Magnetic Fields on Solar-Type Stars: The Solar-Stellar Connection

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Variability of Solar/Stellar Magnetic Activity, CS19

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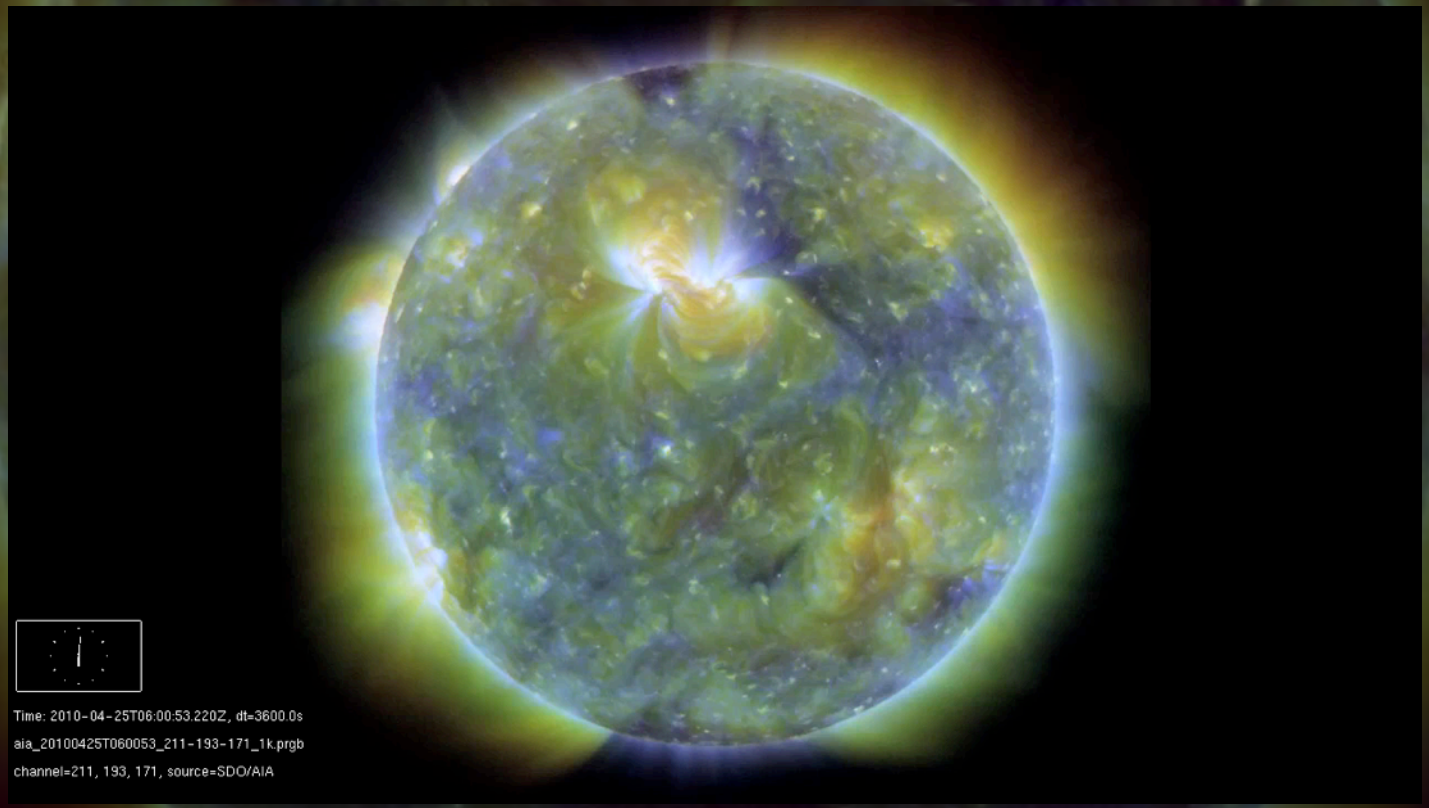
Our Star



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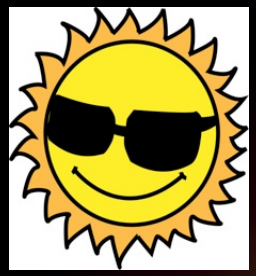
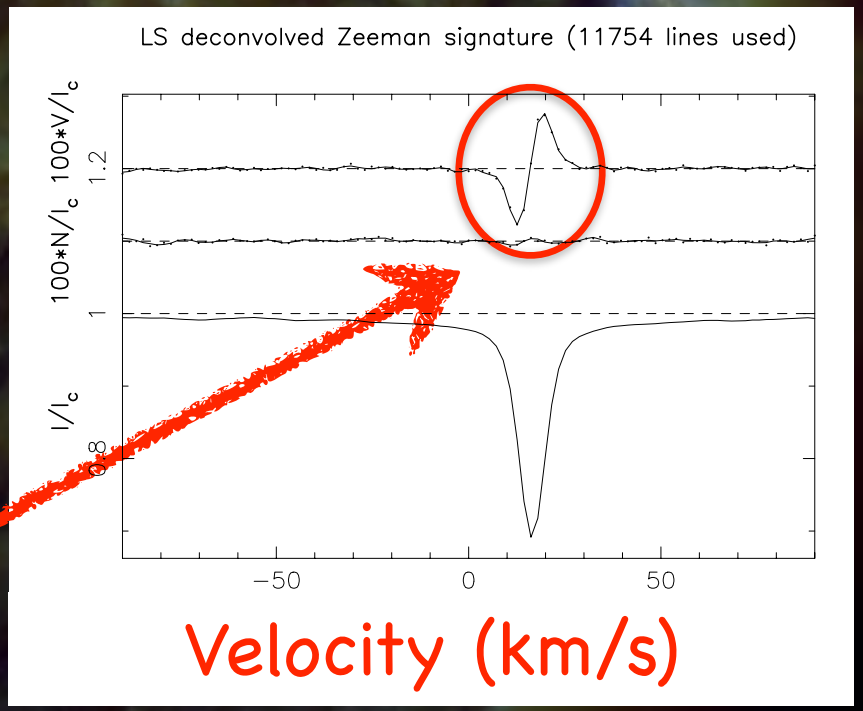


Detecting Magnetic Fields

Use spectropolarimetric (circular polarisation) observations of solar-type stars to detect the magnetic fields

- BCool has studied 200+ stars
- Mid-F to Mid-K
- Many mature stars
- Mostly Dwarfs

