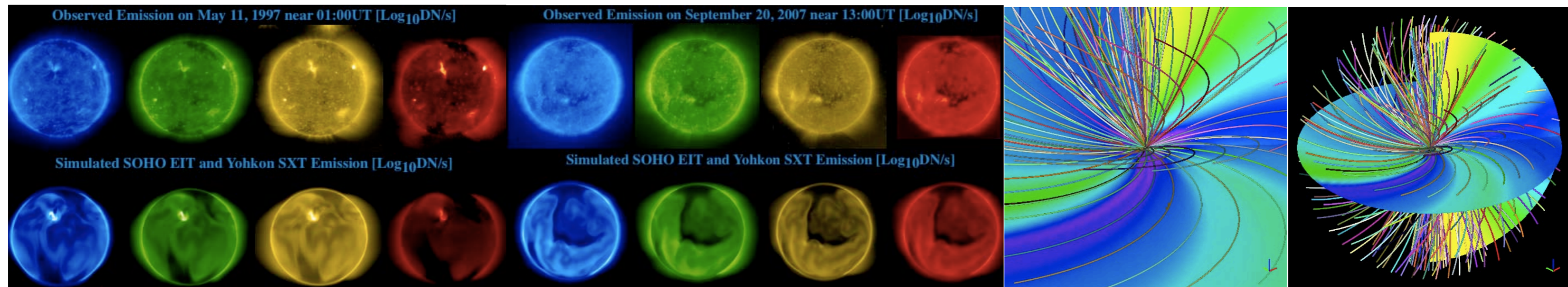


MHD Modeling Support for HMI



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Students:

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Introduction

- Understanding the connections between the solar surface, corona and solar wind underlie many of the key unsolved questions in solar physics
- SDO, in conjunction with other heliophysics missions, will sample diverse regions, both in parameter space and real space
- Coronal/Solar Wind models are required to synthesize these measurements into a coherent picture
- Coronal MHD models have now reached the point where they can be computed routinely
- Computing solutions “automatically” presents many challenges:
 - Sacrifices made in model fidelity for robustness
 - We are still experimenting and learning how to do this

Introduction (continued)

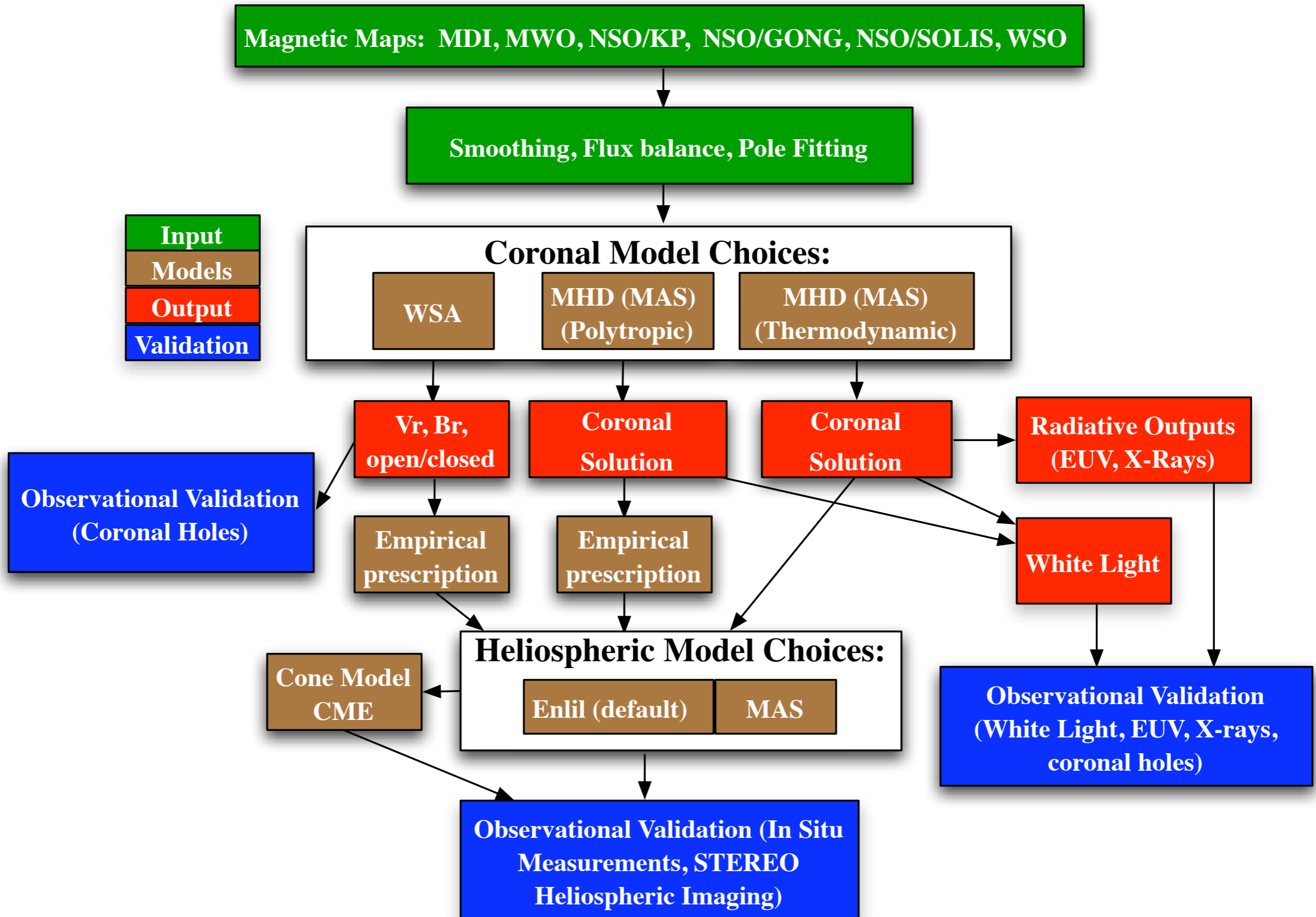
- Desired capabilities of coronal models:
 - Use photospheric magnetic maps (& perhaps other data) as input
 - Predict magnetic structure and topology
 - Predict solar wind structure (e.g fast wind streams)
 - Understand background through which CMEs propagate
 - Provide magnetic connection of SEPs to the Sun
 - Provide Alfvén speed in and structure of active regions
- History:
 - Potential field models (PFSS, PFCS, WSA)
 - Polytropic MHD models
 - “Thermodynamic” MHD models
- We have developed “CORHEL” (Corona-Heliosphere), a modular coronal and solar wind model that includes WSA, MAS (coronal MHD), & Enlil (heliospheric MHD)



CORHEL

- Supported by CISM (an NSF STC) and LWS Strategic Capabilities (NASA, NSF, & AFOSR)
- Institutions & People (Strategic Capabilities):
 - PSI (J. Linker, R. Lionello, Z. Mikic, P. Riley, V. Titov, J. Wijaya)
 - AFRL (N. Arge, C. Henney)
 - Lockheed-Martin (K. Schrijver)
 - NSO (J. Harvey)
 - Stanford (T. Hoeksema, Y. Liu)
 - U. of Colorado/NOAA SWPC (D. Odstroil)
 - Informal collaboration with UCLA/Mount Wilson (R. Wilson, L. Bertello)
- CORHEL distributed thus far to CISM, CCMC, & AFRL
- CORHEL solutions available to HMI/SDO:
 - Runs on Demand (CCMC)
 - PSI web site (<http://www.predsci.com/hmi>) (Not really public yet, for HMI use)

CORHEL: Present Status



Input
Models
Output
Validation

**Observational Validation
(Coronal Holes)**

Cone Model
CME

Heliospheric Model Choices:
Enlil (default) | MAS

**Observational Validation (In Situ
Measurements, STEREO
Heliospheric Imaging)**

**Radiative Outputs
(EUV, X-Rays)**

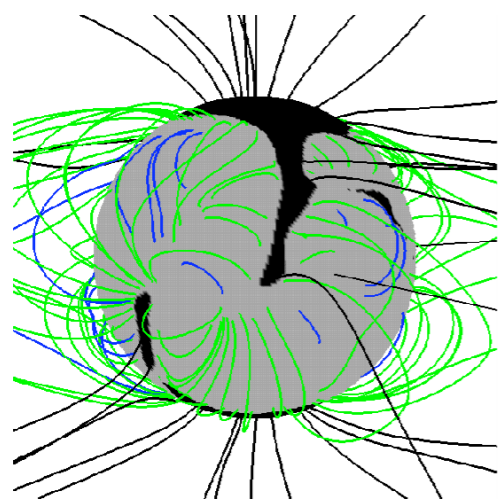
White Light

**Observational Validation
(White Light, EUV, X-rays,
coronal holes)**

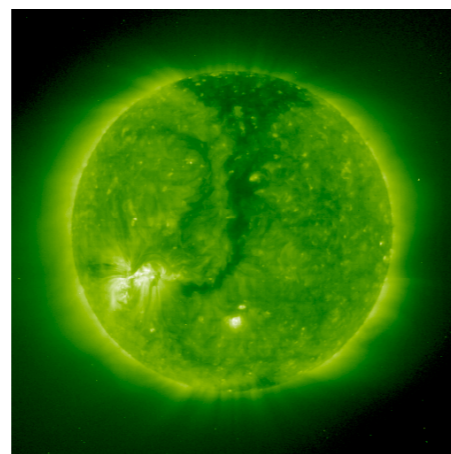
Polytropic MHD Models

- MHD models with simple energy physics can describe coronal structure qualitatively:

