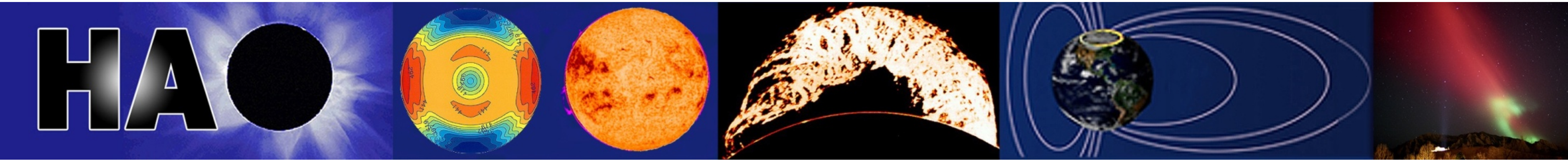

ChroMag and Vector Magnetic Fields

Vector Magnetic Fields and ChroMag

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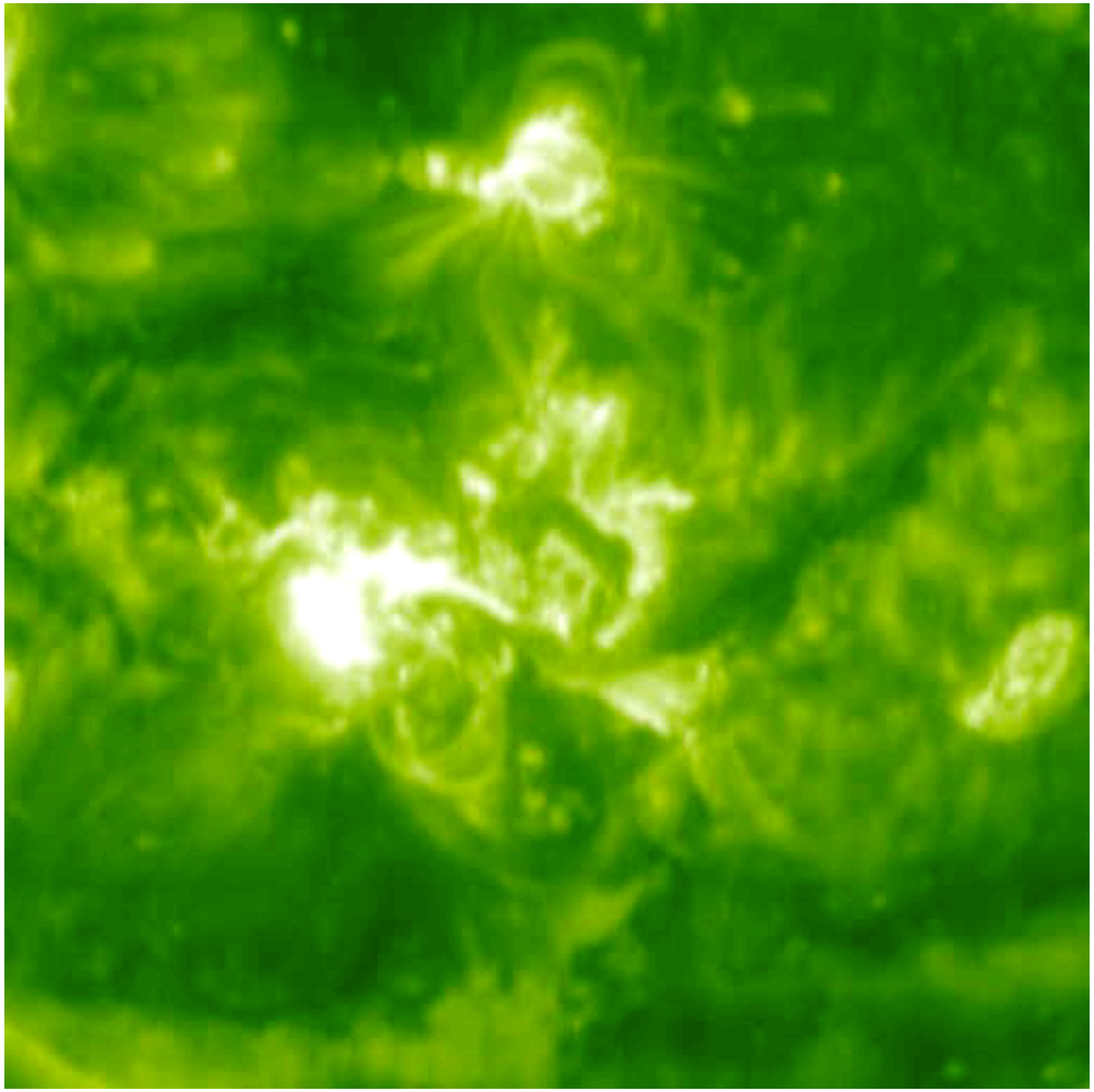
NCAR

