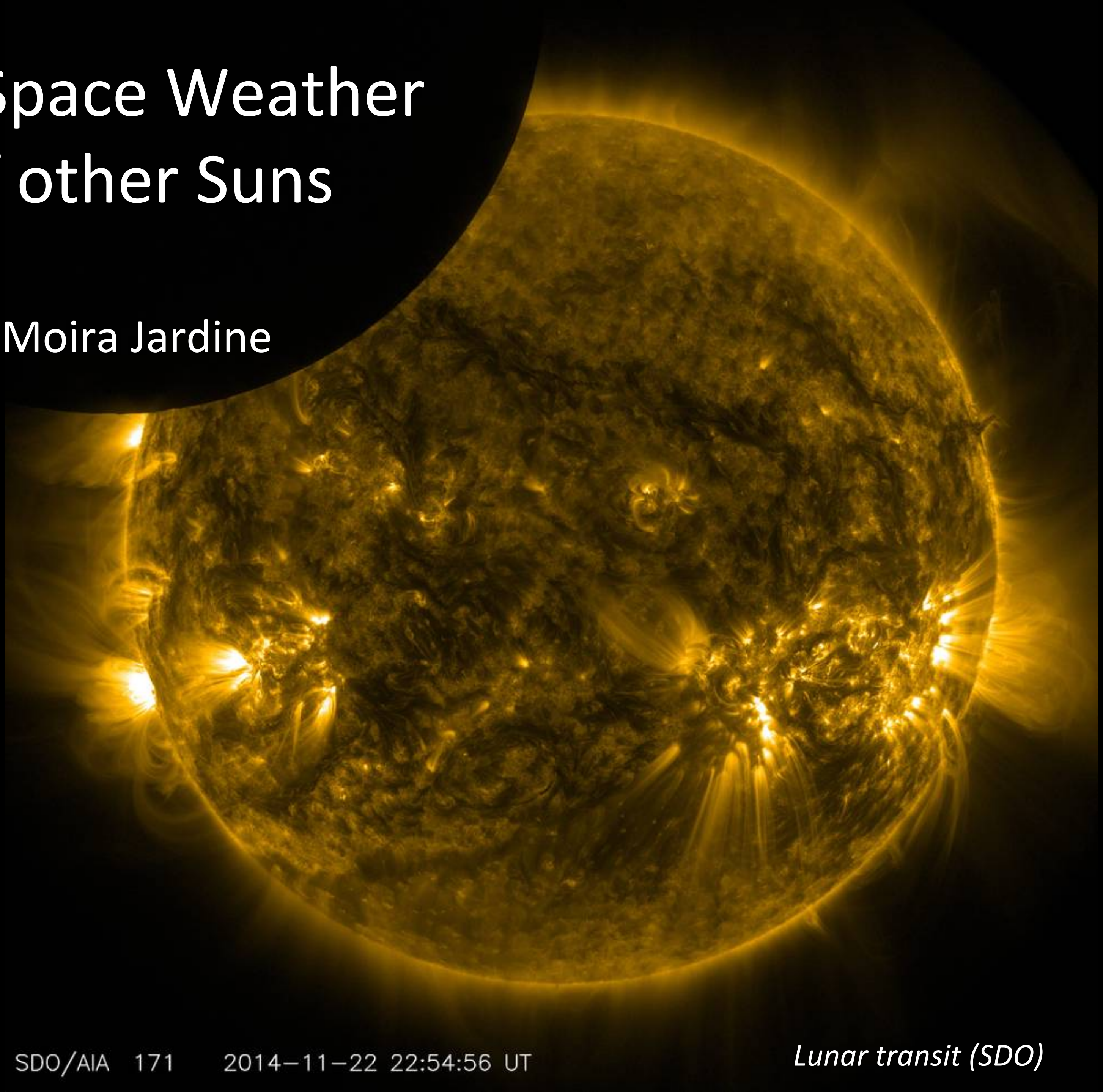
The Space Weather of other Suns

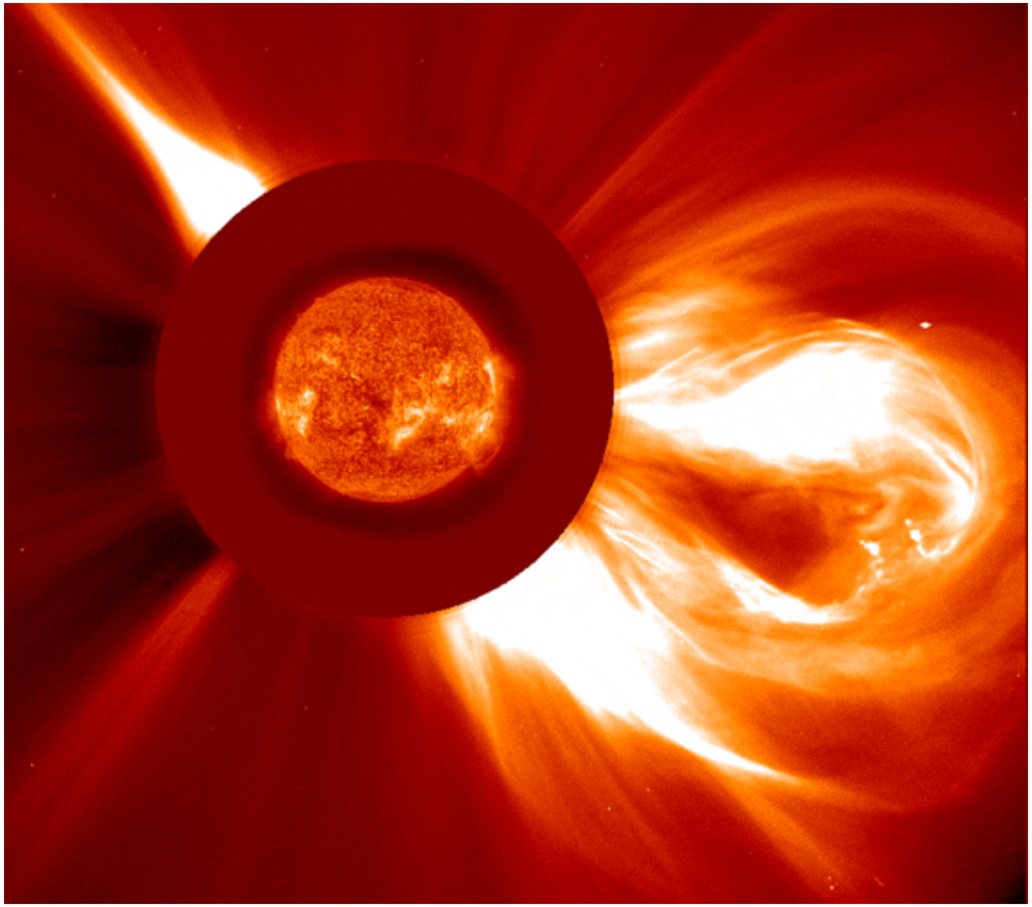
Moira Jardine



Lunar transit (SDO)

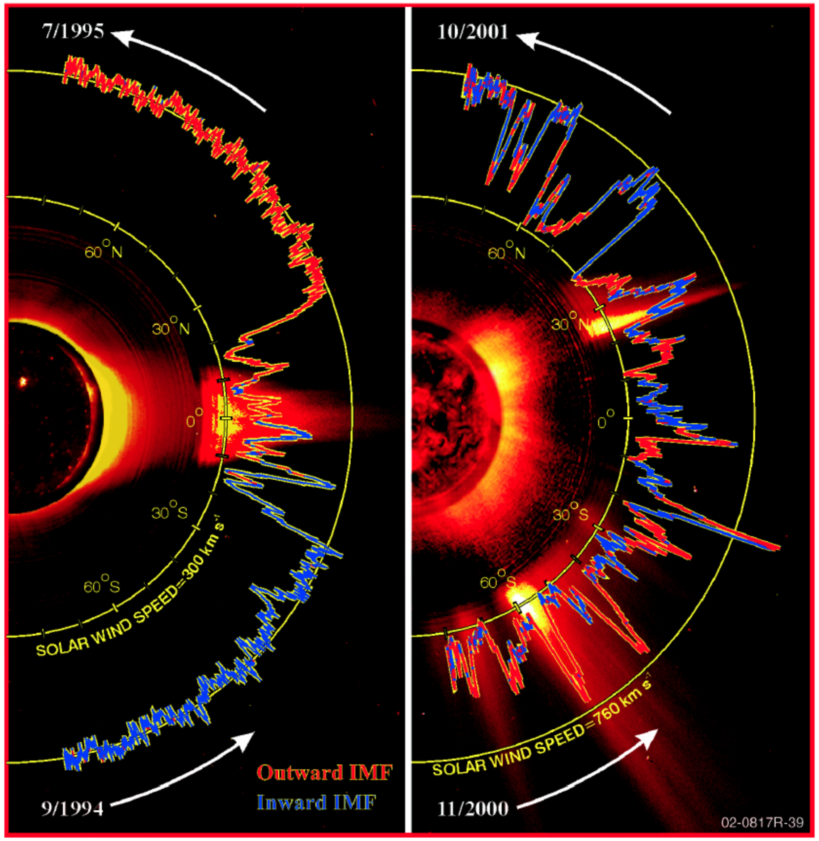
How typical is solar space weather?

