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Magnetic field generation in terrestrial bodies: from planetesimals to large exo planets

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Of the terrestrial bodies Earth, Mercury and Ganymede generate magnetic fields and the detection of remnant magnetization in old crustal rock indicates on magnetic field generation early in the evolution of Earth, Mars and the Moon. Even small bodies like planetesimals have possibly generated fields during the first tens million years as suggested by the remnant magnetization in meteorites.
The necessary conditions for a dynamo in terrestrial bodies are the existence of an iron-rich core that is undergoing intense fluid motion. The fluid flows must be sufficiently rapid to ensure the field is regenerated faster than its ohmic decay. It is widely accepted that the fluid motion is caused by convection driven either by thermal buoyancy and/or by chemical buoyancy. Both the thermally and the chemically driven dynamo require that the core is cooled at a sufficient rate by the mantle. For the thermally driven dynamo with a purely fluid core the heat flow from the core into the mantle must be larger than the heat conducted along the core adiabat to allow a convecting core. This threshold depends on core pressure and is a few mW m-2 for small bodies such as Mercury and Ganymede but can be as large as a few tens mW m-2 for Earth and Venus. Thermal evolution models indicate that in the early evolution of a terrestrial body these thresholds can be exceeded, thus allowing for a thermal dynamo at that time. The duration and strength of the thermal dynamo then depends on the heat transport mechanism and the initial temperature distribution, i.e. both increase with increasing heat transport efficiency and initial super heating of the core.
For the chemical dynamo, the chemical buoyancy is released upon the growth of an inner core. Thus, the core temperatures need to be in-between the solidus and liquidus of the core material but the requirements on the core heat flow are less restrictive. Inefficient heat transport in the mantle even via conduction may be sufficient for a chemical dynamo as suggested for Mercury.
In the present paper, the conditions favourable for either thermal or chemical dynamo action will be discussed with a focus on the variation of planetary body mass (size), considering that the efficiency of the heat transport and relevant parameters for the magnetic field generation such as the melting temperature and the core adiabat are pressure depend. The mass (size) range considered includes planetesimals and exoplanets with up to ten Earth masses.