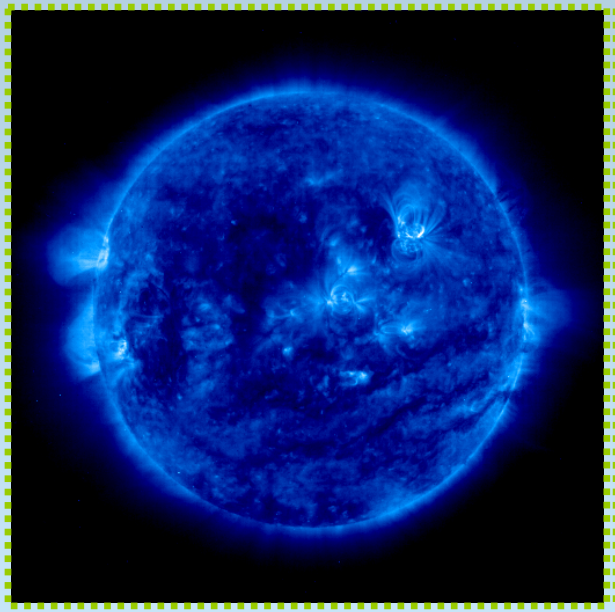
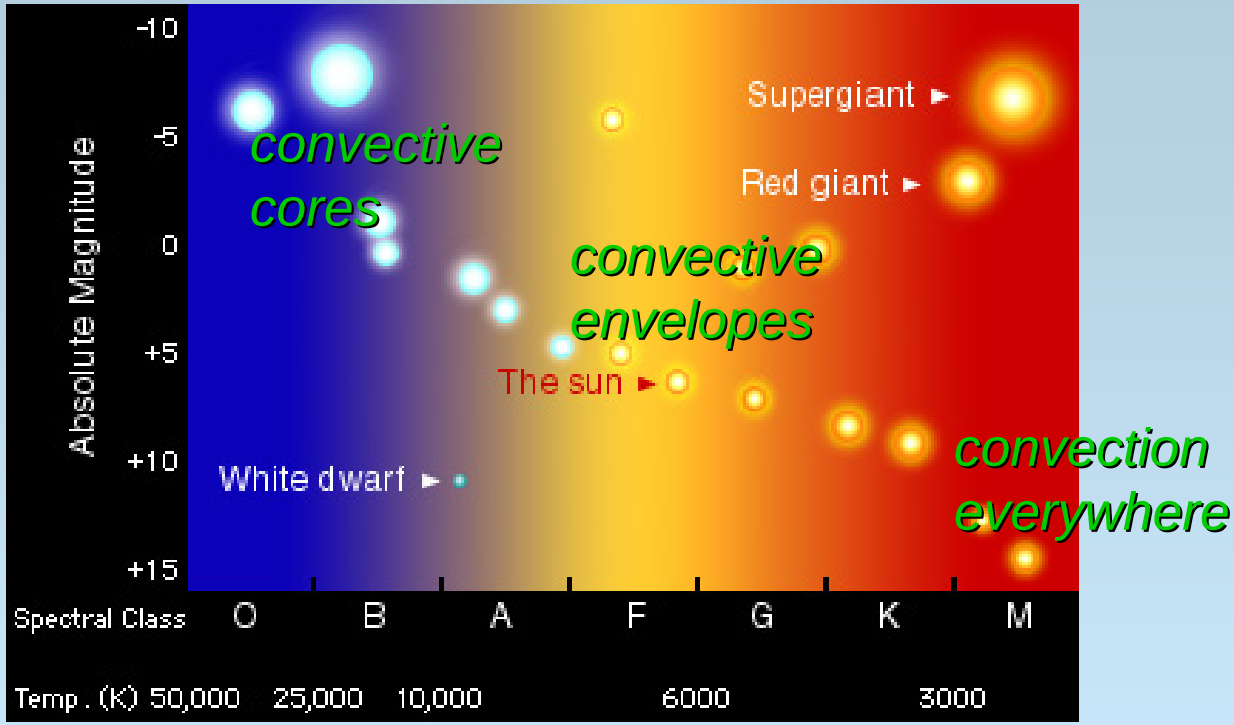
Convection and Magnetism in simulations of low-mass M-stars



Matthew Browning (U Chicago, UC Berkeley)

