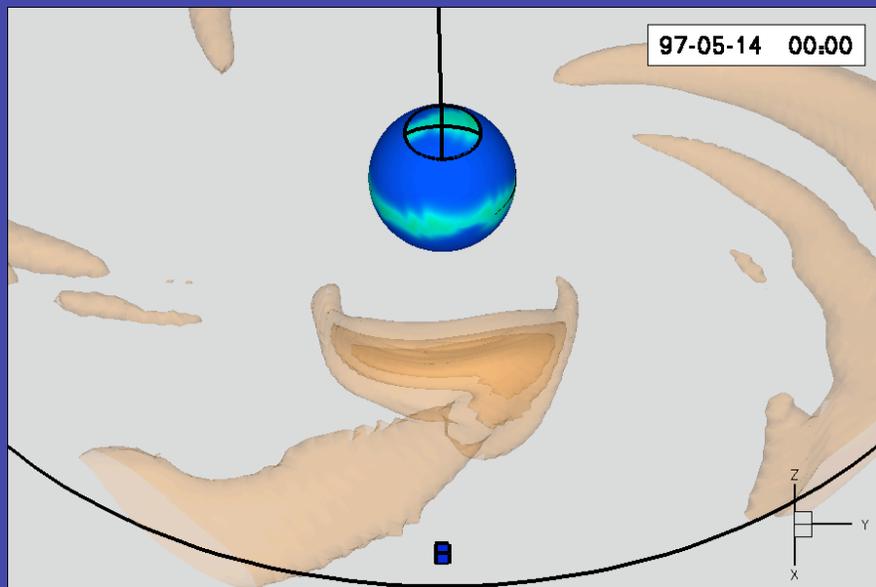
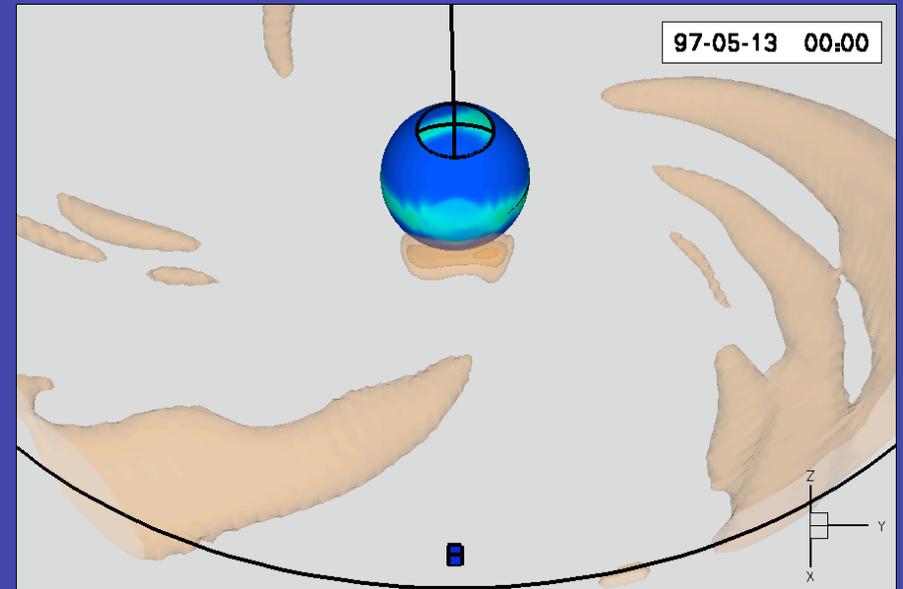
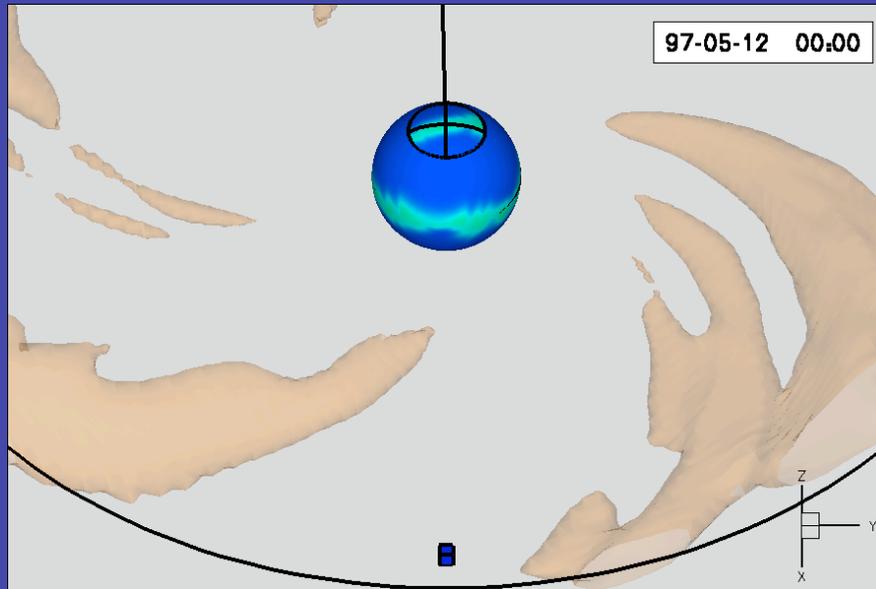
12 May 1997 Event

Latitudinal Distortion of ICME Shape



ICME propagates into bi-modal solar wind

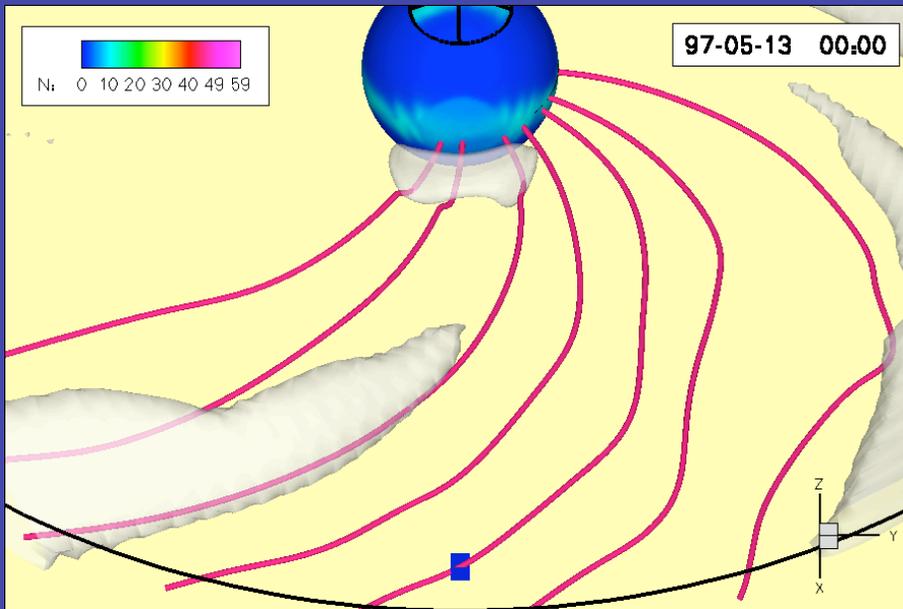
Evolution of Density Structure



ICME propagates into the enhanced density of the streamer belt flow

Connectivity of IMF Lines

Early time

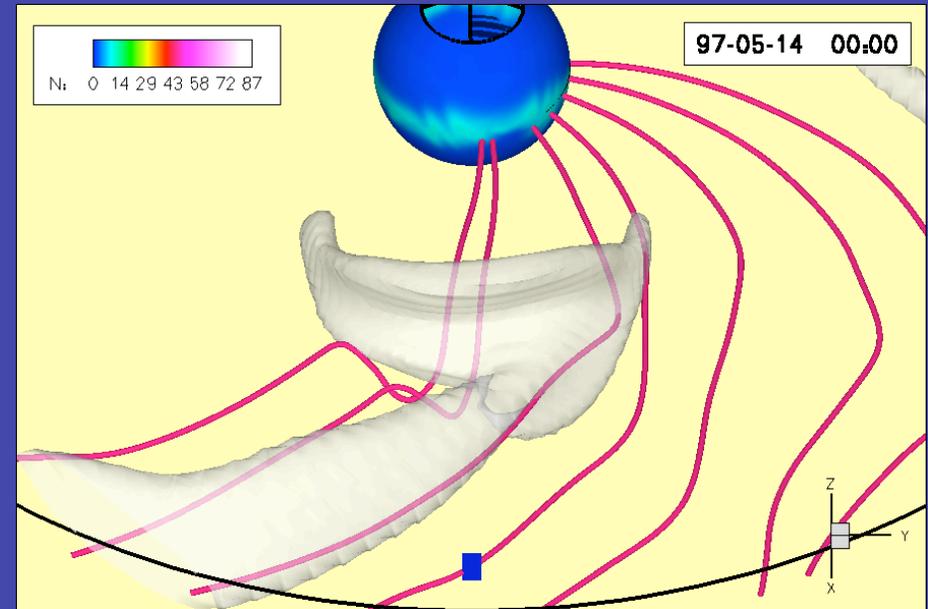


IMF line connected to Earth by-passes the shock structure

=>

Interplanetary CME-driven shock cannot generate energetic particles observed at Earth

