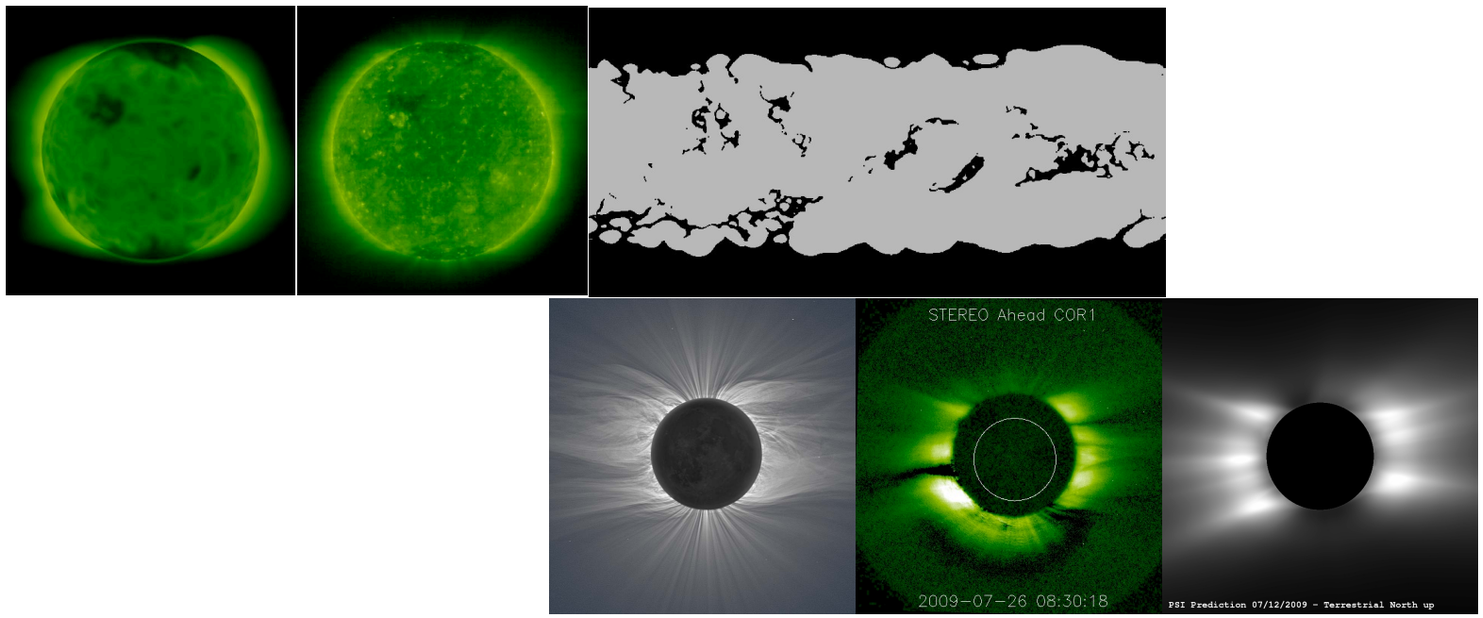
Comparison of High Resolution MHD Models with EUV and White Light Observations*



Jon A. Linker, Zoran Mikic, Roberto Lionello, Pete Riley, Slava Titov

Predictive Science, Inc. (PSI)

9990 Mesa Rim Rd, Suite 170

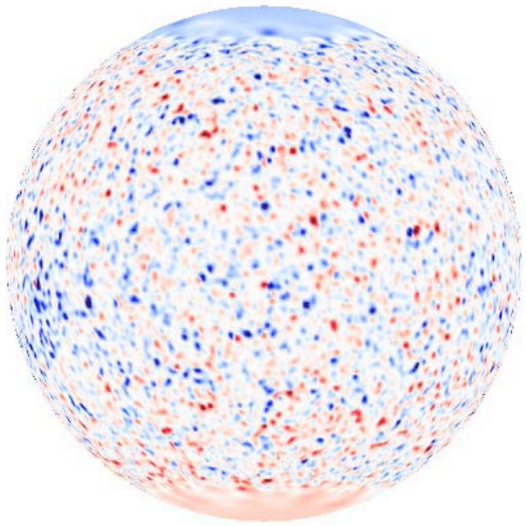
San Diego, CA 92121, USA

http://www.predsci.com

*Work supported by NASA, NSF, &AFOSR

Introduction

- For ~15 years, our group has predicted the structure of the corona prior to total solar eclipses: **http://www.predsci.com**
- Advances in modeling capability have allowed us to perform the most recent calculations (August 1, 2008; July 22, 2009) at very high resolution



Map based on high resolution MDI magnetograms

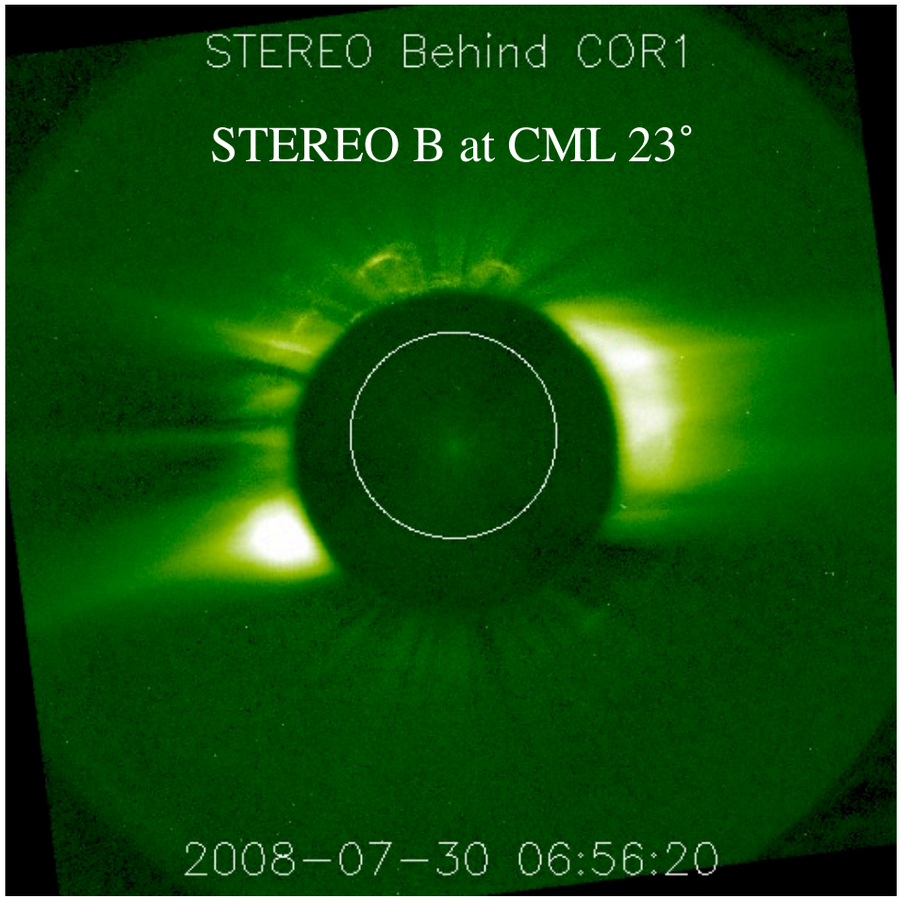
- The August 2008 prediction was very successful.
  - The detailed structure in the simulations has led to new ideas about the origin of the slow wind (not discussed today).
  - We noticed deficiencies in the emission comparison (1st part of the talk)
  - We attempted to improve the heating specification to for the 2009 prediction
  - The result we obtained was somewhat unexpected.... (2nd part of the talk)

