EPSC Abstracts
Vol. 12, EPSC2018-740, 2018
European Planetary Science Congress 2018

# Core dynamo in mantle-stripped asteroids

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## Abstract

Core dynamo is one of the most efficient mechanism to produce magnetic field in the planetary bodies of the solar system. However, also minor bodies like asteroid show evidence of a past magnetic field: Vesta [1, 2] and Psyche [3, 4] are the most common examples. In particular, Psyche is the metallic residual core after a mantle-stripping. In this regard, it is interesting to evaluate how the thickness and composition of the residual overlying rocky lid influences the thermal convective evolution of the core [5].

## 1. Introduction

The generation of a magnetic field is possible if the core of the body is: 1) metallic; 2) liquid; 3) in convection. In the small bodies of the solar system, these three conditions are hardly respected due to the low temperatures generally reached in their interior. Typical timescales of core dynamos are of the order of 10-100 Myr after the formation of the body [6, 7]. The role of the "crust" (the upper silicate layer) is crucial in the core dynamo evolution. In this work we have analyzed different initial configurations, characterized by different crustal thickness. The methodology adopted in this work is to investigate the thermal convection evolution of these bodies and to use a scaling law (based on the mixing length theory) in order to estimate the magnetic field evolution.

## 2. Numerical Model

The model solves the Navier-Stokes equations with the buoyancy term, in the Boussinesq approximation:

$$\rho \frac{\partial \vec{u}}{\partial t} + \vec{\nabla} \cdot \left[ (\eta \vec{u} \times \vec{u}) \right] = -\vec{\nabla} \cdot p\vec{I} + F, \qquad (1)$$

where $\eta$ is the dynamic viscosity (considered temperature-dependent), $\vec{u}$ the convective velocity, $\rho$ the density, $p$ the pressure and $F$ is the bouyancy term.

We also impose that:

$$\rho \left( \vec{\nabla} \cdot \vec{u} \right) = 0, \qquad (2)$$

which physically means no sinks or sources.

The system of equations is completed by the heat equation:

$$\rho c_p \frac{\partial T}{\partial t} + \rho c_p \vec{u} \cdot \vec{\nabla} T + K \vec{\nabla} \cdot \vec{\nabla} T = 0, \qquad (3)$$

where $c_p$ is the specific heat and $K$ is the thermal conductivity.

The convective velocity is calculated according to [9]:

$$u = \left( \frac{4\pi G \alpha R_c^2 F_{conv}}{3 c_p} \right)^{1/3}, \qquad (4)$$

where $\alpha$ is the thermal expansivity, $R_c$ the core radius, $F_{conv}$ is the convective, estimated through the heat equation.

A non-dimensionalisation approach is adopted, following the scheme of [8], in order to control the thermal evolution through two key-parameters, the Prandtl and Rayleigh numbers. The core (100 km in size) is modeled as a mixture of iron and nickel, while the crust has the typical thermal properties of the silicate rocks. The initial temperature is such that the core is initially fully melt.

## 3. Results & Conclusions

The shielding of the crust is crucial in the duration of the melting of the core and of the dynamo. In case of very thin crust (1 km) the dynamo is not generated, while in the other cases we have explored (10 to 40 km crustal thickness), the timespan of the dynamo core ranges from 25 to about 70 Myr, less than the typical values found in literature [6,7]. A comparison with the cooling rates of the IVA meteorites is also provided. This study could support, from a theoretical point of view, future missions dedicated to this kind of asteroids, like Psyche.

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