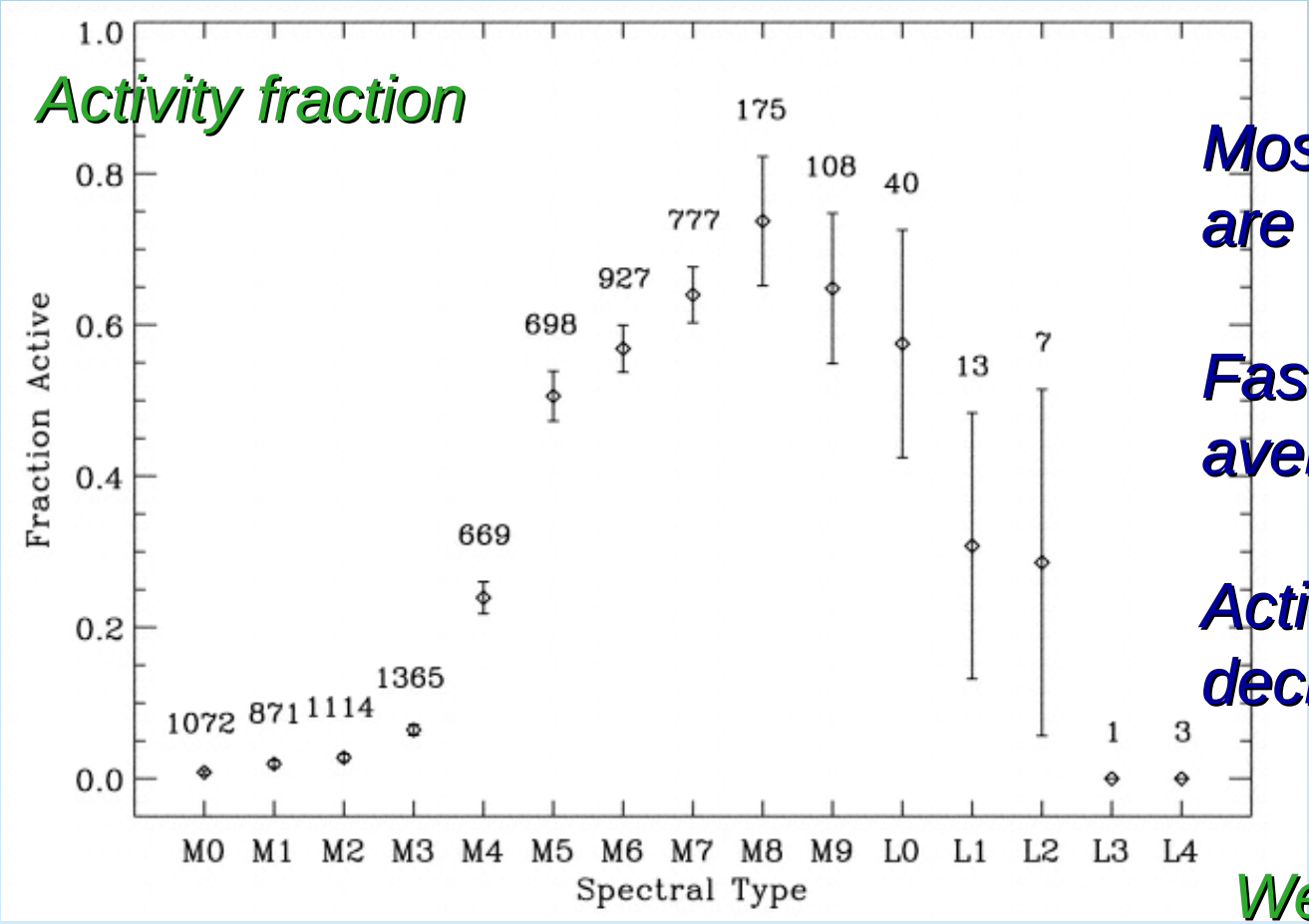
with Gibor Basri and the ASH mob

A reminder: the stellar zoo



- Convection in envelopes, cores, or full interiors
- Connection of convection, magnetism, rotation
- Summation of solar dynamo work: it's pretty handy to have a tachocline

Fully convective stars show strong magnetic activity



Most mid-late M-stars are active

Faster rotating on average than early-M

Activity fraction declines near M9/L0

West et al. (2004)

Observations of large-scale magnetic field in fully convective star

Rapidly rotating M-dwarf

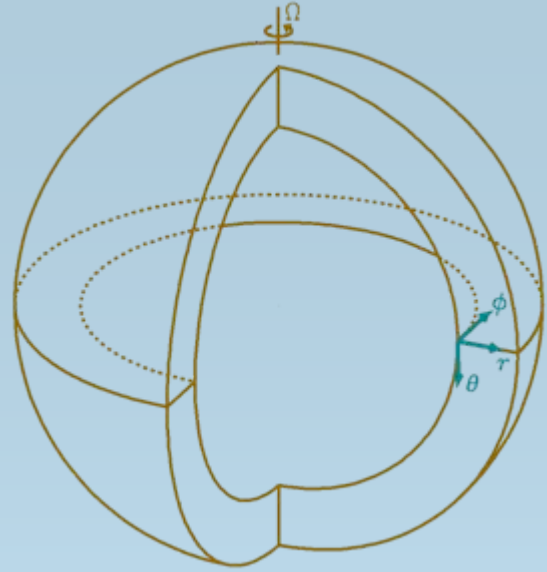
Zeeman Doppler suggests large-scale, axisymmetric field (~kG)

But no differential rotation

HOW?

