CSEM – CCMC Collaborations and Plans for the Future

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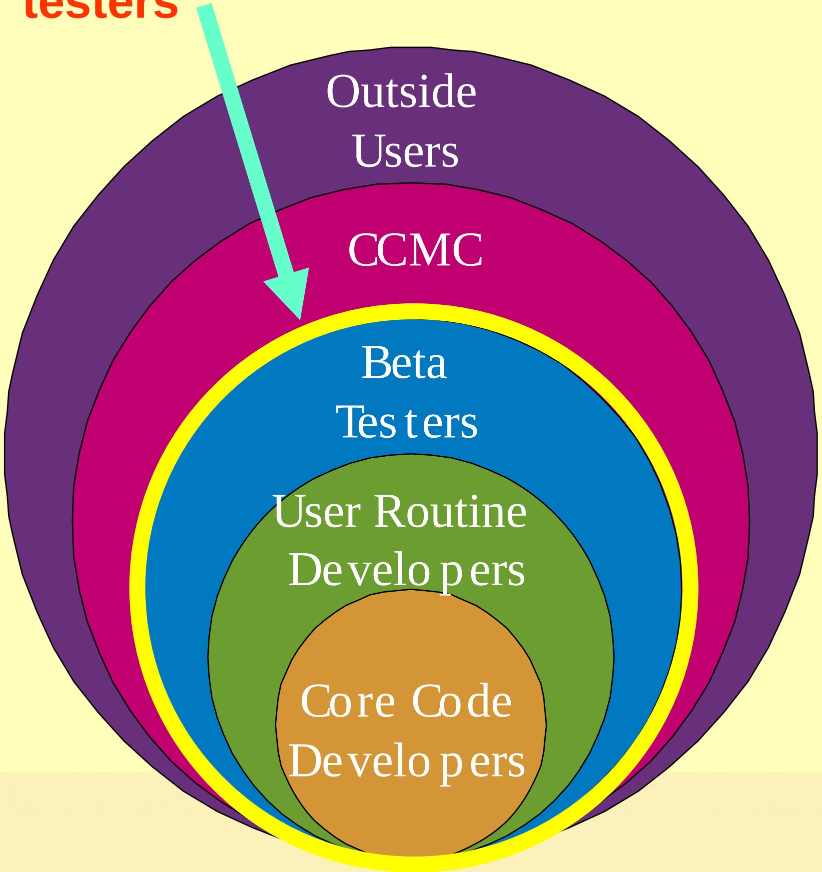
CCMC Workshop
November 5-8, 2007
Arecibo, Puerto Rico

http://csem.engin.umich.edu

CSEM

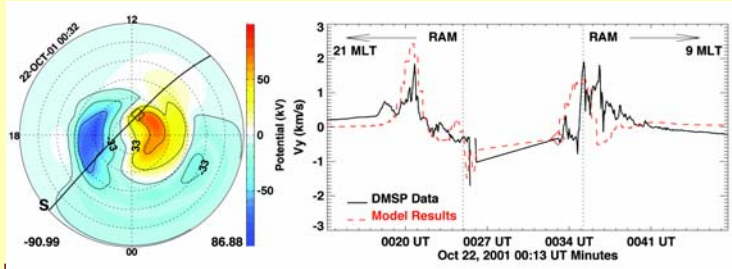
- **Core code developers**
  - SWMF
  - In BATS-R-US equations are separated from the numerical scheme
  - Grids and AMR
  - Riemann solvers
- **User routine developers**
  - Specify physics problem
    - Corona, magnetosphere, etc…
  - Boundary conditions
  - Couplers
- **Beta testers**
  - Apply code to address science question
  - New GUI makes life easier

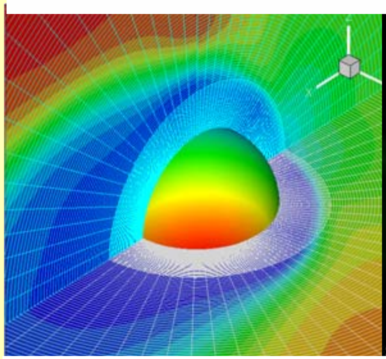
CSEM is a tightly integrated group of core code developers, user routine developers and beta testers

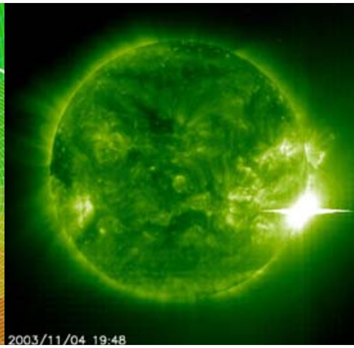


BATS-R-US is a Multi-Physics Code

- **Compressible fluid dynamics**
- **Ideal MHD**
- **Resistive MHD**
  - Resistivity models are poorly understood
  - Numerical resistivity often dominates
- **Hall MHD**
  - Keeps the Hall term in Ohm's law
  - More realistic reconnection rate
- **Semi-relativistic MHD**
  - Displacement current in Ampère's law
  - Limits all wave speeds by c
- **Multi-fluid MHD**
  - Each ionic species has its own continuity, momentum and energy equation
  - Electron momentum equation is replaced by Ohm's law.
- **Goal: semi-relativistic, multi-fluid Hall MHD with anisotropic pressure.**







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are needed to see this picture.

SWMF Summary

- **The Space Weather Modeling Framework uses efficient and flexible methods to couple and execute physics models.**
- **Hardware/OS**
  - SWMF runs under Unix, Linux, or Mac OSX.
  - It runs on laptops, Linux and Mac clusters, SGI Altix, Compaq etc.
- **Performance**
  - Good scaling to 1600 PEs (did not try on more)
- **SWMF is easily configurable**
  - One can select a subset of the implemented models with a single command.
- **Adding/implementing new physics-based models**
  - Takes about 2 weeks for 2 people (usually the developer of the model and a developer of the SWMF).

