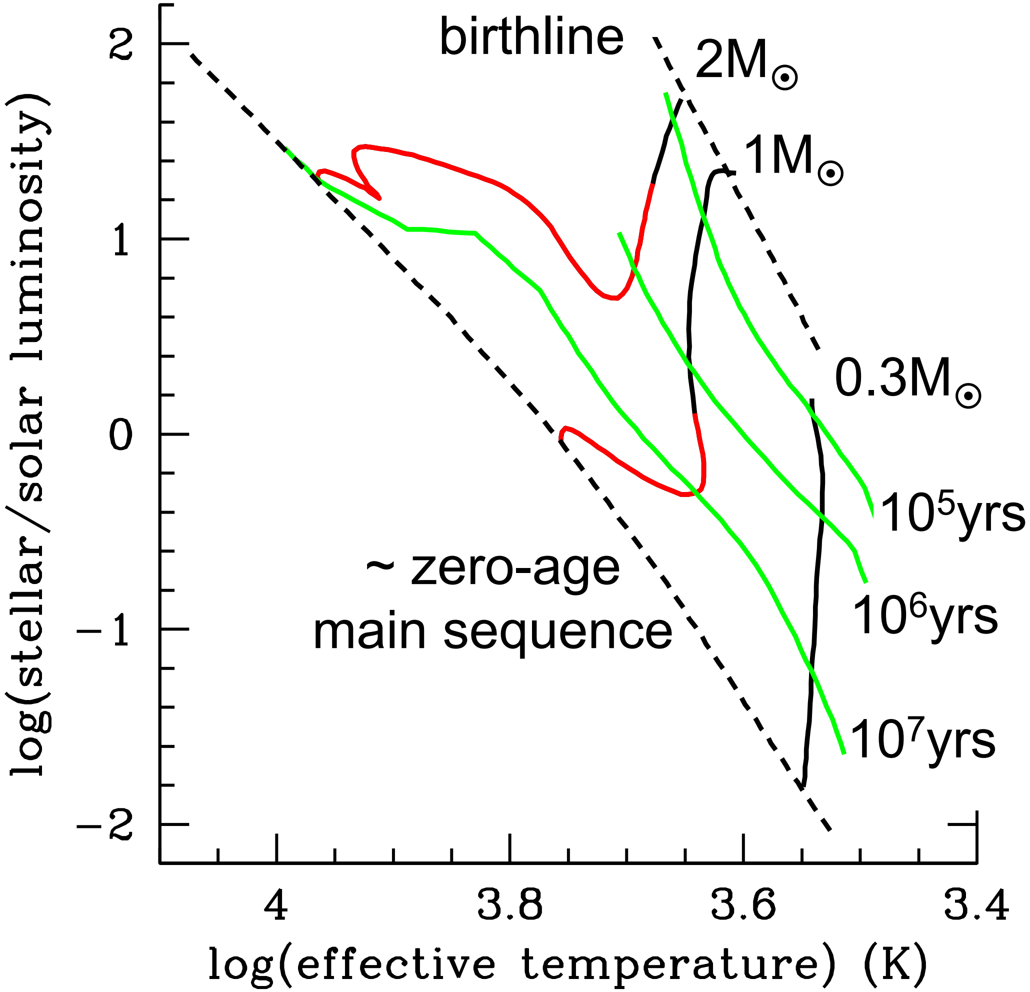
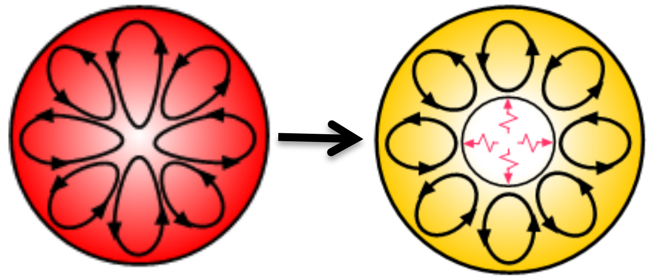
Can we predict the global magnetic topology of a PMS star from its position in the H-R diagram?

