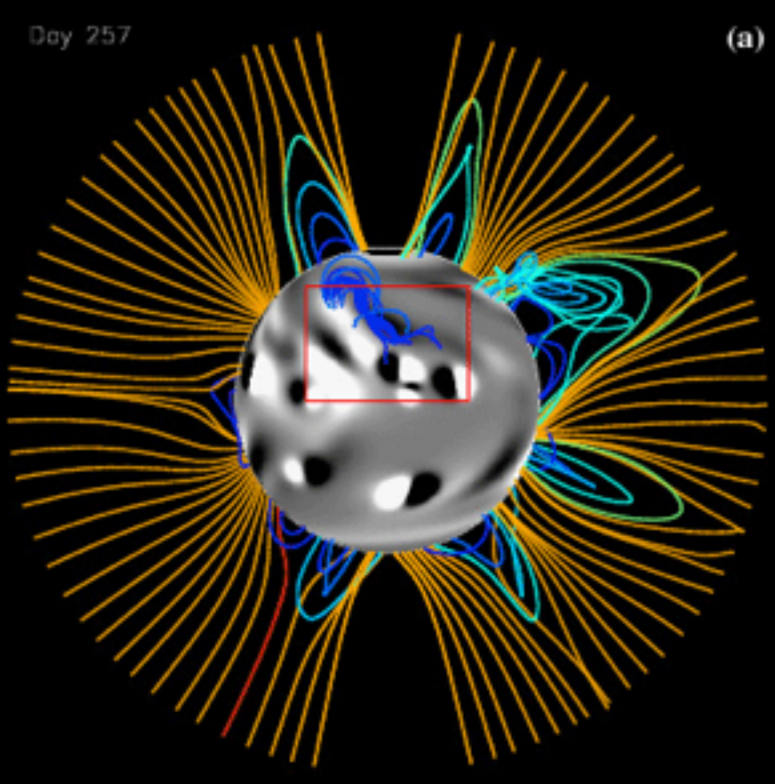
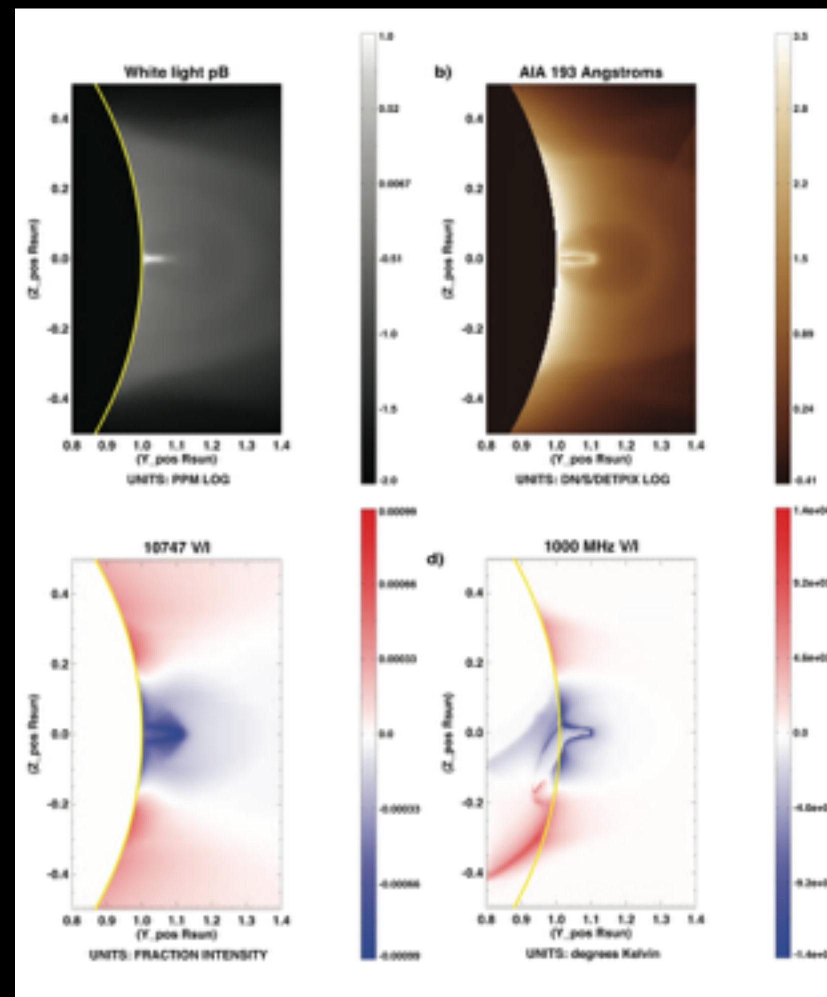
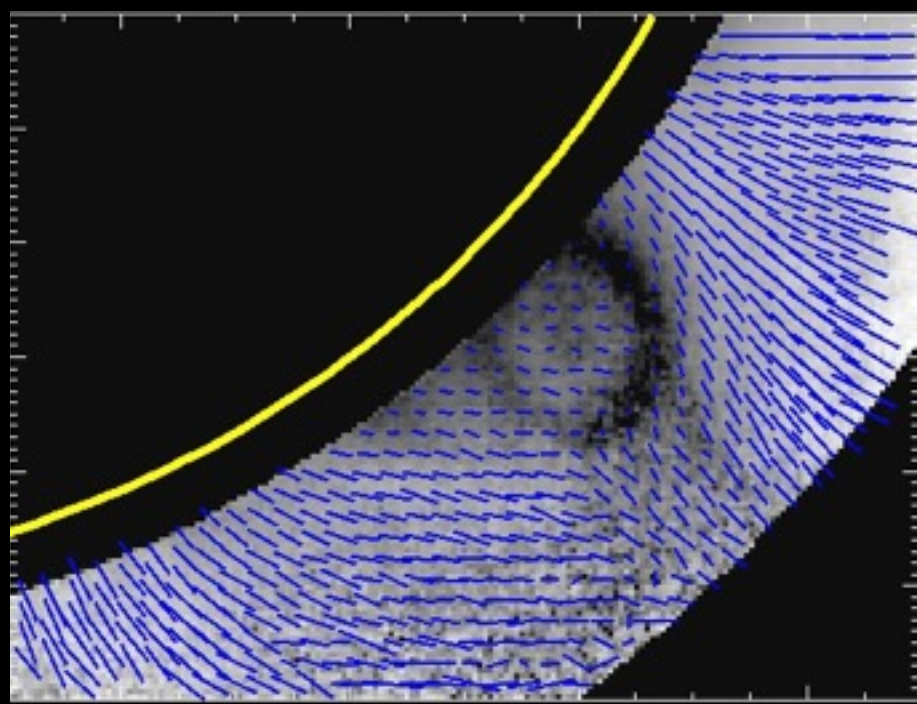
Towards a Data-Optimized Coronal Magnetic Field Model (DOC-FM):