Magnetic field detections for ~40% of targets

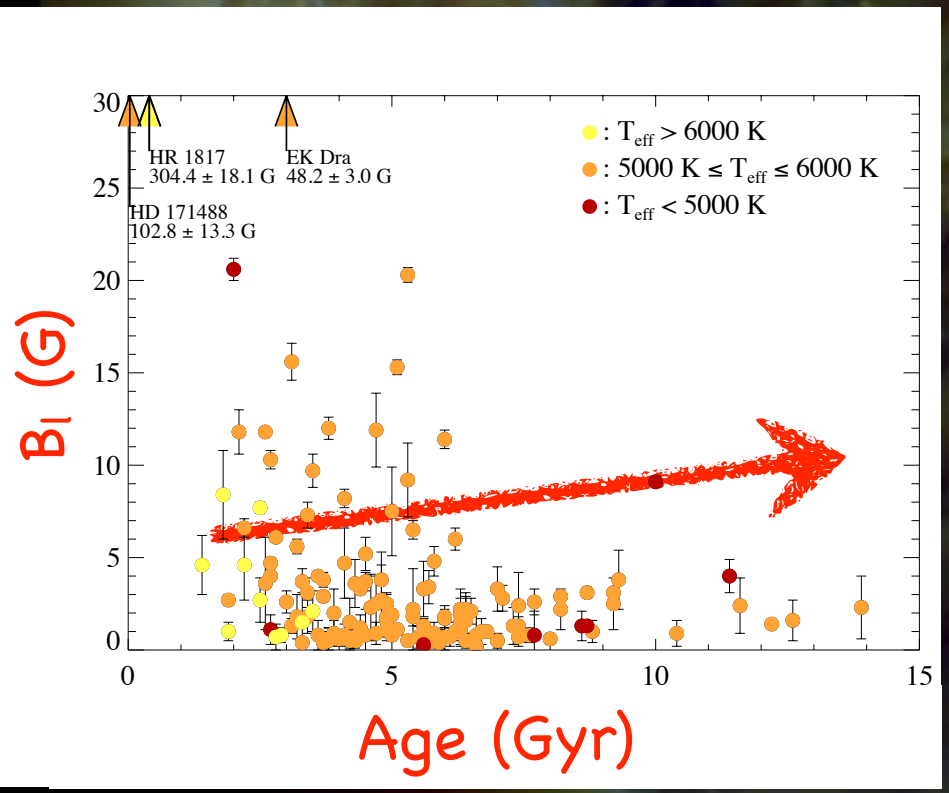


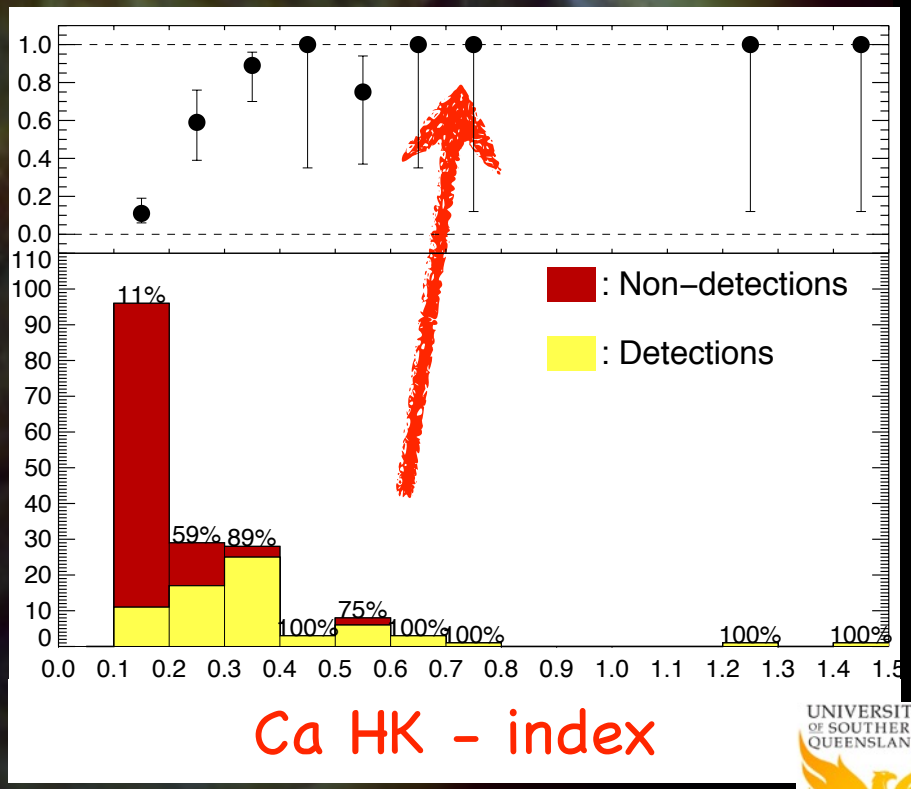
Epsilon Eridani - Marsden et al. (2014)

Snapshot Results

From a "snapshot" we can measure the mean surface field (B_l). B_l follows expected trends.

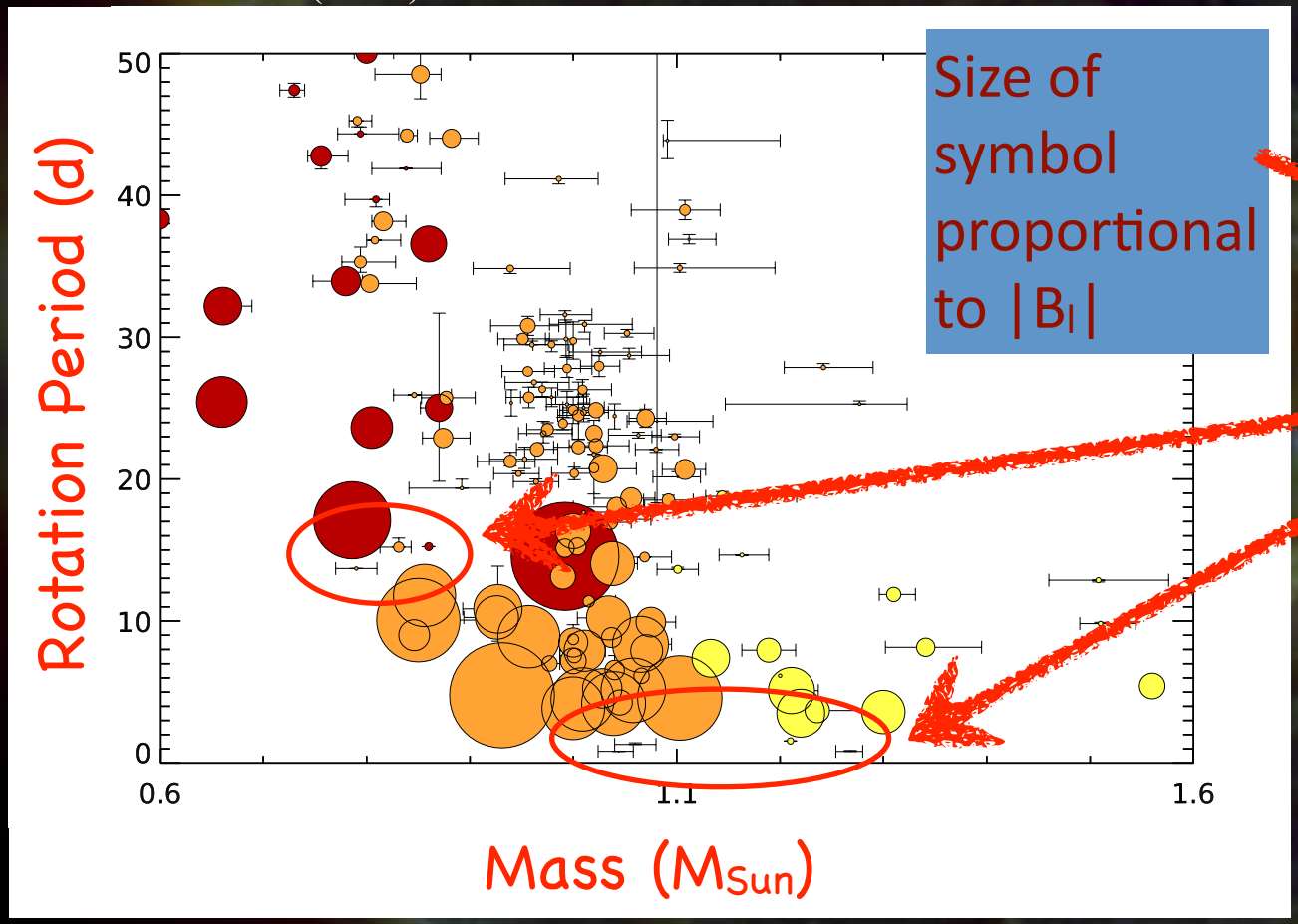
Marsden et al. (2014)