Later time



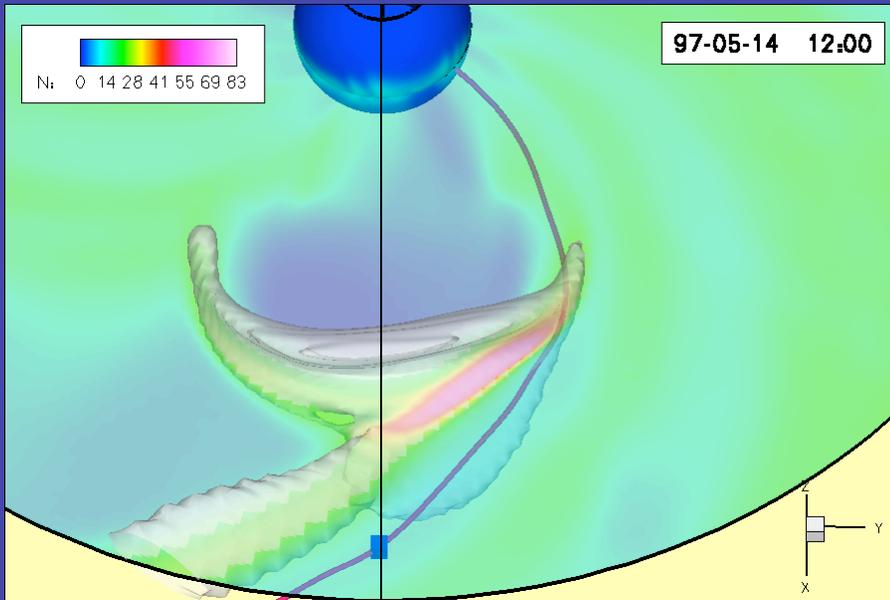
IMF line connected to Earth passes through the shock structure

=>

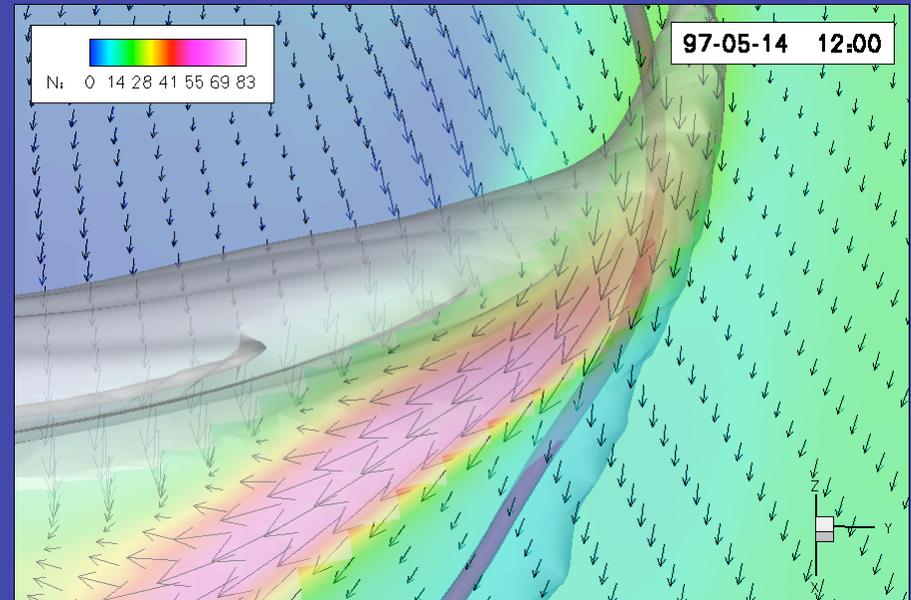
Quasi-perpendicular shock can generate energetic particles under certain circumstances

Connectivity of IMF Lines

Global view



Detailed view



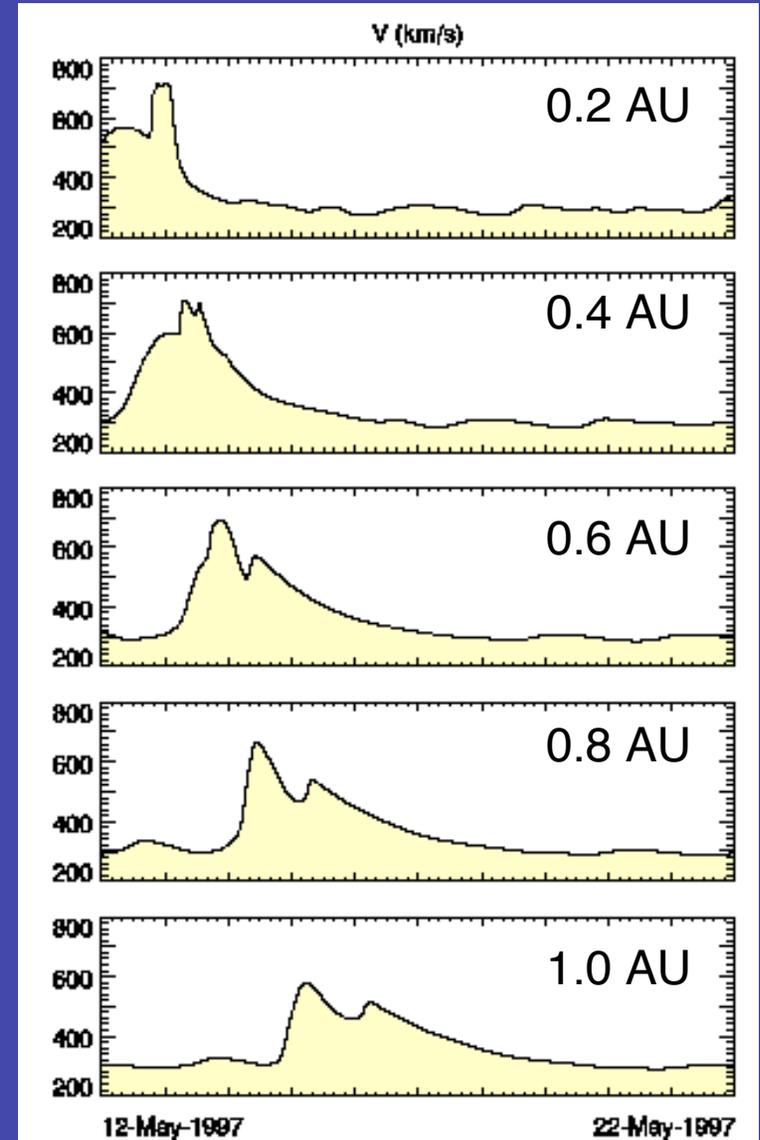
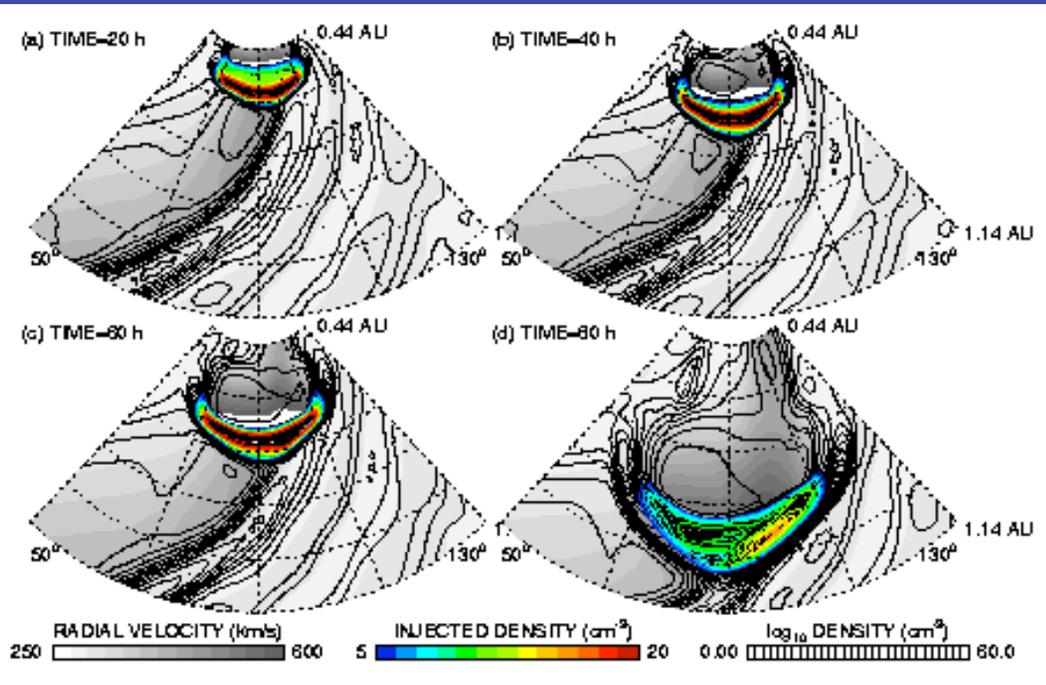
Important effect occurs away from the Sun-Earth line