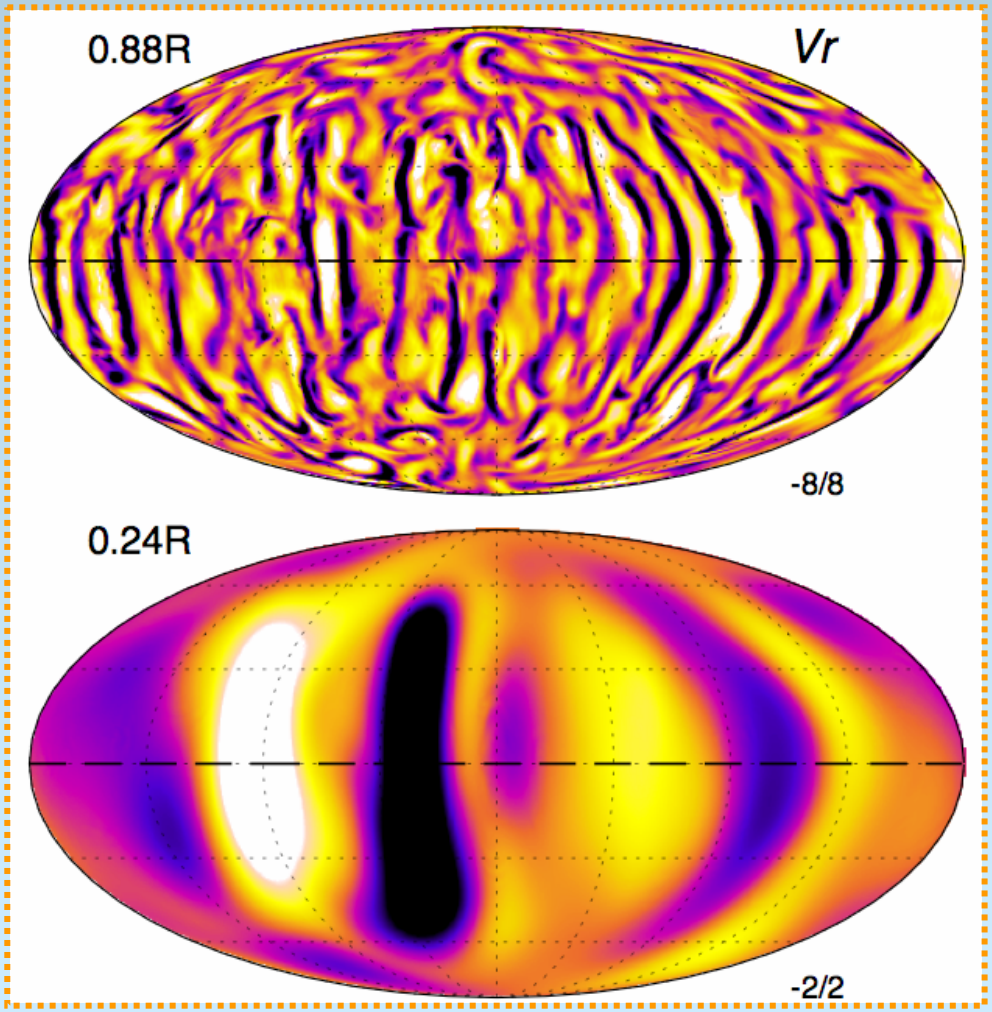
Donati et al. (2006), Science

Computational Approach for 3-D Simulations



- Utilize 3-D *Anelastic Spherical Harmonic* (ASH) code in spherical geometry
- Realistic stratification, radiative opacity
- Simplified physics: perfect gas, subgrid turbulent transport, etc
- Model 0.3 solar mass stars rotating at the solar angular velocity, from 0.06-0.96R

