Magnetic fields of cool active stars

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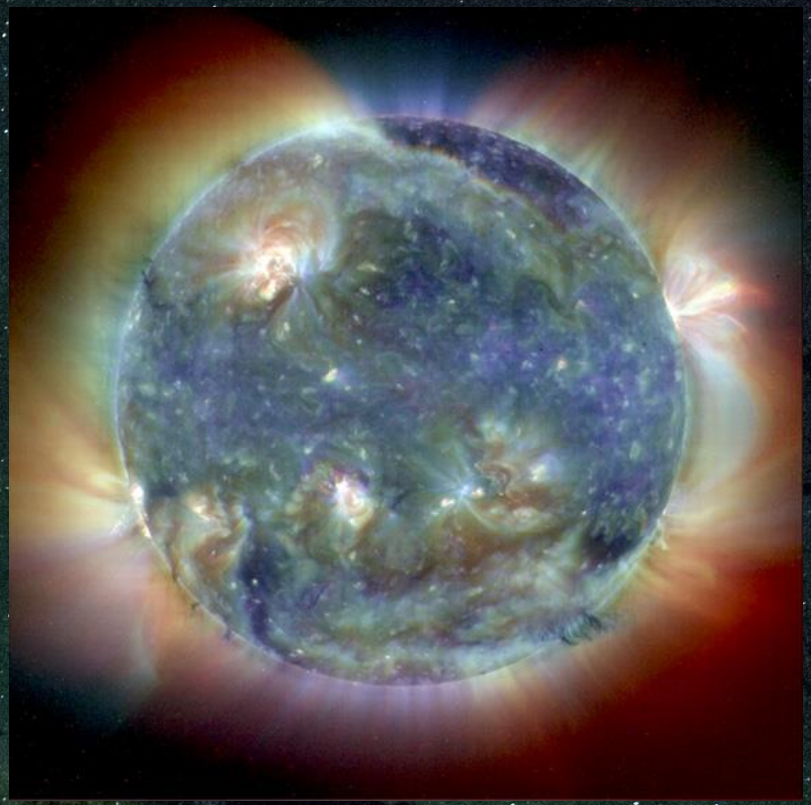
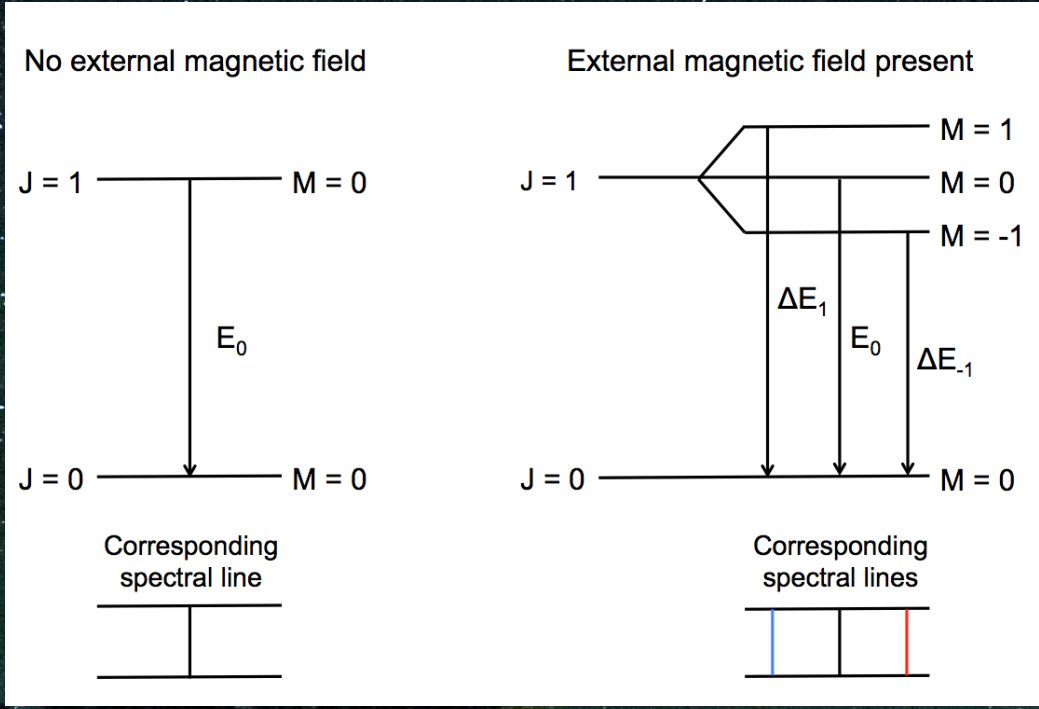
Stellar magnetic fields