Enhanced shock interaction together with quasi-perpendicular propagation relative to IMF lines favors particle acceleration and generation of radio emission

May 12, 1997 – Interplanetary Shock

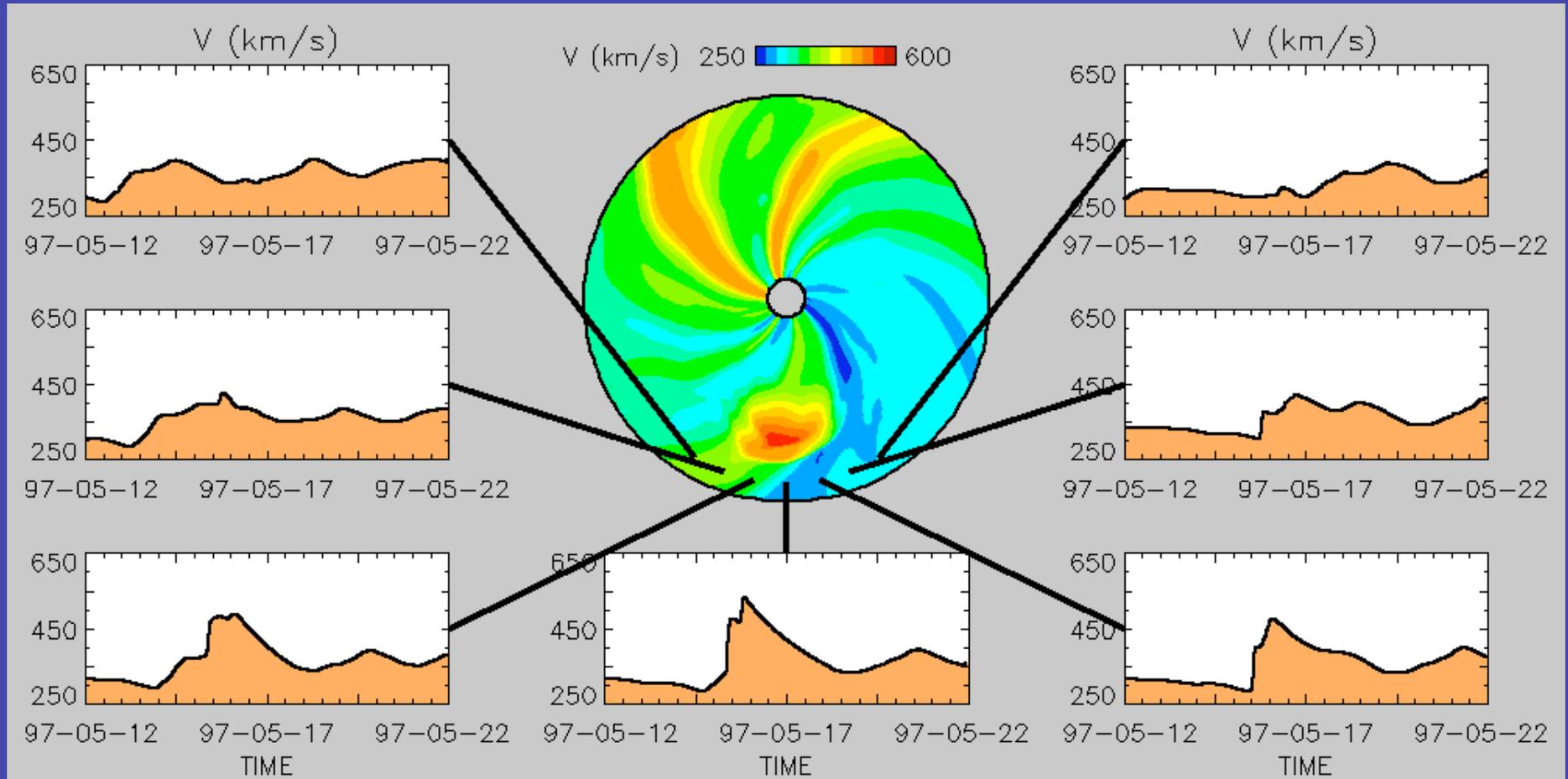
Distribution of parameters in equatorial plane

