Can slowly rotating stars have magnetic cycles?

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Context

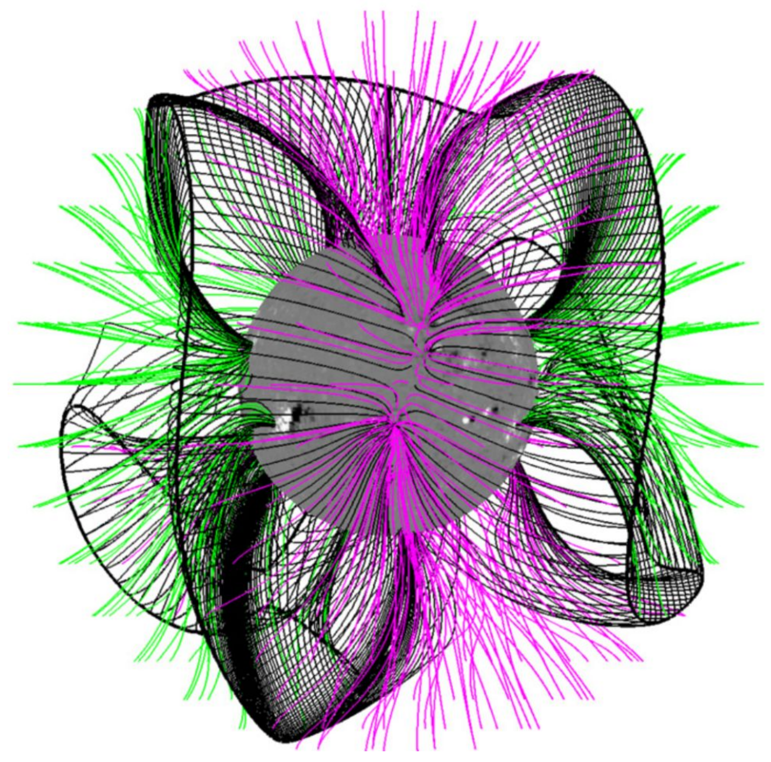
The solar magnetic field is generated and sustained through an **internal dynamo**. In stars, this process is determined by the combined action of **turbulent convective motions** and the **differential rotation** profile. It can sometimes lead to magnetic cyclic variabilities, like in the Sun with the 11 years cycle. Traces of **magnetic cycles** have been detected for other stars as well, ranging from a few years to a few tens of years. How are these cycles controlled?

$\Omega(t) \propto t^{-1/2}$

Skumanich's law

Dynamo generation →

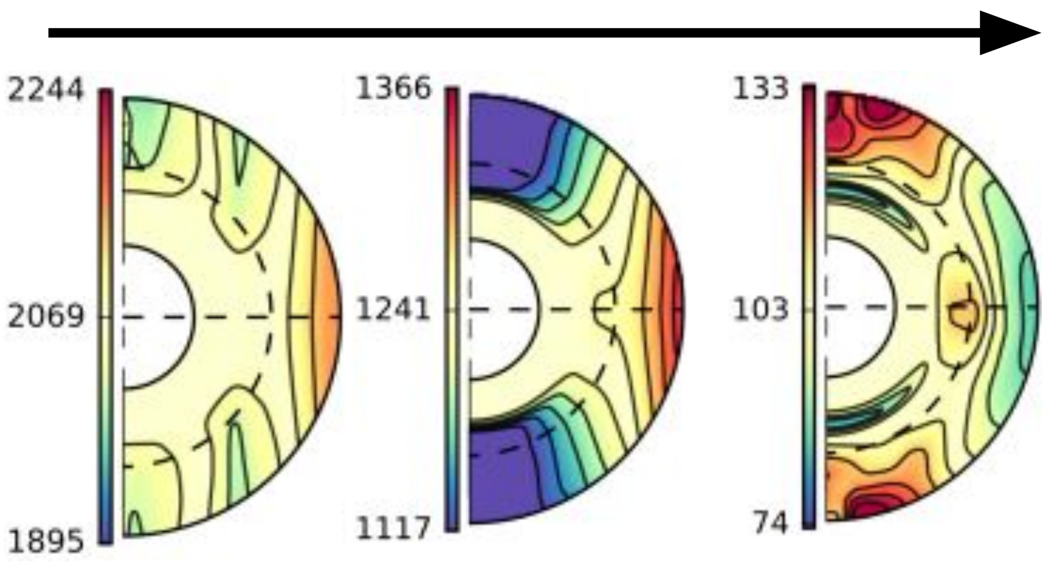
← Magnetic feedback



De Rosa, Brun et al. (2012)