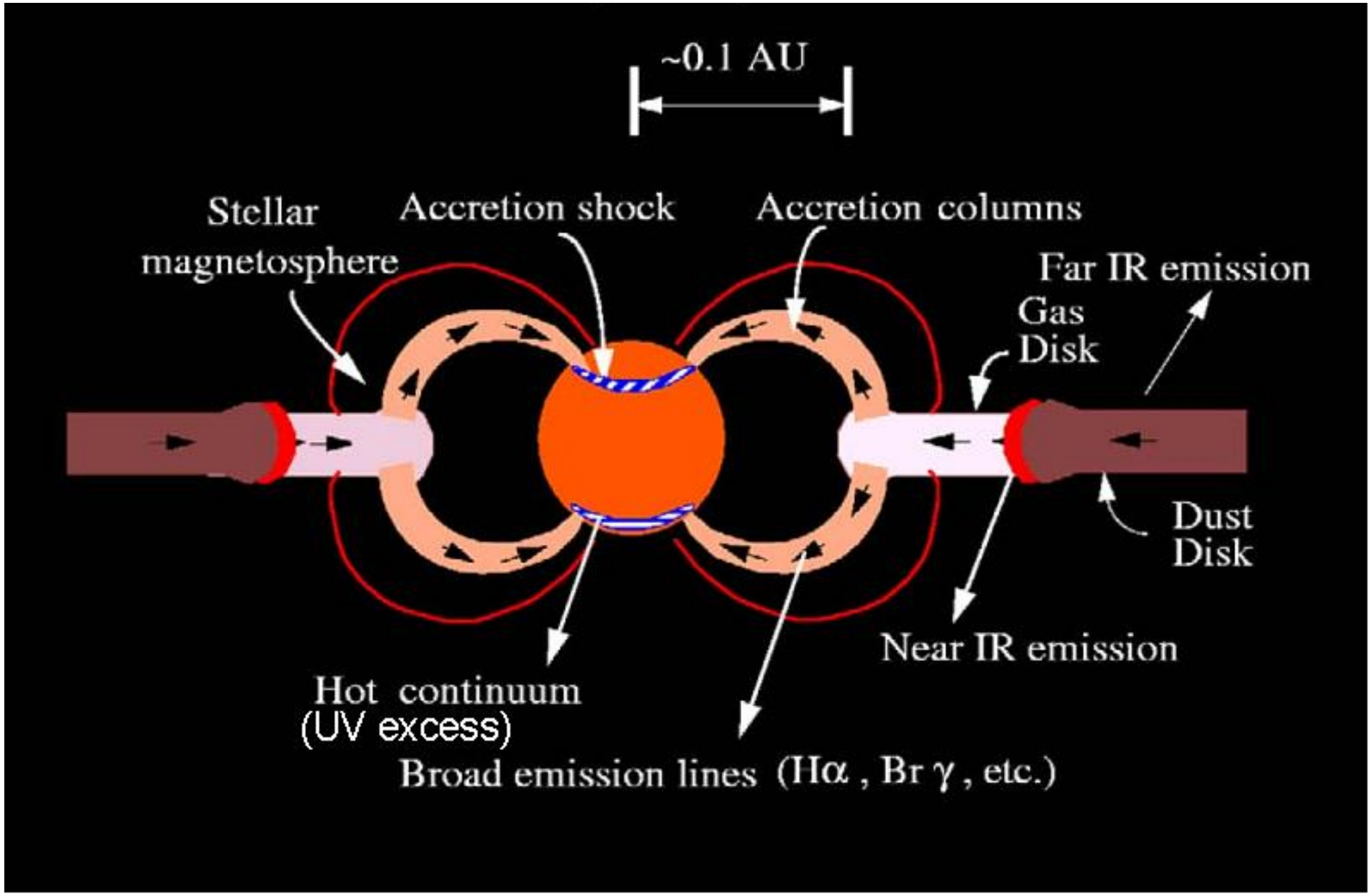


- Stars > 0.35 $M_\odot$ transition from fully (black portion of mass track) to partially convective with a radiative core (red portion of mass track) during their pre-main sequence contraction.



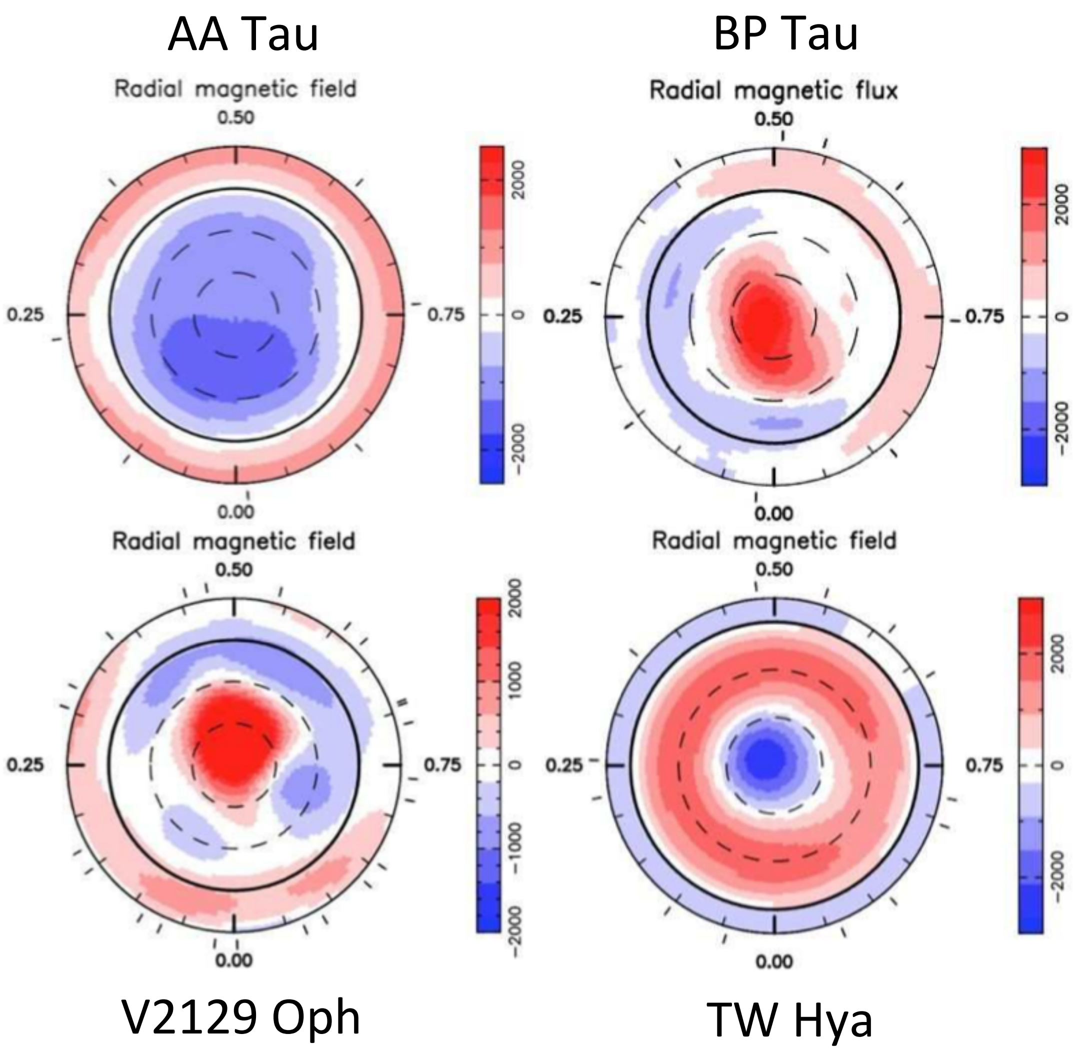
Scott G. Gregory (St Andrews, UK)