Convective everywhere, but vigorous convection more localized



Convective flows are

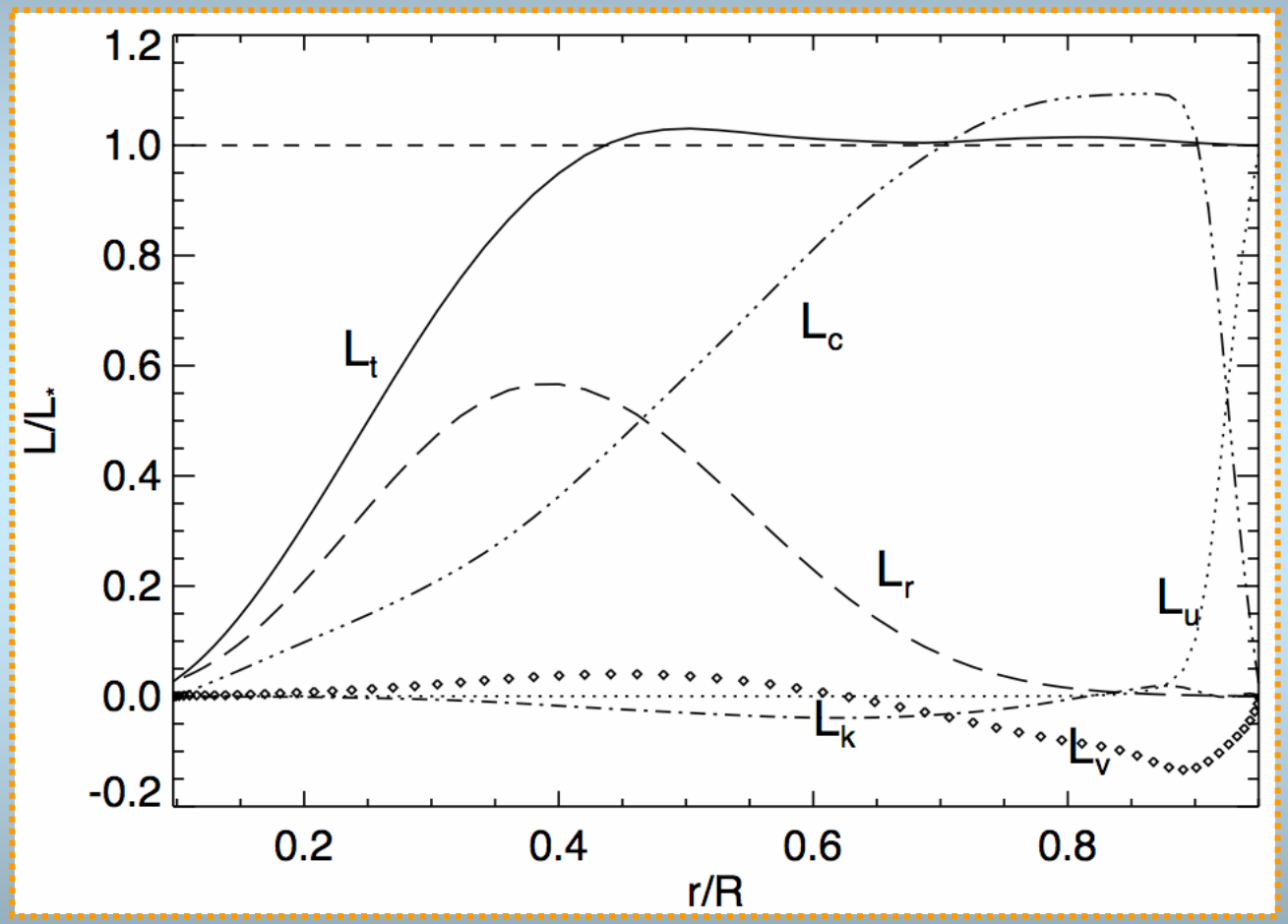
Vigorous and small-scale near top

Gentle and large-scale near bottom

One implication:
Turnover time (hence rotational influence) much smaller near top

