Magnetic fields in T Tauri stars

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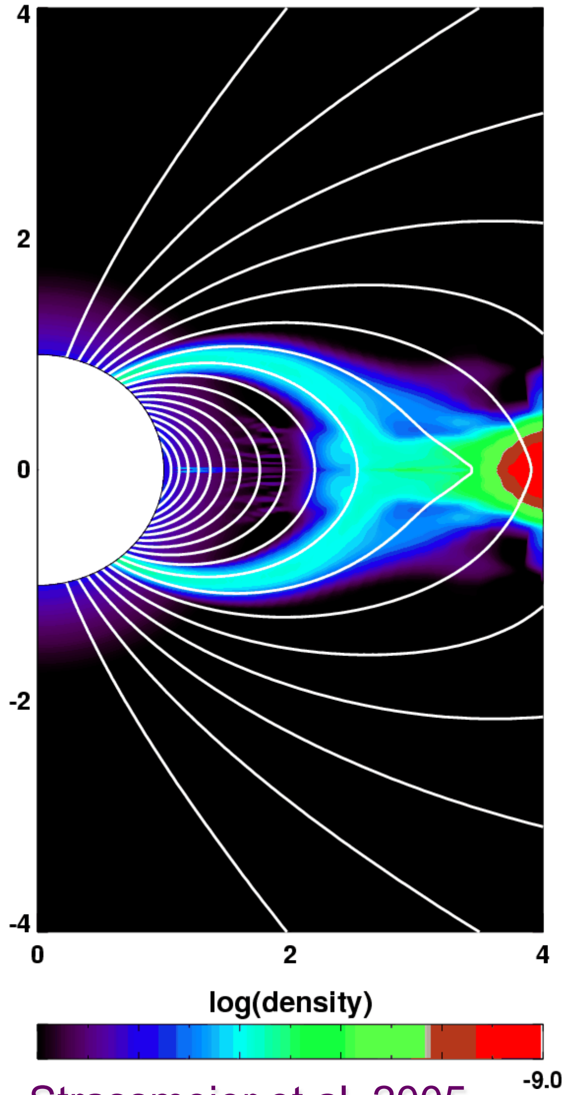
MaPP: Magnetic Protostars and Planets
J.-F. Donati, J. Bouvier, S. Gregory, T. Montmerle, A. Maggio, C. Argiroffi, E. Flaccomio, F. Walter, M. Jardine + 32 Co-Is.
http://lamwws.oamp.fr/magics/mapp
IMTTS: E. Alecian, G. Herczeg, T. Lüftinger, + 9 CoIs.

Magnetospheric accretion in T Tauri stars

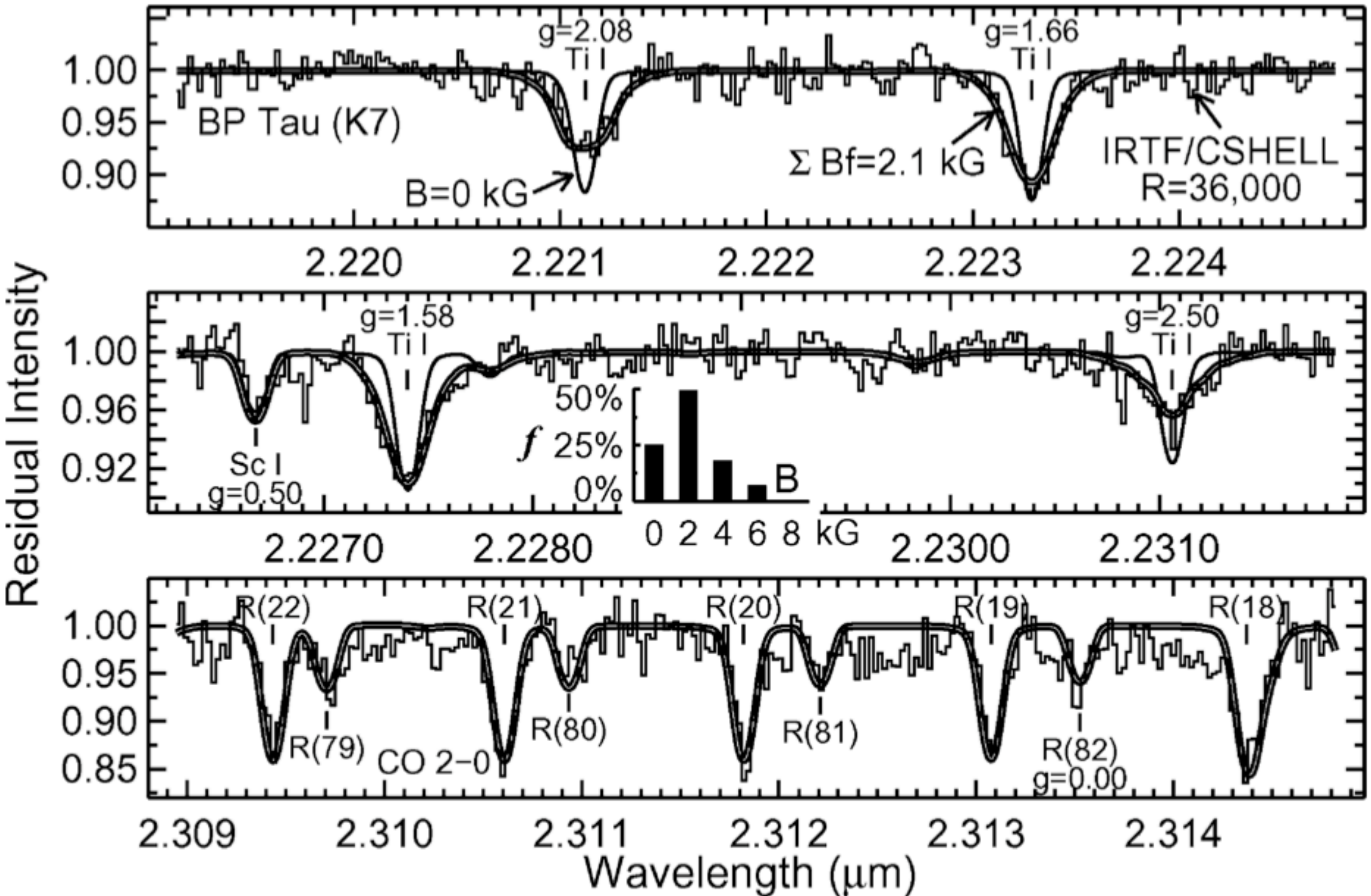
Magnetic fields disrupt disks

- Rotation rates
  [Camenzind 1990, Cieza et al. 2007, Matt et al. 2008, 2010]
  Analytic magnetic braking
  [Königl 1991, Collier Cameron & Campbell 1993, Shu et al. 1994]
- Disk evolution via irradiation/ photoevaporation
  [Gorti & Hollenbach, Ercolano et al. 2009, Owen et al. 2011]
- Planet migration
  [Romanova et al. 2006, 2010]



Strassmeier et al. 2005

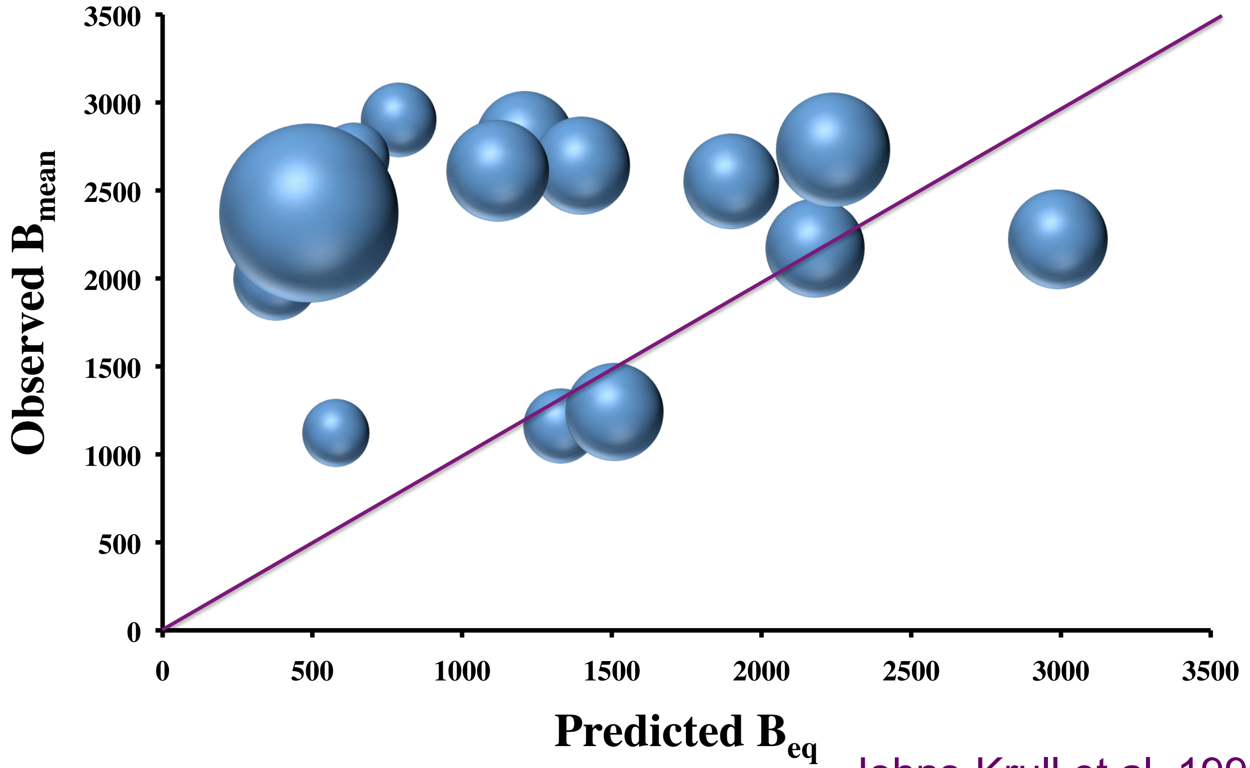
Techniques: Zeeman Broadening (ZB)