Magnetically controlled accretion onto a PMS star



(Hartmann 1998)

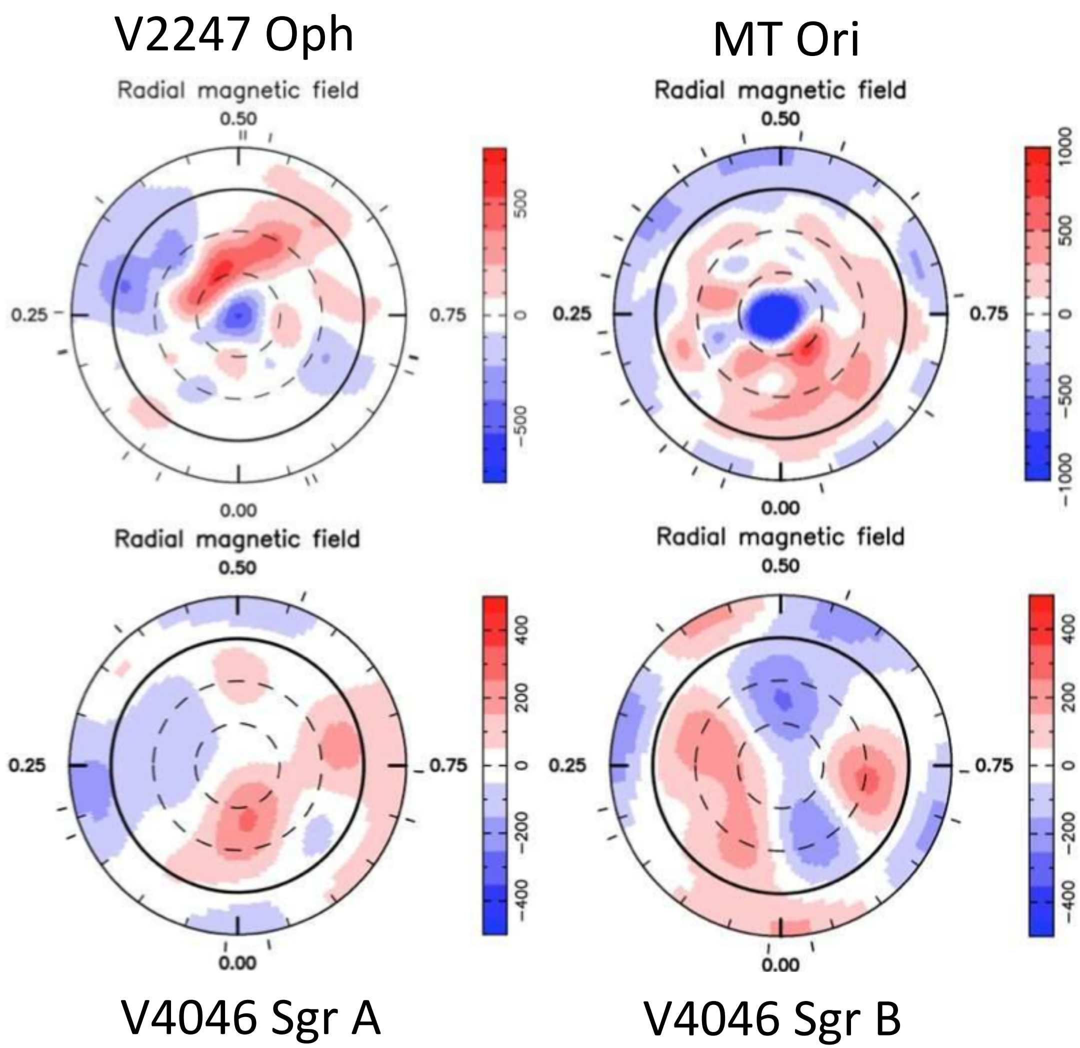
Newborn stars with dipole-octupole large-scale fields



(Donati et al 2008a, 2010b, 2011a,b; Gregory & Donati 2011)

- About half of the stars with published maps have large-scale fields consisting of a tilted dipole plus a tilted octupole.
- Fields of TW Hya & V2129 Oph are different at other epochs – non-stationary dynamo; magnetic cycles?

