AAP China Scholarship Council - CSC 2023

PROJET DE RECHERCHE DOCTORALE (PRD)

Titre du PRD : Investigation of Mercury dynamics: BepiColombo observations and numerical simulations

DIRECTION de THESE

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Ecole doctorale de rattachement : ED127 - AAIF

Nombre de doctorants actuellement encadrés : 3

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Ecole doctorale de rattachement : Sélectionner

Nombre de doctorants actuellement encadrés : 0

CO-TUTELLE INTERNATIONALE envisagée : ☐ OUI ☒ NON

DESCRIPTIF du PRD :

*Ce texte sera affiché en ligne à destination des candidates et candidats chinois : il ne doit pas excéder **2 pages** doit être rédigé en **ANGLAIS***

Unlike other planets in our solar system, Mercury's magnetosphere is highly dynamical mainly due to its proximity to the Sun and its weak planetary magnetic field. Mercury's environment was first explored by the NASA/Mariner 10 flybys in 1974–1975. Since then it has been extensively studied thanks to the NASA/MESSENGER mission for more than 4 years, from the orbit insertion in 2011 until the final operations in 2015. Despite the wealth of observations that the MESSENGER mission provided about the planet and its ionized and neutral particle environments, the spacecraft payload featured a limited set of plasma instruments. Among these instruments the ion mass spectrometer "Fast Imaging Plasma Spectrometer" (FIPS, Andrews et al., 2007) could not resolve ion species heavier than Na+ because of its limited mass resolution. Moreover, MESSENGER did not include any experiment dedicated to "wave" measurements, namely high frequency electric and magnetic field fluctuations, which are crucial to understand the dynamical processes particularly at the kinetic scales (cf. wave-particle interactions, energy dissipation, etc).

The BepiColombo – an Euro-Japanese joint mission launched in 2018 will significantly expand our understanding of Mercury and its environment thanks to its comprehensive instrumentation. The mission consists of two spacecraft: MPO (Mercury Magnetospheric Orbiter) led by the European Space Agency (ESA) and dedicated to studying the solid planet; and Mio (former MMO: Mercury Magnetospheric Orbiter) led by Japan Aerospace Exploration Agency (JAXA) and dedicated to analyzing the Hermean plasma environment, i.e. its magnetosphere and its interaction with the nearby solar wind. The orbit insertion is scheduled for December 2025, until then the spacecraft is in cruise phase and will perform 9 gravity assist maneuvers in total (one around Earth, two around Venus and six around Mercury).

On June 23rd 2022, BepiColombo performed its second gravity assist maneuver at Mercury. Even though BepiColombo is in a so-called "stacked configuration" during cruise, meaning that the instruments cannot yet be fully operated, the instruments can still make interesting observations. Particularly, despite their limited field-of-view or being not yet deployed, the particle sensors and the plasma wave instruments allowed us to get a hint on the ion composition and the wave dynamics at Mercury, respectively. During this second flyby of Mercury, the Mass Spectrum Analyzer (MSA, Delcourt et al. 2016) revealed the presence of planetary He2+ and He+ close to the planet with a very low abundance of heavier ions, such as Na+ -group and O+ -group ions. Moreover, clear variations in the ion distribution was observed in the foreshock region in the outbound portion of the orbit [Hadid et al. in prep.]. During the same flybys the PWI/search-coil magnetometer detected the first high frequency waves in the Hermean environment [Ozaki et al., in prep., Sahraoui et al. in prep.]

The thesis project consists in studying the multiscale interaction of the Mercury magnetosphere to the highly dynamical and varying solar wind. It involves strong synergy between numerical simulations and spacecraft observations. The observational part will use first the BepiColombo data acquired during the various flybys for the 2 first years of the PhD project before expanding the work after the final orbit insertion in Dec 2025 when the instruments will be deployed and will be working at their full capabilities. The numerical part will use two types of numerical codes: Hybrid-PIC simulations (based on the LATHyS code) to analyze the global response of Mercury's magnetosphere and its neighboring regions (foreshock, magnetosheath, magnetopause and exosphere) and 3D full PIC simulations to analyze small scale structures. The global Hybrid-PIC simulations will allow us to i) map the location of the various boundaries (e.g., bow shock and

magnetopause) depending on the upstream solar wind conditions, and to ii) characterize the MHD and ion scale dynamics (turbulence, 3D structures, …) in the magnetosheath to better understand mass and energy transport through the magnetopause. The 3D full PIC code will be used to analyze smaller localized regions of the Hermean environment subject to energetic phenomena such as reconnecting current sheets where the processes of wave-particle interactions are active. The results of the numerical simulations will be compared to the low frequency wave data from the MAG and PWI to that of the ion measurements from the MPPE/MSA instruments. The full PIC simulations will be confronted to those of the electron measurements of the MPPE/MEA and PWI/DBSC instruments (electron acceleration, high frequency wave emissions, …). Comparisons with data from the Messenger spacecraft will be planned when needed.

This project involves strong international collaborations involved in BepiColombo. The numerical part will be performed in collaboration with Pr. Ronan Modolo (LATMOS) and Dr. Pierre Henri. The observational work will be done in collaboration with Dr. Dominique Delcourt (Co-PI of MPPE/MSA, LPP/LPC2E), Nicolas André (Lead-CoI of MPPE/MEA) and with other international teams, mainly ISAS/JAXA (Japan), PWI teams (Tohoku-JP, Kanazawa-JP and Uppsala-SW Universities), Michigan University (USA), MAG teams (Germany and Austria).

AVIS de l'Ecole Doctorale :

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à l'école doctorale de rattachement et à csc-su@listes.upmc.fr