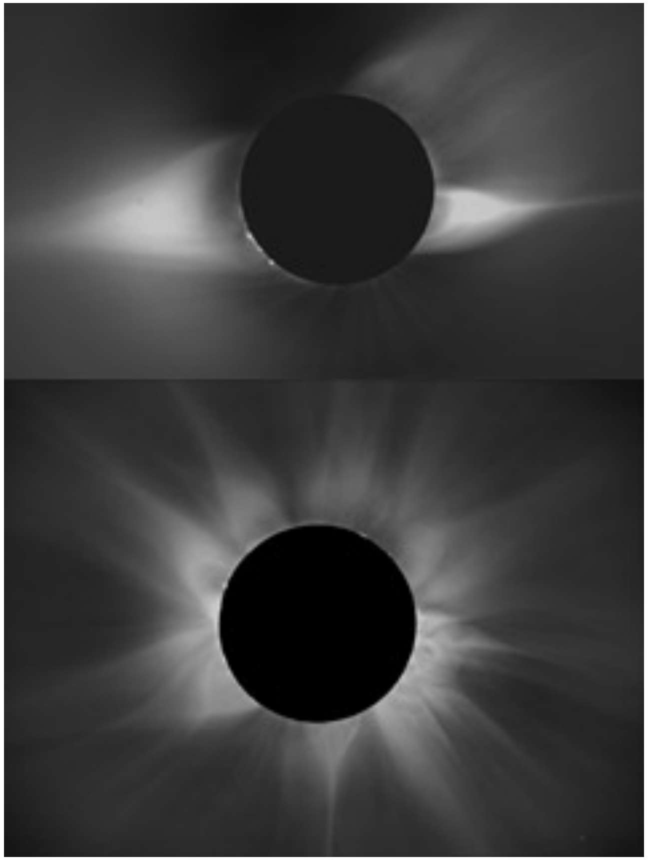
- Coronal mass ejections vary in *number* and *latitude* through solar cycle
- These variation track the change in the large-scale field topology



Variations with the solar cycle

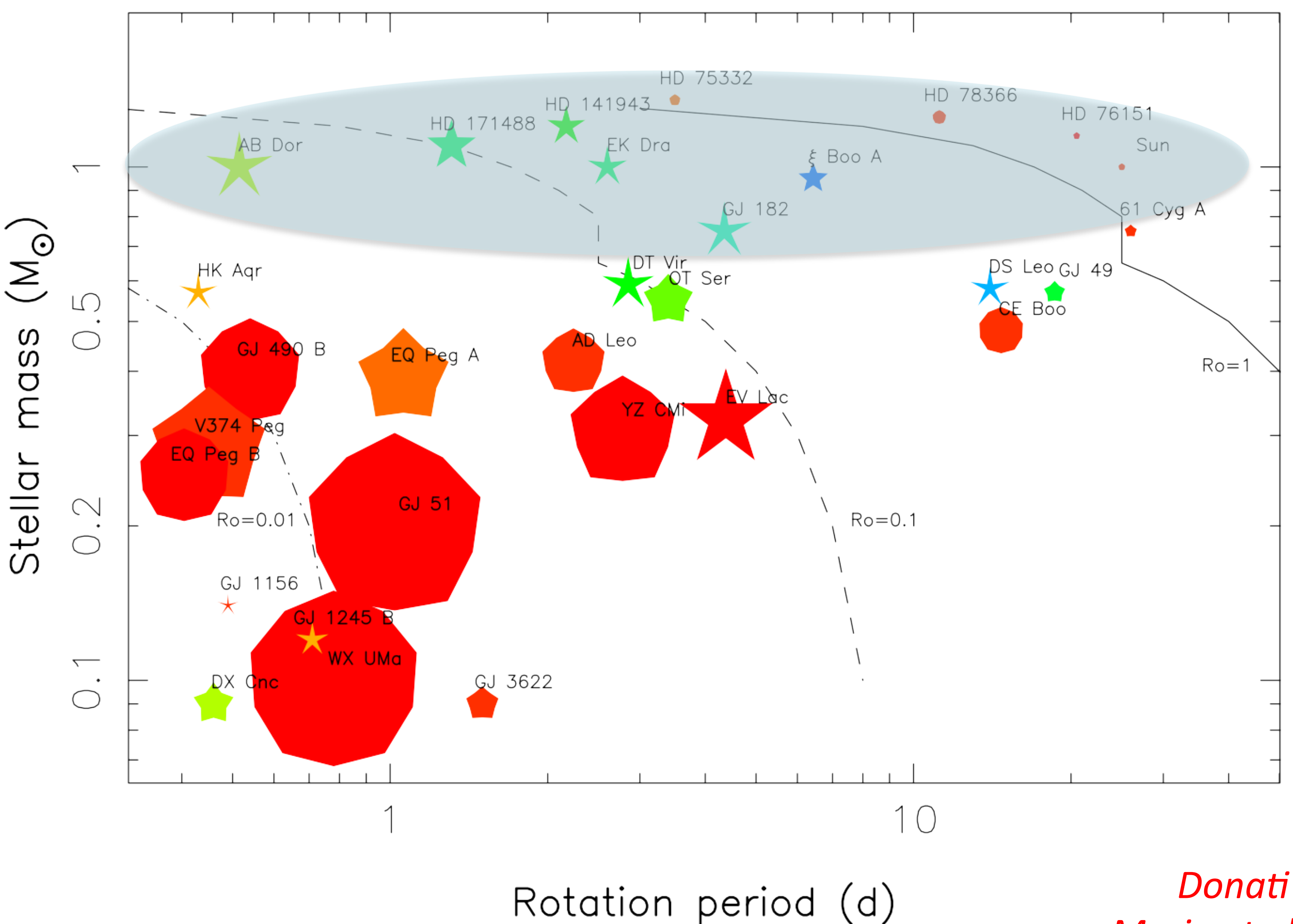
Changes in morphology of large-scale corona and wind