Synthetic Test Beds and Multiwavelength Forward Modeling

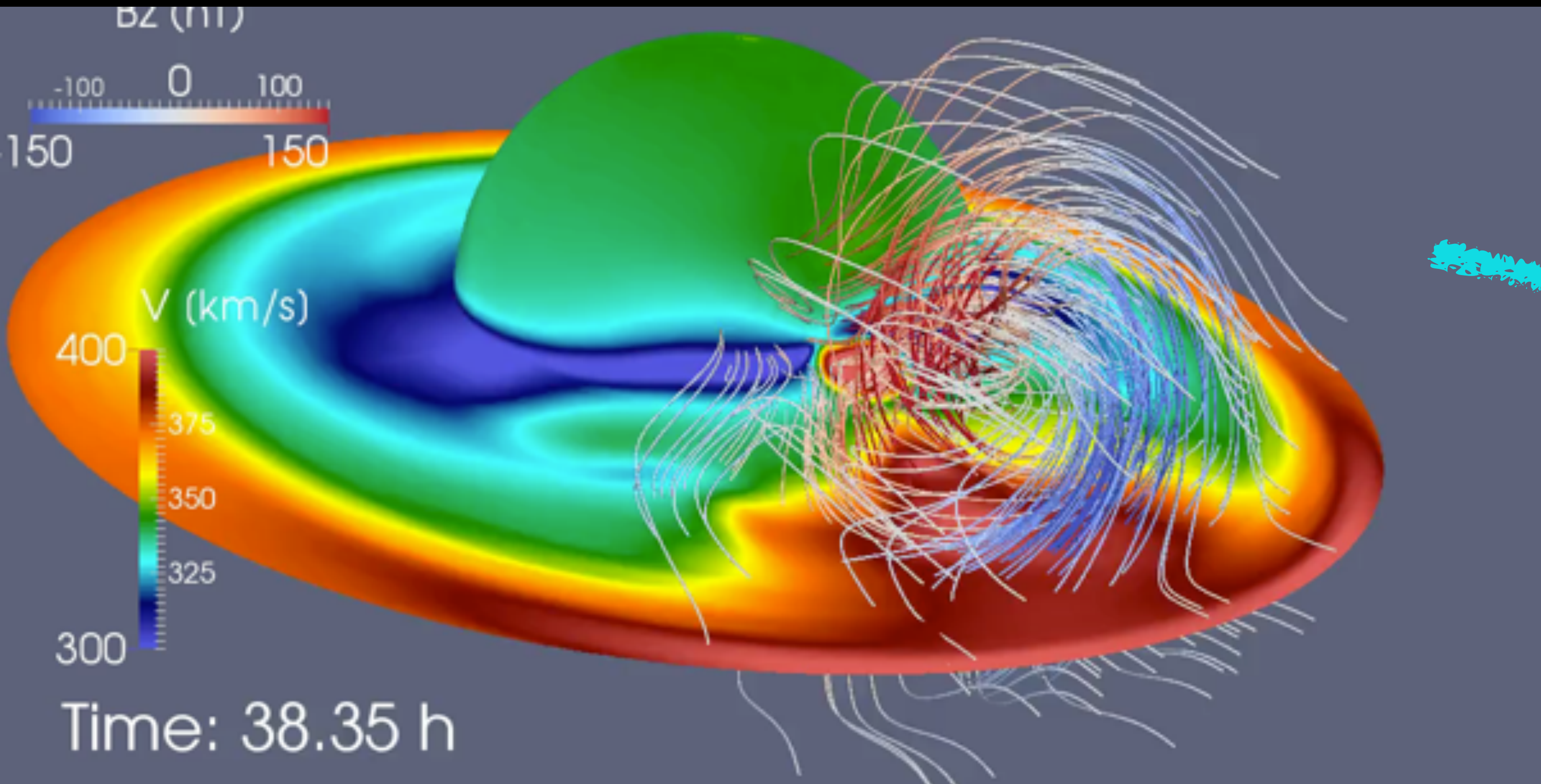


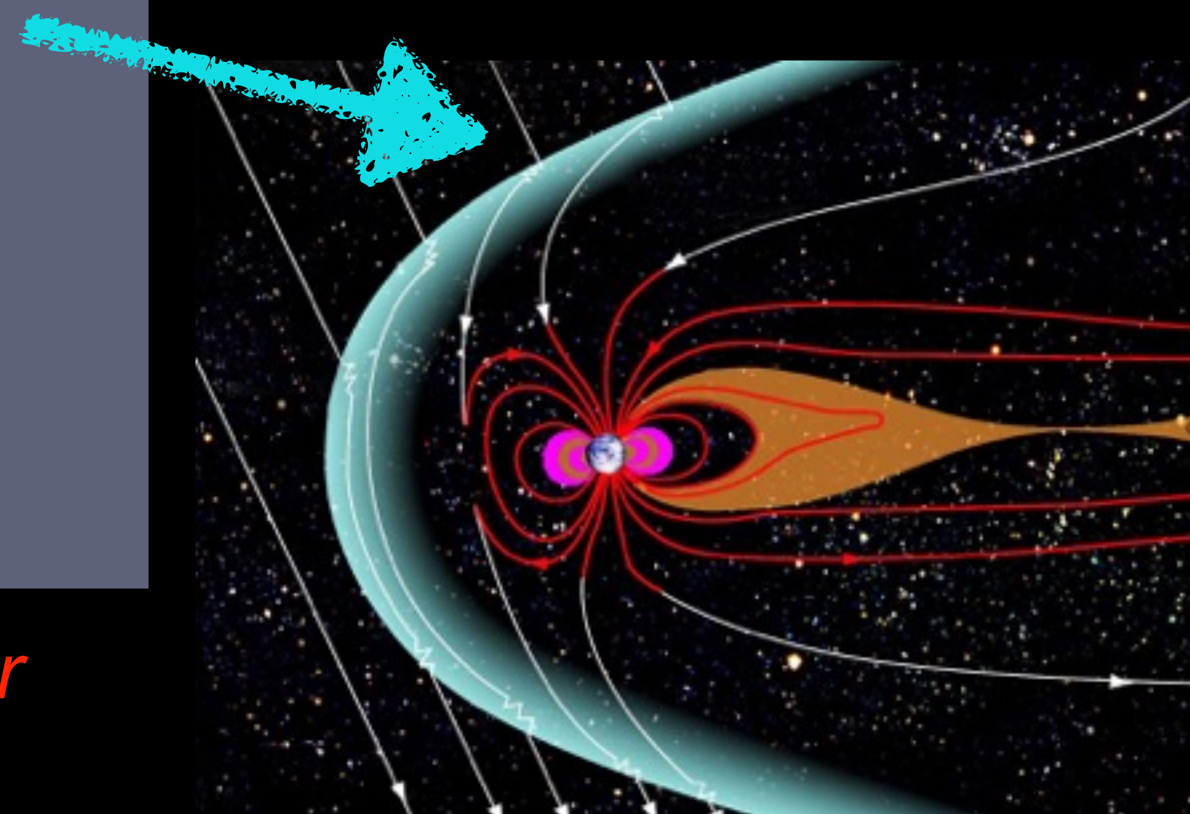




Sarah E Gibson, Kévin Dalmasse, Yuhong Fan, Silvano Fineschi, Duncan MacKay, Matthias Rempel and Stephen M White,

Why do we need coronal magnetometry?





Courtesy Merkin, Lyon, Wiltberger

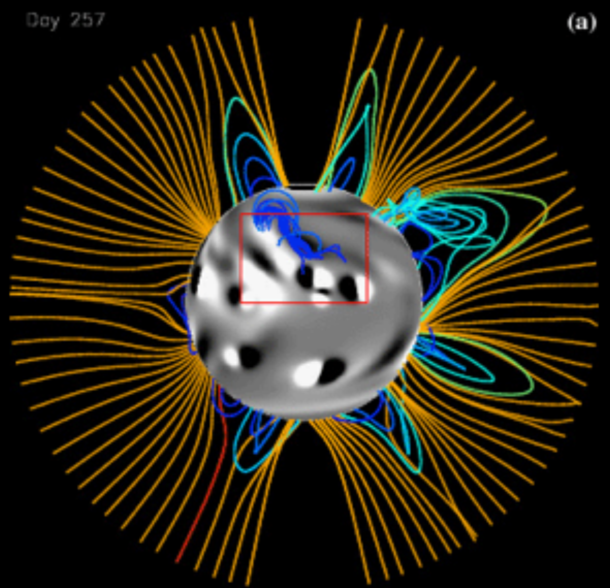
If we ever want to predict Bz at the Earth, we need to be able to quantify the *global* coronal magnetic field

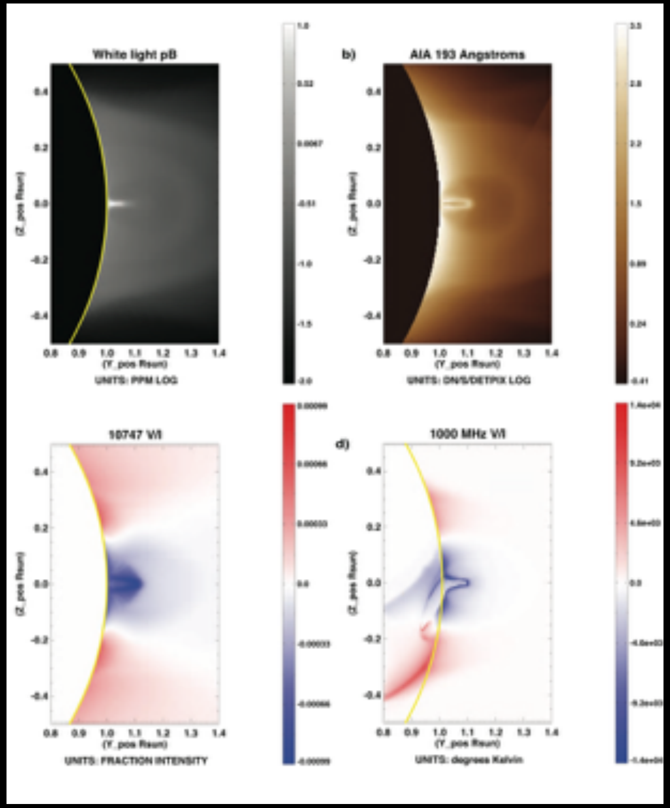
Take-home message: multi wavelength coronal observations (polarimetric and other) have great potential for constraining the global coronal magnetic field, and are largely underutilized

Coronal magnetometry

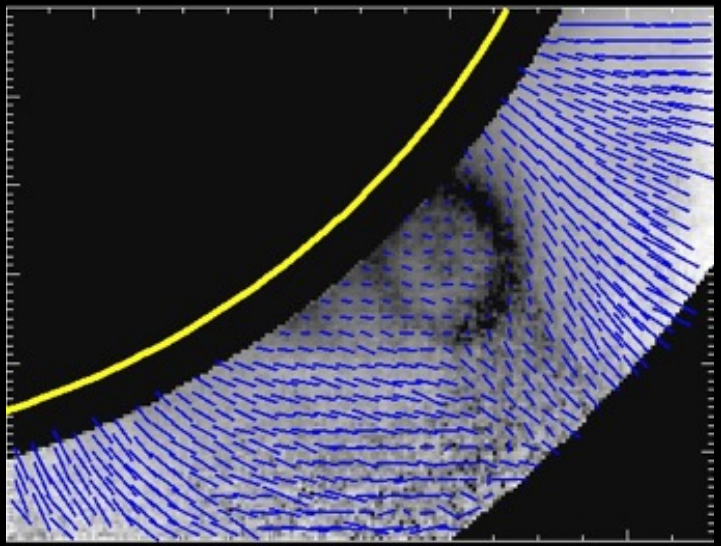
Solving an inverse problem requires three things:

- a means of specifying the **physical state** (e.g., the distribution of density, temperature, velocity, and magnetic field)
- a well-defined forward calculation (i.e., the **physical process** relating the physical state and the observations)
- the **observations** themselves.