Newborn stars with more complex large-scale fields

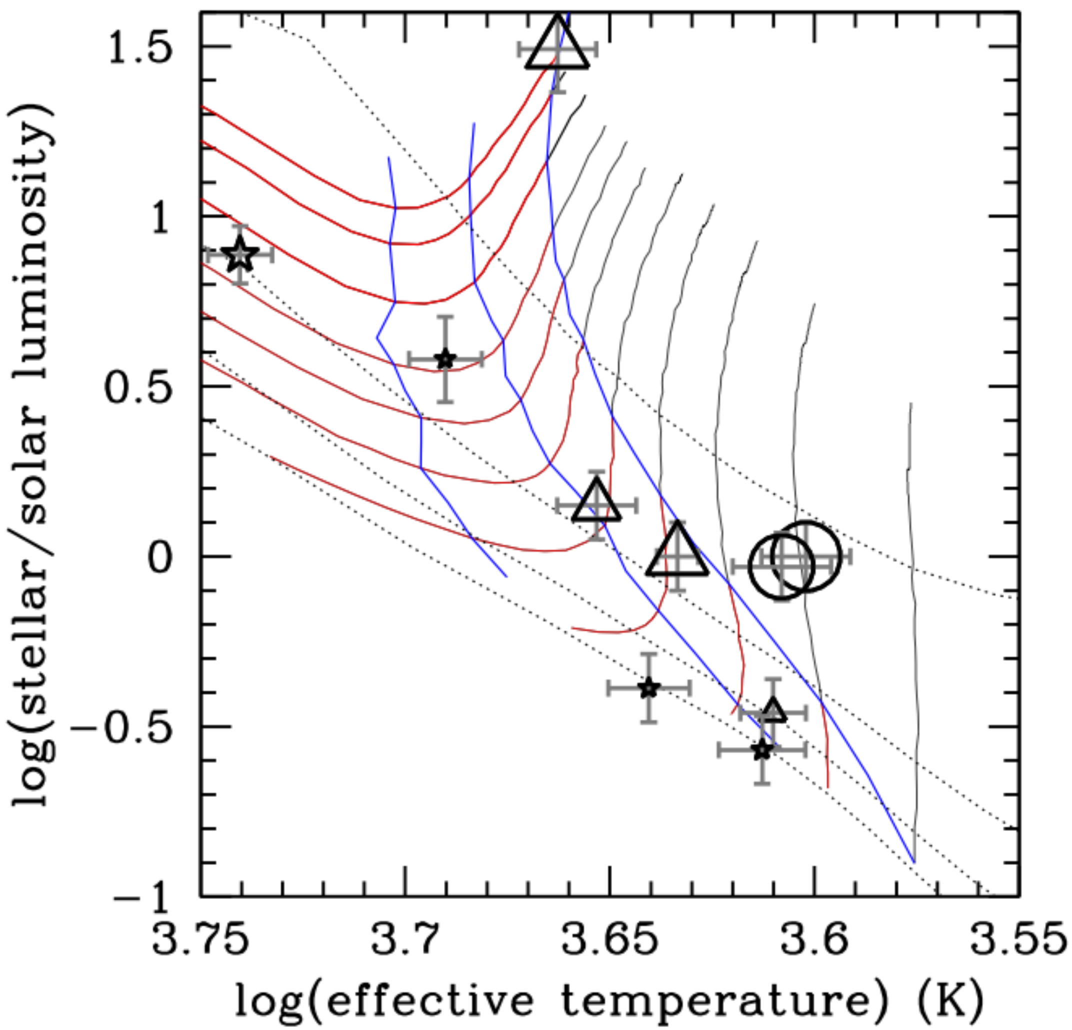


(Donati et al 2010a, 2011c;
Gregory & Donati 2011)

- The other half have more complex large-scale fields; predominantly non-axisymmetric.

- MT Ori well described by a dipole + octupole + dotriacontapole + ℓ = 7 field modes.

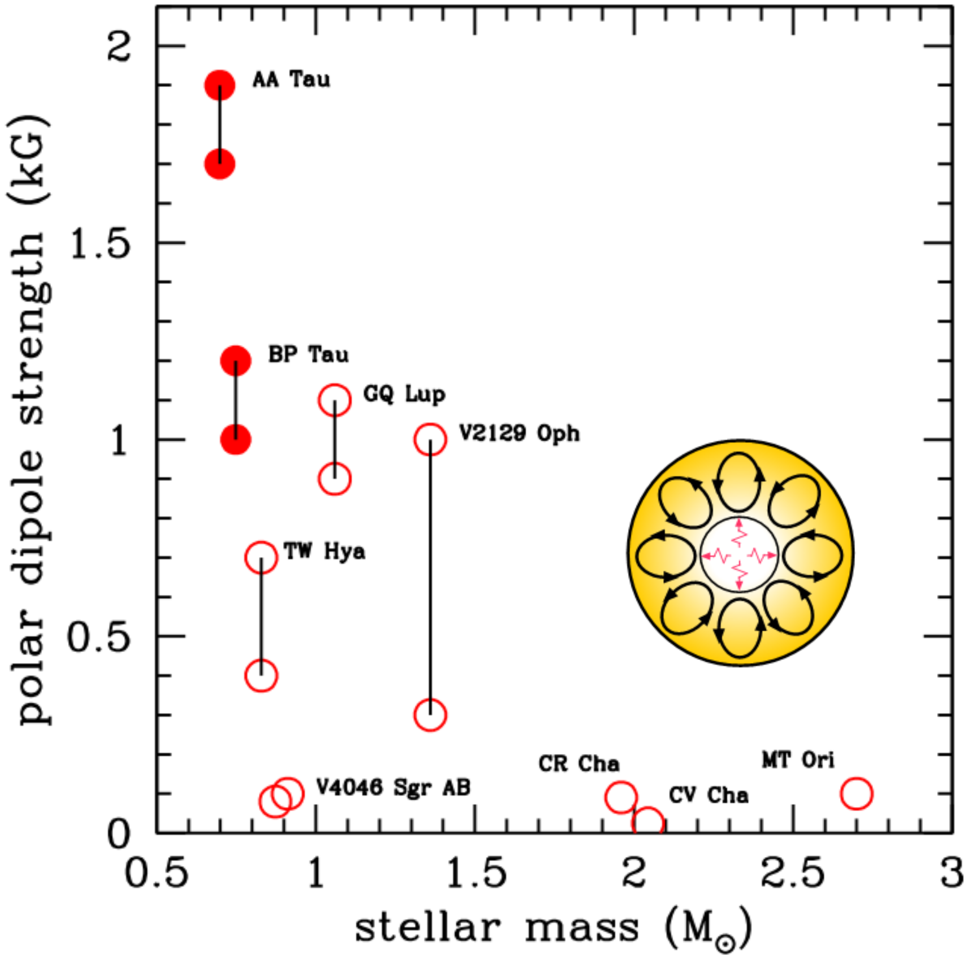
H-R diagram with internal structure contours