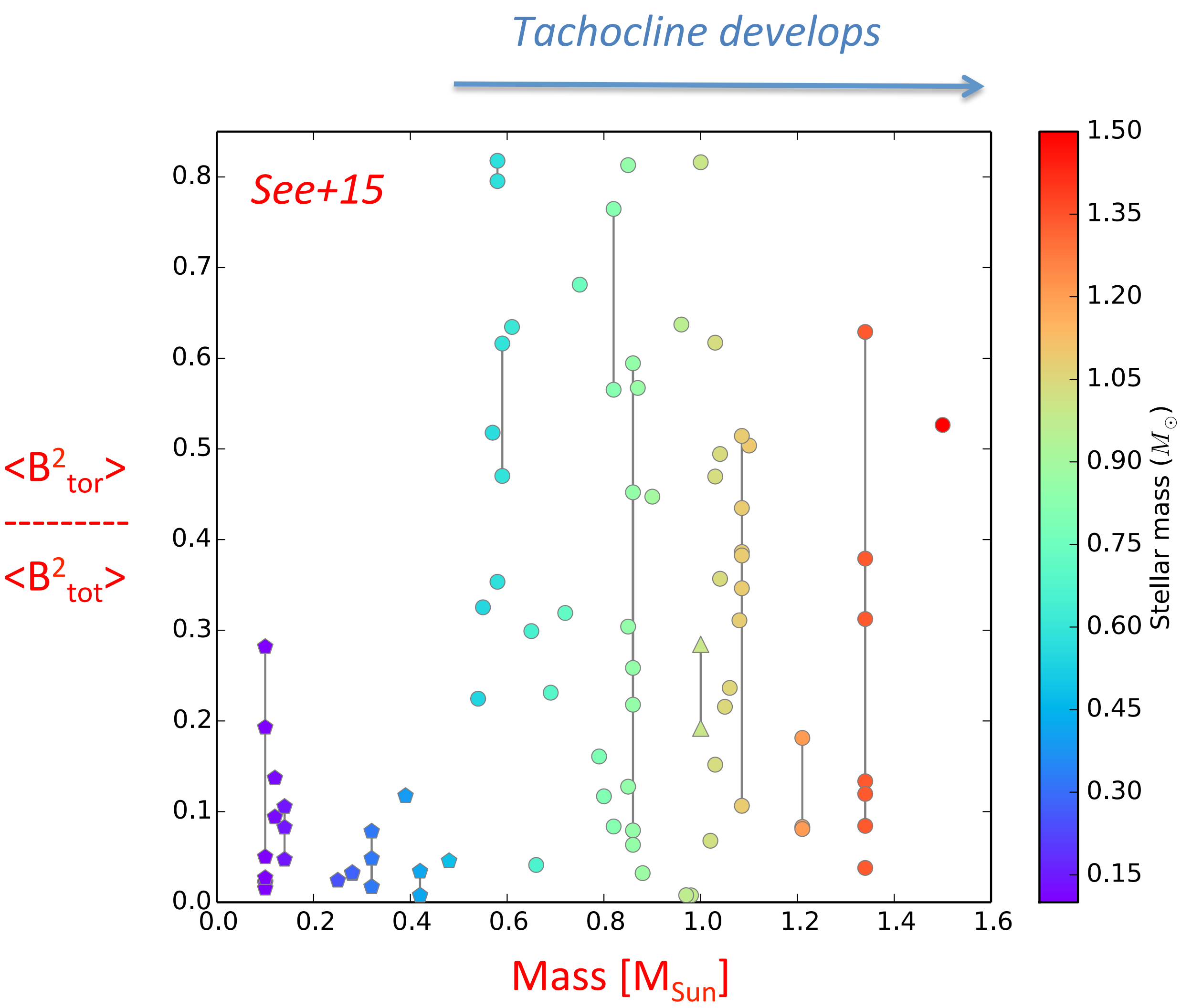
Images courtesy of UCAR's High Altitude Observatory and Rhodes College.

Field strength and geometry varies with mass and rotation period

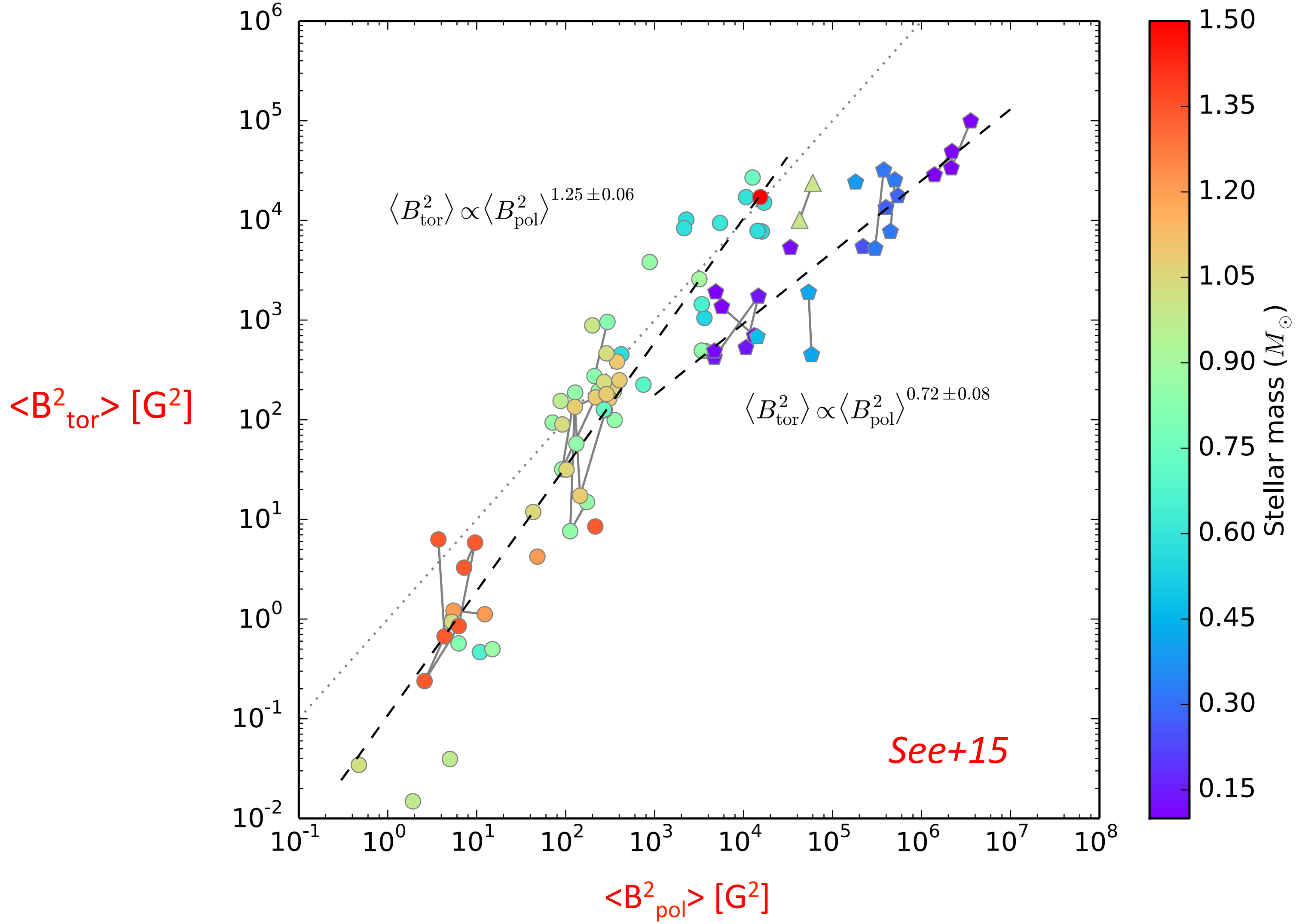


Donati et al 2008, Morin et al 2008,2009

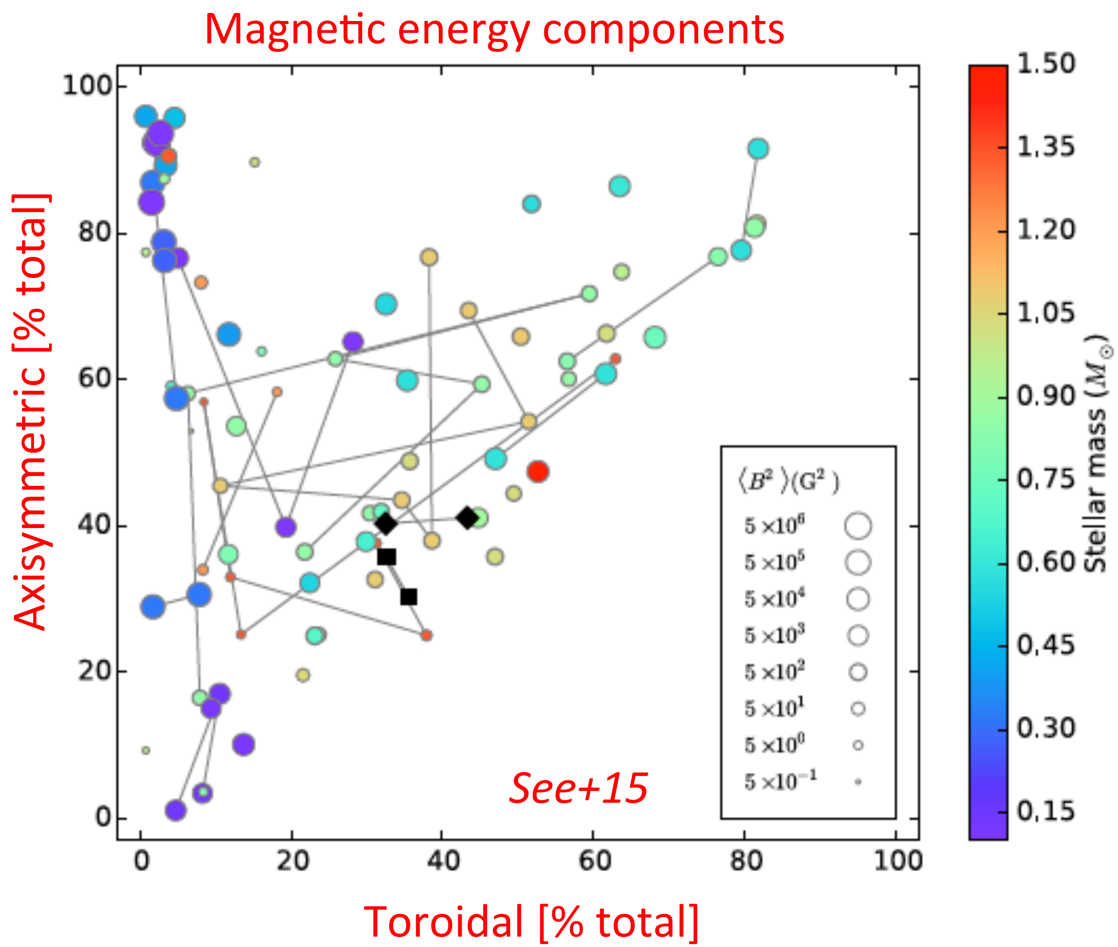
Strong toroidal fields are characteristic of stars with tachoclines