Evolution of velocity on Sun-Earth line

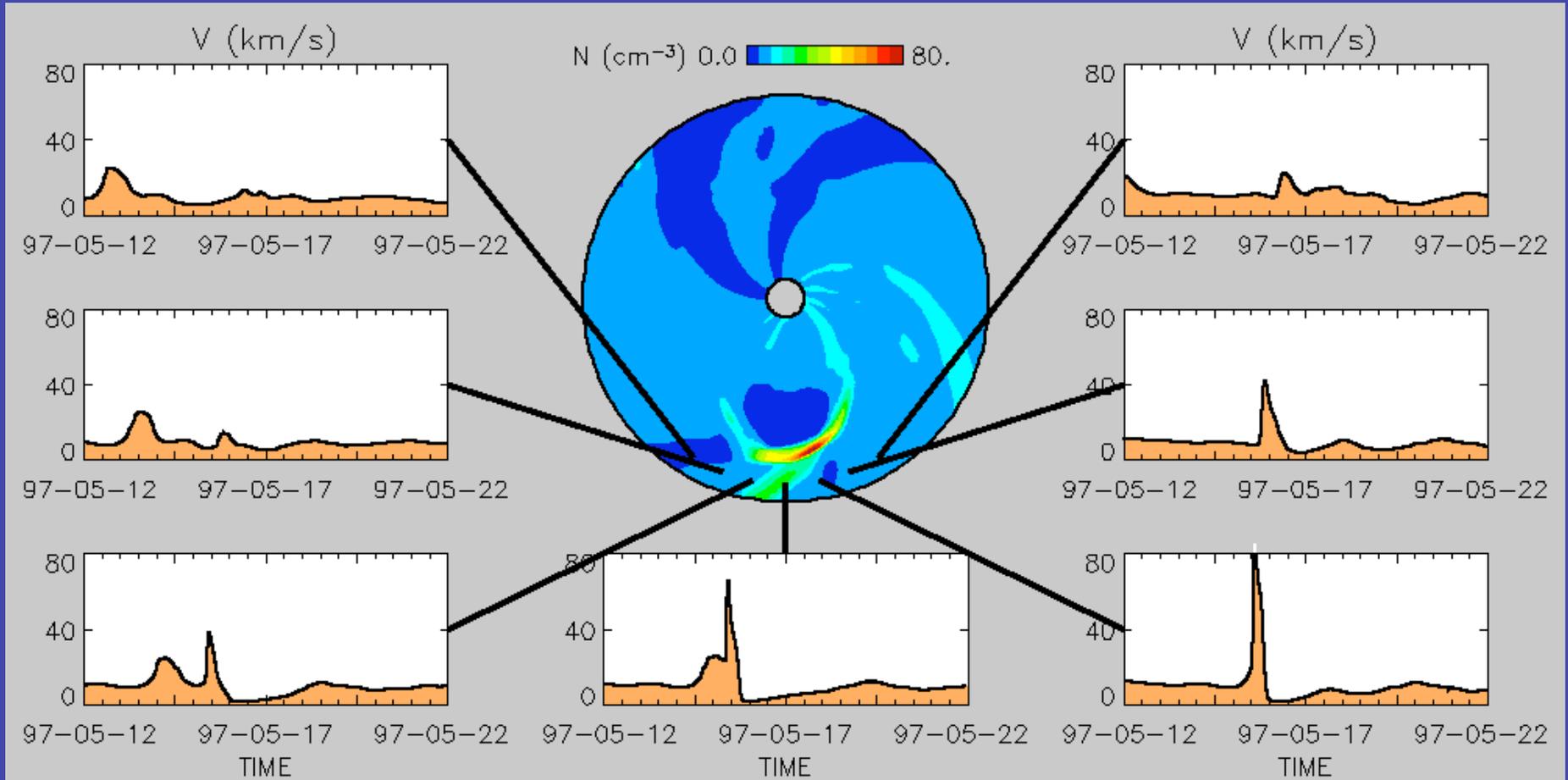


- Shock propagates in a fast stream and merges with its leading edge

Interplanetary Disturbances



Interplanetary Disturbances



Case A1

Case A3

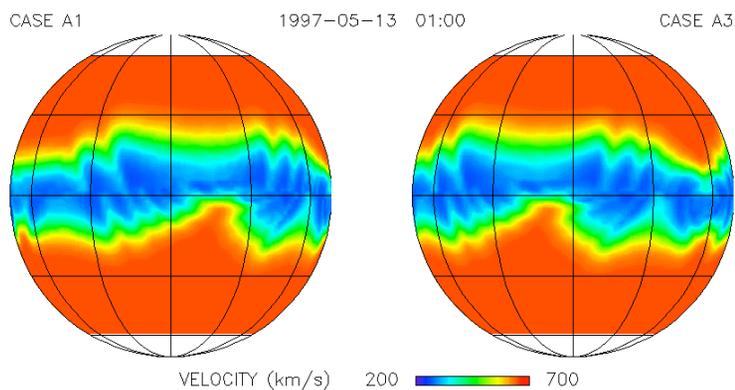
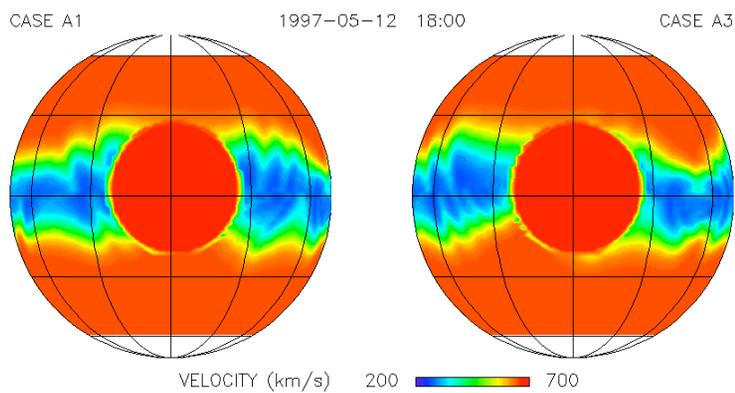
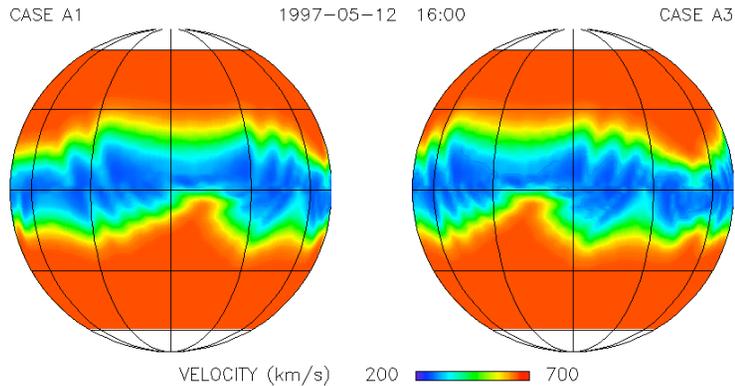
Fast-Stream Position

[SAIC maps -- Pete Riley]

Ambient state before the CME launch

Disturbed state during the CME launch

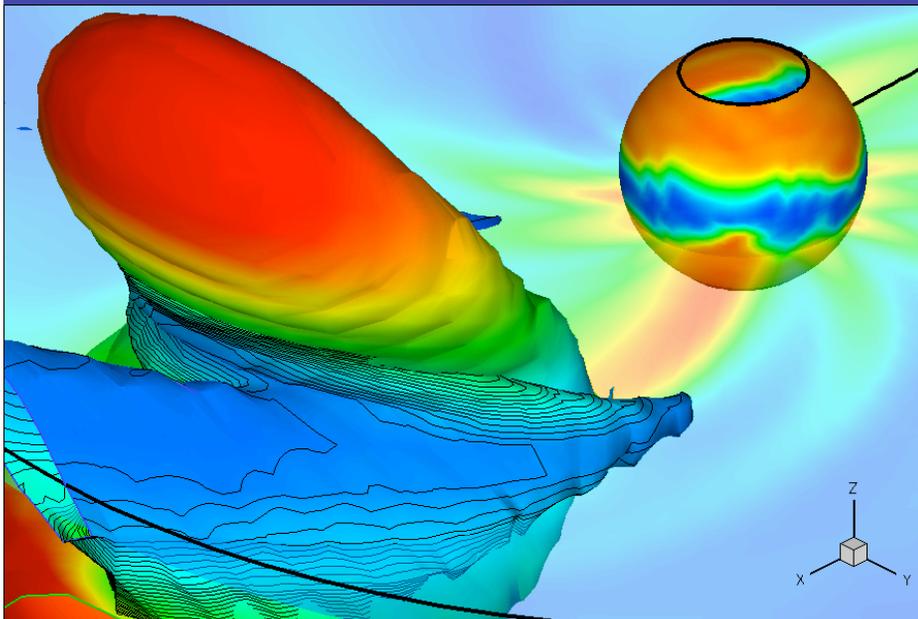
Ambient state after the CME launch



Effect of Fast-Stream Position

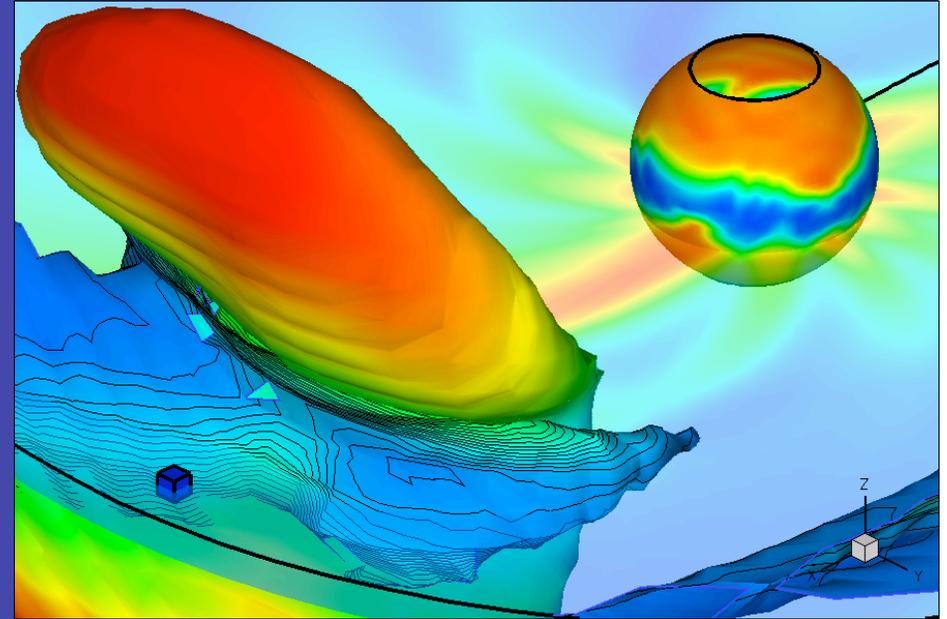
[SAIC maps -- Pete Riley]

Case A1



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

Case A3



Earth : Shock and CME (*observed but 3-day shift is too large*)

Case A2

Case B2

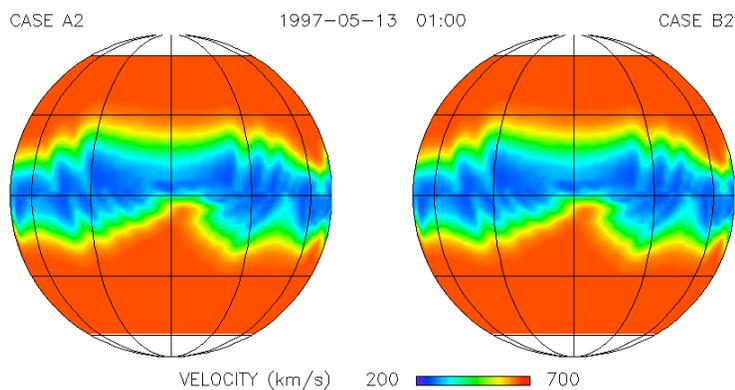
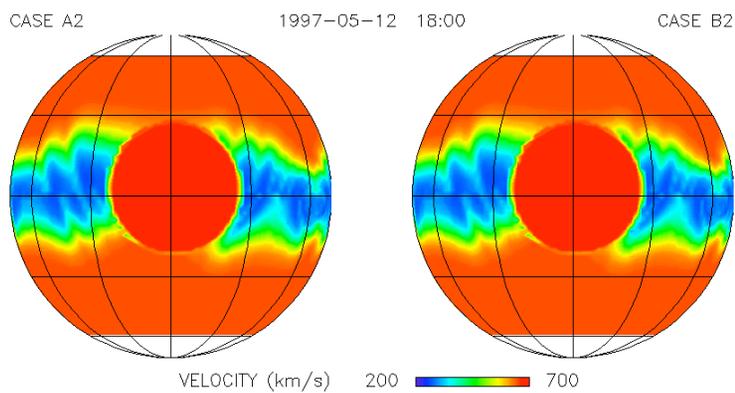
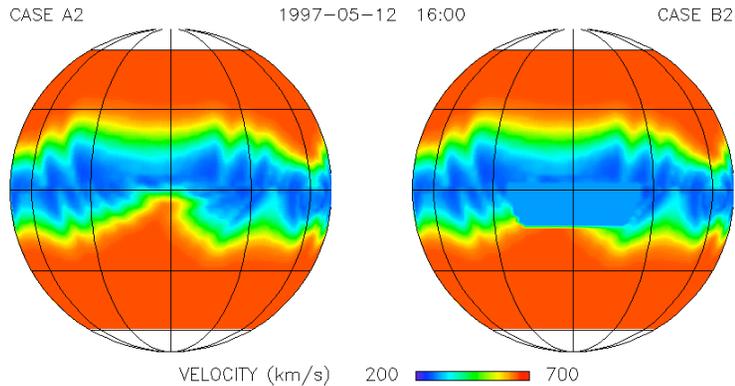
Fast-Stream Evolution