- Wide variety of stars
  - 85% cooler and less massive than the Sun
- Small fraction of the hot massive stars are magnetic
  - Stable and dipole like
  - Strong
- All cool low mass stars (M up to ~1.5$M_{\odot}$) are magnetic
  - Complex and evolving
  - Relatively weak



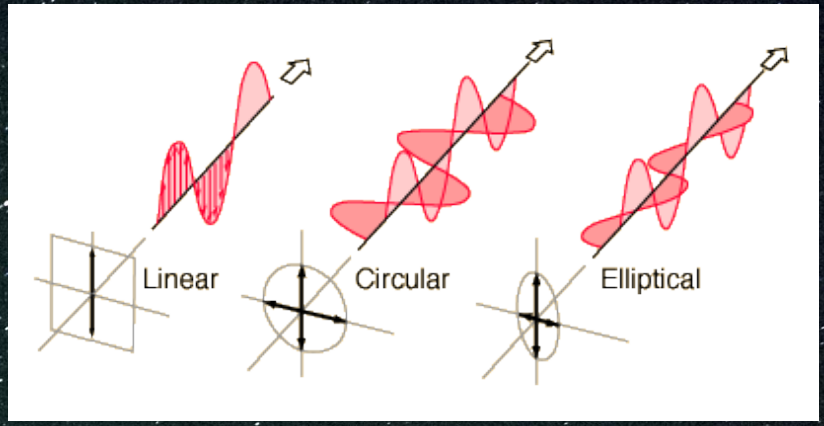
Zeeman effect – Line splitting

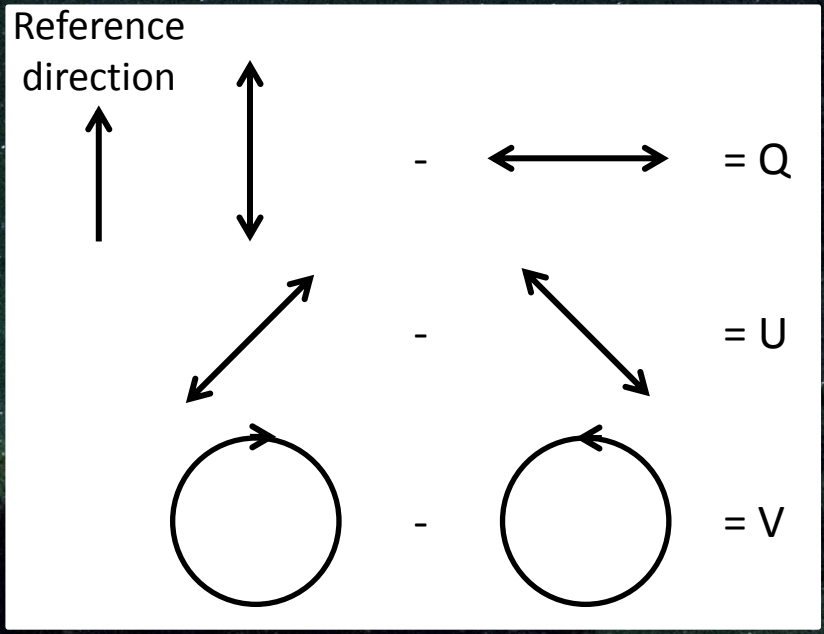


✧ Requires a magnetic field of several kG!

Zeeman effect - Polarization

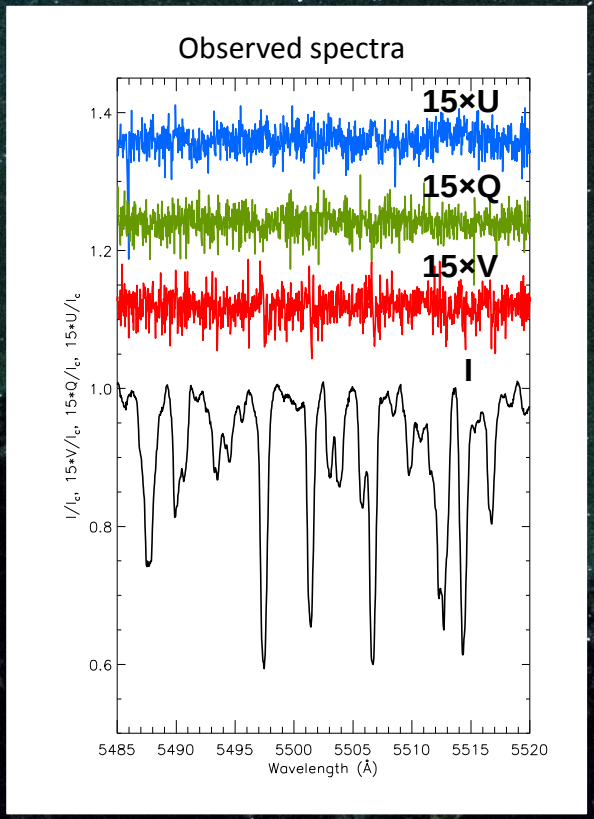
- Degree of polarization proportional to magnetic field strength
- Can be used to detect fields of ~0.1 G strength
- Stokes parameters IQUV
- Unpolarized light (I)
- Linear polarization (QU)
- Circular polarization (V)