(Gregory et al 2012)

- Isochrones (dotted) 1, 5, 10, 15 Myr.
- Mass tracks (solid; black=fully convective, red=radiative core) 0.5, 0.7… 1.9, 2.2, 2.5, 2.7 $M_\odot$.
- Internal structure contours (blue) M_{core}/M_*=0, 0.4, 0.8.
- Stellar structure data from the Siess et al (2000) models.

Dipole component of the magnetic fields of accreting PMS stars

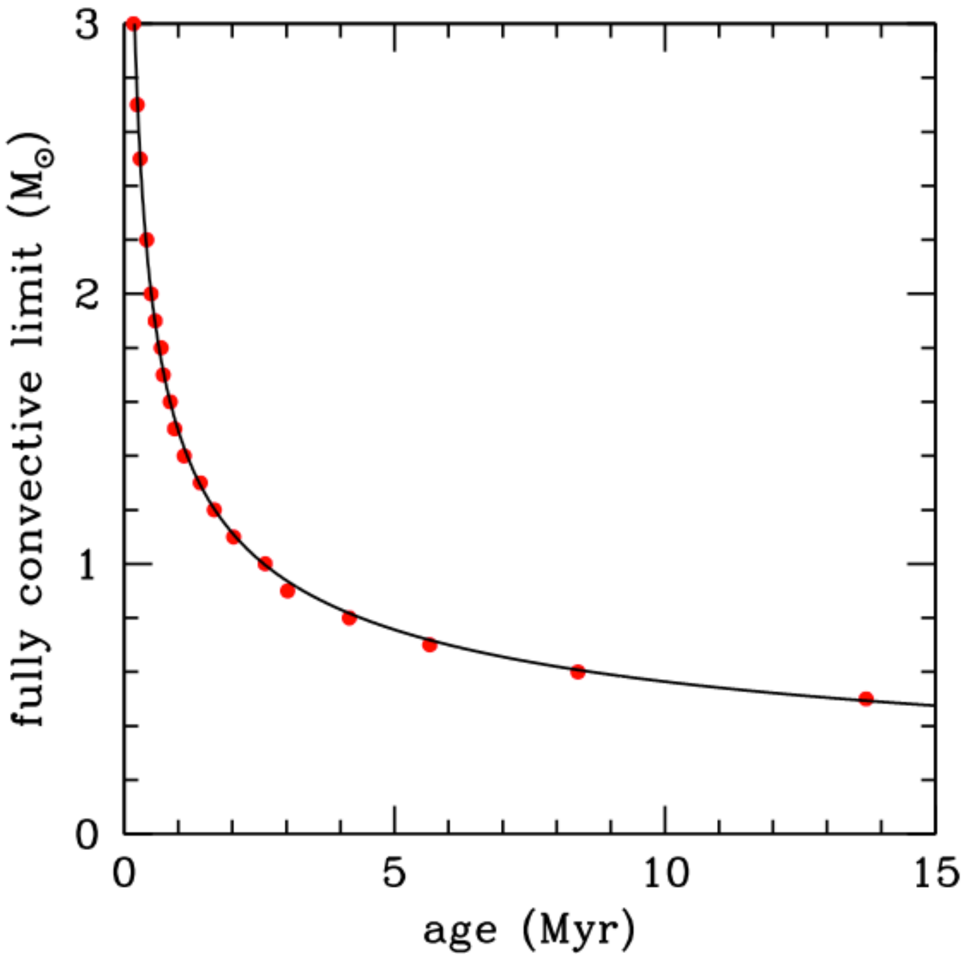


(Gregory et al 2012)

- Fully convective stars (● symbols) have strong dipole components.
- Stars with radiative cores (○ symbols) have weaker dipole components.
- Older and/or more massive stars have weaker dipole components.

(Donati et al 2007, 2008a, 2010a,b, 2011a,b,c; Hussain et al 2009; Gregory & Donati 2011)