Johns-Krull 2009

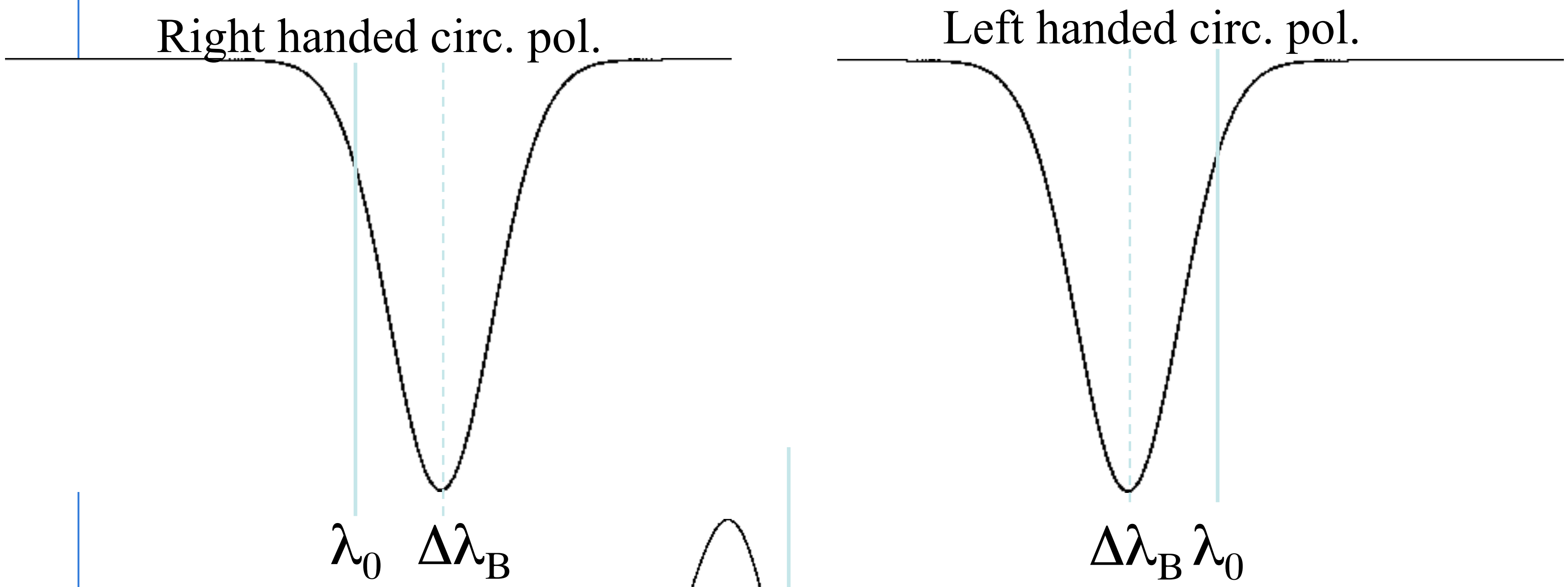
Results: ZB vs. theory

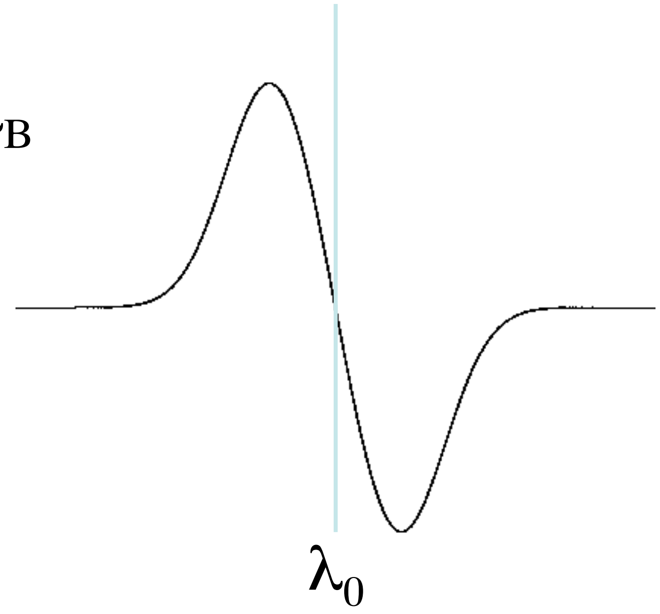
$$B_* \sim \frac{\alpha M_*^{5/6} \dot{M}_*^{1/2} P^{7/6}}{R_*^{\,3}}$$



Johns-Krull et al. 1999, 2007, 2009

Techniques: Circularly Polarised Spectra



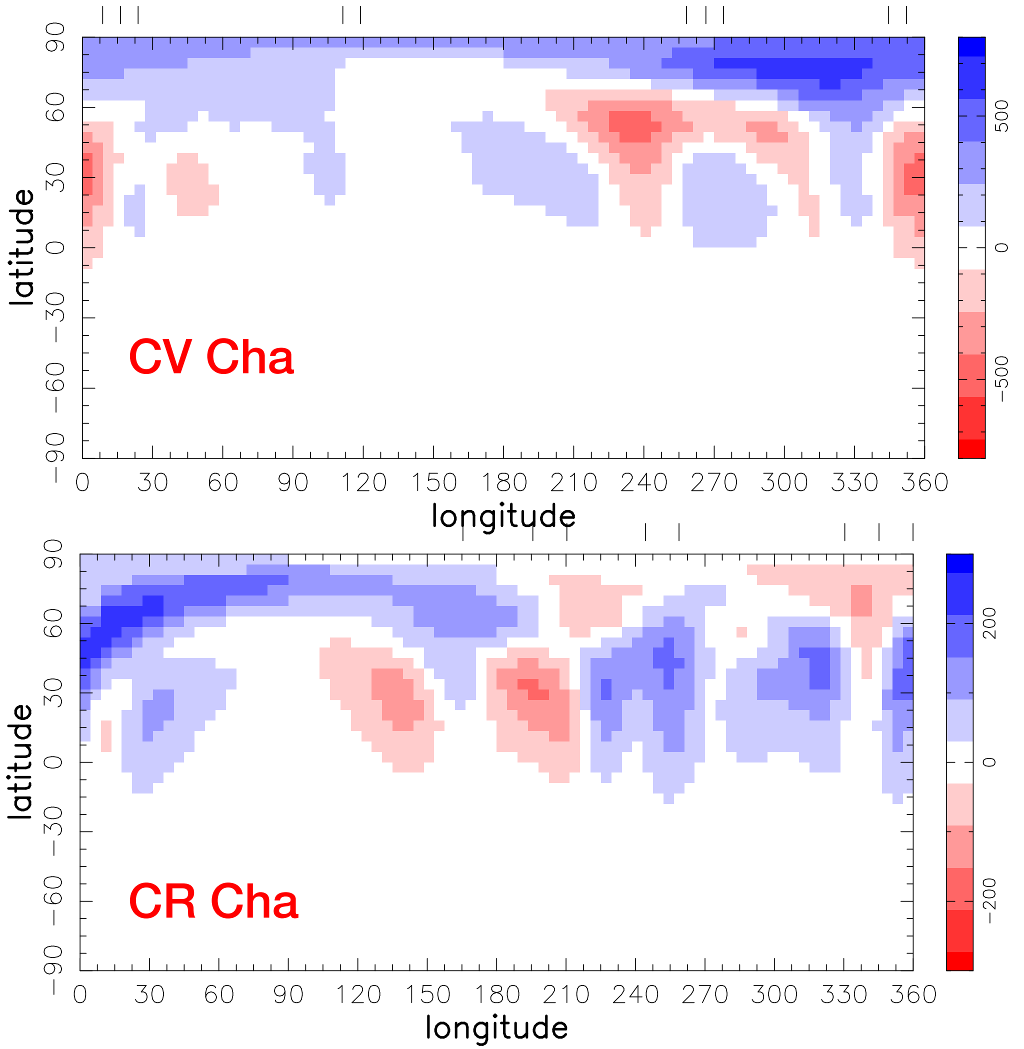


- Circularly polarised profiles sensitive to line-of-sight $\mathbf{B}_\theta$

- Zeeman effect:
$\Delta\lambda_B$ scales with λ, $\mathbf{B}_\theta$, g (provided $\Delta\lambda_B < \Delta\lambda_D$)

