Is SWMF Ready for R2O?

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What is Needed for Space Weather Forecasting?

- Solve the data sparsity problem
  - Solar tomography
  - Ionospheric tomography
  - But what about the space between the corona and the ionosphere?
- Develop coupled model chains
  - SWMF (Michigan)
  - CISM model chain (BU)
  - Magnetosphere-Ionosphere model (UNH)
- Validate
  - Sub-grid parametrization
  - Missing physics
  - Ensemble forecasting

Single Spacecraft Observations

In situ space weather observations are like spear fishing: you can get one fish at a time (if you are good and lucky).

Multiple Spacecraft Observations

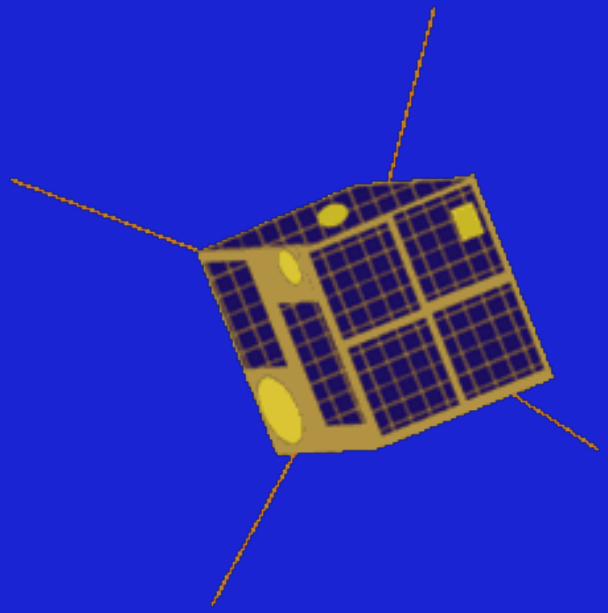
Modern spear fishing equipment can be very expensive and sophisticated, but one can get only one fish at a time (if you do not miss…).

Large Fleet of Simple Spacecraft

Fishing nets contain a very large number of simple (and identical) nodes and are capable to catch huge quantities of fish.