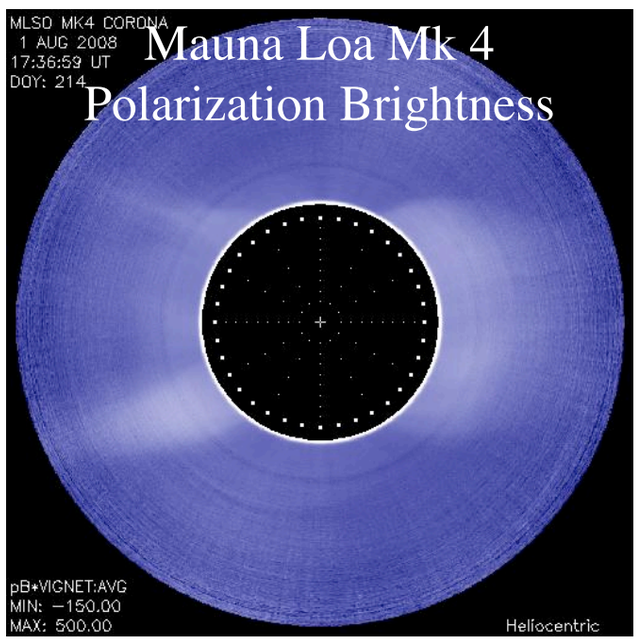
August 1, 2008 Total Solar Eclipse

- Eclipse Image:
  - Developed from multiple images, different exposure times
  - Sharpening algorithm applied
  - Brightness/density relation not obvious
  - This is not what the naked eye sees
- Predicted Polarization Brightness:
  - Newkirk filter applied

Predicted Magnetic Field Lines (MHD Model)

August 1, 2008 Total Solar Eclipse



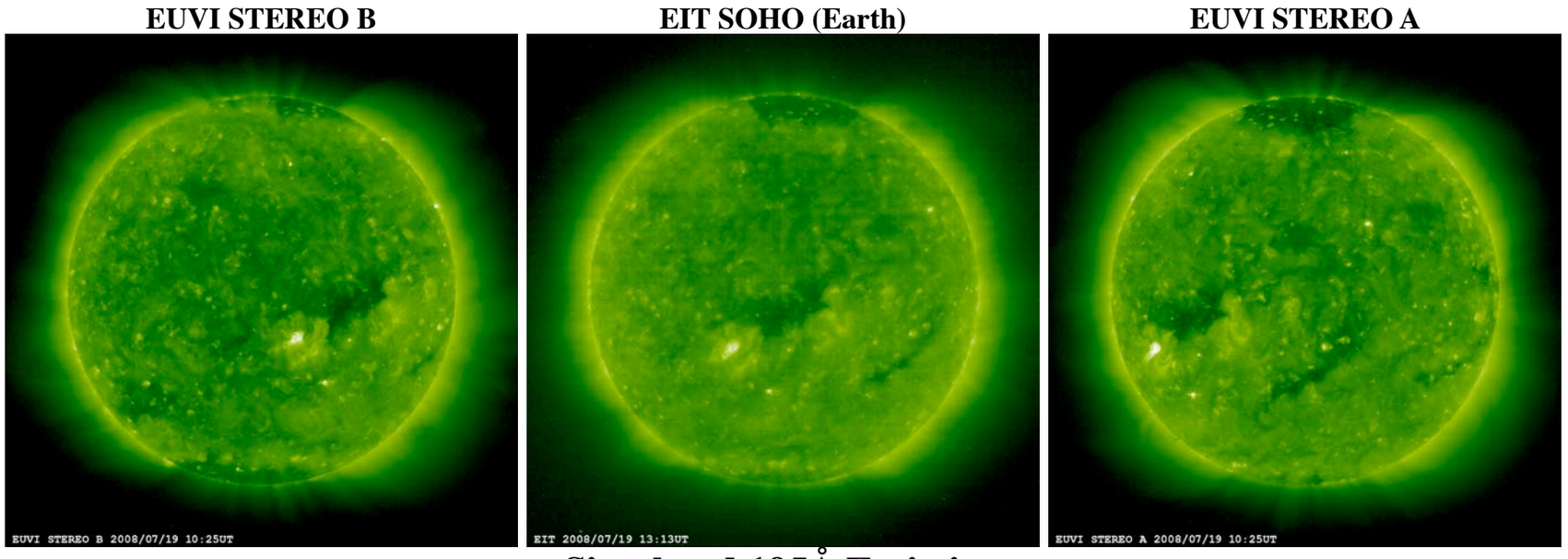


Magnetic Field Lines (MHD)

There is Good Correspondence Between the Different White Light observations

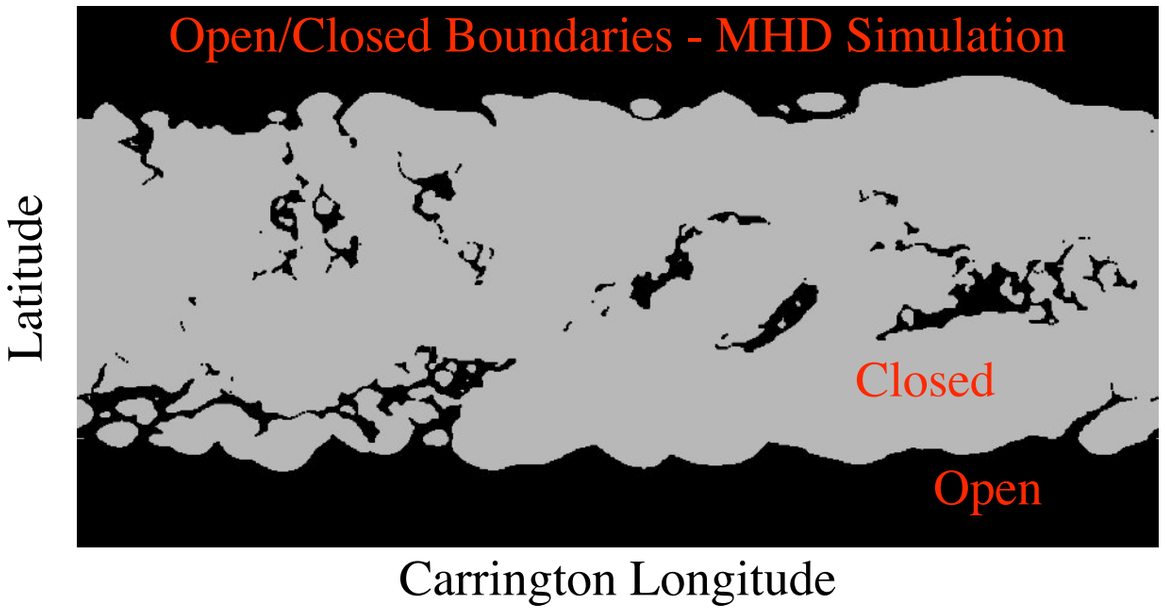
Carrington Rotation 2071+2072 Comparison: SOHO EIT & STEREO EUVI

Observed 195Å Emission on July 19, 2008 near 13:06UT



- There is reasonable correspondence between observed and simulated coronal holes.
- Modeled coronal holes are too large and too dark.
- No point spread function - might account for some of the low emission in simulated coronal holes.

Carrington Rotation 2071+2072 Comparison: "Synoptic" Maps



STEREO A EUVI 195 Synoptic: CR2071

Comparison of rotations shows variability of CHs

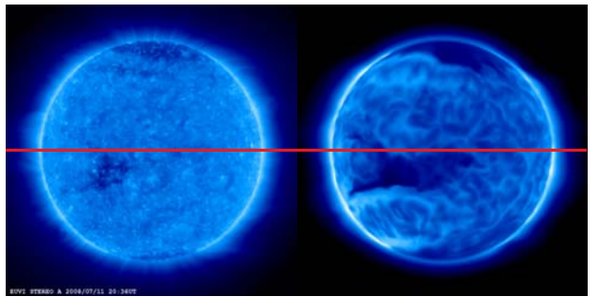
EUVI 195A - MHD Simulation

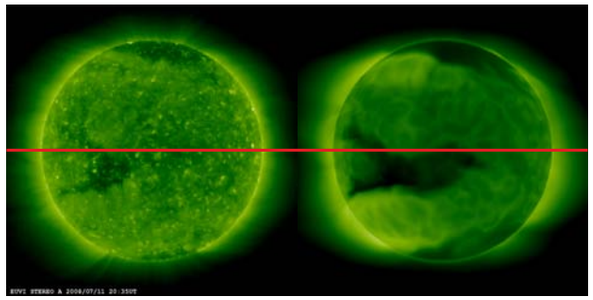
STEREO A EUVI 195 Synoptic: CR2072

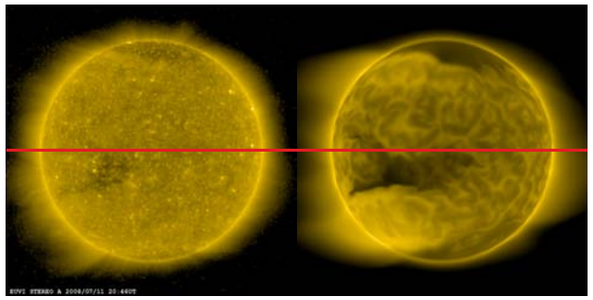
- Simulated "synoptic" emission has no obscuration by overlying structures.
- Dark regions and open fields correspond closely but not exactly in simulations.

