8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Regimes and branches of geodynamo action

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Planetary magnetic fields are produced by dynamo action through turbulent motions of an electrically conducting fluid within the interior of the planet. Recent numerical experiments of dynamo action relevant to the geomagnetic field have produced different regime branches identified within bifurcation diagrams[1]. Notable are separate branches (Fig. 1) in which the resultant magnetic field is either weak or strong (when compared with the fluid flow), as long predicted[2]. Weak field solutions can be identified by the prominent role of viscosity on the motion whereas the magnetic field has a leading order effect on the flow in strong field solutions. The existence of these distinct branches and bistability between them is reliant on a large enough magnetic Prandtl number, Pm, for each chosen Ekman number, E.

Performing simulations with 'large' Pm whilst reducing the viscosity (by lowering E) is computationally demanding. Hence obtaining strong field solutions relevant for Earth's core at required lower values of viscosity is challenging. Nevertheless, as computing power has advanced, some numerical simulations of the geodynamo models claim to be ever more appropriate for understanding the dynamics of Earth's core. This is despite the wider parameter space remaining under-explored. One measure of the success of models is their ability to replicate the expected balance between forces operating within Earth's core; Coriolis and Lorentz forces are predicted to be most important. The importance of considering lengthscale dependent force balances[3] and 'gradient-free' solenoidal forces has been highlighted[4] (Fig. 2).

Here we review the branches/bifurcations of dynamo action previously explored and introduce new results of branching across wider parameter space. Time permitting, we also review the (lengthscale-dependent) forces and solenoidal forces within geodynamo simulations and examine their ability to identify regimes and branches of dynamo action.

References

[1] E. Dormy *et al*, Fluid Dynamics Res. **50**, 011415 (2018)

[2] P. Roberts, In: Cupal, I. (ed.), Proc. First Int. Workshop on Dynamo Theory and the Generation of the Earth's Magnetic Field pp. 7–12. Czech. Geophys. Inst. Rep (1979)

[3] T. Schwaiger *et al*, Geophys. J. Inter. **219**, S101–S114 (2019)

[4] R. J. Teed & E. Dormy, J. Fluid Mech. **964**, A26 (2023)

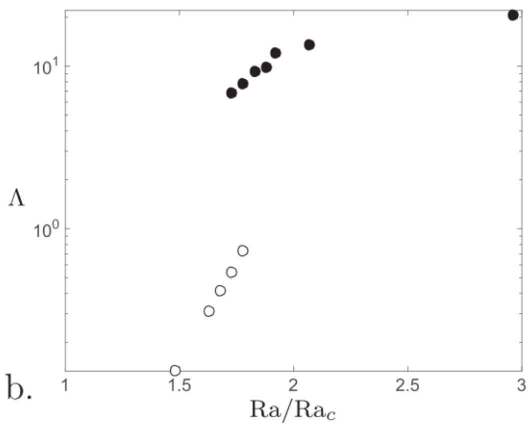

Figure 1: Log plot of Elsasser number, Lambda, as a measure of magnetic field strength as a function of convective driving strength, Ra/Ra_c. Weak field (open circles) and strong field (filled circles) branches for $E=3\times10^{-4}$, Pm=18. Plot taken from [1].

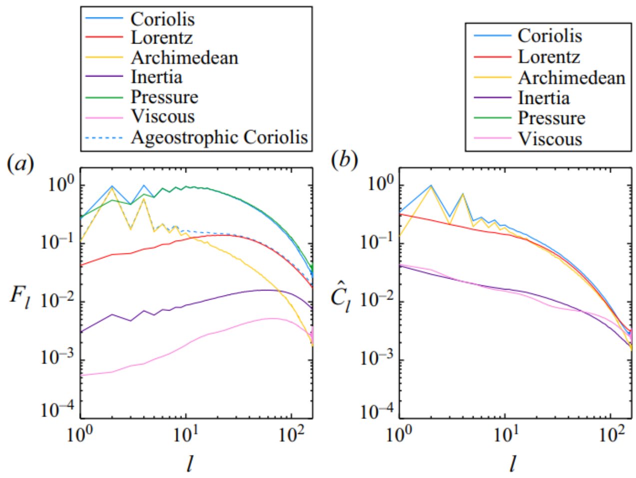

Figure 2: Forces, F_l, and solenoidal forces, C_l, as a function of spherical harmonic degree, l (i.e. as a function of inverse lengthscale). Plots taken from [4].