How to Solve the Data Sparsity Problem

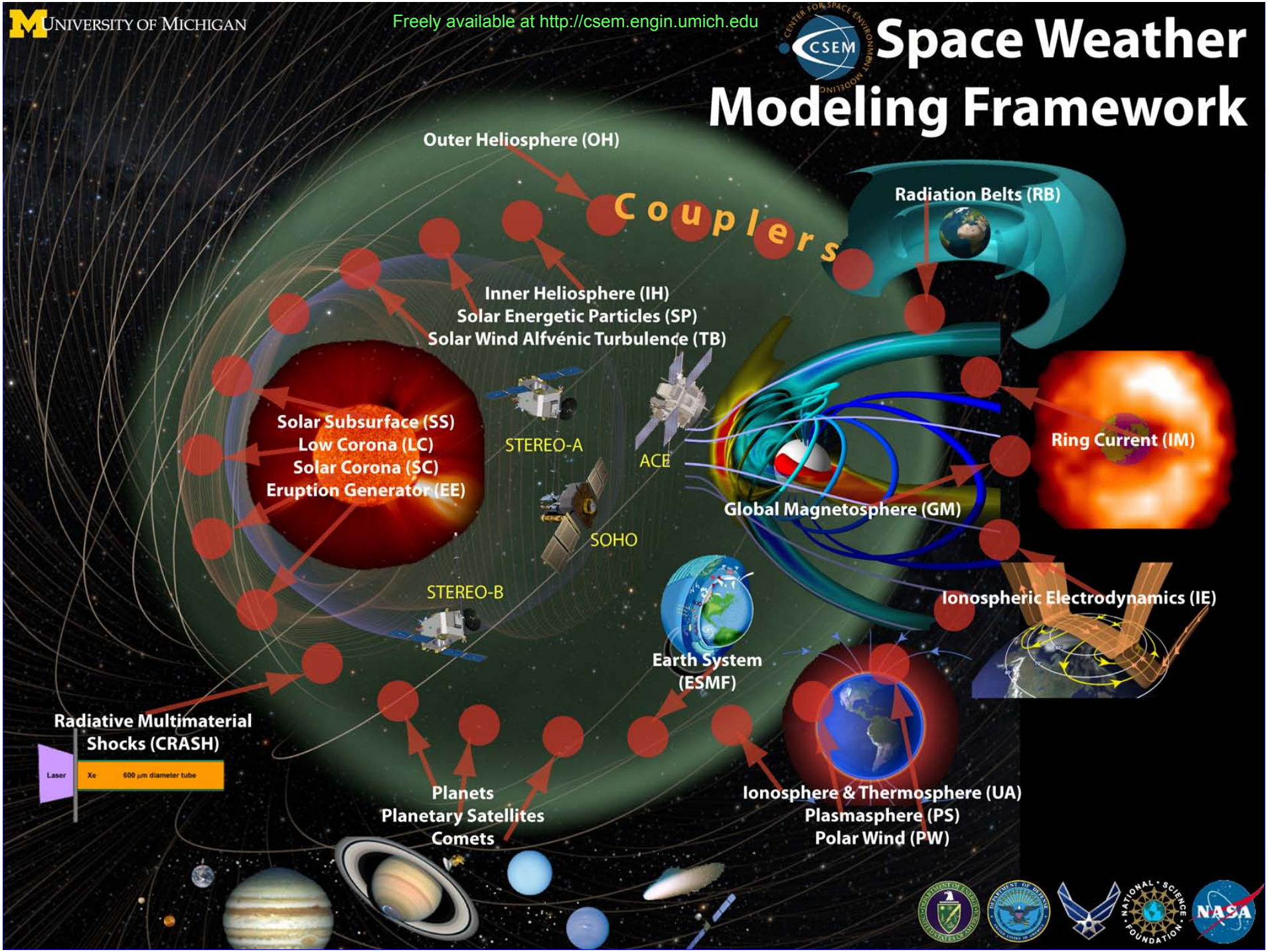
>$1B for 4 sophisticated spacecraft for a two year prime mission (gold plated spear fishing)



$1M for a simple CubeSat mission. One can have >1000 identical CubeSats “netfishing” in the space environment and create a new paradigm of space weather observations

What is Needed for Space Weather Forecasting?

- 5 large spacecraft orbiting the Sun
  - 1 L1 monitor
  - 2 STEREO type s/c 120° from Earth
  - 2 Ulysses type s/c above the N/S poles
  - Identical instrumentation
    - Coronagraphs
    - EUV and soft x-ray images/spectroscopy
    - Vector magnetograms
    - Megnetometer, plasma and SEP package
- A fleet of ~10^3 CubeSat type “space weather stations”
  - Magnetometer, thermal plasma package and SEP detector
- At least two (but preferably 3) independent Sun-to-Earth model chains that provide ensemble forecast