Mass vs. Rotation

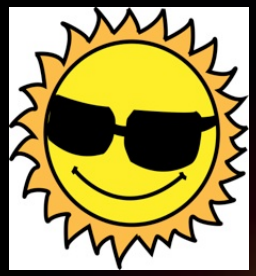
Marsden et al. (2014)



Shorter periods

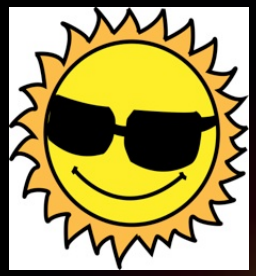
Stronger magnetic fields

Although not all fit this trend



Snapshot Summary

- 200+ solar-type stars observed with ~40% detections
- B_l tends to follow expected trends (decreases with age and rotation rate)
- Mean value of $|B_l|$ is 3.9 G for F-stars, 3.4 G for G-stars and 6.1 G for K-stars
- 20 new mature-age solar-type stars (> 2 Gyr) with mag. field detections (prior to this study only 5 known)

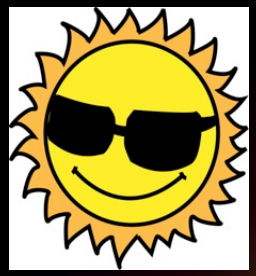


Mapping the Stars

In addition to the snapshot observations the surface magnetic field can be mapped using ZDI

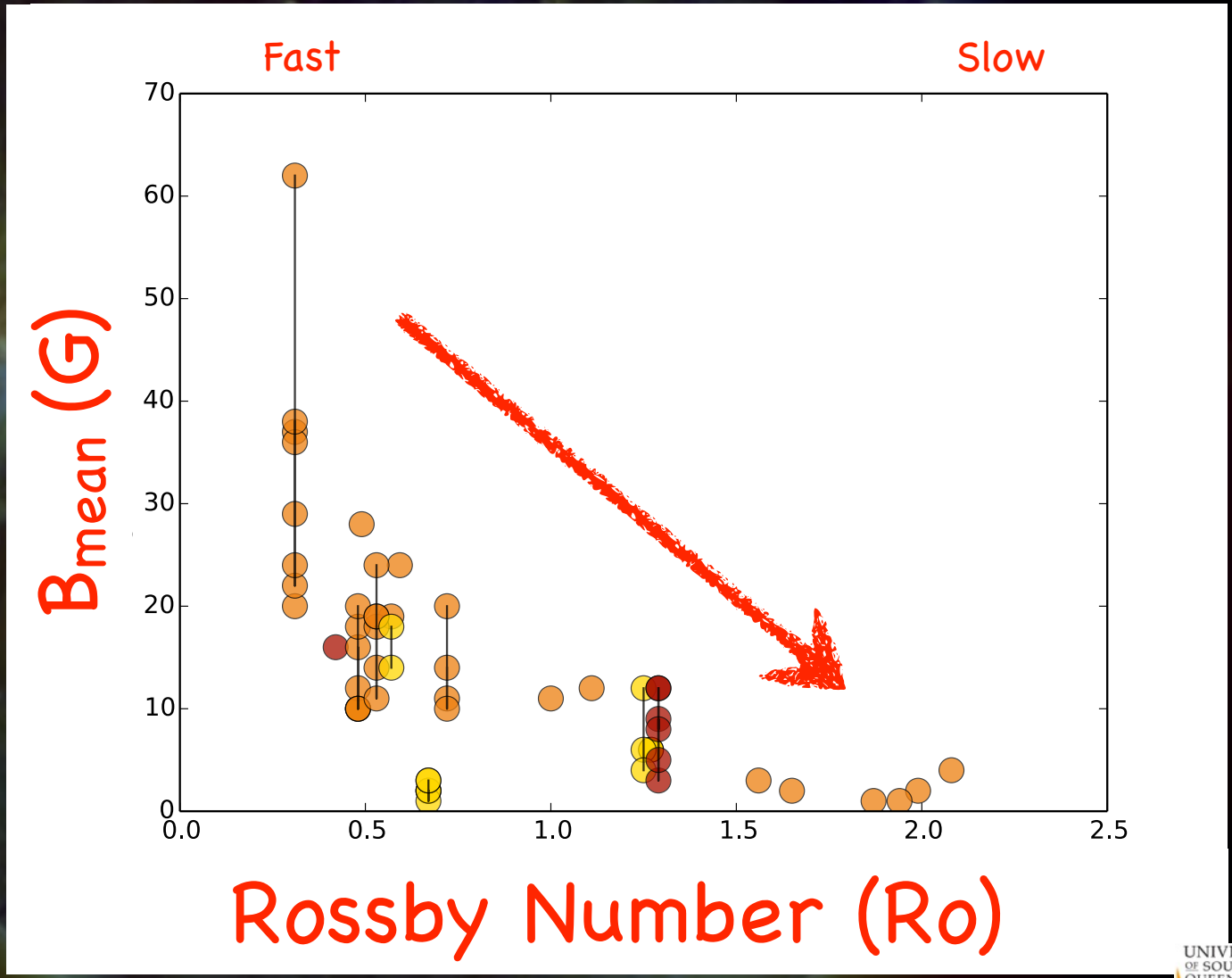
ZDI recovers the global/large scale magnetic field of these stars

A number of stars have been observed at multiple epochs so we can look for cyclic activity



