

## 2-years Postdoc Position

Title: Mantle anomaly detection for Moon and Mars using tidal deformation and the Earth geophysics software CITCOM / CITCOM-Moon : comparison with analytical approaches and non-linear rheologies.

Starting date : 2nd semester 2025

Duration : 24 months

Institution : Géoazur, Observatoire de la côte d'Azur, Université Côte d'Azur

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After the Moon accretion, its mantle was entirely molten. According to some models, during the cooling of the lunar magma ocean, fractional crystallization led to a spontaneous "mantle overturn" when the last (denser) layers crystallized and sank into the mantle. This event may have formed a cumulate layer rich in dense minerals, including ilmenite, at the base of the lunar mantle. Today, there seems to persist a dense layer at the base of the lunar mantle, known as the LVZ (Low Viscosity Zone). Such a process may have occurred on all terrestrial planets that had a magma ocean. The objective of this project will be to characterize the current 3D structure of the Moon, Mars, and Mercury using tidal tomography developed at Géoazur, based on available (Mars Express, MRO, Mars Odyssey, MGS) and upcoming (Bepi-Colombo) space mission data for the Moon, Mars and Mercury.

The tool used for the modelization of the 3D structure is the fine-element software CitcomSVE (Zhong et al. 2022)

A first phase of the project is already initiated with a PhD working on the introduction in CitcomSVE of viscosity, shear modulus and density anomalies in the planetary mantle and first results in terms of shear-stress maps and Love numbers are promising.

For this postdoc, we propose three axes of research:

The first aspect to consider is the comparison with analytical modeling such as Love3D (Rovira-Navarro et al. 2024). These analytical modellings are very fast and can be an interesting tool for possible MCMC explorations for finding the location of heterogeneities. However, calibration with a full finite element integration is also necessary. This is why we propose to process such a calibration by comparing stress fields obtained with CitcomSVE and those obtained with Love3D.

A second direction of research could be the introduction of the Andrade rheology in CitcomSVE. So far only the Maxwell rheology was considered in the finite element software, but it has been demonstrated that for bodies other than the Earth, non-linear rheologies such as Andrade reflect in a more realistic way the dissipation of other terrestrial bodies. As the focus of our project are mainly Moon, Mars and Mercury, it is a reasonable motivation for introducing the Andrade rheology in CitcomSVE.

Finally, it will be interesting to give a timescale to the detected anomalies. Basically, we will address the question of how the detected 3D anomalies persist over billions of years. This is precisely the novelty of this proposal. We expect that the concentrations of heat producing elements in the initial cumulate layers are fundamental to the long-term preservation of 3D dynamic structures. We propose here to extend Stegman et al. (2003) model to evaluate how the dynamics of this dense layer left an imprint in the lunar interior after 4 billion years of cooling. This work will be done under the supervision of N. Coltice in using the Stagygy software (Tackley 2008).