- Stokes V amplitude increases linearly with $\mathbf{B}_\theta$

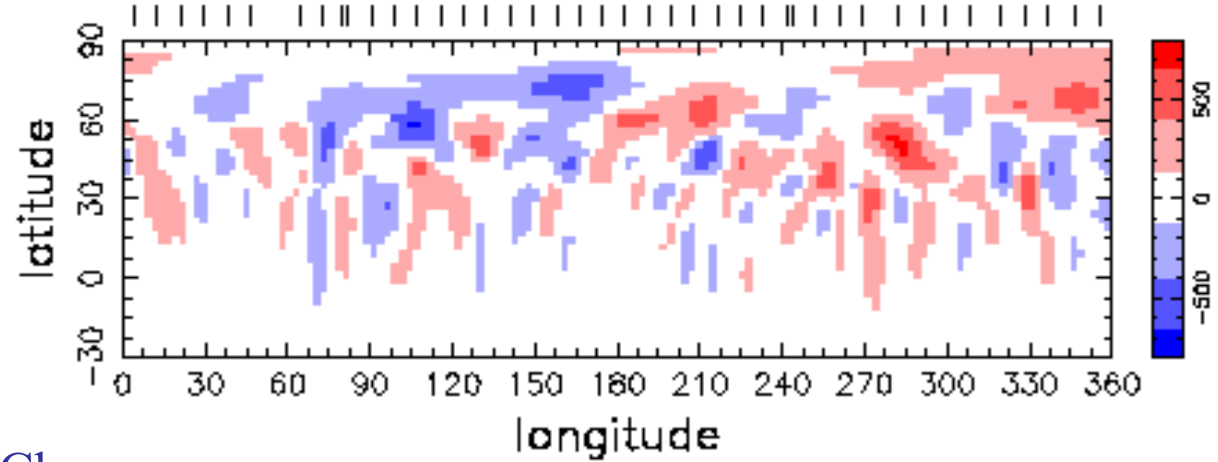
Surface magnetic field maps: Chamaeleon IMTTS



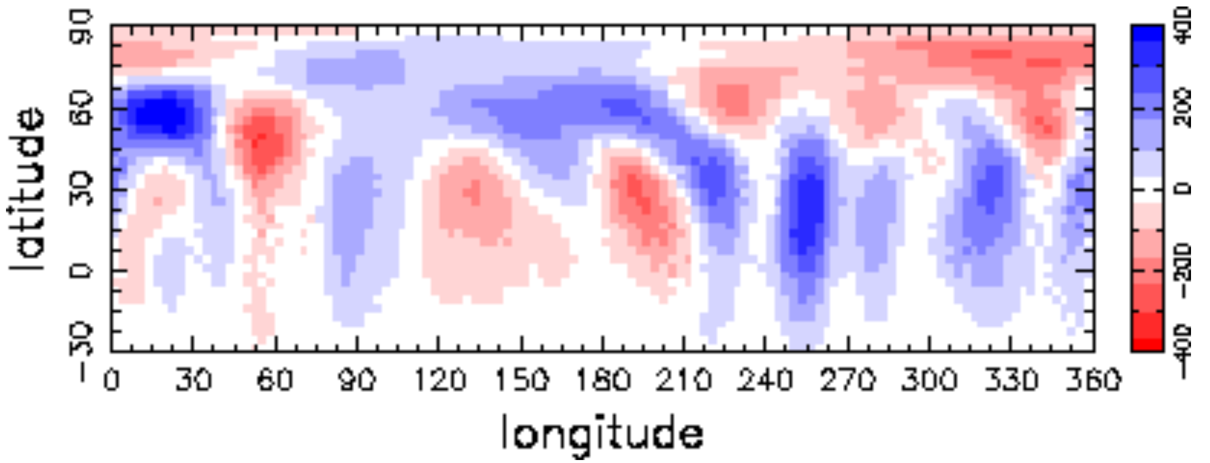
Hussain et al. 2009

Surface maps: comparison with AB Dor

ZAMS, K0V



CV Cha



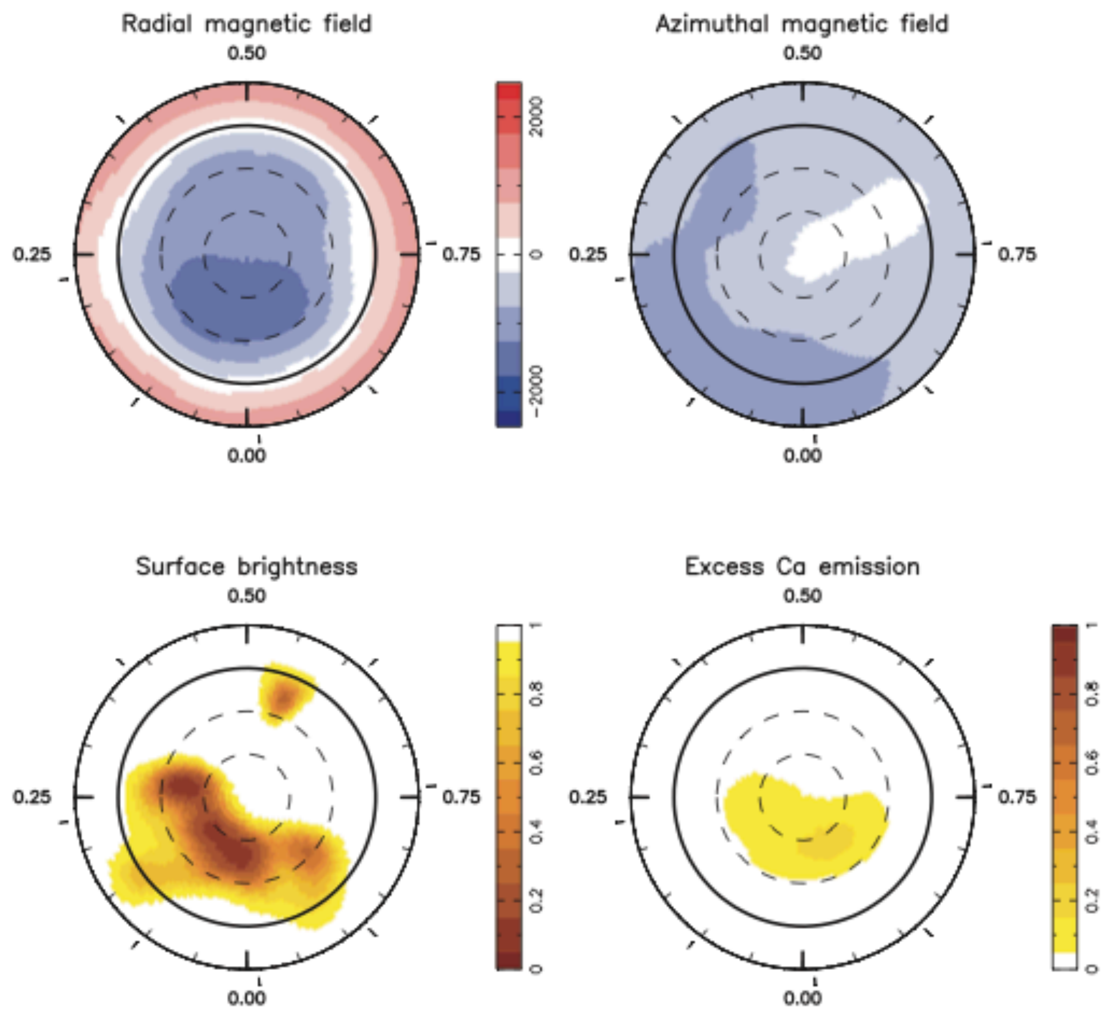
Hussain et al. 2009

Techniques: Zeeman Doppler imaging (ZDI)