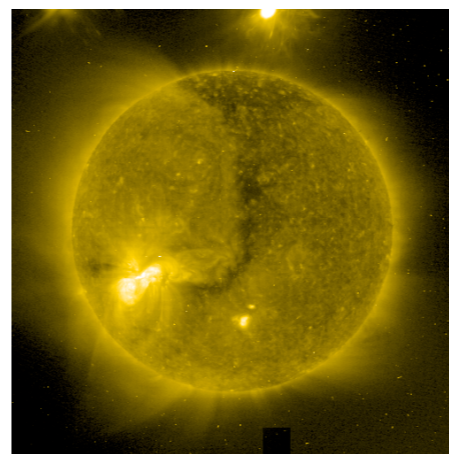
- Streamer boundaries, coronal holes
- Location of HCS



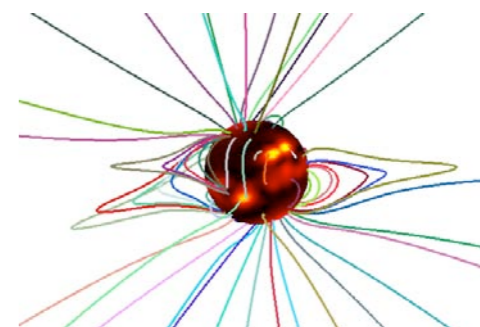
Open Field Lines
(MHD Model)



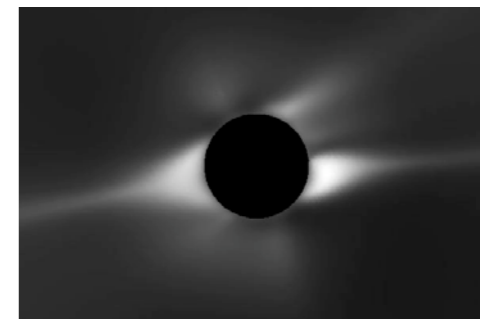
EIT FeXII 195Å Image



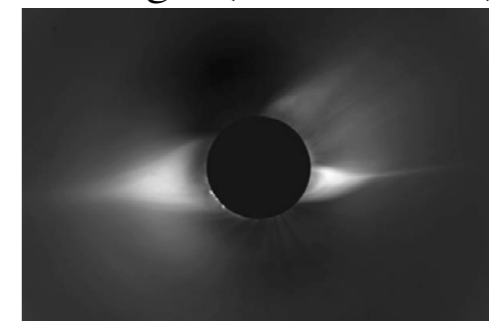
EIT FeXV 284Å Image



Field Lines (MHD Model)



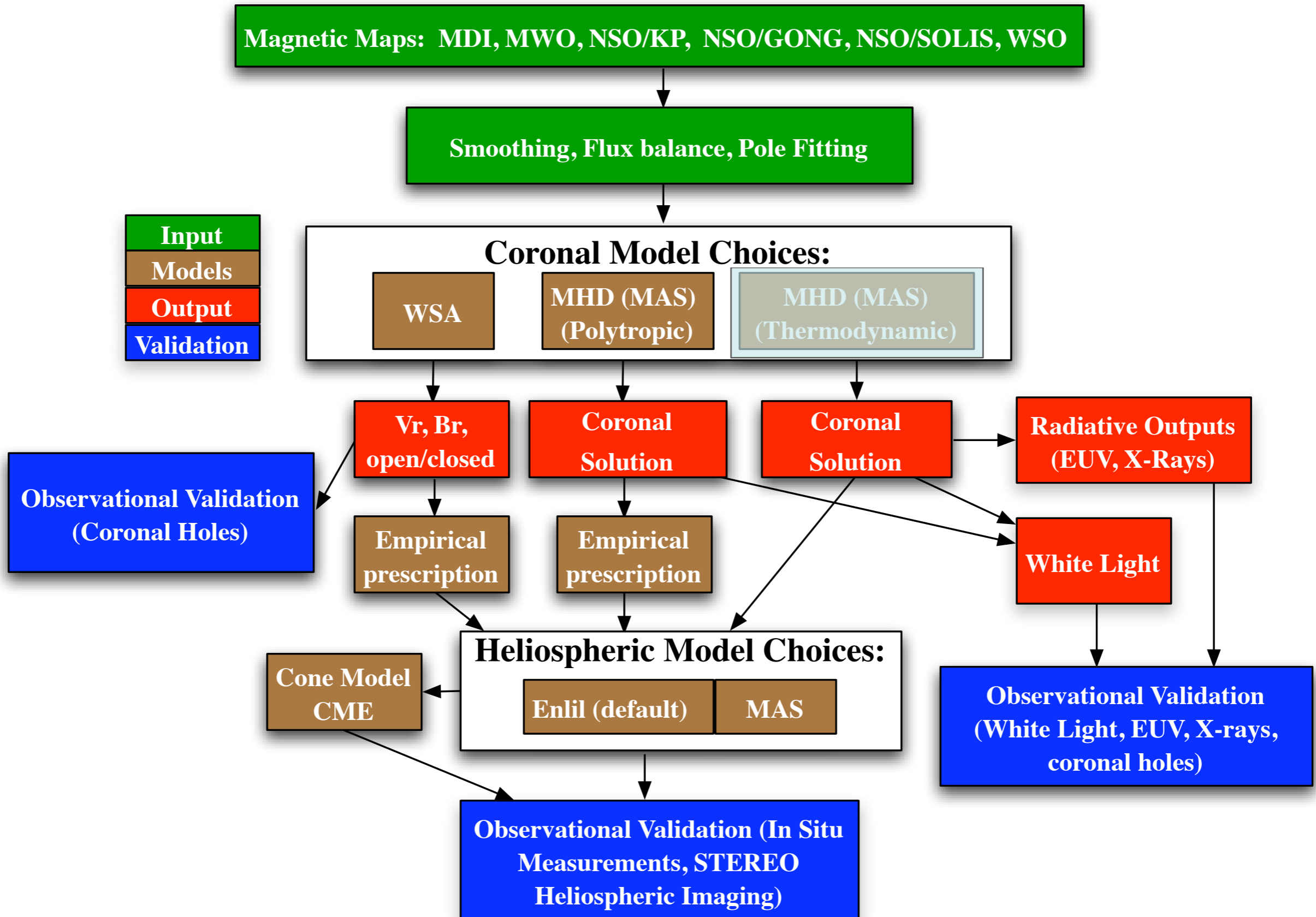
White Light (MHD Model)



Eclipse Image taken in Chile,
Nov. 1994 (HAO)

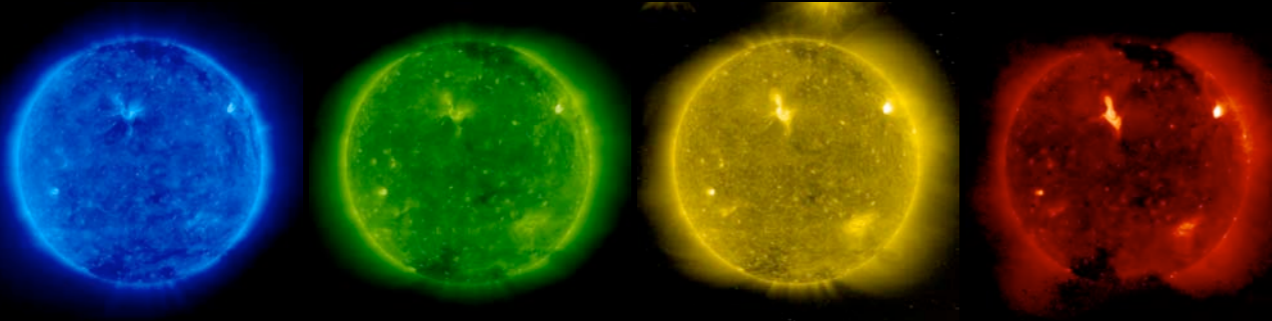
- They don't describe quantitatively:
 - Temperature
 - Density in active regions (too low) or coronal holes (too high)
 - Solar wind properties
- An empirical prescription is required to obtain realistic solar wind speeds