During their life, the rotation of stars is subject to complex evolution. Once they reach the **main sequence** (MS), their global rotation rate decreases, following approximately the empirical Skumanich's law. **Old stars therefore tend to be slow rotators**.

→ Increasing Rossby



$$Ro = \frac{v}{2\Omega L} \sim \frac{\text{Advection}}{\text{Coriolis}}$$

Brun, Strugarek et al. (2017)

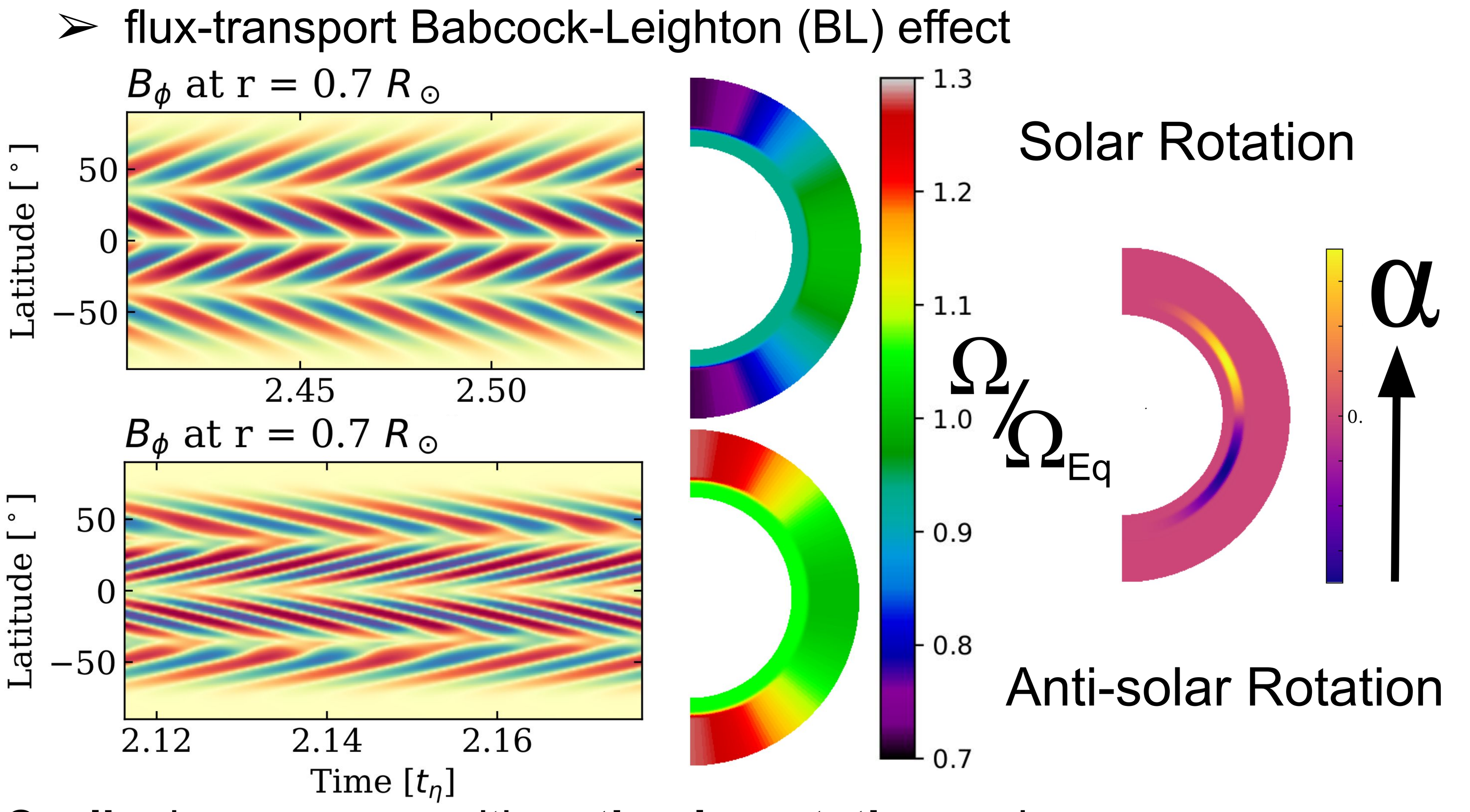
Recent 3D numerical simulations of solar-like stars show that **different regimes of differential rotation** can be characterized with the **Rossby number**. In particular, anti-solar differential rotation (fast poles, slow equator) may exist for a high Rossby number (slow rotators).