CSEM and CCMC

- **CSEM provides CCMC with state-of-the-art space science models and frameworks.**
- **CCMC makes CSEM models available to the research community through "Runs-on-Request" system.**
- **CCMC**
  - Tests CSEM models capabilities and robustness.
  - Provides independent V&V and metrics.
  - Supports models transition to operations.

BATSRUS v5.31 was the **first model** at CCMC (2000)
BATSRUS v6.07 was the **first RoR model** (2001)
Real-time run of SWMF/BATSRUS (since 2002)
SWMF transitioned to CCMC (2004)

So far CCMC had **555 requests** for SWMF/BATSRUS (out of 788 total magnetosphere runs).

  234 requests in 2006-2007.

Publications and Presentations

  > 50 presentations by RoR users (2002-2006)

  17 publications by RoR users + 6 by CCMC staff (2002-2006)

  2 Ph.D. dissertations

Simulations in Support of NASA missions

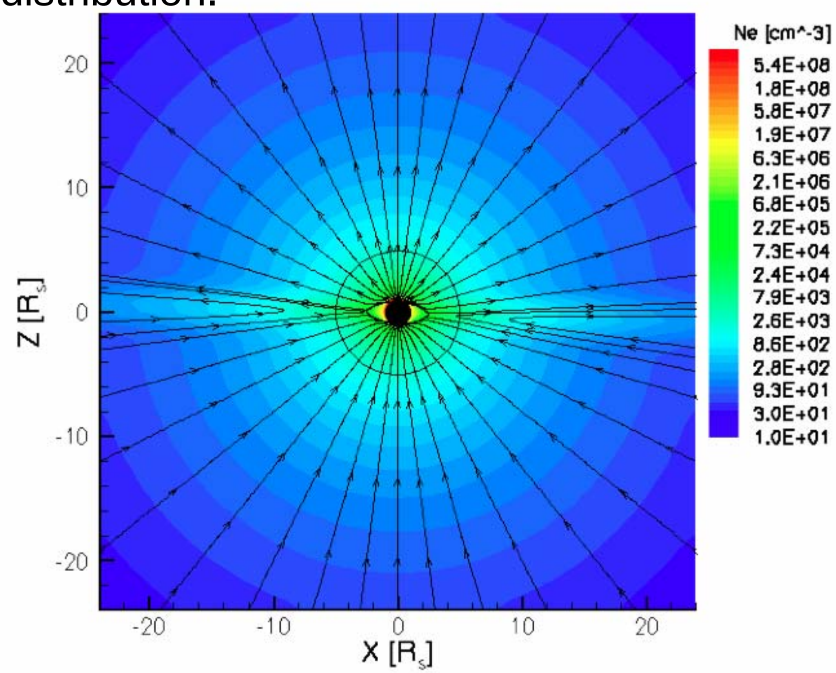
Special Requests (runs with 15 -20 million grid cells)

Empirical Solar Wind MHD Models (Ofer Cohen & Igor Sokolov)

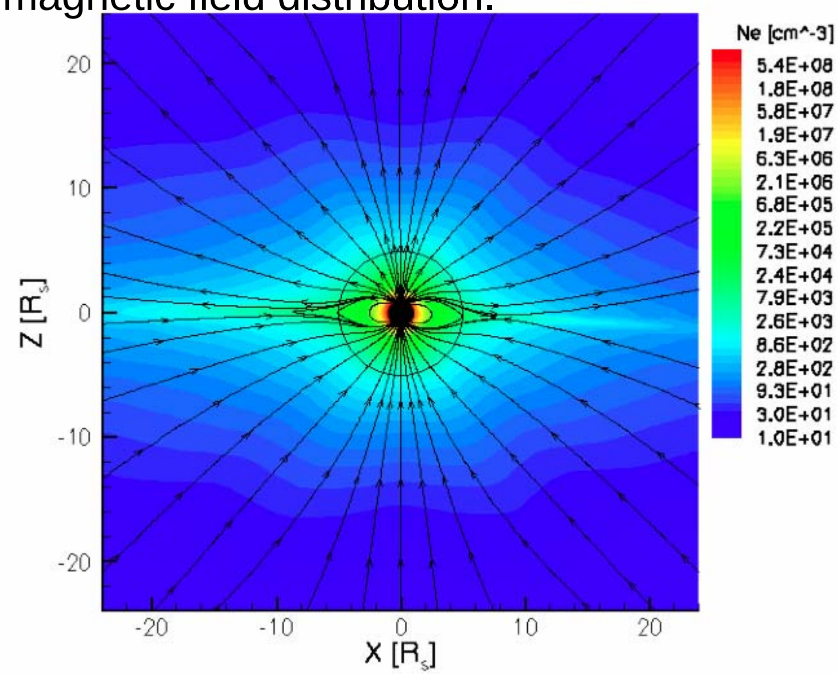
n_e-MHD: We specify the boundary conditions for γ using an empirical, magnetic latitude dependent electron density distribution extracted from white-light images (Guhathakurta et. al, JGR, 111, 2006). Because the magnetic field is independently obtained the electron density distribution is not fully consistent with the magnetic field distribution.

WSA-MHD: We specify the boundary conditions for γ using the ultimate solar wind speed calculated by the WSA model. The WSA model uses the potential field expansion factor to calculate the final solar wind speed. We also scale the base density and temperature with the expansion factor so the physical parameters are drived self-consistently (but necessarily correctly).