Multi-line technique

- Weak field => weak polarization
- No visible polarization signatures in individual spectral lines
- Apply the multi-line technique least-squares deconvolution (LSD)
  - All lines in the spectrum are scaled version of a mean profile
  - Each line weighted by central depth, wavelength and magnetic sensitivity



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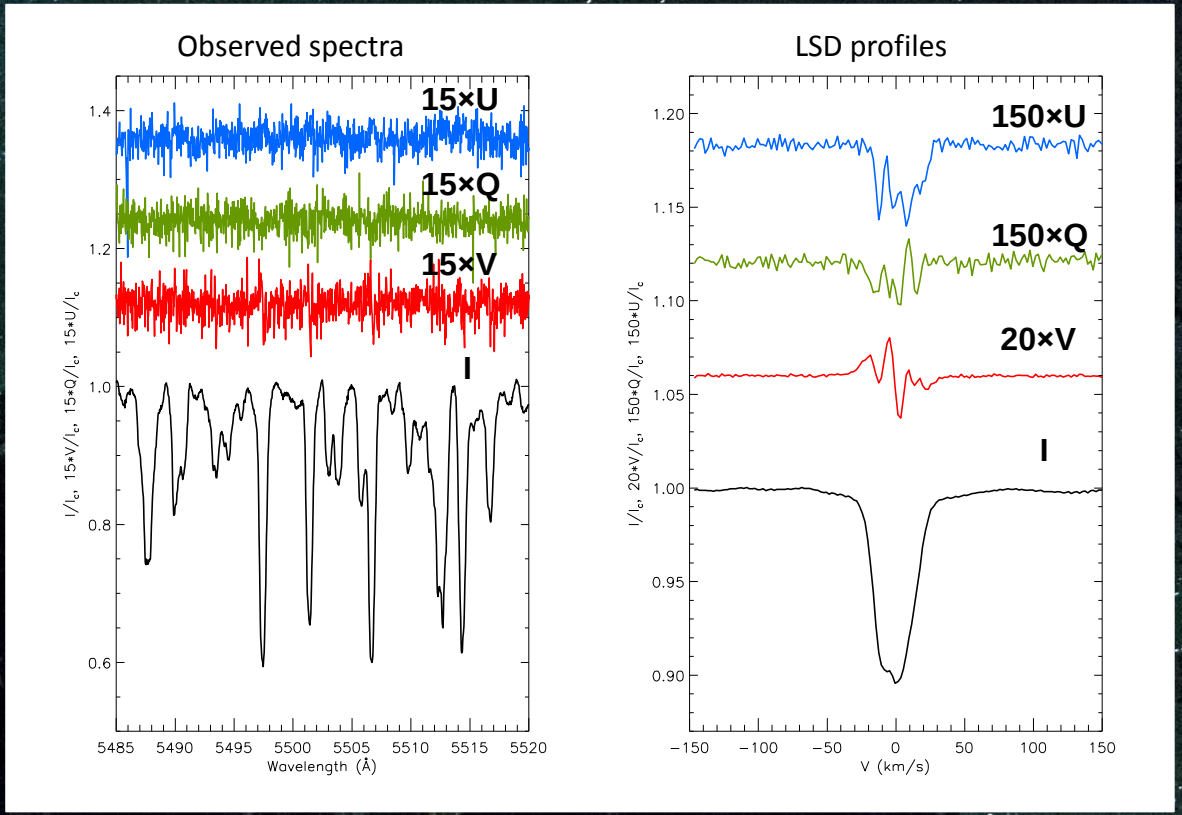
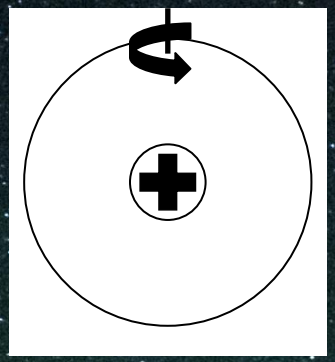
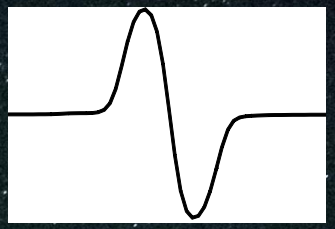
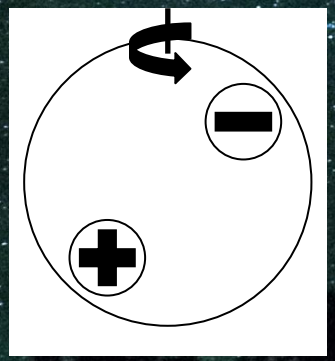