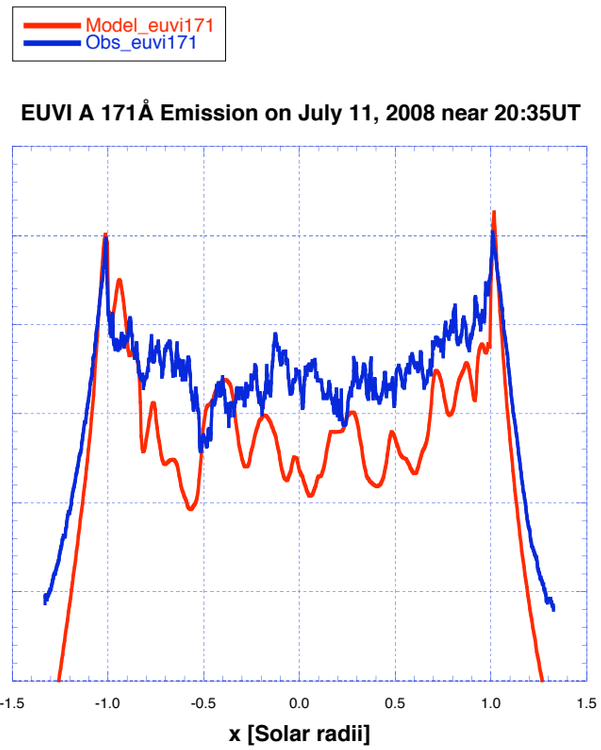
Carrington Rotation 2071+2072 Comparison: STEREO EUVI

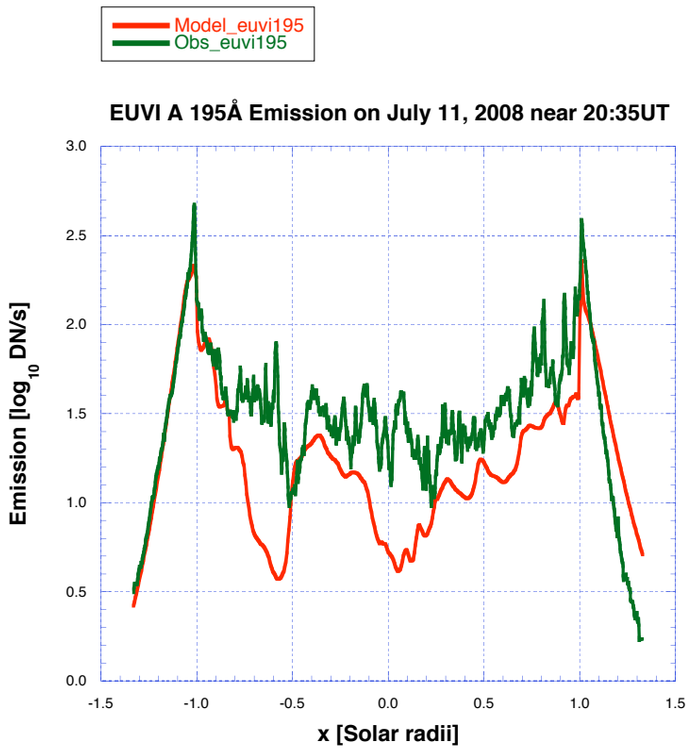
Comparing EUVI A Emission with Simulated Emission on July 11, 2008 near 20:35UT (Equatorial Cut)