Motivation for New Diagnostics

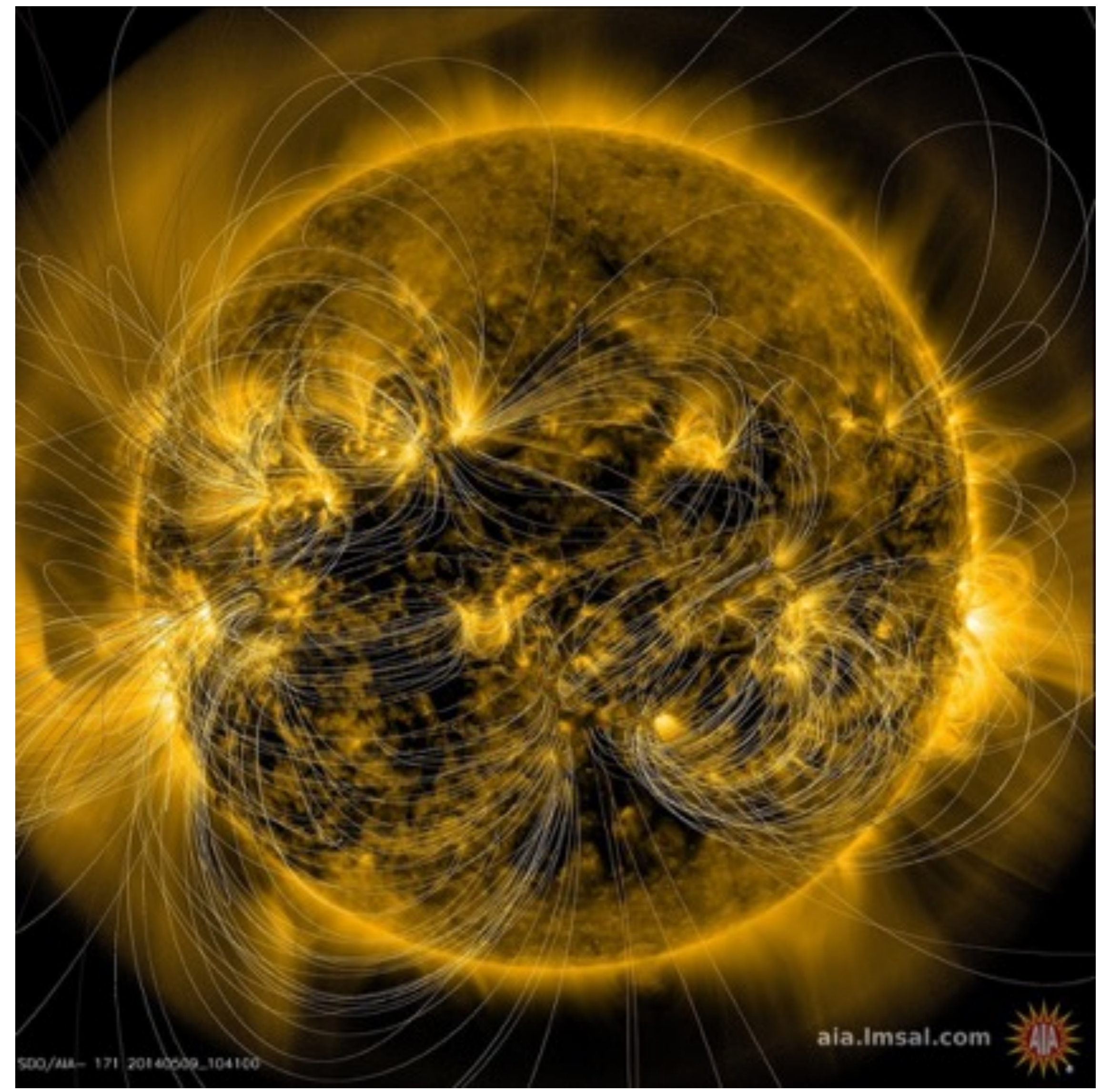
- Chromospheric and coronal structure is dominated by magnetic field.
- We must know the magnetic field through the solar atmosphere and up into the heliosphere in order to understand solar activity: flares, CMEs, etc.
- Extrapolating from photospheric (vector) field does not work.

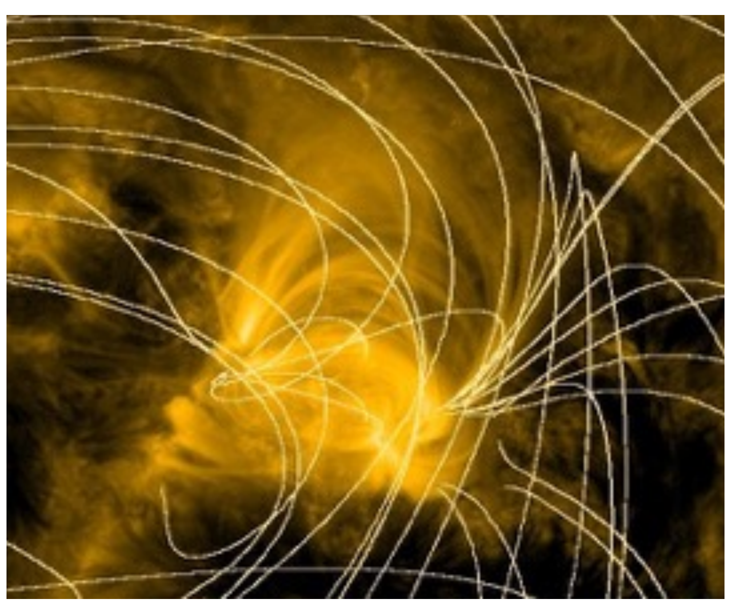
Space Weather Drivers



The Difficulty

Space Weather is driven by solar magnetic activity, but our diagnostic capabilities fall short of our needs.





Understanding Space Weather

Photospheric diagnostics do not give us the information we need to understand Space Weather drivers and events because of poor linkage to the heliosphere.

We must determine the thermodynamic and magnetic state in the solar chromosphere at the base of the heliosphere.

Driving Requirements

- Desire to know the vector magnetic field at various heights in the solar atmosphere
- Needs measurements of V_{Dop} and **B** at fast cadence to follow the evolution of dynamic events
- Should observe the full solar disk in a synoptic fashion for Space Weather™

- We need spectral lines with a chromospheric contribution of which the formation is understood that are sensitive to magnetic field.
- We would prefer lines in the optical or near-infrared.
- We're in luck: He 1083.0 nm and the Ca IR triplet 849.8/854.2/866.2 nm.