Polarization profile analysis



Stokes V





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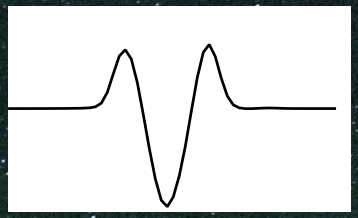

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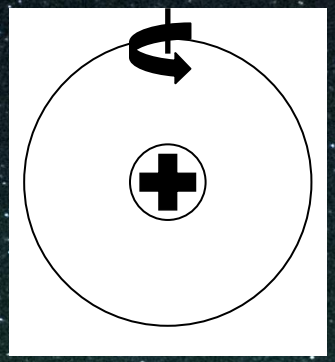

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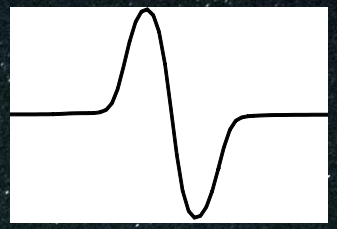
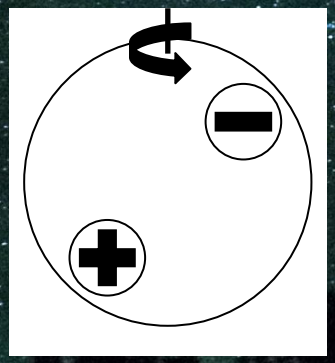


$\langle B_z \rangle$ large



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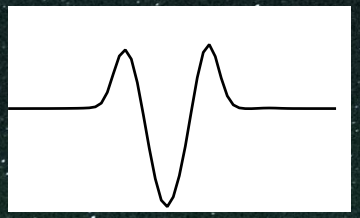
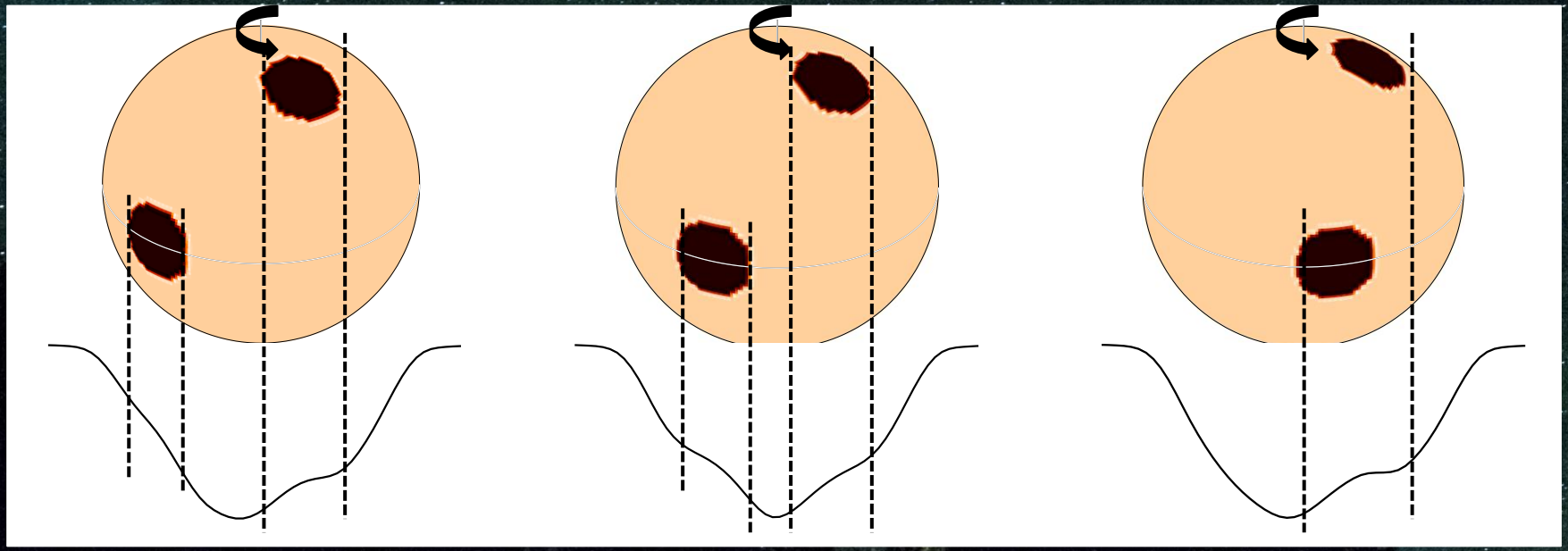