CORHEL: Present Status

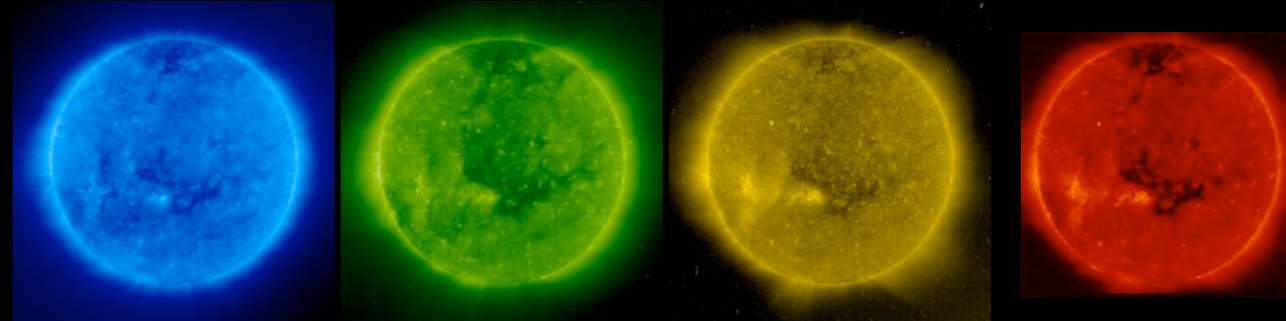


Comparison of Simulated and Observed Emission: 4 Time Periods

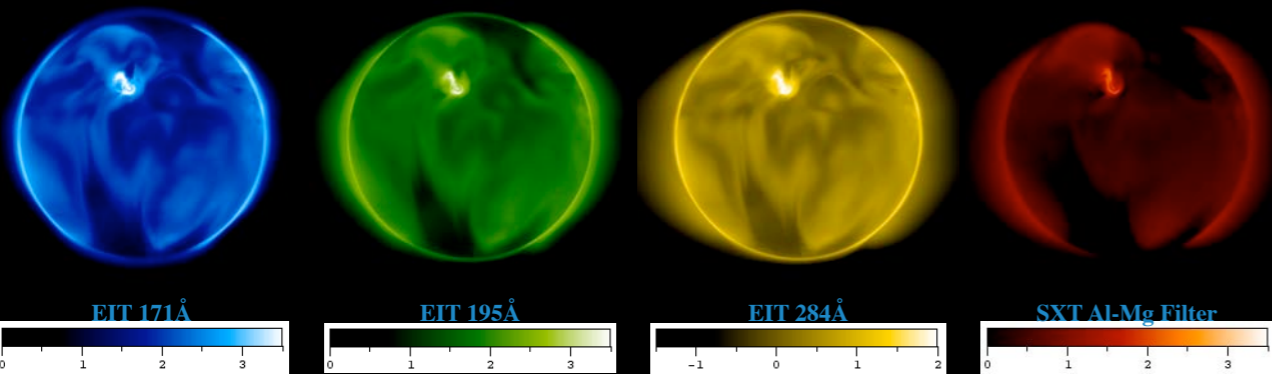
Observed Emission on May 11, 1997 near 01:00UT [Log₁₀DN/s]



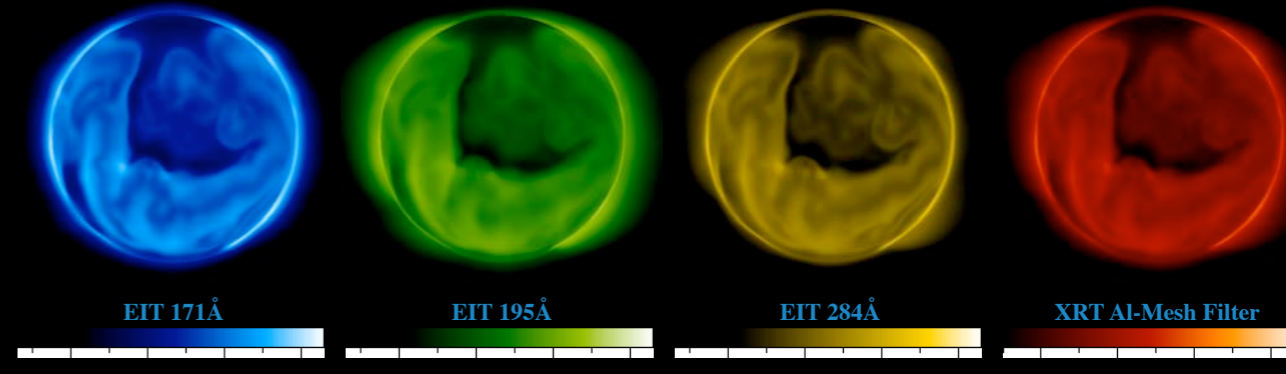
Observed Emission on September 20, 2007 near 13:00UT [Log₁₀DN/s]



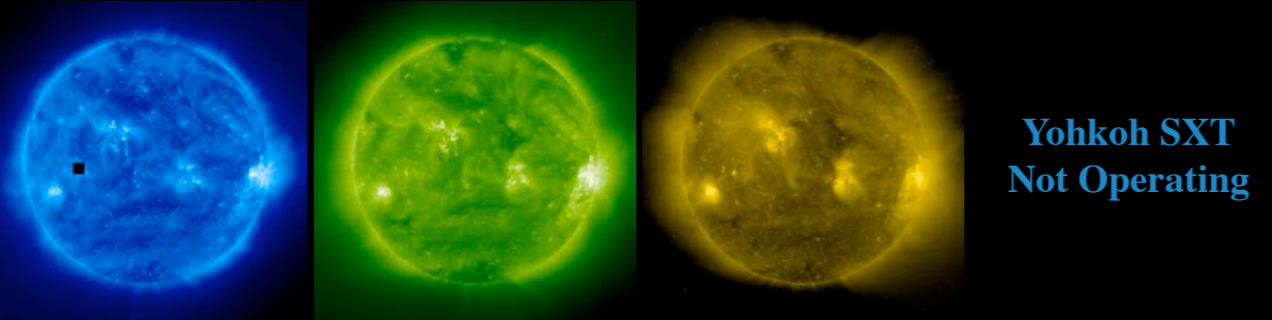
Simulated SOHO EIT and Yohkon SXT Emission [Log₁₀DN/s]



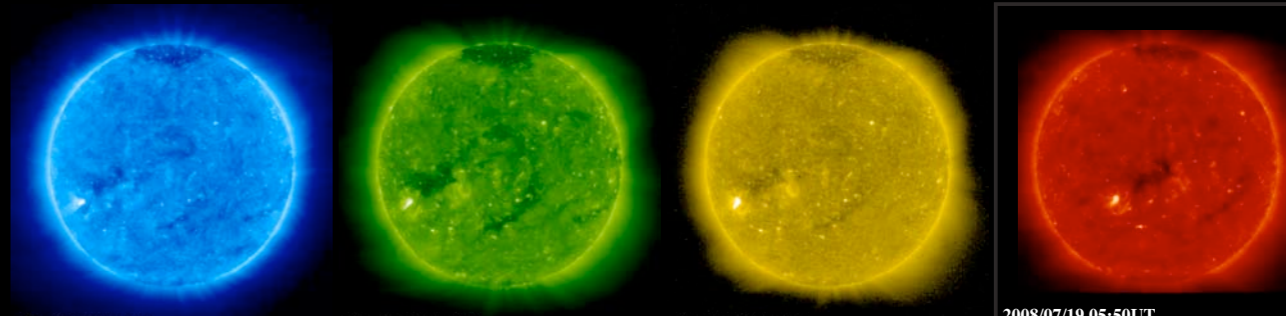
Simulated SOHO EIT and Yohkon SXT Emission [Log₁₀DN/s]



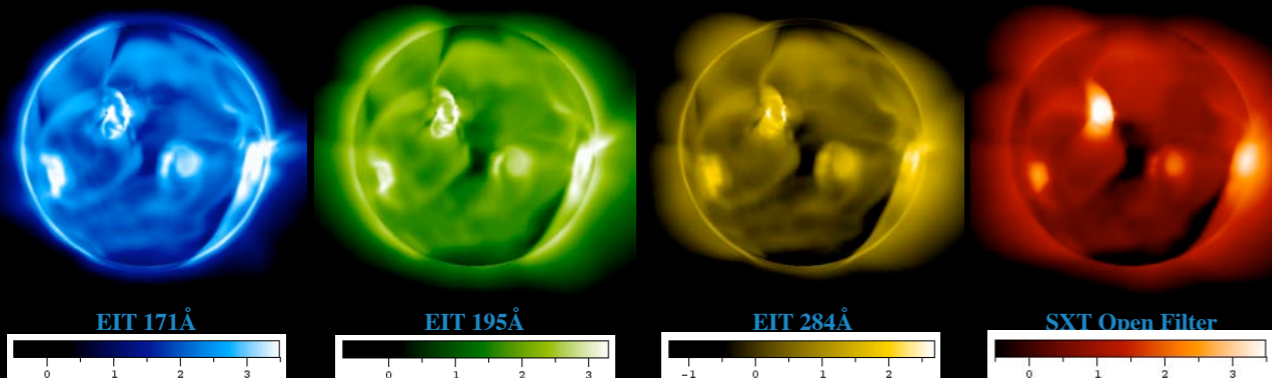
Observed Emission on May 13, 2005 near 11:36UT [Log₁₀DN/s]