- Time-series of circularly polarised and intensity profiles of photospheric lines + Ca II IRT
- Invert assuming simplest possible image
- Describe magnetic field in terms of spherical harmonics

→ Brightness, accretion & magnetic flux maps

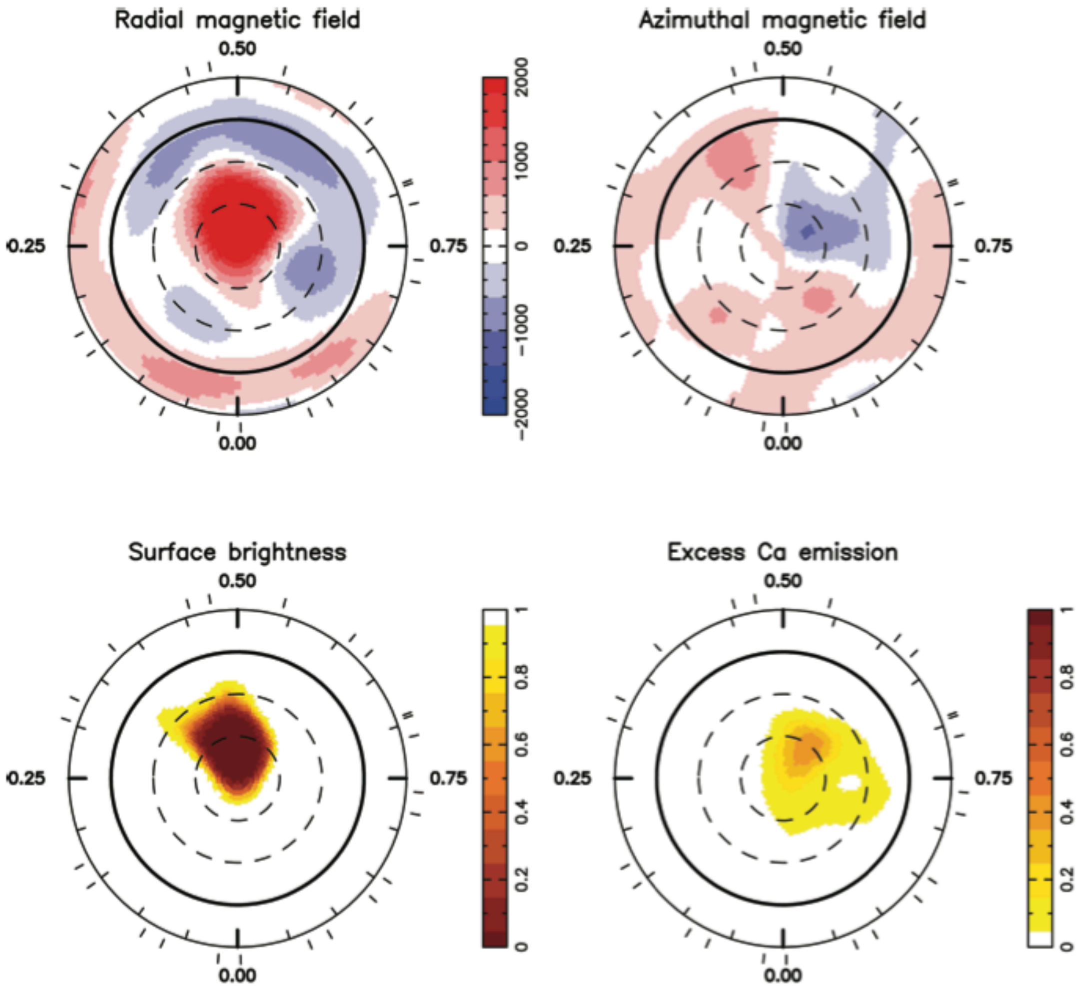
AA Tau: Magnetic & accretion maps



Donati et al. 2010

- 8.2 d, 11.3 km/s, 0.7 M_{sun}, 4000 K
- Fully convective
- 2–3 kG dipole, tilt≈20°