[SAIC maps -- Pete Riley]

Ambient state before the CME launch

Disturbed state during the CME launch

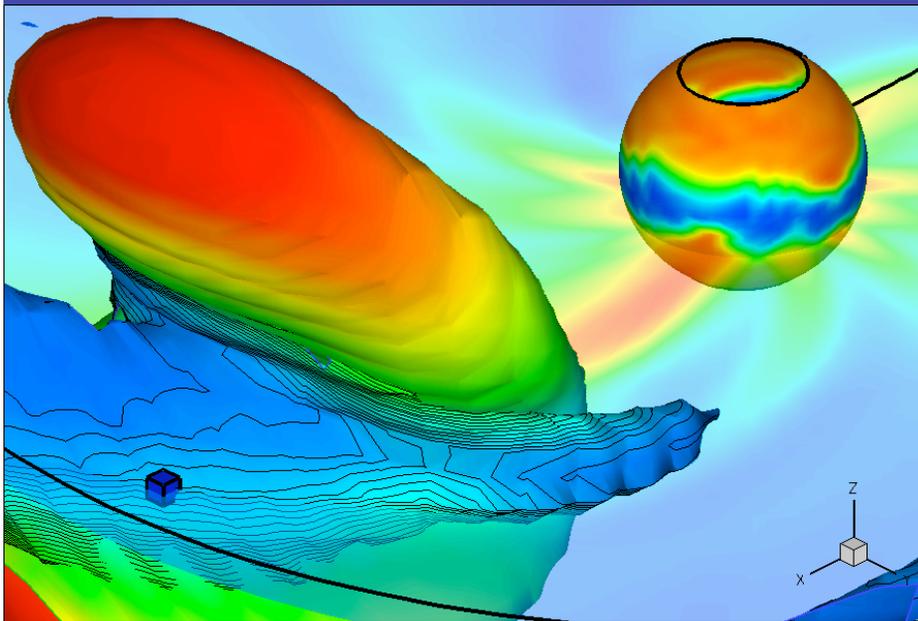
Ambient state after the CME launch



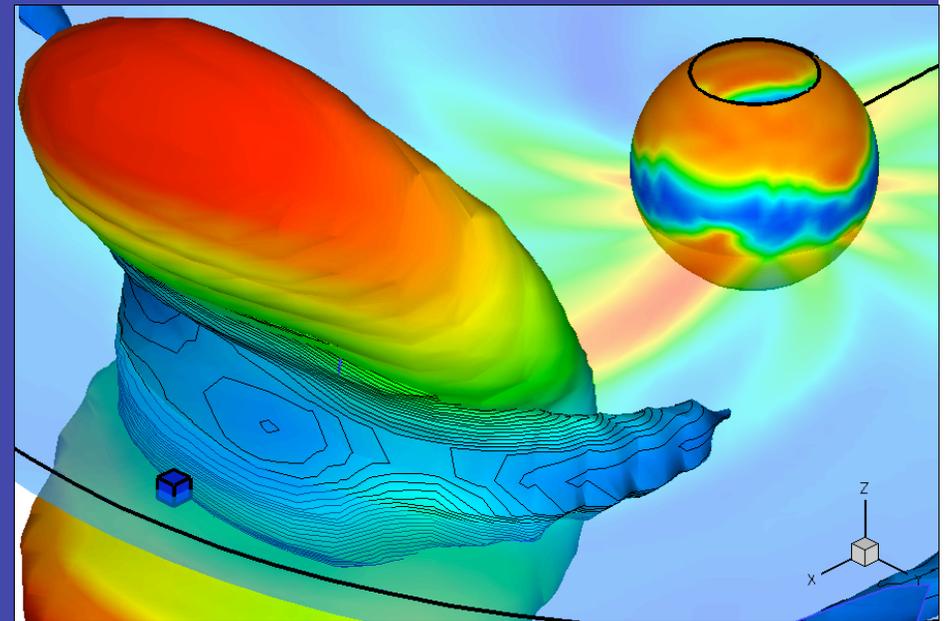
Effect of Fast-Stream Evolution

[SAIC maps -- Pete Riley]

Case A2



Case B2



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

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

Case A2

Case B2

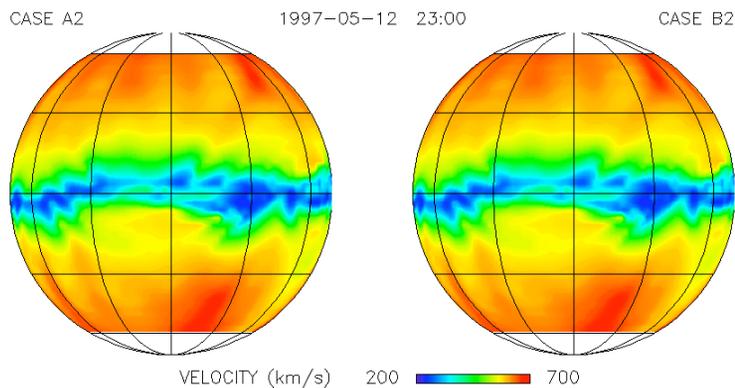
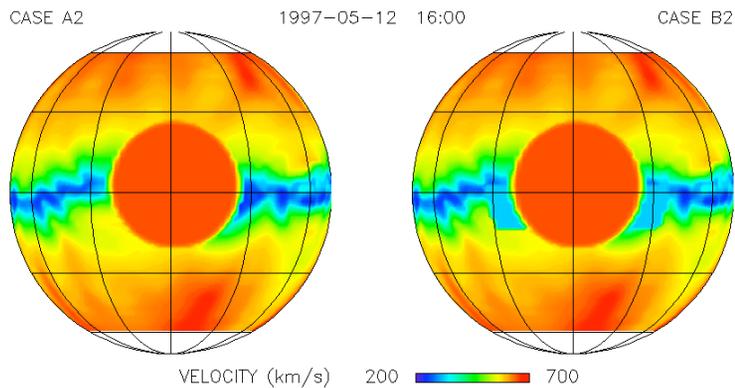
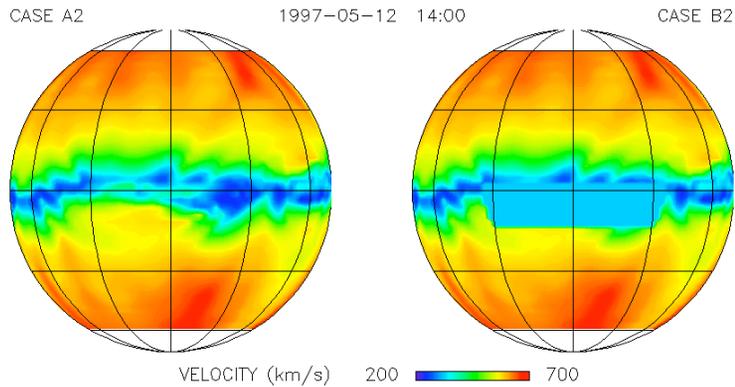
Fast-Stream Evolution

[WSA maps -- Nick Arge]