Browning (2008), ApJ 676, 1262

Insight from Energy Transport



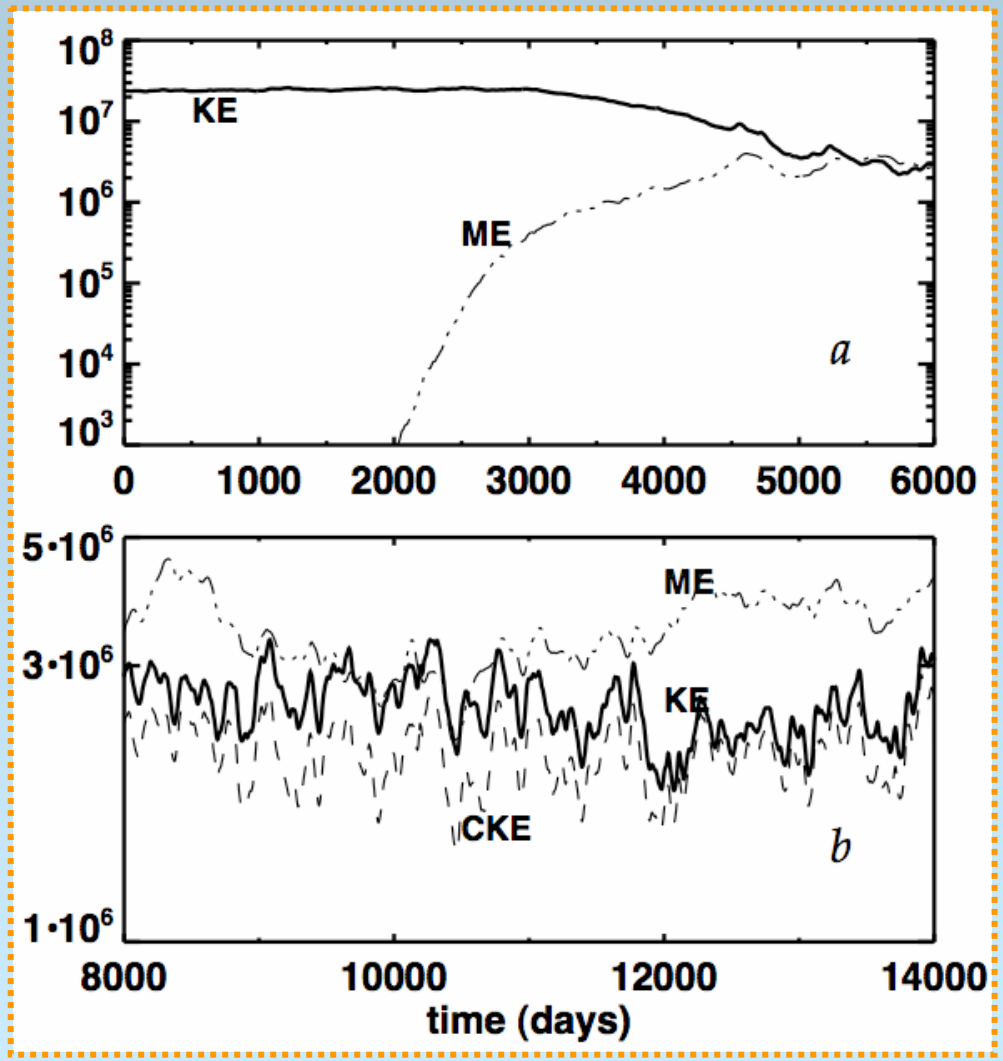
Radiation carries most of L at depth

Convective L much greater near top

$L_c \sim (M/R)\, v_c^{\,3}$

Convection carries most of the energy only above about 0.5R