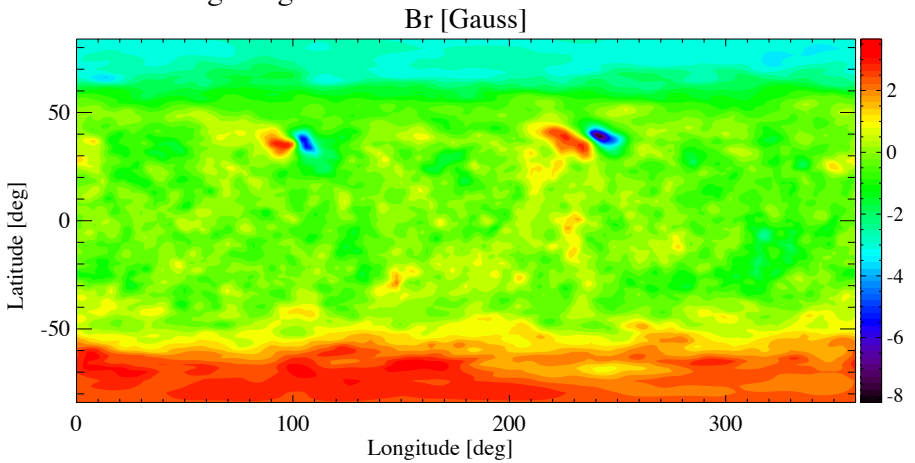

University of Michigan
Freely available at http://csem.engin.umich.edu
CSEM
Center for Space Environment Modeling
Space Weather Modeling Framework
Outer Heliosphere (OH)
Couplers
Radiation Belts (RB)
Inner Heliosphere (IH)
Solar Energetic Particles (SP)
Solar Wind Alfvénic Turbulence (TB)
Solar Subsurface (SS)
Low Corona (LC)
Solar Corona (SC)
Eruption Generator (EE)
STEREO-A
ACE
Ring Current (IM)
Global Magnetosphere (GM)
SOHO
STEREO-B
Ionospheric Electrodynamics (IE)
Earth System
(ESMF)
Radiative Multimaterial
Shocks (CRASH)
Laser
Xe
600 μm diameter tube
Planets
Planetary Satellites
Comets
Ionosphere & Thermosphere (UA)
Plasmasphere (PS)
Polar Wind (PW)
National Science Foundation
NASA

Thermodynamic Solar Wind Model (van der Holst, Oran and Sokolov)

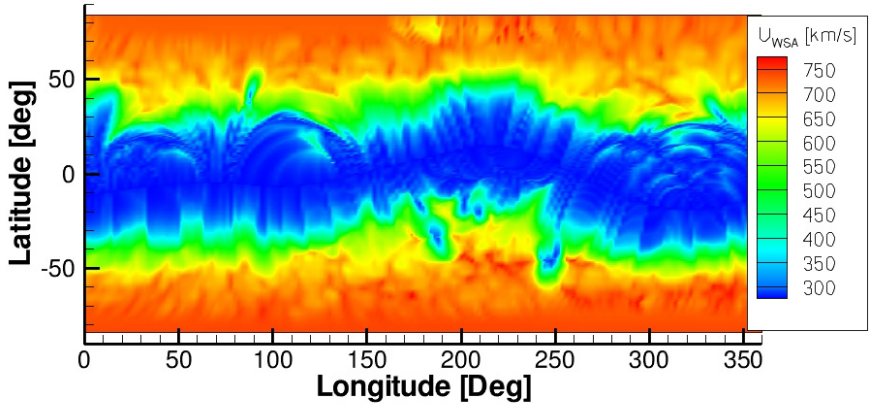
- Sub-photosphere model
  - Multigroup radiation transport
  - MHD
  - Magnetic flux emergence
- Low corona ($1R_\odot r<2.5\ R_\odot$)
  - $\gamma=5/3$, single temperature
  - Heat conduction
  - Transport and dissipation of total energy of Alfvénic turbulence ($E_\pm$)
    - Wave dissipation represents sources for the plasma momentum and internal energy
  - Additional coronal heating is obtained from the “unsigned flux” model (Abbett 2007) and observed X-ray luminosity (Pevtsov 2003)
- Corona ($2.5R_\odot<r<20R_\odot$)
  - $\gamma=5/3$, separate ion and electron temperatures
  - Transport and dissipation of frequency resolved Alfvén wave intensity, $I_\pm(\omega)$
    - Kolmogorov spectrum is assumed at the inner boundary
- Observational inputs:
  - Magnetogram driven potential field extrapolation (synoptic maps from GONG or MDI)
  - Density and temperatures near the sun are predicted by the DEMT (Differential Emission Measure Tomography) results of Vasquez and Frazin (2009).
  - WSA formula determines total Alfvenic turbulence energy at the surface