$\langle B_z \rangle = 0$

✧ Mean longitudinal magnetic field $\langle B_z \rangle$

Temperature mapping – Doppler imaging

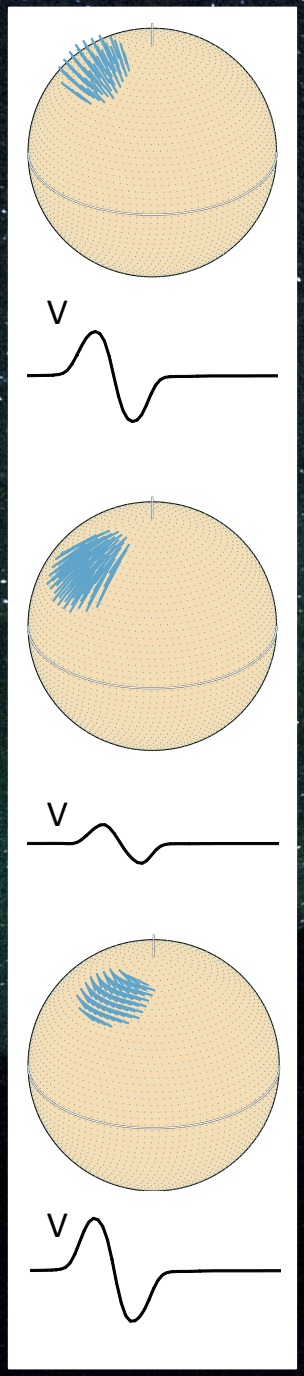
- Stokes I
- Dark cool spot will cause bump in profile
- Each point in profile corresponds to longitude on the star
- Latitude is determined by where the corresponding bump is visible in the profile and how fast it moves across the profile

