

Constraints on Dynamo Evolution from Spectropolarimetry of Solar Analogs

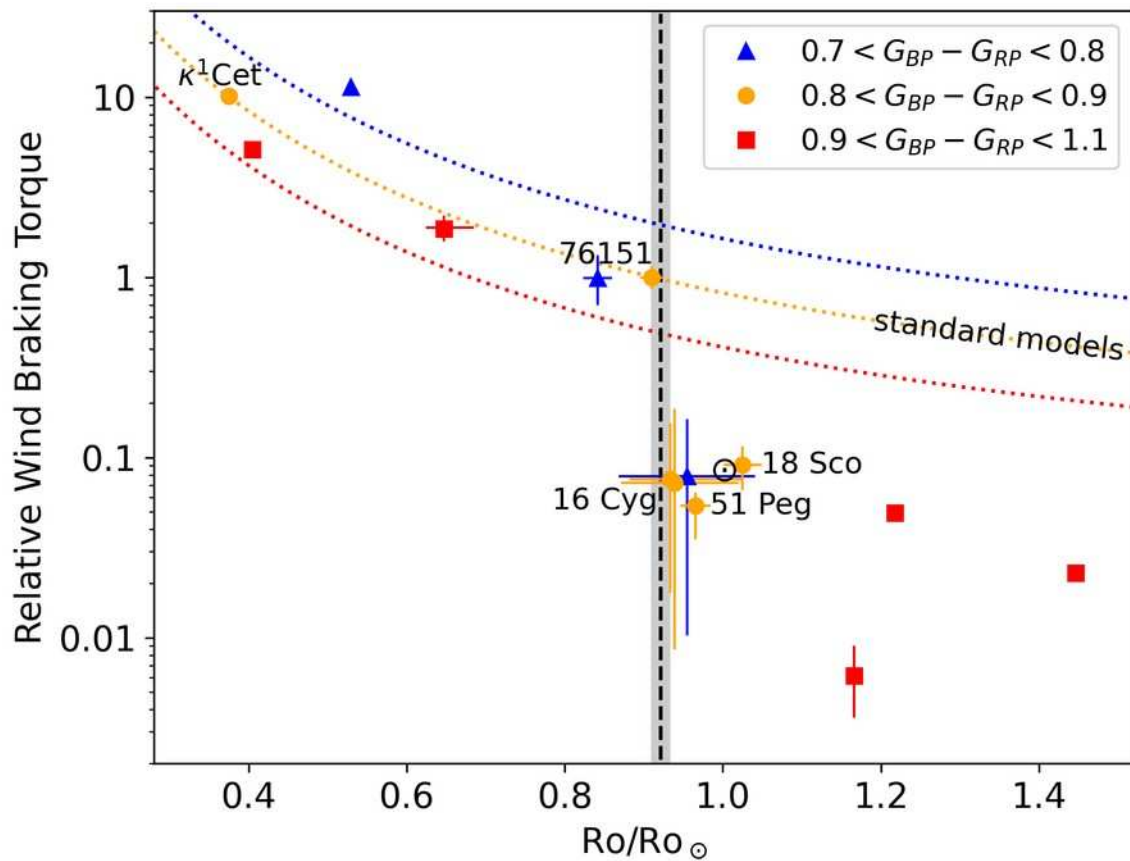
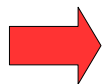
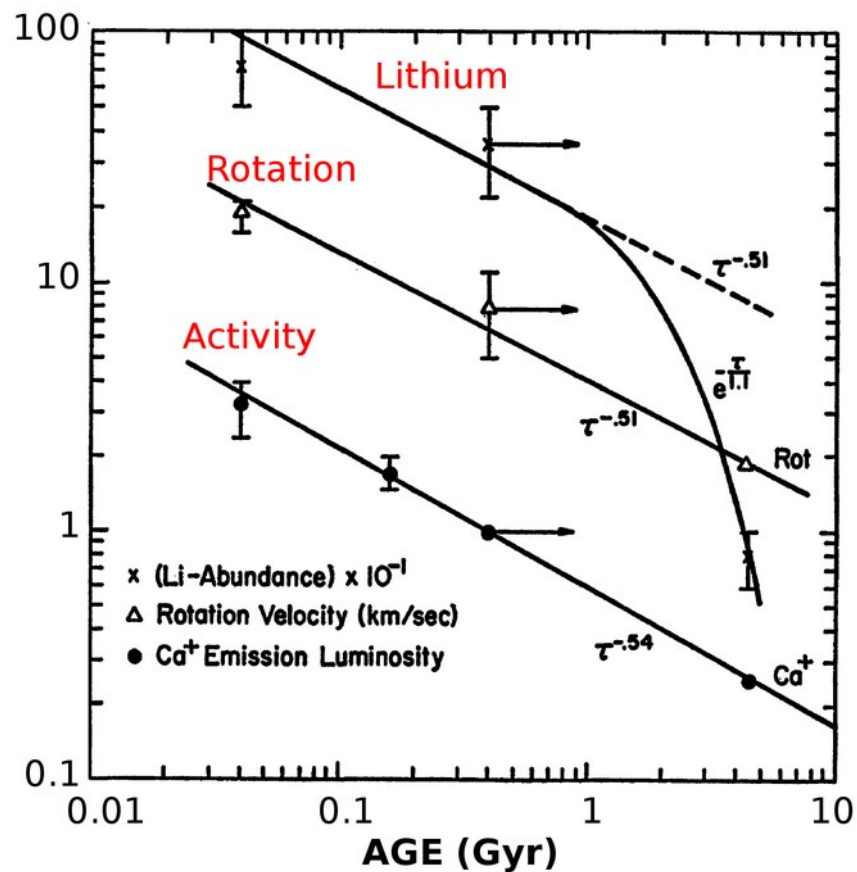
Travis Metcalfe
White Dwarf Research Corp.