If this **anti-solar regime** occurs during the main sequence, and in general for slow rotators, we may wonder how the magnetic generation through **dynamo process will be impacted**. In particular, can slowly rotating stars have magnetic cycles?

We present a numerical **multi-D study** with the STELEM and ASH codes to understand the magnetic field generation of solar-like stars under **various differential rotation** regimes, and focus on the existence of **magnetic cycles**.

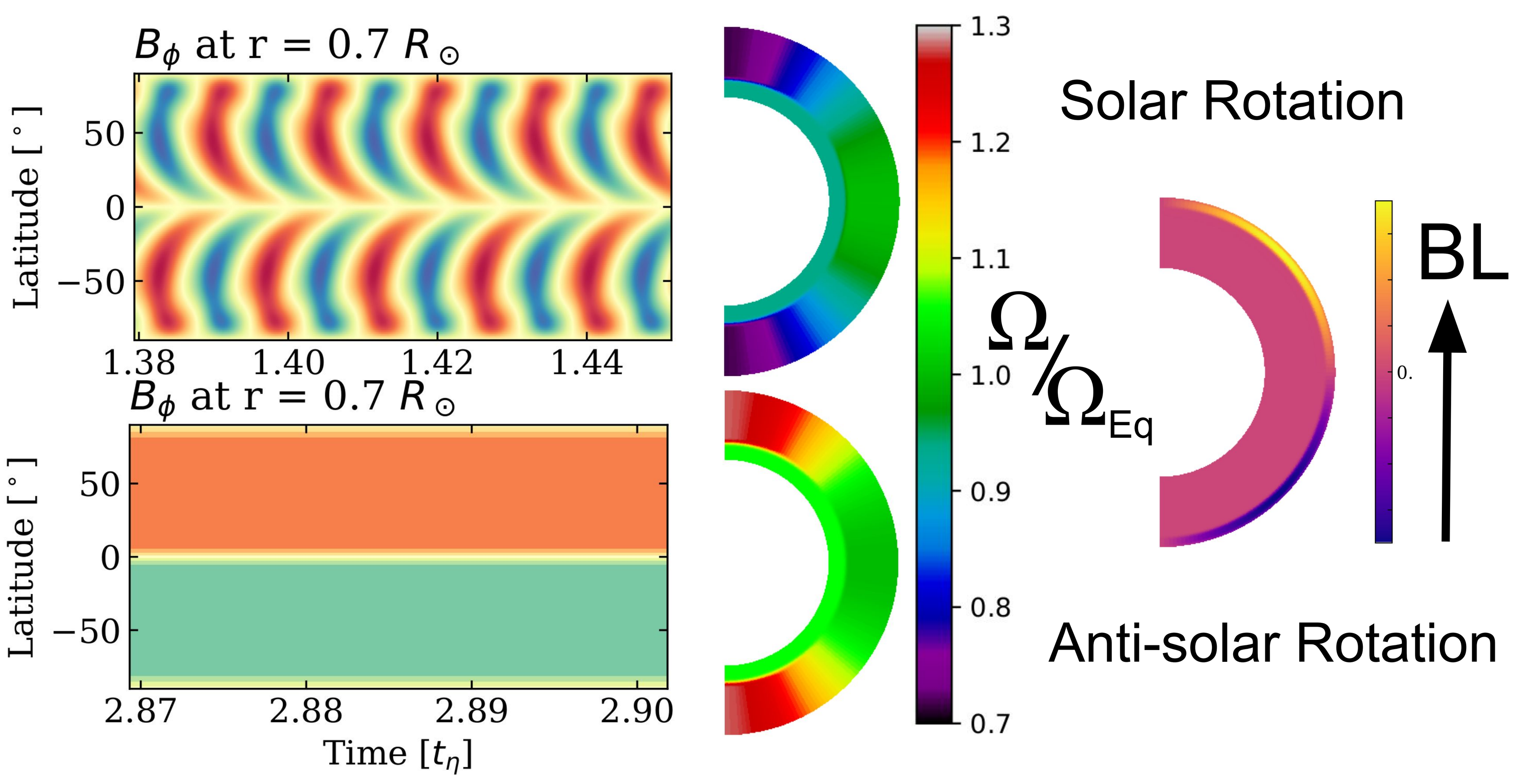
Mean-field dynamo

- Mean-field kinematic dynamos (STELEM)
- Parametric study
- 2 types of mean-field dynamo mechanisms along with the Ω-effect :
  - α-effect distributed at various locations
  - flux-transport Babcock-Leighton (BL) effect



Cyclic dynamo case with **anti-solar rotation** regime :

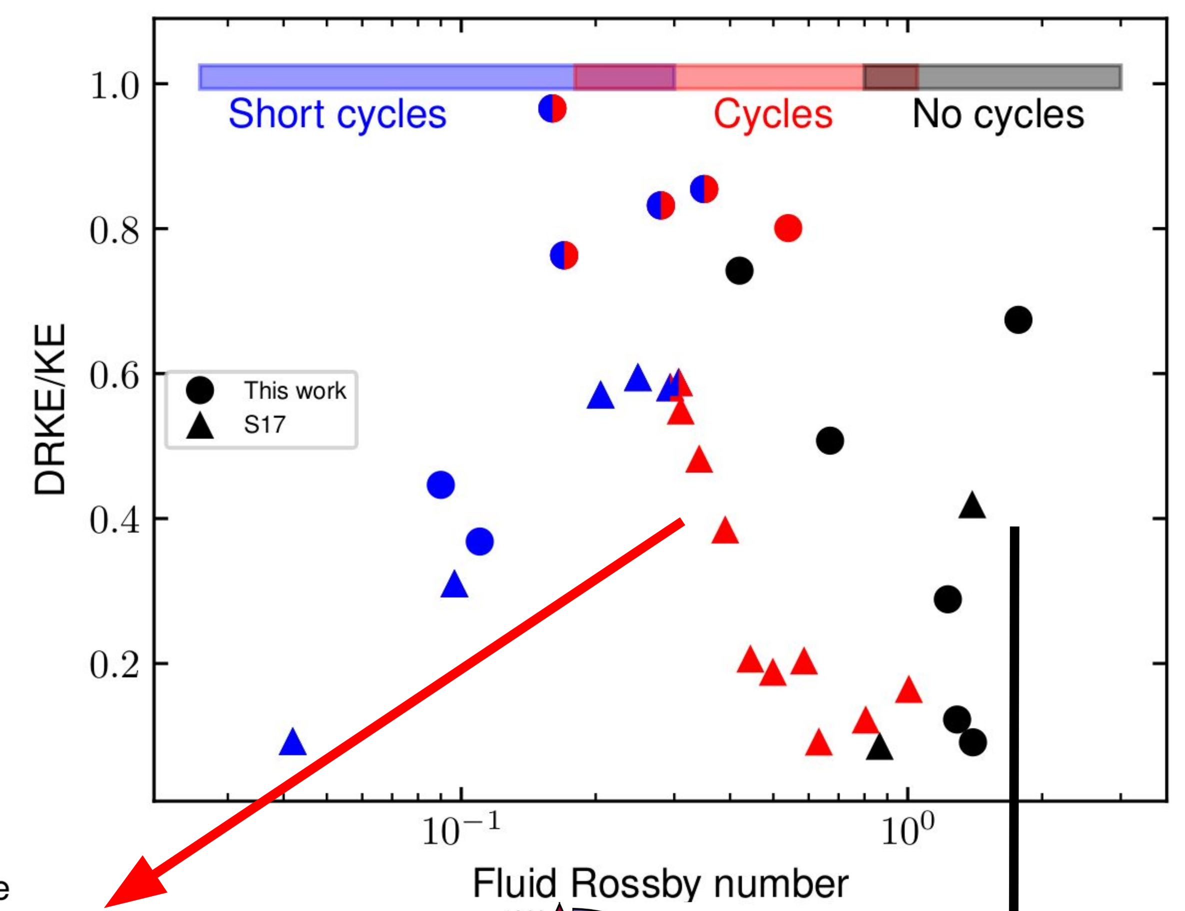
- **α-effect** : ✅ If α confined at the base of the convective envelope
- **BL-effect** : ❌ Steady for all BL model considered