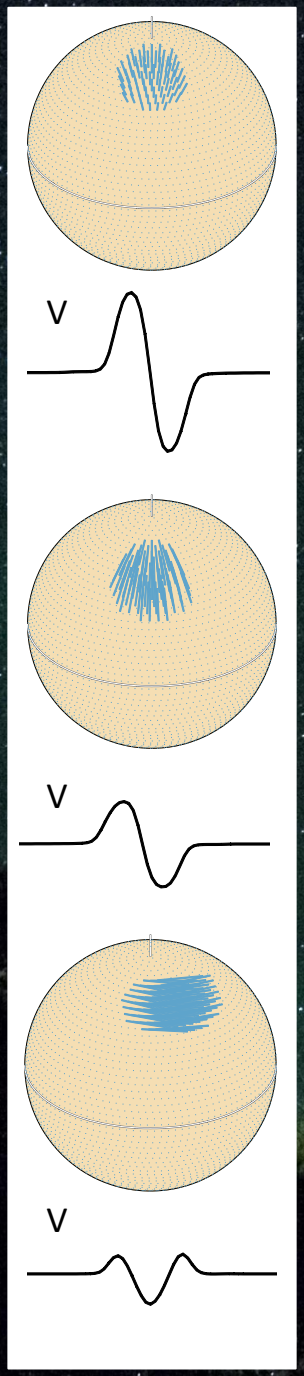


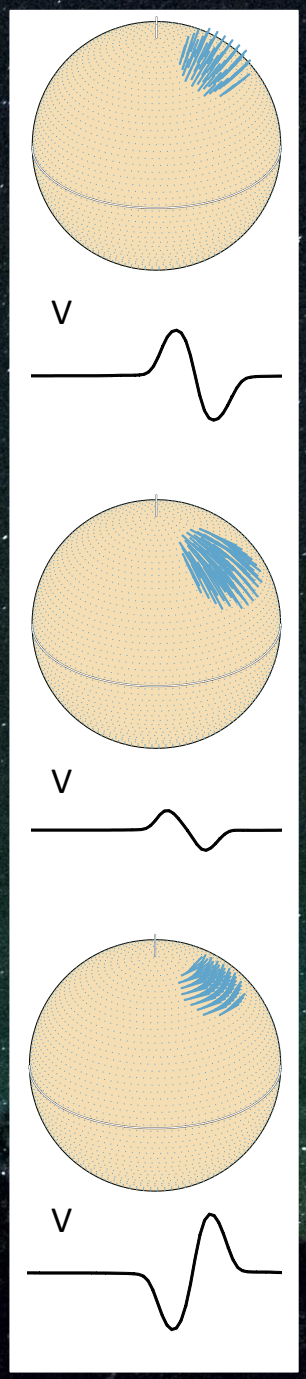
Radial

Meridional

Azimuthal





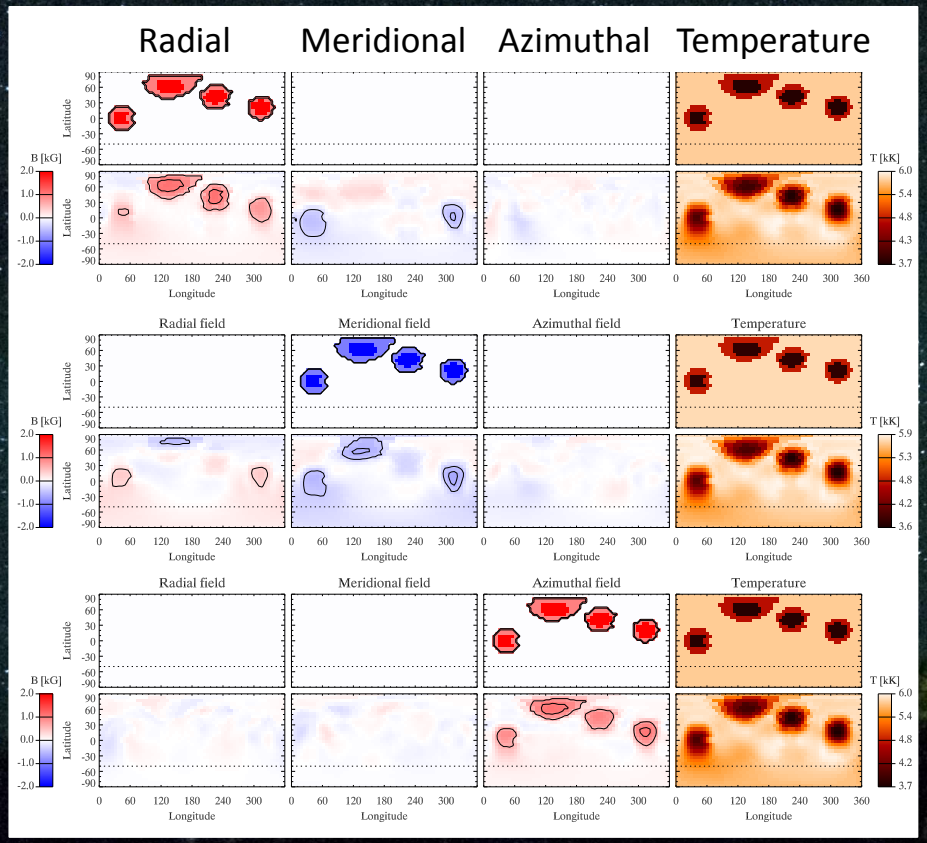


Zeeman-Doppler imaging of cool stars

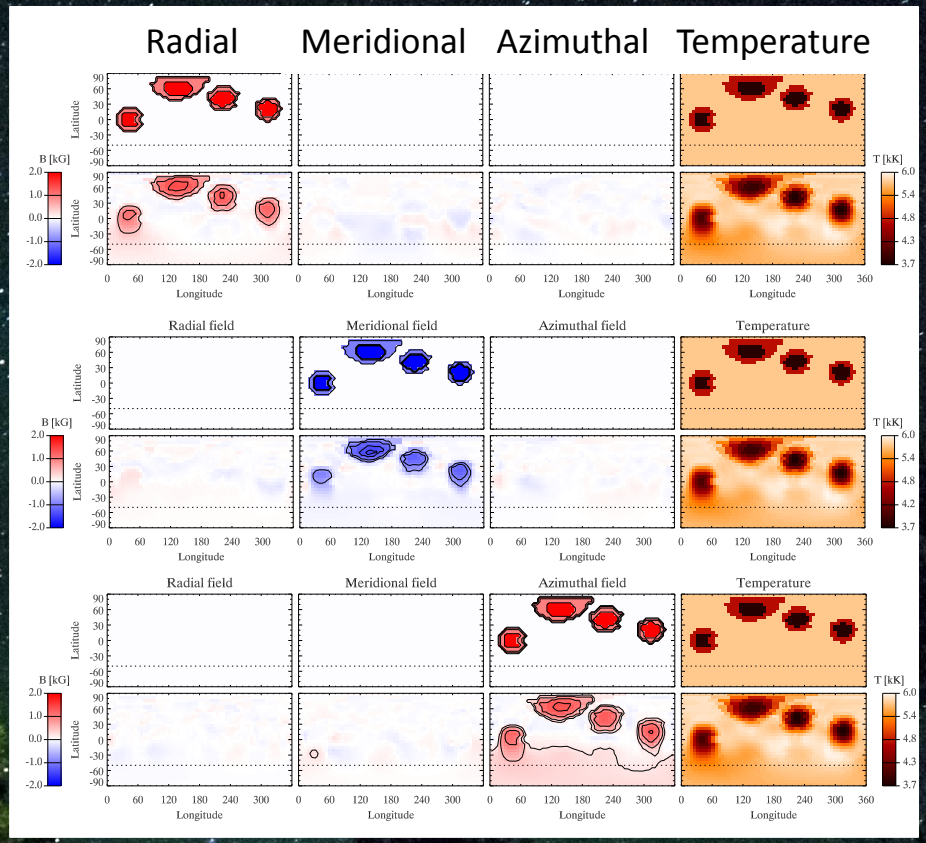
- Cool stars in general have relatively weak magnetic fields => weak polarization
- Circular polarization is up to 10 times stronger than linear polarization
- Circular polarization sensitive to line-of-sight component of magnetic field vector
- Magnetic fields of cool stars are currently studied using circular polarization only – not optimal
- Linear polarization sensitive to transverse component of magnetic field vector