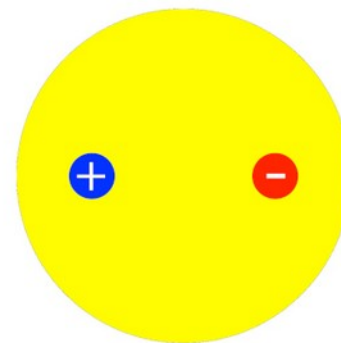
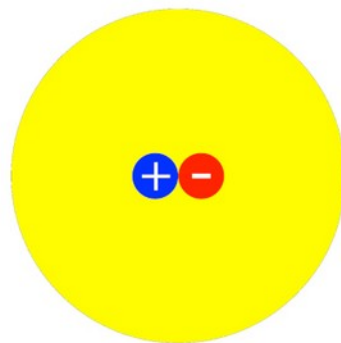
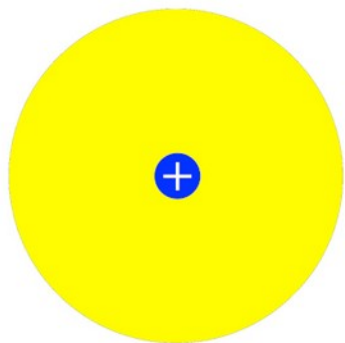
Collaborators: Jennifer van Saders (U.Hawaii), Ricky Egeland (NASA), & many others



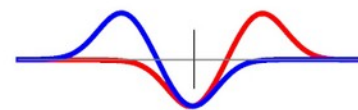
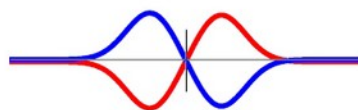
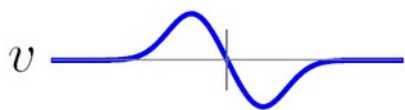
A paradigm shift for magnetic evolution



Geometry

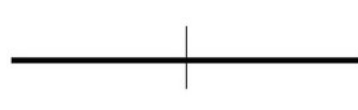
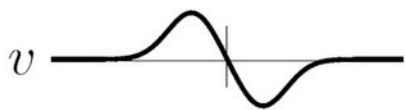


Stokes V signal (components)



Signals doppler shifted
due to rotation

Stokes V signal (net)

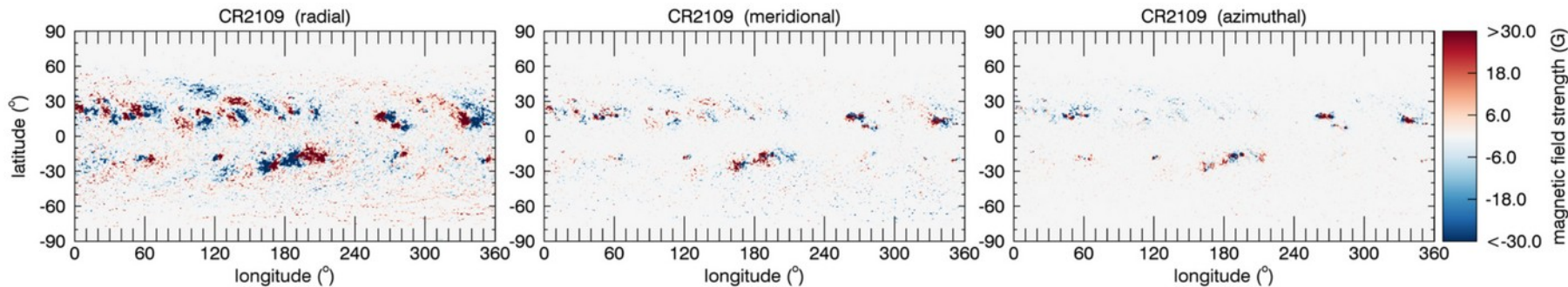


radial

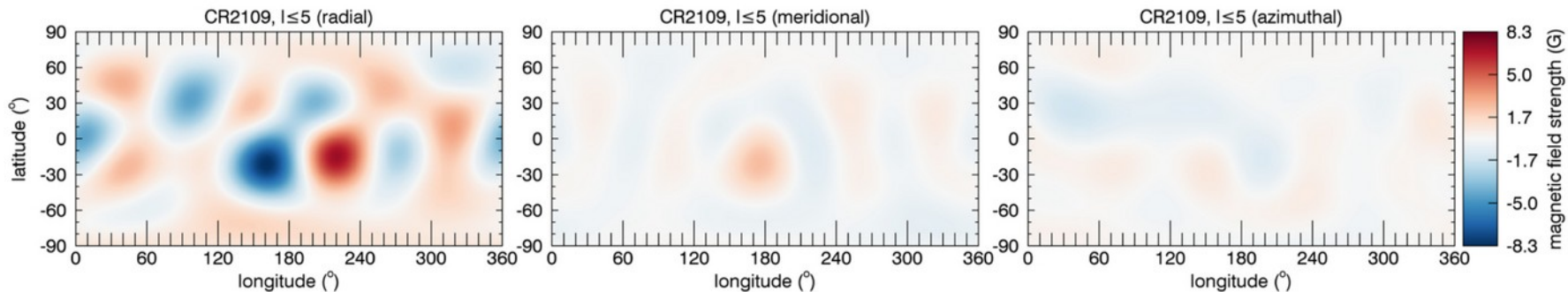
meridional (N-S)

azimuthal (E-W)