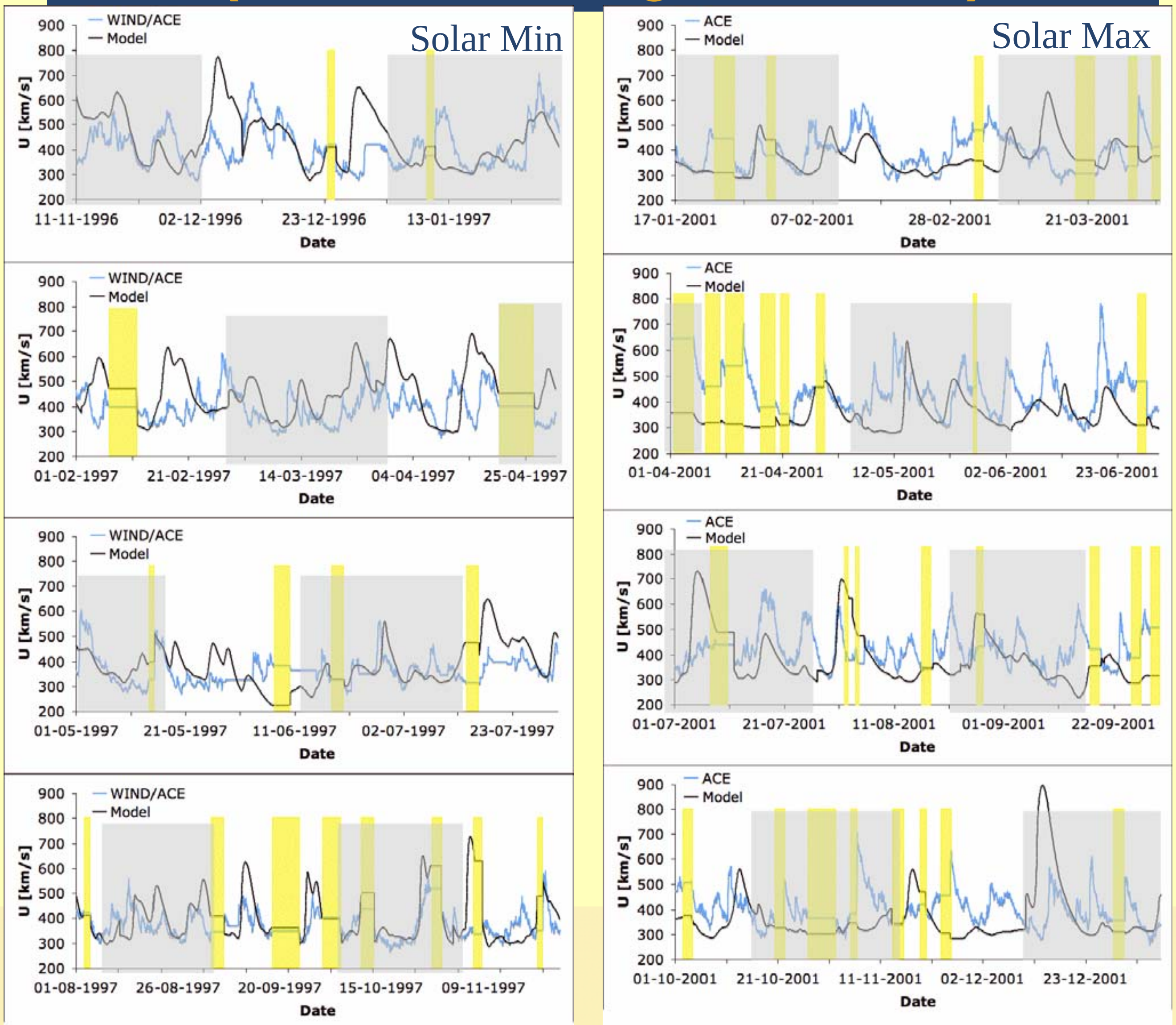
Initial (empirical) n_e and the potential field distribution.



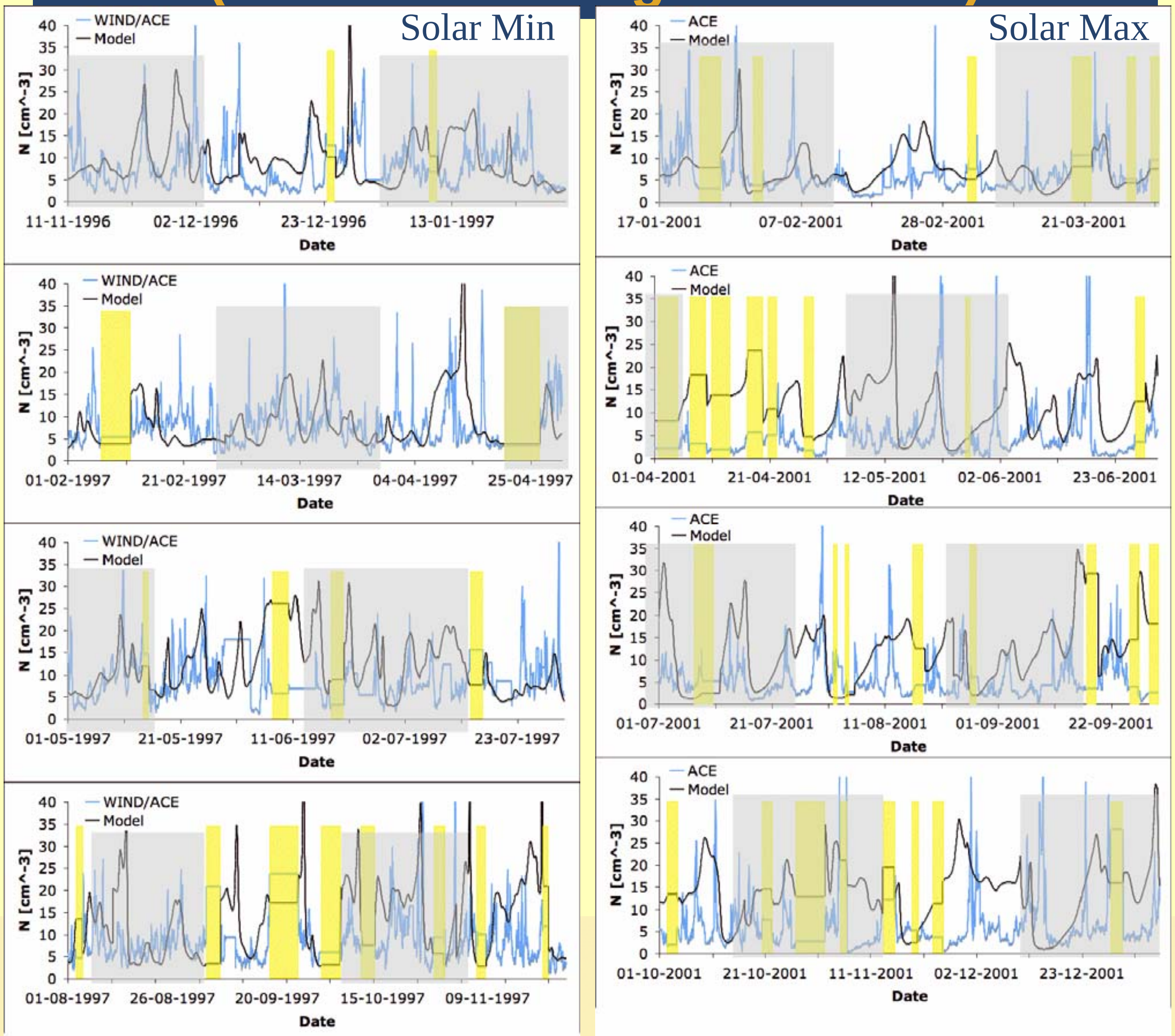
MHD steady state solution for n_e and magnetic field distribution.



