Rotating spherical shell dynamos at low magnetic Prandtl

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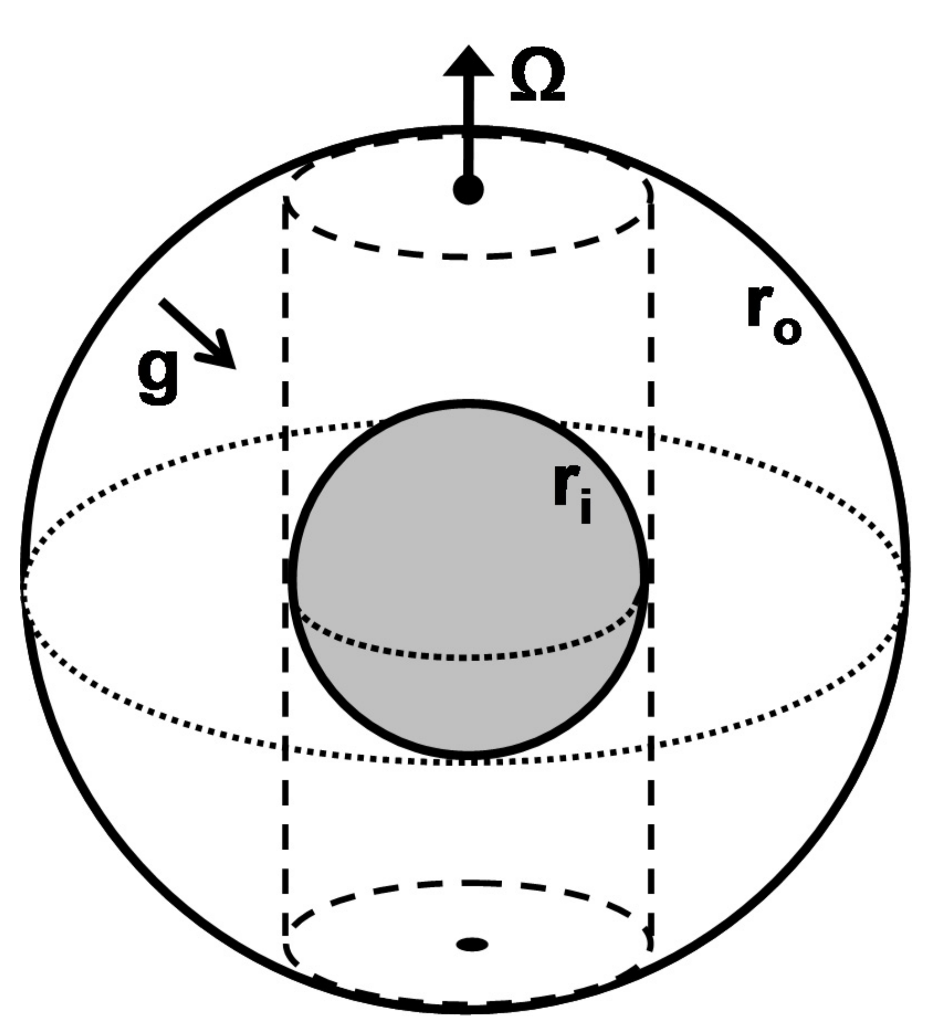
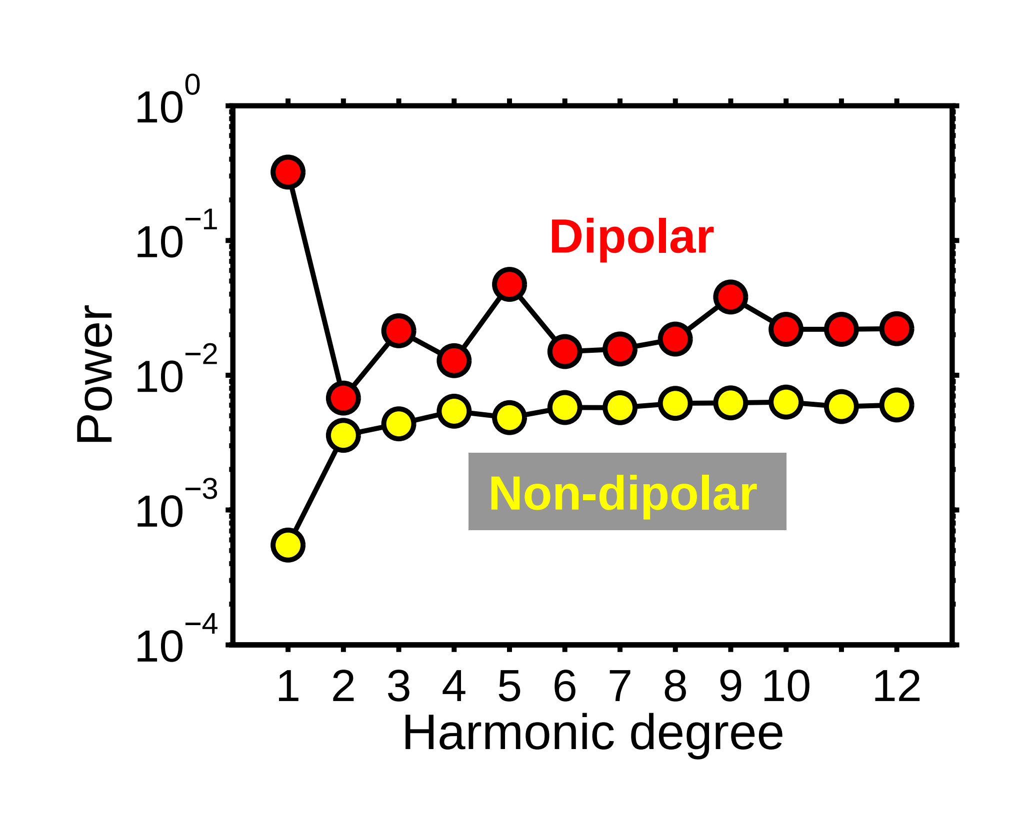
Outline of dynamo models