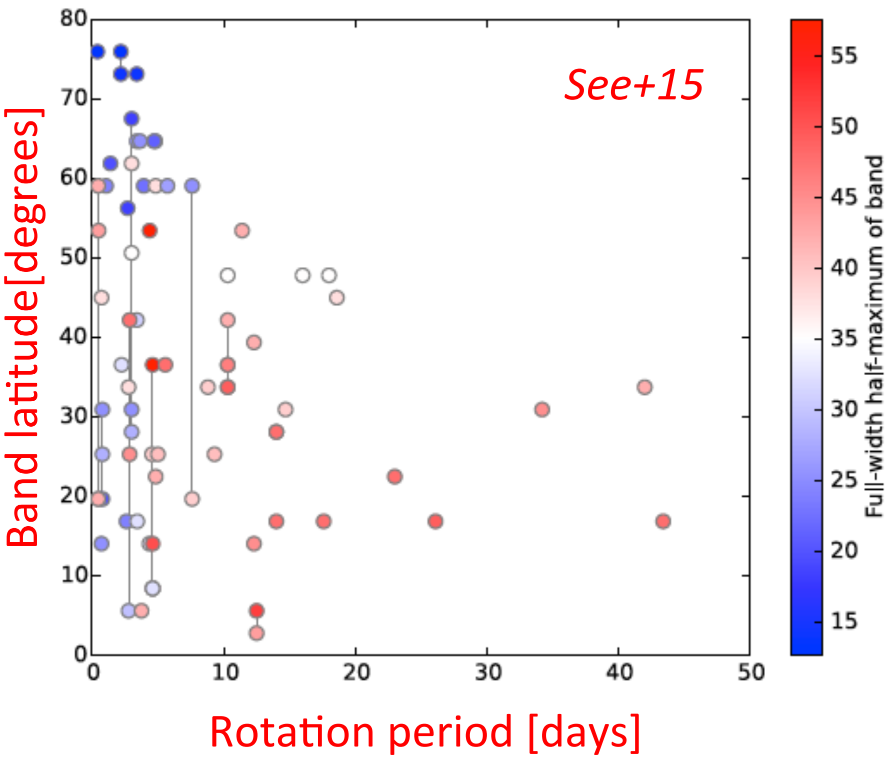
Indications of two dynamos?

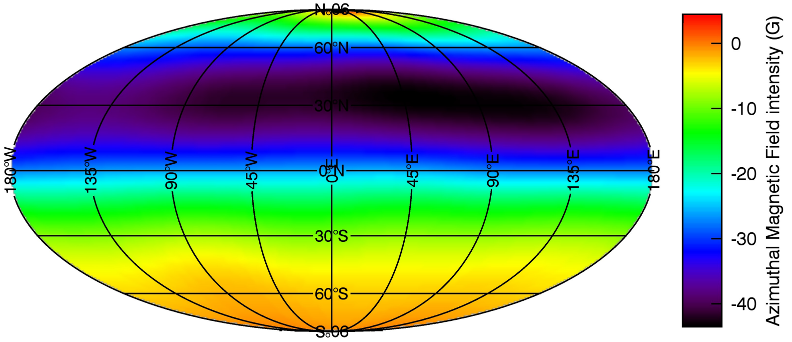


Strong toroidal fields are preferentially axisymmetric



The toroidal field is predominantly supported by azimuthal bands





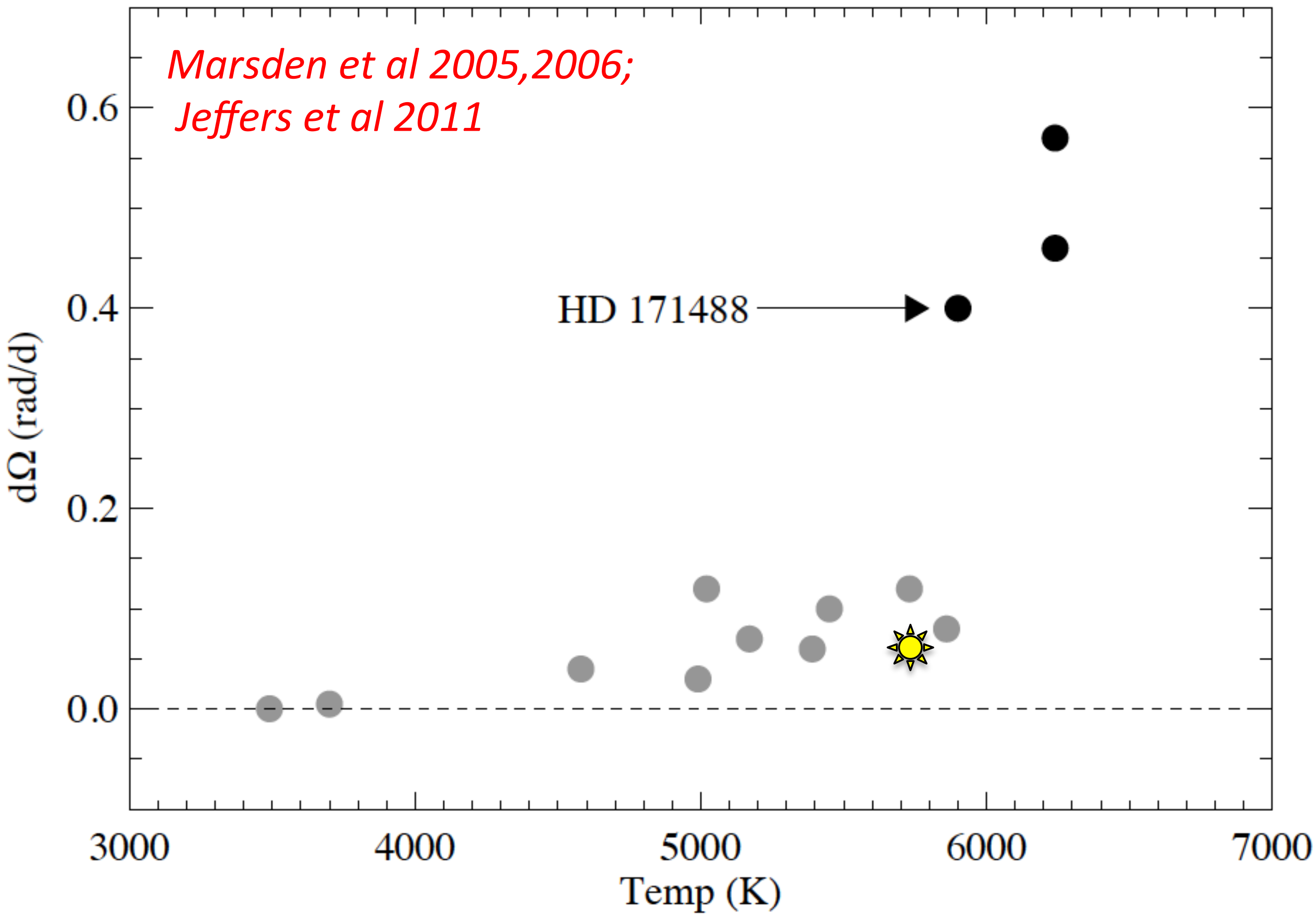
GJ 569a

These extend to higher latitudes in rapid rotators

What are the surface drivers of this field?