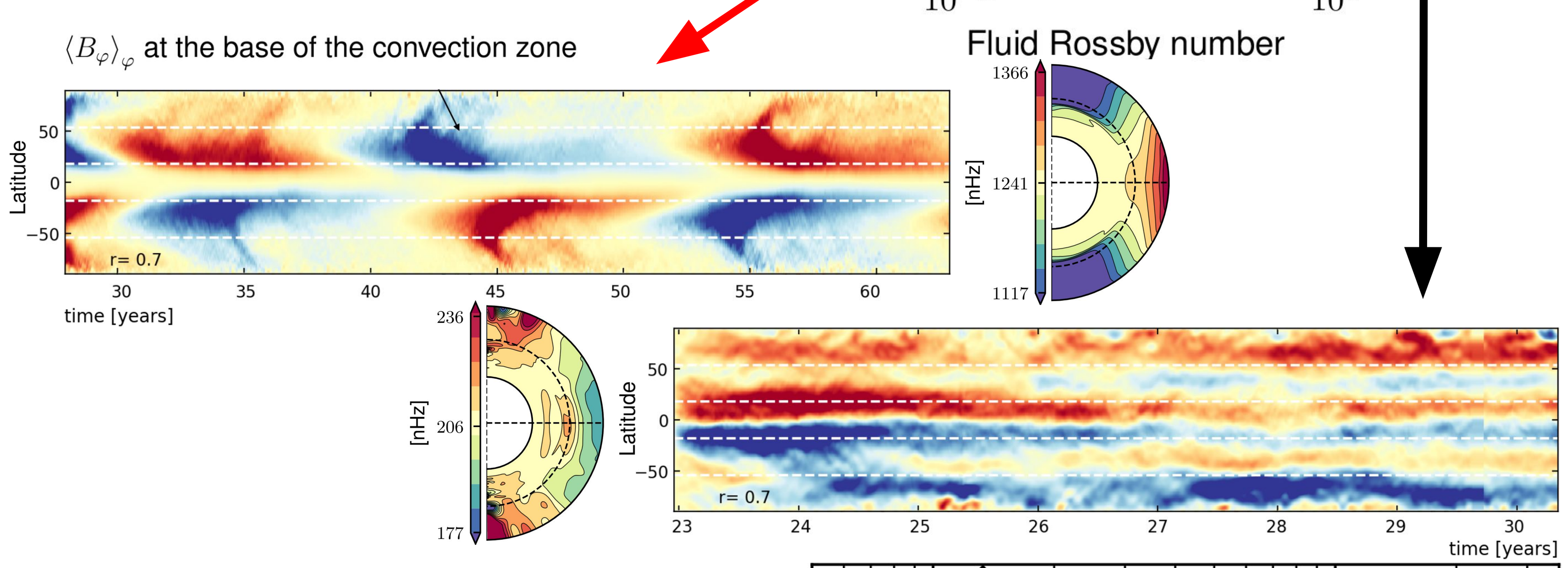


3D MHD turburlent simulations

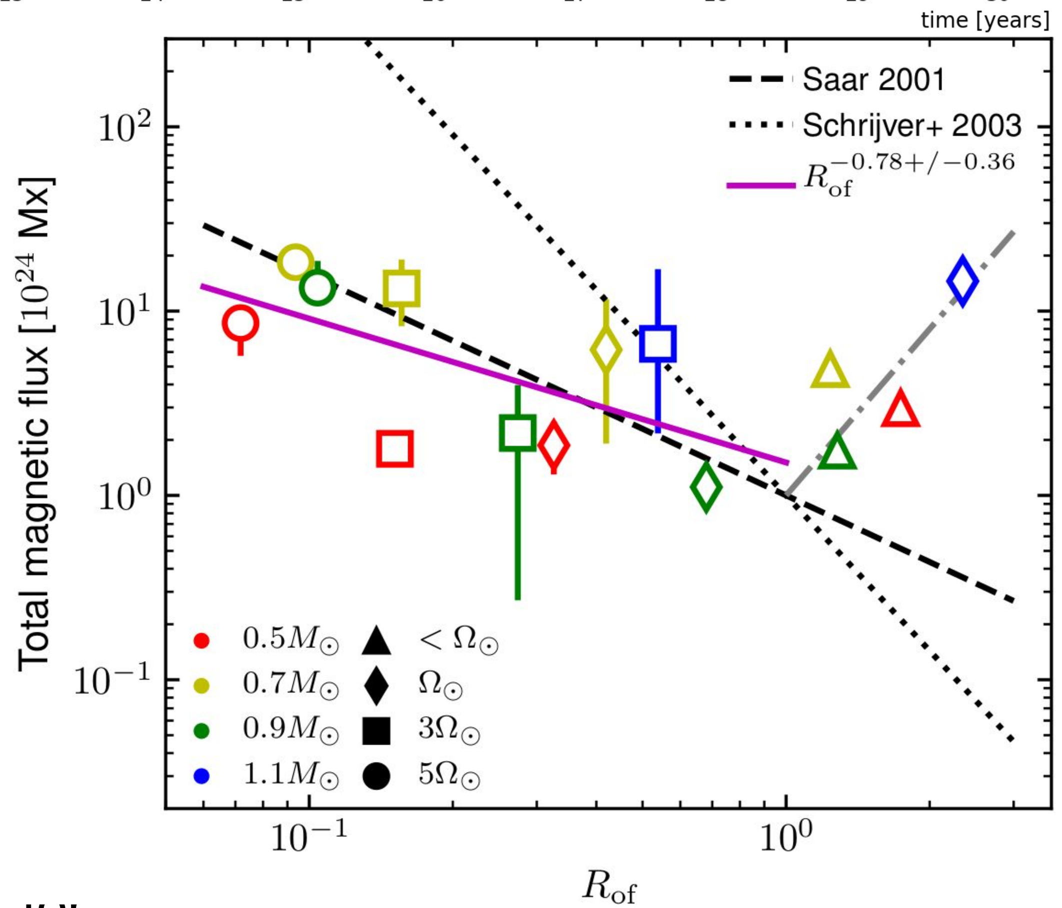
- Non-linear and self-consistent 3D simulations (ASH)
- systematic study
- Our models predict two type of **magnetic cycles when Ro < 1**

  (solar-like and fast rotators)





- Dynamos in **anti-solar regime** (high Rossby) are **steady**
- Magnetic flux trend might change for high Rossby



Conclusions

We find that short cycles are favoured for small Rossby numbers (fast rotators), and long cycles for intermediate (solar-like) Rossby numbers. **Slow rotators (high Rossby numbers)** are found to produce only steady dynamo with **no cyclic activity** in most cases considered. Magnetic cycles can be produced with anti-solar differential rotation only if the alpha effect is fine tuned for this purpose.

We conclude that **slow rotating stars in the anti-solar differential rotation regime can sustain magnetic cycles** only for very specific dynamo processes. A detection of magnetic cycles for such stars would therefore be a tremendous constrain on deciphering **what type of dynamo is actually acting in solar-like stars**.

References

Skumanich (1972)
De Rosa, Brun et al. (2012)
Brun, Strugarek et al. (2017)
Noraz, Brun and Strugarek (in prep)
Brun, Strugarek et al. (in prep)

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