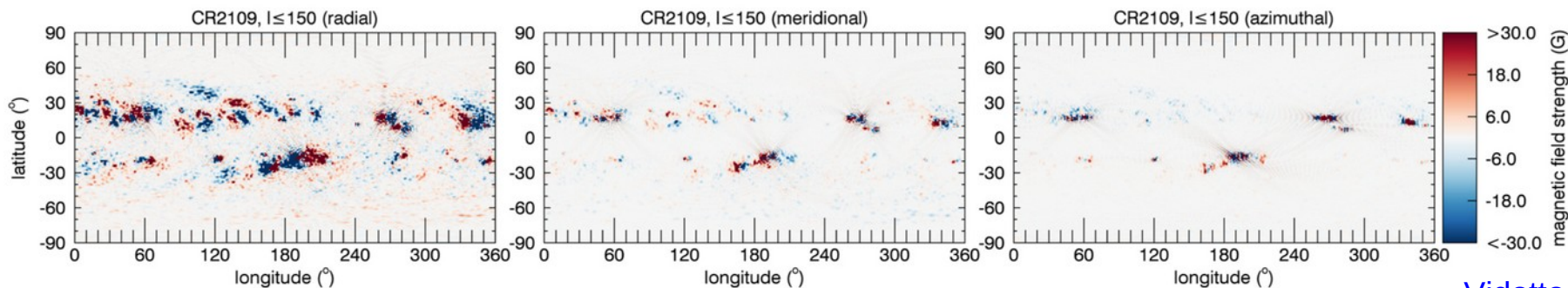
obs



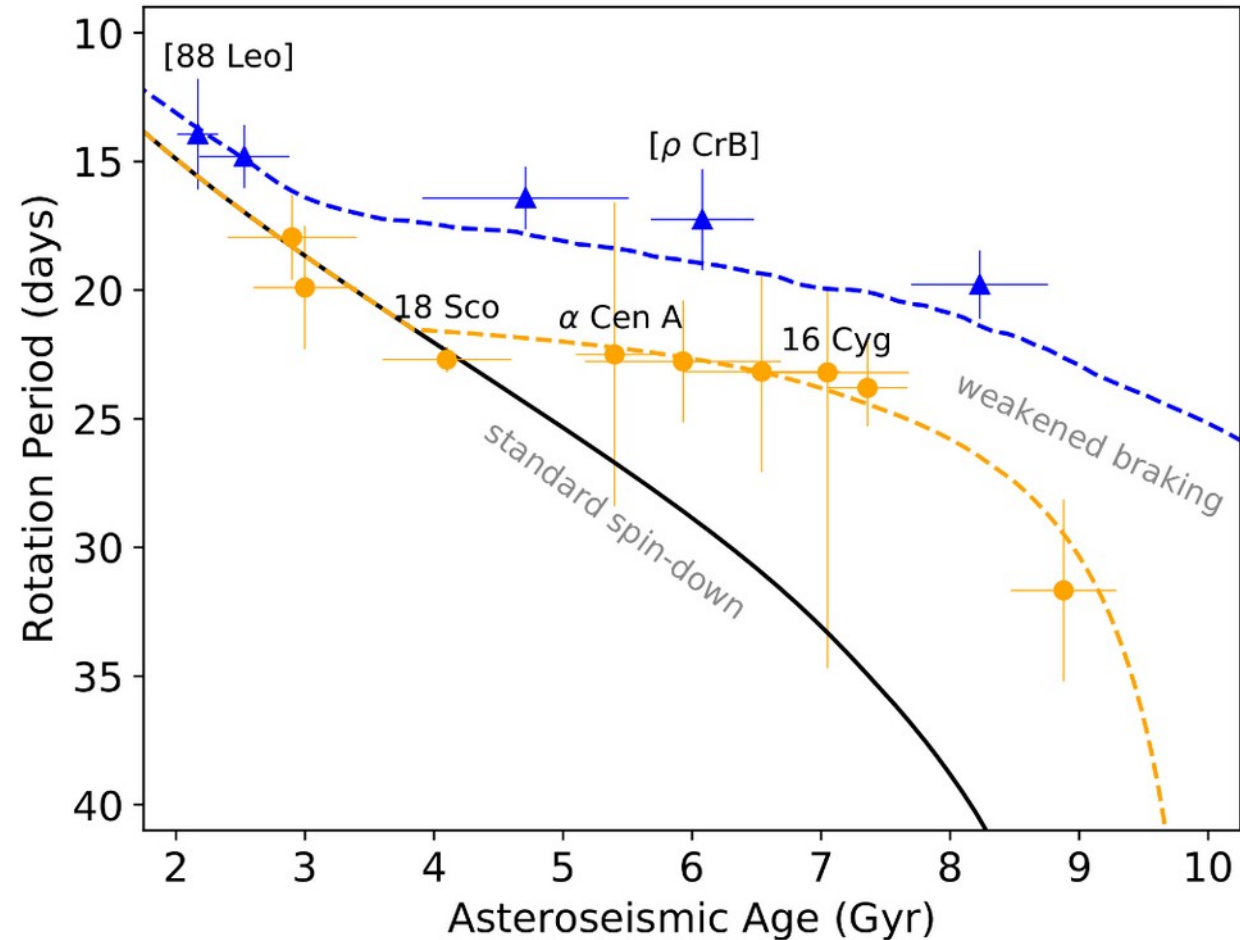
$l < 5$



$l < 150$

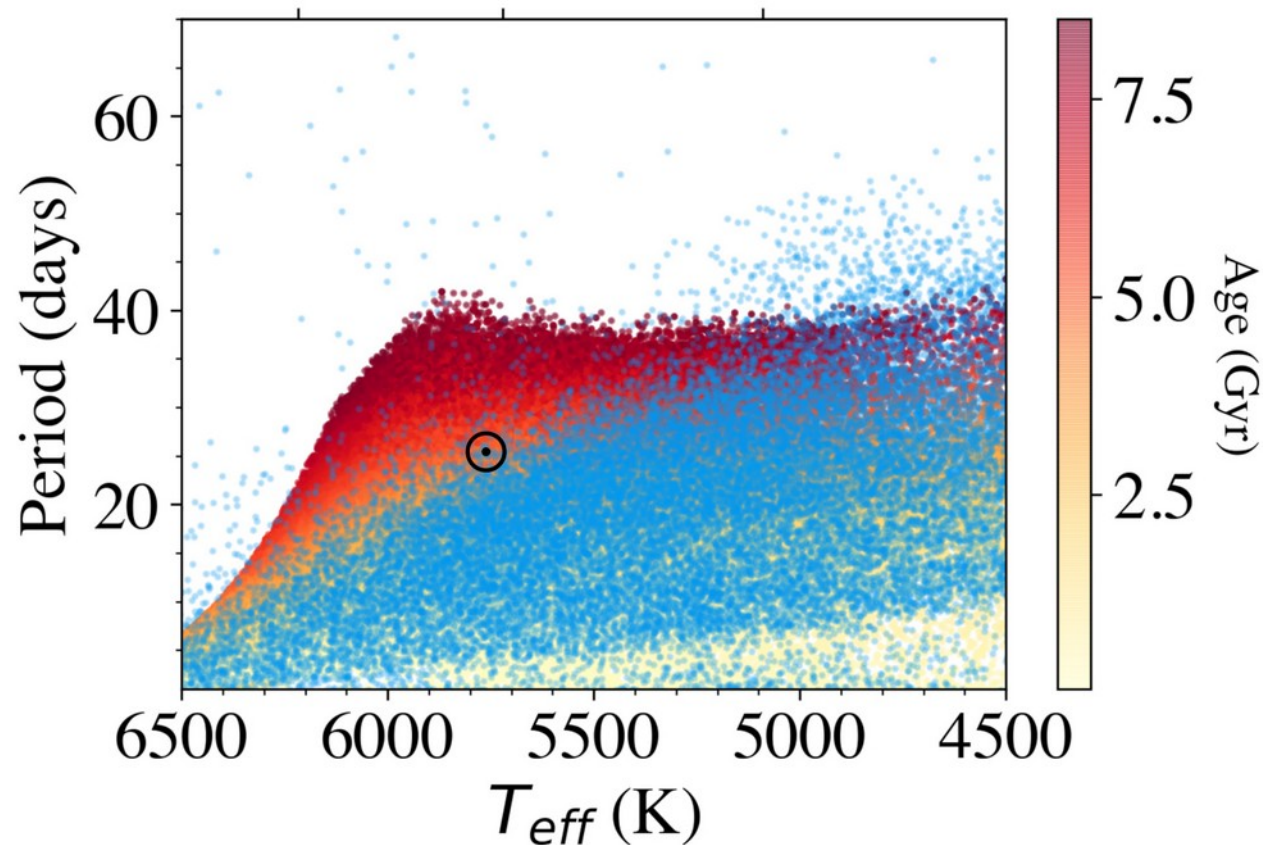


Weakened magnetic braking suspected



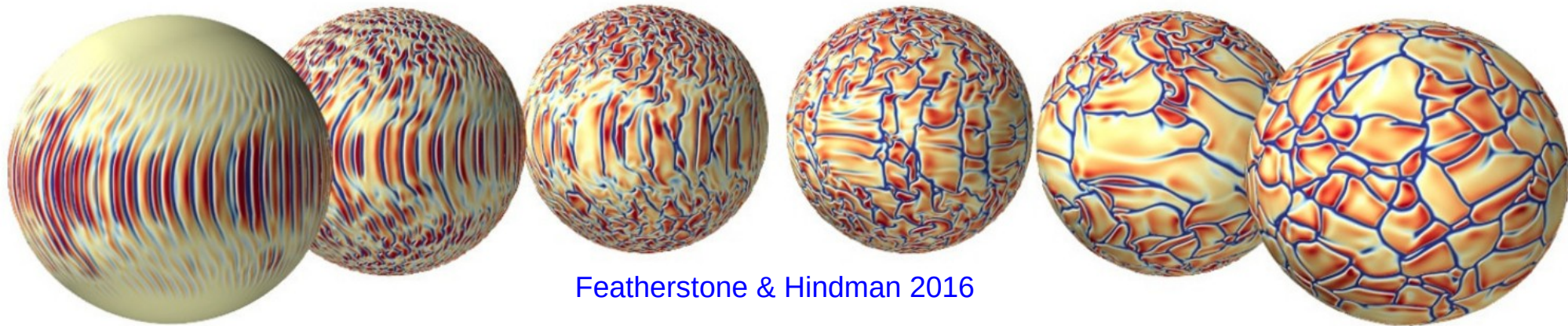
- Older Kepler field stars rotate more quickly than expected from theory
- Discrepancy appears at critical Rossby number, $Ro = (P_{\text{rot}} / \tau_c) \sim Ro_{\odot}$
- Models with weakened magnetic braking beyond Ro_{\odot} reproduce the data