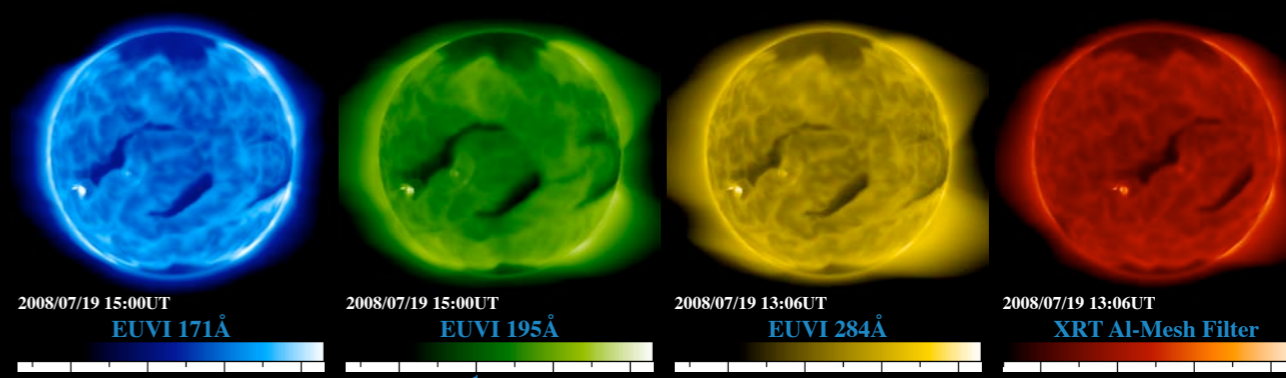
Observed Emission on July 19, 2008 near 15:00UT [Log₁₀DN/s]



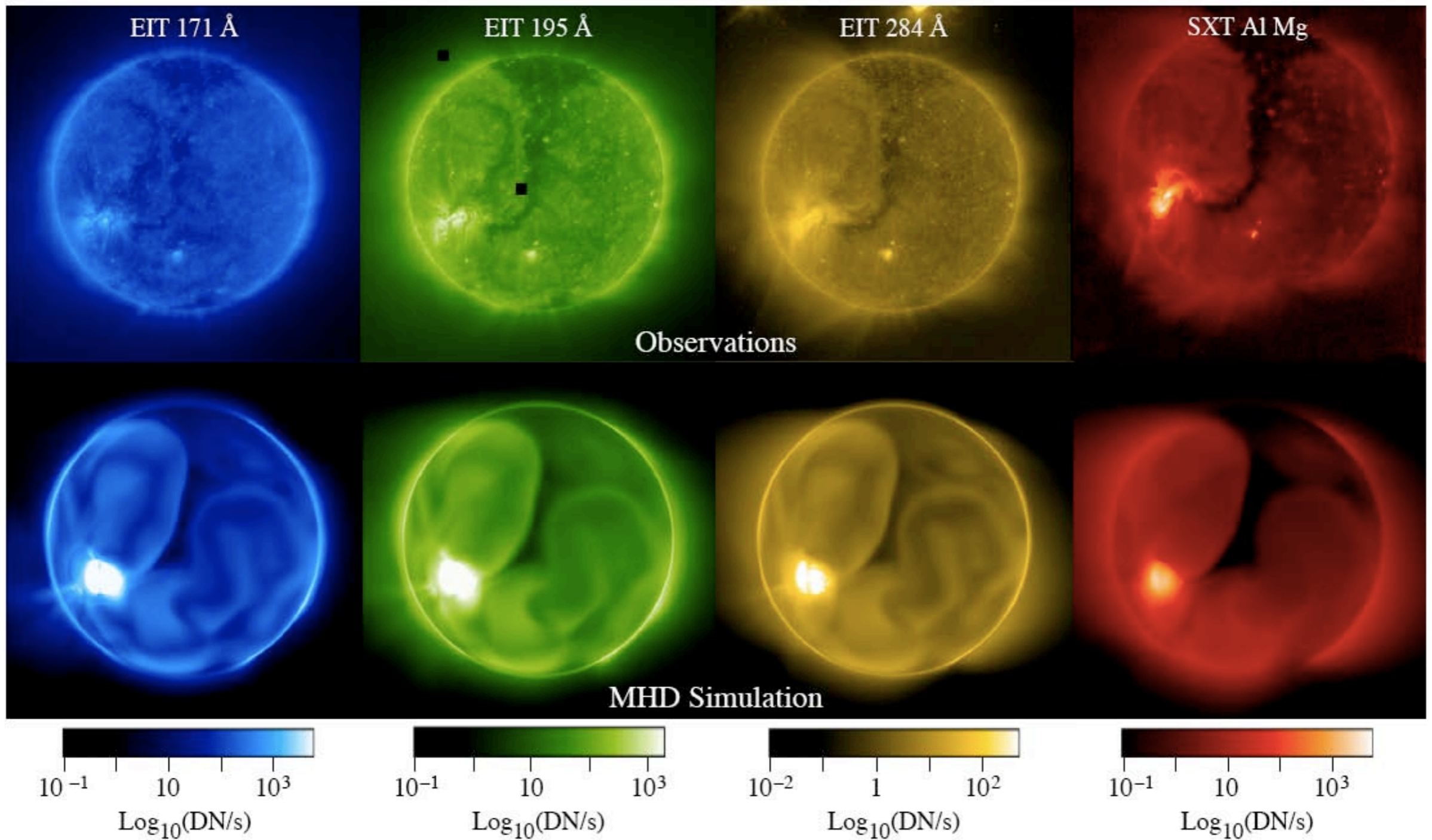
Simulated SOHO EIT and Yohkon SXT Emission [Log₁₀DN/s]



Simulated STEREO A EUVI and Hinode XRT Emission [Log₁₀DN/s]

