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Numerical study of dynamo action in a rotating spherical shell at low Ekman numbers

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We study rapidly rotating spherical MHD dynamos through classical pseudo-spectral 3D simulations. Self-exciting dynamos with a wide variety of the Ekman numbers down to 10^{-6} are found as well as the magnetic Prandl number down to 0.2. It is found that the onset of dynamo action begins at the Rayleigh number 4-5 times the critical value, and that the critical magnetic Reynolds number for successful dynamo stays between 40 and 50. These are the features independent of the Ekman and magnetic Prandtl numbers. The flow structure is characterized by the small-scale columns at low Ekman number, whereas strongly dipolar configuration dominates the magnetic field. In such situation, viscous dissipation is dominated by the small-scale eddy; the Ohmic dissipation by the large-scale field, and the latter exceeds the former by a factor of 10. The axial torque balance in the vorticity equation is investigated, and it is found that contribution from the buoyancy force is nearly balanced by that from the Coriolis force with less contributions from the Lorentz, inertial and viscous forces. This fact indicates that the magnetic field plays an insignificant role in the global flow dynamics, although it plays some roles locally. As for dynamo action, generation of the local magnetic energy is investigated. Preliminary analysis shows that the stretching term acts against the diffusion term, with the residual balanced by the advection. It is suggested that main energy balance is satisfied by the stretching and diffusion terms, complemented by the local energy injection or ejection by the advection term.