Building and maintaining a solar tachocline through convective dynamo action

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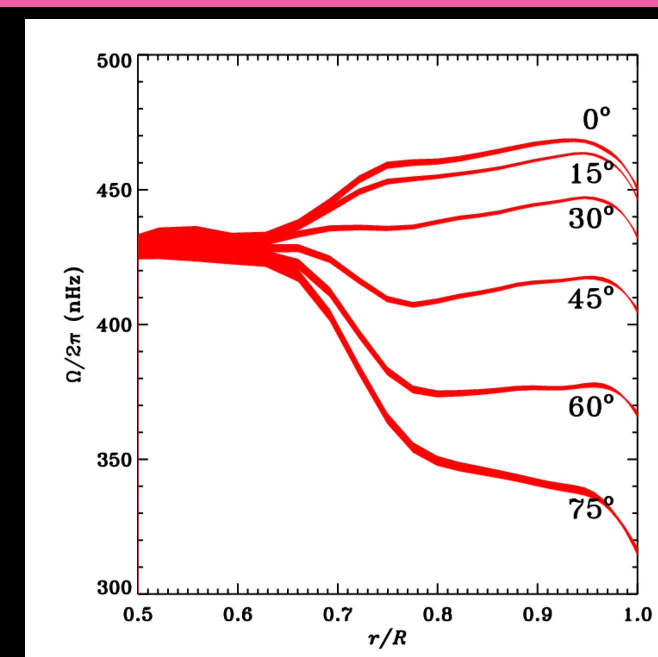
1. The thin solar tachocline

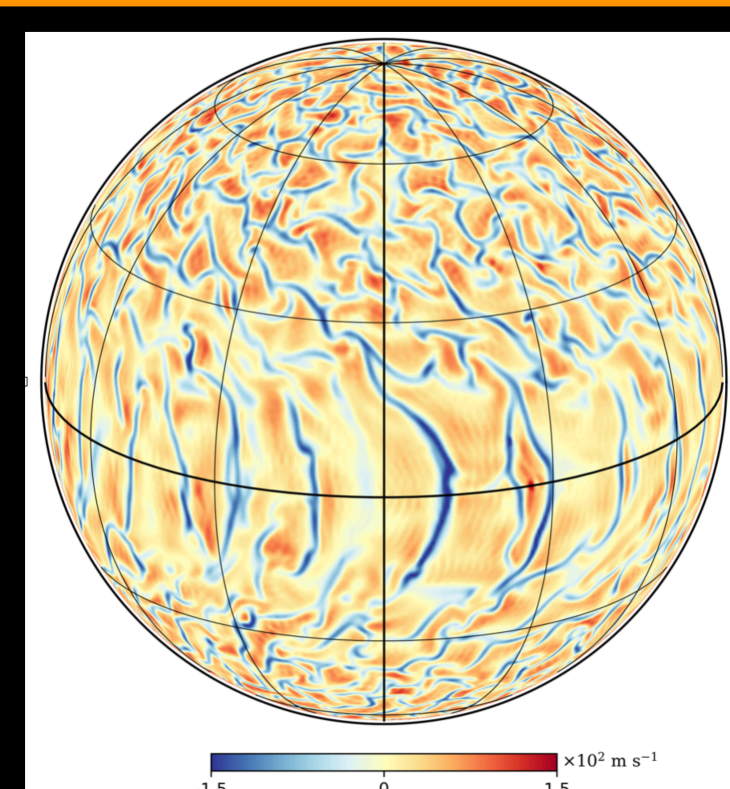
- Helioseismology revealed a tachocline, thickness < 5% $R_\odot$ (Howe et al. 2000)
- Spiegel & Zahn (1992) showed DR should have spread by ~40% $R_\odot$
- Some other mechanism must transport angular momentum from equator to pole



- Mechanism #1 (**Fast tachocline, Spiegel + Zahn 1992**): anisotropic turbulence
- Mechanism #2 (**Slow tachocline, Gough + McIntyre 1998**): primordial magnetic field
- **Neither mechanism has been shown to fully work**