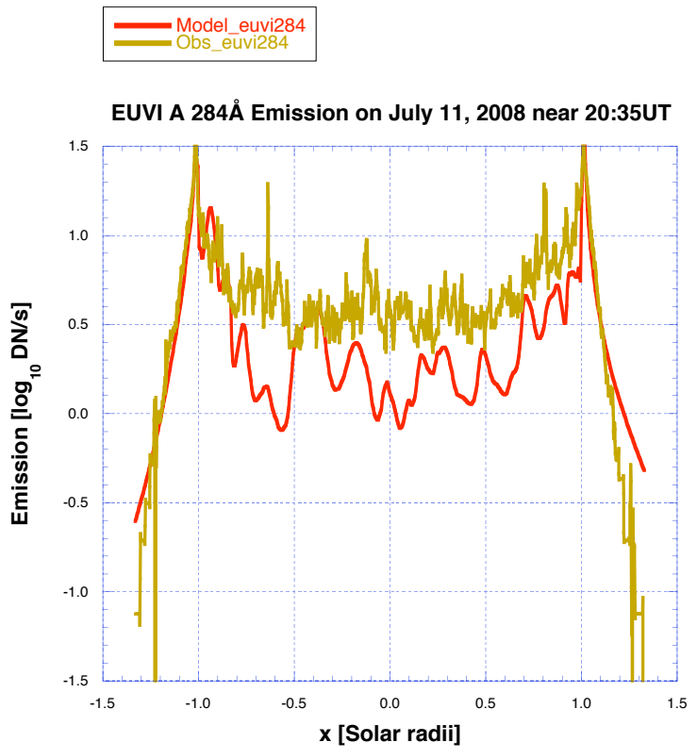






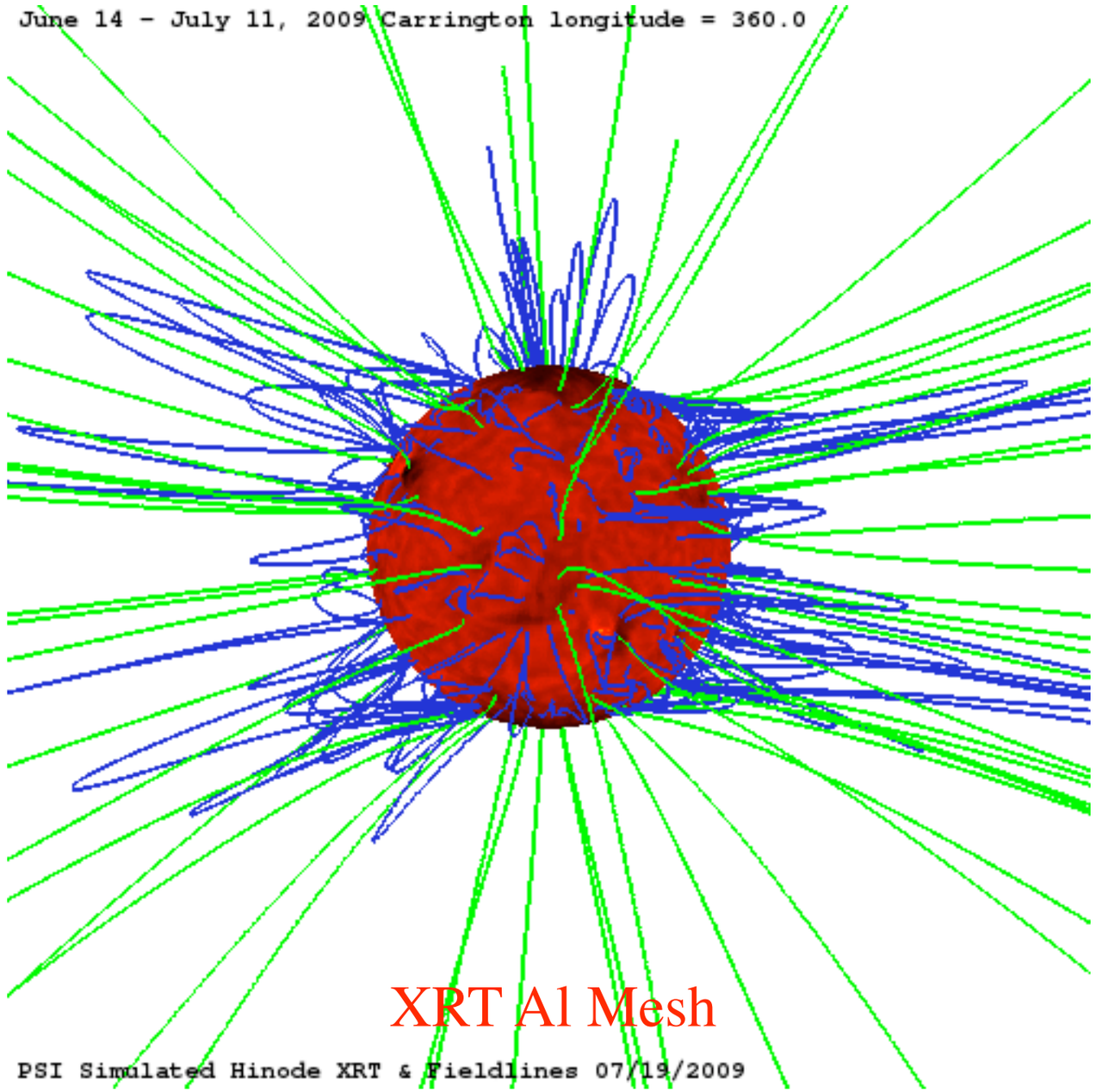






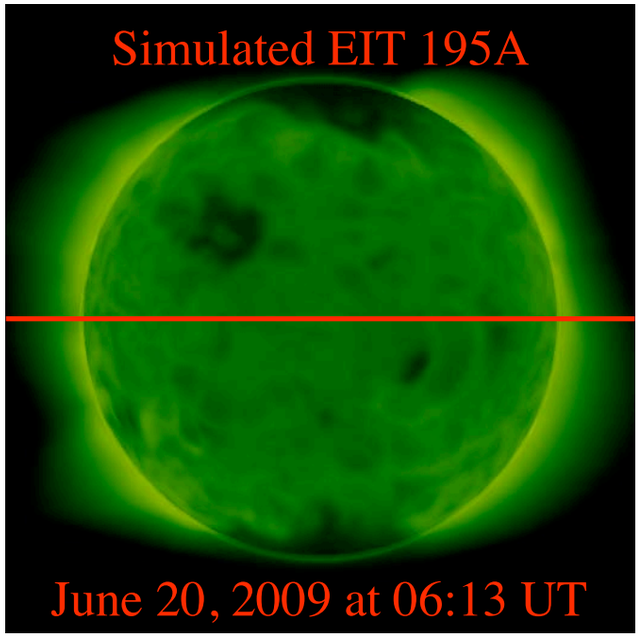
- Background emission is too low - indicates heating model can be improved.

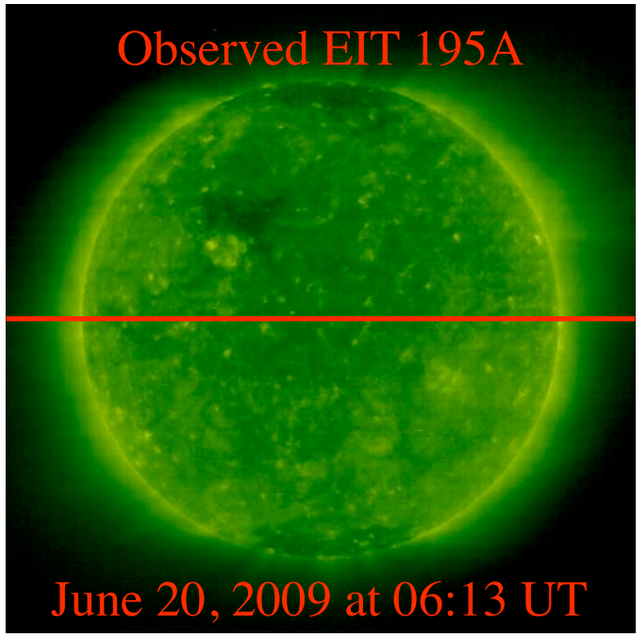
July 22, 2009 Total Solar Eclipse: 3D Structure

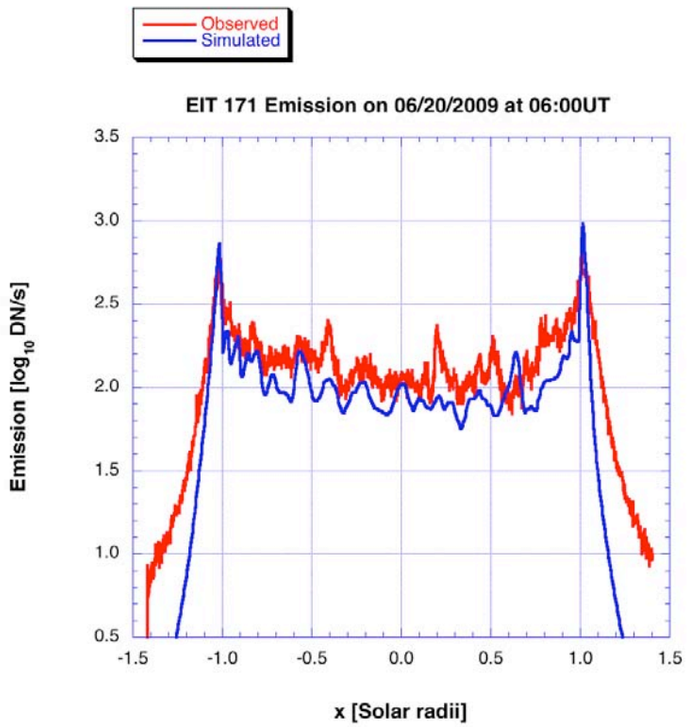


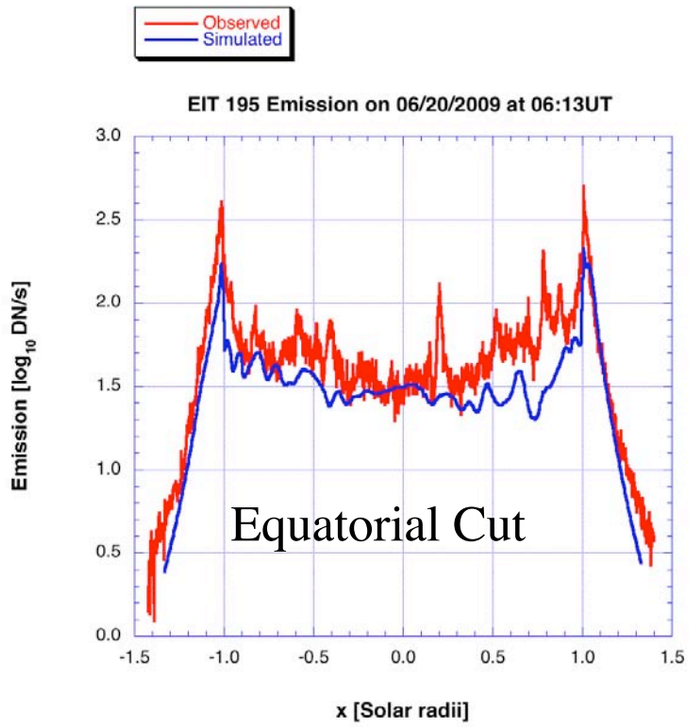
- Blue field lines are closed, green are open
- There are lots of small-scale open fields that don't obviously correspond to coronal holes in simulated emission