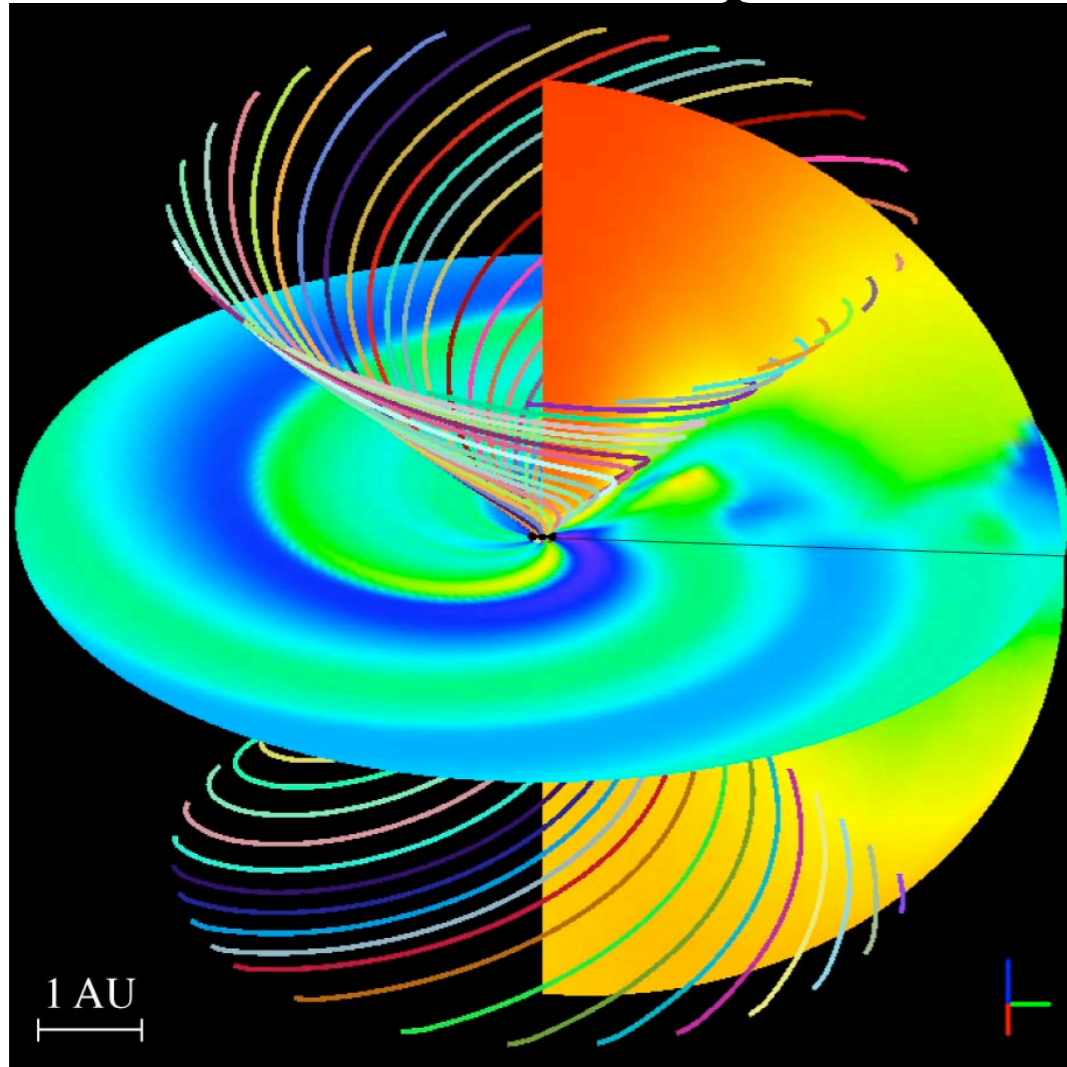


Quantitative Emission Comparison: August 1996

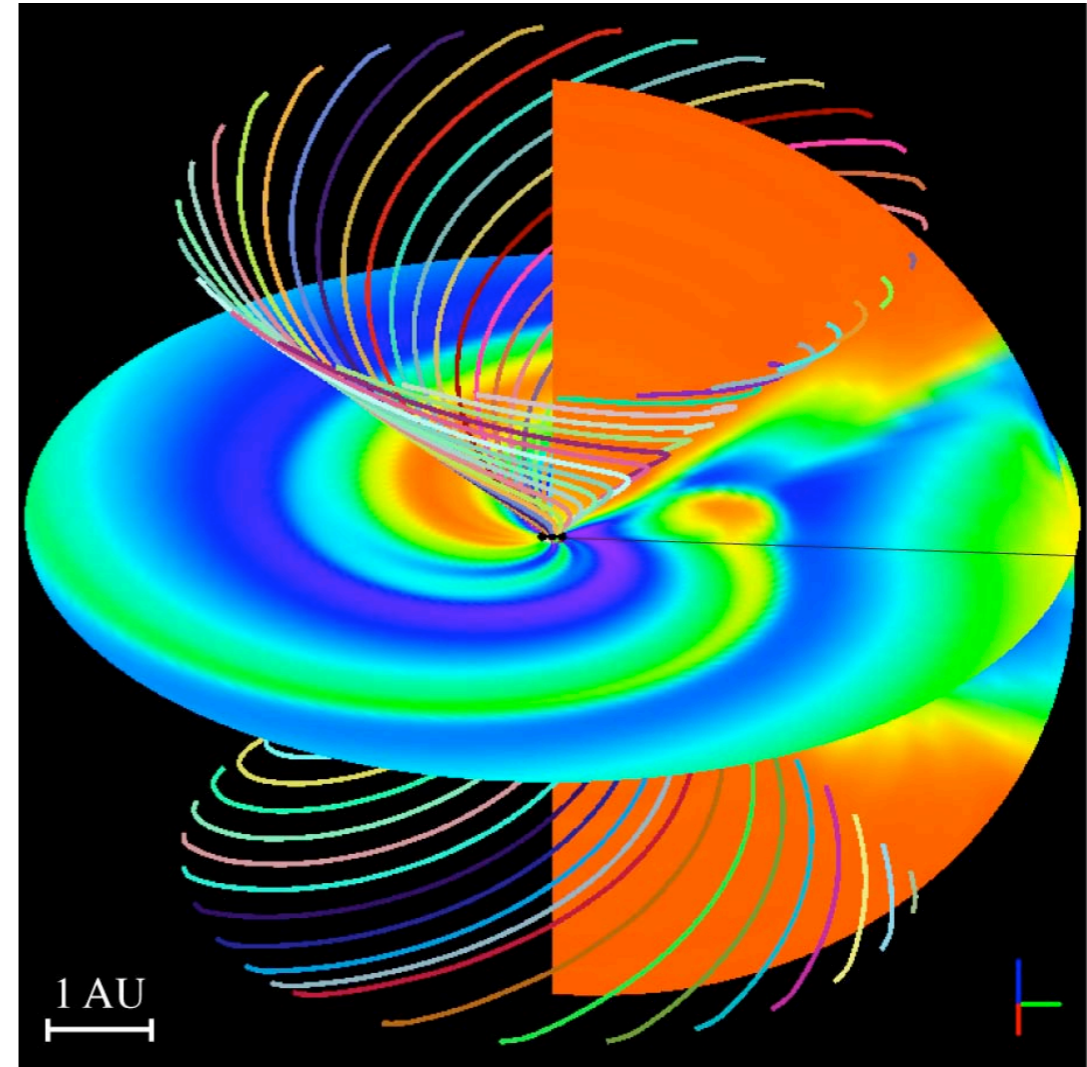


Lionello, Linker, Mikic, ApJ 2009, 690, p. 902

Heliospheric MHD Solutions

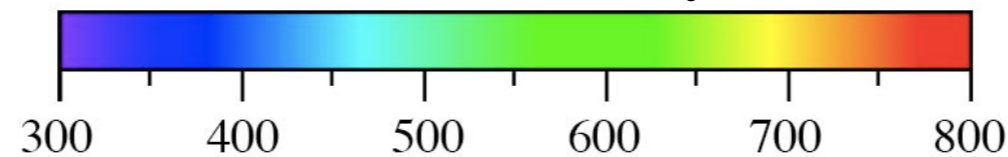


WSA Coronal and MAS Helio solutions



MAS Coronal and MAS Helio solutions

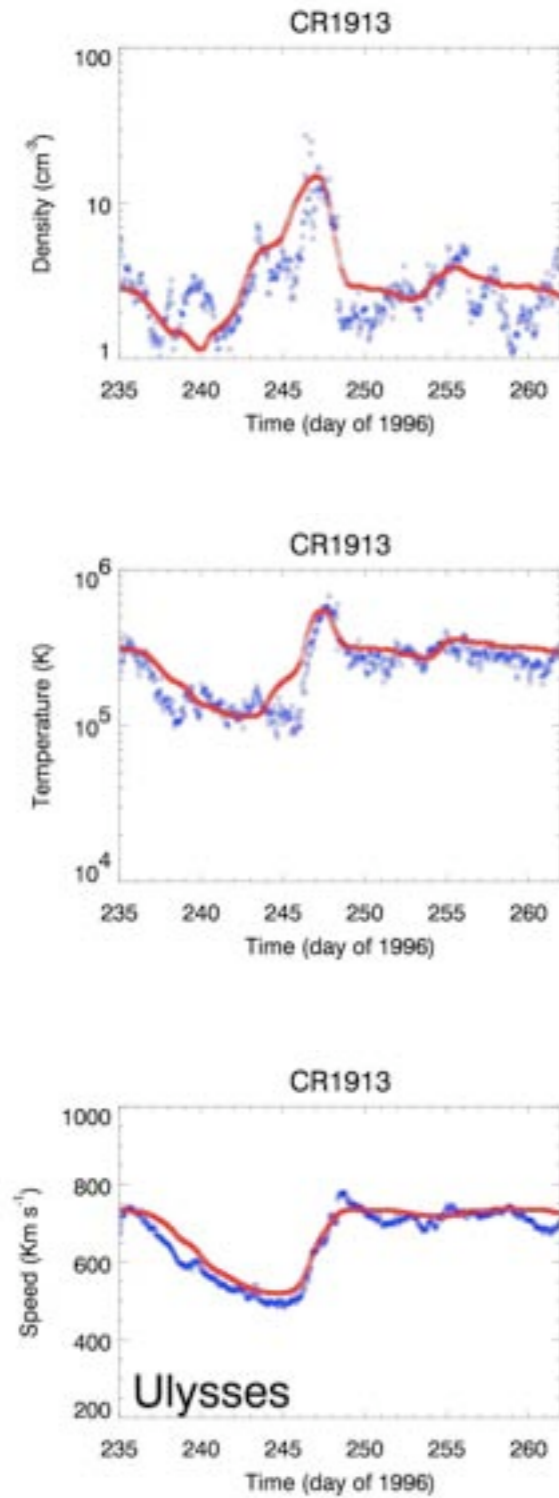
Radial Velocity



- Can use either Enlil (developed by Dusan Odstrcil) or MAS
- Input from either WSA or MAS coronal solutions