Weakened magnetic braking confirmed

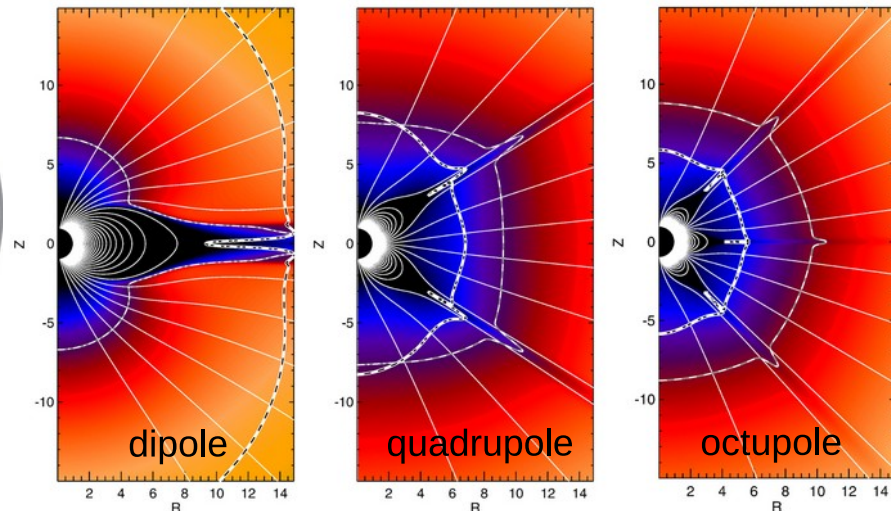
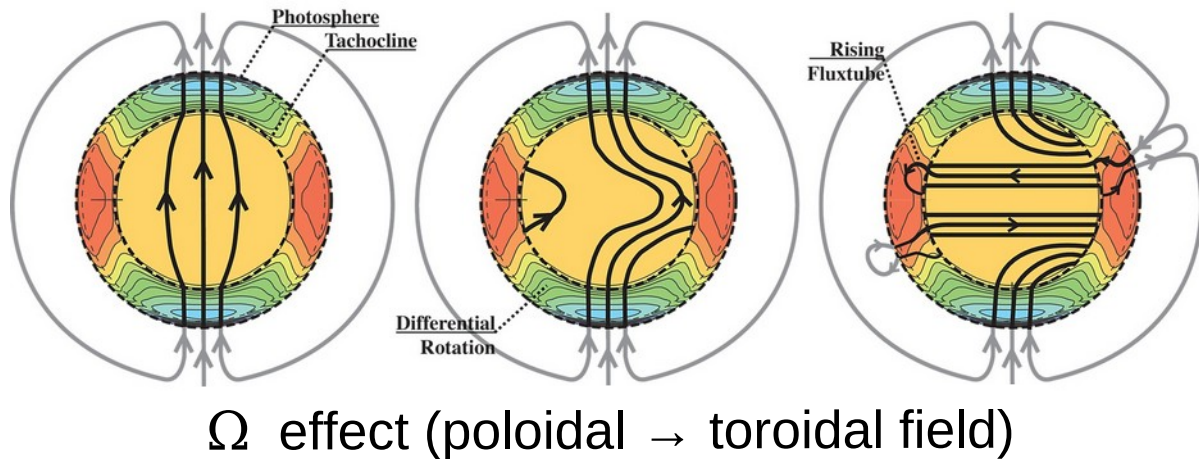


- Distribution of rotation periods in the Kepler field shows long-period edge
- No detection bias: rotation from asteroseismology shows similar distribution
- Pile-up confirmed: sample with precise T_{eff} shows range of ages near edge

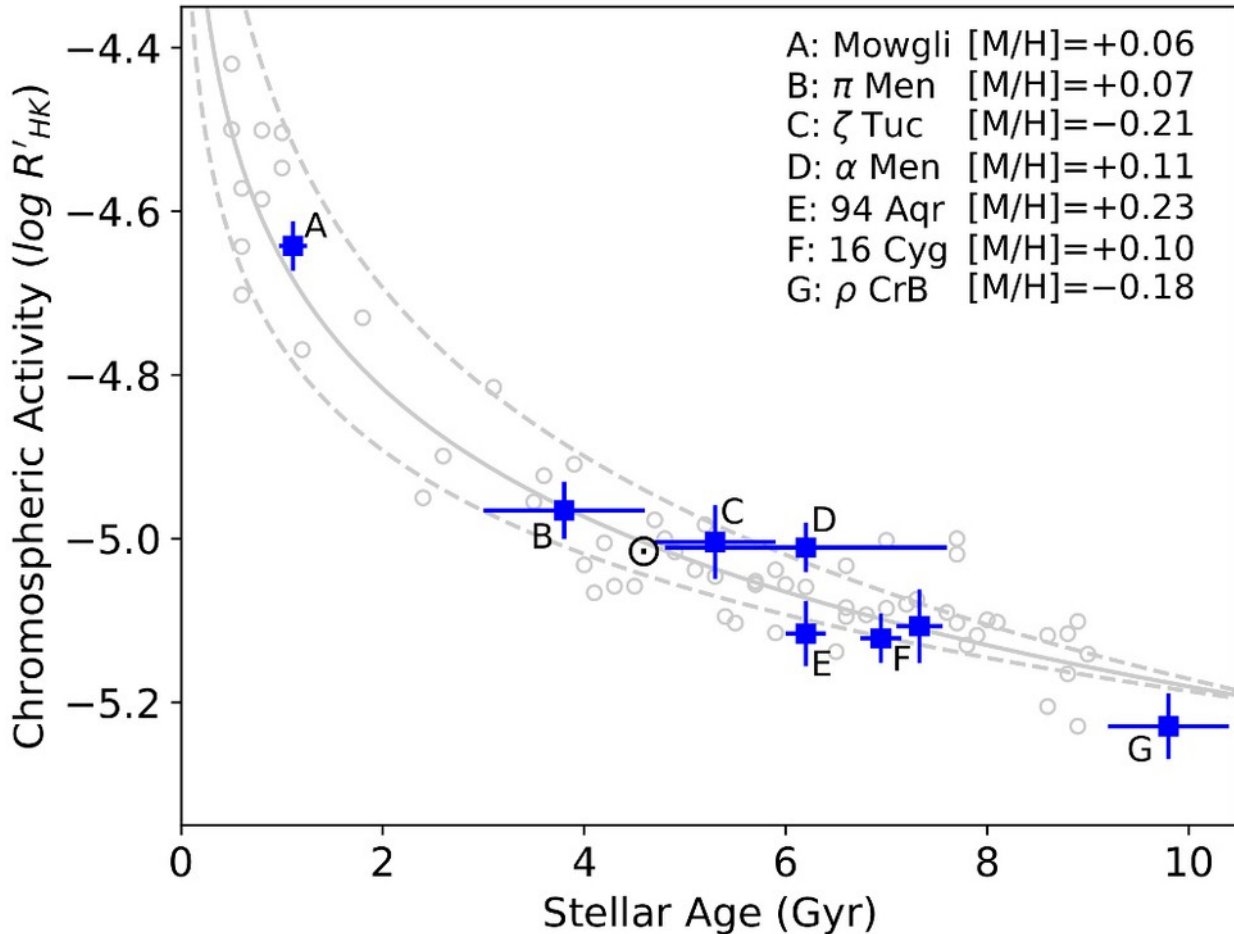
1. slow rotation becomes non-differential