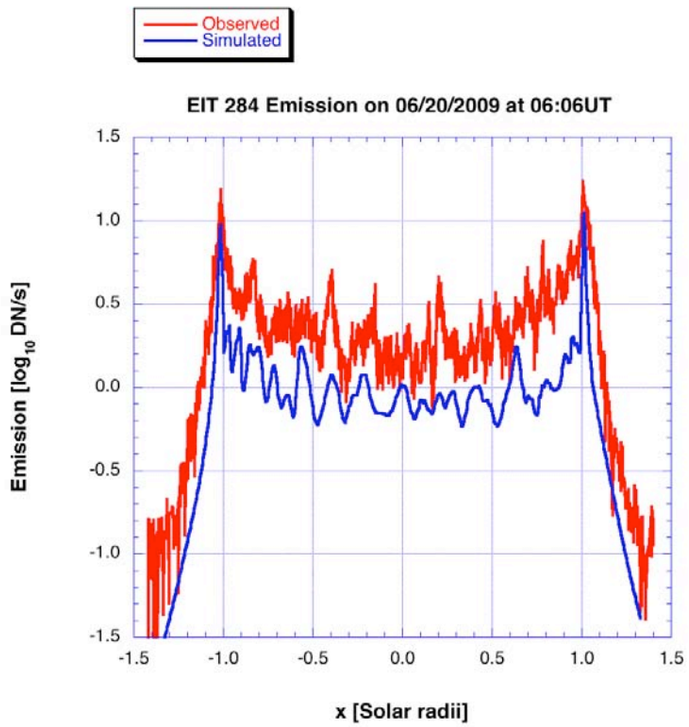
Carrington Rotation 2084+2085 Comparison: SOHO EIT





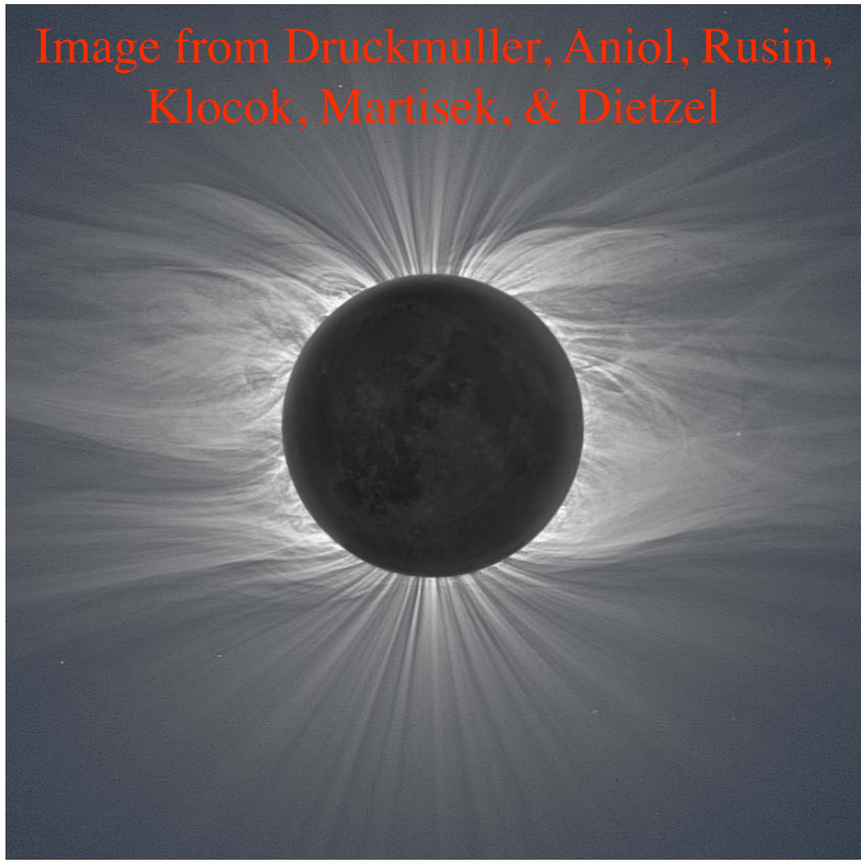


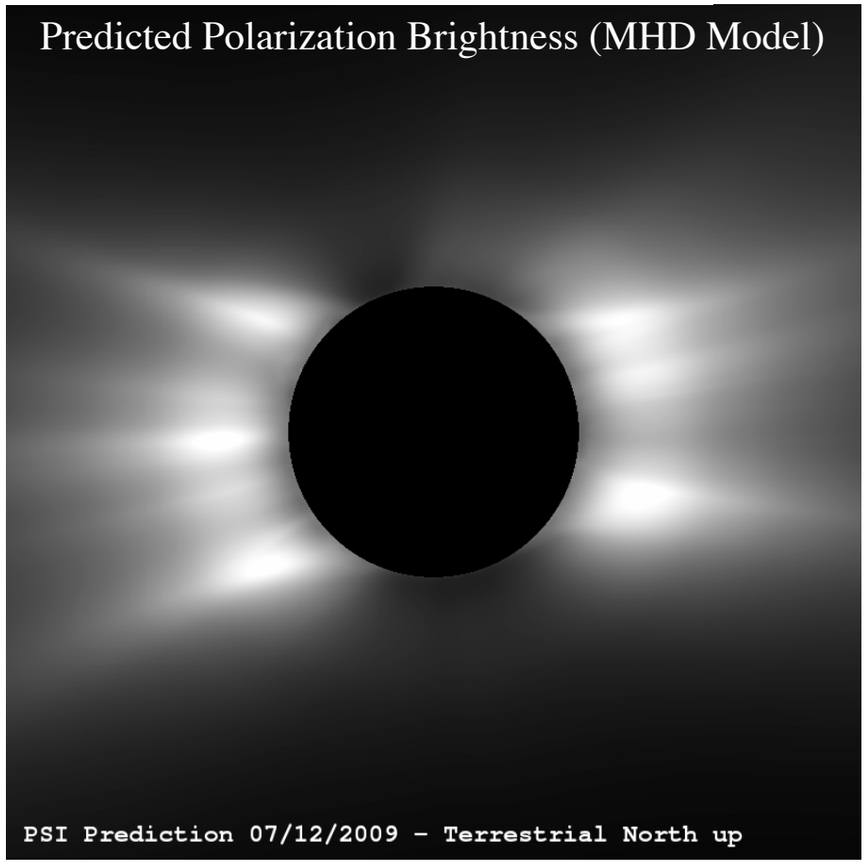


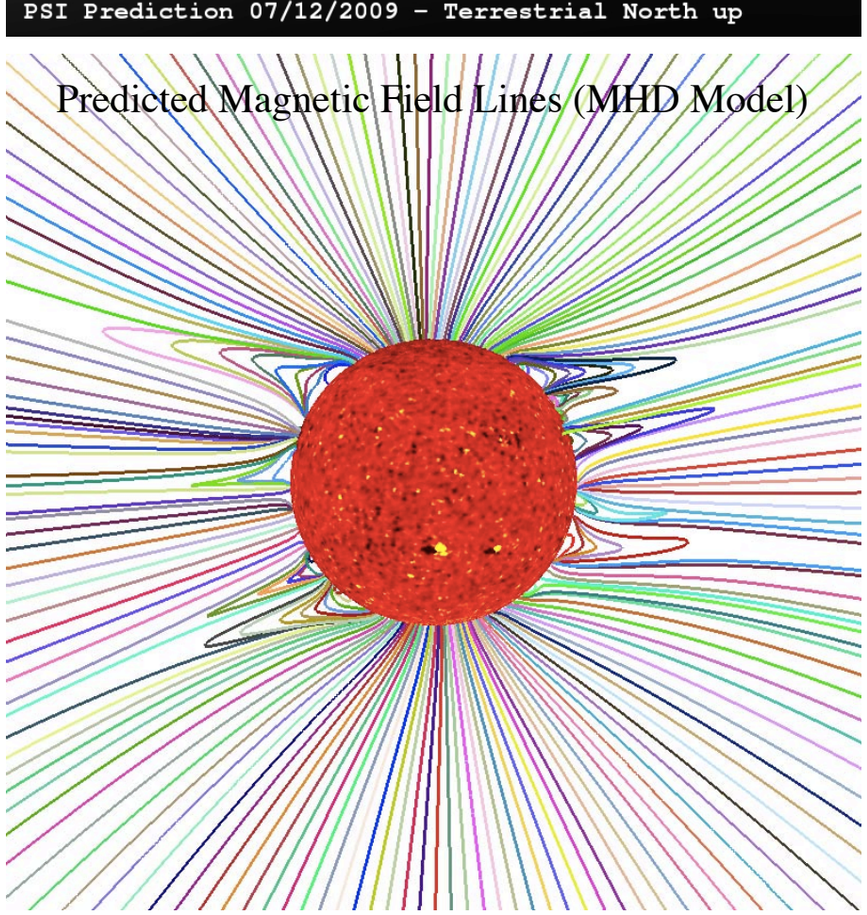


- Simulated emission level matches observed level reasonably well
- The match is improved compared to August 2008