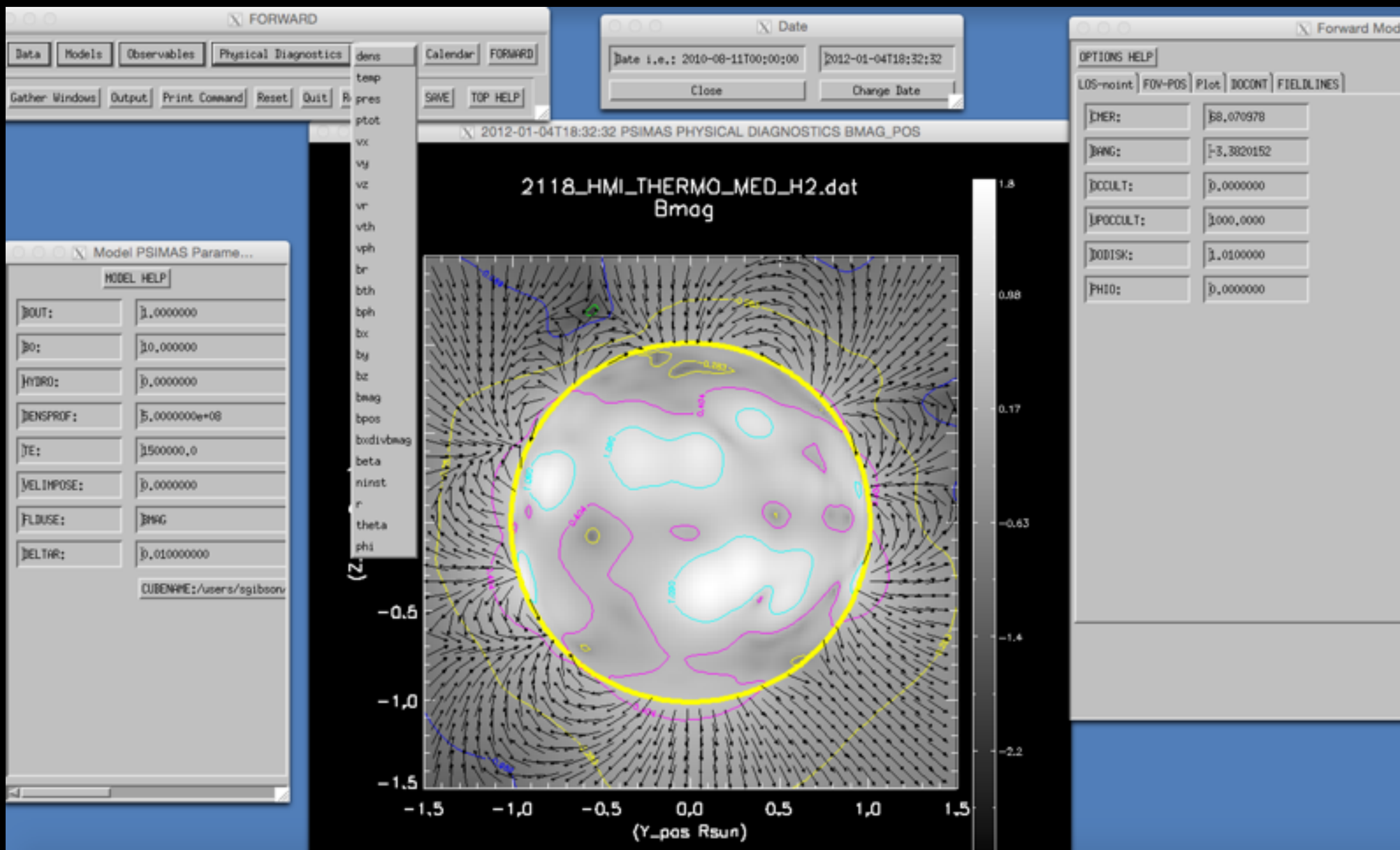




The FORWARD SolarSoft package incorporates all three

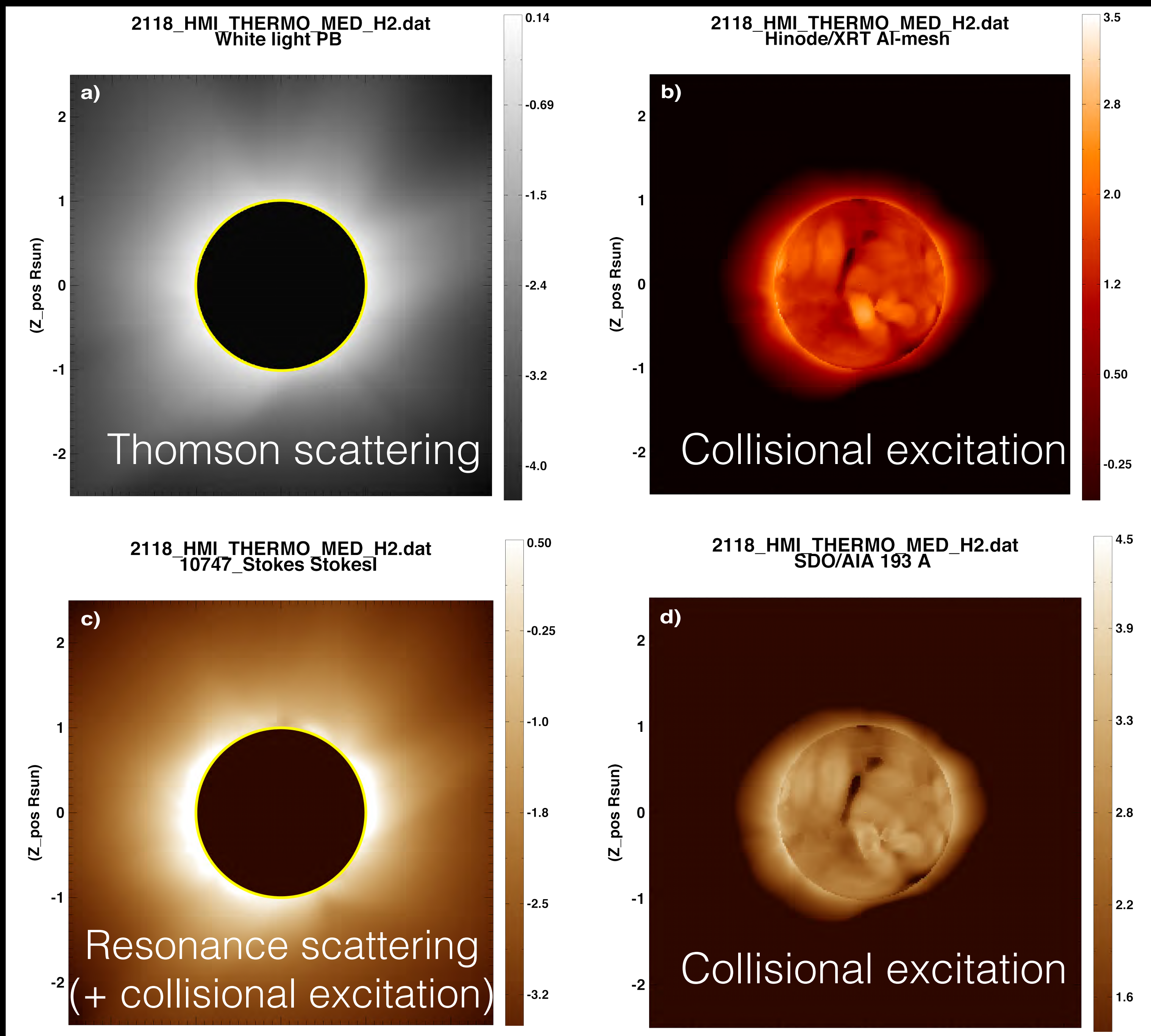


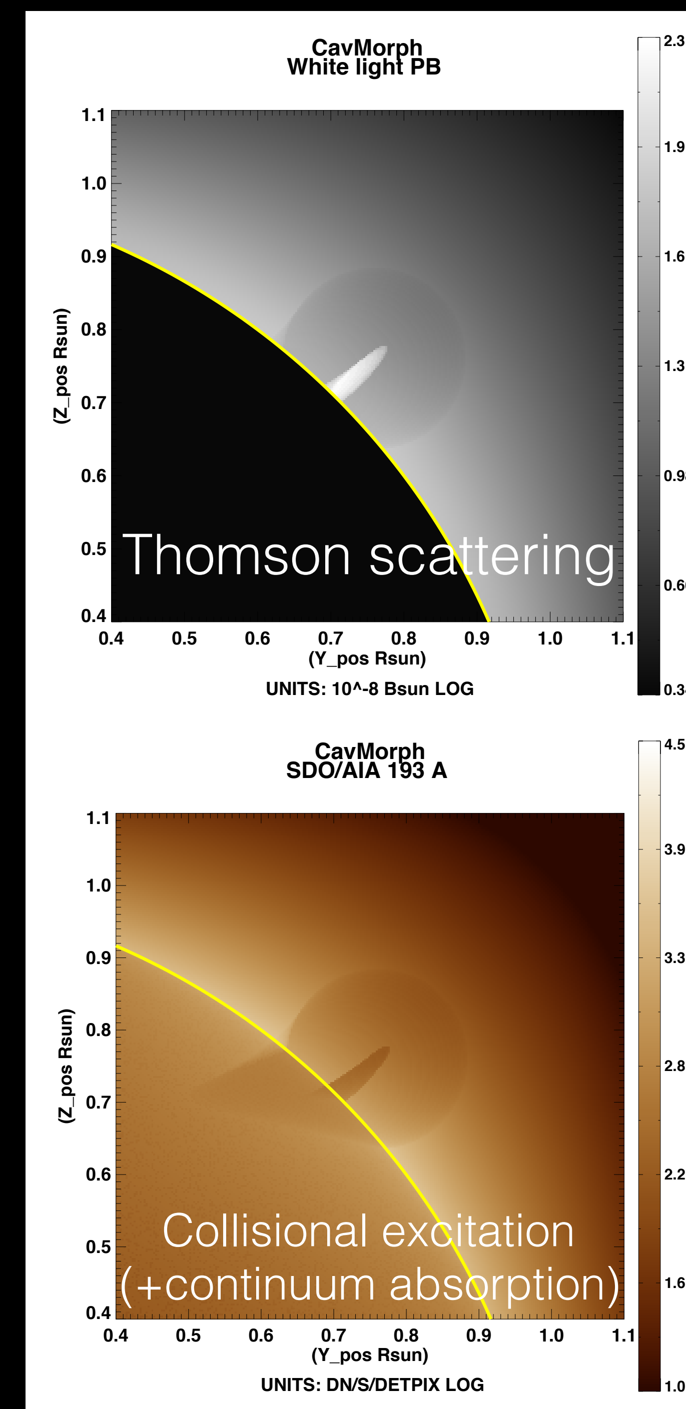
Physical State



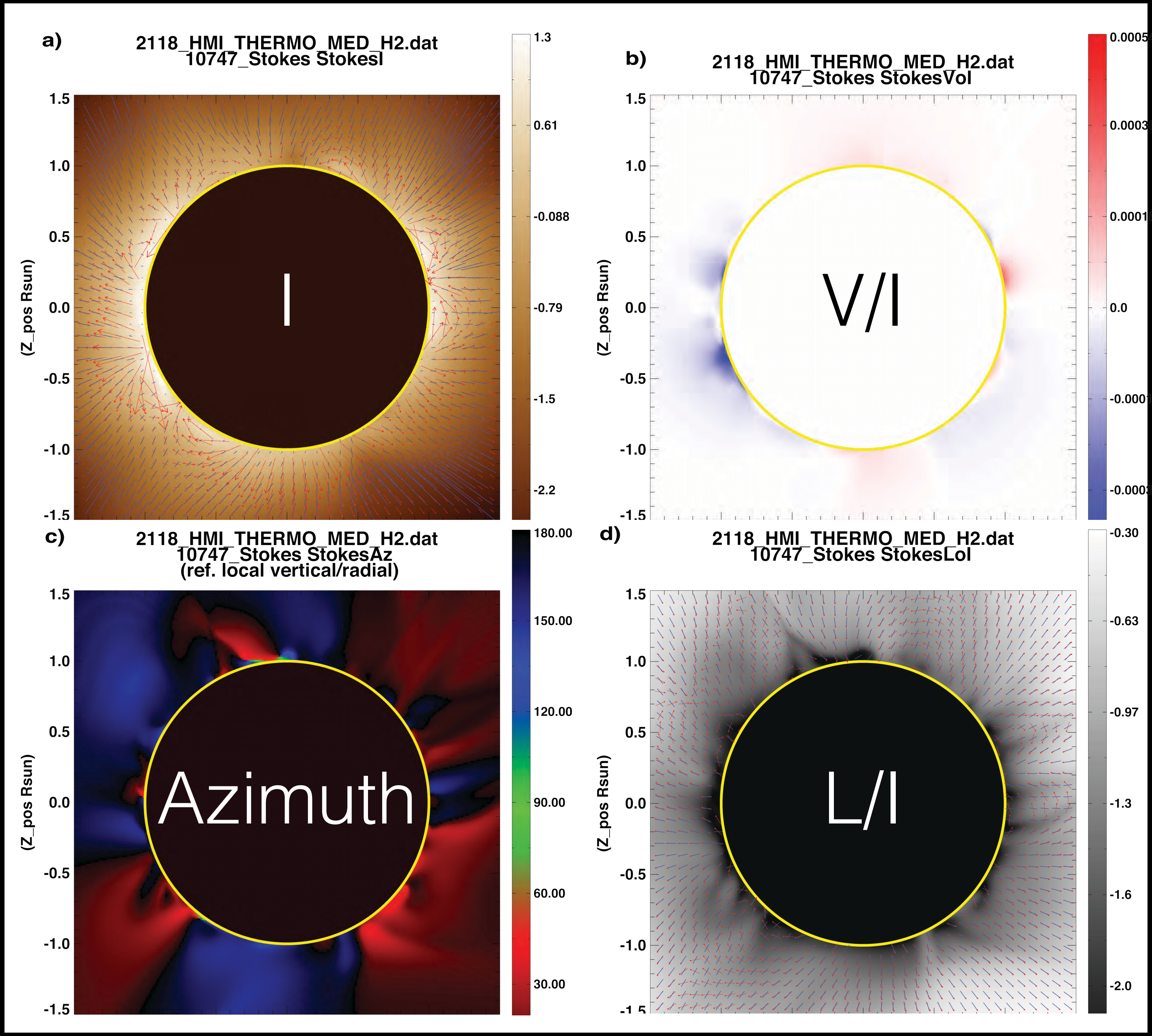
- analytic, numerical (user-inputted), or web-accessed (PFSS, MAS)