Field Strength

The mean field strength decreases with Rossby number

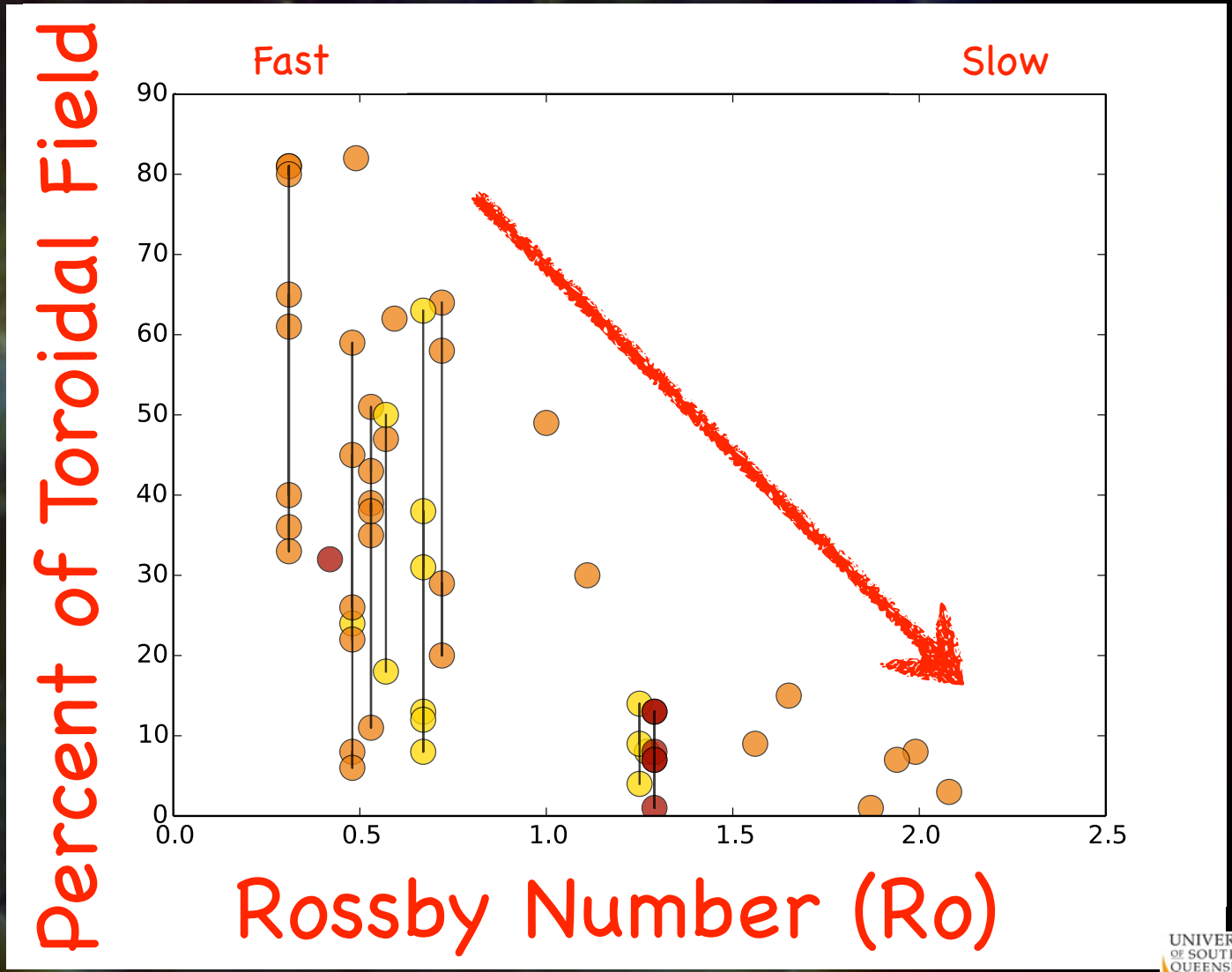


Petit et al. (in prep.)

Toroidal Field

Petit et al. (in prep.)

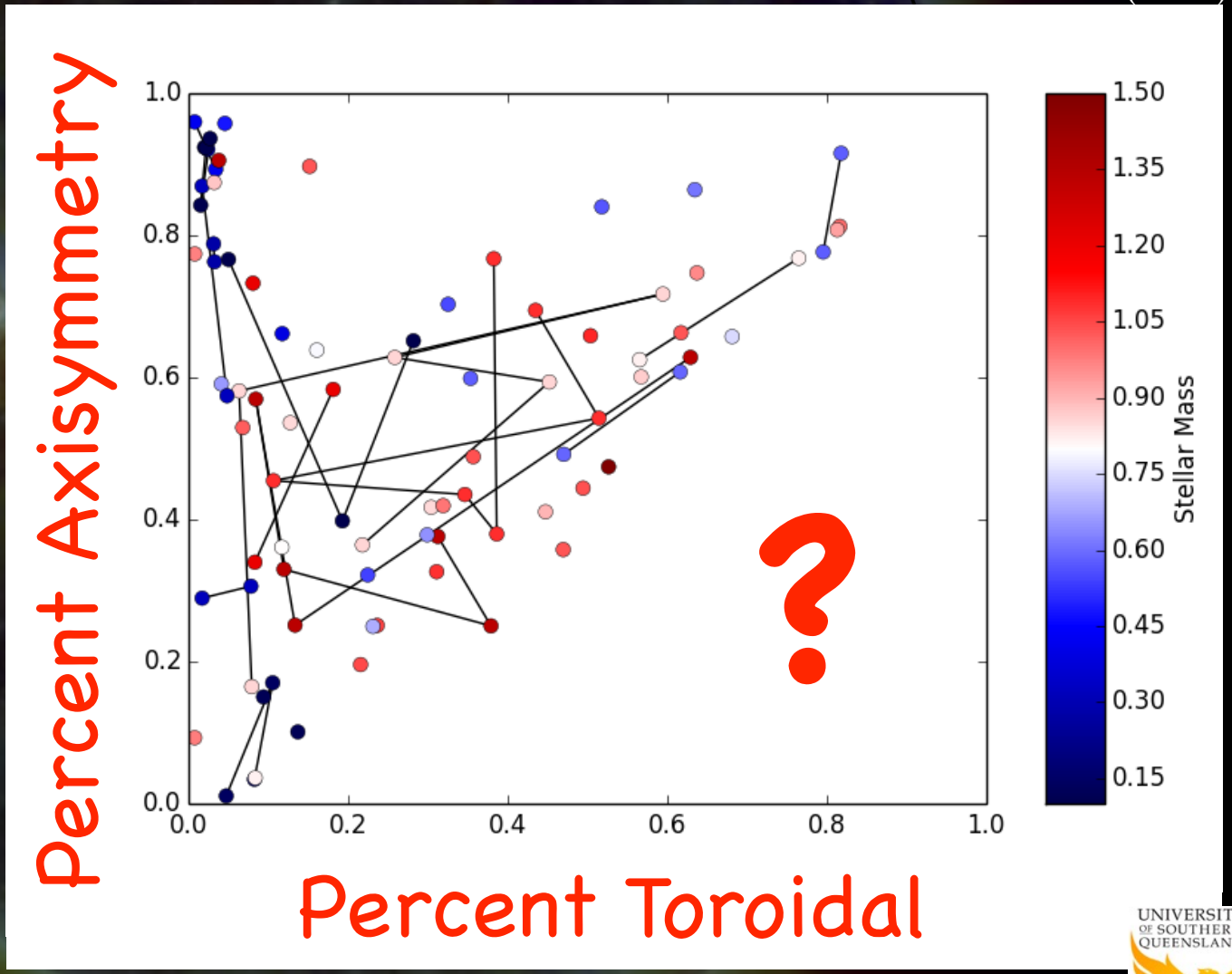
Same for the percent of the Toroidal field



Axisymmetry

See et al. (2015)