Ambient state before the CME launch

Disturbed state during the CME launch

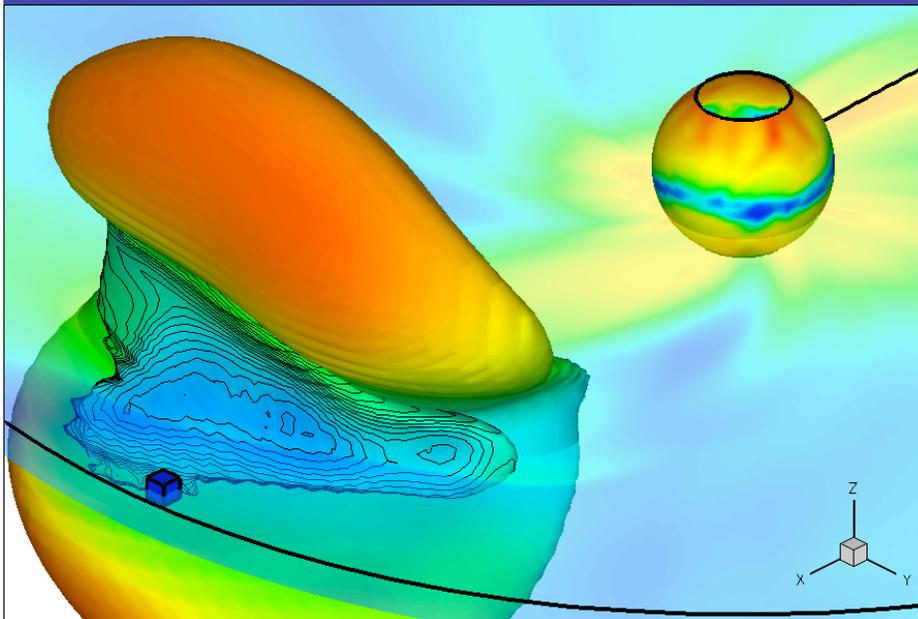
Ambient state after the CME launch



Effect of Fast-Stream Evolution

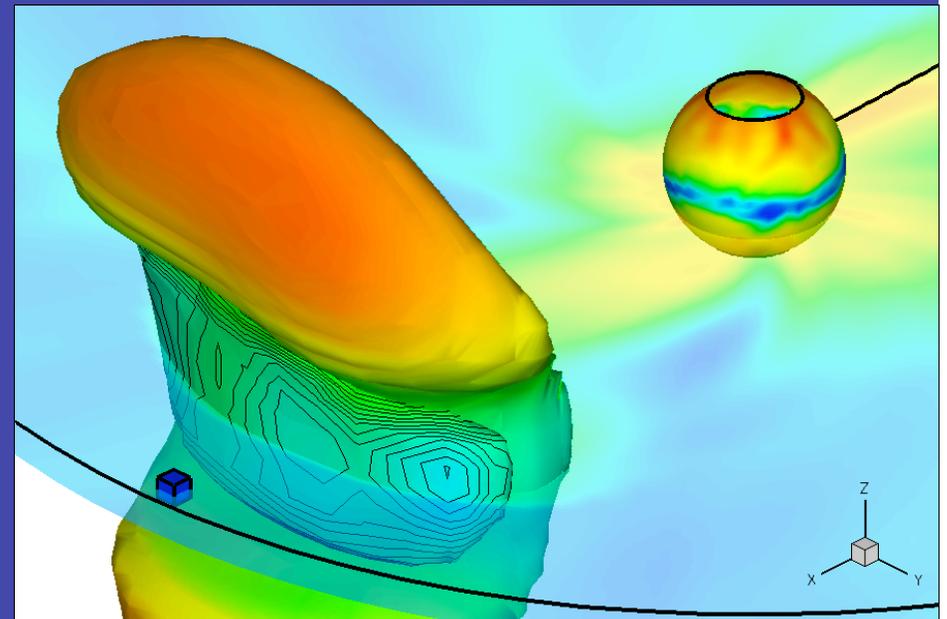
[WSA maps -- Nick Arge]

Case A2



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

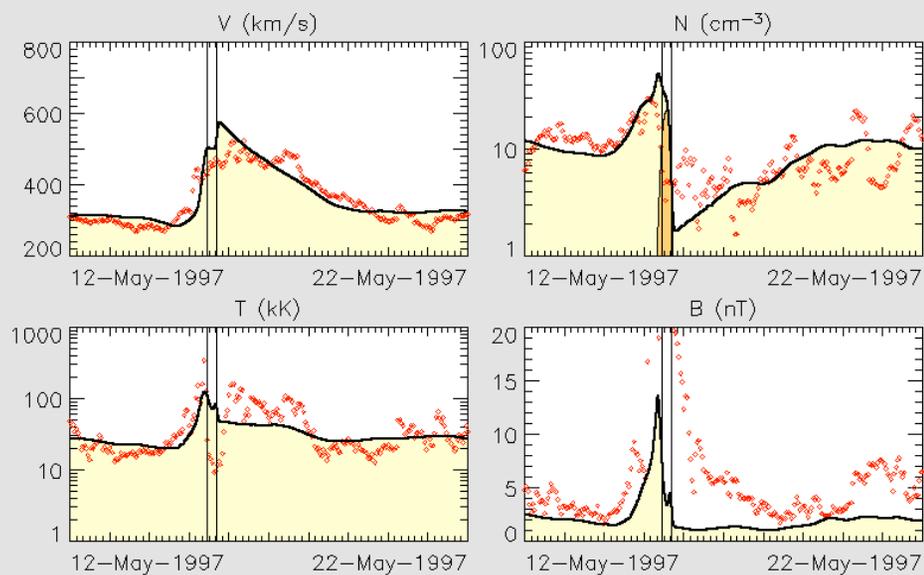
Case B2



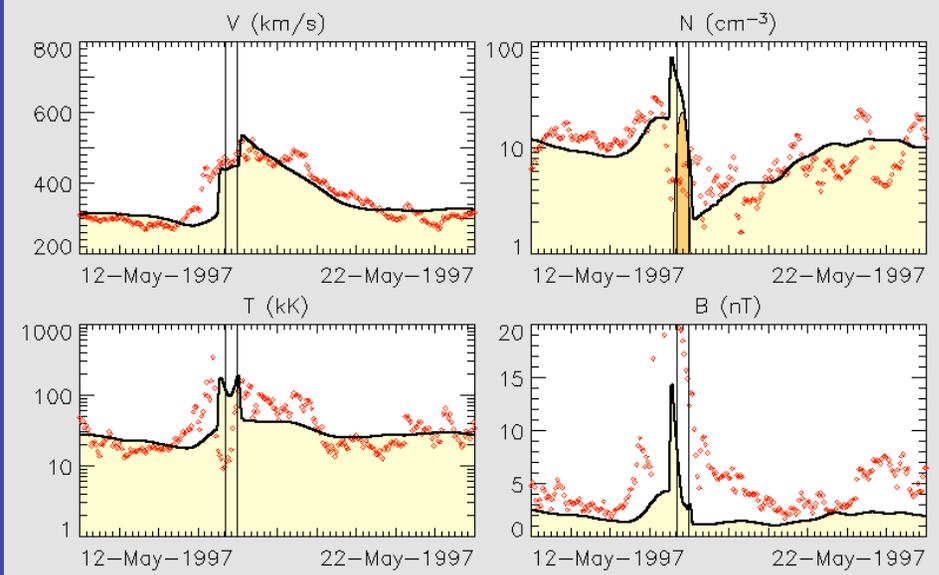
Earth : Shock and CME (*observed but shock front is radial*)