2. Numerical experiment

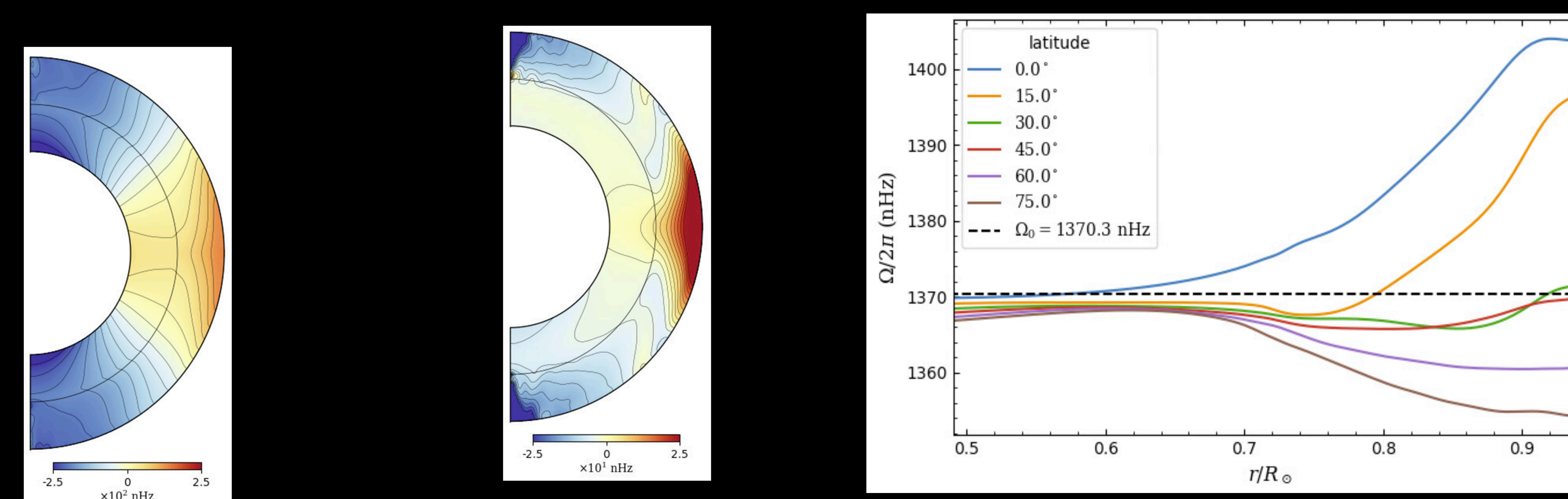
- Hydro simulations with convection zone (CZ) overlying radiation zone (RZ)
- Use anelastic MHD equations (see several recent publications by Matilsky et al. and Bice et al. for review)
- Rotate 3 x solar Carrington



- Background state has ds/dr = 0 in CZ joined quartically to ds/dr > 0 in RZ
- **Thermal** Pr = 1, $\nu = \kappa \propto \rho^{-1/2}$)
- Boundary conditions: fixed thermal energy flux, impenetrable, stress-free
- After equilibration add small random B (~ 1 G)

