Subject offered for a contract starting october 2017

SUBJECT TITTLE:

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Host lab/ Team : *please fill in and leave out meaningless information*
IPGP – Geological Fluid Dynamics / Geomagnetism

Financing: Doctoral contract with teaching assignment

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Presentation of the subject: (1 or 2 pages)

Geodynamo simulations in the Earth's core dynamical regime: a systematic study

Over the past twenty years, numerical geodynamo simulations have been extremely helpful to understand the generation mechanisms and the properties of Earth's magnetic field. However, these simulations have long operated in a physical parameter regime far from that of the Earth's core, raising doubts on whether the modeling successes were obtained for the right physical reasons. Until recently, the correct parameter regime was also thought to be completely out of reach, given the recent evolution of the available computer power.

These paradigms have recently shifted with an advance recently presented by our group (Aubert, Gastine, Fournier, spherical convective dynamos in the rapidly rotating asymptotic regime, Journal of Fluid Mechanics, 2017). We have elaborated numerical simulations of the geodynamo that enable access to the correct physical regime of the Earth's core at a reasonable computer cost. The success of this approach relies on two essential ingredients: 1) follow a relevant parameter space path connecting classical models and Earth's core conditions, and 2) parameterize the strong hydrodynamic turbulence in the system through a physically sound large-eddy simulation scheme. For the first time, the simulation results have exhibited the expected asymptotic properties relevant to the rapid rotation regime in which Earth's core resides. A geophysical investigation of the physical system underlying the geomagnetic observations at hand is thus now made possible with a previously unattained physical realism.

The objective of this Thesis is to fully exploit these results through a systematic parameter space sampling of the region between classical models and Earth's core. The research goals are fourfold:

1) **Elaborate a cross-path regime diagram.** Though the robustness of the asymptotic regime attained has been demonstrated as one moves along the path, interesting physical transitions can be observed as one moves transversally, and knowledge of these transitions is needed in order to achieve a full understanding of the system.
2) **Refine the turbulence closure scheme.** The large-eddy simulations that have been used to obtain our initial results are rather simple, as they rely on a physically controlled hyperdiffusive treatment of the physical quantities. Removing the hyperdiffusivity and upscaling the model resolution enables to simulate turbulence, understand its characteristics and elaborate new closure schemes with the promise of higher accuracy.
3) **Study the interaction of turbulent convection and magnetohydrodynamic waves.** One of the most promising aspects of our new simulations is that they are able to clearly separate the temporal domains in which convection and magnetohydrodynamic waves exist, and to realistically render their interactions. A wealth of new physical phenomena are thus accessible, with possible important geophysical signatures that would enable to know more about the physical properties of Earth's core.
4) **Scale the covariance matrices along the path.** Geomagnetic data assimilation (one of the strong assets of the IPGP group) requires the description of numerical dynamo solutions in the form of statistical covariance matrices. Currently our geomagnetic forecast schemes use the matrices of classical models, rendering a dynamics which is only partially accurate. Being able to scale these covariance matrices to more realistic conditions holds the promise of performing more accurate forecasts of the future geomagnetic field evolution.

We seek a candidate with background and interest in Deep Earth Geophysics, Geomagnetism, Applied Mathematics and high-performance computing. A first experience in fluid dynamical numerical simulations will be appreciated. A good level in English is a pre-requisite for the completion of this project.