Physical processes



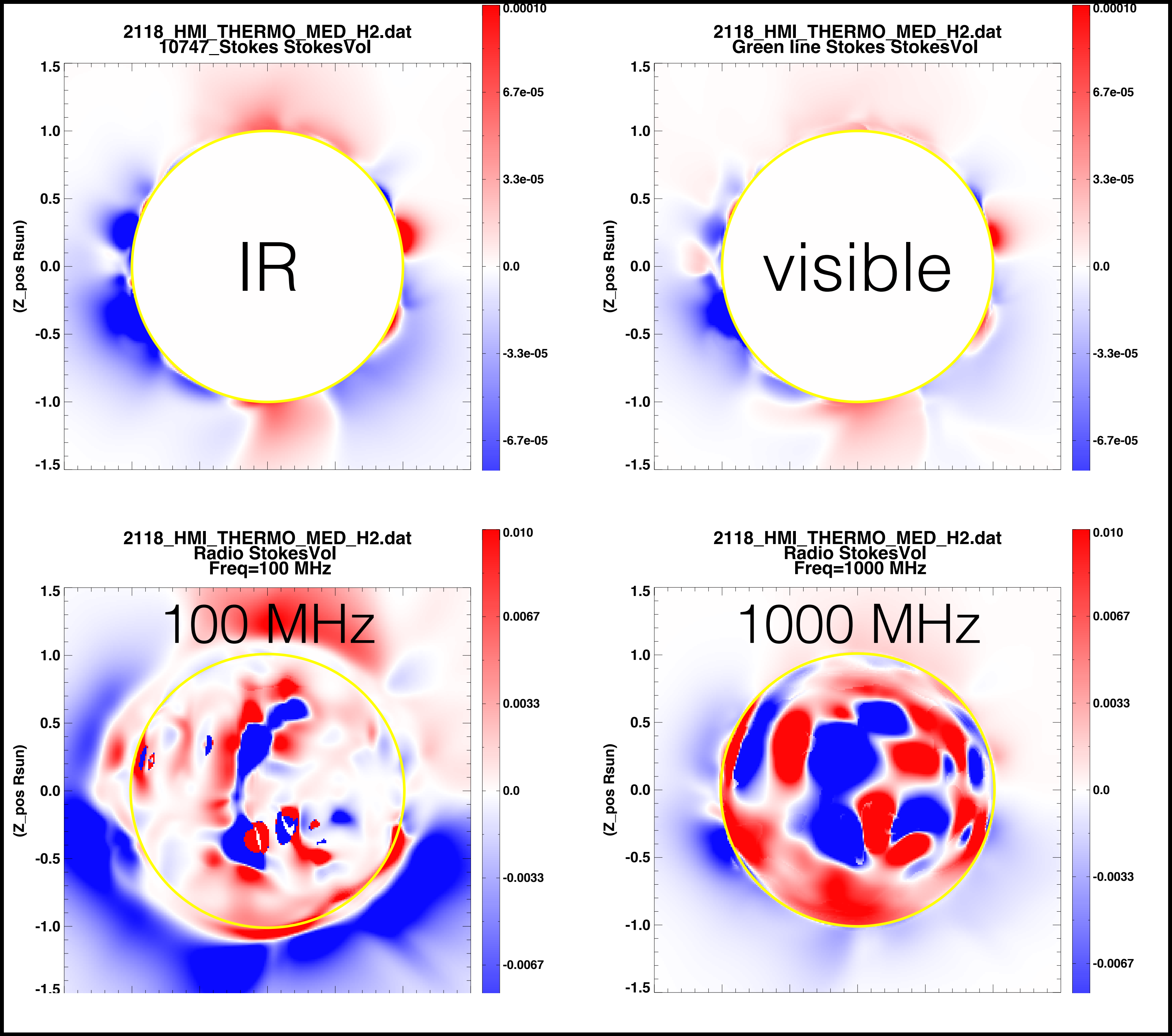


Physical processes



Polarization (Zeeman, saturated Hanle)

Physical processes



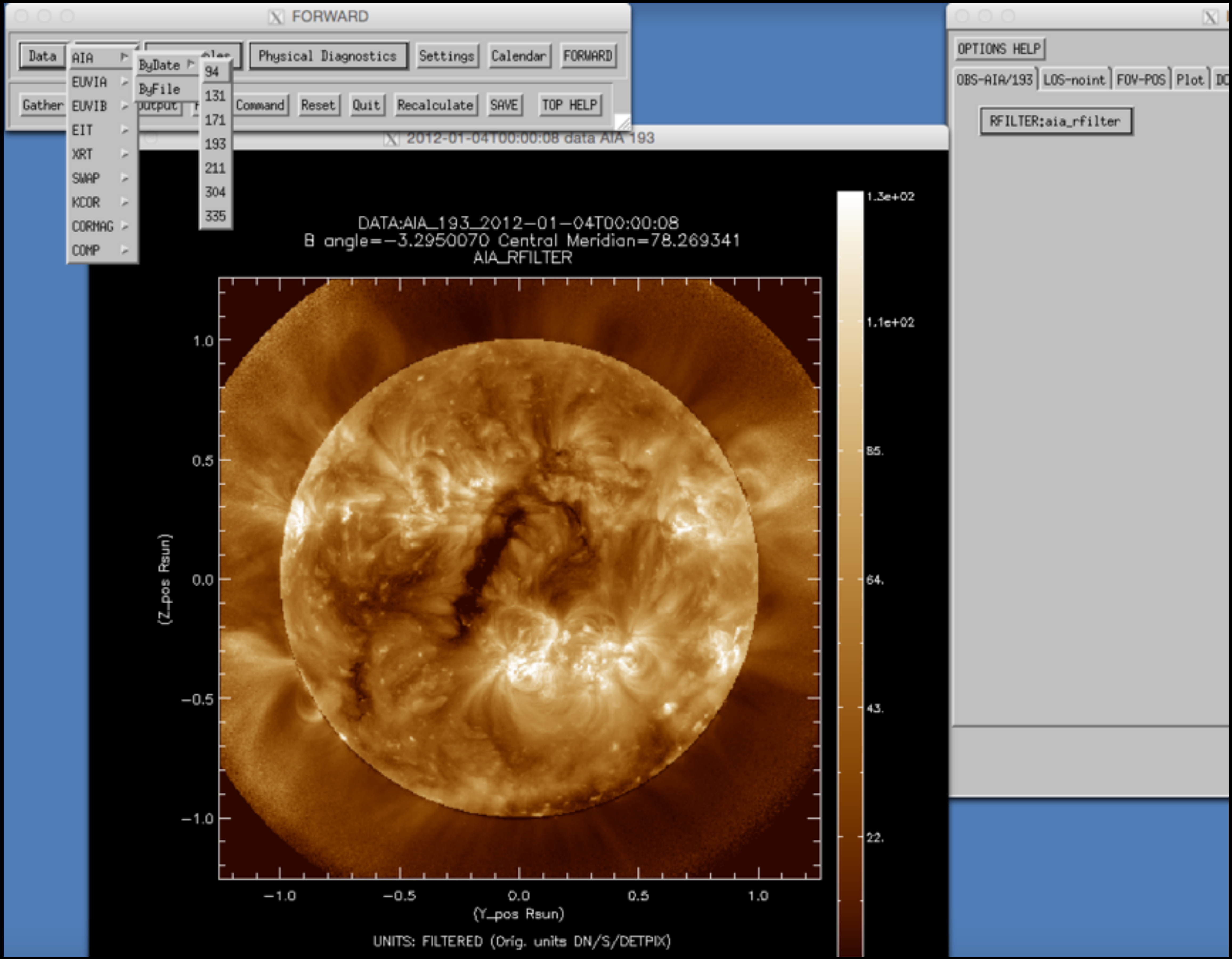
Circular polarization at different wavelengths:

different dependencies on plasma along the line of sight

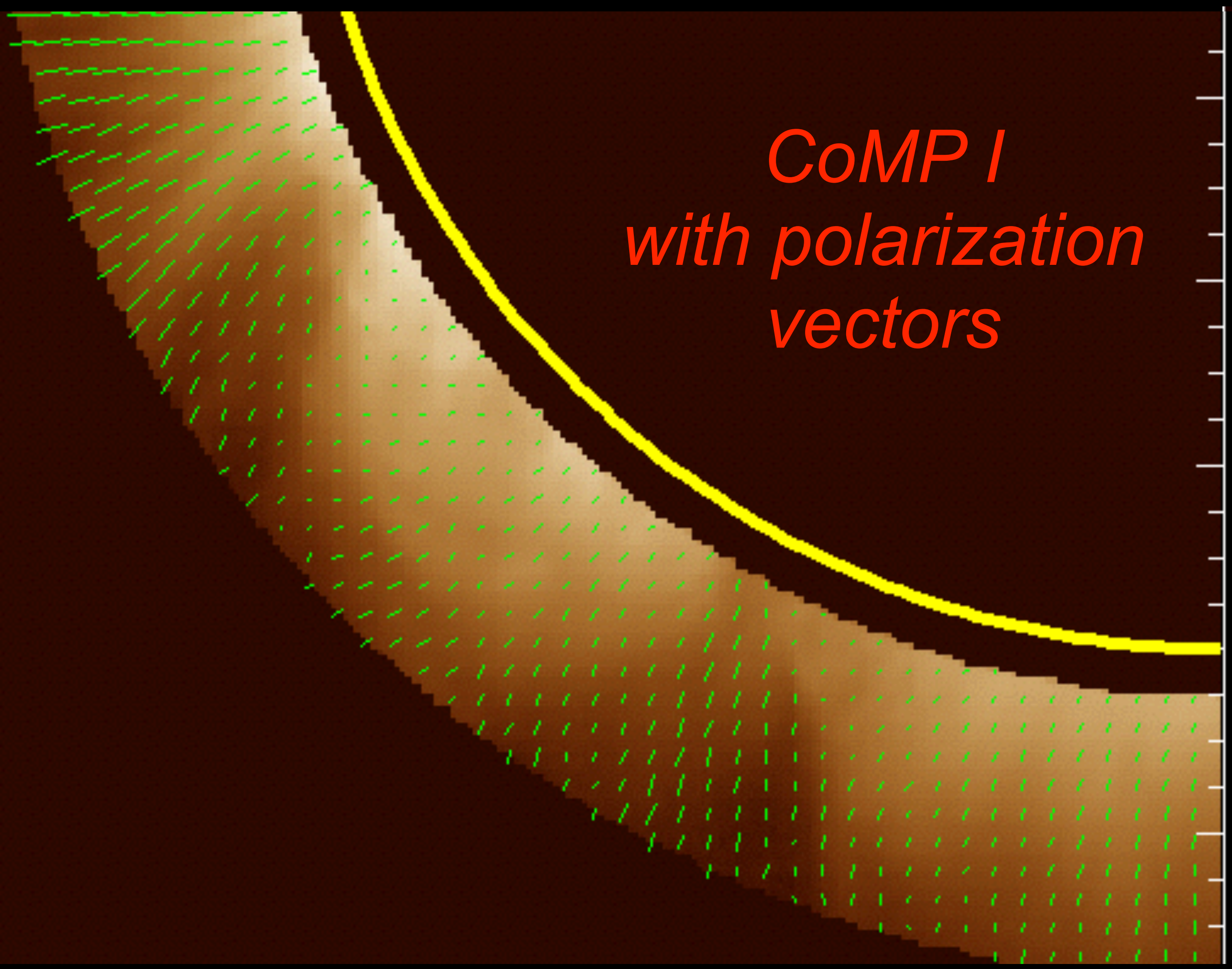
Physical processes

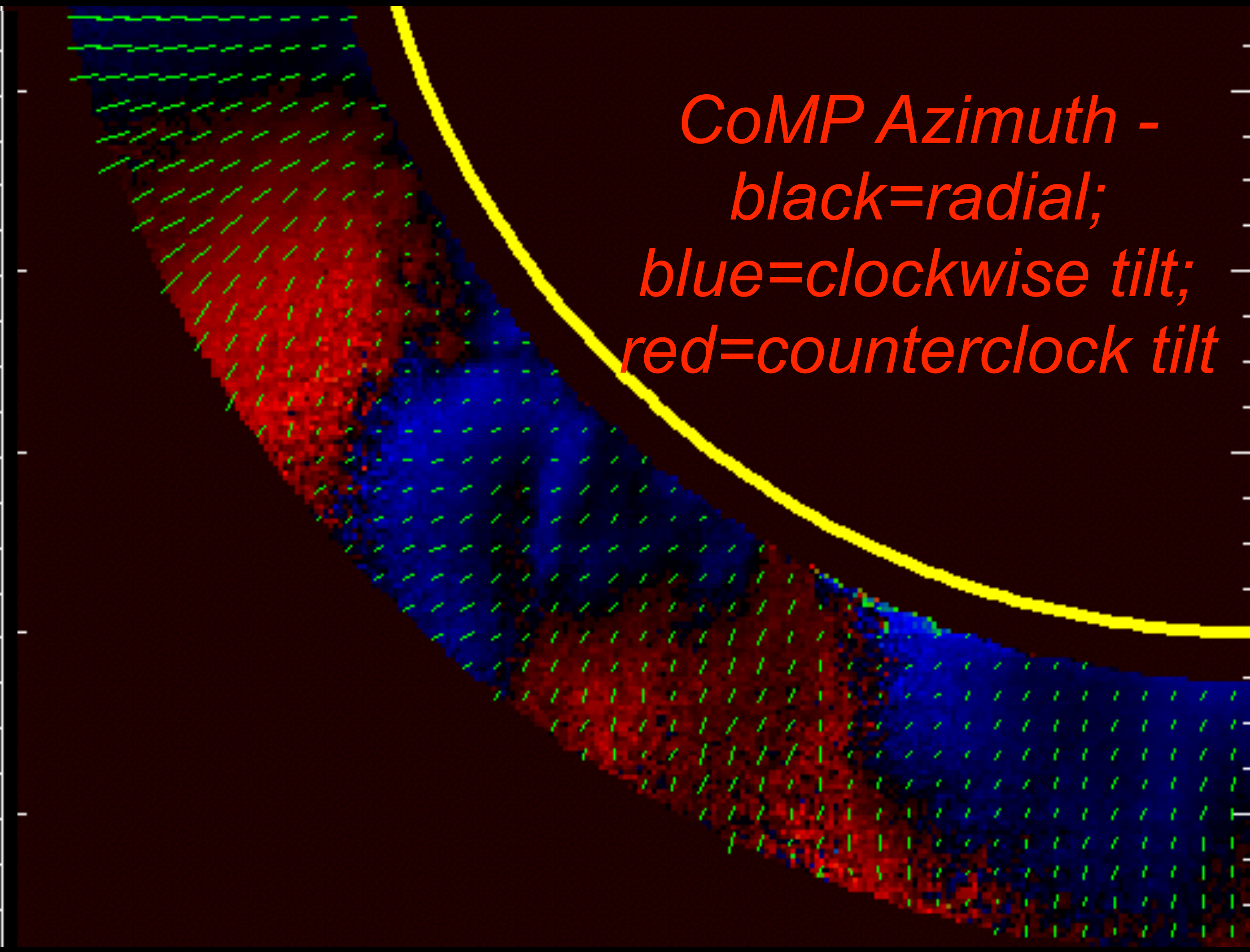
Process	Physical-state dependency	Observation	Magnetic quantity probed
Thomson scattering	electron density	White-light pB, TB	Plasma structured by field (e.g. closed vs. open field boundaries, flux surfaces)
Collisional excitation	electron density, temperature	IR/Visible/EUV/SXR emission	Plasma structured by field (incl. loops, closed/open boundaries, flux surfaces)
Continuum absorption	chromospheric population density, electron density, temperature	EUV absorption features	Can indicate magnetic geometry suitable for prominence formation
Resonance scattering; polarization	electron density, temperature, vector magnetic field	Visible/IR spectra	B_{los} from Stokes V; Magnetic field direction from Stokes Q, U
Doppler shift	electron density, temperature, velocity	Visible/IR spectra	B_{pos} and field line direction from waves; flux surfaces from bulk flows
Thermal bremstrahllung	electron density, temperature, vector magnetic field	Radio emission (intensity and circular polarization) as a function of frequency	B_{los} from Stokes V
Gyroresonance	electron density, temperature, vector magnetic field	Radio emission (intensity and circular polarization) as a function of frequency	Surfaces of constant magnetic field strength at each frequency
Faraday rotation	electron density, temperature, vector magnetic field	Rotation of plane of polarization	B_{los} from rotation measure

Observations



Observations

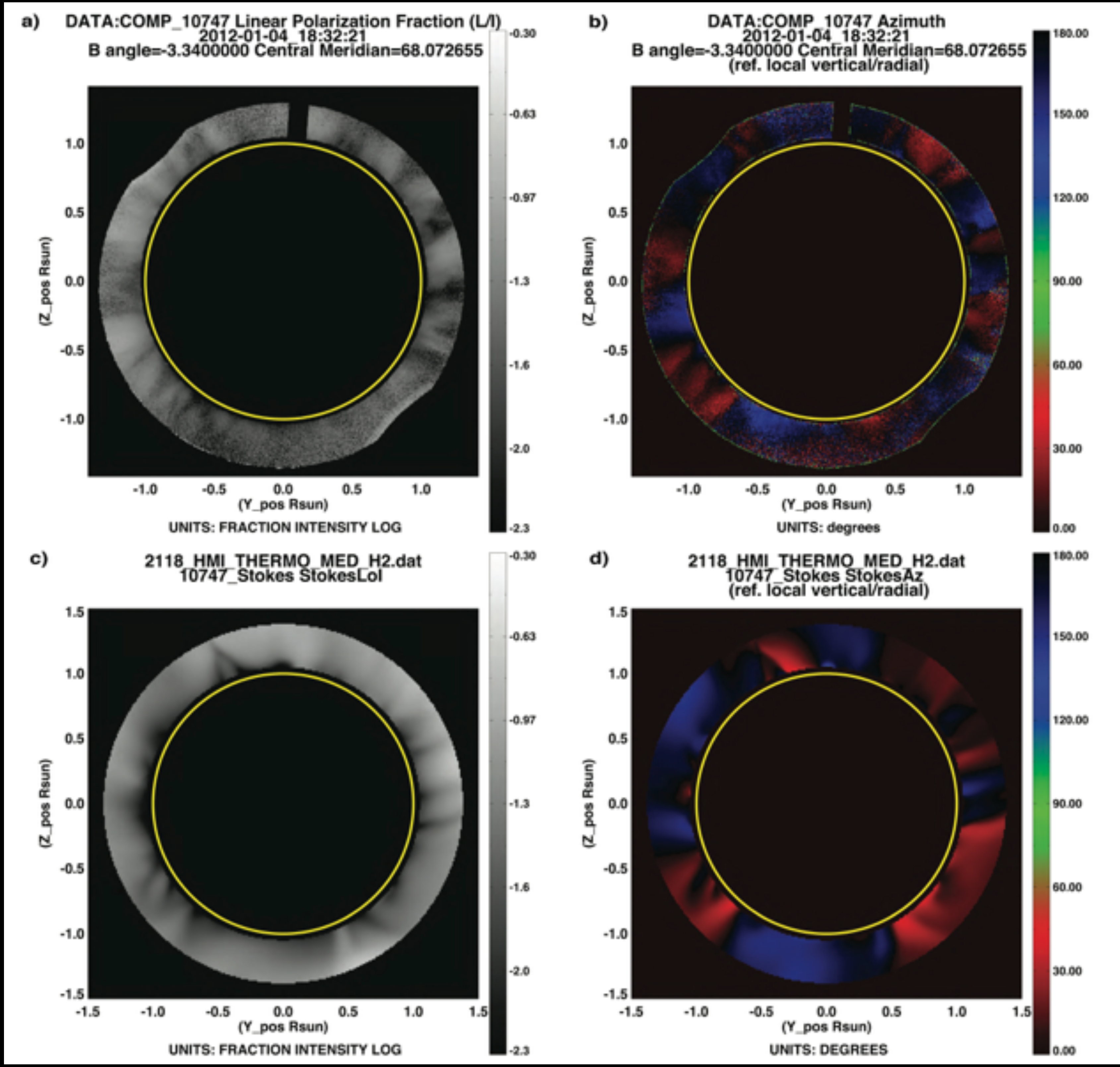




- Measures POS magnetic direction (with 90 degree flip when crosses V. Vleck angle)
- Quantifies expansion of flux tubes (significant to solar wind acceleration)