Interplanetary Disturbances

Case A



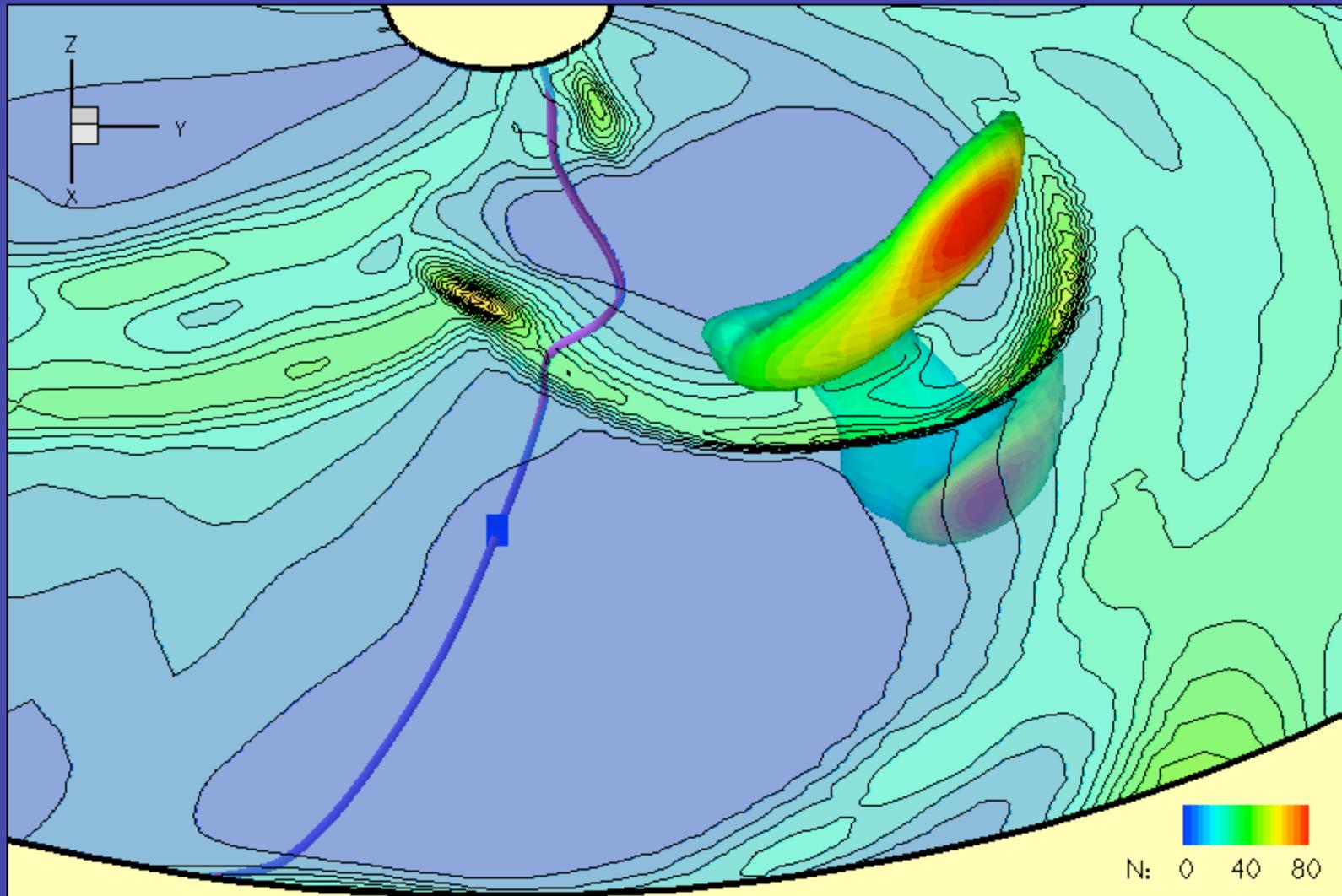
Case C



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

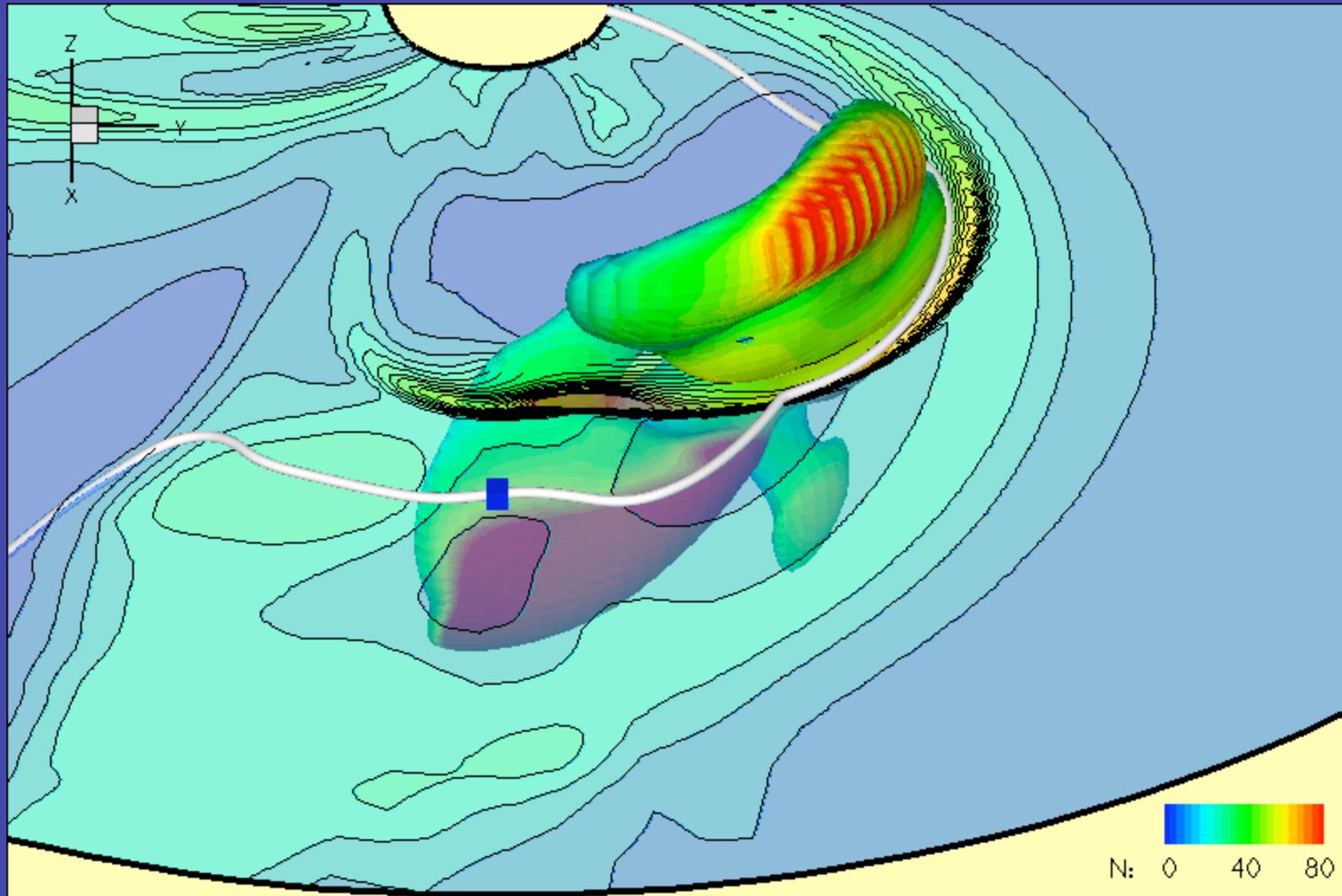
Backup

21 April 2002



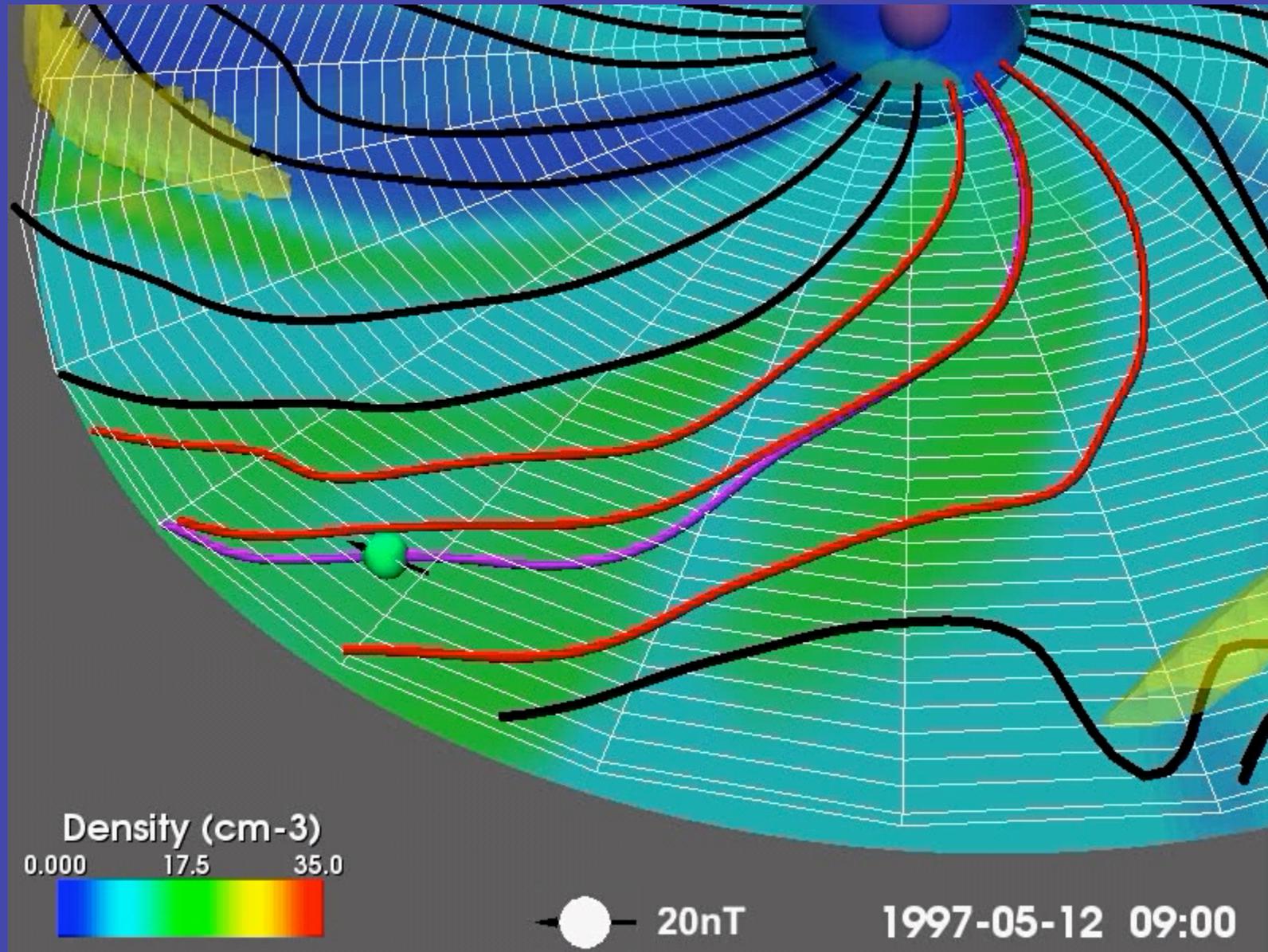
Quasi-parallel shock

24 August 2002



Quasi-perpendicular shock

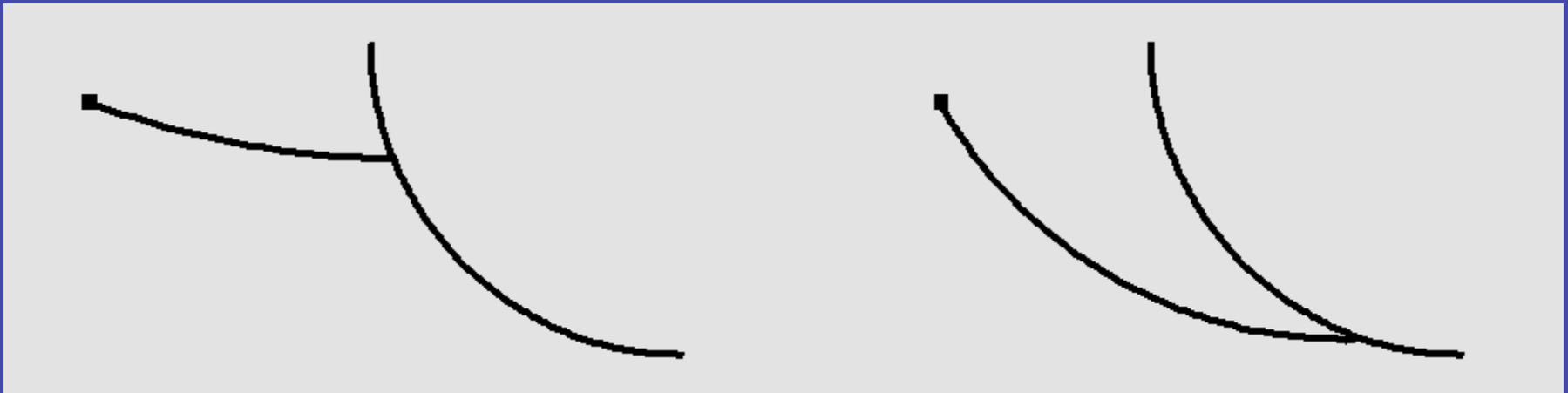
Interplanetary Disturbances



Connectivity of Magnetic Field Lines

2002-04-21 Interplanetary Event

2002-08-24 Interplanetary Event



Quasi-parallel shock

Quasi-perpendicular shock

CDP – Sample Web Pages



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ENLIL Heliospheric Model

Information

 documentation: ENLIL: Data Conventions and Structure

Referenced Catalogs

 Project: 1997 May 12 Interplanetary Event

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ENLIL Heliospheric Model > Project: 1997 May 12 Interplanetary Event >

Case: c115a2b1 boundary values, 256x60x180 grid