2. loss of shear disrupts field conversion 3. decaying dipole stalls braking

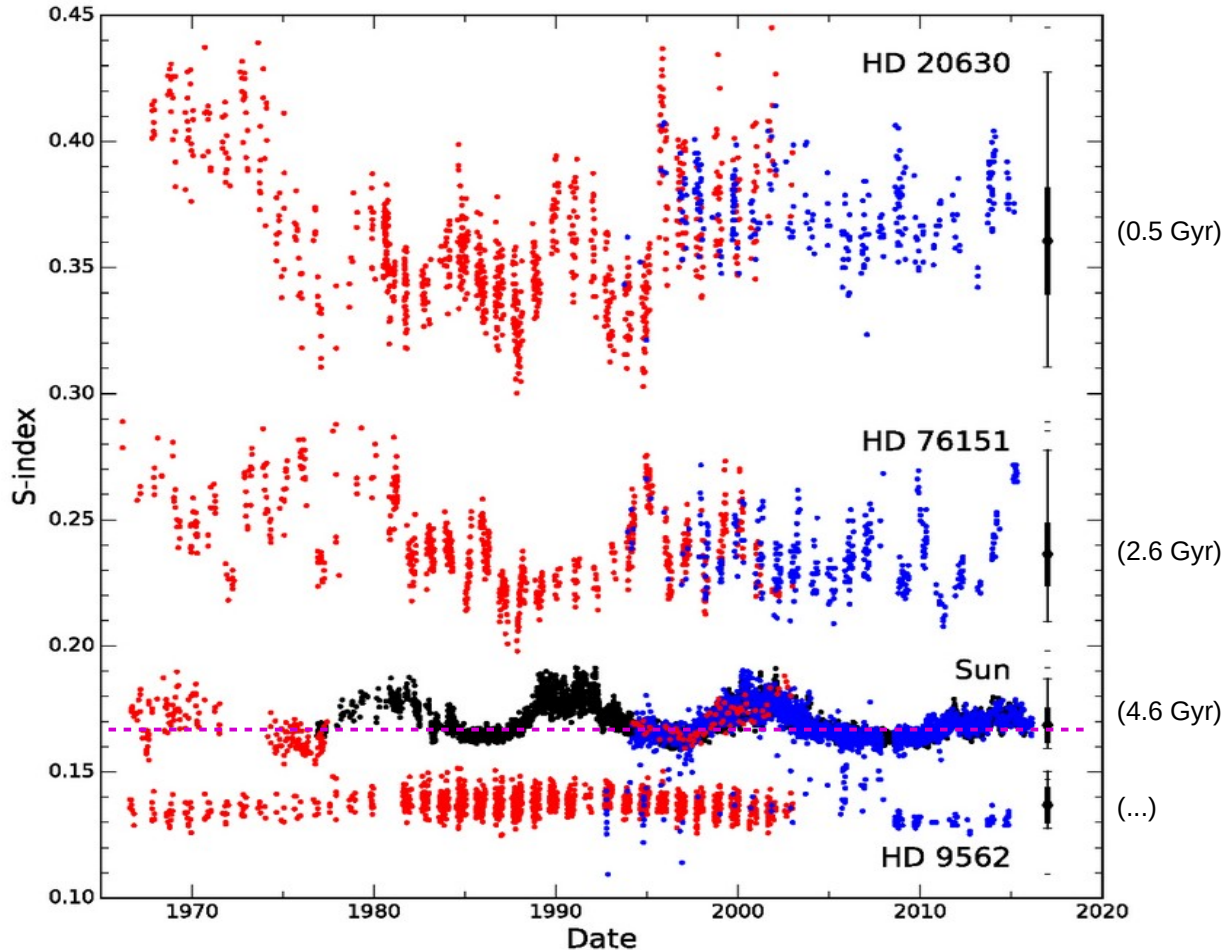


Activity level evolves continuously with age



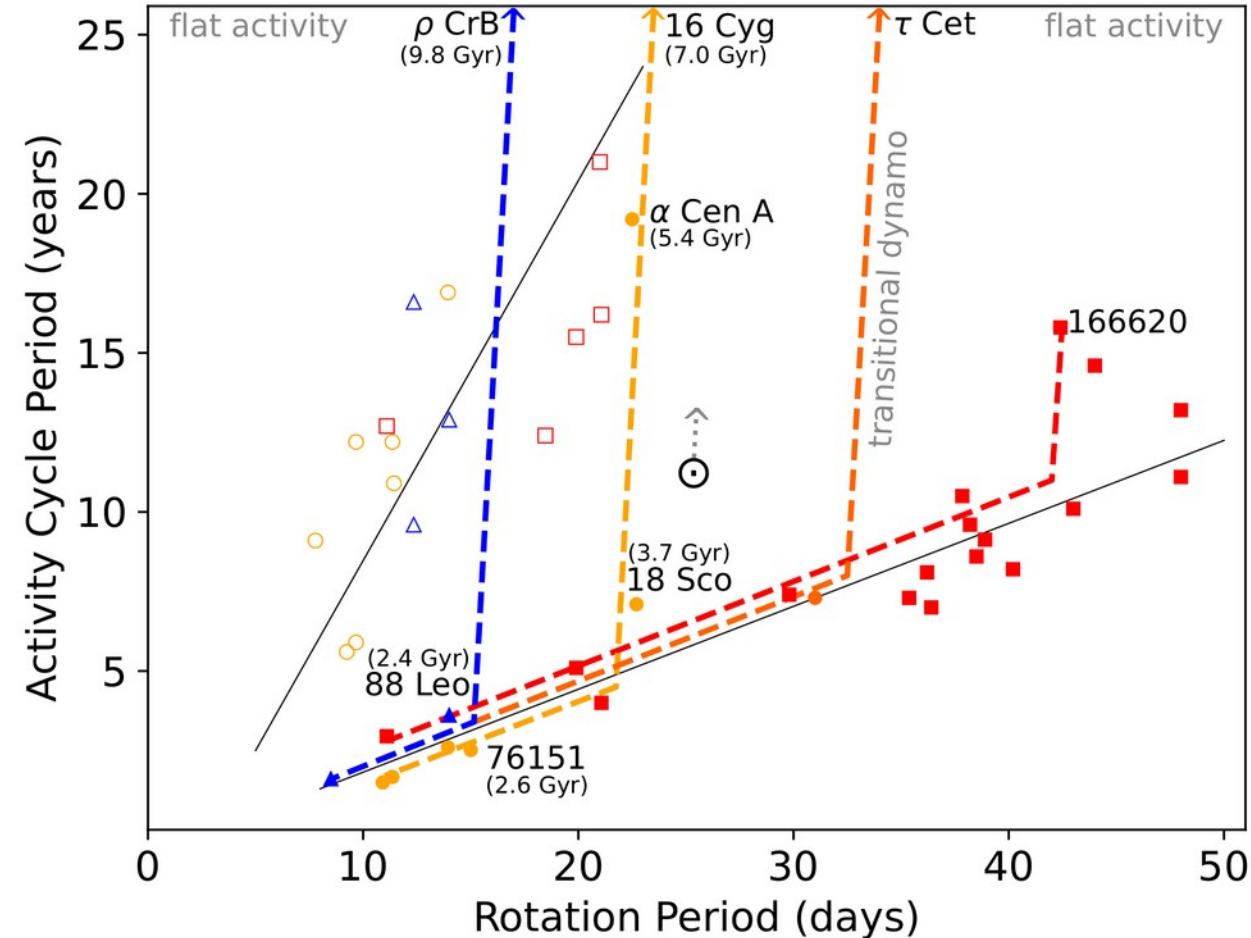
- Activity of solar analogs and asteroseismic targets decline continuously
- Solar dipole field is ~ 1 G while unstructured quiet Sun has $\langle B \rangle \sim 170$ G
- Disruption of large-scale organization is irrelevant to integrated activity level

