Weakened Magnetic Braking: what it tells us about stellar dynamos

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Rotation rates of old stars support WMB



van Saders+2016, Hall+2021, Saunders+2024

Decrease in estimated wind braking torque



- Direct estimates of largescale magnetic field from LBT spectropolarimetry
- Empirical mass-loss rate per unit surface area from correlation with X-ray flux
- Combine with rotation period, radius, and mass to estimate braking torque

Finley & Matt 2018, Wood+2021, Metcalfe+2024

Slow rotation weakens large-scale field



Credit: SolarCycleScience.com

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 similar Rossby number
- Solar cycle appears to be in the transition, and may disappear in a few Gyr

Böhm-Vitense 2007, Metcalfe & van Saders 2017

Intermittent cycle as activity level declines



- Critical Ro is equivalent to a critical activity level log R'_{нк} ~ -4.95 (dashed)
- Stars shift from cycling to flat activity as they evolve through this critical level
- Magnetic grand minima become longer and more frequent in this transition

Baum+2022, Vashishth+2023, Metcalfe+2024

Born-again dynamo in evolved subgiants

- F-type main-sequence stars eventually become subgiants with cycles
- After losing any original cycle, rotation slows with expansion onto the SGB
 - As convection zone grows deeper, longer timescale reinvigorates the dynamo

Metcalfe+2020, Metcalfe+2024

Slow rotation reduces flux emergence

 Ω -effect: weaker differential rotation acting on weaker large-scale field

Complex field throttles stellar mass-loss

Stellar wind escapes along open magnetic field lines

Credit: Miloslav Druckmüller

Garraffo+2015, Shoda+2023

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