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The Structure and evolution of Mercury's core

DURATION
15/12/2019 - 15/03/2022

BUDGET
196 200 €

PROJECT DESCRIPTION

Mercury is the only terrestrial planet of the Solar System, other than the Earth, to have a magnetic field generated by dynamo action in its core. Spacecraft data indicated that the core contributes a much larger fraction to the total mass of the planet than do cores of the other terrestrial planets and also gave clues about the composition of the core. Many other, often even basic, characteristics of the core are not yet known. For example, firm evidence of the existence of a solid inner part of the otherwise liquid core is still lacking but also the general thermal and chemical evolution of the core and the working of the dynamo mechanism remain shrouded in mystery.

This project aims at reaching a better insight into the core of Mercury by improving modelling approaches used for the interpretation of geodesy data. Planetary geodesy, the field of study of the rotation, gravity field and shape of a planet, currently gives the clearest view on Mercury's core, but requires theoretical models to link the observational data to the interior. Here we will develop two complementary and innovative aspects of those models: (1) a theoretical model (mixing length theory) to better understand the thermal evolution of the core, and (2) an assessment of the influence of flow in the liquid part of the core on the rotation rate variations (called librations) of Mercury by magneto-hydrodynamical calculations. For the first objective, we will calculate the local temperature and convective flux at each position in the core, which will allow us to determine the core temperature profile and to track the evolution of a likely region of stability against convection, wherever it starts in the core. Such a layer not only influences Mercury's evolution, but is also suggested to be a key ingredient to explain Mercury's magnetic field. For the second objective, we will go beyond the classically used hypothesis that the core fluid can be assumed to perform an essentially rigid body rotation. To describe the fluid dynamics inside the core, we will use a model based on the resolution of the Navier-Stokes equation coupled to the magnetic induction equation accounting for the dynamics of the magnetic field. We will investigate how core flow can modify the rotation of the planet and compute Mercury's librations for a range of different control parameters of the system, such as the size of the solid inner core, the mantle's moment of inertia, the fluid core viscosity, the imposed magnetic field, the magnetic diffusivity, and the conductivity of the mantle at the core-mantle boundary.

Both proposed research lines go well beyond current approaches and build on the existing expertise at the Royal Observatory of Belgium in rotation theory, modelling Mercury's interior, and fluid dynamics. The results will improve the interpretation of data relevant for the core of Mercury of the NASA MESSENGER mission (in orbit around Mercury from March 2011 until April 2015). In particular, this project will improve the conclusions about the interior that can be drawn from the main libration of Mercury, which currently is the most important source of information on the core.

This project will not only help optimizing the science return of the NASA MESSENGER mission but will also be a major asset for the interpretation of upcoming data of the ESA/JAXA BepiColombo mission, launched in 2018 to Mercury. It will not only provide better insight into Mercury's interior, but will also deepen our global understanding of the evolution of terrestrial planets and satellites in general. The results will be applicable to other terrestrial planets such as Mars, and satellites, like Ganymede, the largest satellite of the Solar System. Our results will provide deeper insight into the diversity of the terrestrial planets and will help better appreciating the different evolution tracks a terrestrial planet can follow. They therefore also have implications for the study of terrestrial-like exoplanets, a topic of intense international investigations.

The project will contribute to Belgium taking a leading role in the scientific exploitation of data of BepiColombo. It will strengthen existing expertise at the Royal Observatory of Belgium in planetary geodesy and geophysics and will facilitate starting up new initiatives in Mercury research and planetary research in general. The scientific results will be published in peer-reviewed journals in planetary sciences and we will communicate them widely at various international conferences. The numerical codes developed will be made publicly available.

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