Increased Toroidal field appears to be Axisymmetric

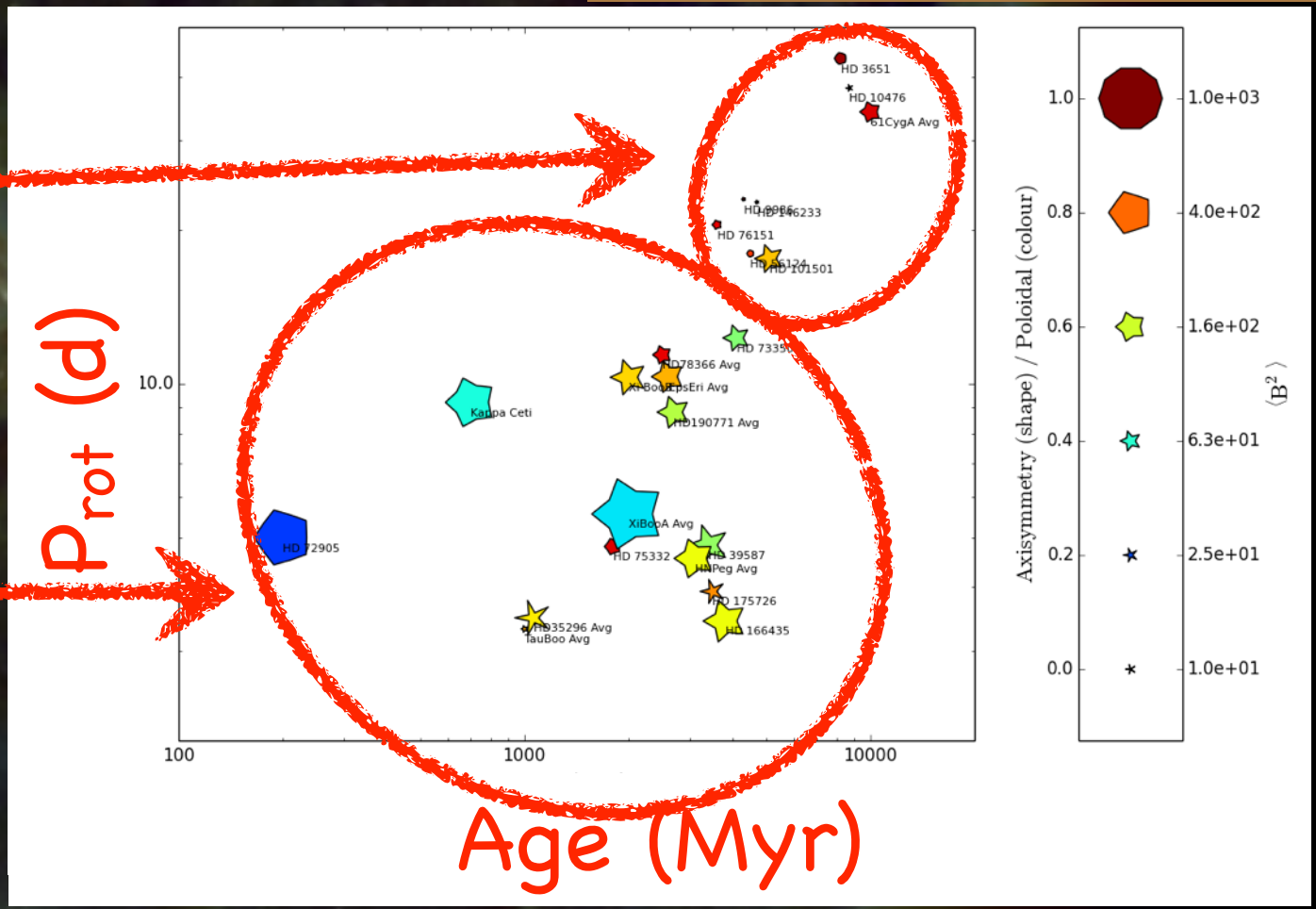


Field Topologies

Size: Field Strength,
Colour: Poloidal to Toroidal,
Shape: Poloidal field axisymmetric (●) to Poloidal field non-axissymmetric (★)

Older/slower stars have weaker, predominantly poloidal, field

Younger/faster stars have stronger fields with more toroidal component



Petit et al. (in prep.)

Simple Cycles

HD 78366 shows 2 polarity reversals, possibly indicating a magnetic cycle with a length around 3 years

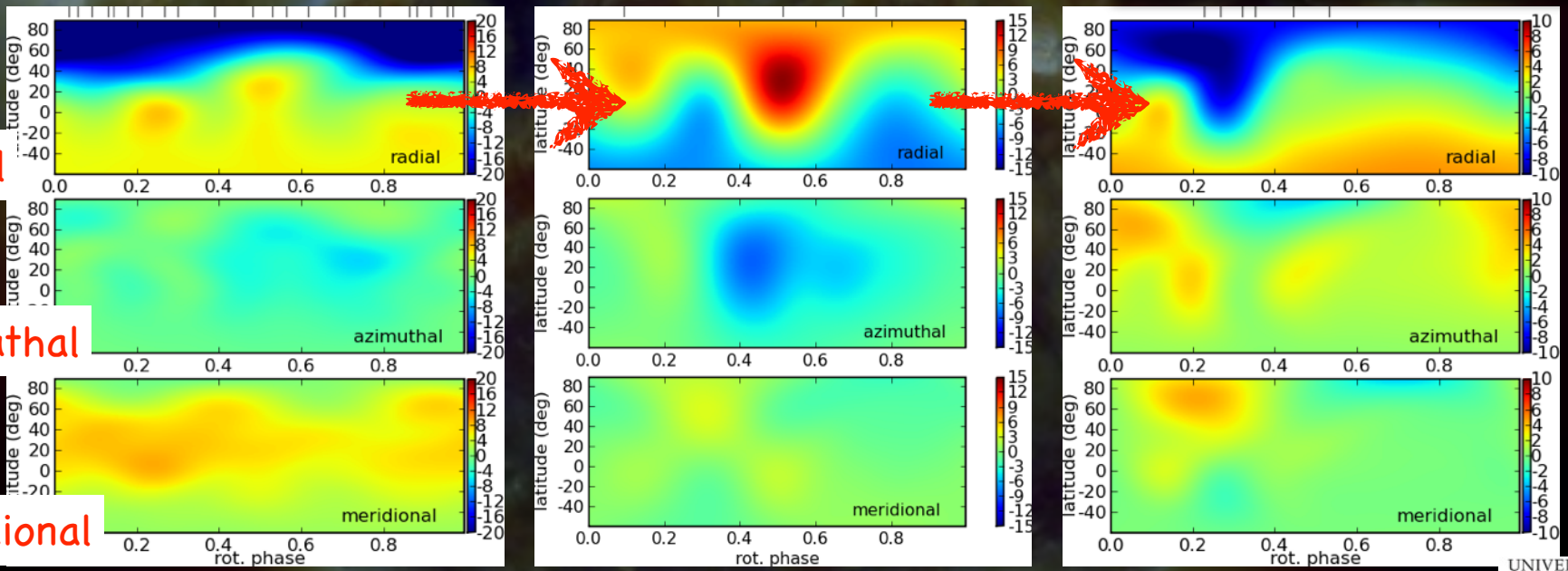
Morgenthaler et al. (2012)

HD 78366
$M = 1.34 \pm 0.13\ M_{Sun}$
$P_{rot} = 11.4 \pm 0.1$ days
$T_{eff} = 6014 \pm 50$ K
vsin(i) = 3.9 ± 0.5 km/s