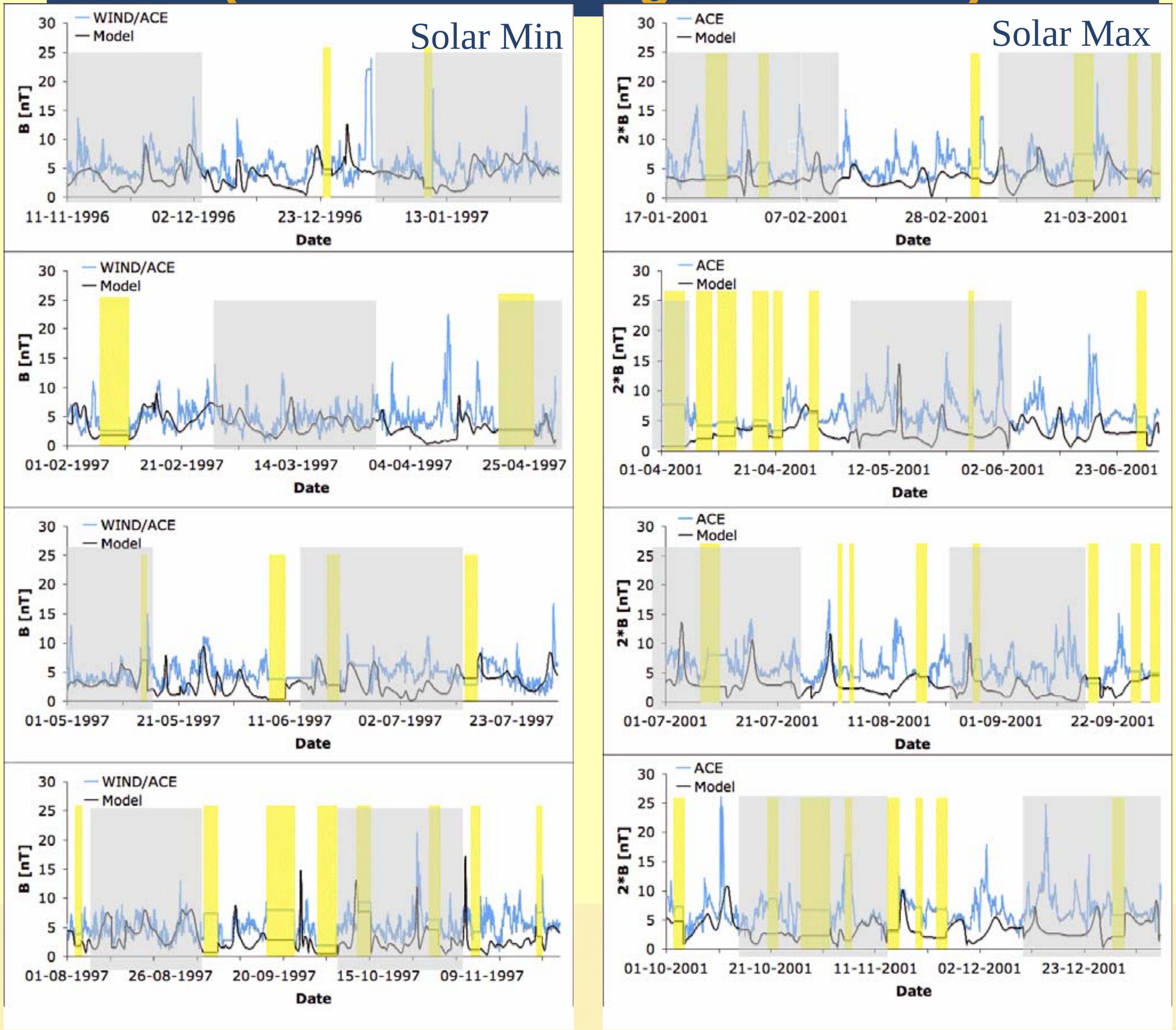
WSA-MHD: Velocity
(Ofer Cohen & Igor Sokolov)