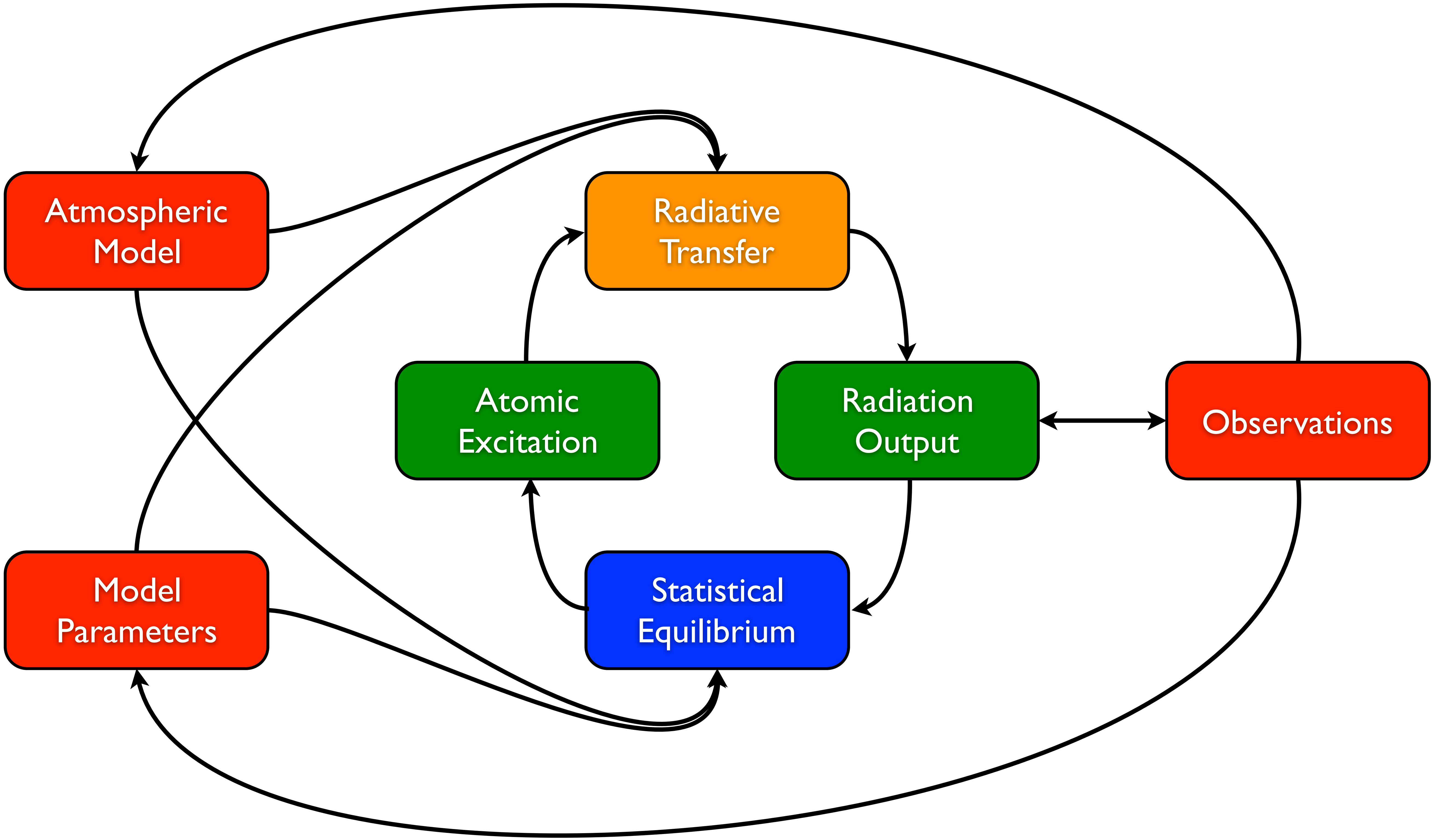
- How can we make quantitative measurements?
- We can infer plasma parameters from full-Stokes spectral line profiles.
- Actual inversion of the profile is not tractable, so we solve the forward problem: synthesize a line, compare with the observation, and repeat until a match is found.

- Both He and Ca are promising diagnostics, and several inversion codes already exist. But:
- Radiative transfer of the Ca IR triplet is difficult and 2 of the lines suffer from blends.
- He 1083.0 nm is very weak outside of active regions.

- We need a spectrograph or a wavelength-tunable imager to measure the line profiles.
- Detectors are 2D, but observation space is 3D: 2 spatial, 1 spectral dimension.
- We have to slice the cube somehow.
- And observing is never easy anyway.