Radial

Azimuthal

Meridional



Northern Winter 07/08 *Northern Winter 09/10* *Northern Winter 10/11*

Variability of Solar/Stellar Magnetic Activity, CS19

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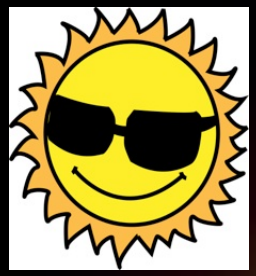
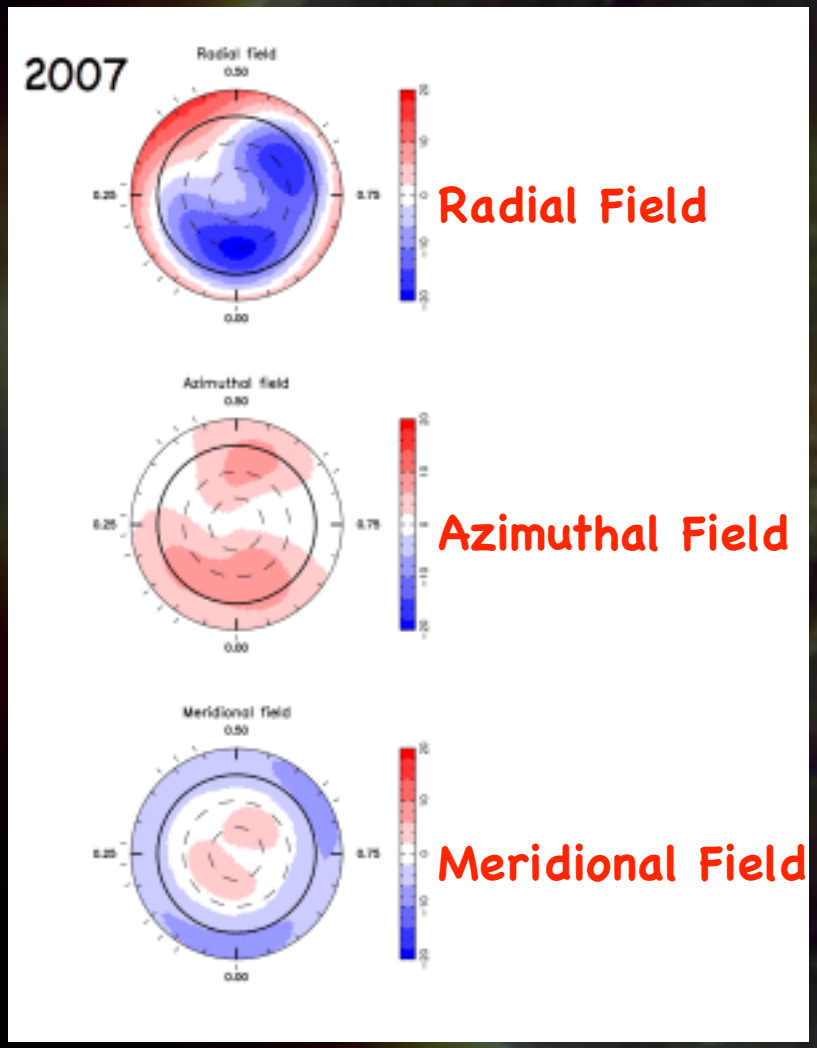


61 Cyg A

Boro Saikia et al. (2016)

HD 201091 (61 Cyg A)
$M = 0.66\ M_{Sun}$
$P_{rot} \sim 34$ days
$T_{eff} = 4545 \pm 40$ K
vsin(i) ~ 1.0 km/s



Radial Field

Azimuthal Field

Meridional Field

Shows a simple magnetic cycle :

- Polarity reversal in both Rad. and Azi. fields
- Follows Ca HK cycle (and coronal cycle)
- Increased complexity before reversal

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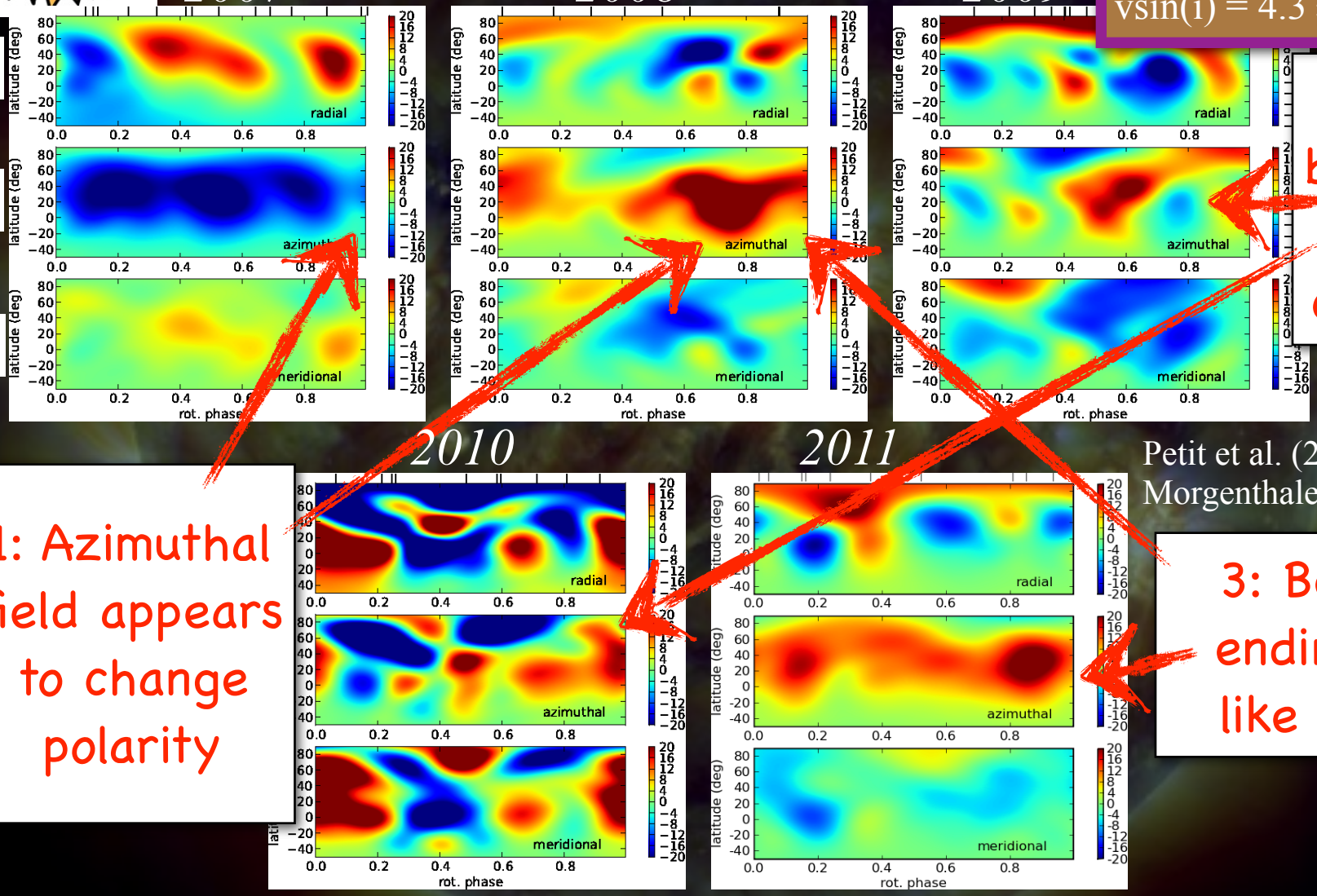
Complex Variability

HD 190771
$M = 0.96 \pm 0.13\ M_{Sun}$
$P_{rot} = 8.8 \pm 0.1$ days
$T_{eff} = 5834 \pm 50$ K
vsin(i) = 4.3 ± 0.5 km/s

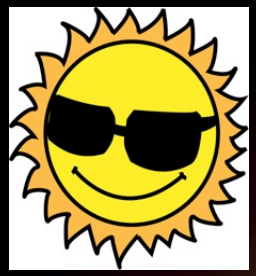


2: Then becomes more complex

1: Azimuthal field appears to change polarity

3: Before ending up like 2008

Petit et al. (2009), Morgenthaler et al (2011)