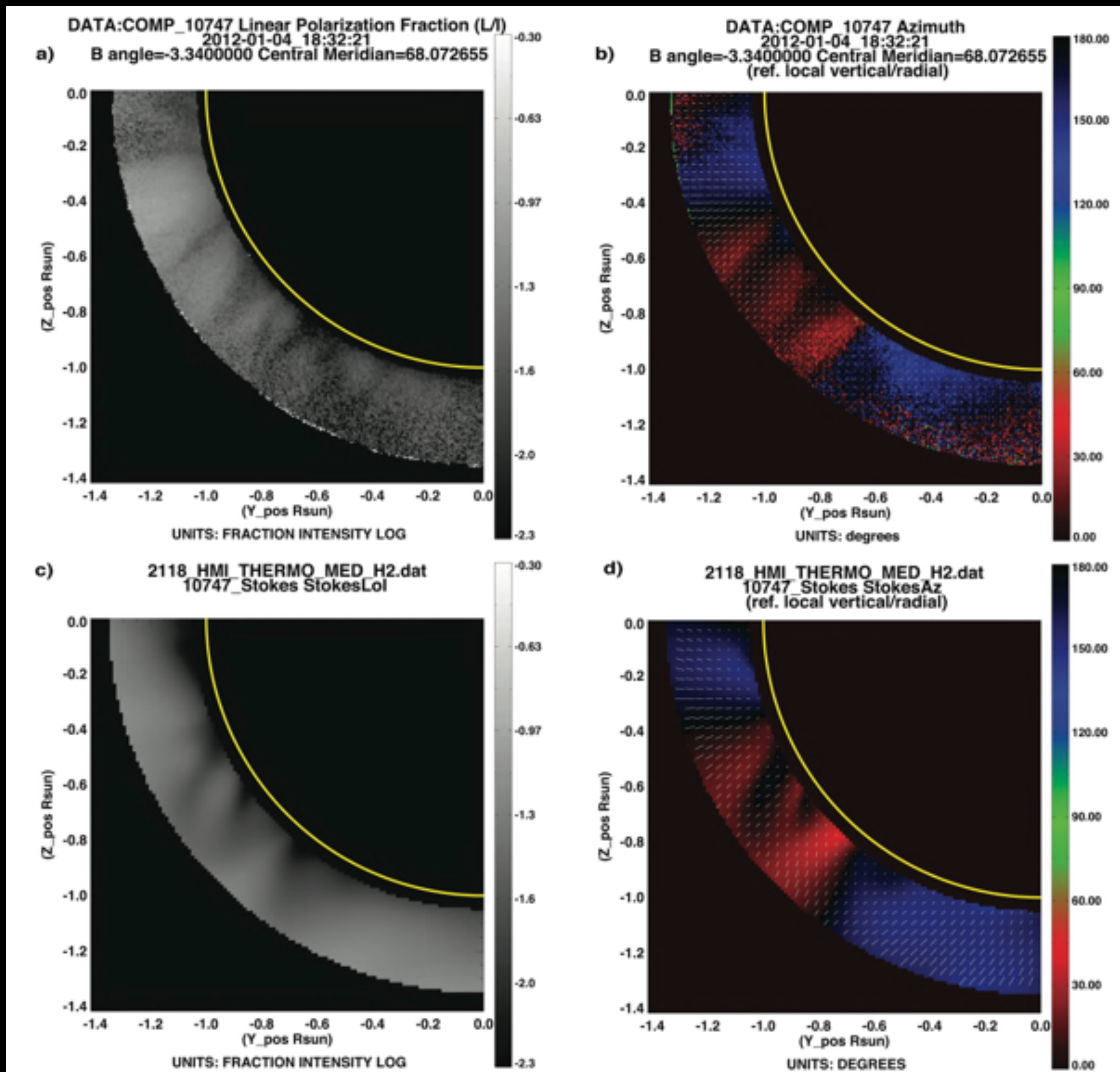
Model-data comparison

Model validation

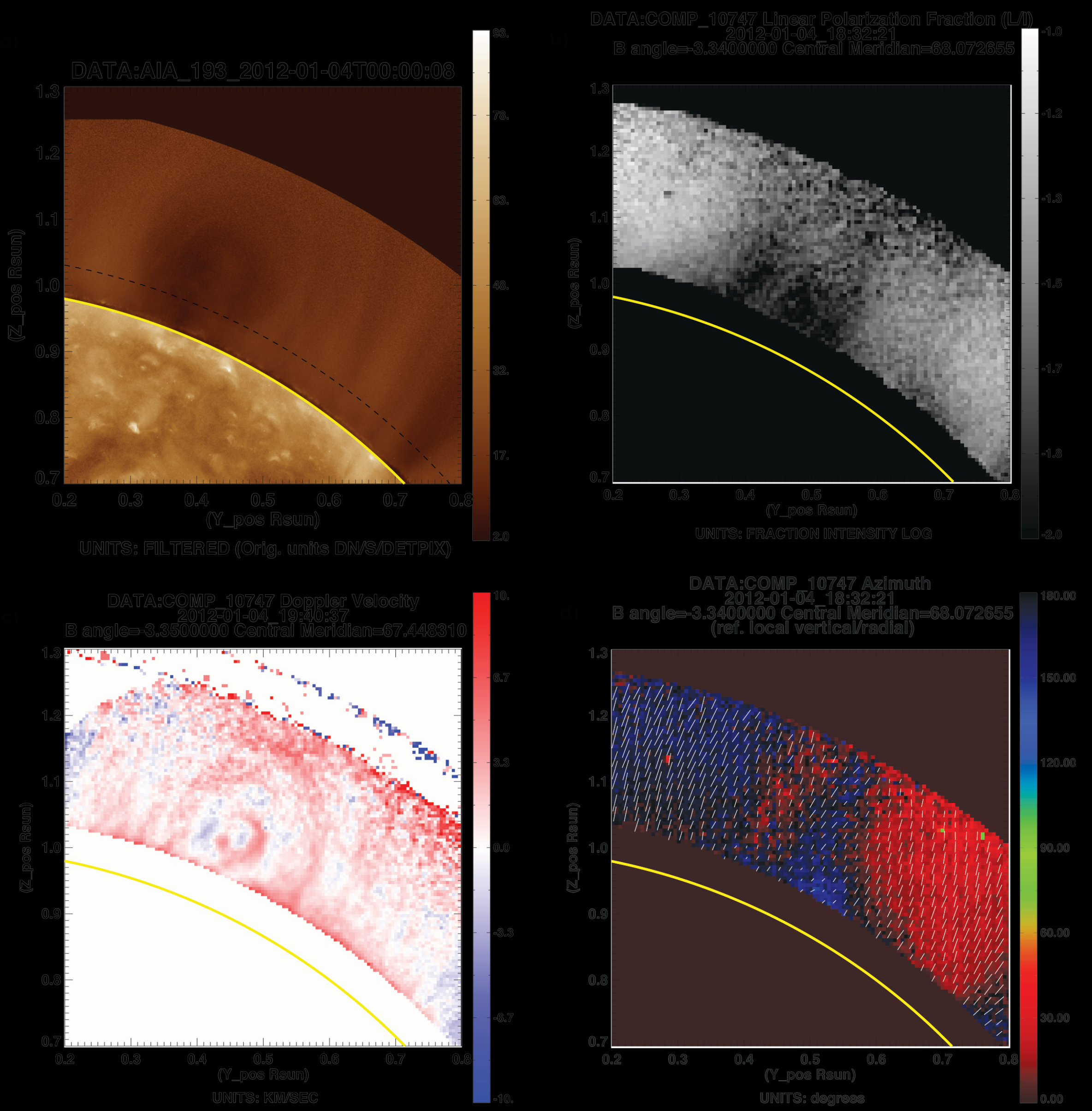


Model-data comparison

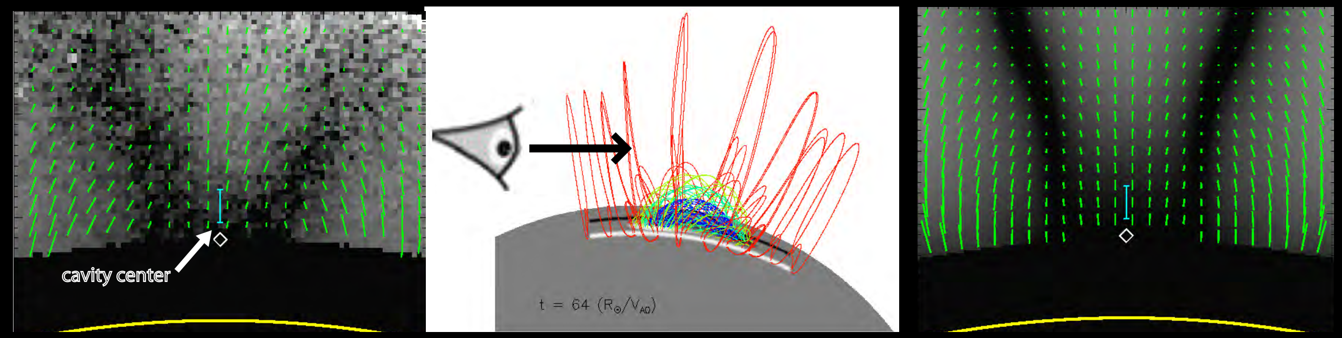
Model validation



Model-data comparison



Building intuition

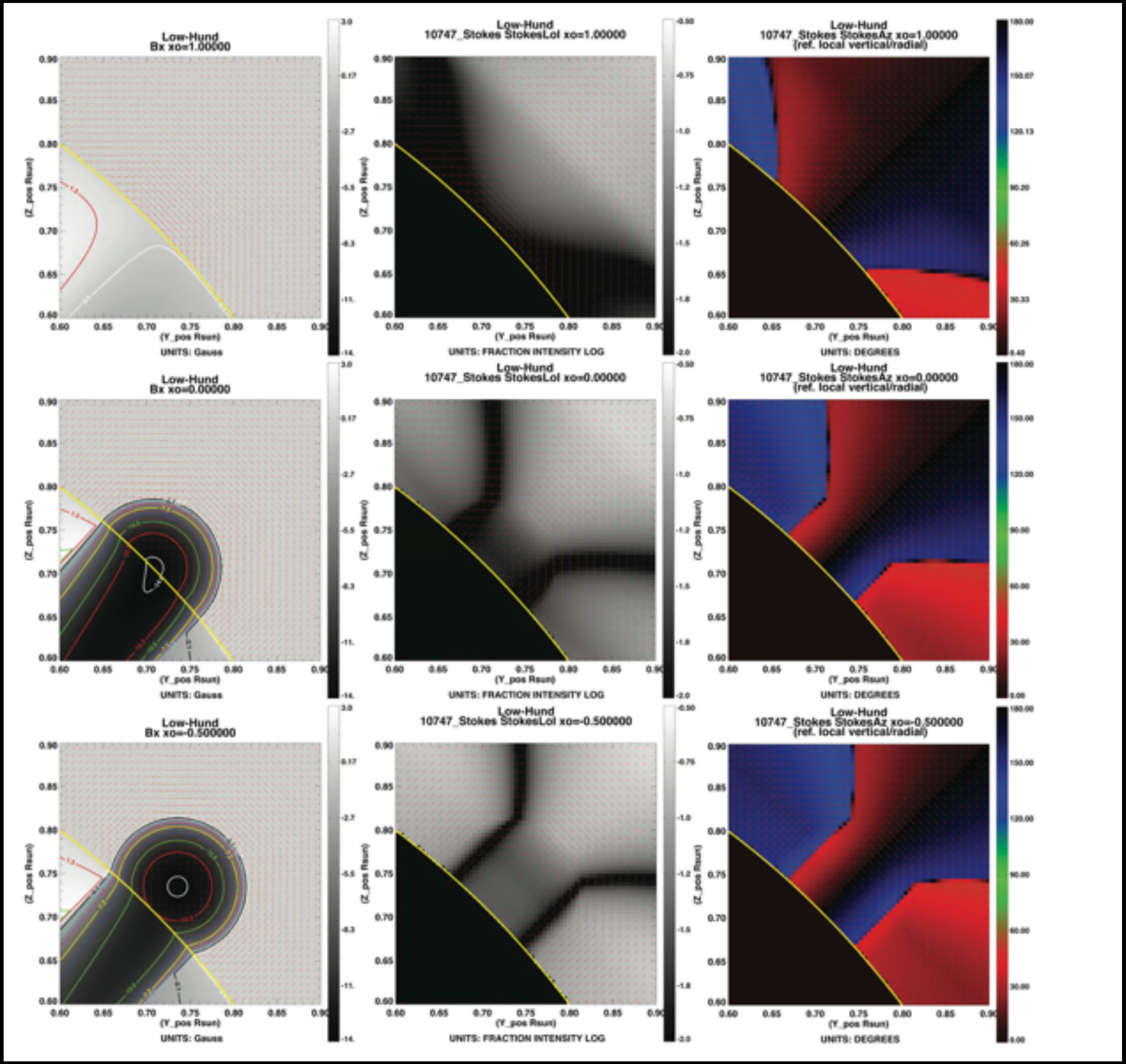


Bak-Steslicka et al., 2013

- Coronal cavities well-modeled by magnetic flux ropes
- Line-of-sight alignment minimizes projection issues
- **Degree of polarization (+ azimuth) good diagnostic of magnetic topology**