Zeeman Doppler imaging

Using Stokes I and V



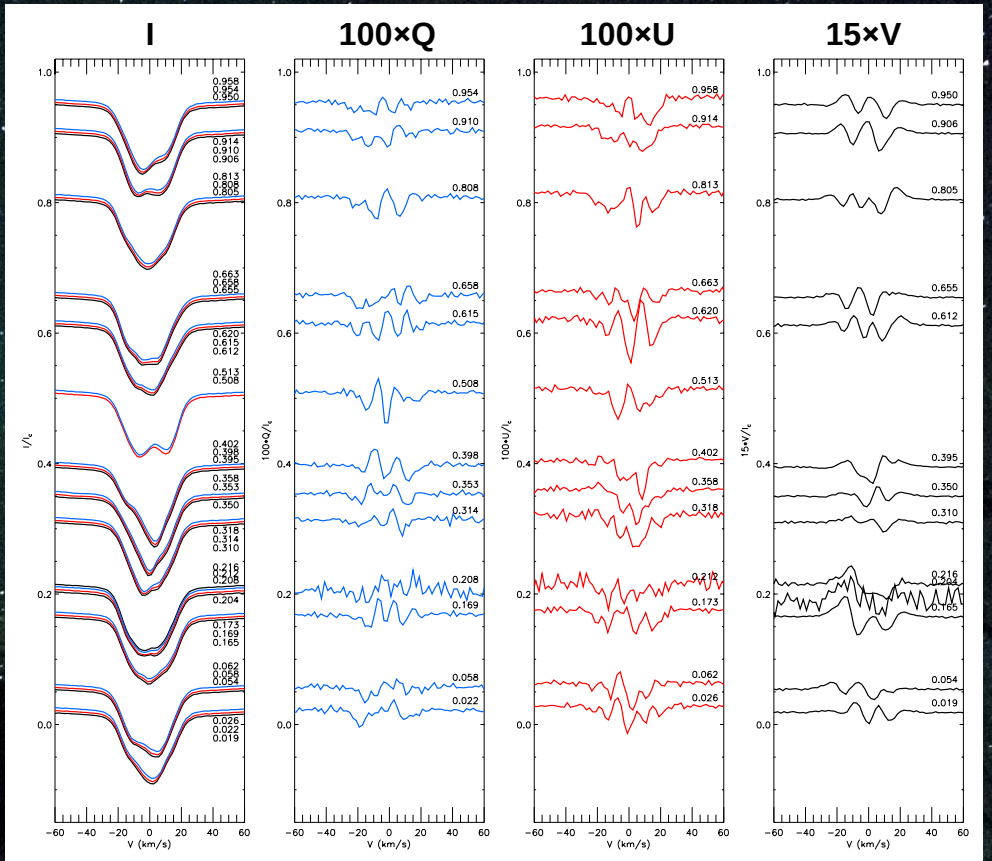
Using Stokes IQUV



- ✧ Very accurate spot geometry and positioning
- ✧ Almost no crosstalk

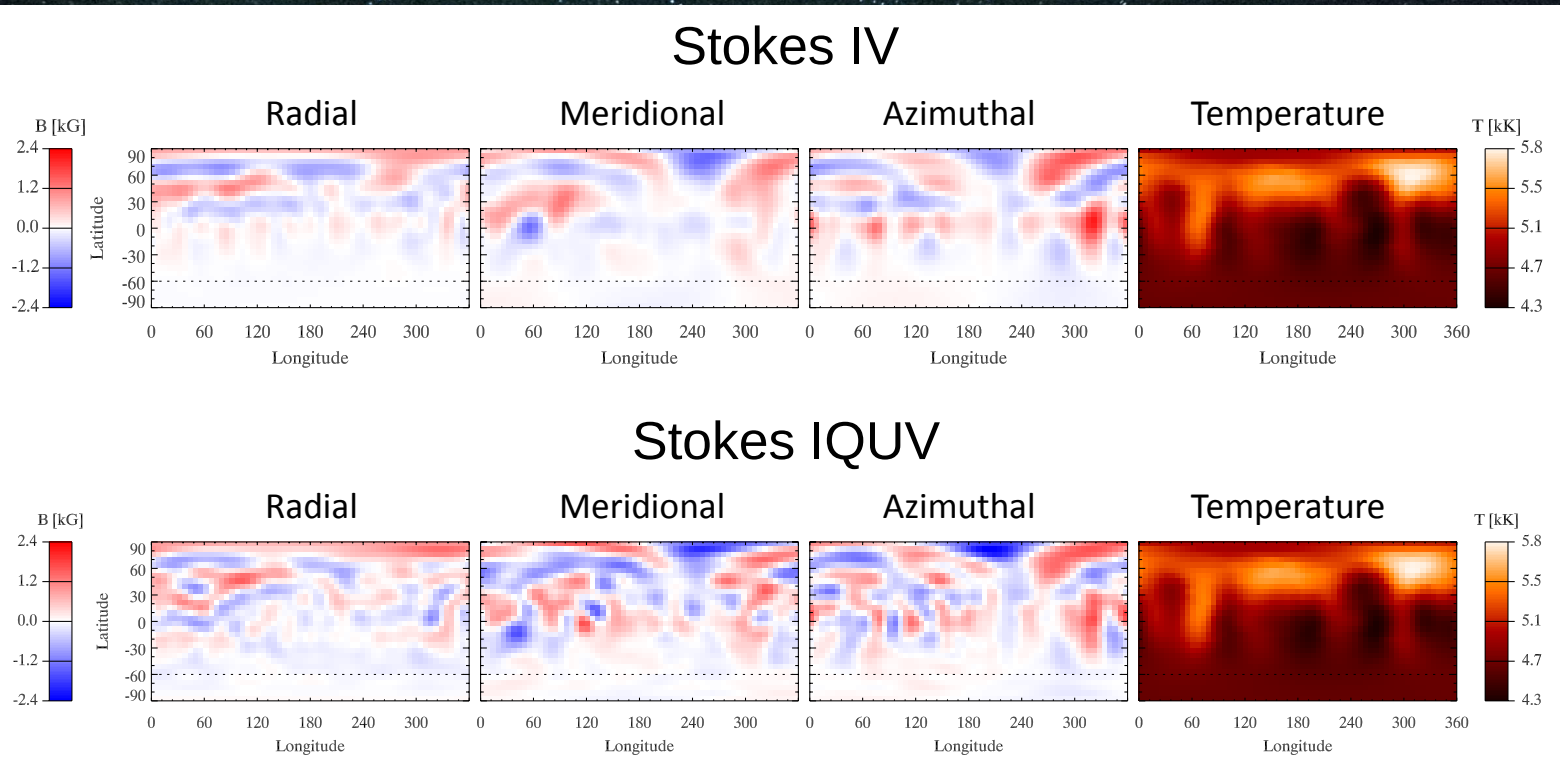
New observations – II Peg

- ✧ Unique set of observations from CFHT
- ✧ 12 complete phases
- ✧ Continuously high activity



Preliminary results – II Peg

✧ More detailed structures when using all 4 Stokes parameters




Thank you!