- Boussinesq equations for convection-driven MHD flow
- Rigid inner and outer boundary
- r_i / r_o = 0.35
- Fixed temperature contrast, no internal heat sources

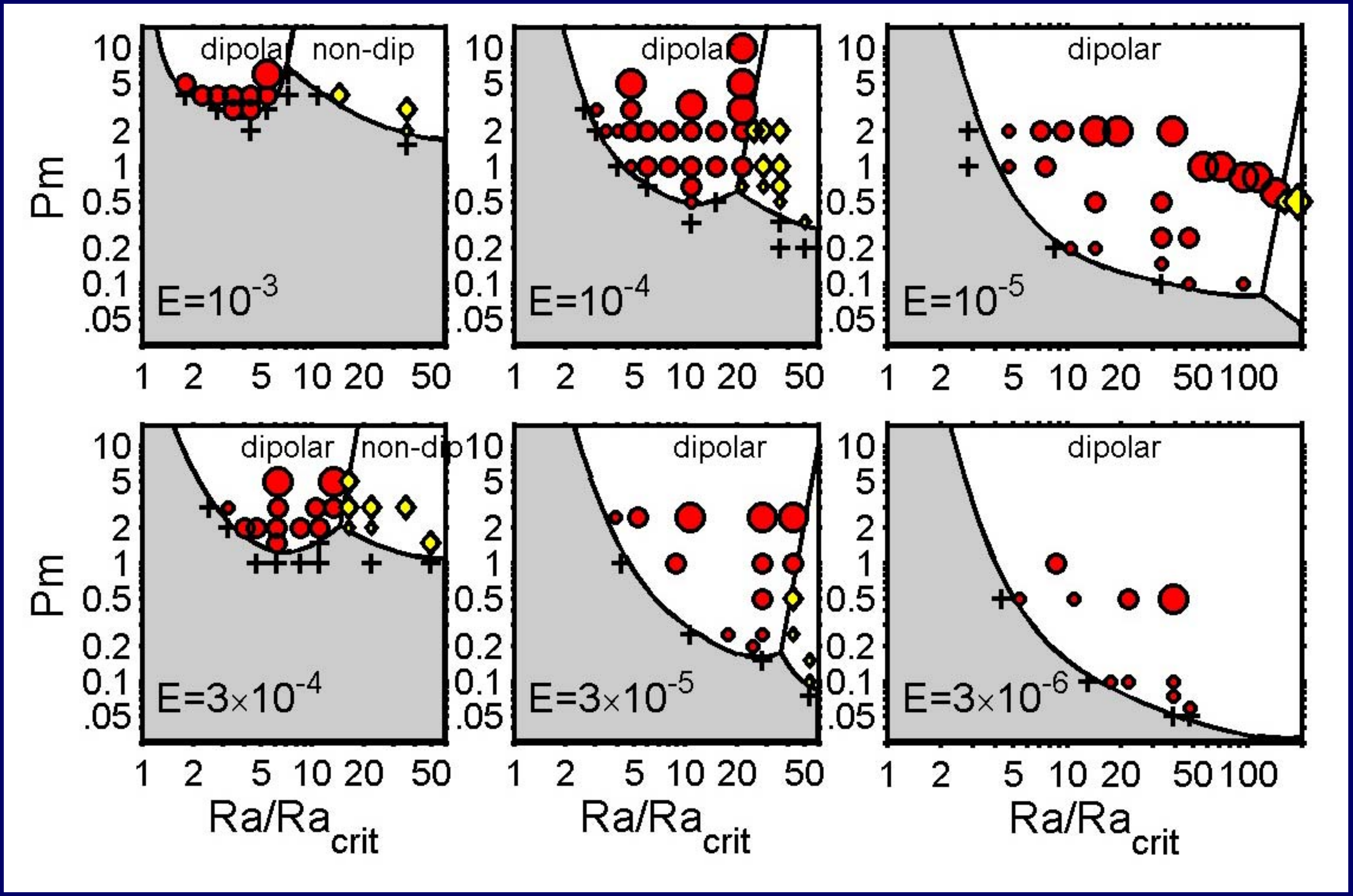


Two dynamo classes



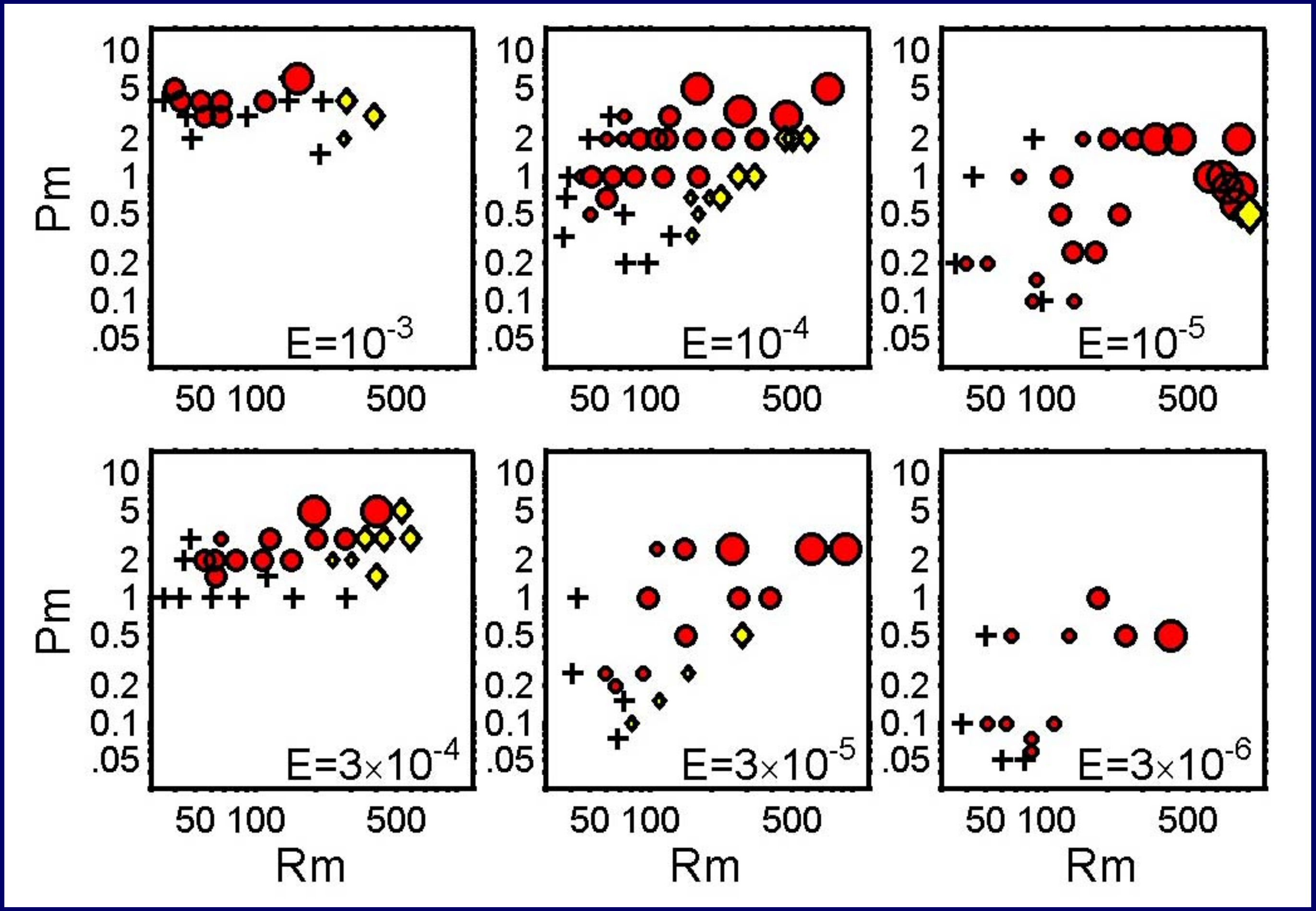
Typical power spectra of surface magnetic field