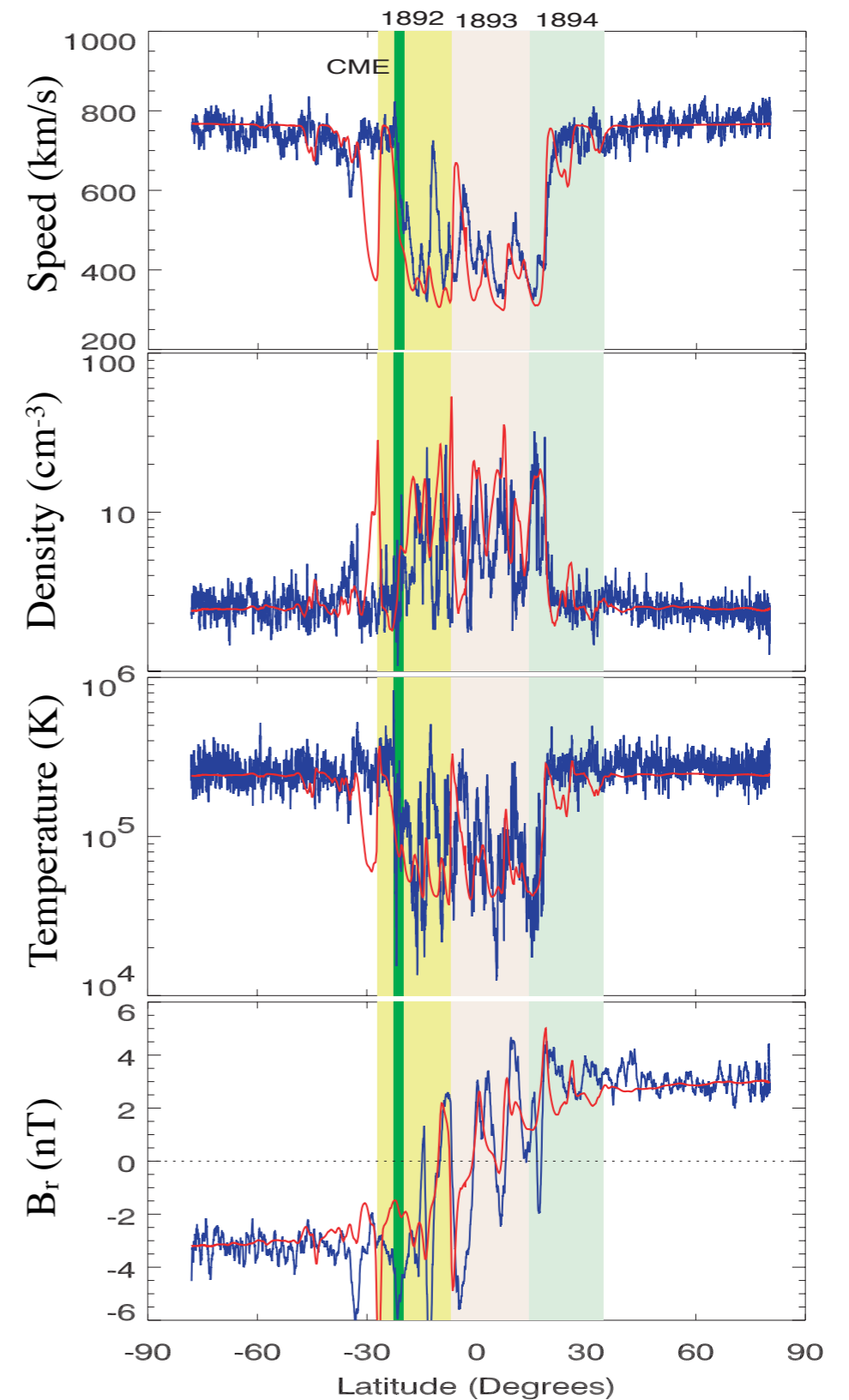
We have good rotations

Whole Sun Month

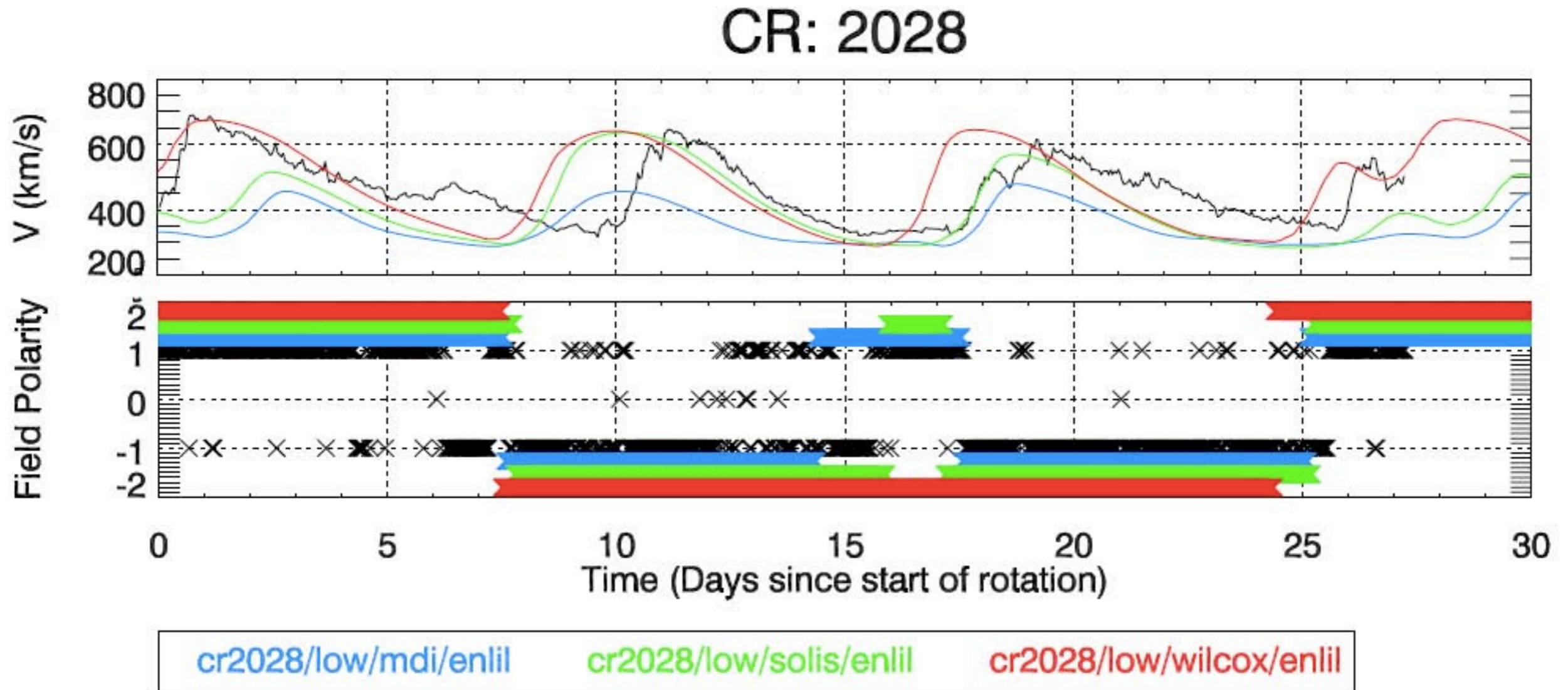


Riley et al. 2001

Fast Latitude Scan

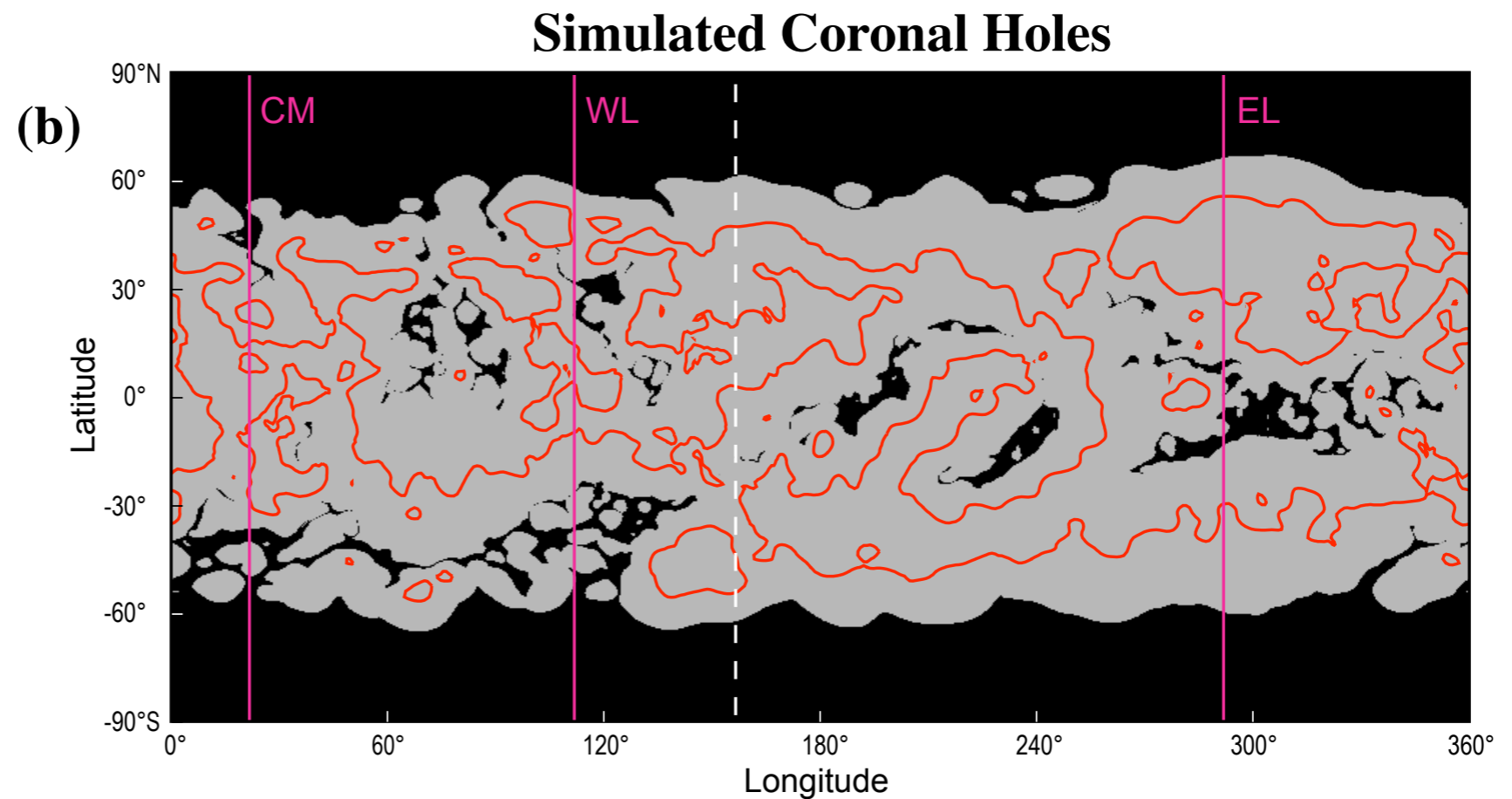
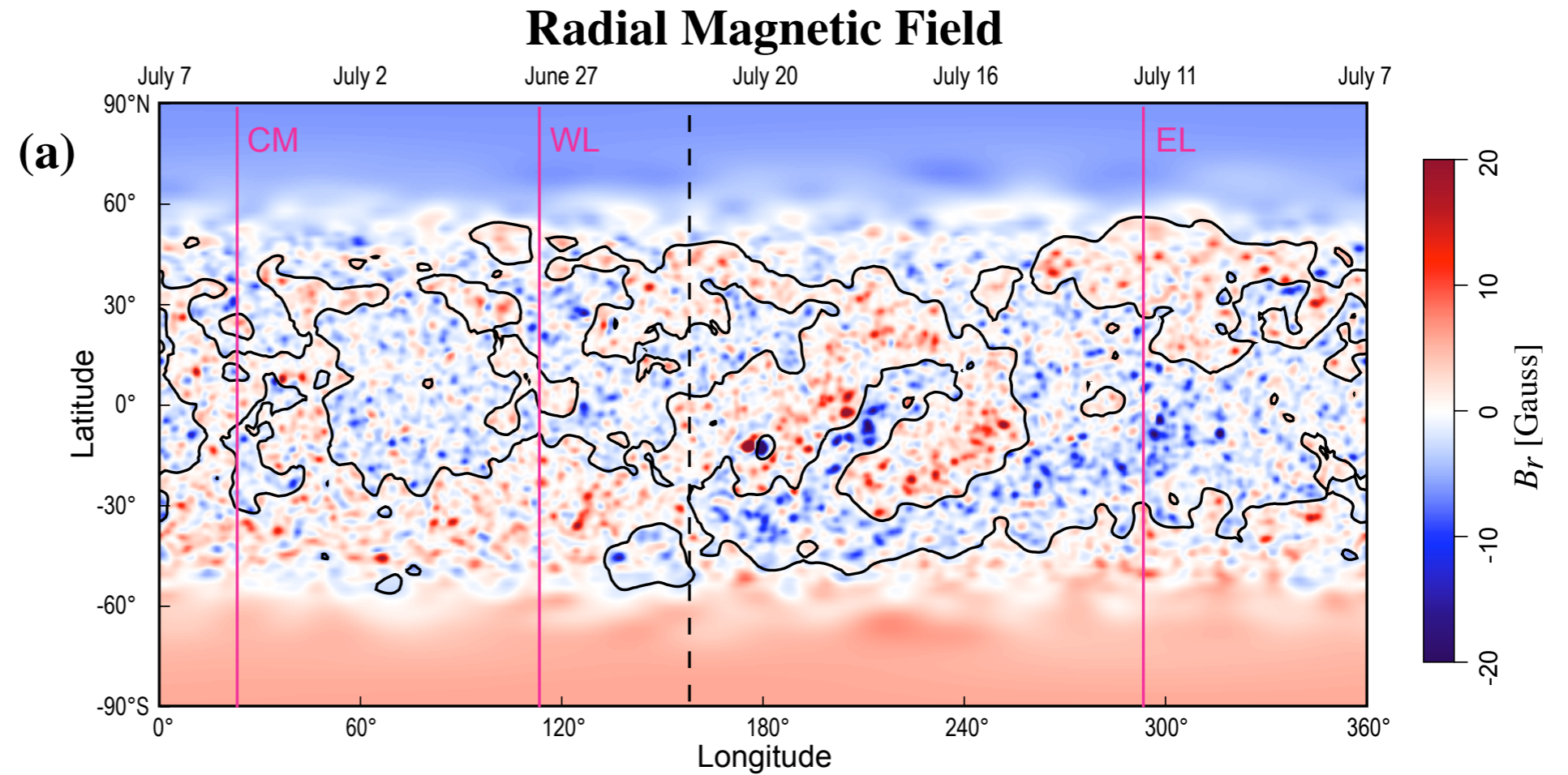