Differential rotation increases with mass (*Barnes +05,Reiners+06*).

-> The surfaces of hotter stars are sheared more rapidly than cooler stars



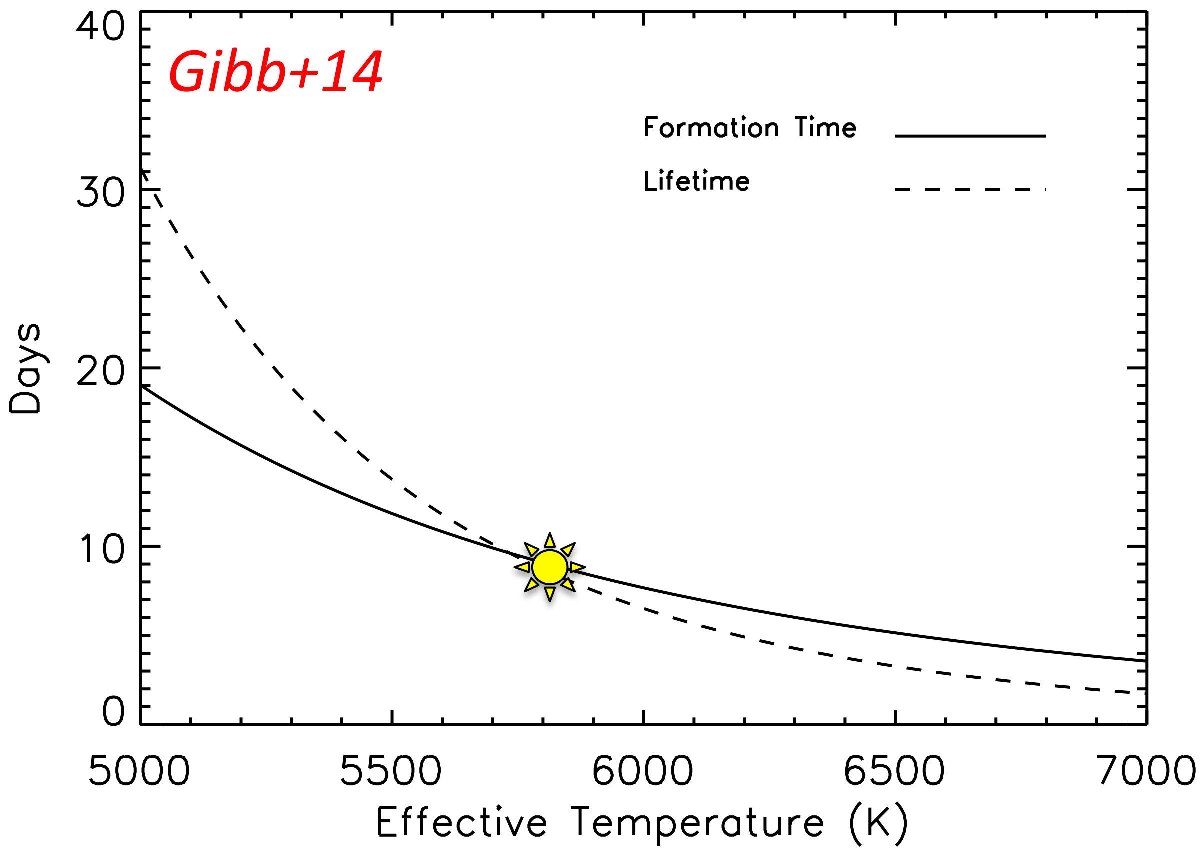
How does the corona respond as surface shear increases?

Pilot study (*Gibb+14*):

- Emerge a simple bipole through stellar surface
- Evolve coronal magnetic field with magnetofrictional approach (Yang 86)
- Track formation and evolution of flux ropes (blue) that are precursors to coronal mass ejections.

Higher surface shear -> more dynamic coronae

Hotter stars have more dynamic coronae



$d\Omega = 3.03[T_{eff}/5130\ K]^{8.6}$ deg/day (Collier Cameron 07)

Full-star, long term evolution

25 models, each evolved for 1 year:

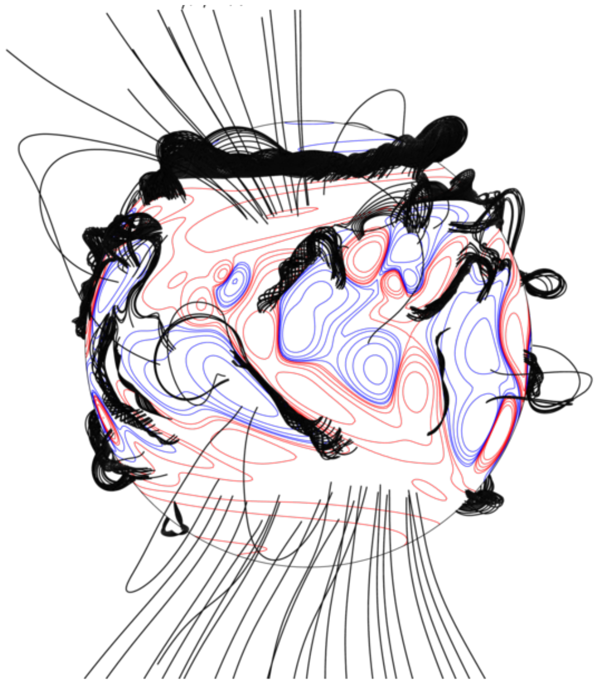
- (1-5) x solar flux emergence rate
- (1-5) x solar differential rotation

Resolution:

- Spatial: 1^o at equator, less at poles
- Temporal: 1 day

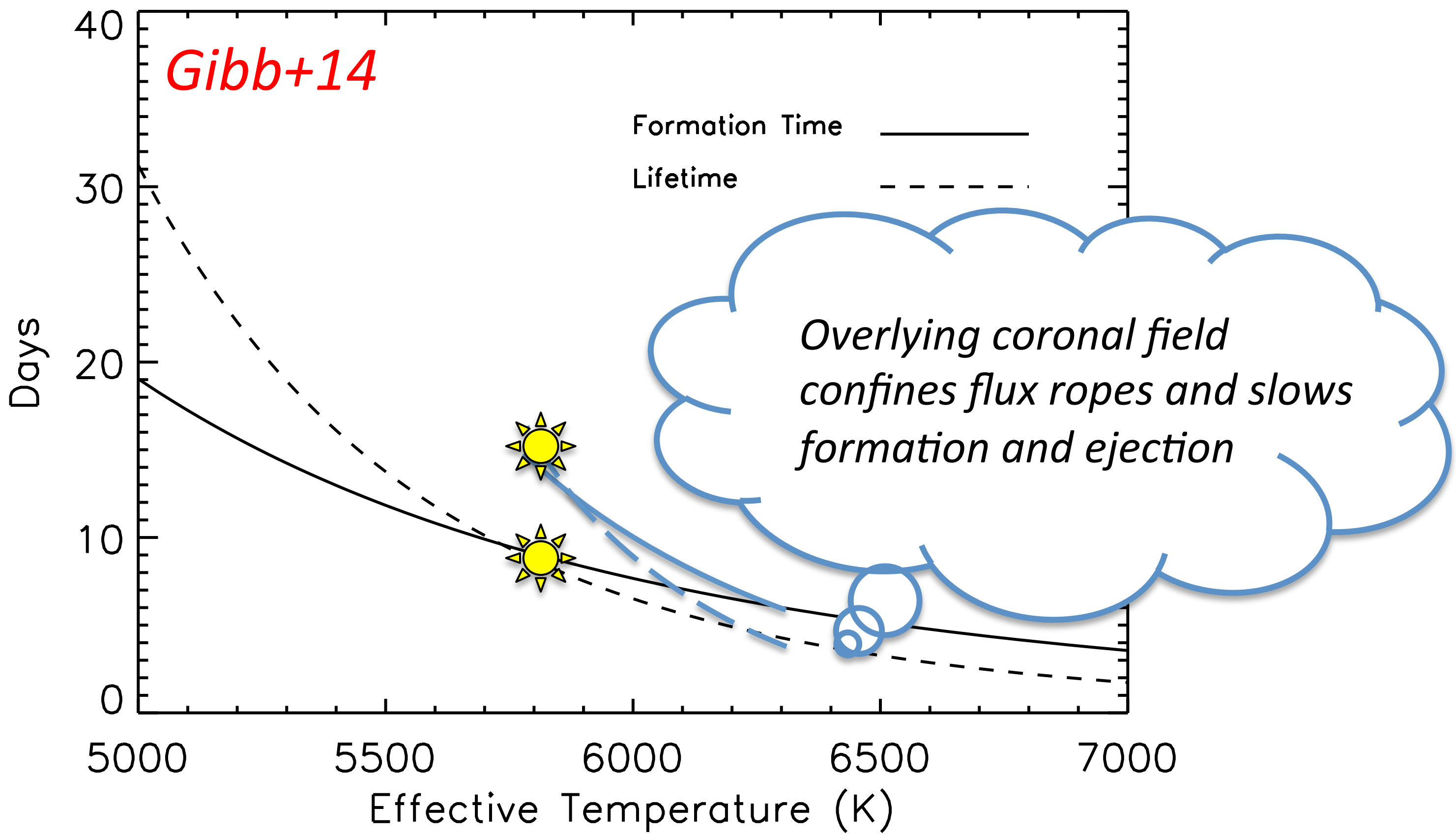
Boundary conditions:

- open at 2.5R_*, B_r at surface



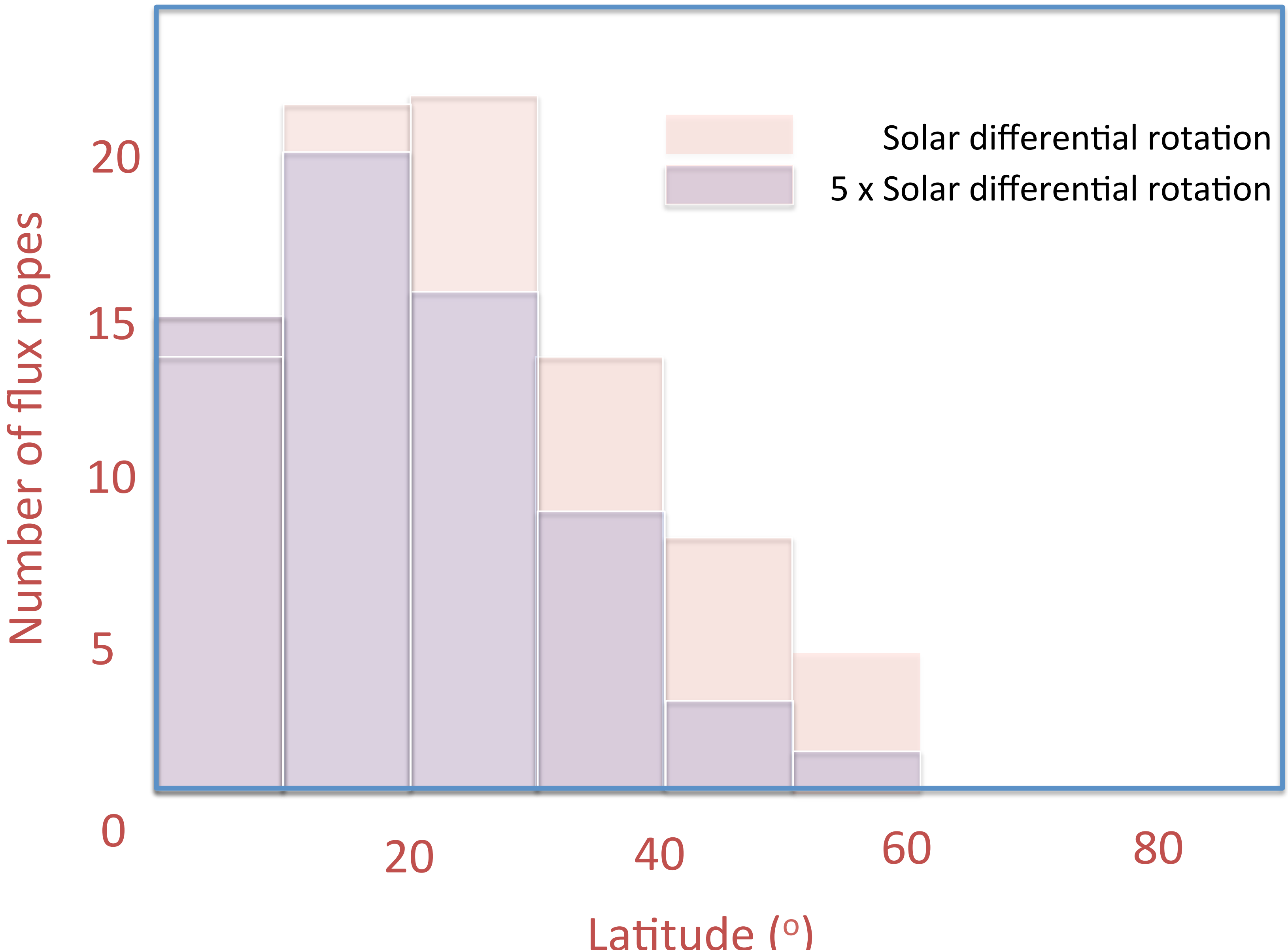
Gibb+16

Full-star, long term evolution also shows that hotter stars have more dynamic coronae.

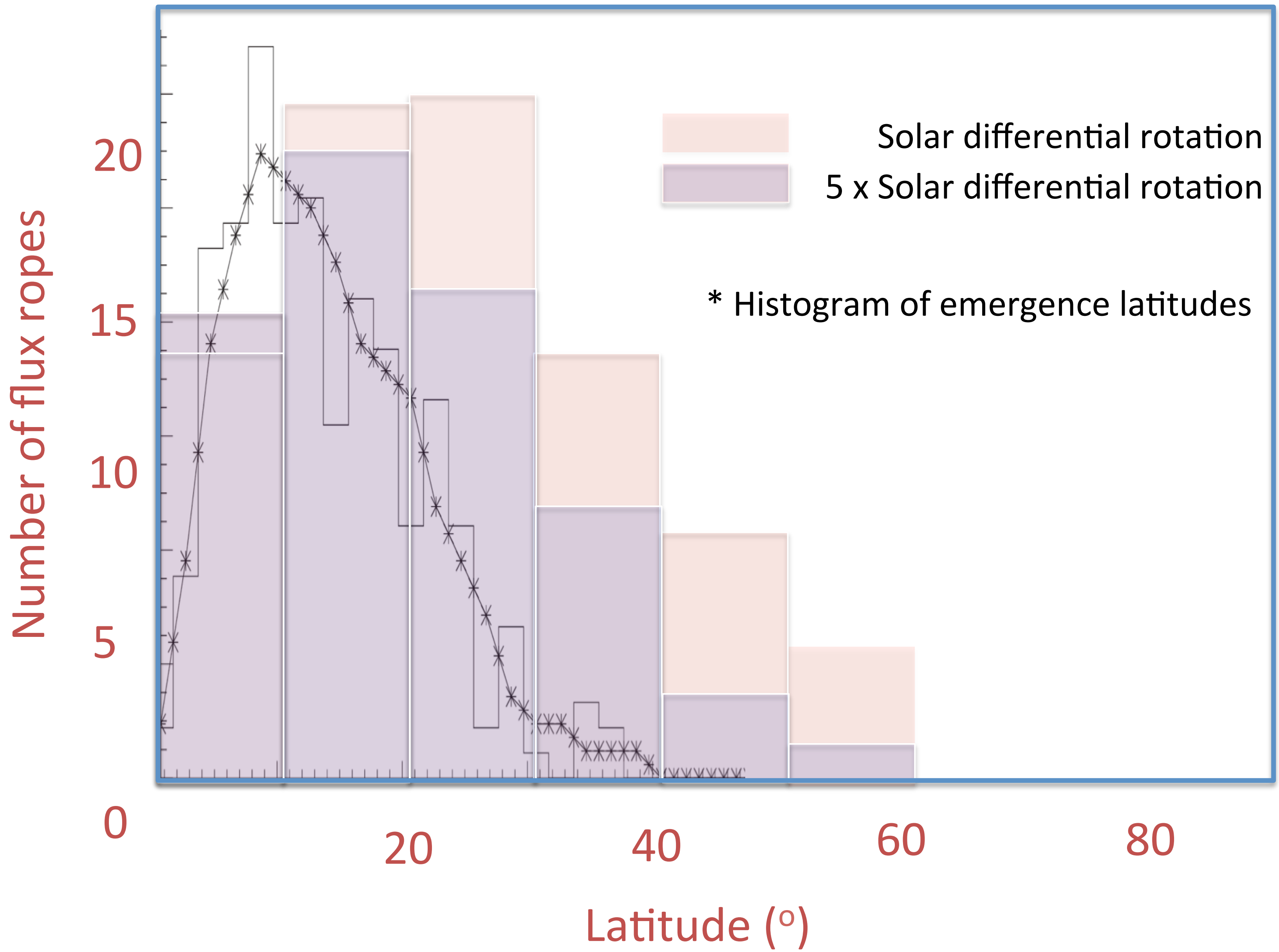


$d\Omega = 3.03[T_{eff}/5130\ K]^{8.6}$ deg/day (Collier Cameron 07)