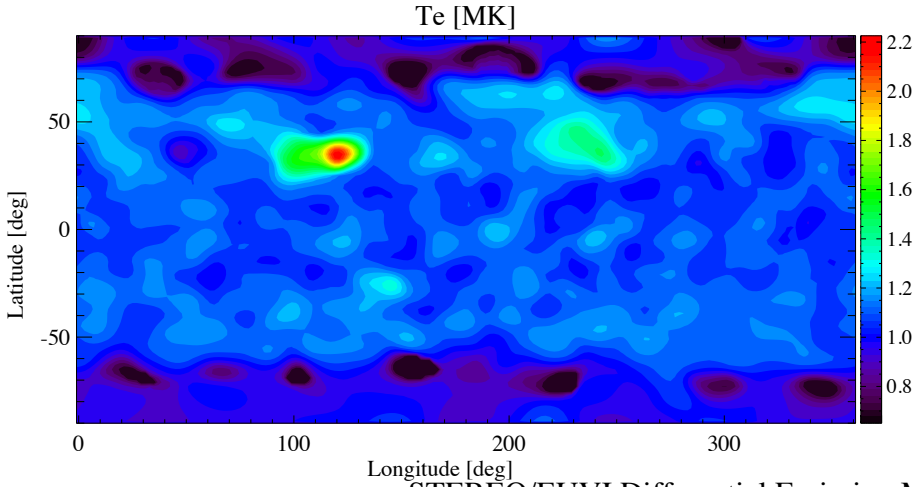
Boundary Conditions for CR2077 with no Free Parameters