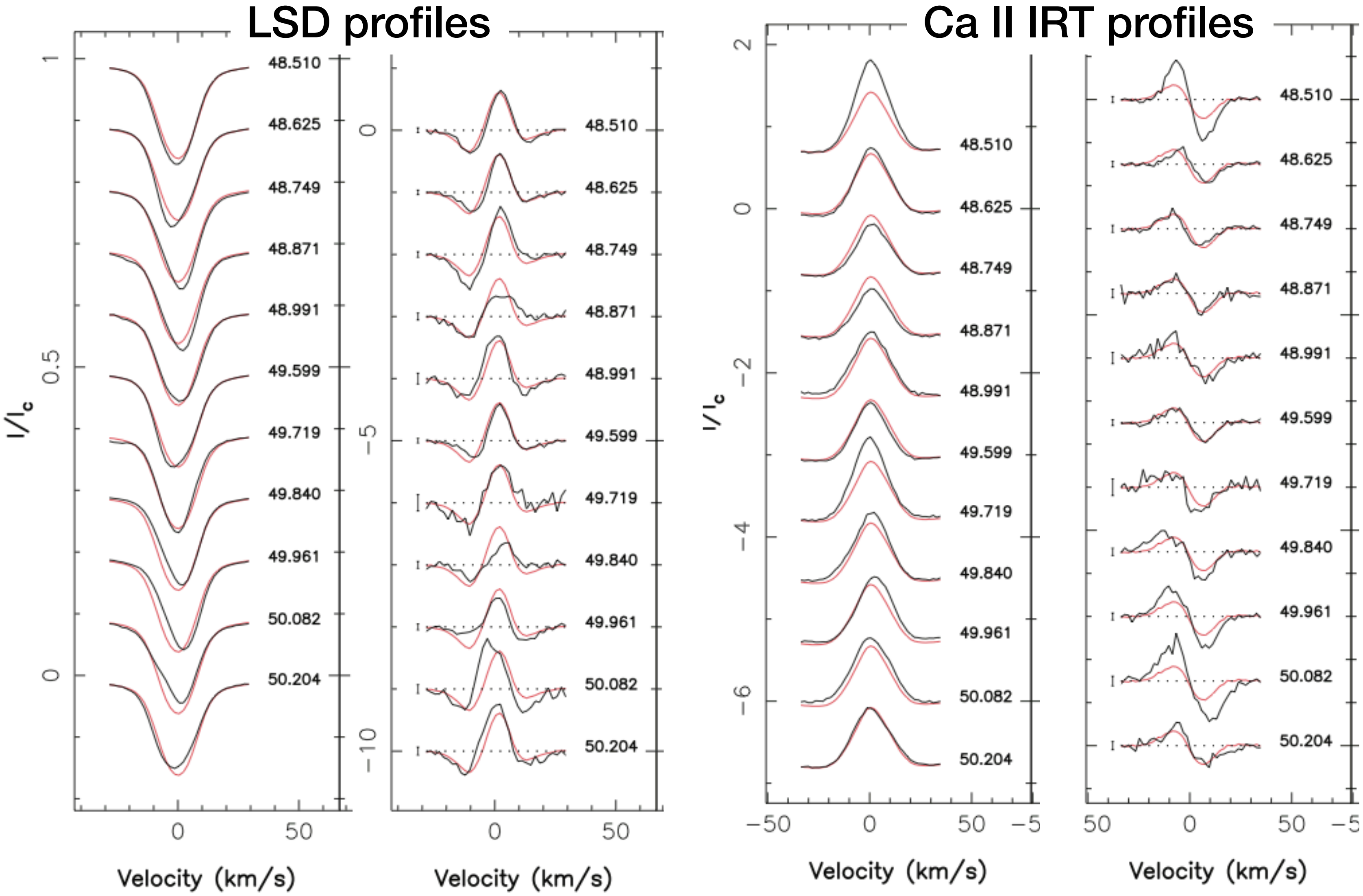
V2129 Oph: Magnetic & accretion maps



Donati et al. 2009

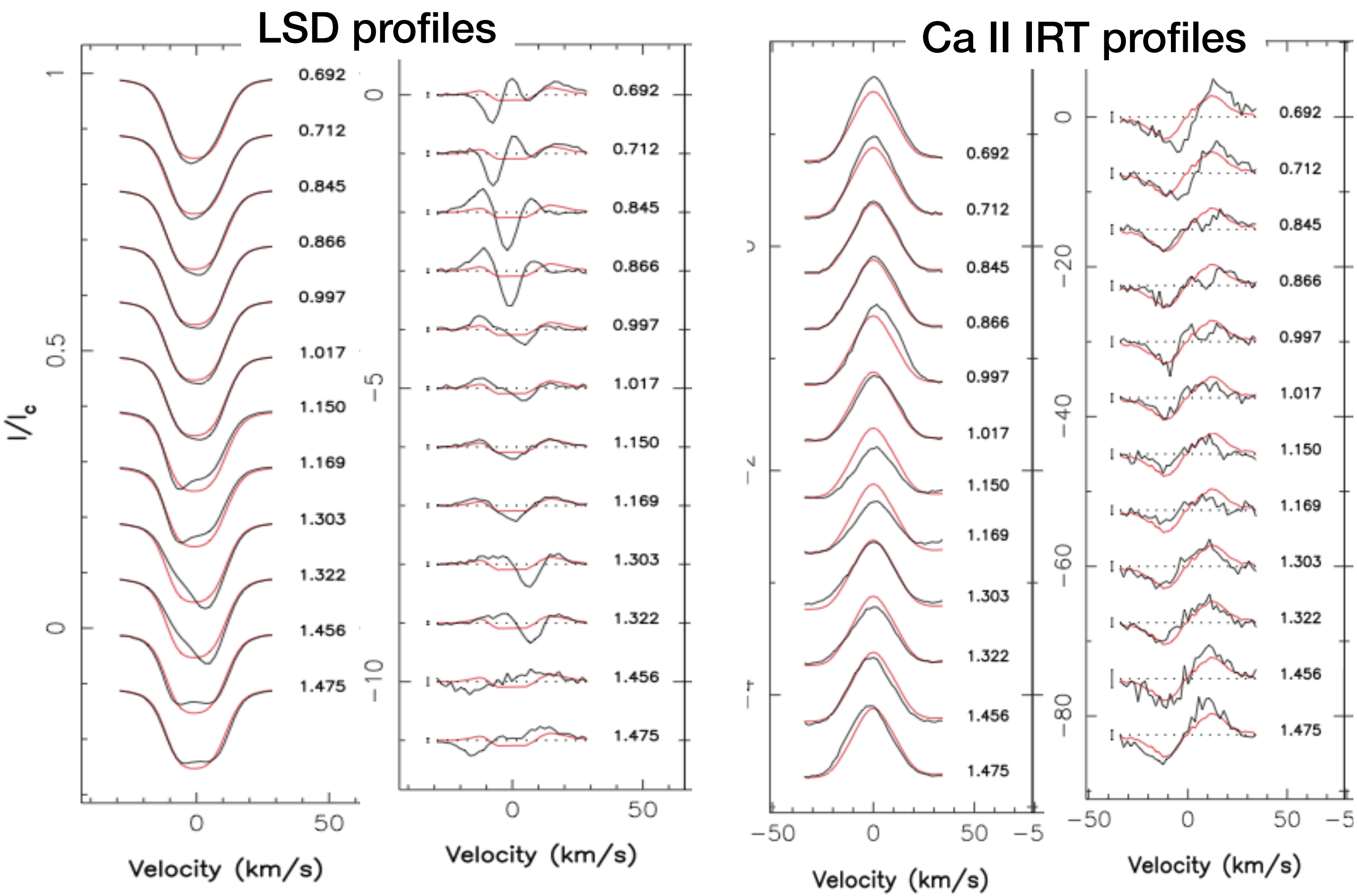
- 6.5 d, 13.5 km/s, 1.5 M_{sun}, 4500 K
- Radiative core ~0.3M_*
- Octupole~2.1kG + dipole~0.9kG; tilt ~ 20°