Dynamo activity in MHD models

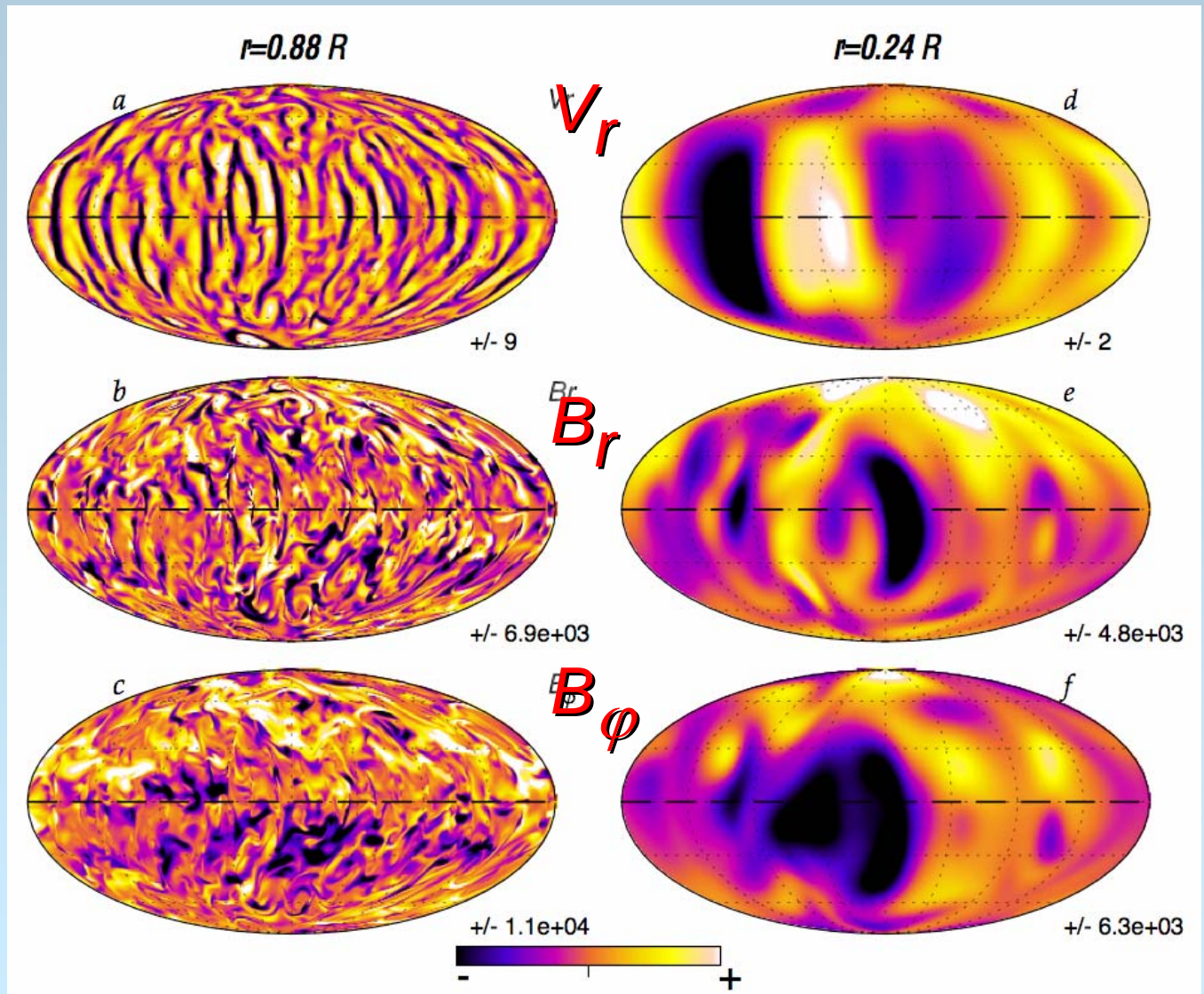


With increasing ME, drop in KE

Final ME ~120% KE (for Pm=5)

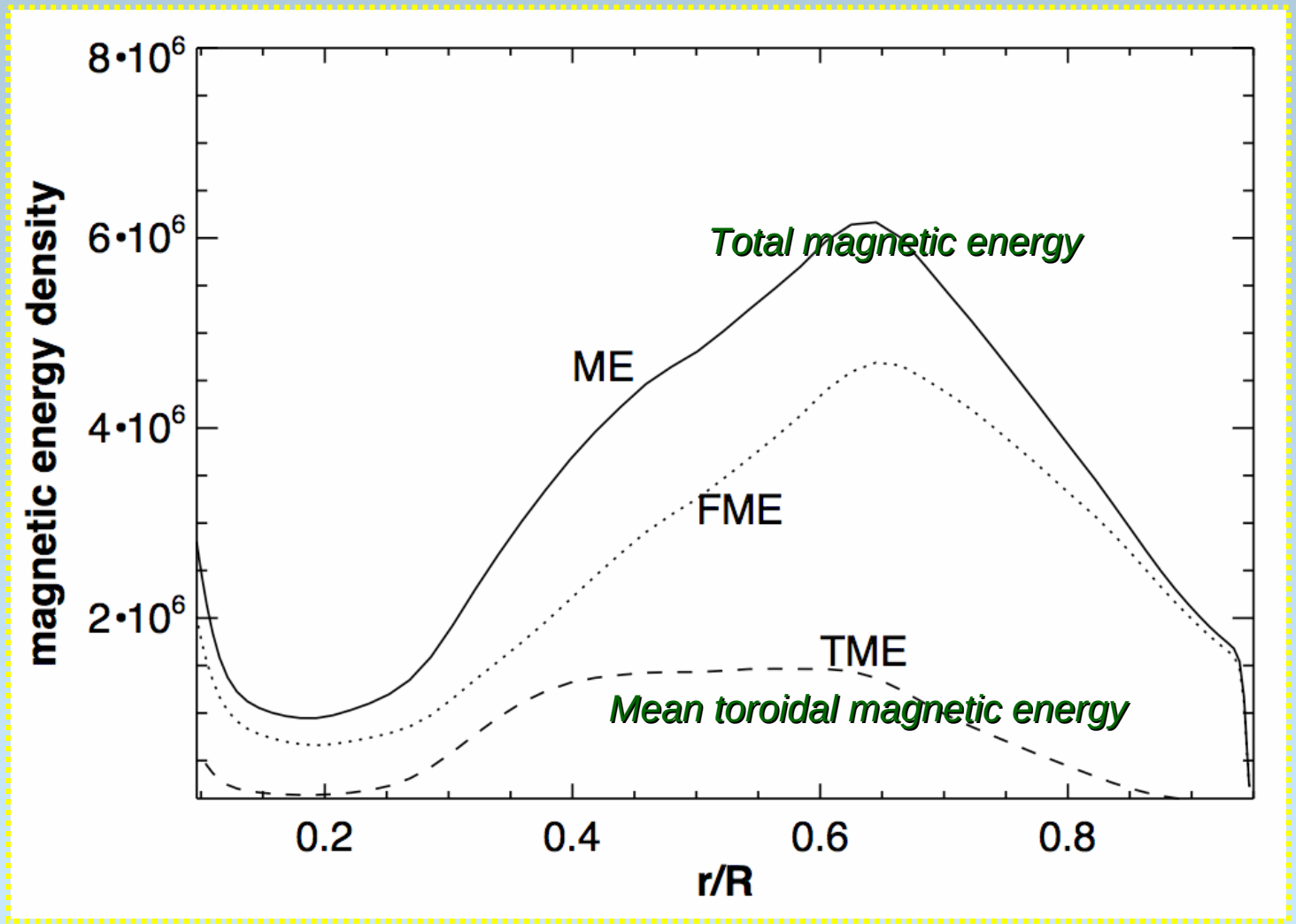
Convective motions amplify a tiny seed field by many orders of magnitude