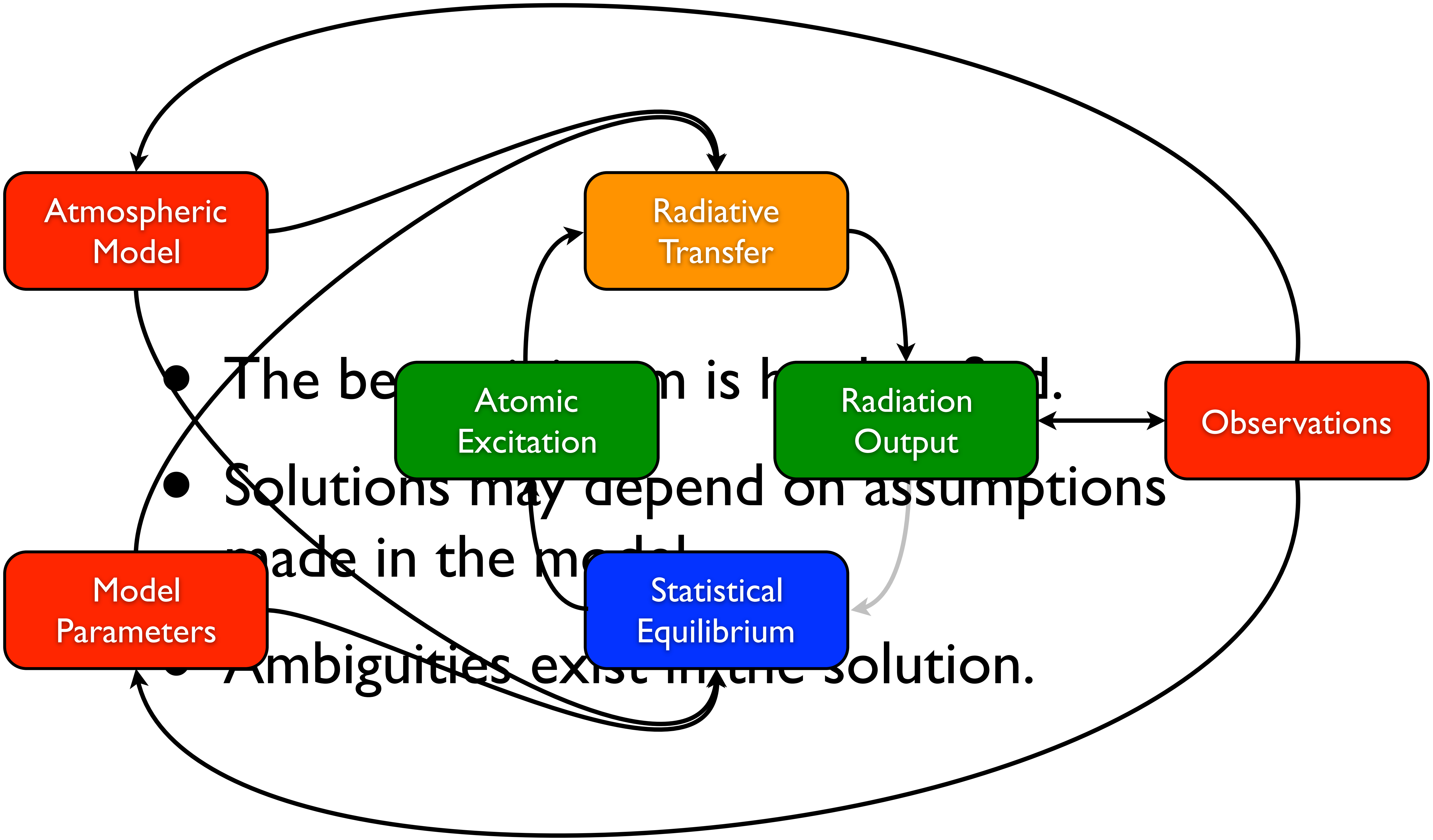
- Why is quantitative polarimetry difficult?
- Detectors are sensitive to intensity.
- We must encode the Stokes 4-vector into intensity measurements, and decode it from the observations. Polarimetry is by necessity a difference measurement.
- Polarization signals are small compared to intensity.

- How do we analyze the data?
- Remember the “inversion” process: synthesize, compare, repeat.
- We need a model atmosphere, and calculate polarized radiative transfer.
- So why is that so difficult?



Atmospheric Model
Radiative Transfer
Atomic Excitation
Radiation Output
Observations
Model Parameters
Statistical Equilibrium

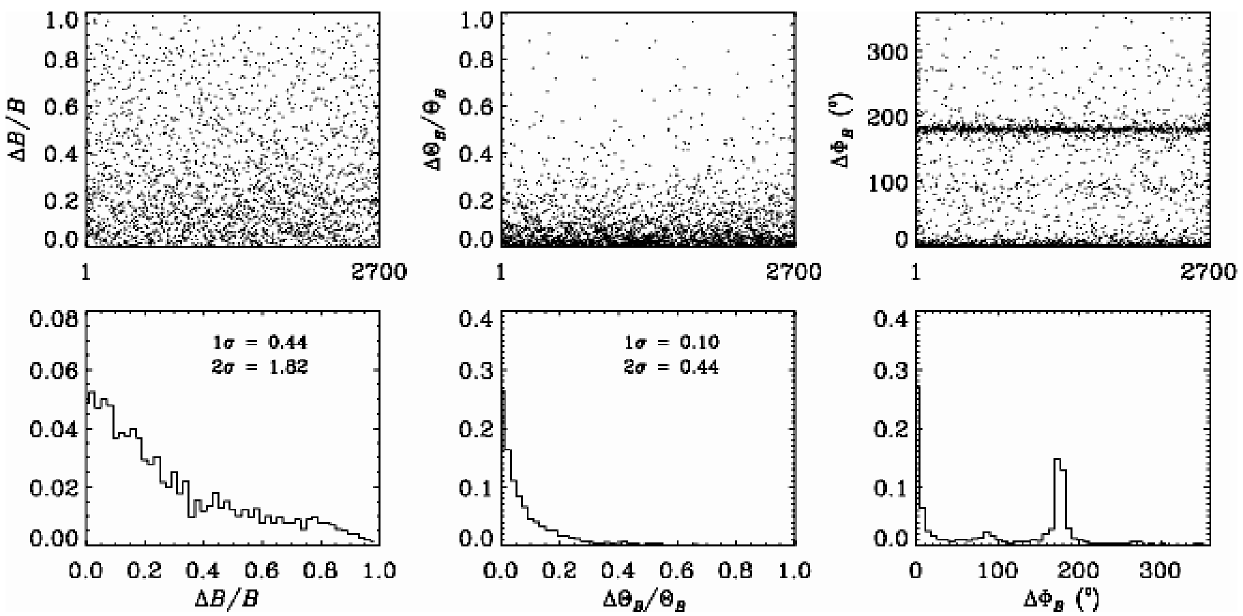
- The be… n is h… d.
- Solutions may depend on assumptions made in the mo…
- Ambiguities exist in the solution.