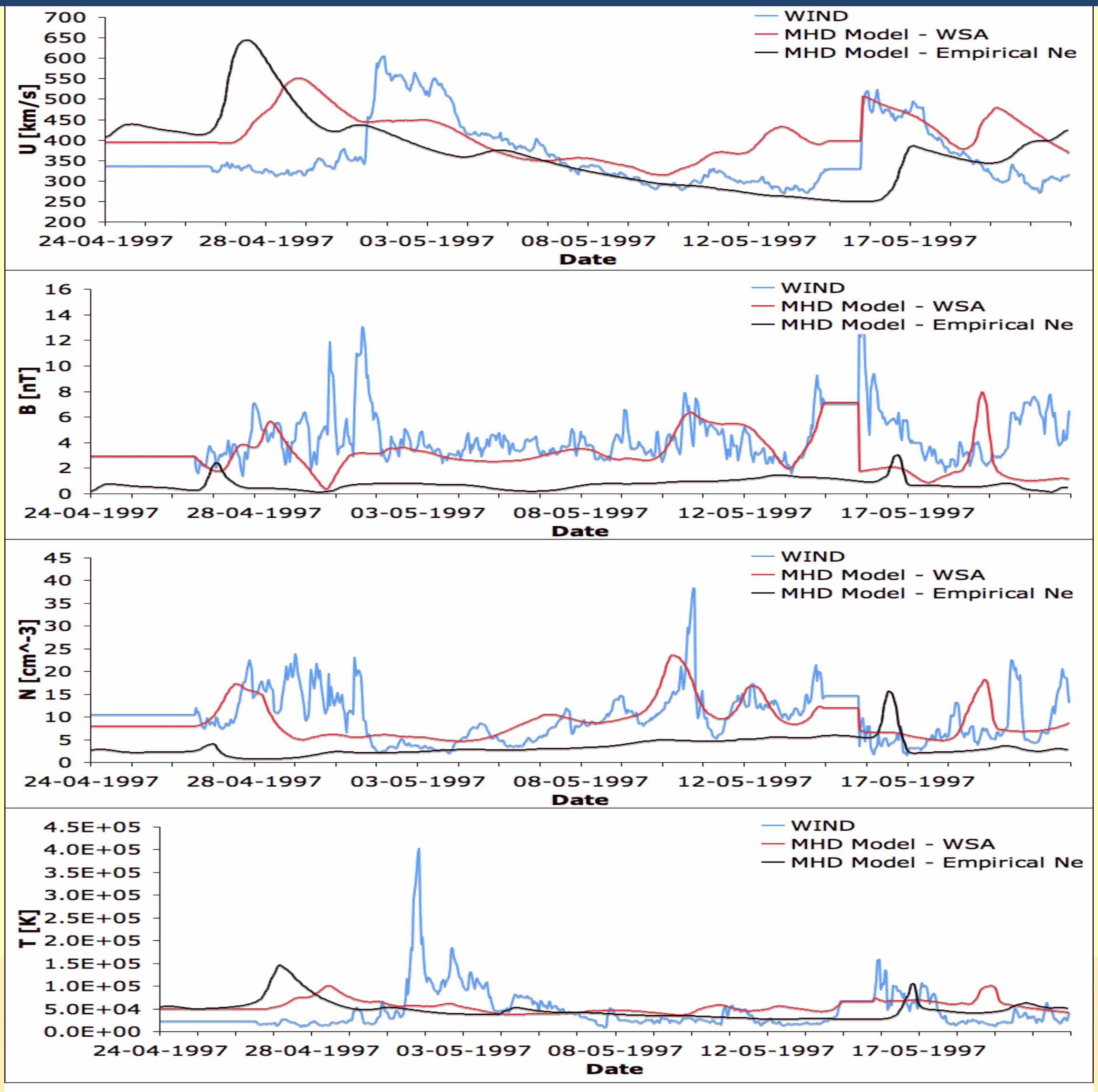
WSA-MHD: Density
(Ofer Cohen & Igor Sokolov)

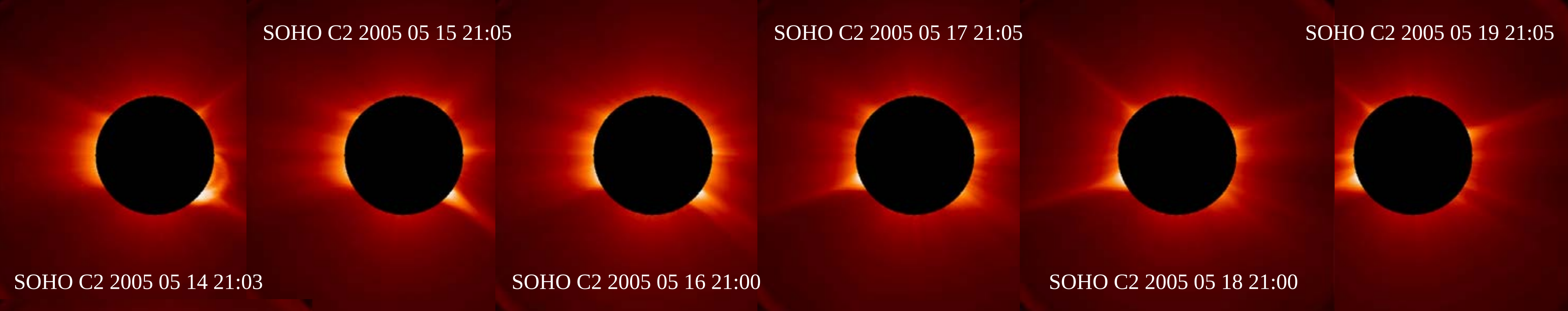


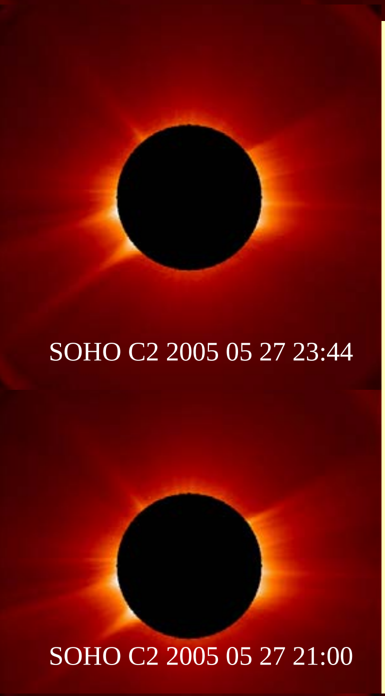
WSA-MHD: Magnetic Field (Ofer Cohen & Igor Sokolov)