July 22, 2009 Total Solar Eclipse





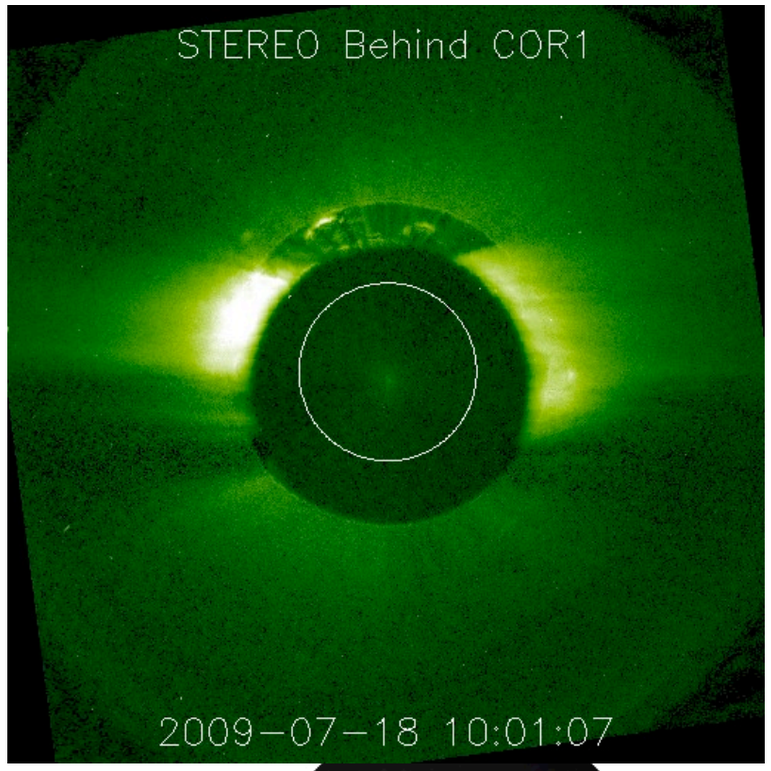


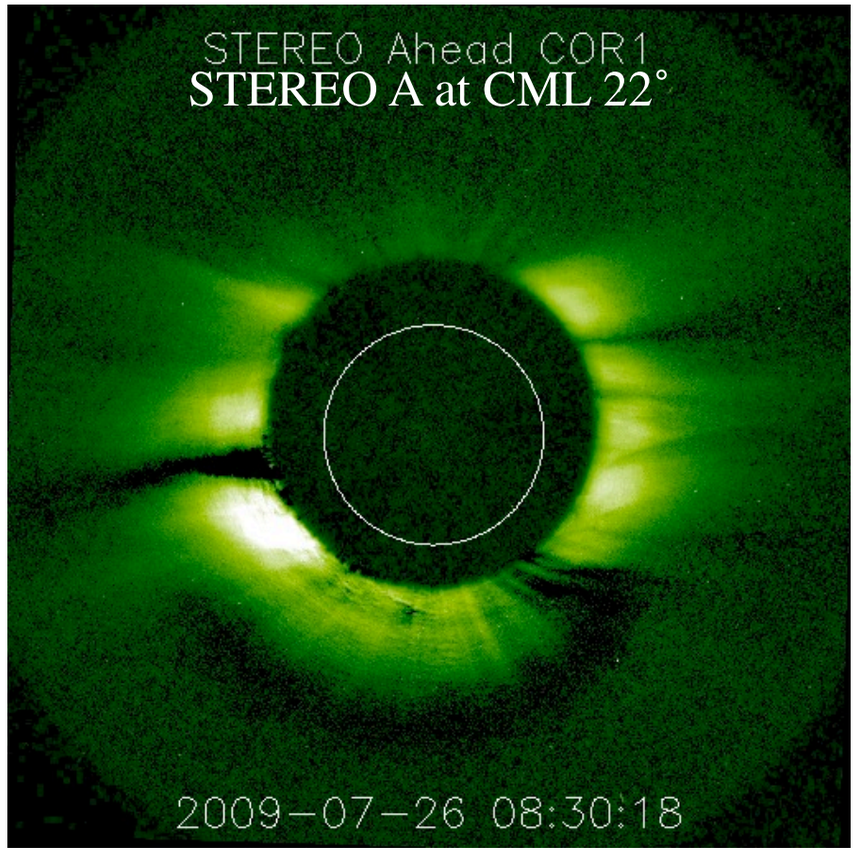
- Eclipse Image:
  - Approximately rotated to terrestrial north up
  - Sharpening procedure, as in 2008
  - Coronal structures look very non-radial
- MHD Calculation:
  - Streamers look too small and too radial
  - Our corona has a very complex structure, and a poor resemblance to the eclipse image

July 22, 2009: Eclipse STEREO, MLSO Comparison

Image from Druckmuller, Aniol, Rusin, Klocok, Martisek, & Dietzel

Mauna Loa MK 4
Provided by Joan Burkepile





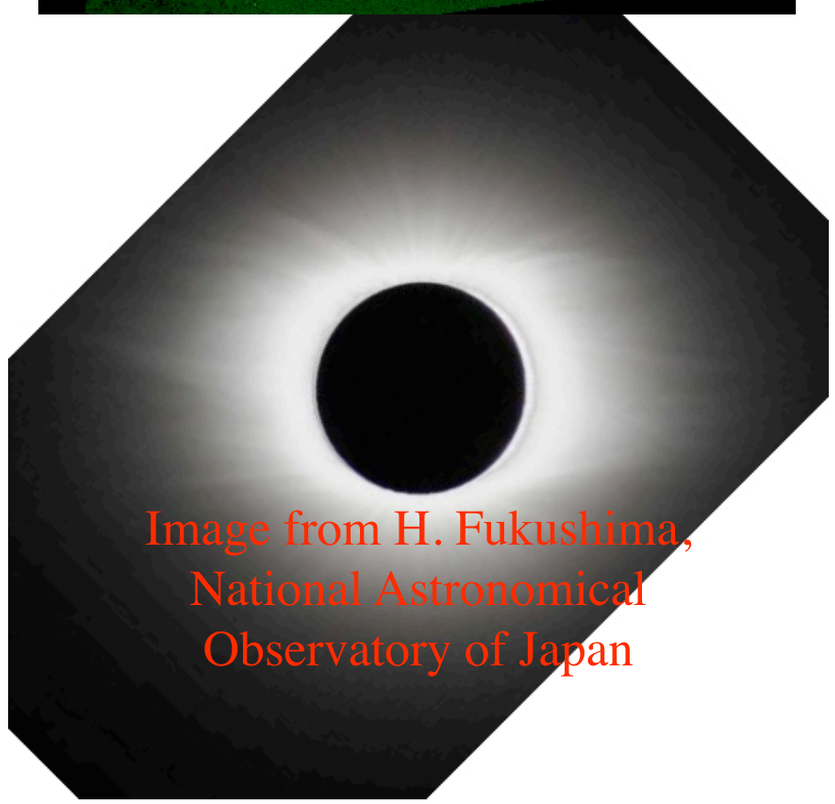
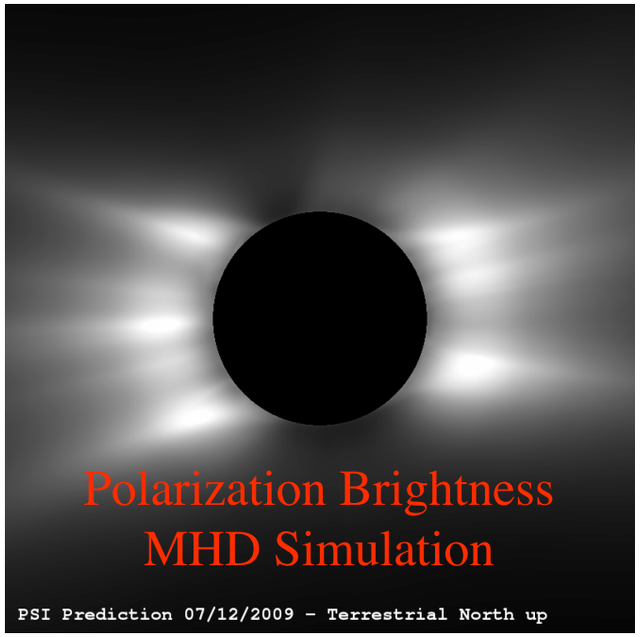