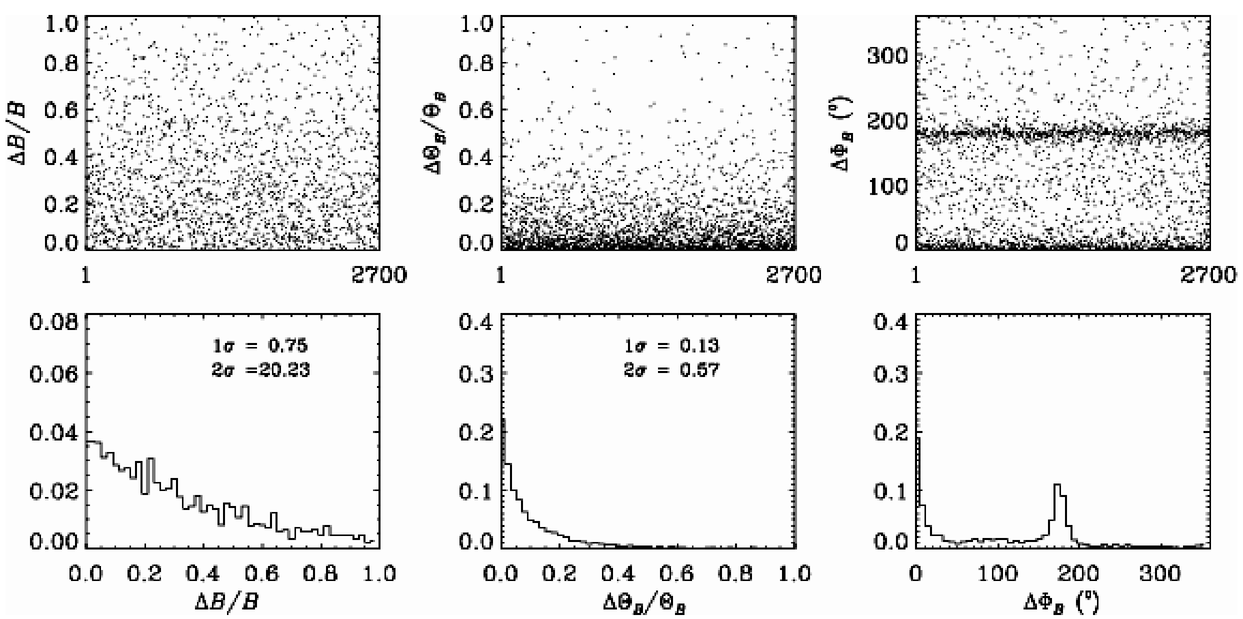
Spectro-polarimeter

R = 180000 (0.048 Å sampling)

