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PROPOSITION DE SUJET DE THESE

Intitulé : Multiscale simulation of lunar dust electrostatic charging and transport

Référence : **PHY-DPHY-2024-17**
(à rappeler dans toute correspondance)

Début de la thèse : 01/10/2024	**Date limite de candidature :** 31/03/2024

Mots clés

Lunar dusts, electrostatic charging, multiscale simulation, Space plasmas

Profil et compétences recherchées

Plasma physicist or general physicist with competences in computational physic

Engineer school or master degree in physics

Présentation du projet doctoral, contexte et objectif

The Apollo missions demonstrated that the lunar regolith, composed of very small dust particles of micrometer to sub micrometer sizes, is a potential threat to any mission on or close to the moon surface. The absence of atmosphere and the constant ionizing radiation favors a very strong electric charge and a chemical reactivity that make dust stick to almost everything. To protect and preserve the mechanisms, optics, thermal control coatings, sealing and health of astronauts, it is of paramount importance to understand the underlying charging mechanisms of dust under a representative environment, both numerically and experimentally.

Committed for nearly 10 years to the study of electrostatic charging and adhesion of dust in Space, ONERA conducts several studies with ESA and the EU through dedicated experimental facilities and numerical simulations. The Spacecraft Plasma Interaction Software (SPIS – www.spis.org) is an open source software worldwide used and whose numerical core is mainly developed by ONERA since its creation 20 years ago. Originally created to simulate the electrostatic charging and discharges due to Space environment, SPIS is now used in a broad range of application and in particular the simulation of lunar dust environment.

The electrostatic charging of the lunar dust grains is suspected to be a key ingredient of the observation of dust levitation above the lunar surface and of the formation of a dust haze that may extend to several tens of kilometers in altitude. The dust ejection from the ground and subsequent motion is, though, to be due to a combination of factors including micrometeorite impacts and electrostatic forces. The latter is expected to be amplified by the lighting variation on the irregular moon surface, in particular close to the crater rims. The ejected dust particles can be deposited on landers on the moon surface.

To investigate for potential lunar mission risks, the capabilities of the spacecraft–plasma interaction simulator (SPIS) have been extended to include the modeling of the lunar dust charging, ejection, dynamics in the plasma, and deposition on surfaces (of rovers or Spacecraft's) in the frame of an ESA collaboration and funding (SPIS-DUST). SPIS-DUST has also been used to understand the charging behavior at the microscopic scale. At the smaller scales, the dusts grains are not uniformly charged in the depth of the dust layer. The dust charge arrangement could be a key factor to understand the physics of the adhesion and ejection of a dust layer. Even if existence of electrostatic negative and positive charges has been demonstrated on simple geometry (sphere), the modelling of the small-scale charge transport and arrangement depending on the dust electrical properties need to be improved. In parallel, the experimental observations of such charges have started in the ONERA DROP facility. The small scales simulations in conjunction of the experimental observations is an important objective to tackle the question of the electric properties of the lunar dusts.

In addition, there is an important coupling between the small-scale description of the dusts and the largest scale behavior in the natural plasma environment or inside on ground experiments. The dust's interactions solar wind plasma or the experimental conditions on ground are influencing the dusts trajectories. They directly influence the quantity of dust transport. It has a direct influence on the contamination by dusts in the realistic conditions. For scientific mission or on ground experiments, the trajectory modifications are influencing the probability to measure the dusts on the instruments.

The PhD student will have to work on different aspects of dust transport and charging with the objectives to improve the physical modelling at the smaller scale to the larger scales. The content of the PhD will be organized as follow:

1) Review of the dusts charging modelling at the individual dust scale and at the scale of a dust layers
2) Use of the SPIS-DUST existing models to identify the agreements/discrepancies with respect to experiments
3) Improvement of the existing models in SPIS-DUST, identification of the numerical modeling strategy in a multi-scale and multi-physic and implementation in SPIS
4) Exploitation of the new models on application cases: for example, to demonstrate their influence on the dust contamination in a realistic situation such as a Lunar rover or to improve the design of the dust measurement instruments

During the PhD, the student will have to develop its competencies in plasma physics modelling (solar wind plasma interaction with matter, photo-emission, photoelectron sheath) and electrical properties of dielectrics (electron secondary emission on dusts, electrical conductivity) , in computational physics (multi-scale 3D unstructured mesh, particle-in-cell methods, Monte-Carlo method), in scientific software development (written in JAVA) and in numerical simulation using SPIS.

Collaborations envisagées

Collaboration with ESA/ESTEC

Laboratoire d'accueil à l'ONERA

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Pour plus d'informations : https://www.onera.fr/rejoindre-onera/la-formation-par-la-recherche