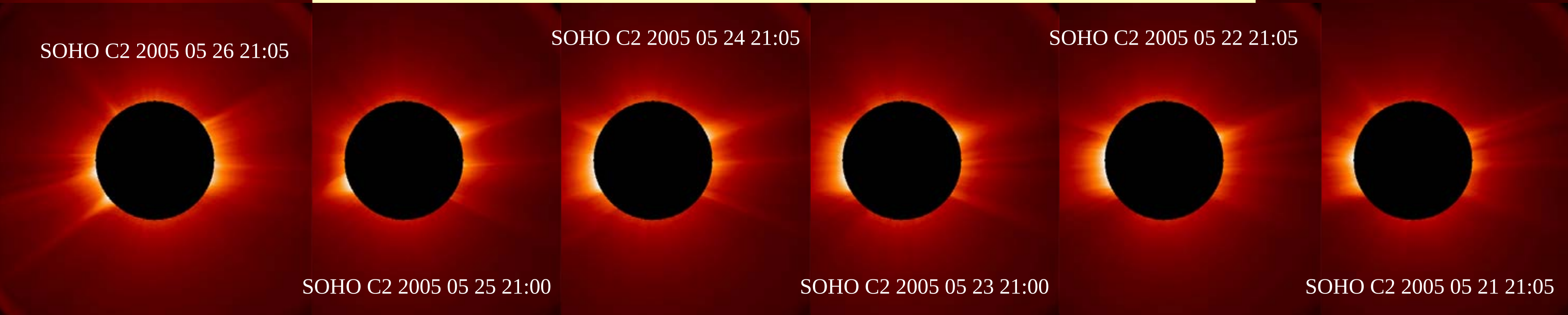
Synoptic Model Comparison with ACE (Ofer Cohen & Igor Sokolov)







Rich Frazin brought 3D tomography capability to CSEM. His line-of-sight image inversion technology can reproduce the global coronal electron density distribution using coronagraph images. It takes half a solar rotation of imaging data to create a full 3D electron density distribution between 1 R_s and ~6 R_s.



Tomography and WSA-MHD Field Lines (Rich Frazin & Chip Manchester)

$n_e=10^6$

$n_e=5\text{x}10^5$

QuickTime™ and a
BMP decompressor
are needed to see this picture.

n_e Tomography and WSA-MHD Comparison (10^5/cc isosurface) (Rich Frazin & Ofer Cohen)

QuickTime™ and a
BMP decompressor
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CME Initiation by Magnetic Flux Rope (Ilia Roussev & Chip Manchester)

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Sorenson Video 3 decompressor
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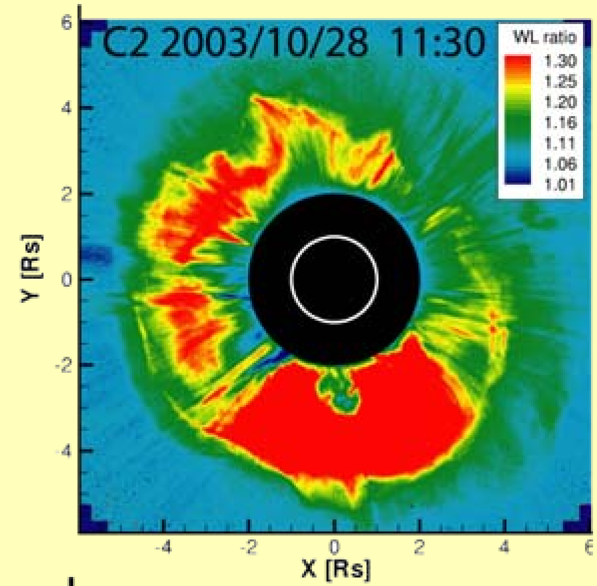
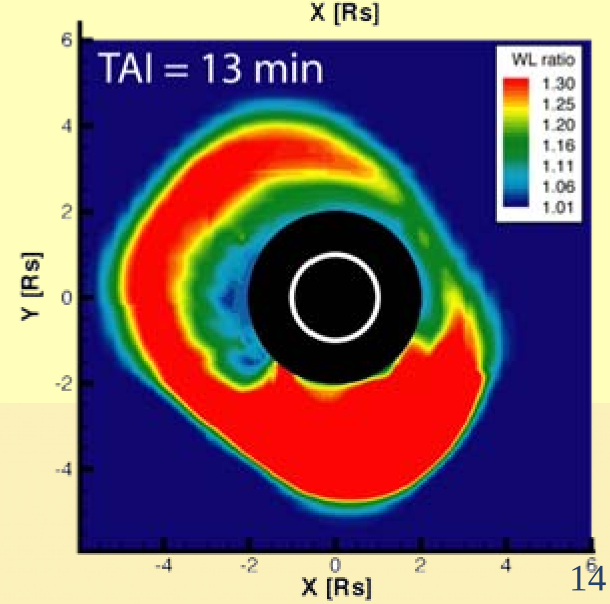
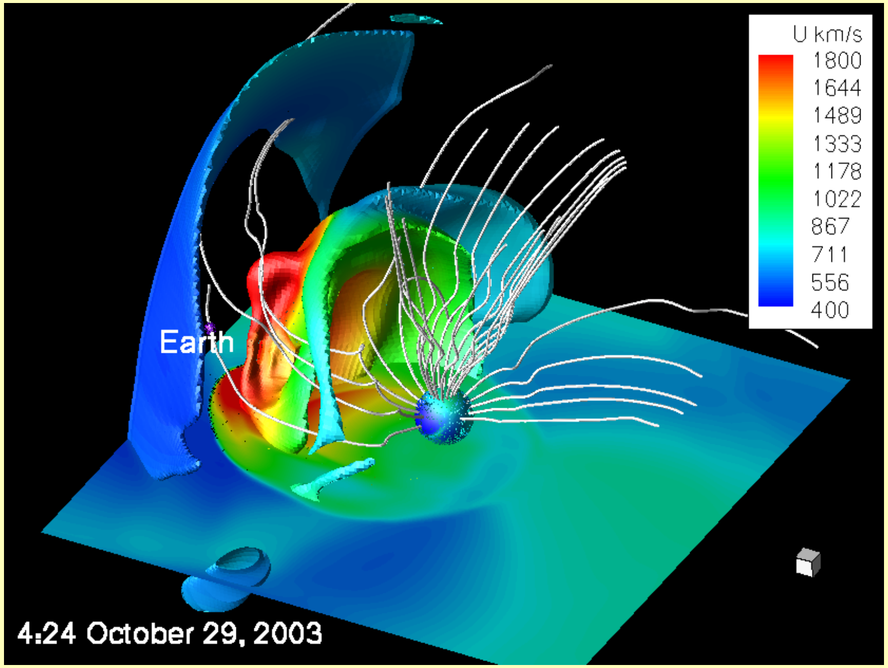




