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**Subject title: Full-sphere geodynamo simulations**

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**IPGP- Team Geomagnetism – UMR7154**

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***Presentation of the subject:***  (Maximum 2 pages)

The Earth’s dynamo, the so-called geodynamo, is sustained by thermal-chemical convection in its liquid outer core. Cold and dense material sinks from the core-mantle boundary, where heat is extracted from the core by the overlying mantle, and light material and latent heat are released at the inner core boundary by the ongoing crystallization of the inner-core. At present-day, this crystallization is thought to be the major contributor to the power budget that is necessary to quench the geodynamo’s thirst (e.g. Lister, 2003; Labrosse, 2015).

The current radius of the inner core (1221 km) amounts to approximately one third of the core radius (3485 km). The time in the past when the crystallization started is uncertain and controlled by the thermal evolution of the Earth as a whole over its geological history. A key parameter controlling the thermal state of the core as it cools is its thermal conductivity, estimates of which span almost one order of magnitude in the recent literature (e.g. Ohta et al., 2016; Zhang et al., 2020; Landeau, Fournier, et al., 2022, for a review). This is not without consequences, as high values of the thermal conductivity preclude a pre-inner core dynamo based on thermal convection alone, and demand additional sources of energy to be sought (e.g. Badro, Siebert, and Nimmo, 2016; O’Rourke and Stevenson, 2016). In any event, the inner core is a relatively young structure of the Earth’s interior, as recent estimates of its age range between 500 Ma and 1.3 Ga (Zhang et al., 2020, and references therein).

Yet, paleomagnetic analyses of ancient rocks indicate that the geodynamo has been operating for at least 3.4 Gyr, producing a magnetic field whose strength was large enough to be properly recorded (Tarduno, Blackman, and Mamajek, 2014). This implies that the geodynamo has been a full sphere fluid dynamo for most of its life. Some of the most intriguing paleomagnetic features, such that the hyperreversing regime recently put forward by e.g. Bazhenov et al., 2016; Gallet, Pavlov, and Korovnikov, 2019, could have been the product of such a full-sphere dynamo.

Full sphere dynamo action sustained by thermal convection alone has received little attention in a geophysical context, notwithstanding the work of Landeau, Aubert, and Olson, 2017 who compared a handful of simulations of dynamo action in the present-day, spherical shell geometry with a handful of simulations in the full-sphere geometry. Their conclusions are the following:

* Inner-core nucleation leaves no long-term trend in the paleointensity record
* Interestingly, the absence of an inner core enables a non-dipolar and hemispherical dynamo regime that could have caused short-lasting paleomagnetic anomalies.

These findings demand confirmation based on a more systematic analysis, as they may dramatically impact our interpretation of paleomagnetic intensity measurements.**The overarching goal of this PhD is to investigate the properties of thermally-driven dynamo action in a full sphere geometry through a systematic exploration of parameter spac**e. End products will include an extension of the scaling laws currently available for the spherical shell dynamo (e.g. Christensen, 2010) to the full-sphere dynamo, the determination of the boundaries between dipole-dominated and multipolar dynamo regimes, and an analysis of the reversing properties of such dynamos, in order to facilitate the interpretation of paleomagnetic data.

Simulations will rest on the open-source, pseudo-spectral MagIC code (<https://github.com/magic-sph/magic>), whose main developer is co-advisor Thomas Gastine. MagIC is equipped with a full-sphere technology which makes it possible to run full-sphere simulations without being penalized by the unwanted concentration of grid points in the vicinity of the center of a sphere. This high-performance, massively parallel code is routinely run on the local S-CAPAD cluster and national facilities. It was used by former PhD students Tobias Schwaiger to investigate the force balance in the present-day geodynamo (Schwaiger, Gastine, and Aubert, 2019) and Théo Tassin’s thesis to study double-diffusive convection and dynamo action in a spherical shell (Tassin, Gastine, and Fournier, 2021).

This thesis work falls within the general framework of modeling the dynamics of geophysical and astrophysical fluids, in particular by studying instabilities and establishing scaling laws. It involves developing strong skills in physical and numerical modeling. We seek an individual with a solid background in geo- or astro-physics, or fluid mechanics. Experience with parallel programming and/or paleomagnetic data is a plus. Depending on the PhD student’s interests, emphasis may be placed either on the paleomagnetic interpretation of our findings, through interaction with paleomagnetists (at IPGP and beyond), or on the fluid mechanics of thermal-chemical convection in a full sphere geometry.

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