Global views of complex flows and fields



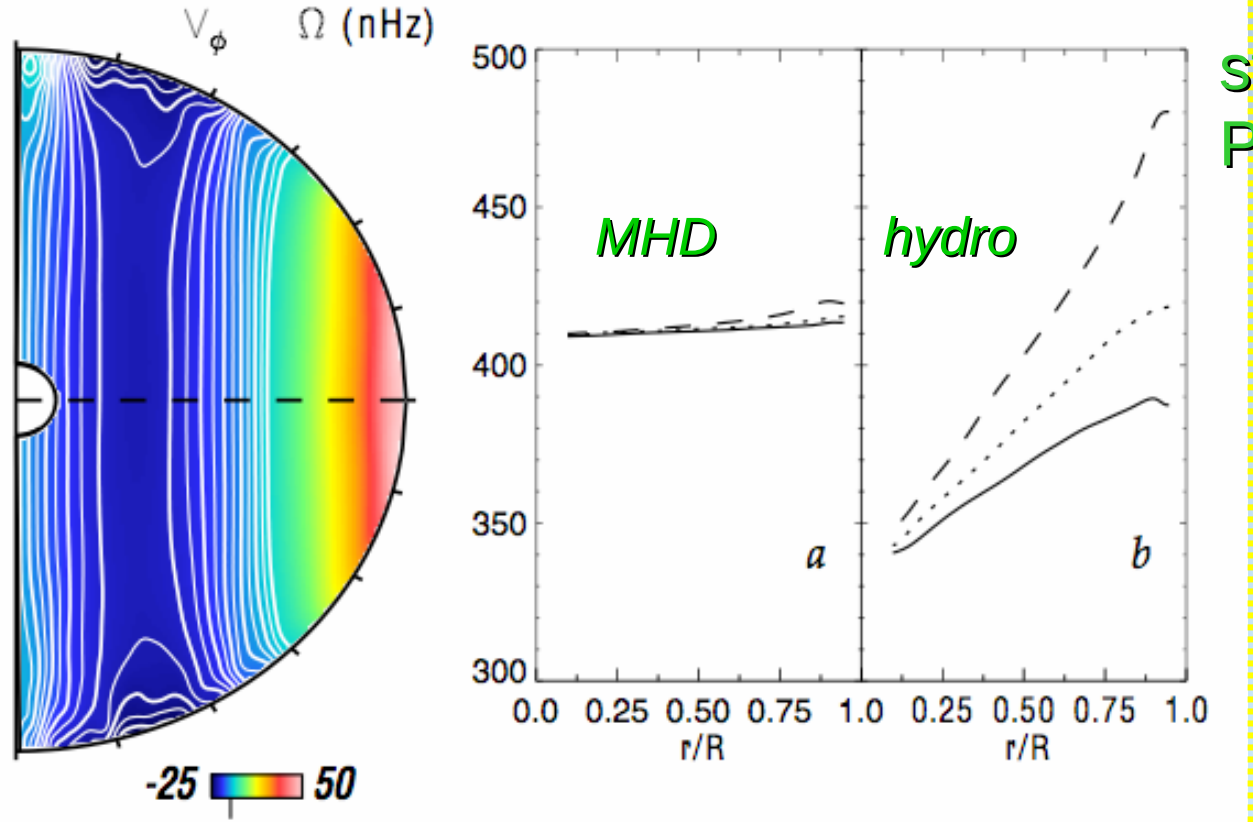
Structure on a variety of spatial scales

Fluctuating and axisymmetric fields



Although fluctuating fields dominate, mean fields are much larger than in solar simulations w/o tachocline