No noise



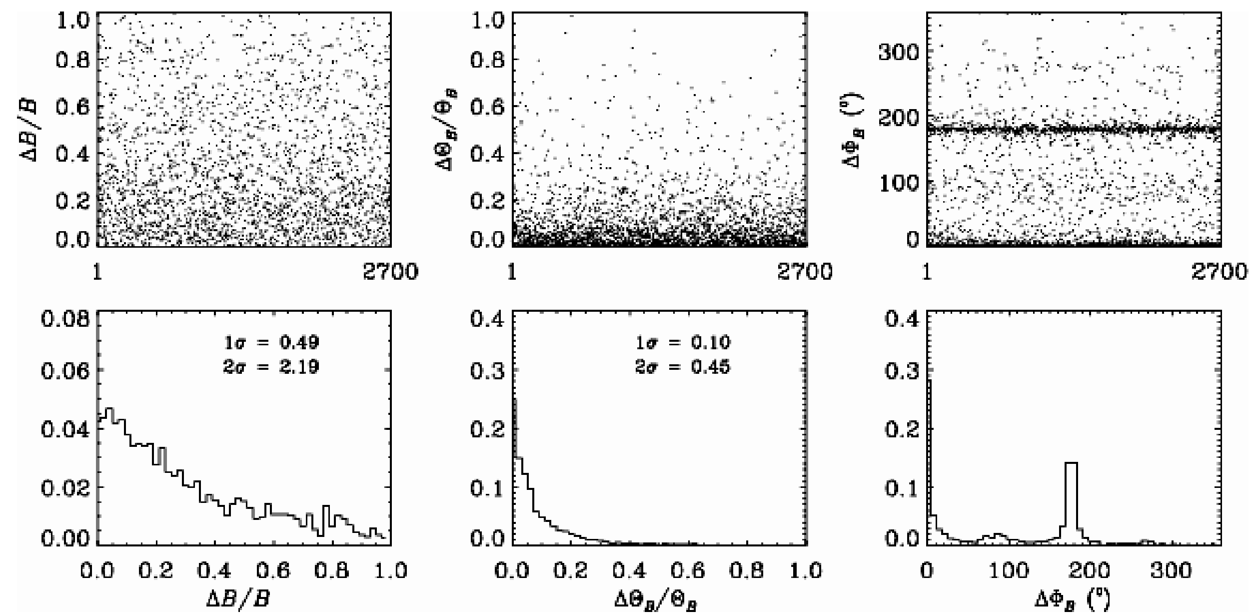
S/N = 10^3



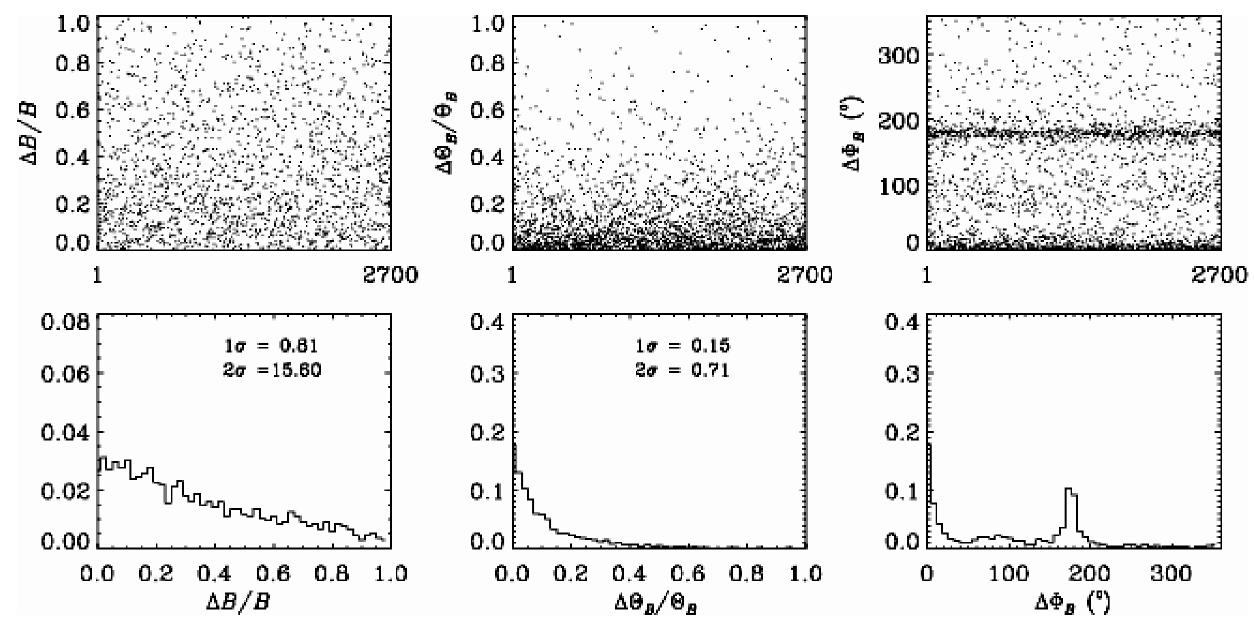
Lyot filter (ChroMag)

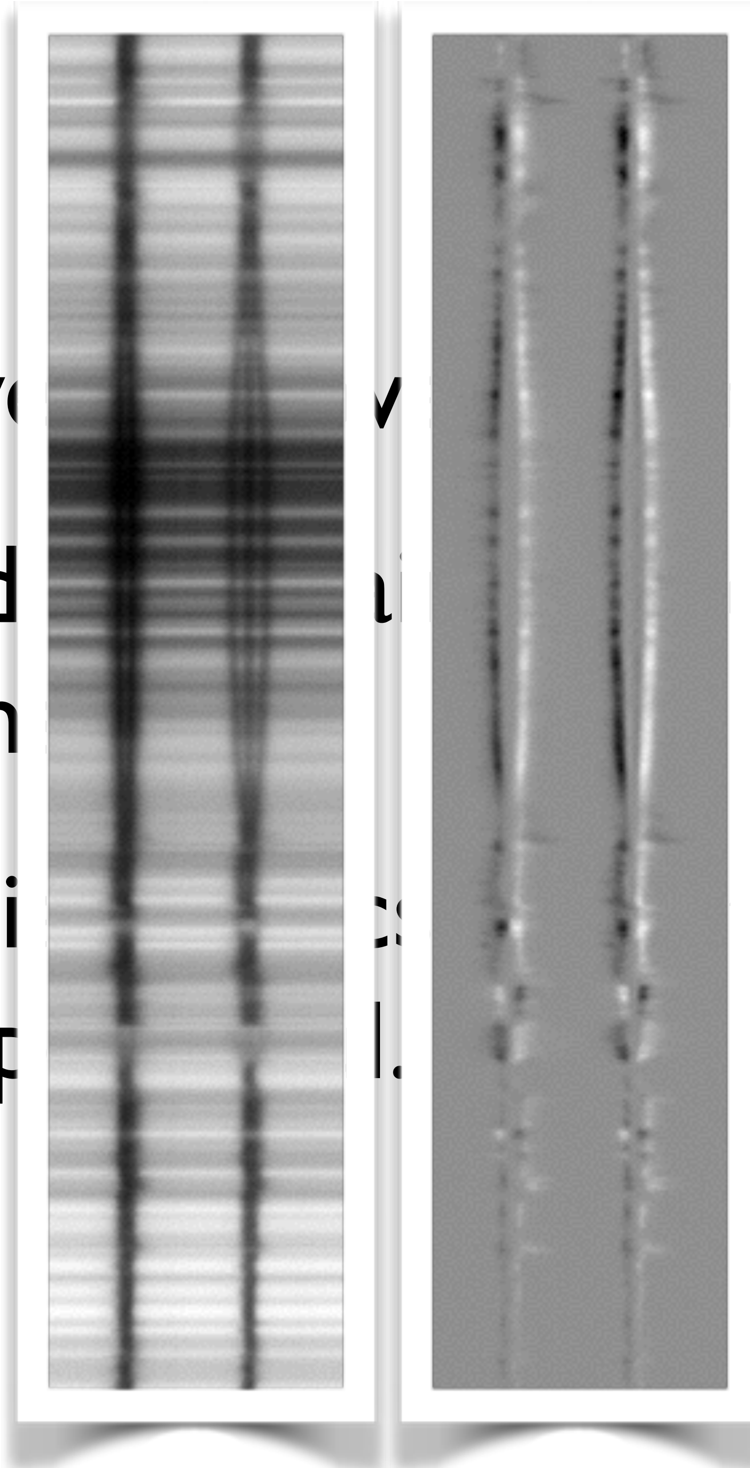
FWHM = 0.2 Å, 0.1 Å sampling

No noise



S/N = 10^3



- How can w  easurements?
- We can add … ugh more observation…
- Multi-line di … ticular turn out to be very p… l.