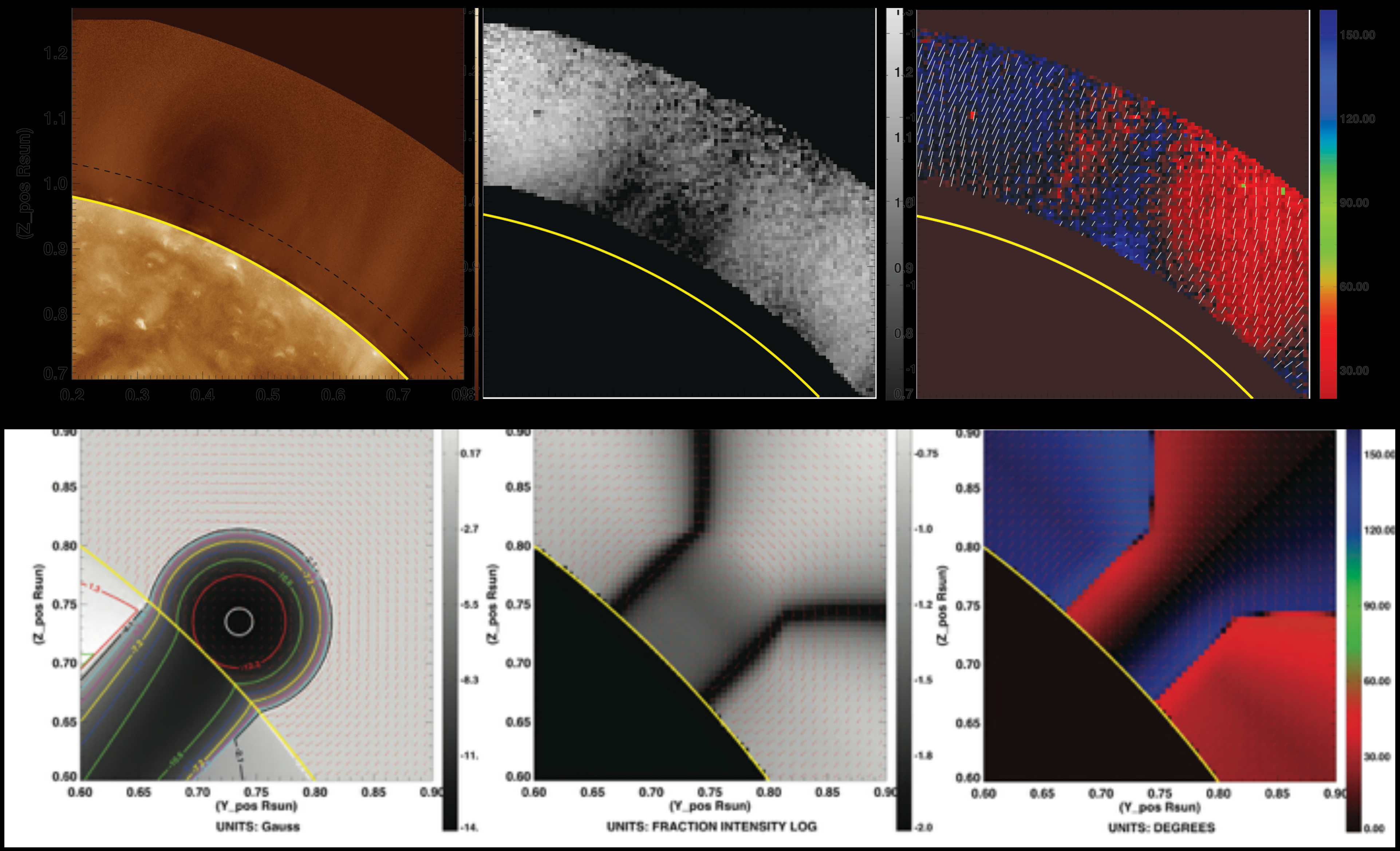
Model-data comparison

Forward fitting



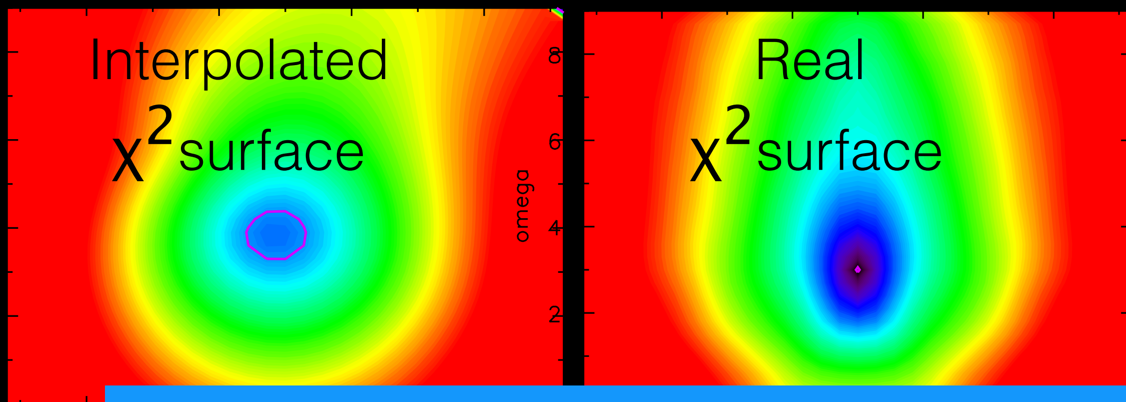
Model-data comparison

Forward fitting



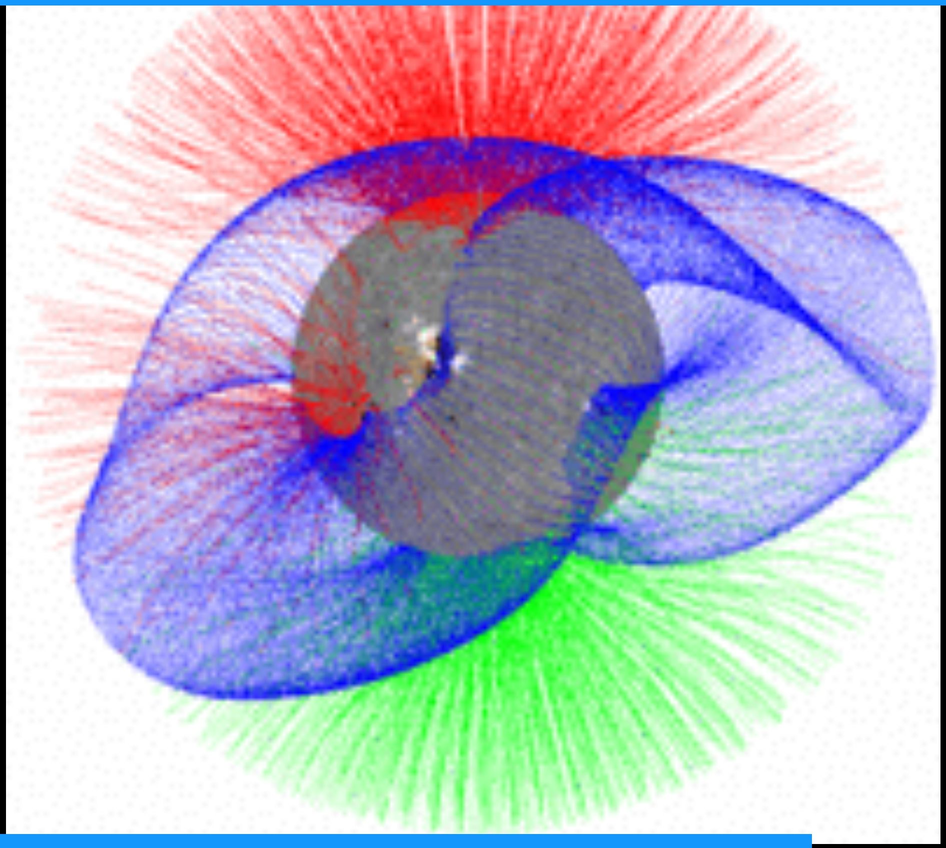
Data-optimized coronal field model (DOC-FM)

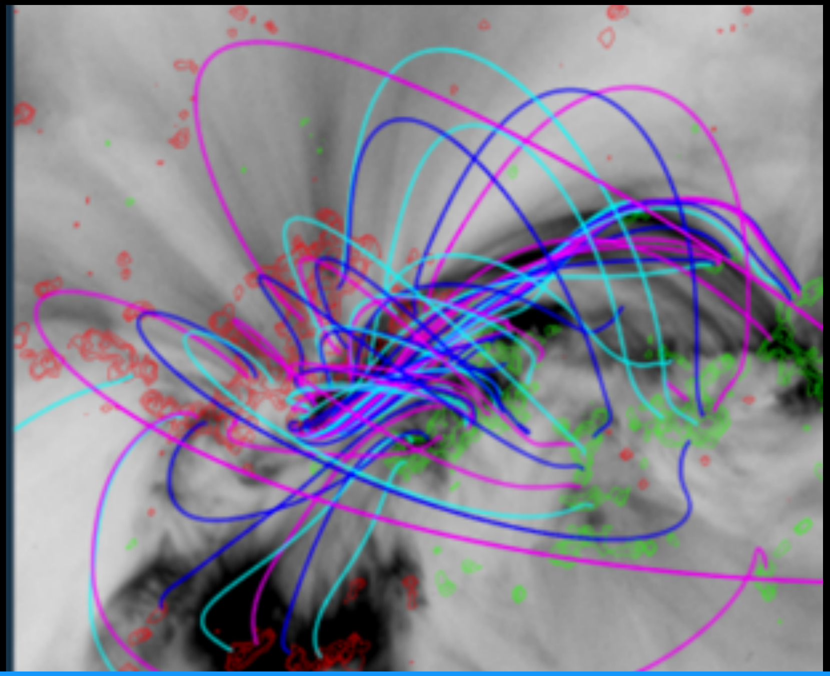
- MHD-model based approach to forward-fitting the global field (AFOSR funded NCAR-CfA collaboration)



Solve for best fit parameters (location, orientation, strength, height of ropes).