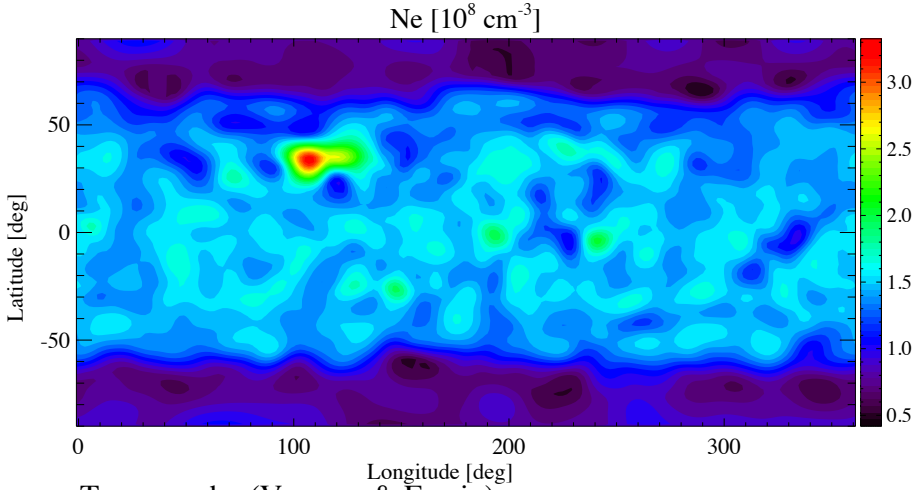
GONG magnetogram



WSA relation

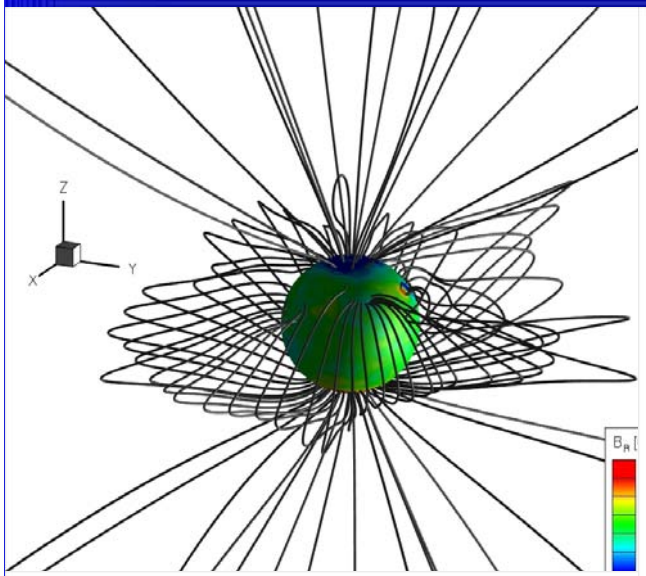




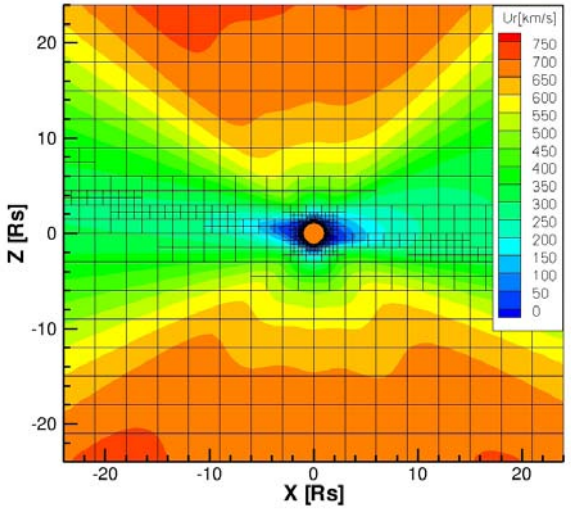


STEREO/EUVI Differential Emission Measure Tomography (Vasques & Frazin)