Variability is Sun-like before disappearing



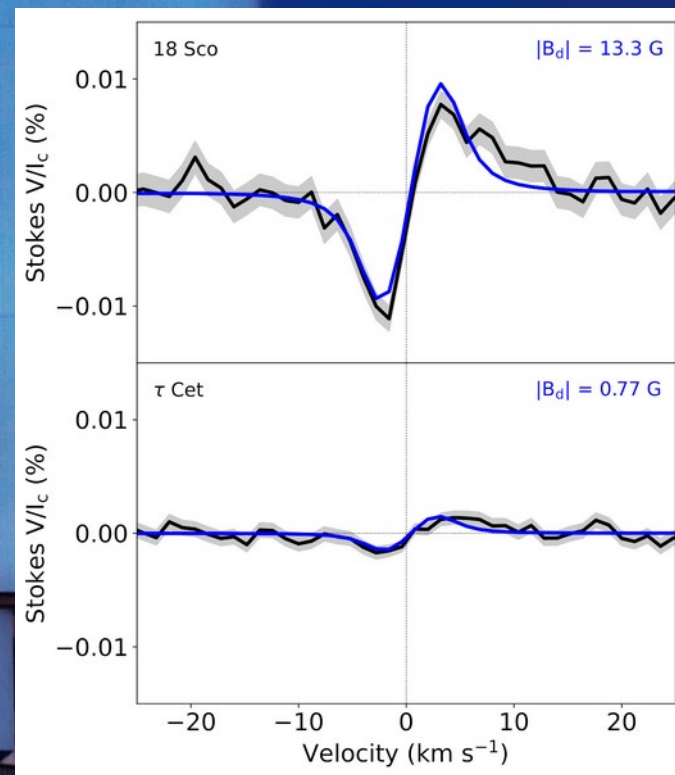
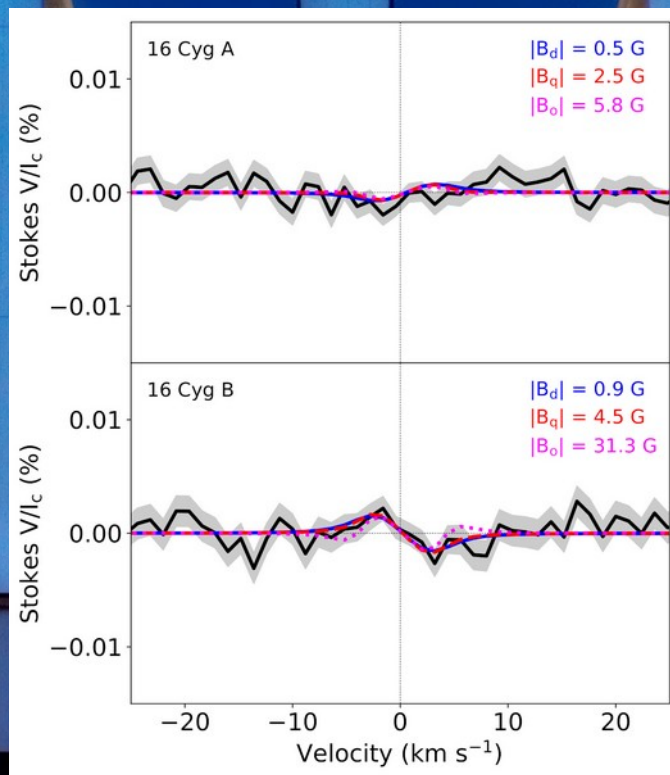
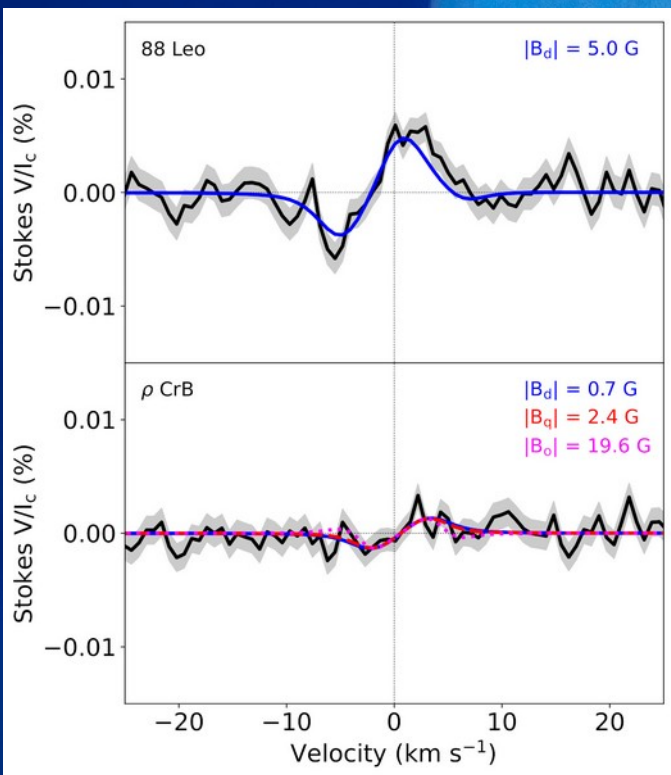
- Variability in young solar analogs is multi-periodic, often appears irregular
- Sun-like cycles appear at high Rossby number, evolving to “flat activity”
- Grand minima could be intermittency as activity evolves across threshold