AA Tau: Stokes profiles



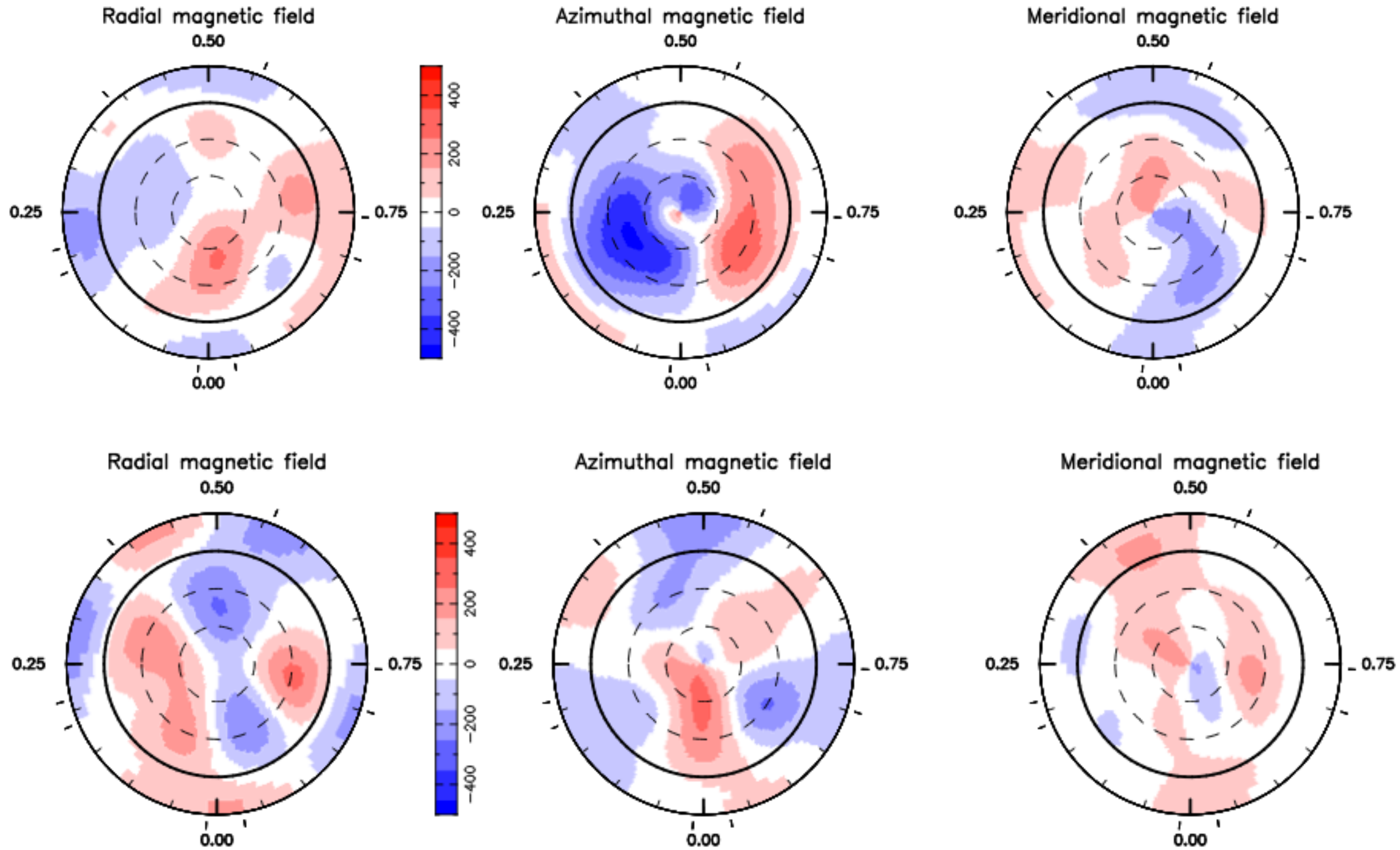
Donati et al. 2010

V2129 Oph: Stokes profiles

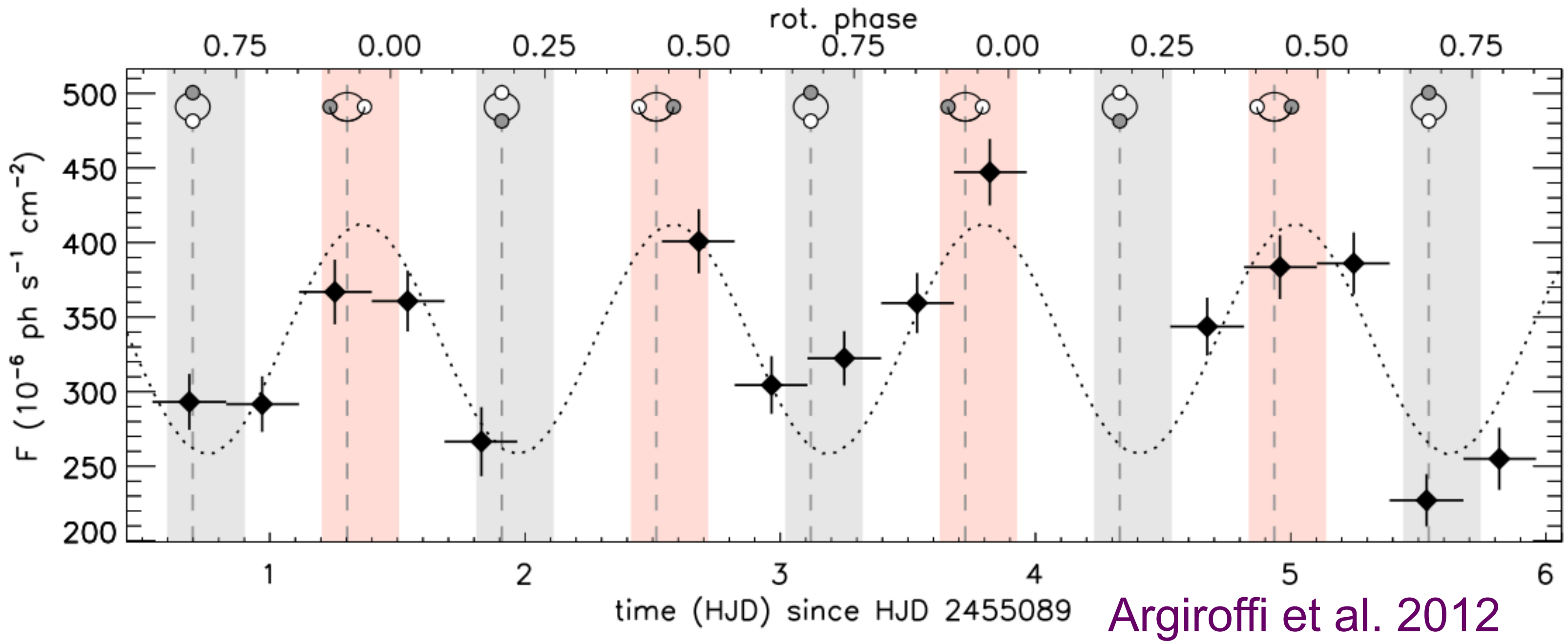


Donati et al. 2010

Multi-wavelength: V4046 Sag



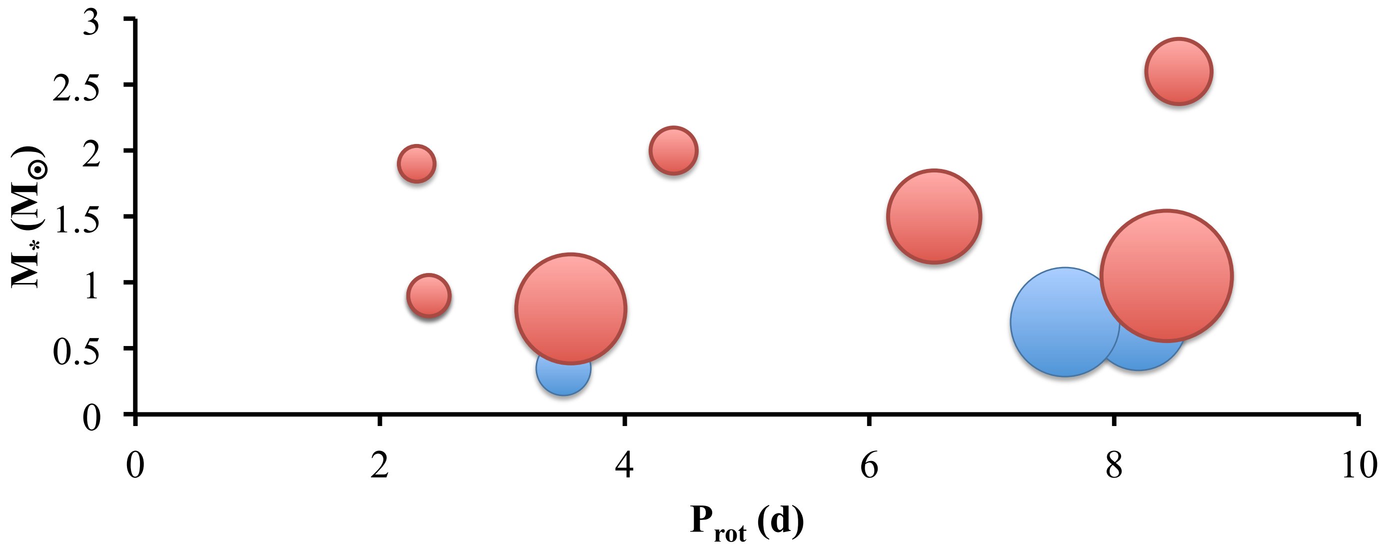
Multi-wavelength: V4046 Sag

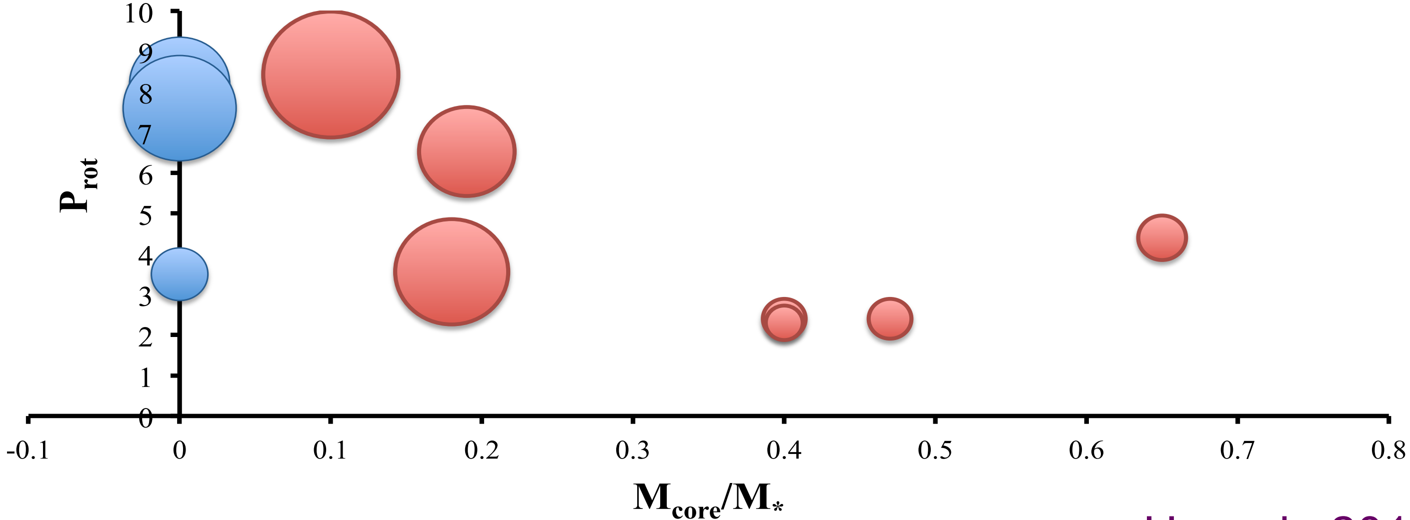


Argiroffi et al. 2012

- CFHT (8nights); TNG (5 nights); XMM-Newton (300 ksec 3 orbits)
- 4250K, 0.9Msun, ~1.04+1.12Rsun, i=35 degrees, Prot=2.4 d, separation=8.8Rsun