Information

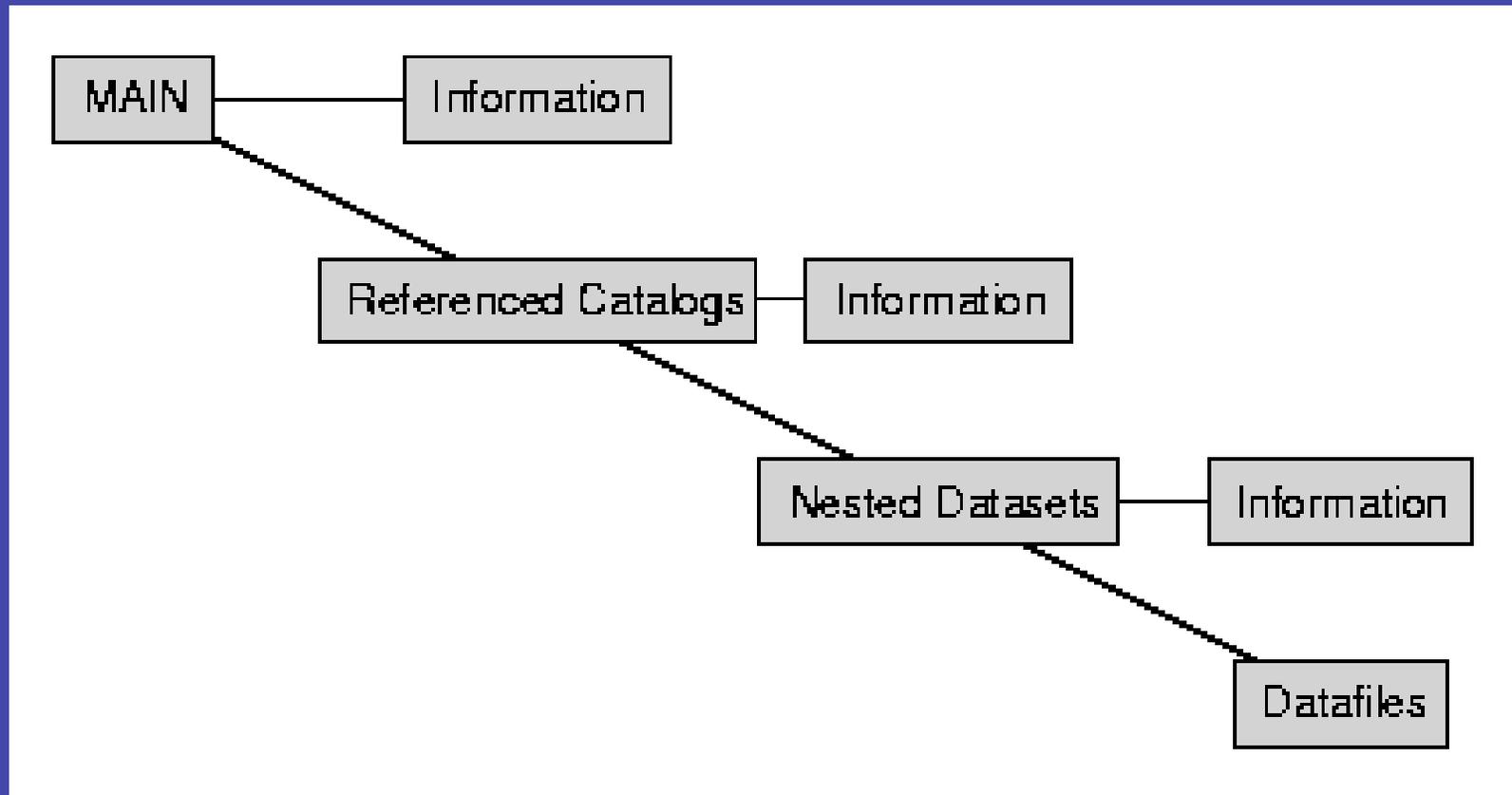
 documentation: Case plots

1-28 of 28 datafiles

Datafiles	Metadata	Format	Type	Size	Download	Related
1. INPUT: 1x60x180 grid specs	NetML	NetCDF		5044	HTTP	
2. INPUT: 256x60x180 grid specs	NetML	NetCDF		9124	HTTP	
3. INPUT: 1x60x180 grid boundary values	NetML	NetCDF		5209880	HTTP	
4. INPUT: case parameters		ASCII		513		
5. OUTPUT: values within the computational domain at time level 0001	NetML	NetCDF		110597632	HTTP	
6. OUTPUT: values within the computational domain at time level 0002	NetML	NetCDF		110597632	HTTP	

[<http://dataportal.ucar.edu>]

CDP – Organization of Data



- MAIN – main entry for heliospheric data (top level CDP catalog)
- Information – metadata, textual description, parameters, representative plots
- Referenced Catalogs – computational project
- Nested Datasets – case (input data), code (numerical model), run (output data)
- Datafiles – input or output data (stored in NetCDF)