Dynamo regimes (at Pr=1)

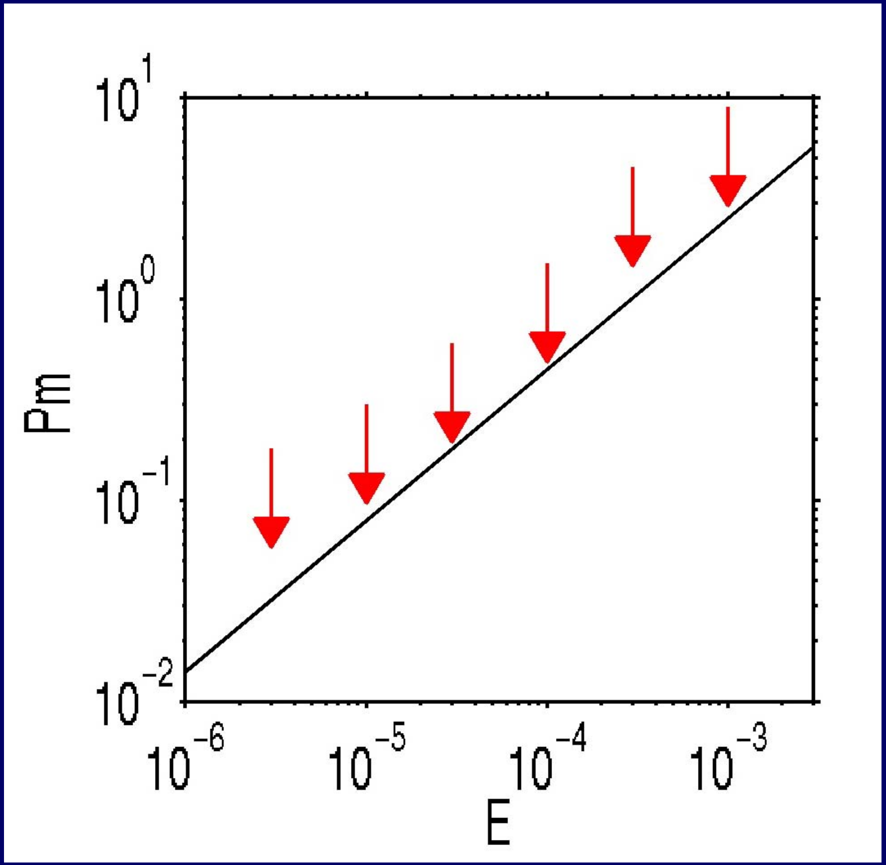


As the Ekman number is lowered, dipolar dynamos occupy a broader region and are found at lower magnetic Prandtl #

Dynamo regimes (at Pr=1)