And not-so-good rotations

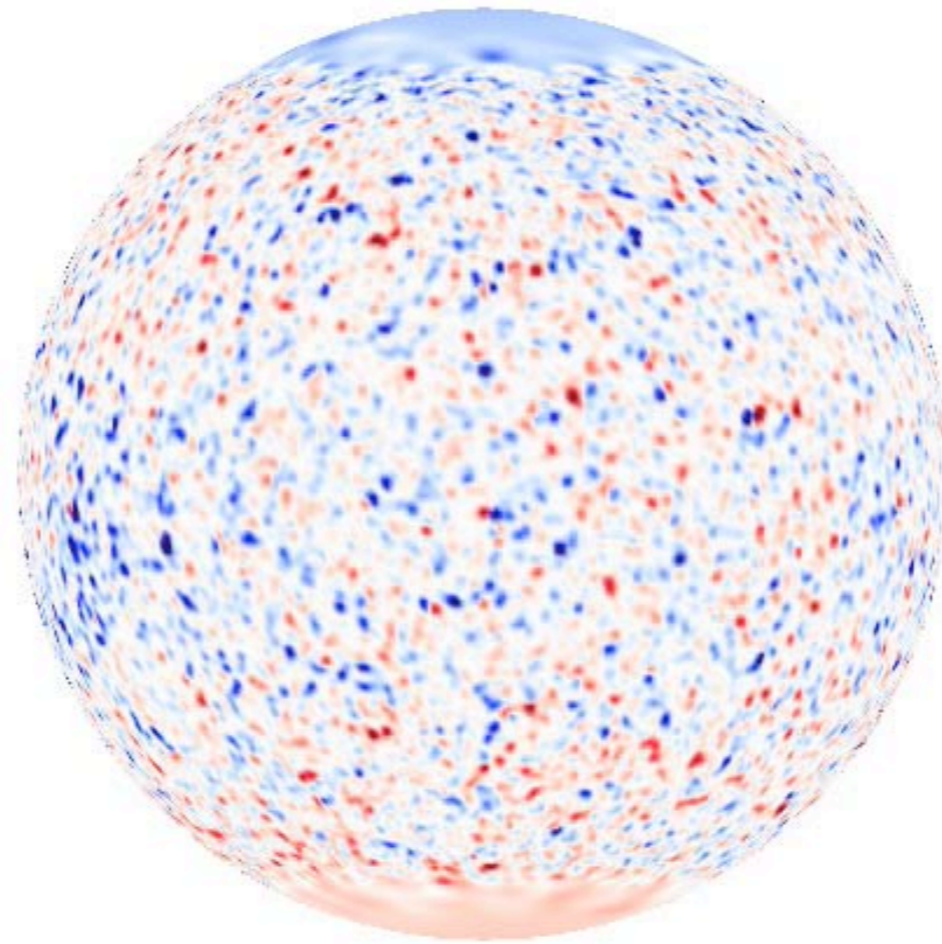


- Different Observatories yield different solutions (all with problems)
- Polarity prediction is reasonable from all of the observatories