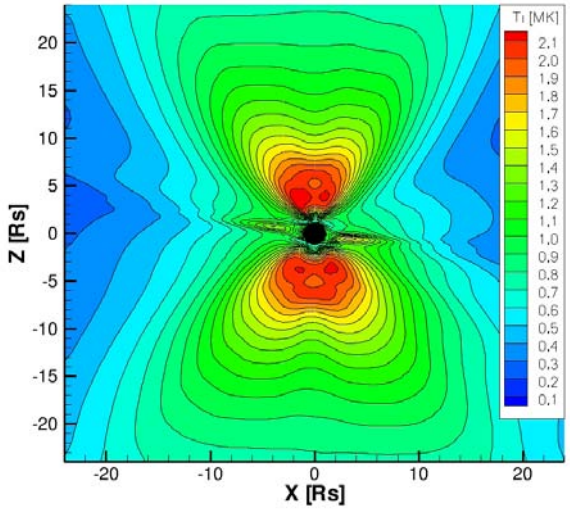
CR2077: Two State Solar Wind



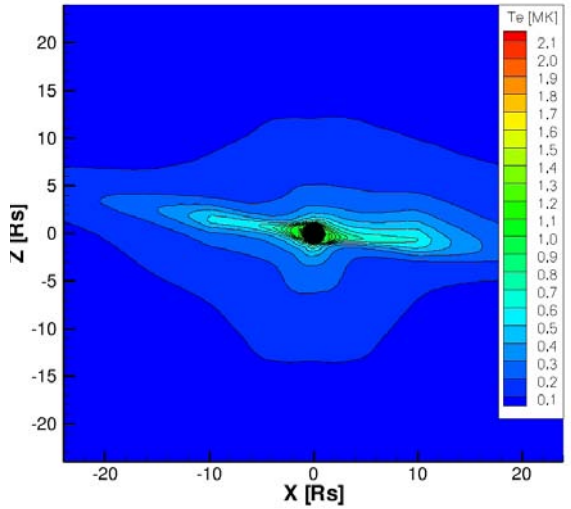
Radial velocity



Ion temperature



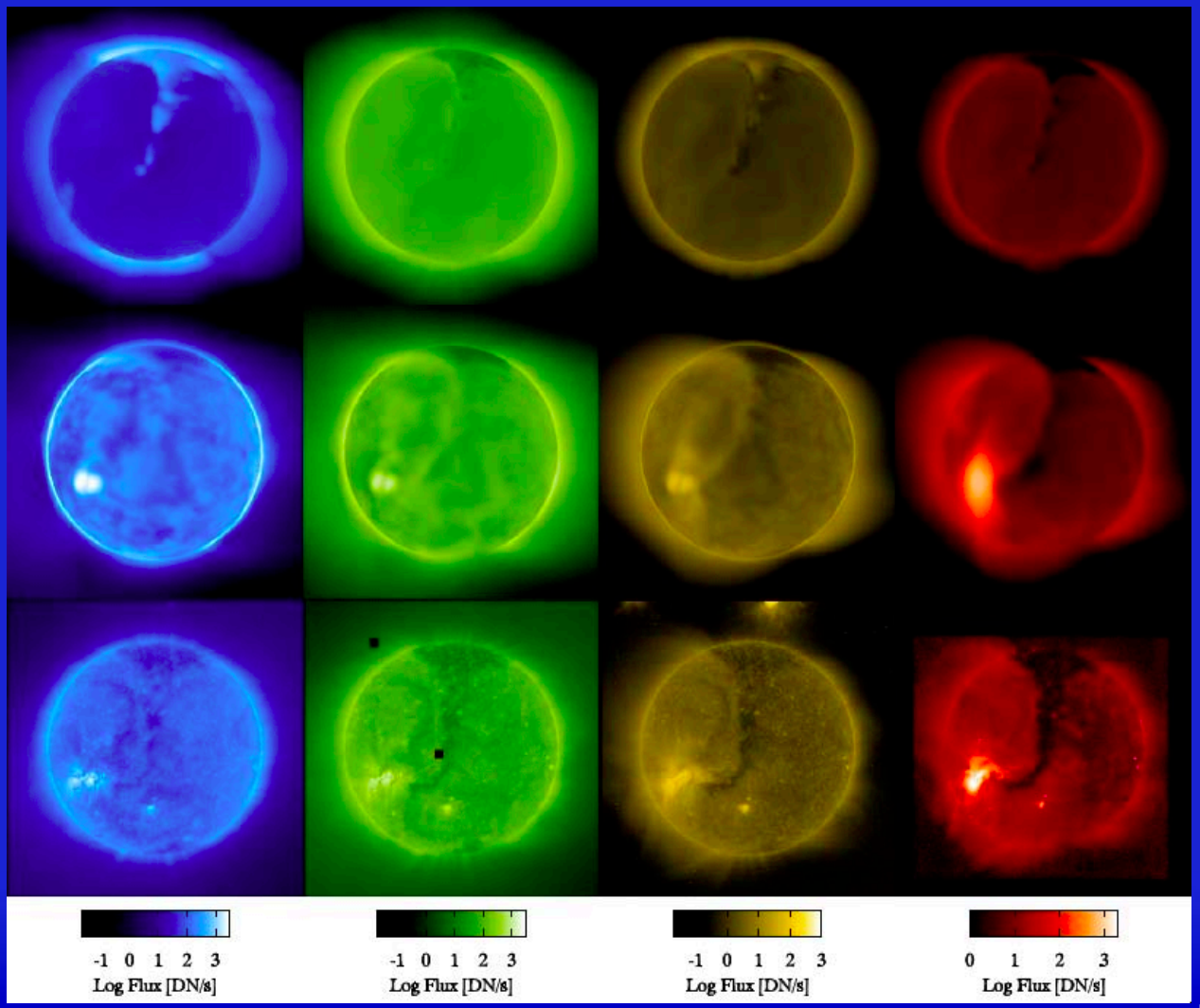
Electron temperature



- In the fast wind
  - Electrons are cold (due to adiabatic cooling)
  - Ions are hot (due to Alfvén wave heating)
- In the slow wind
  - Electrons are hot (due to heat conduction)
  - Ions are cold (no Alfvén wave heating)

New Corona Model

EIT 171Å EIT 195Å EIT 284Å SXT AlMg



CR1913

Old SC model synthesis

New LC model synthesis

Observation: Aug 27, 1997

Downs et al., *ApJ, 712*, 1219, 2010

Is SWMF Ready for R2O?

- Is it user friendly/robust?
  - Good user manual
  - Multiplatform/portable
  - Wide accuracy/robustness trade space
  - Runs 24/7 at CCMC since 2002
- Strengths
  - Shock arrival time is ±10h
  - All clear prediction
  - Open/closed field line boundary
  - CPCP, Dst, regional dB/dt, open/closed boundary, etc
  - Continuously evolving
- Weaknesses
  - Validation is incomplete
  - Too many knobs to turn
  - Continuously evolving
- Ready for R2O, but buyer beware!