Increased shear confines flux ropes to active belts



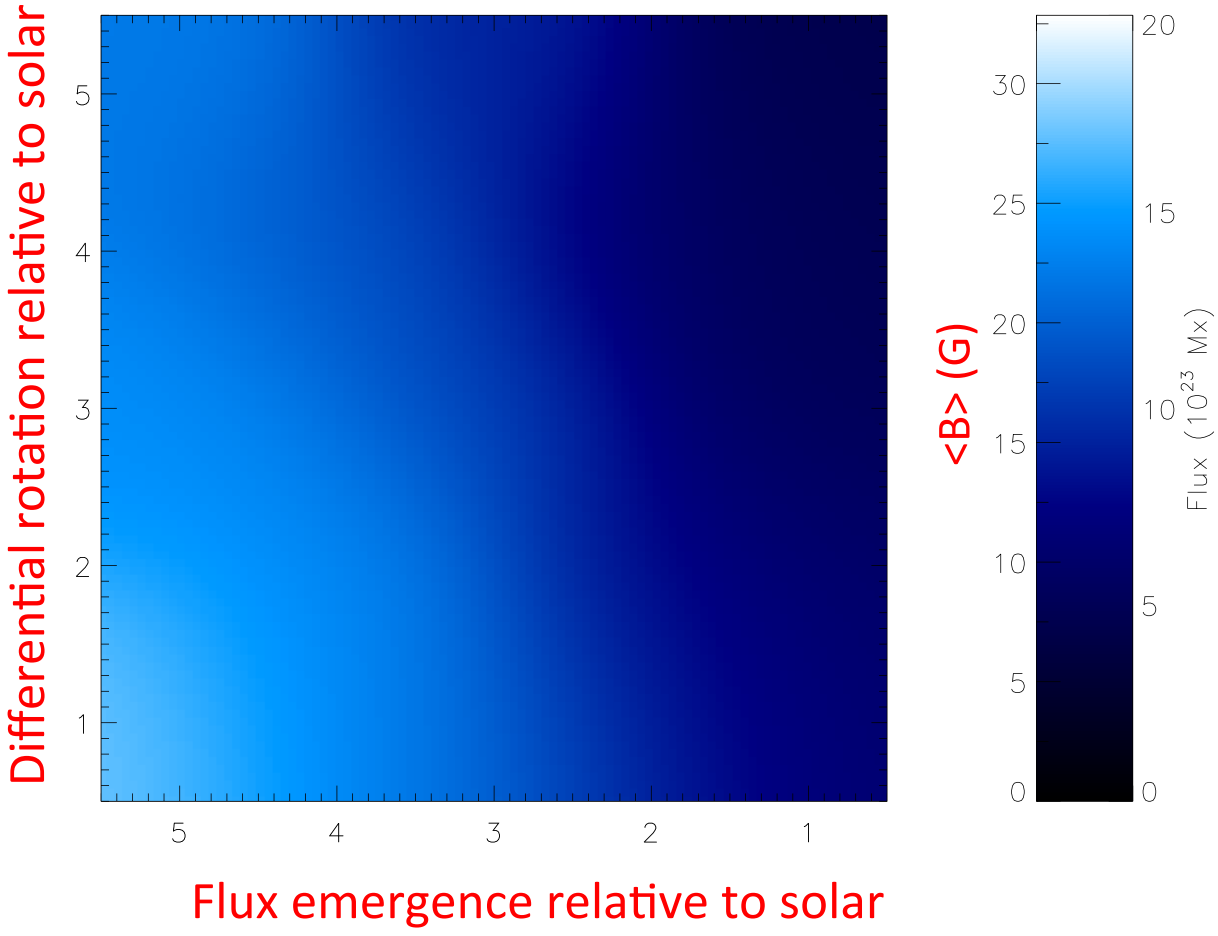
Increased shear confines flux ropes to active belts



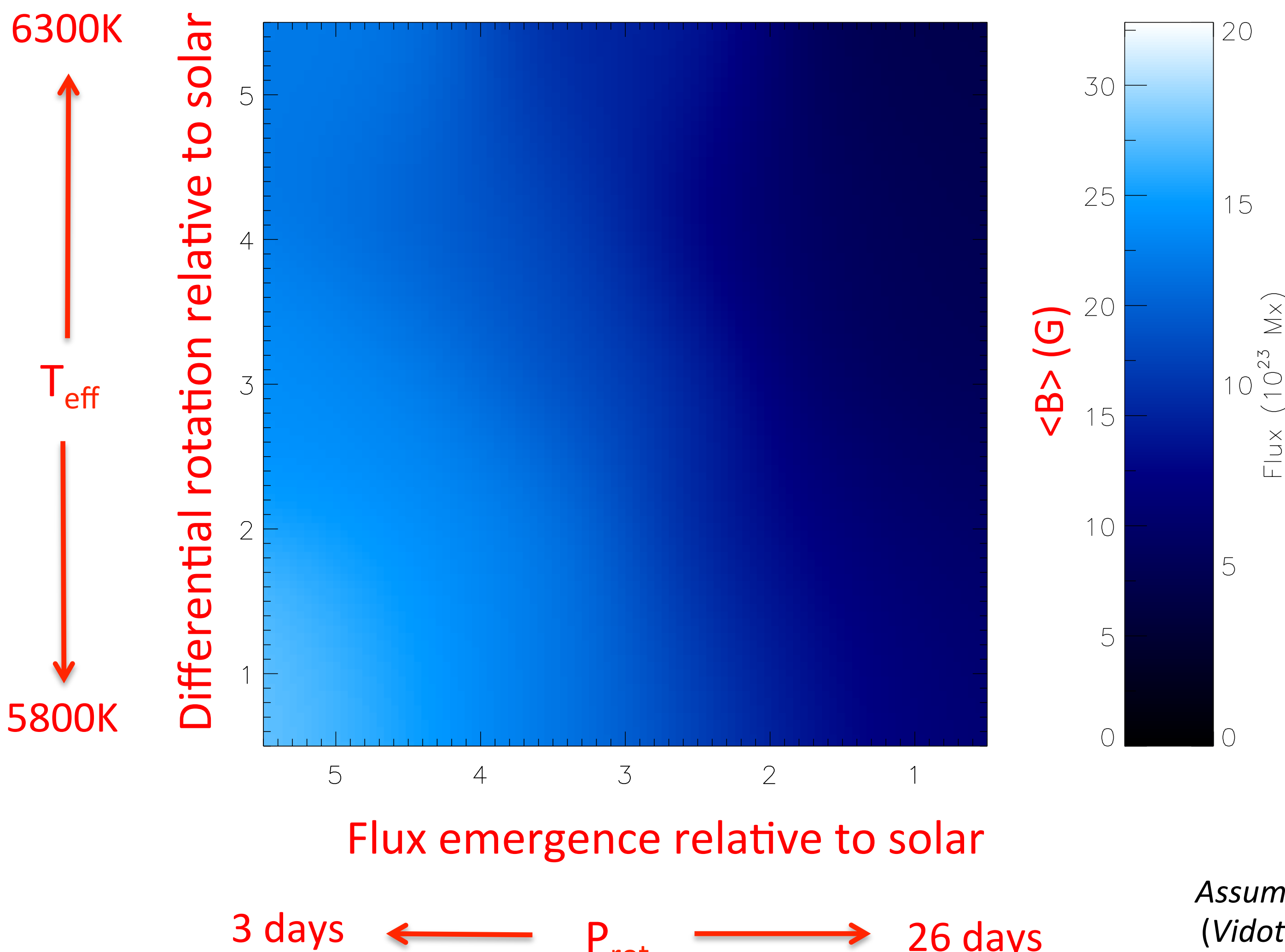
Increasing shear leads to a more open corona