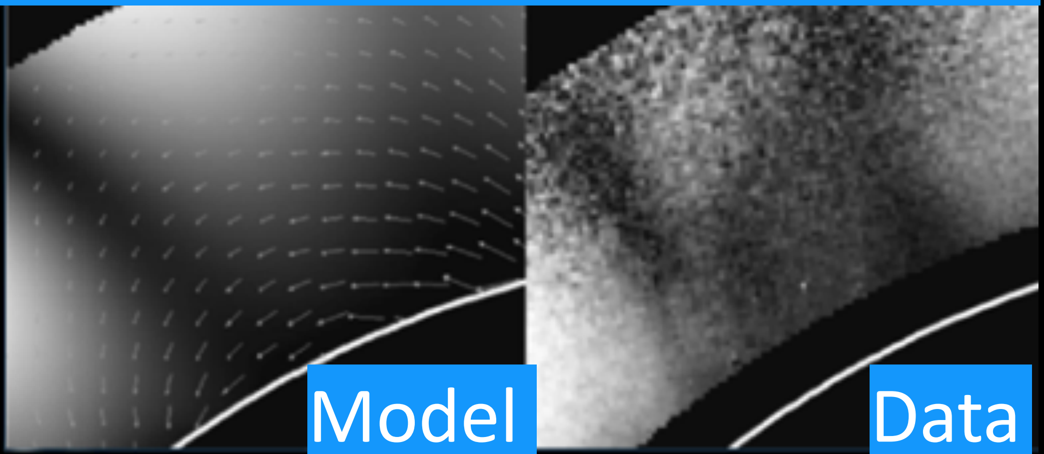
Initial guess global magnetic field



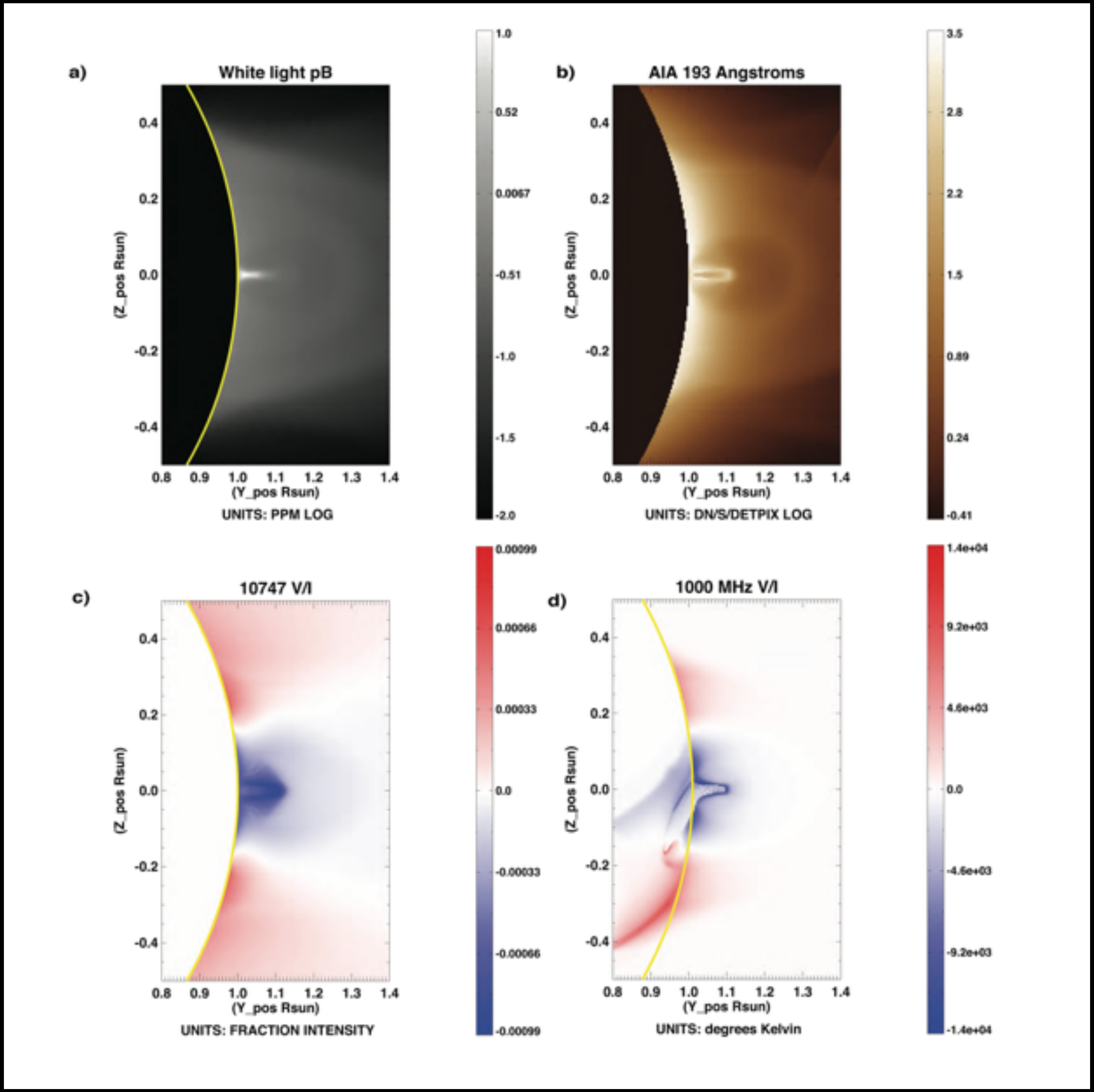


Add currents (flux-rope insertion) where don’t match

Generate synthetic observables



Synthetic test beds

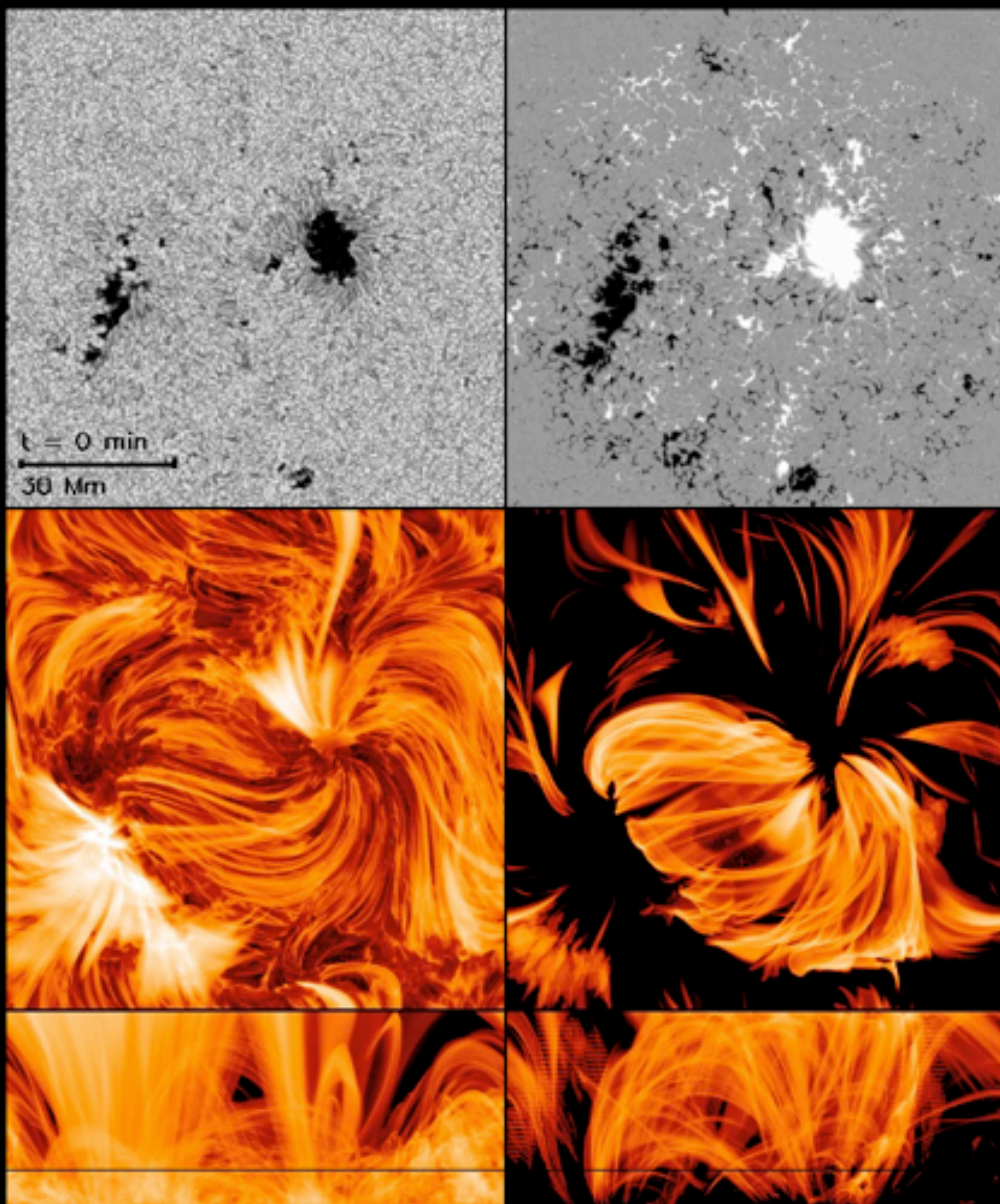


Conclusions

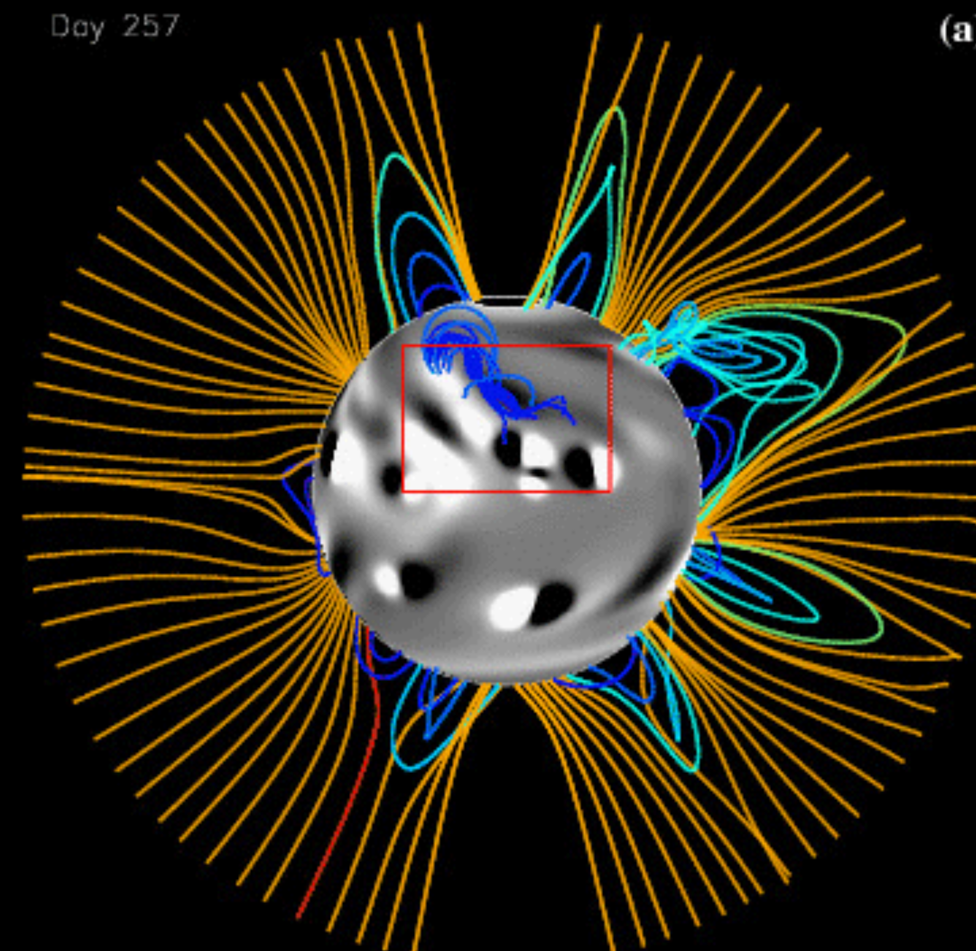
- A range of magnetically sensitive physical processes have observational signatures **in the corona** at wavelengths from radio to soft Xray
- FORWARD is a community toolset for model-data comparison, enabling model validation, building intuition for coronal magnetic signatures, and forward fitting/inversion applications
- Synthetic testbeds provide a “ground truth” against which to test new methodologies for multi wavelength coronal magnetometry

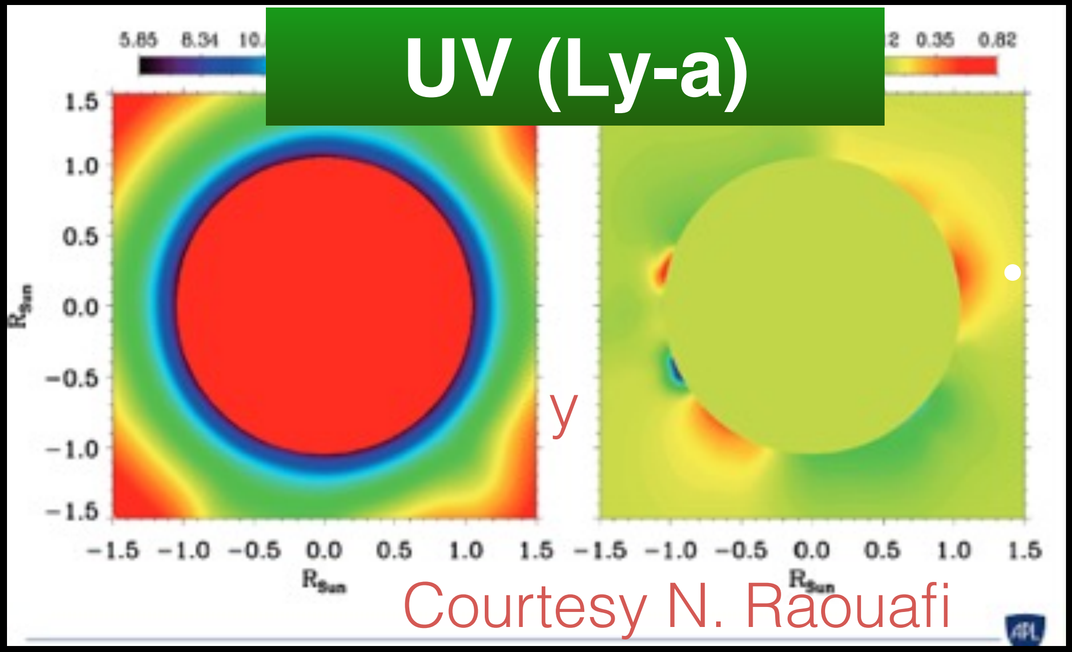
Future plans

- Active region testbed



- Global corona testbed





UV unsaturated Hanle physical process