Development of a radiative core

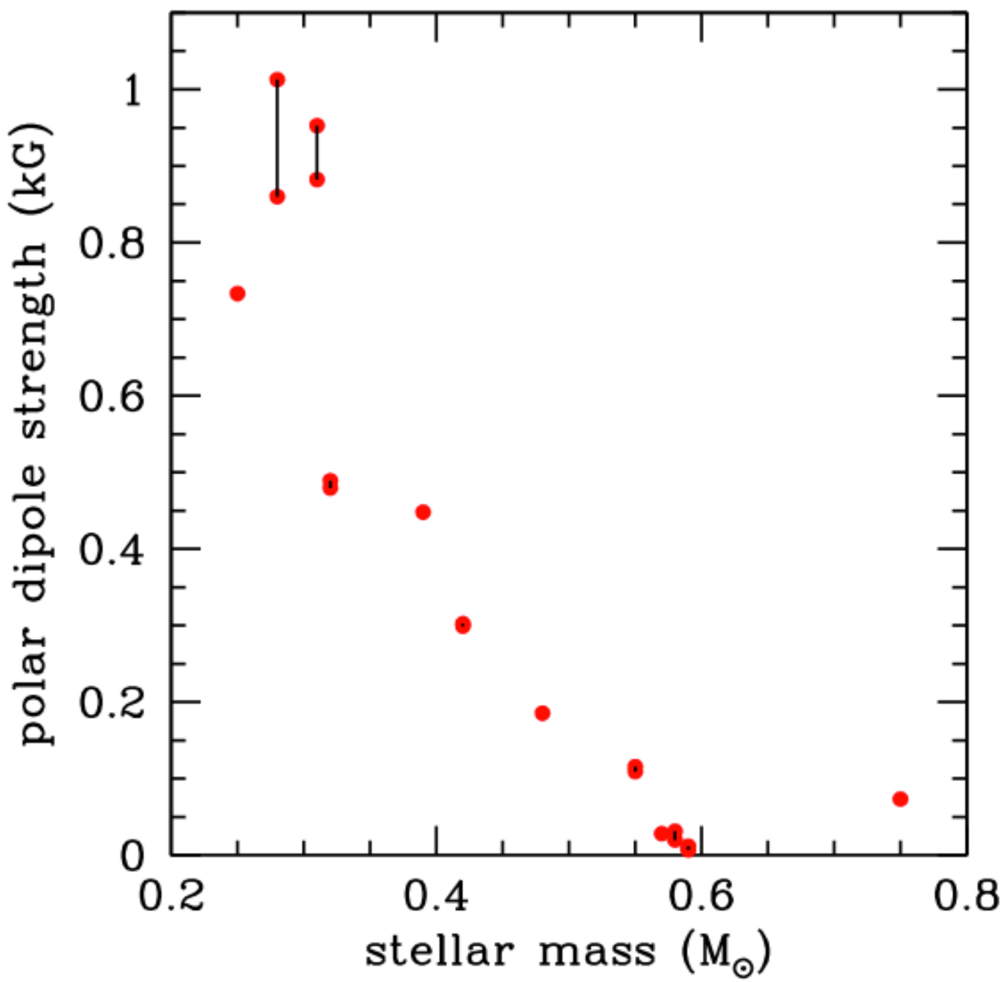


(Gregory et al 2012)

- An old but low mass star may have a radiative core while a young but high mass star is still completely convective.
- Stellar structure data from the Siess et al (2000) models.
- Age at the end of the fully convective phase:

$$age[\mathrm{Myr}] \approx (1.494/M_*[\mathrm{M}_\odot])^{2.364}$$

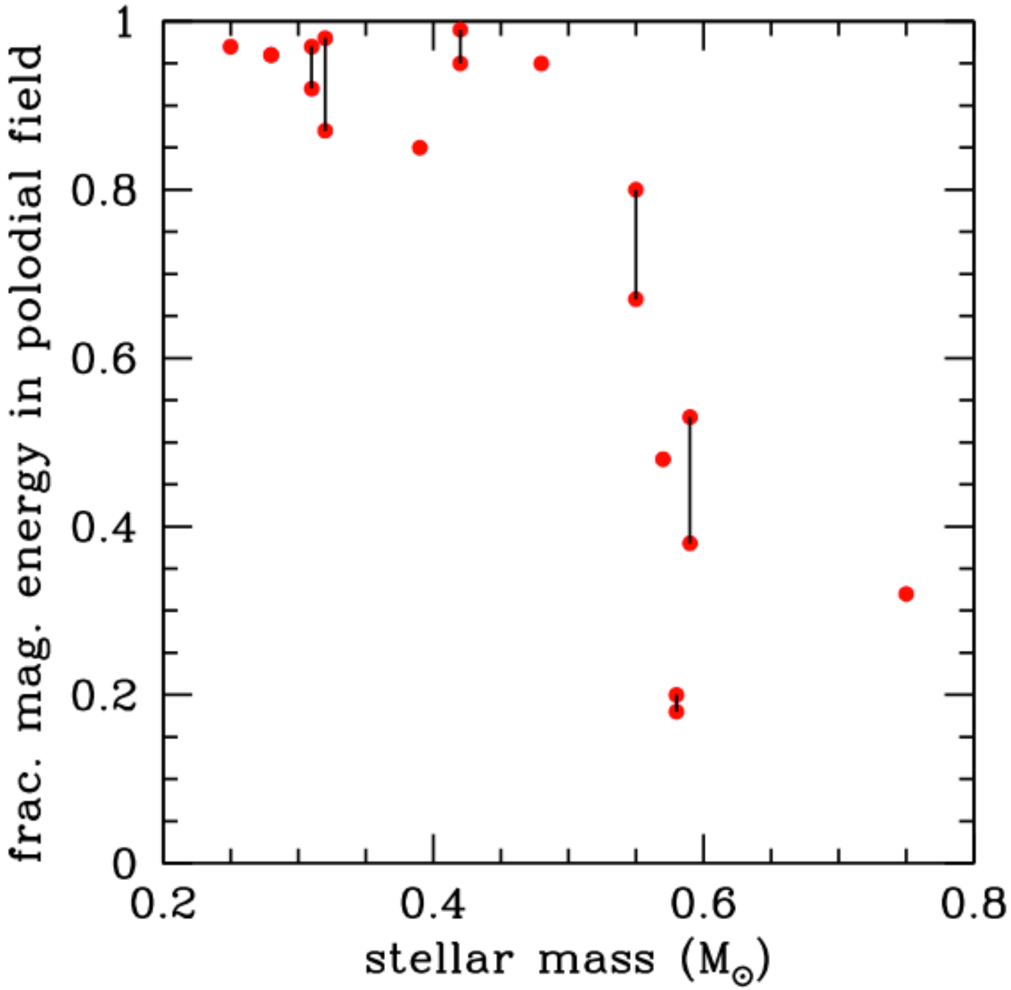
Main sequence M-dwarfs



(Gregory et al 2012)

- Data presented in Morin et al (2008b) & Donati et al (2008b).
- Stars below ~0.35 $M_\odot$ are fully convective. More massive stars have outer convective envelopes.
- Rapid drop in the strength of the dipole component across the fully convective divide.