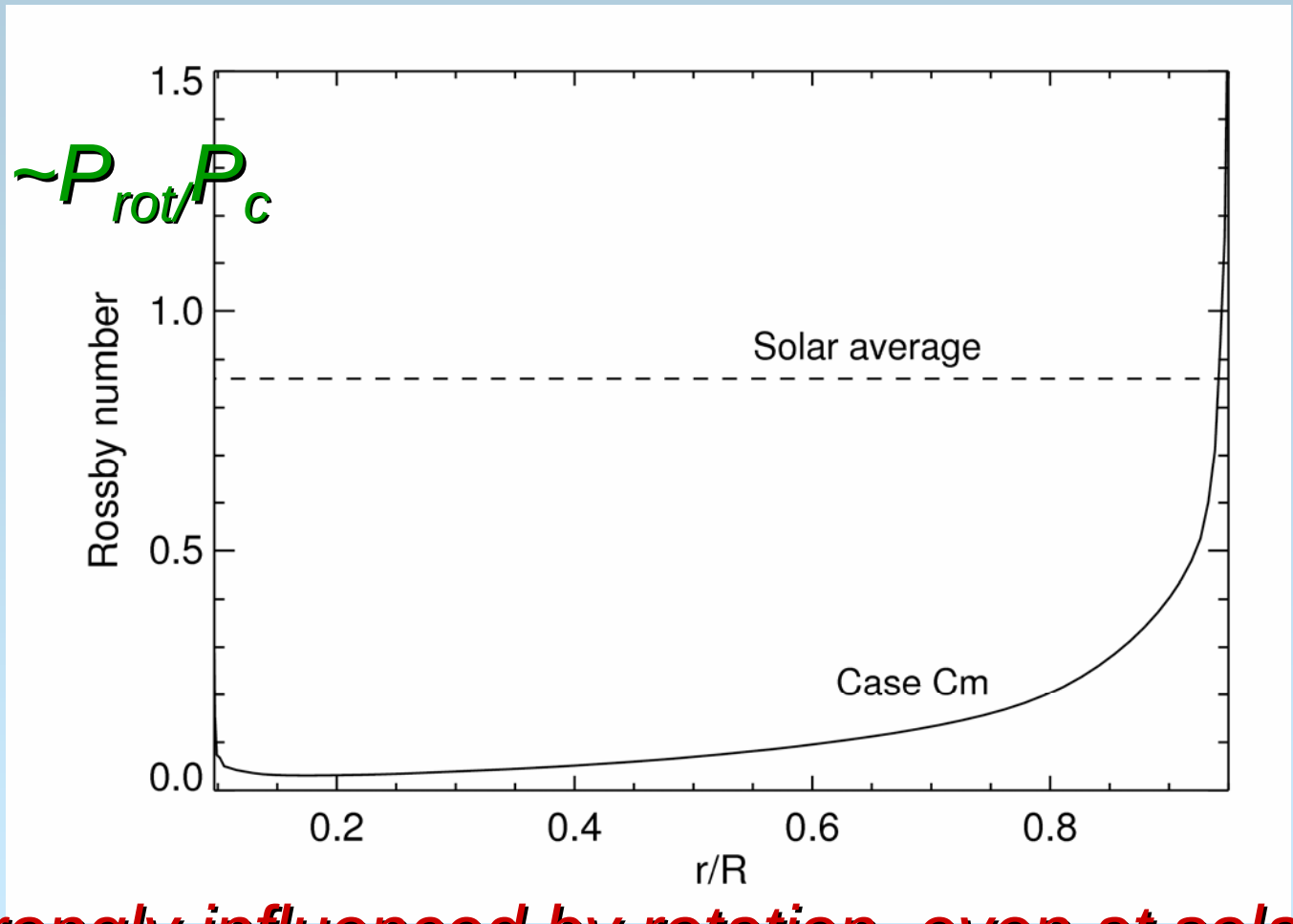
Establishment and Quenching of Differential Rotation



strong Taylor-Proudman constraint

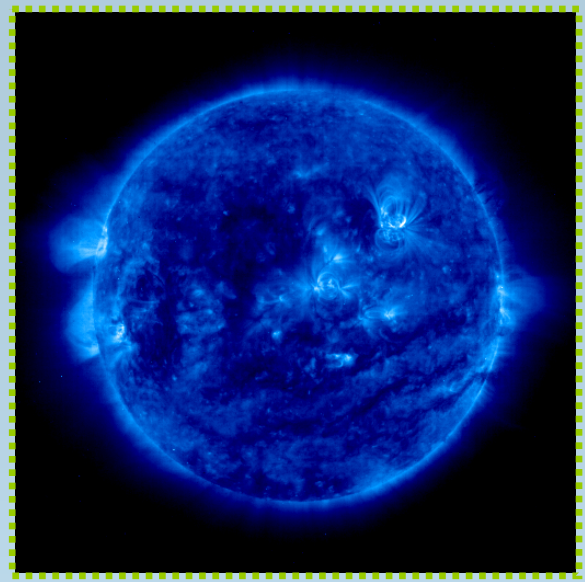
Differential rotation established in hydro, eliminated in MHD

Strong rotational influence in an M-star



Strongly influenced by rotation, even at solar angular velocity (which is approximately the minimum detectable rotation velocity in an M-star)

Summary and reflections



- Simulations suggest fully convective stars can build fields that *have strong large-scale components*
- Those fields can *quench the differential rotation established in hydrodynamic cases*
- Strong influence of stratification and rotation upon magnetic field strength and geometry: leads to some observational predictions