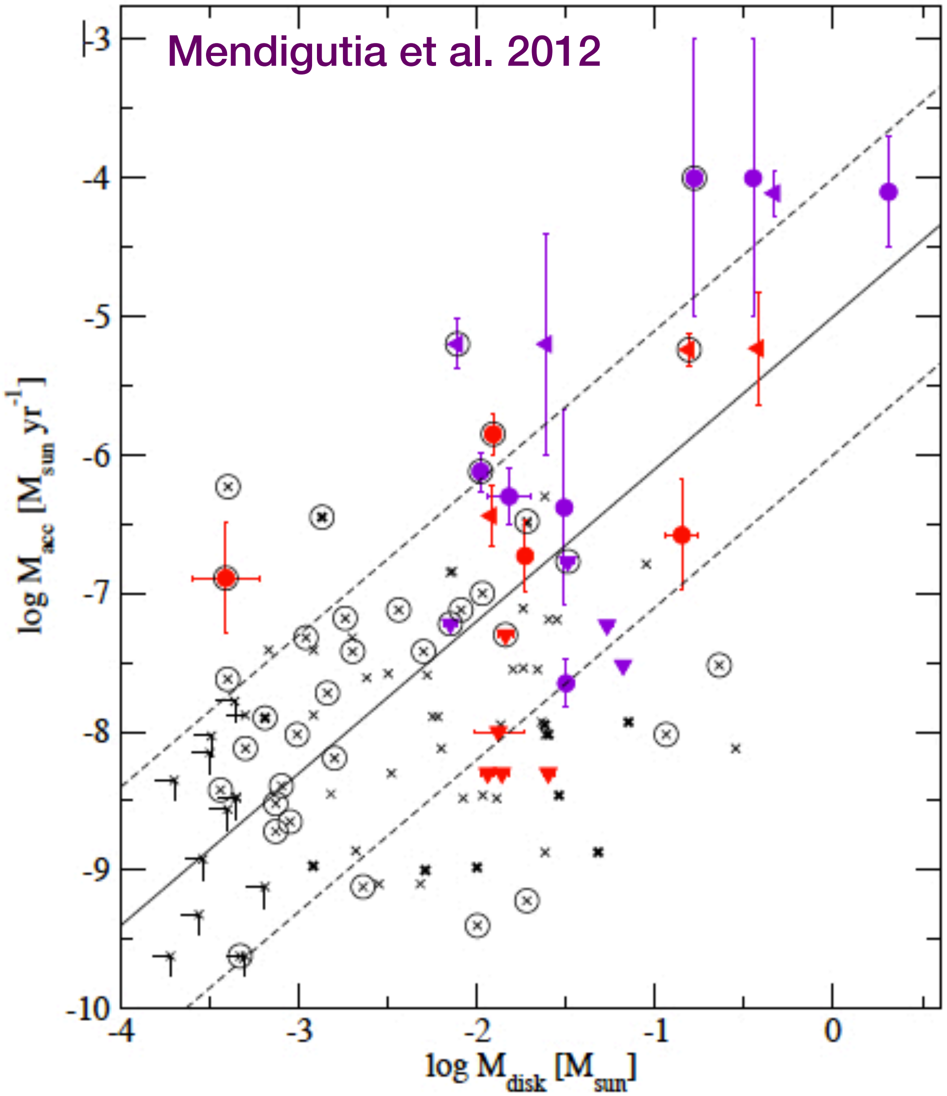
T Tauri star magnetic topologies: the picture today





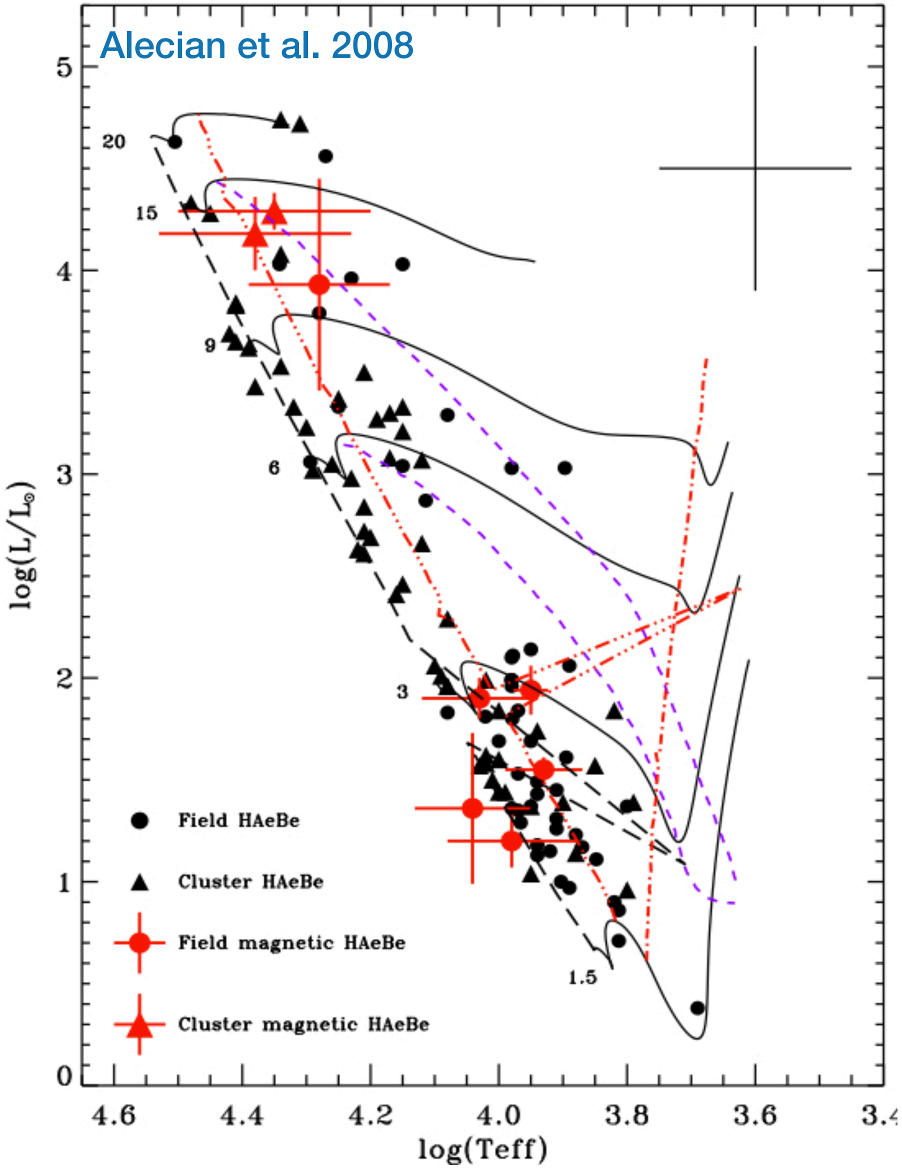
Hussain 2012, updated

Going to intermediate mass (1.3-6M_{sun})



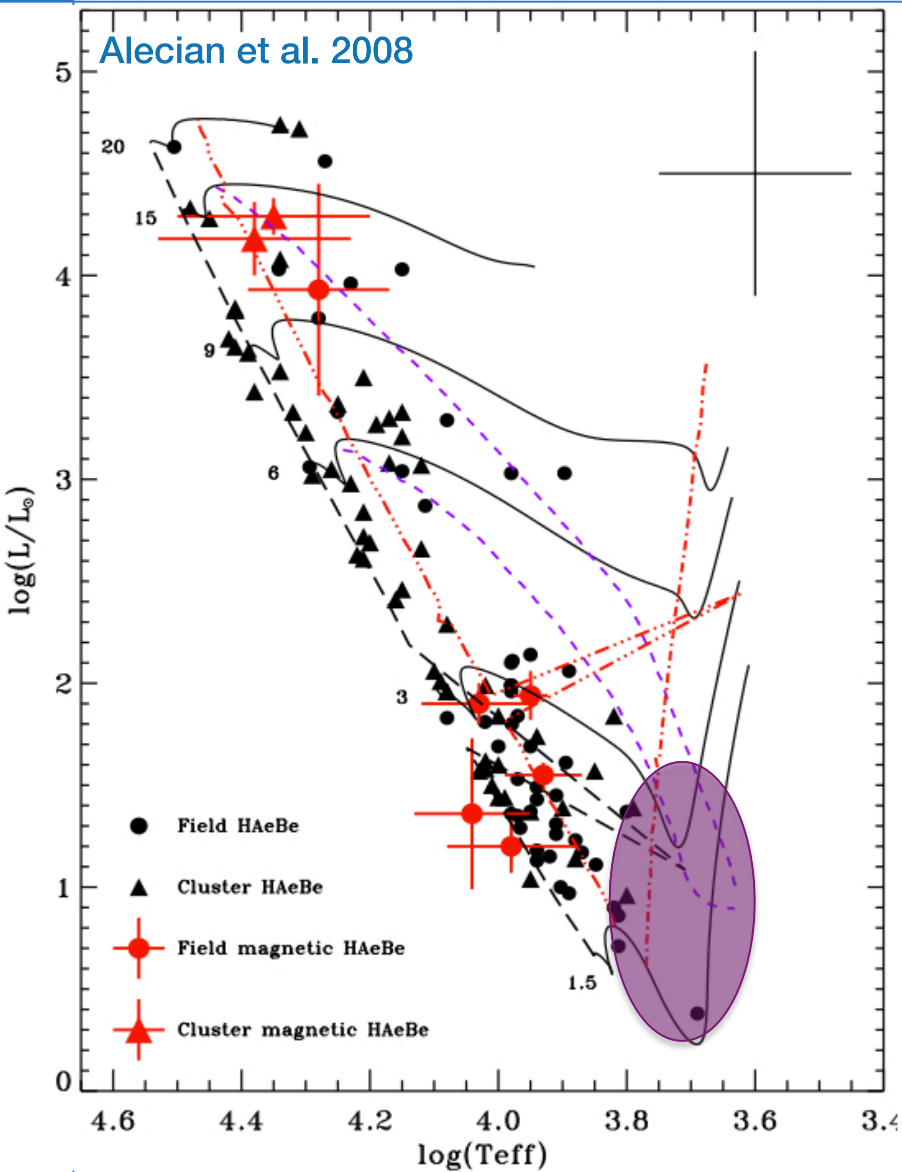
- Accretion measurements from low mass (crosses) to high mass (circles/ triangles)