5x solar differential rotation

<$B_{surface}$> *increases* with flux emergence rate …
….but *decreases* with increased shear

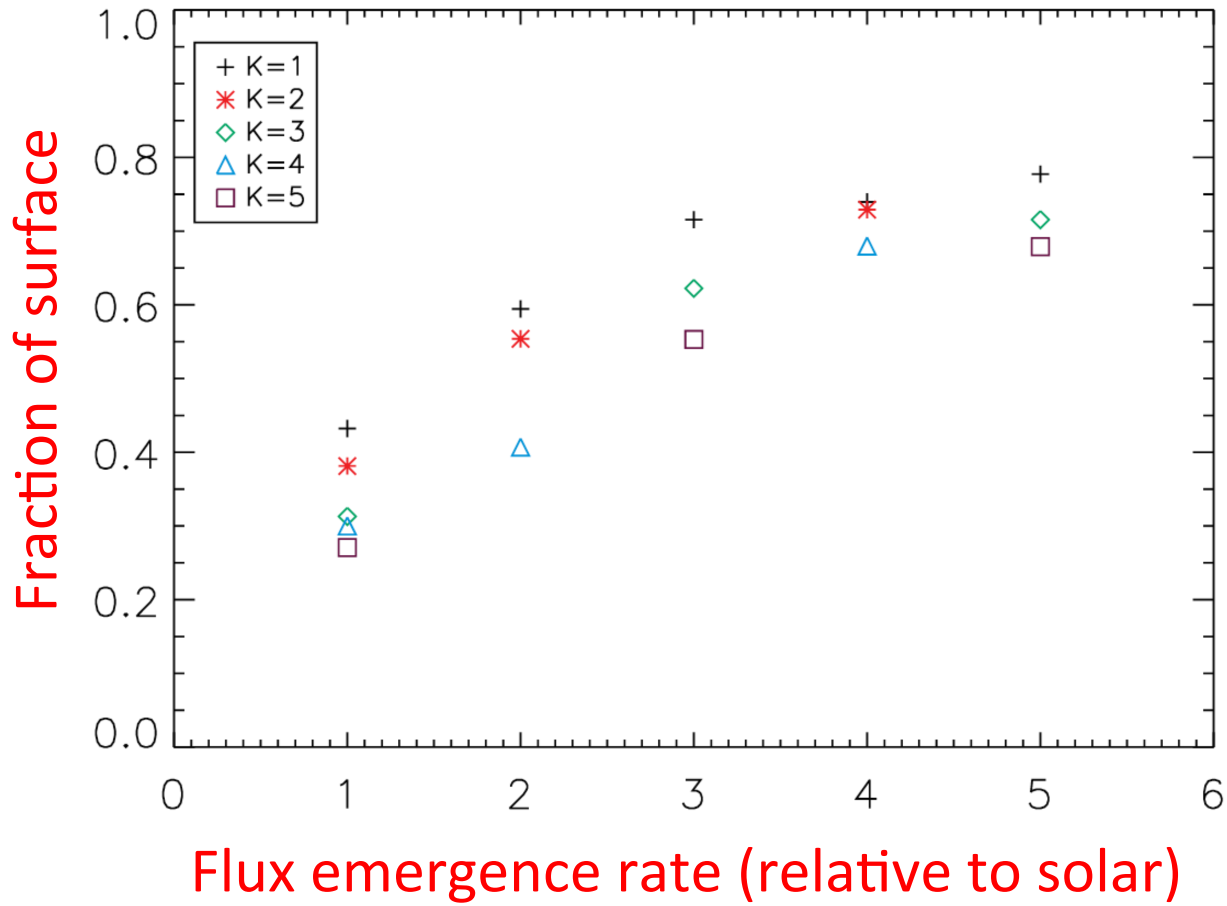


$\langle B_{surface} \rangle$ *increases* with flux emergence rate … ….but *decreases* with increased shear



Assuming <B> ~ $P_{rot}^{-1.32}$
(*Vidotto+14*)

Area with B >10G saturates for high activity…



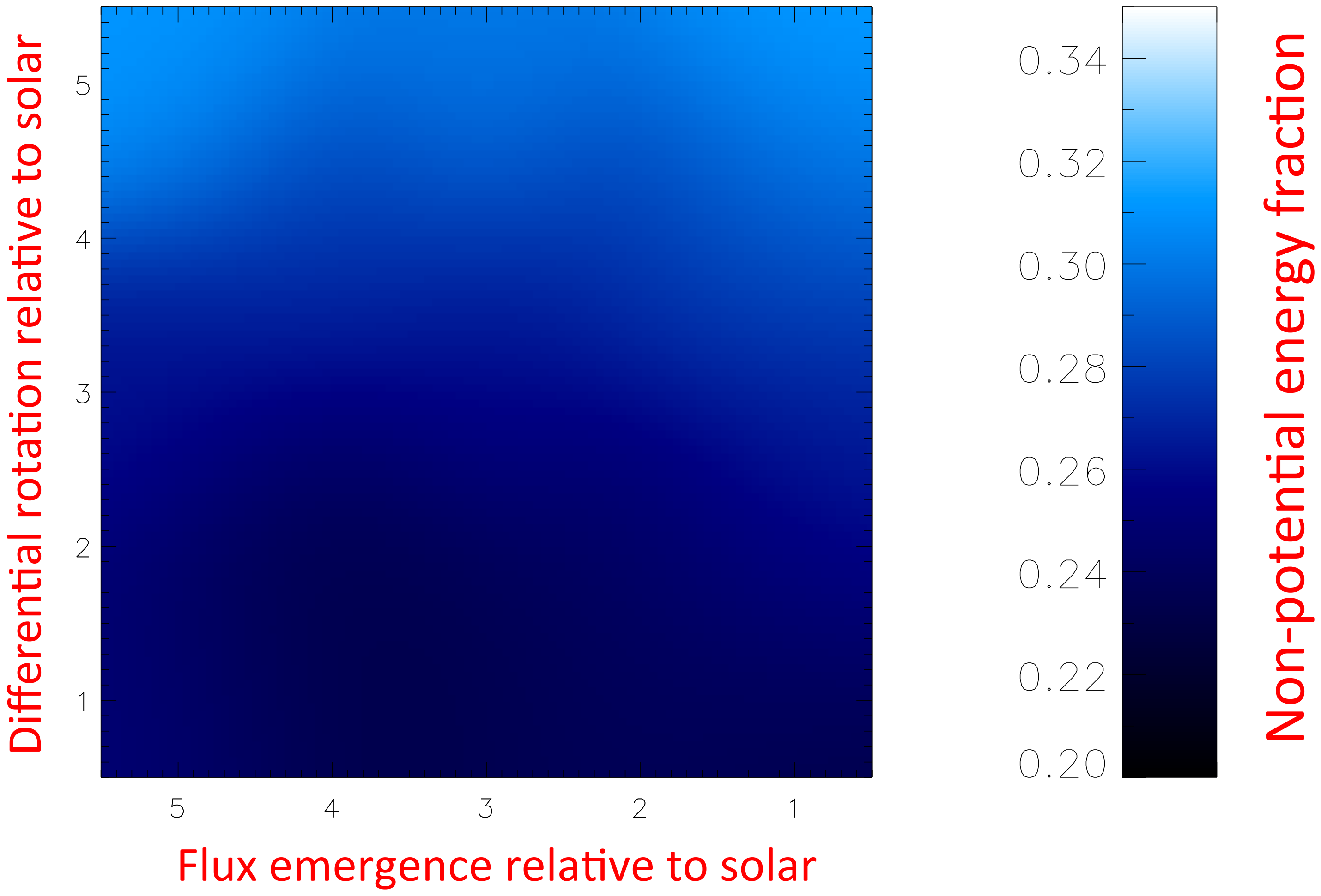
……but decreases with high shear…

At high emergence rates:

- Area of active regions saturates
  - flux emerges into existing active regions
- <B> does *not* saturate
- Emission proxy increases

5x solar flux emergence rate (<B> ~ 30G)

Highly sheared fields contain more free energy



At high shear rates corona has more:

- open flux
- free energy
- a greater eruption rate

5x solar emergence rate plus 5x solar differential rotation

What determines coronal evolution timescales?

Flux emergence rate governs total coronal energy

- *X-ray emission, wind power*

Differential rotation (shear) governs the coronal topology

- *Fraction of free energy, open flux*
- *Timescales for flux rope formation and ejection*