Minimum magnetic Prandtl number for a dipolar dynamo

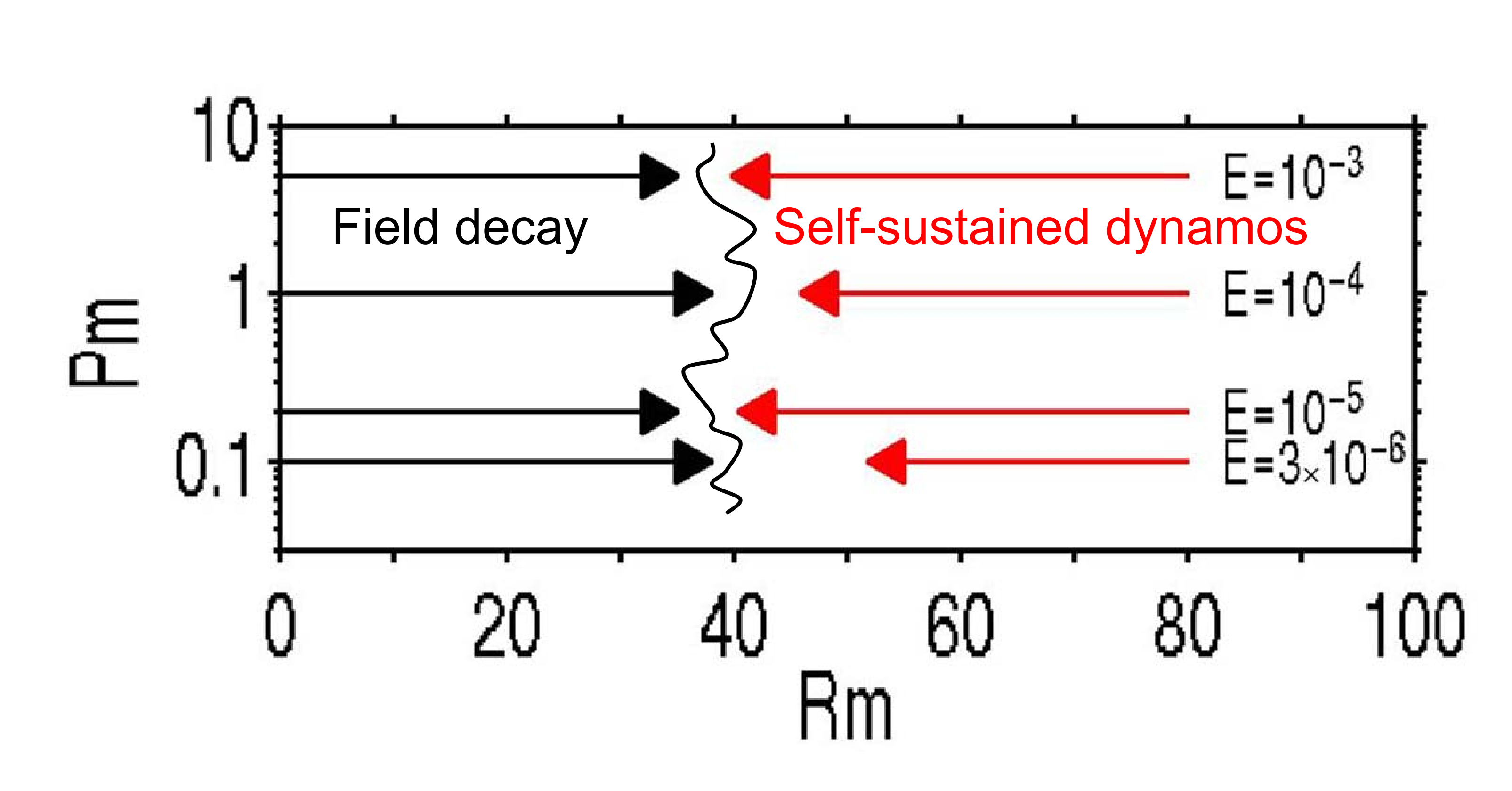


$$Pm_{min} \approx 450\ E^{3/4}$$

Earth values:

$E \approx 10^{-14} \rightarrow Pm_m \approx 2x10^{-8}$

Critical magnetic Reynolds number



$$Rm = U_{rms} D / \lambda$$

Critical Rm ≈ 40 – 45, independent of Pm (at low enough E)

Conclusion

- In rapidly rotating systems, dynamo onset at low Pm occurs at the same magnetic Reynolds number ($Rm_{crit} \approx 40 - 50$) as it does at high Pm
- Lower Pm requires lower Ekman number for onset at a low Rm
- Strong inertial forces, which arise in low-Pm dynamos (where $Re \gg Rm$) and which are detrimental to dynamo action, must be balanced by strong rotational constraints