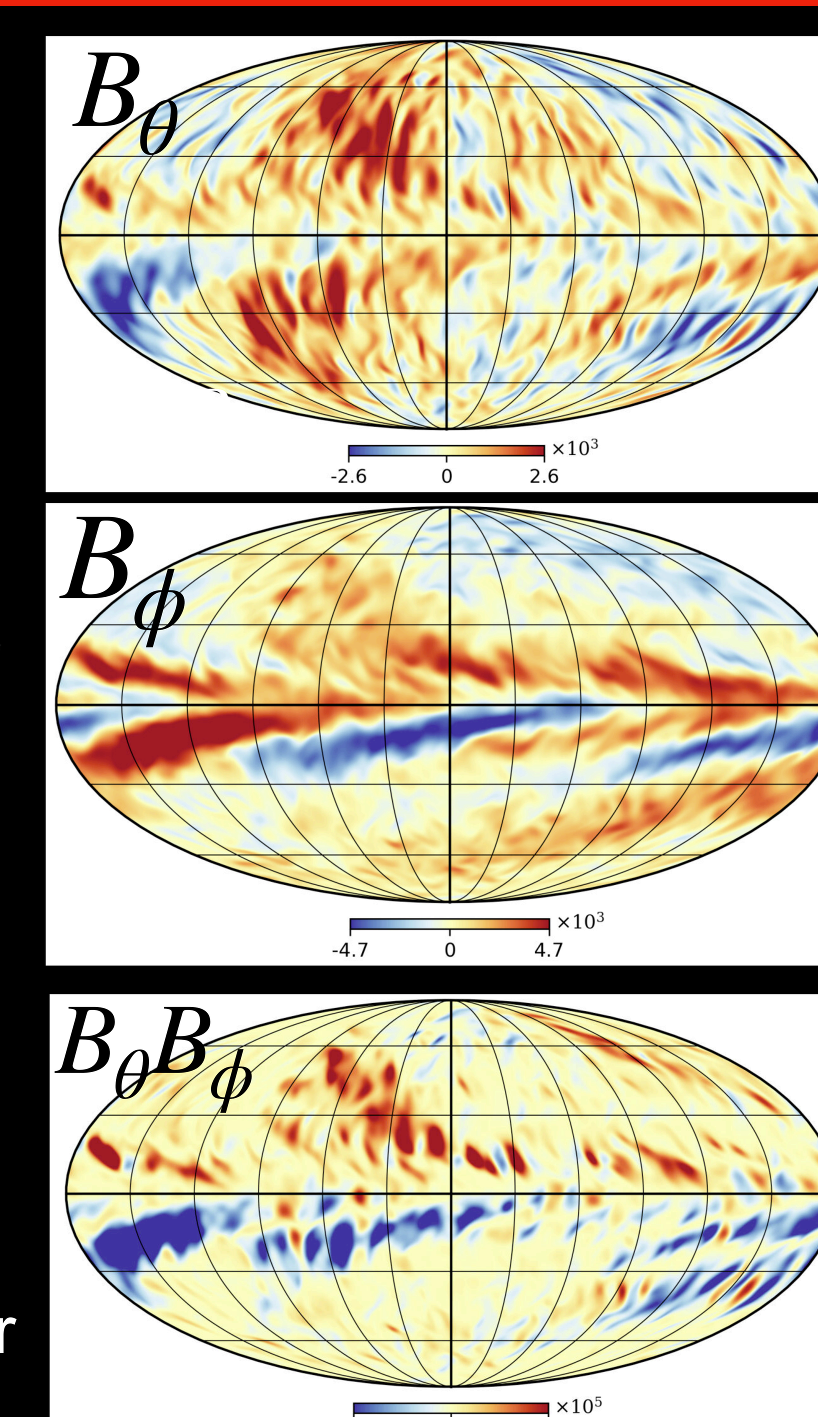
3. Tachocline-like shear layer

- In hydro system, differential rotation imprints viscously from CZ onto RZ (left)
- For dynamo case, RZ is forced into solid-body rotation (middle and right)
- Roughly solar-like differential rotation in CZ, but highly diminished

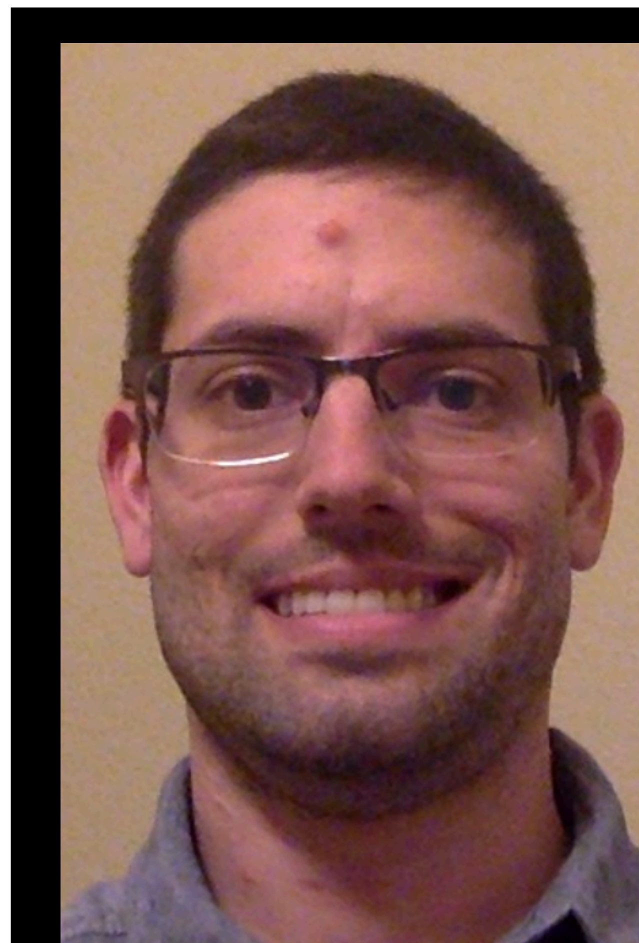


4. Lorentz torques maintain shear

- m = 1 or 2 B_θ →
- m = 1 or 2 B_ϕ (through **latitudinal** shear)
- Correlation $B_\theta B_\phi$ sends angular momentum poleward
- Like **Ferraro (1937)'s Law of Isorotation** ($\mathbf{B}_{\rm pol}\cdot\nabla\Omega = 0$)
- This new magnetic confinement scenario does not rely on primordial field
- Note the similar timescales for Eddington-Sweet and Magnetic diffusion: $\sim 10^{11}$ yr



5. Contact



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