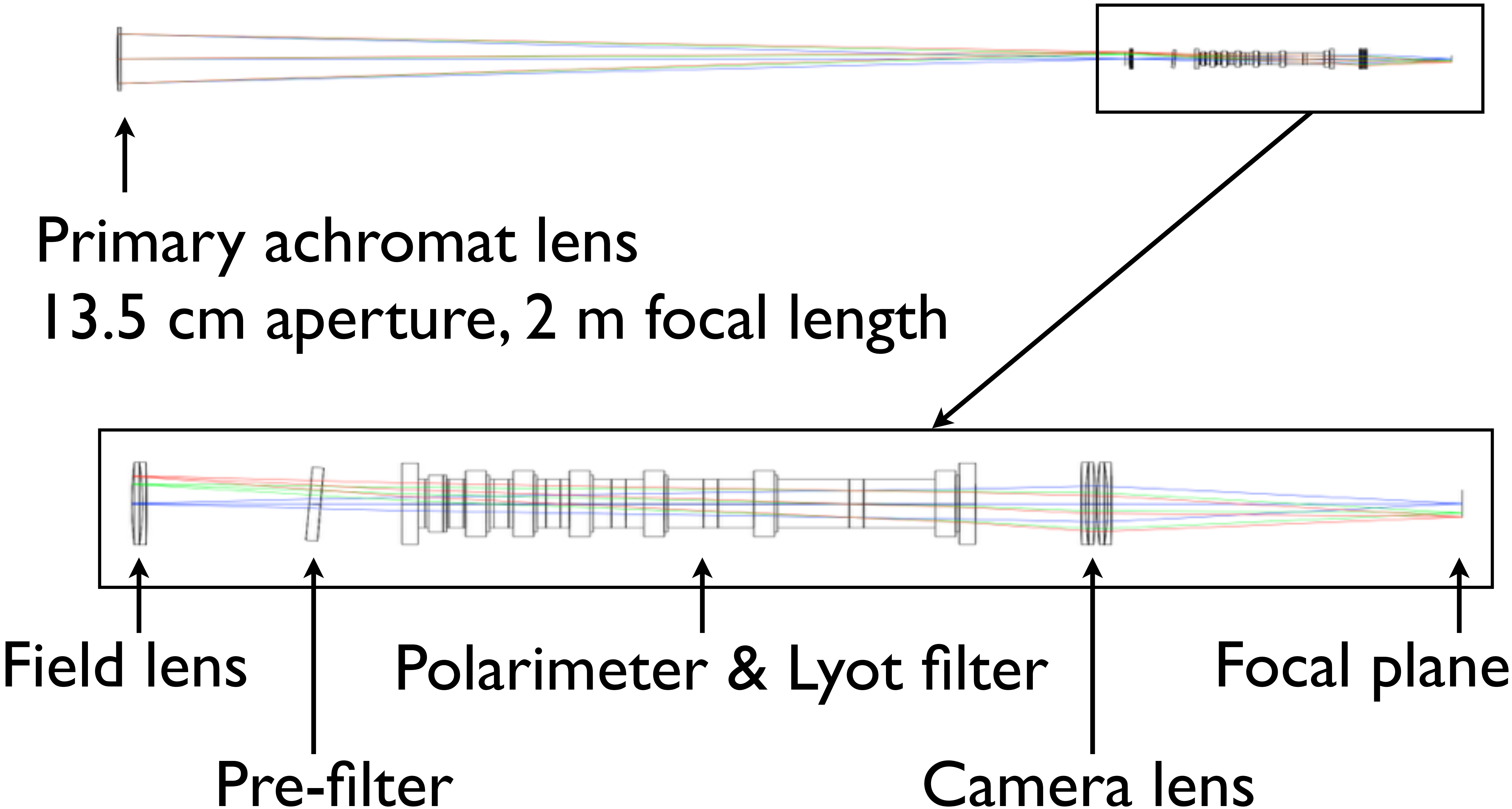
ChroMag

- Provides synoptic imaging spectro-polarimetry in:
  - He I 587.6 & 1083.0 nm: chromospheric magnetograms
  - Hα 656.3 nm: chromospheric structure and dynamics
  - Ca II 854.2 nm: chromospheric magnetograms
  - Fe I 617.3 nm: photospheric magnetograms
- High cadence: < 1 minute for all lines
- Moderate spatial resolution: 2.6 arcsec (1.3 arcsec pixels)
- Field of view: $2.75 \times 2.75\ R_{sun}$
- High polarimetric sensitivity: SNR > 10^3