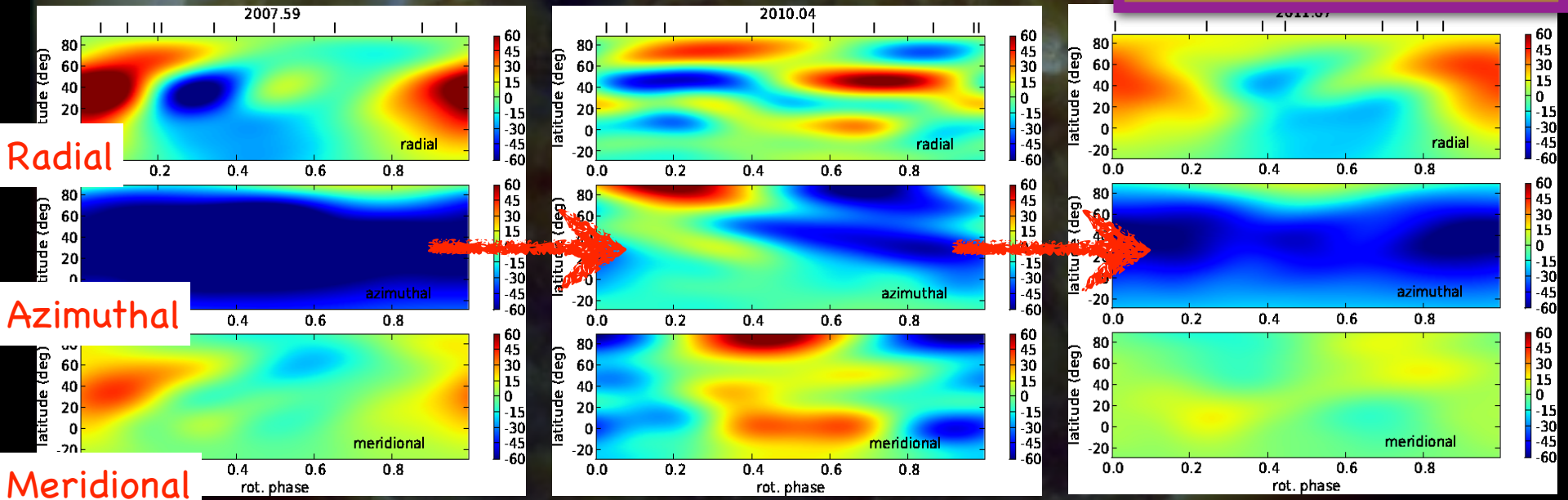


No Polarity Switch?

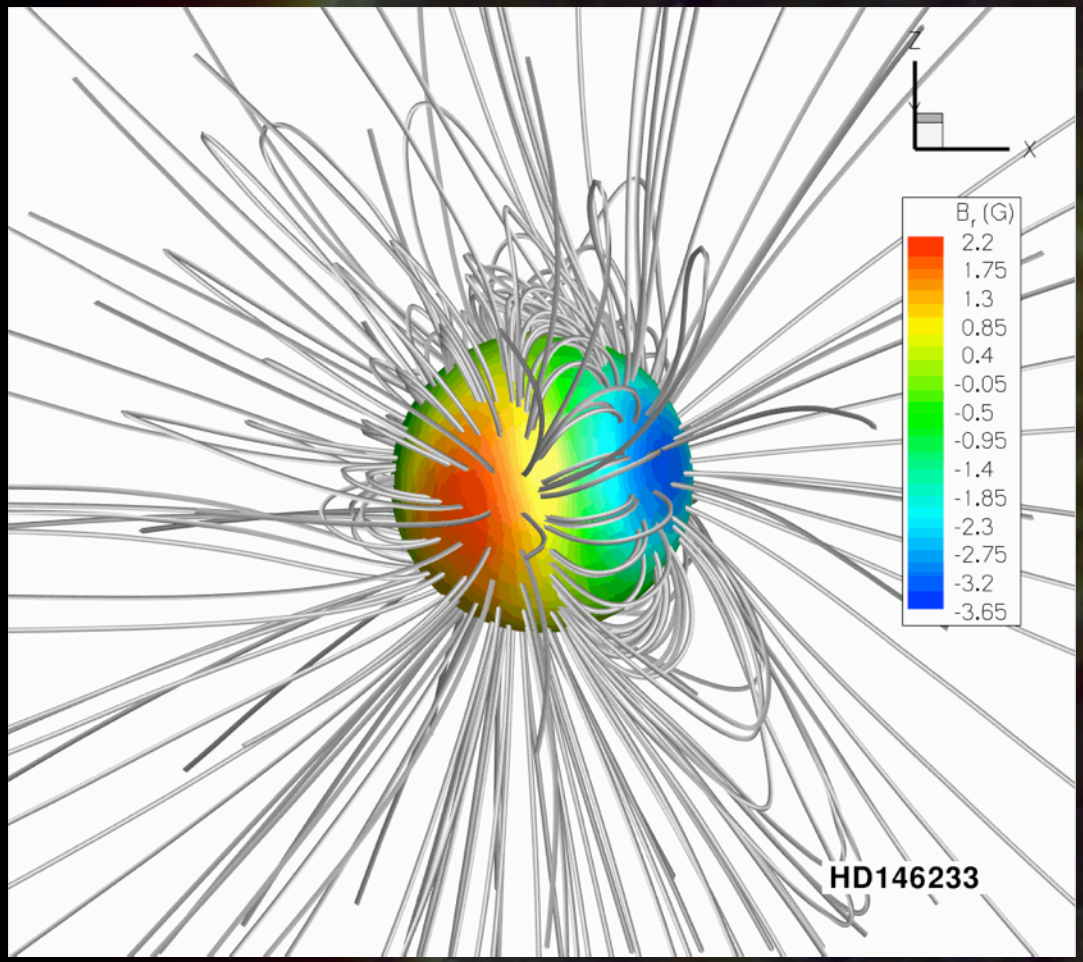
Morgenthaler et al. (2012)

The Azimuthal magnetic field of ξ Bootis A appears to show temporal variability, but no polarity switch (yet)

HD 131156A (Xi Boo A)
$M = 0.86 \pm 0.07\ M_{Sun}$
$P_{rot} \sim 6$ days
$T_{eff} = 5550 \pm 20$ K
$v\sin(i) = 3.0 \pm 0.4$ km/s



MHD models



Vidotto et al. (in prep.)

From the radial field maps the fields lines are extrapolated into the corona

From these MHD models can be used to model the stellar wind

HD 146233 (18 Sco)
$M = 0.98 \pm 0.13\ M_{Sun}$
$P_{rot} = 22.7 \pm 0.5$ days
$T_{eff} = 5791 \pm 50$ K
$vsin(i) = 2.1 \pm 0.5$ km/s