Cycles grow longer and weaker in old stars



















- Stalled rotation coincides with longer activity cycles and weaker variability
- Same pattern observed in hotter and cooler stars at same Rossby number
- Solar cycle appears to be in the transition, and may disappear in a few Gyr




















Magnetic and Rotational Evolution of ρ CrB from Asteroseismology with TESS

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The Origin of Weakened Magnetic Braking in Old Solar Analogs

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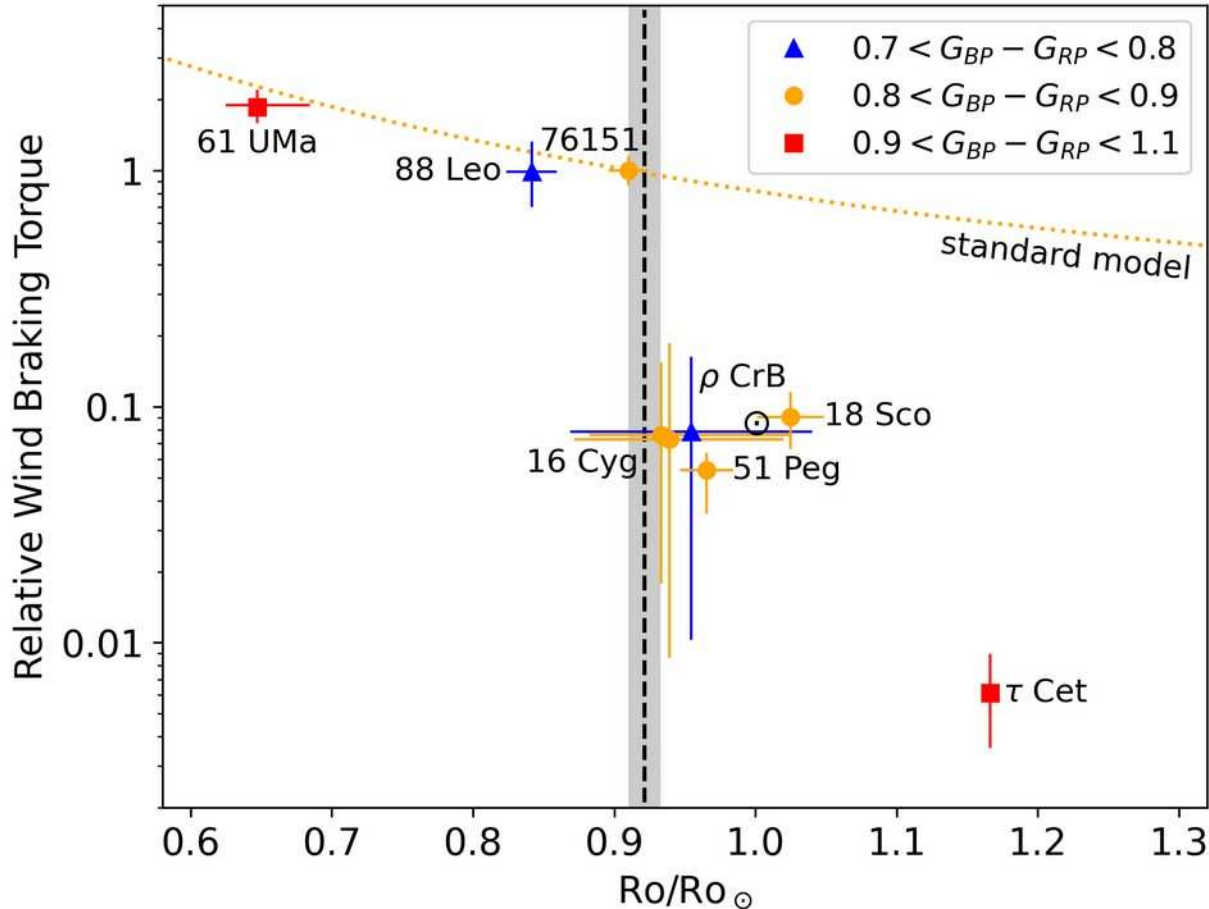


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Constraints on Magnetic Braking from the G8 Dwarf Stars 61 UMa and τ Cet

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Direct estimates of wind braking torque



- Braking torque weakens by $\sim 300\times$ between Ro of 61 UMa and τ Cet
- Empirical value of critical Ro (shaded) constrained by HD 76151 and 16 Cyg
- Larger uncertainties when we only have upper limits on the large-scale field

Summary of conclusions

- At a critical Rossby number comparable to the solar value, magnetic field loses large-scale organization
- At constant rotation period, the magnetic cycle grows longer and weaker on stellar evolutionary timescales
- As stars evolve below a critical activity level, cycles can become intermittent – producing grand minima
- Subgiant rotation slows further and cycles disappear, but then CZ deepens and reinvigorates the dynamo