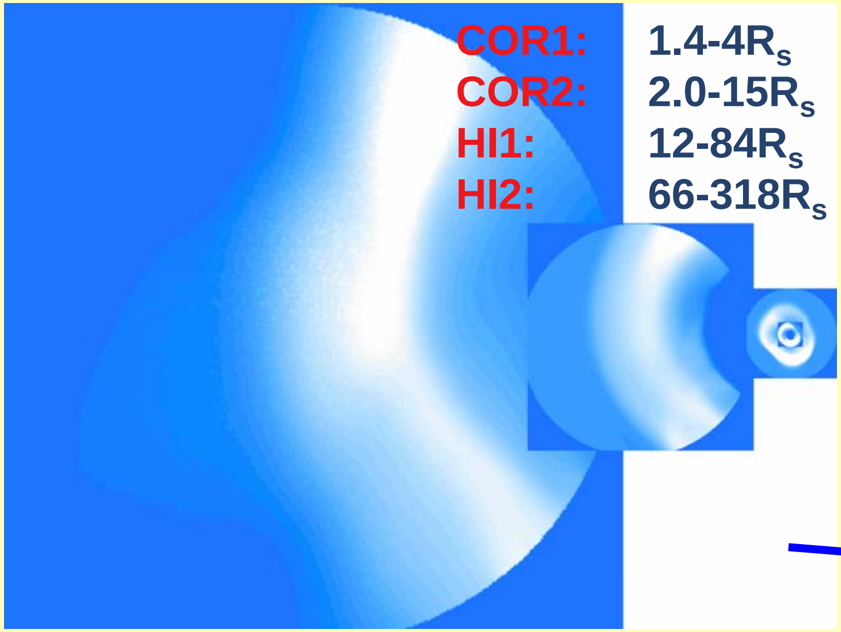
Comparison of Model and Data at 1AU (Chip Manchester)

- 3D density reconstruction (Jackson 2006)

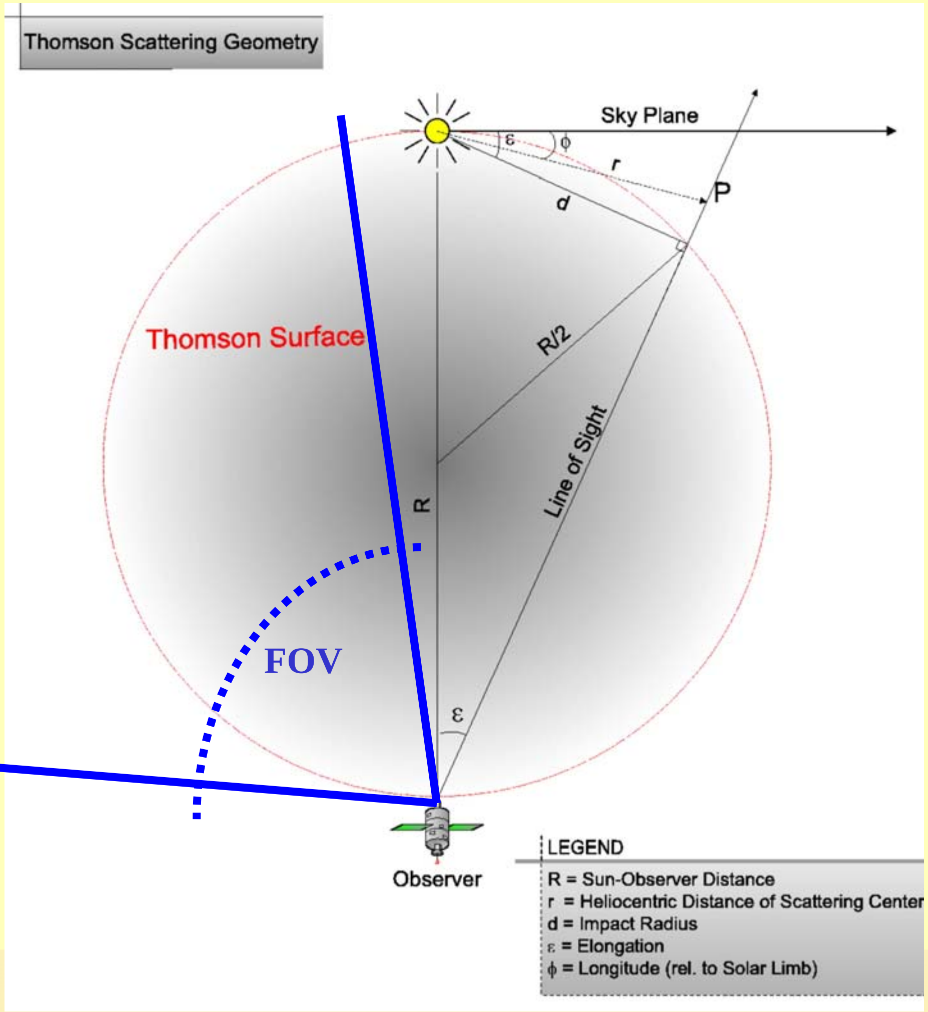
QuickTime™ and a
Microsoft Video 1 decompressor
are needed to see this picture.