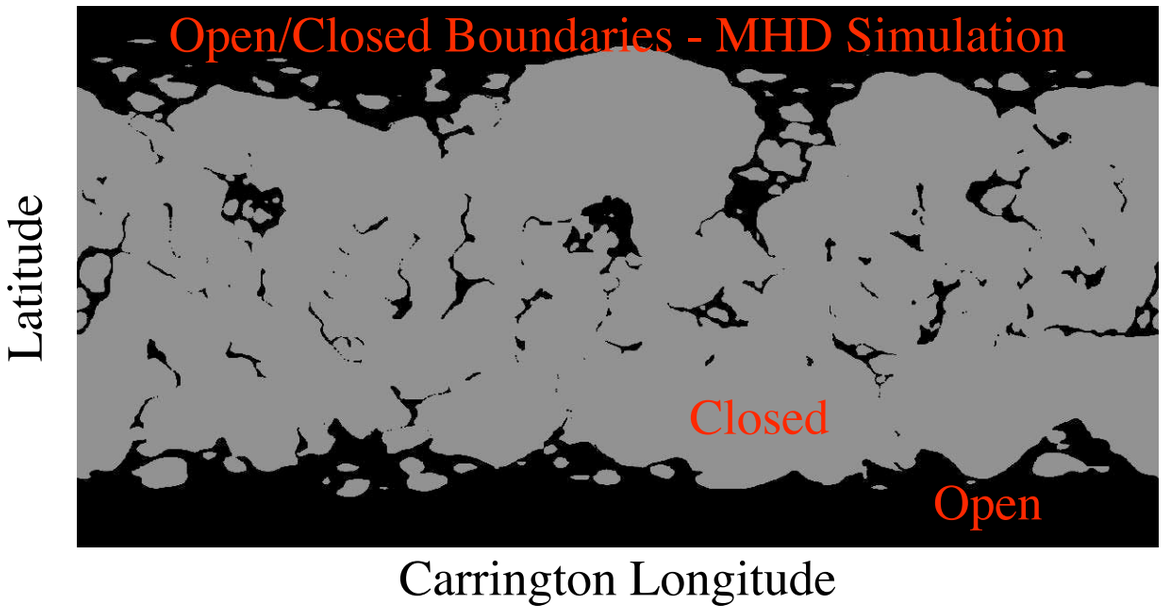
Image from H. Fukushima, National Astronomical Observatory of Japan



Polarization Brightness MHD Simulation

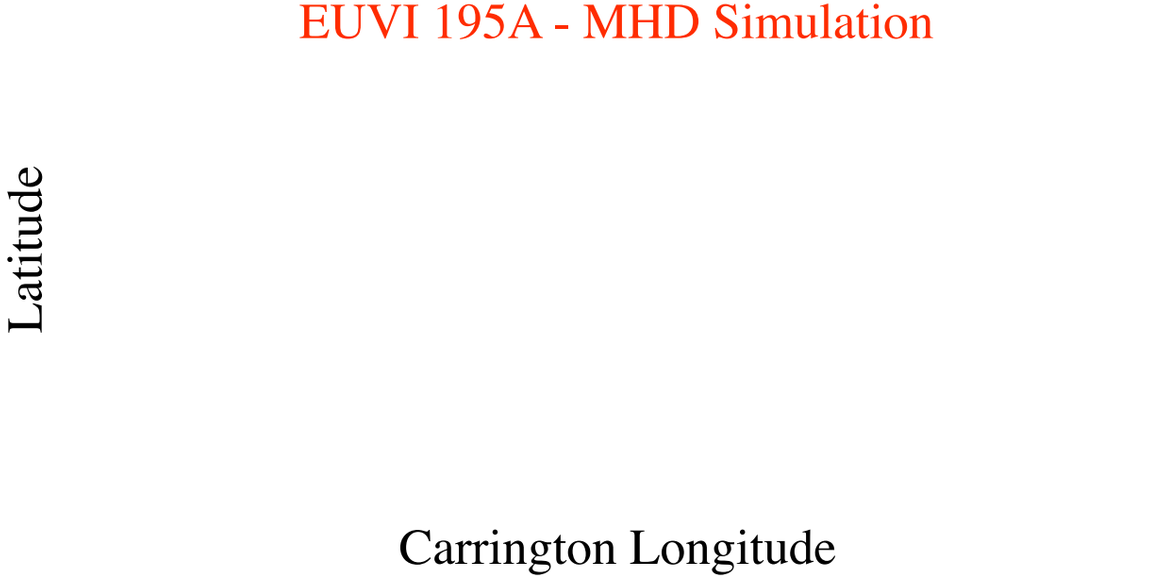
The Correspondence Between the Different White Light Observations is not as clear as 2008

Carrington Rotation 2084+2085 Comparison: "Synoptic" Maps



STEREO A EUVI 195 Synoptic: CR2084

More variability of CHs compared to 2071-2072



STEREO A EUVI 195 Synoptic: CR2085

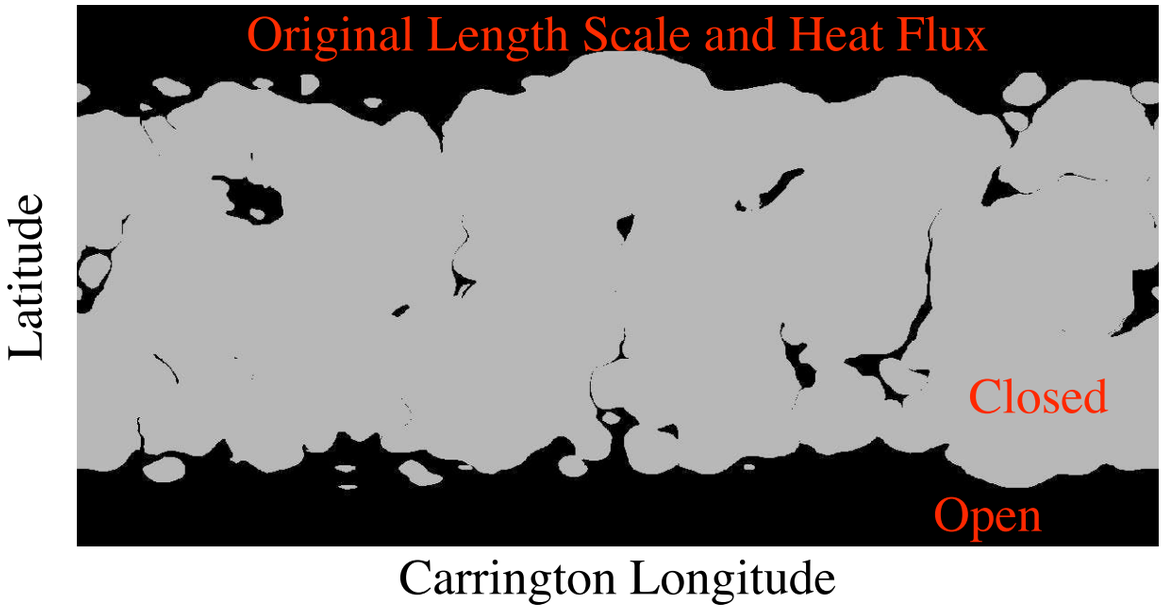
- There are lots of very small scale open fields in the simulation - too many!
- It is very easy to open the weak field of the Sun during this time period.