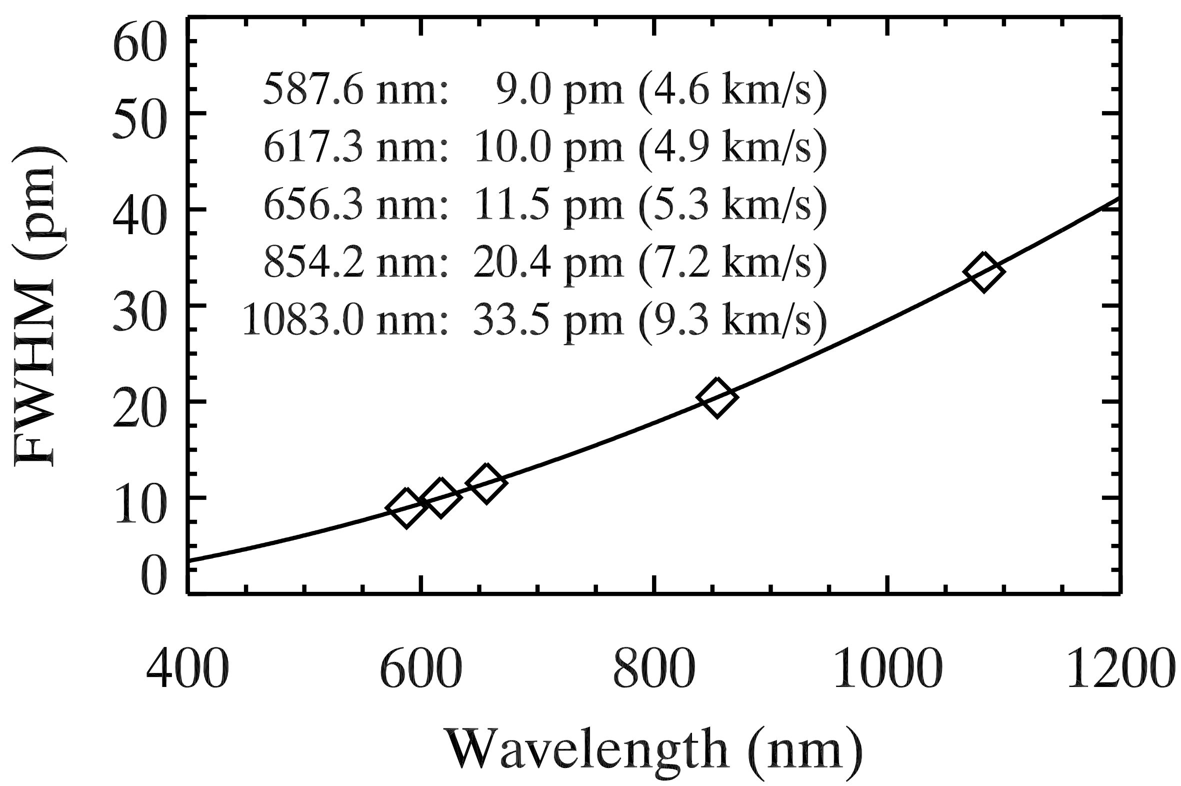
ChroMag Data Products

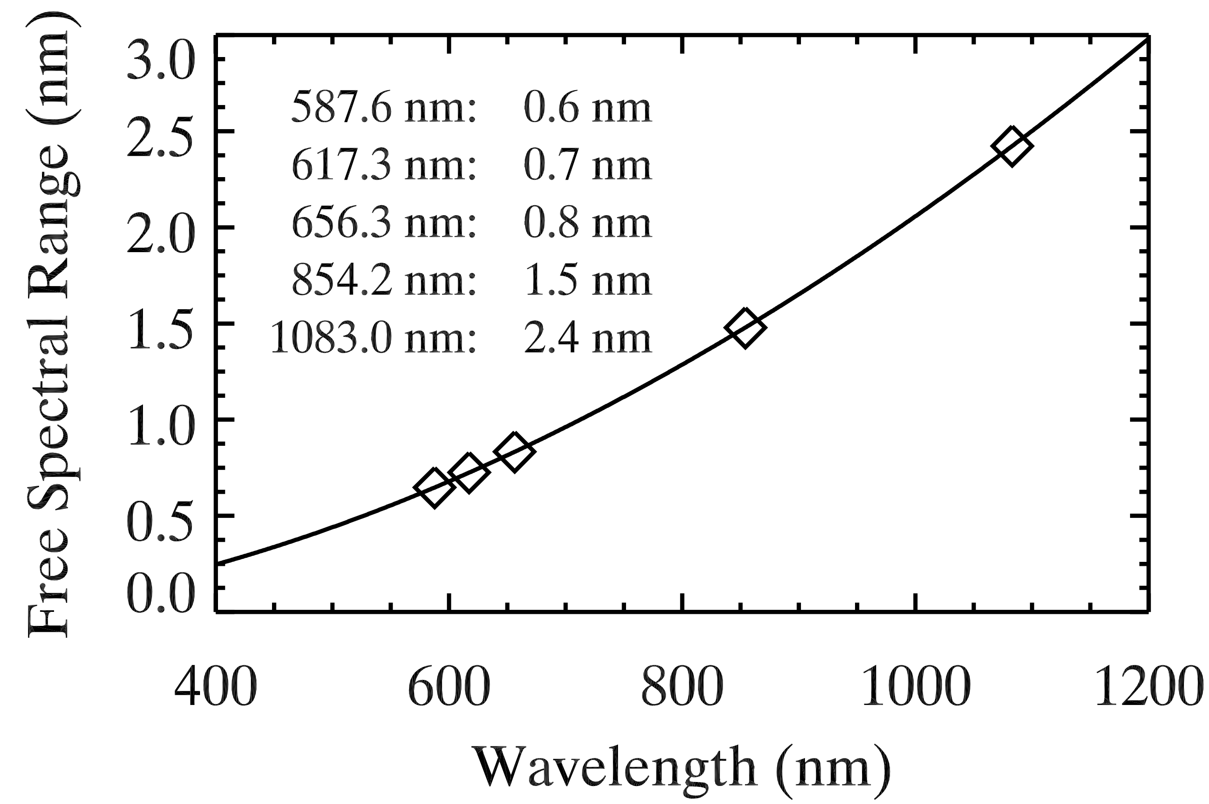
- Line selection, spectral sampling, & cadence are flexible and can be tailored to science cases.
- Low-level product: calibrated line scans
  - Fe I 617.3 nm, Hα 656.3 nm, Ca II 854.2 nm, and He I 587.6 & 1083.0 nm
- Currently planned higher-level products:
  - Photospheric Dopplergrams & vector magnetograms
  - Chromospheric Dopplergrams from Hα & 854.2 nm
  - Prominence & chromospheric vector magnetograms from 1083.0 nm, 854.2 nm? Interpretation techniques are not mature.

Prototype Overview



Lyot filter overview





- Electro-optically tunable with LCVRs (0.2s)
- Usable range: 587–1085 nm
- 6 stages, thickest stage has 88mm of calcite

Where are we now?

- Two years ago: thermal stability problems
- Last year: modulator failure, some more thermal problems, and discovered the LCVR calibration was off
- Now: re-calibration nearly complete, deployment to Mesa Lab imminent
- Future: deployment to MLSO