Going to higher mass (>1.5Msun)



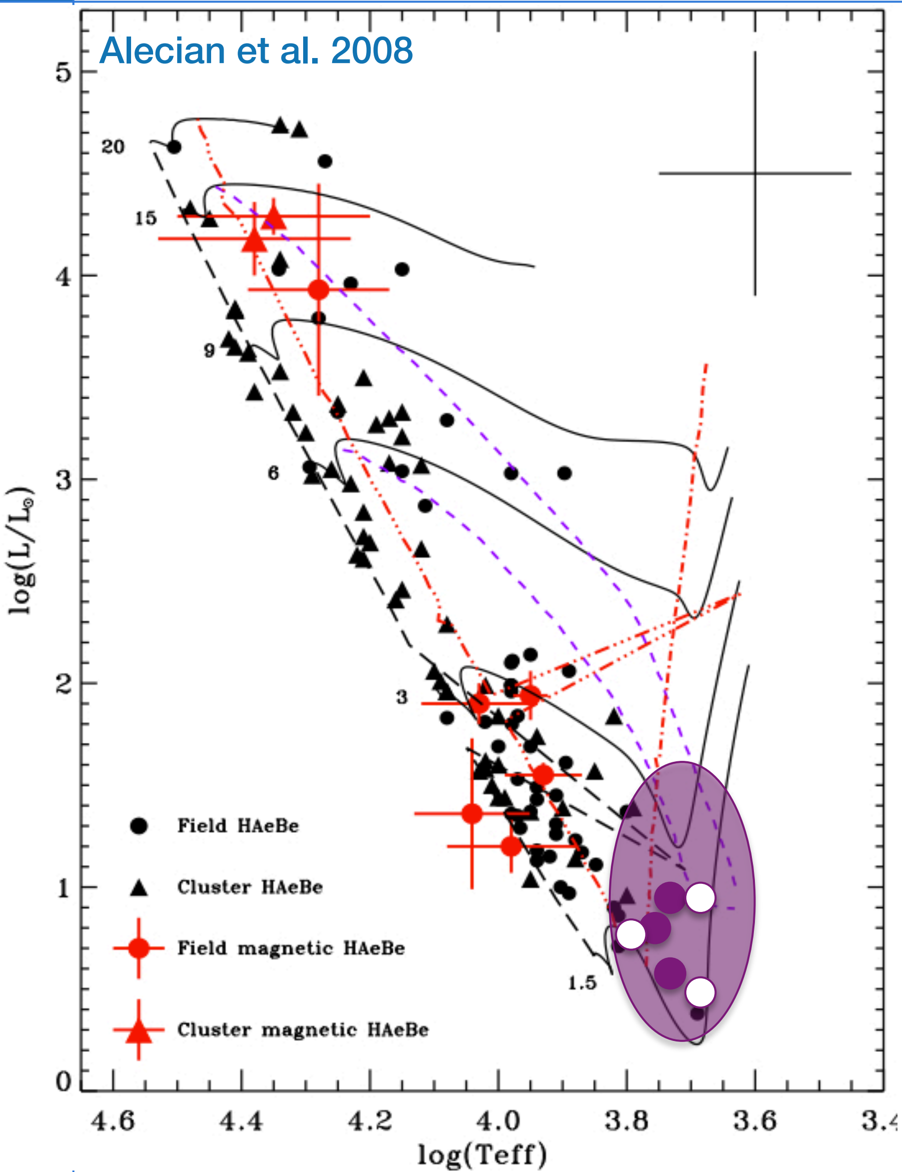
- Magnetic field detections in Herbig Ae/Be stars

Intermediate mass T Tauri stars (IMTTS)



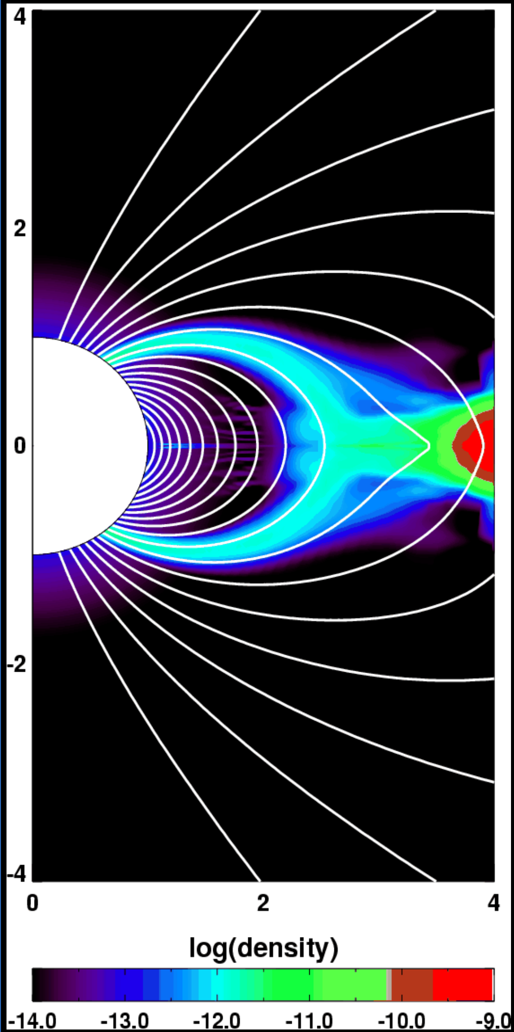
- Intermediate mass TTauri stars: precursors to HAeBes
- Latest observations probe magnetic fields over convective-radiative boundary in PMS stars
- Observations have been scheduled on HARPS, CFHT and CRIRES.

Intermediate mass T Tauri stars (IMTTS)



- HARPSpol observations: Jul 2012
- Full sample will cover >35 IMTTS
- First results show differences with lower mass T Tauri stars: solid/white symbols are detections/non-detections
- **Many more results forthcoming from this study!**

Summary

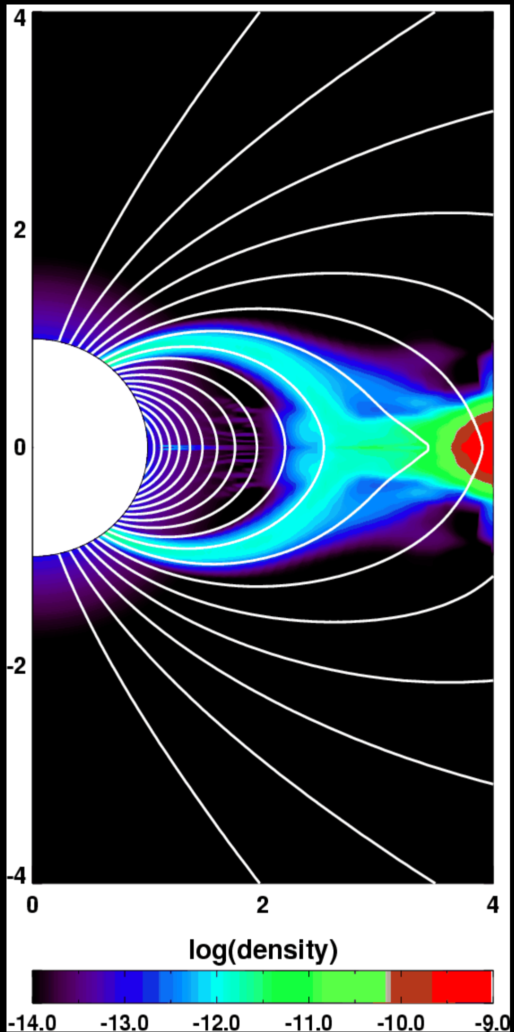


- Surface magnetic fields reconstructed for 10 classical T Tauri systems (11 stars)
- Magnetic field topologies relate to internal structure not M or Prot
  - Fully convective: simple, dipole-dominant
  - Radiative core: multipolar, non-axisymmetric
  - VLM T Tauri stars may be different
- Intermediate mass stars (>1.5 Msun) show similar properties in T Tauri phase.

→When do high mass stars lose their fields?

→ What happens when accretion stops?

Prospects



- MaTYSSE: B fields in weak-lined T Tauri star systems
- Class I stars (e.g., Johns-Krull et al. 2010)
- Multi-wavelength observations to test coronal models
- Accretion models
  - Models (e.g., Kurosawa, Romanova & Harries 2011)
- Disk fields: FU Ors, etc..