August 1, 2008
Solar Eclipse
Coronal Simulation:
Carrington Rotations
2071+2072

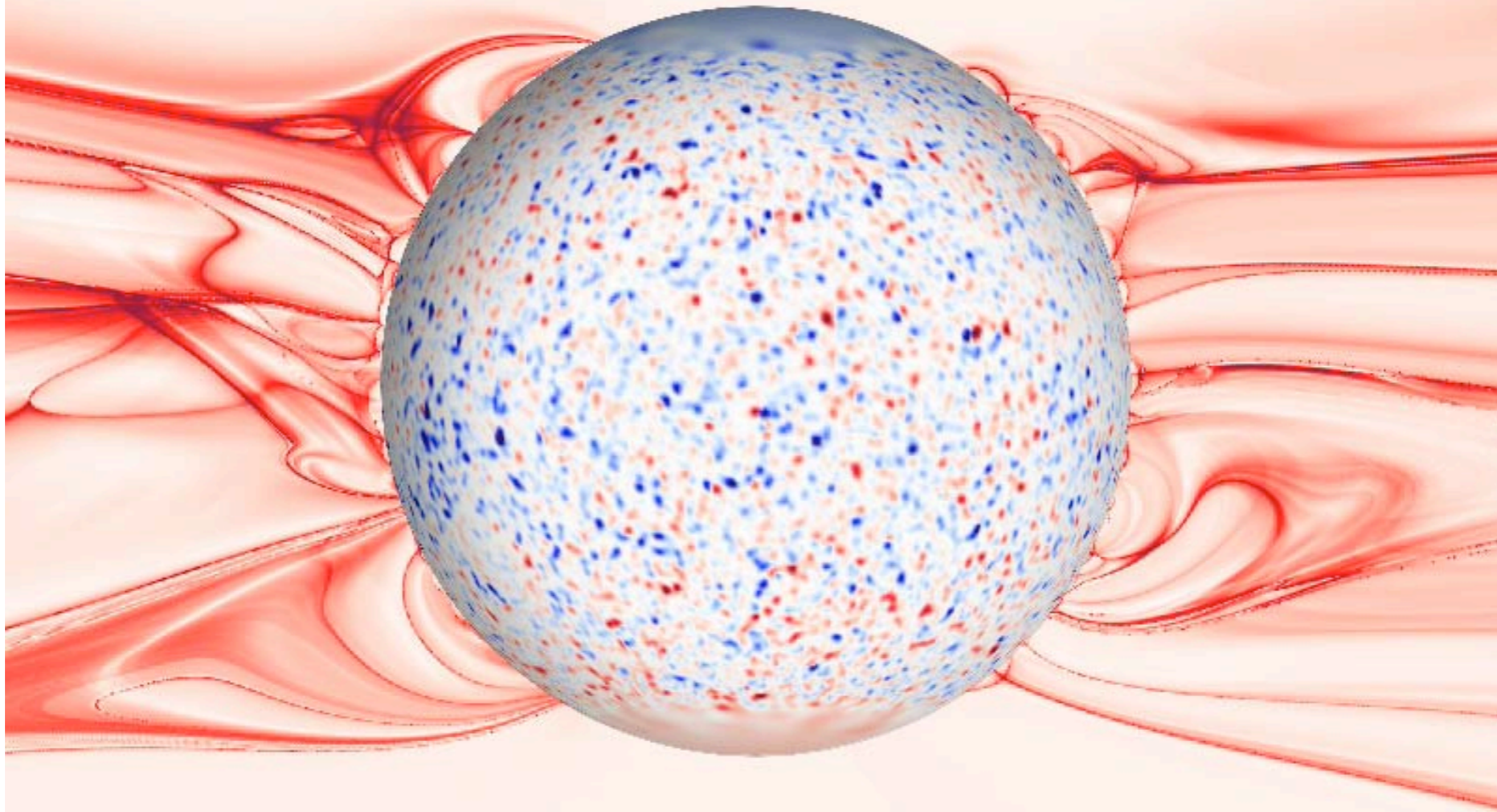


Coronal Structure in High-Resolution Simulations: August 2008 Eclipse



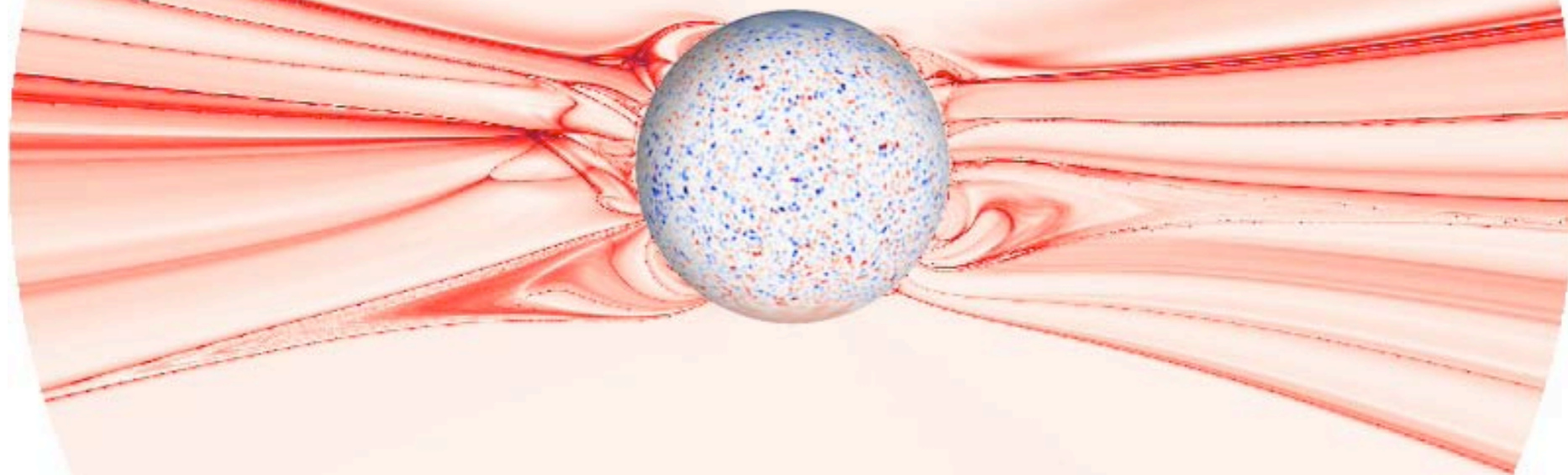
Coronal Structure in High-Resolution Simulations: August 2008 Eclipse

- Log Q reveals detailed structure in coronal field



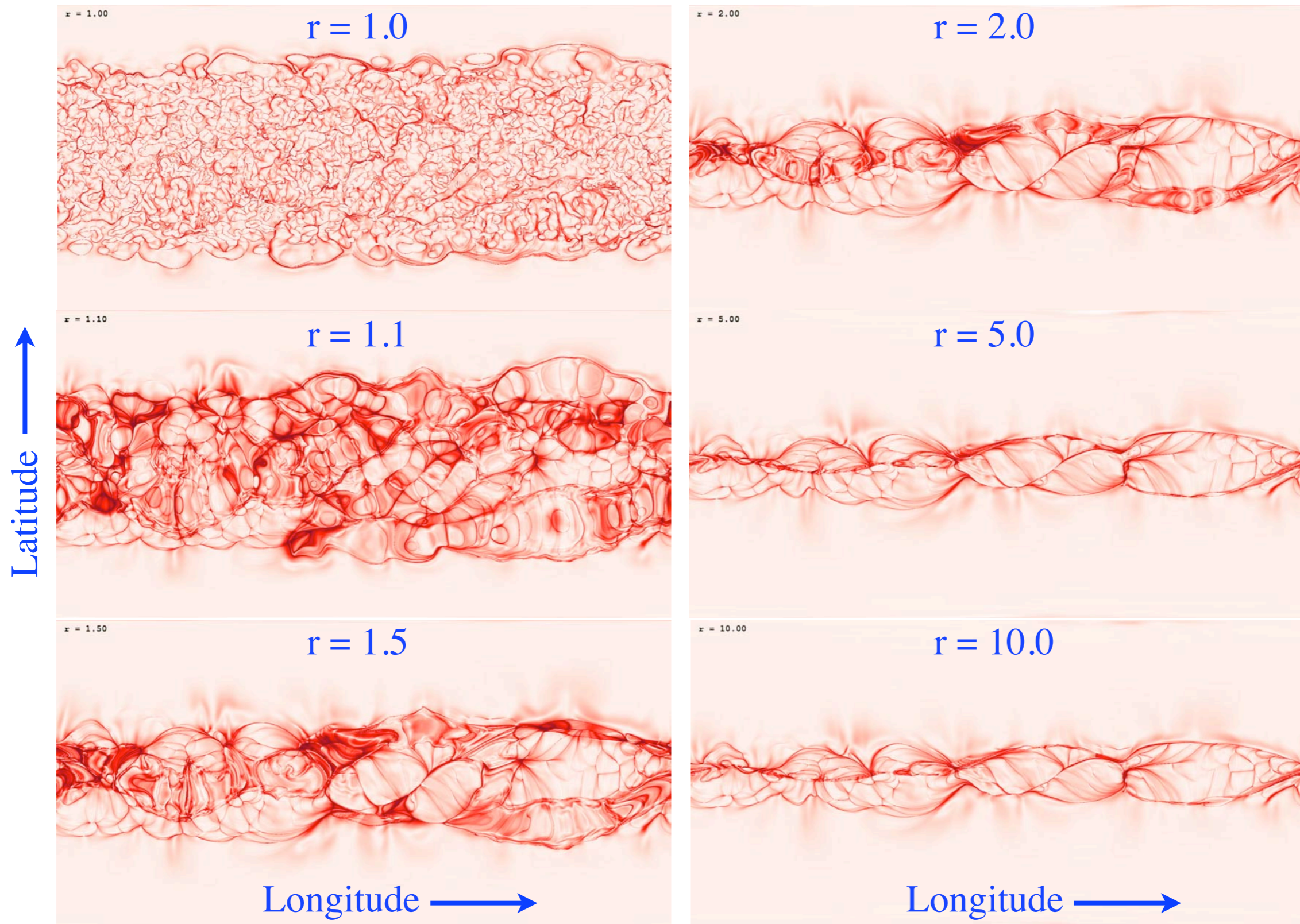
Coronal Structure in High-Resolution Simulations: August 2008 Eclipse

- Log Q reveals detailed structure in coronal field



- Some of this structure is carried out into the solar wind

Squashing Factor (Q) vs. Height



$\log(Q)$

Summary

- We will provide MHD models of the corona and solar wind for HMI/SDO in 3 ways:
 - PSI web site: <http://www.predsci.com/hmi> (Internal HMI use at the moment)
 - CORHEL runs on demand at the CCMC: <http://ccmc.gsfc.nasa.gov/>
 - Individual time periods of interest (Anyone going to Easter Island next July 11?)
- HMI Predictive Science Web Site:
 - Low resolution polytropic solutions presently available
 - Range of standard visualizations
 - Data is downloadable
- Upcoming Improvements:
 - Thermodynamic MHD solutions as a standard product
 - ~2 million grid points
 - Simulated emission images