Kinematic dynamo action driven by top-down compositional convection

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The terrestrial bodies that maintain their intrinsic magnetic fields have dynamos in the fluid cores, in which convection is driven in various ways. As for compositional convection in the Earth's core, it is light element ejection into the outer core caused by inner core growth that fuels compositional buoyancy. In a body, iron ejection due to solidification of iron could occur at the core-mantle boundary under a certain condition, and the solidified iron falls downward like snow drop, that is so-called "iron snow", which would also power compositional convection. It strongly depends on temperature-pressure conditions and bulk sulfur content in the core which sort of compositional buoyancy contributes to convection. In this study, we focus on the iron snow process, which would happen at temperature and pressure lower than those in the Earth's core, and the associated dynamo mechanisms.

First, to understand a basic flow structure and properties of iron snow convection, onset of compositional convection in rotating spherical shells is studied as a linear stability problem. We consider the Boussinesq fluid contained in rotating spherical shells, of which radius ratio in the shell is 0.2. The linearized governing equations, that is, the momentum equation and the transport equation of composition, are solved as an eigenvalue problem at the Ekman number of 10^{-3}. As a result, we find the critical Rayleigh number of 36854, and the critical azimuthal wavenumber of four.

Then, using the eigen-mode velocity field, we solve a kinematic dynamo problem by time-stepping the magnetic induction equation. Stability of the initial dipole magnetic field is investigated. As the control parameter is the magnetic Reynolds number in the kinematic dynamo problem, we search for the critical value, at which growth rate of the initial dipole field is zero. Then, we examine spatial structure of the fastest-growing mode, its amplification process, and sustenance mechanisms of the dipole, i.e. the Bullard process.