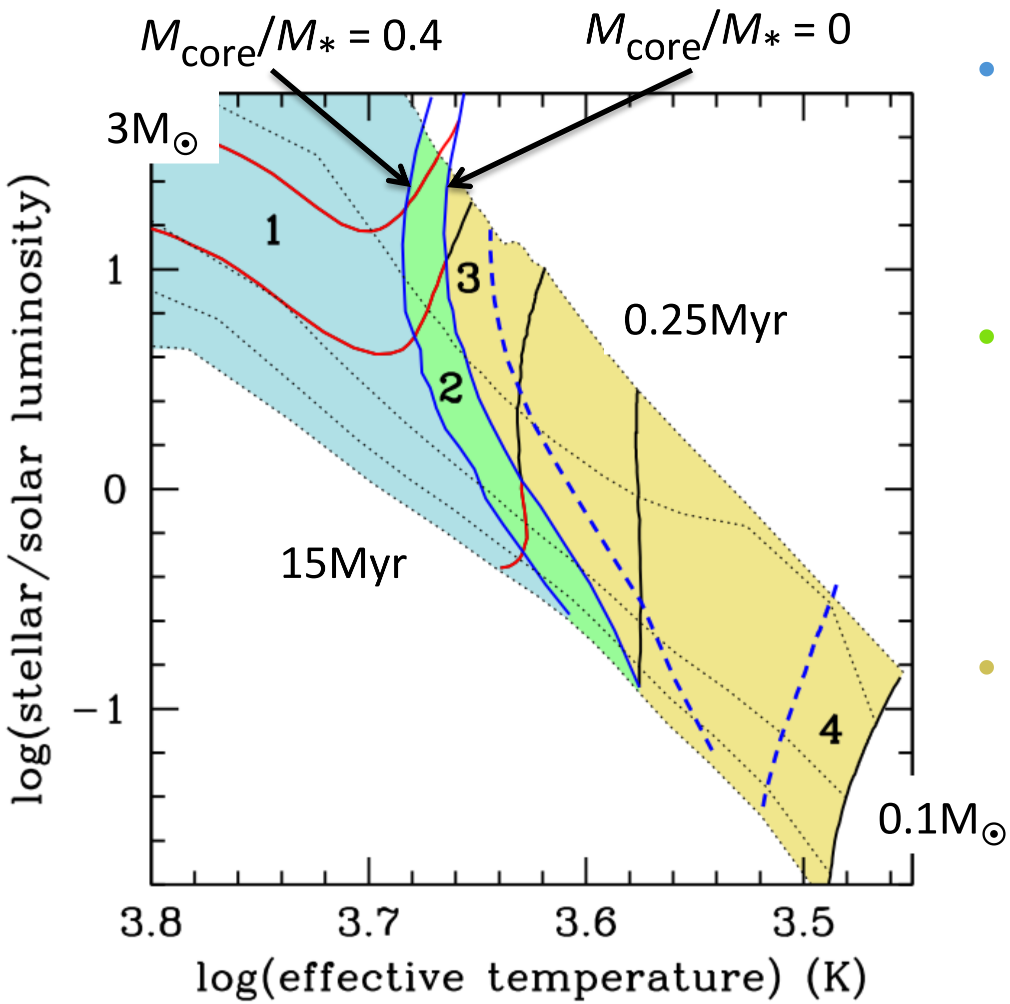
Main sequence M-dwarfs



(Gregory et al 2012)

- Data presented in Morin et al (2008b) & Donati et al (2008b).
- Stars below ~0.35 $M_\odot$ are fully convective. More massive stars have outer convective envelopes.
- Rapid increase in field complexity across the fully convective divide.

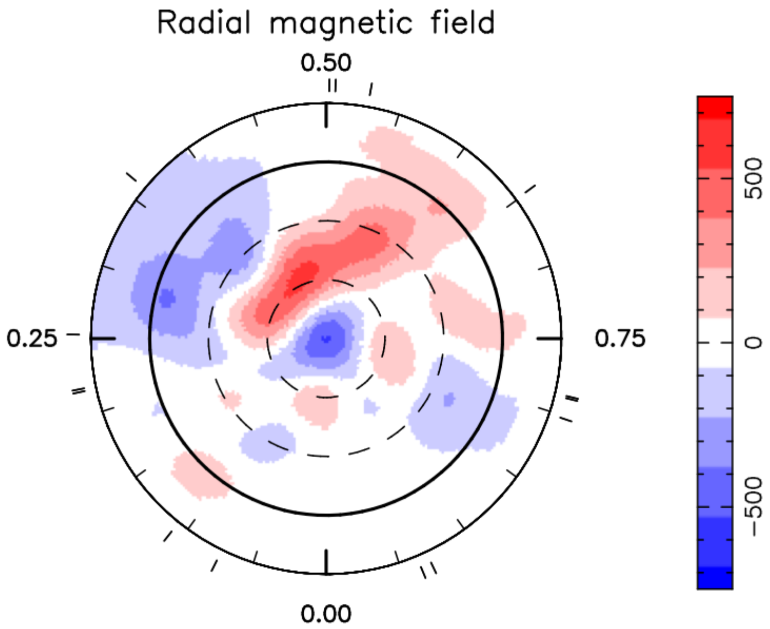
Magnetic fields across the PMS of the H-R diagram



(Gregory et al 2012)

- **Blue** (1): complex, non-axisymmetric, weak dipole components (~0.1 kG).
- **Green** (2): largely axisymmetric, field modes of higher order than the dipole dominate.
- **Yellow** (3): close the fully convective limit – axisymmetric, strong dipole component (~kG). *May be* a variety of field topologies for the lowest mass stars (4).