Space Weather

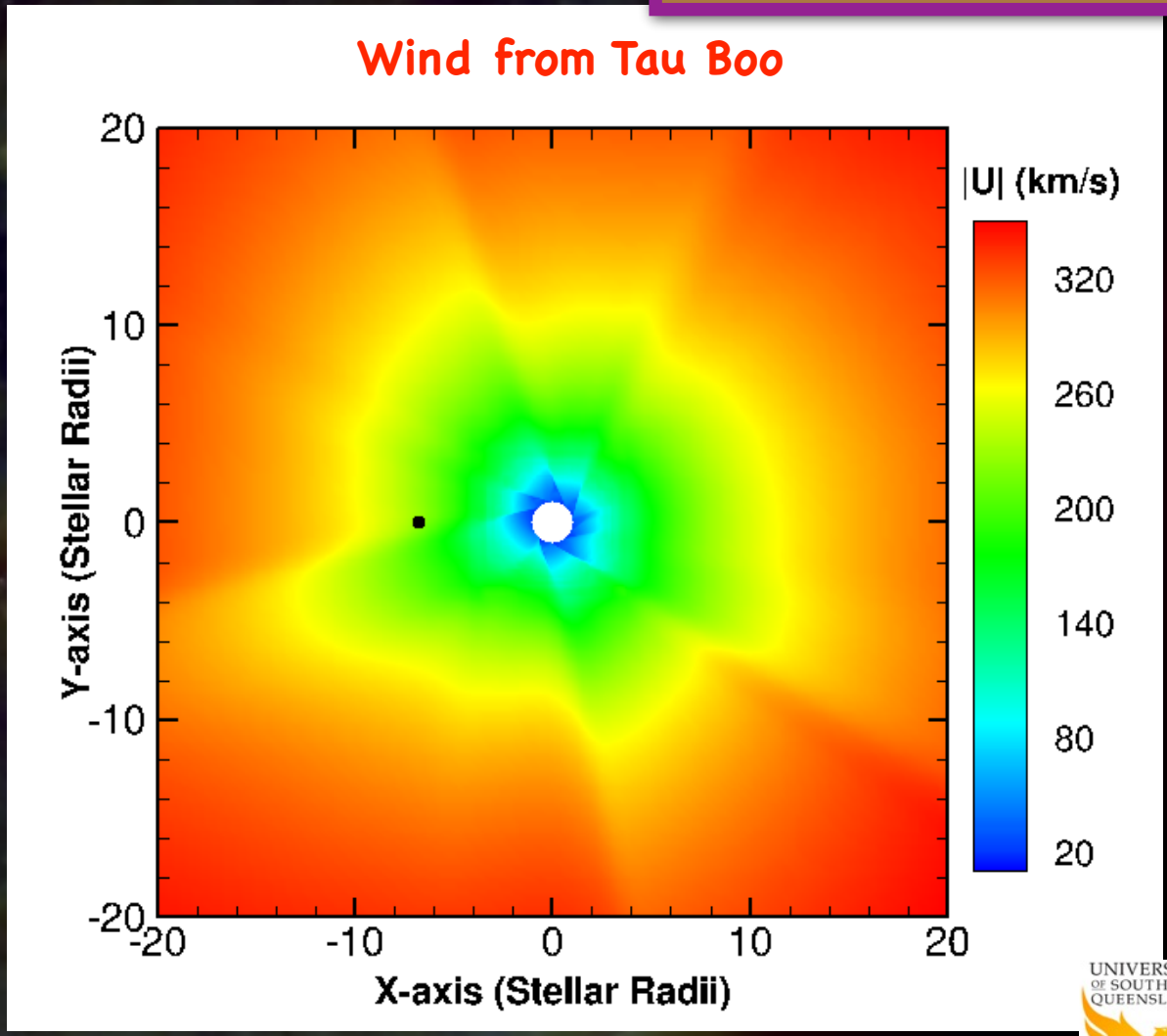
Nicholson et al. (2016) (Poster 64)

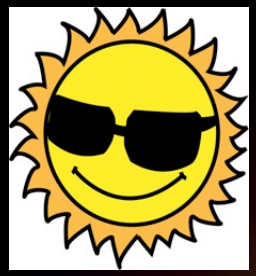
HD 120136 (Tau Boo)
$M = 1.39 \pm 0.25\ M_{Sun}$
$P_{rot} = 3.31$ days
$T_{eff} = 6399 \pm 45$ K
$v\sin(i) = 14.27 \pm 0.06$ km/s

Extending the magnetic field lines outwards

Stellar wind map

This wind impacts on the evolution and habitability of exoplanets





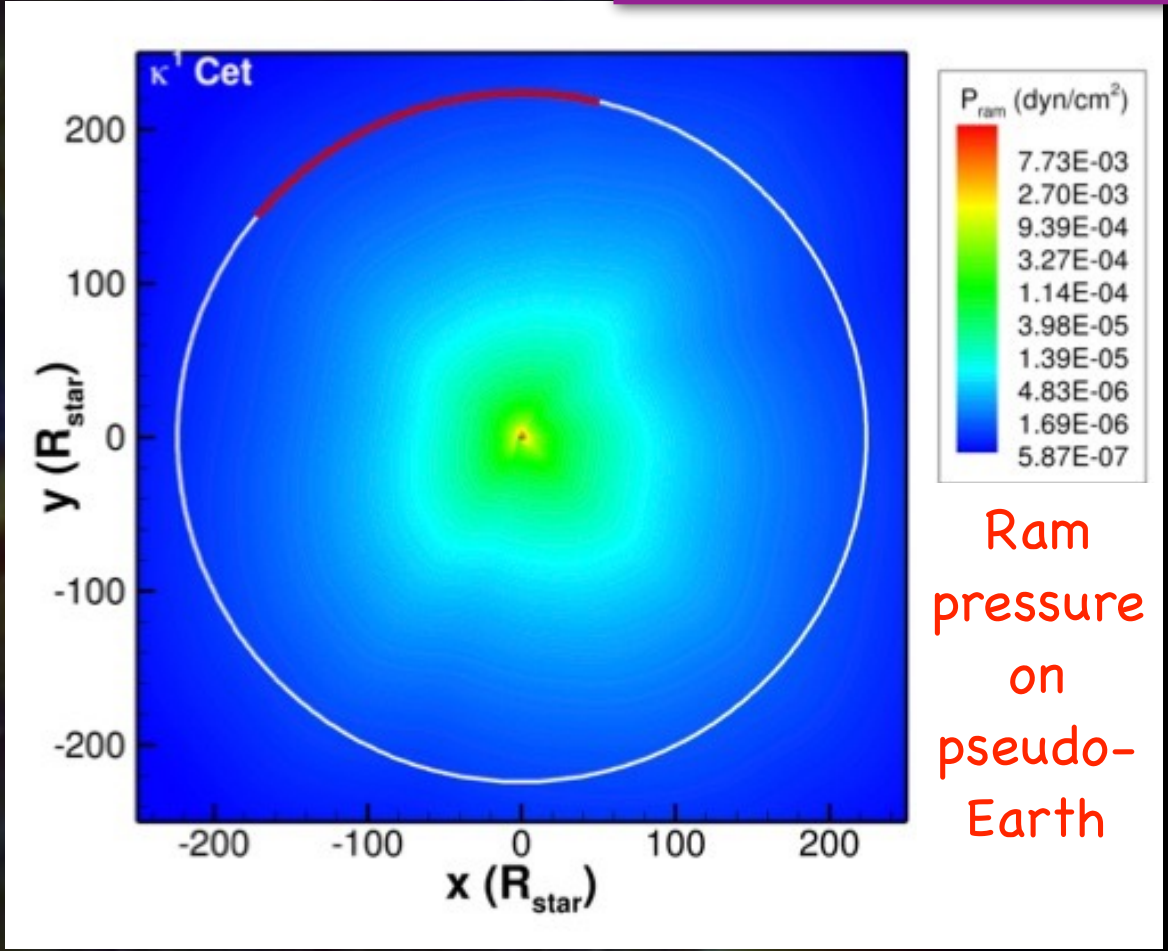
Kappa Ceti

HD 20630 (Kappa Cet)
$M = 1.02 \pm 0.02\ M_{Sun}$
$P_{rot} = 8.8 \pm 0.8$ days
$T_{eff} = 5780 \pm 30$ K
vsin(i) ~ 5 km/s

Kappa Ceti: ~1M_{SUN}, 500 to 900 Myr old

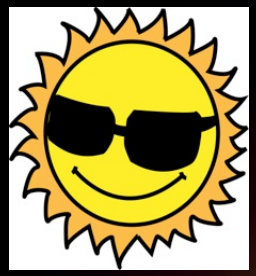
Close to age of Sun when life could have started on Earth

Mass loss rate 50 times the current Solar value



Ram pressure on pseudo-Earth

do Nascimento, Jr. et al. (2016)



Conclusions

- The mean field strength and precent of toroidal field decreases with Rossby number
- Stars similar to the Sun have weak poloidal fields
- Different types (simple, complex, etc.) of cycles may be evident in solar-type stars
- Fast polarity switches appear to occur on rapid rotators
- Only one star (61 Cyg A) found (so far) that has a magnetic cycle like the Sun
- Strong winds from young active stars

Thank you for your attention!

Questions?