Carrington Rotation 2084+2085 Comparison: Coronal Holes

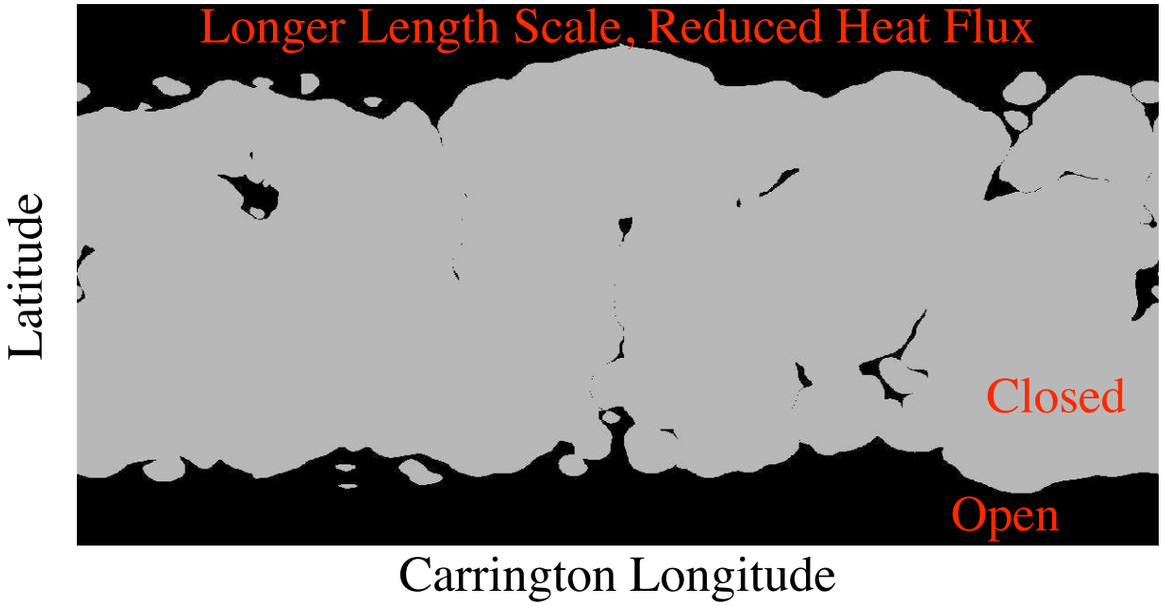
We have now run a number of test cases ....

Positive Polarity Open Negative Polarity Open Closed

Comparison of Coronal Holes for Fast Wind Heating Alone



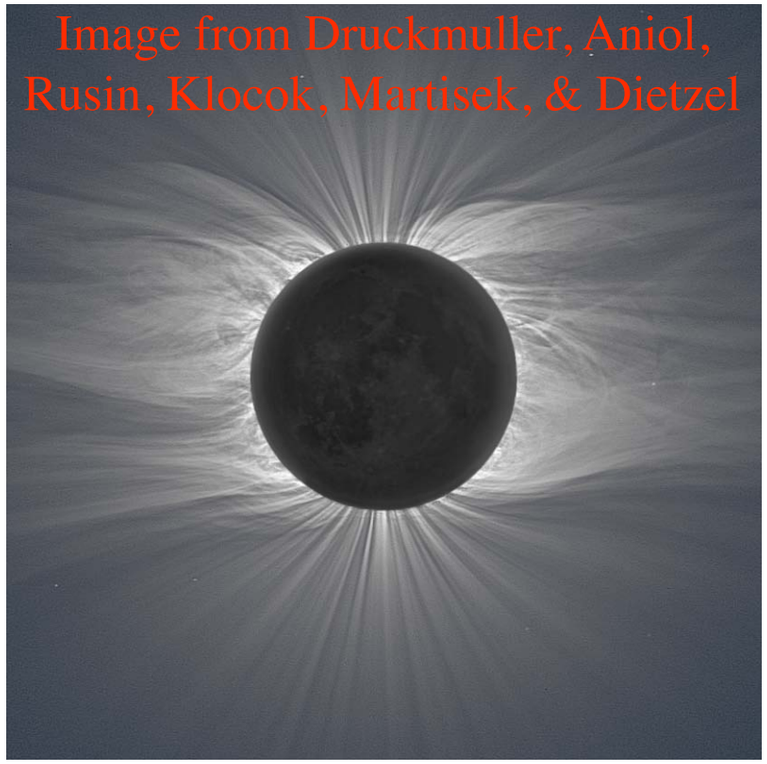
STEREO A EUVI 195 Synoptic: CR2084



STEREO A EUVI 195 Synoptic: CR2085

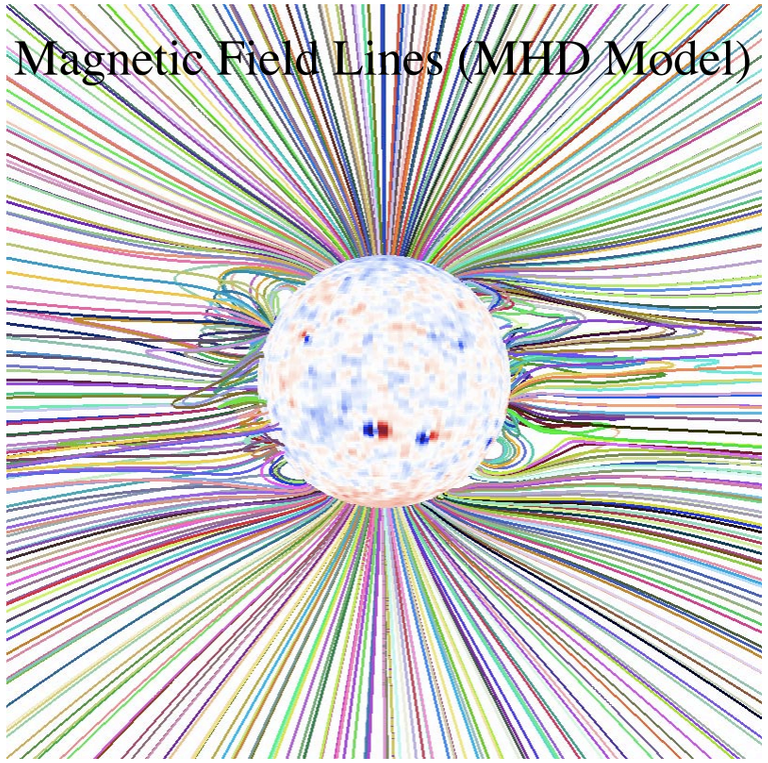
- Fast wind heating is a simple exponential with length scale ~ .7R_S
- Original selection produces coronal holes that are too large

July 22, 2009 Total Solar Eclipse: A Subsequent Model



Mauna Loa MK 4
Provided by Joan Burkepile

Polarization Brightness
MHD Simulation



Summary

- The August 1, 2008 and July 22, 2009 eclipse calculations were much higher resolution than previous calculations. They reveal a great deal of structure in the corona.
- The 2008 simulation reproduced the corona quite well, but the 2009 simulation did not.
  - Are we getting stupider? Hopefully not.
- The difficulty for the models to reproduce the white light corona for July 2009 is at least in part related to this unusual solar minimum:
  - The magnetic field is very weak.
  - The open/closed boundaries and streamer structure are more sensitive to the heating.
  - This is actually good - the sensitivity may teach us about changes in coronal heating/solar wind acceleration during this minimum.
- There are other important effects to consider for obtaining the correct streamer size - e.g., shear in the field.