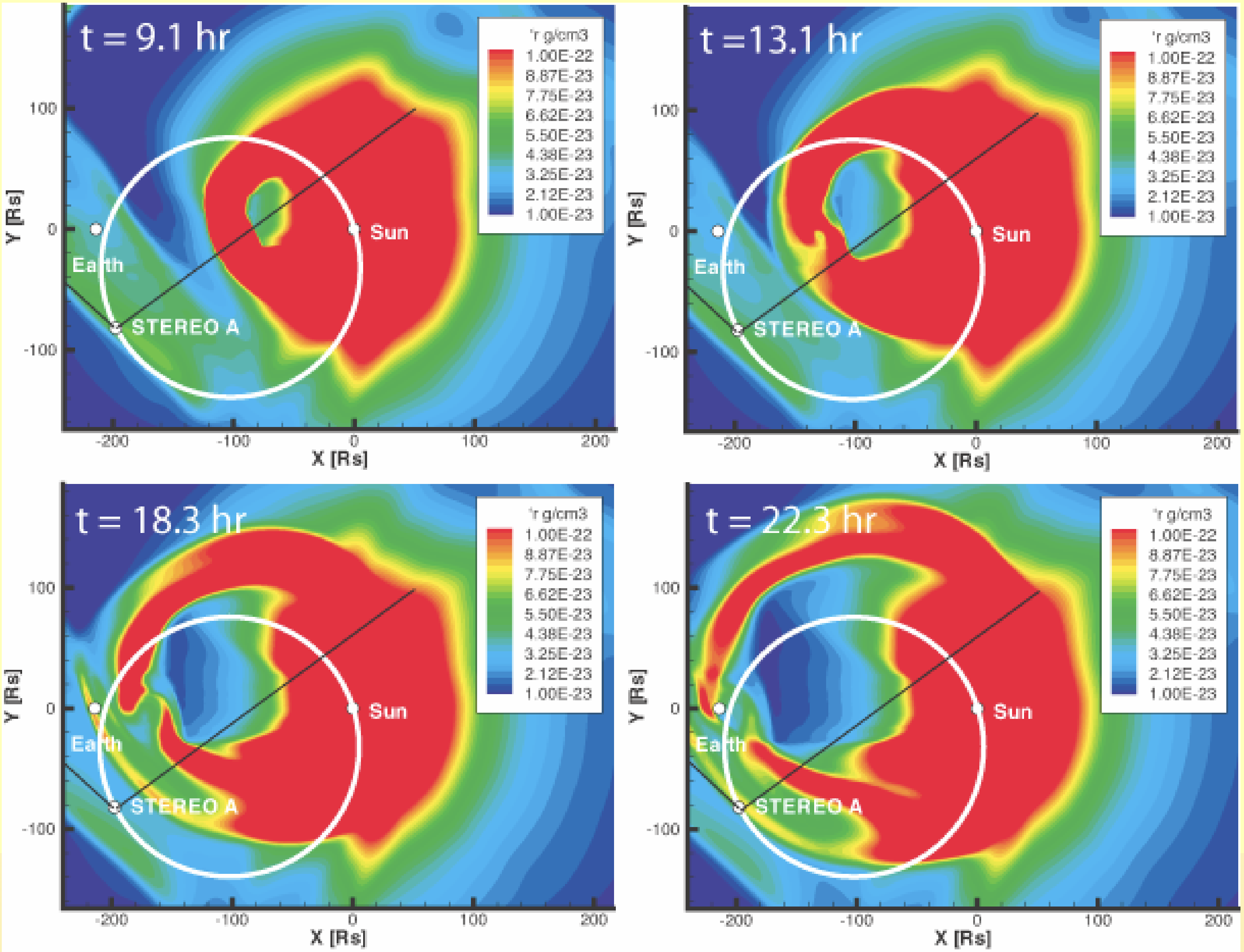
SECCHI Fields of View (Chip Manchester)



- COR1: 1.4-4R_s
- COR2: 2.0-15R_s
- HI1: 12-84R_s
- HI2: 66-318R_s



CME Density Structure near 1 AU (Chip Manchester)



Synthetic SECCHI HI2 Images (Chip Manchester)

QuickTime™ and a
BMP decompressor
are needed to see this picture.

Future Work

- **Code improvements:**
  - Solve equation for T_e and add this as option to all MHD models (ideal, resistive, Hall, multi-species, multi-fluid,…)
  - Make Roe solver work with both Cartesian and spherical grids
- **Data assimilation**
  - Use n_e and T_e coronal tomography to constrain MHD solution (ensemble)
  - Incorporate vector magnetograms and tomography into MHD solution (boundary conditions, nudging)
- **CME initiation**
  - Simulate breakout model
  - Physics-based shear-flow initiation of CMEs
- **STEREO IMPACT (SEP)**
  - Use Flampa and Kota models to simulate real SEP events