V2247 Oph (~0.35 $M_\odot$): a fully convective accreting PMS star with a complex field – bistable dynamos at the lowest masses?



V2247 Oph
(Donati et al 2010a)

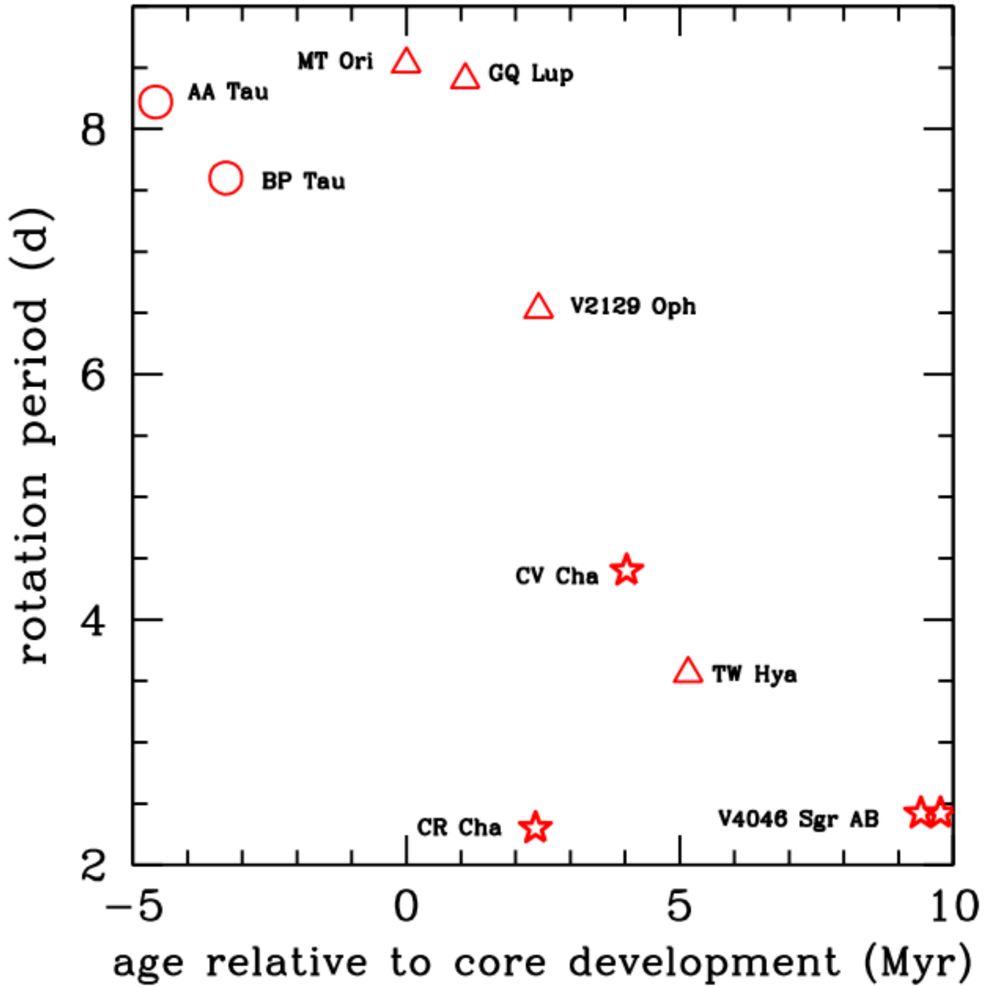
- Evidence for strong surface differential rotation.
- More rapidly rotating (~3.5 d) than than other convective stars BP Tau/AA Tau (~7.6/8.2 d).
- Similar field complexity found for some very-low mass MS M-dwarfs (Morin et al 2010).

The magnetic H-R diagram: cautionary notes

- Ability to predict the general magnetic properties of a PMS star depends on:
  - the veracity of the stellar evolution models.
  - accurate L_* and T_{eff} estimates.
  - how variable are large-scale fields over time?

- More data – MaPP (Magnetic Protostars & Planets); MaTYSSE (Magnetic Topologies of Young Stars & the Survival of close-in massive Exoplanets) programs at the CFHT (1200 hrs, 2008-2016, PI: Donati).

Spin-up of accreting PMS stars at the end of the convective phase?



(Gregory et al 2012; 2013 in prep.)

- *Accreting* stars which have spent longer with radiative cores are spinning faster than the fully convective objects.
- Caused by the drop of the dipole component allowing the disk to push closer to the star?

Conclusion: the emerging magnetic picture

- Cool stars (>0.5 $M_\odot$) (i) are capable of producing strong axisymmetric dipoles when fully convective.

- (ii) start losing their large-scale dipole while maintaining a strong axisymmetric octupole when a radiative core develops.

- (iii) finally end up with weak, mostly non-axisymmetric fields when their radiative core occupies a large enough proportion of the star (~0.4 M_*).

(Donati et al 2011b; Gregory et al 2012; 2013 in prep;
c.f. Morin's work on M-dwarfs)