Ion irradiation of Phobos simulants

*Antonin Wargnier[1,2], Audrey Moingeon[3], Eric Quirico[3], Thomas Gautier[2,1], Pierre Beck[3], Giovanni Poggiali[4], Olivier Poch[3], Vanesa Tobon-Valencia[3], Emma Caminiti[3], Sonia Fornasier[1], Alain Doressoundiram[1]

1. LIRA - Paris Observatory, France, 2. LATMOS, France, 3. IPAG, France, 4. INAF - Arcetri Observatory, Italy

The JAXA Martian Moon eXploration mission will be launched in 2026 toward the martian moon Phobos, which is spectroscopically and photometrically similar to dark asteroids. The mission will give the opportunity to obtain new insights into the study of dark primitive asteroid surfaces, including D-type asteroids. Laboratory experiments have already been conducted to identify suitable Phobos spectroscopic simulants and to investigate the effects of observation geometry [1,2,3,4].

Airless bodies, such as the Martian moons, experience significant space weathering due to the effects of solar wind, galactic cosmic rays, and micrometeorites bombardments [5]. The space-weathering at the surface of Phobos may explain the difference between the blue and red units [5,6], and a comprehensive understanding of space-weathering effects is pivotal to understand the origins of the Martian moons [7]. In this work, we investigate in the laboratory the spectroscopic and photometric modifications of Phobos regolith simulants with space-weathering induced by solar wind.

To accurately represent the surface of Phobos and its spectroscopic properties, several samples were selected, including two Phobos simulants [3,4], olivine, phyllosilicate (saponite), coal (anthracite, DECS-19 from the Penn State Coal Bank), and iron sulfide (troilite). This study investigated the spectro-photometric variations induced by space-weathering using the SHADOWS spectro-goniometer [8] at IPAG (France) with spectroscopic measurements ranging from 0.4 to 3.6 μm with different geometry of observations. Additionally, mid-infrared (MIR) reflectance spectra (1.25 –18 μm) were also obtained to study the modifications of shape and positional shifts of three key MIR features for mineralogical interpretation: the Christiansen feature, the Reststrahlen band, and the transparency feature.

We will present results on the irradiation of samples with 36 keV He^{2+} and 126 keV Ar^{7+} ions. The irradiation experiment was performed using the ARIBE beamline at GANIL (France) with the aim of reproducing the effects of solar wind that reach and alter Phobos' surface. The use of distinct ions allows to explore different deposited dose regimes.

We explored the spectroscopic and photometric modifications induced by space-weathering, with a focus on the evolution of peculiar absorption bands such as the 2.7 μm O-H feature and the 3.4 μm C-H aliphatic and aromatic features. We found no modifications of the 2.7 μm band after ion irradiation in saponite. However, a decrease by a factor of 2 in the C-H absorption band depths was observed on the DECS-19 sample (Fig. 1). This decrease in the C-H feature is consistent with the amorphization observed through Raman spectra associated with this sample (Fig. 2). Furthermore, a redshift of the reststrahlen band in the MIR was observed for both saponite and olivine.

The preliminary analysis of the photometric data reveals no significant variations after irradiation. This may be linked to the quasi-absence of textural modifications of the surface of the irradiated samples observed with Scanning Electron Microscope images, compared with fresh and unaltered parts.

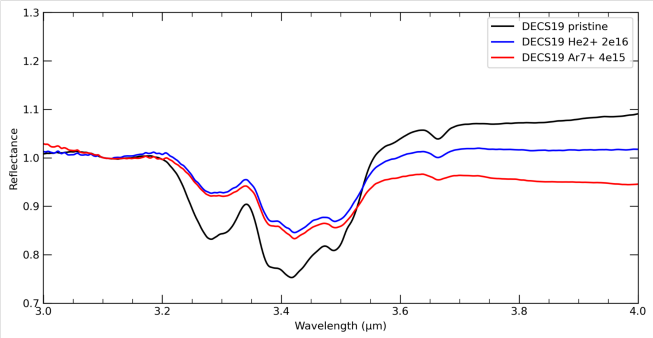
This study provides novel insights into the spectroscopic effects of solar wind on the regolith layer of dark primitive asteroids, focusing in particular on the application to the surface of the Martian moons, in preparation for the MMX mission.

Acknowledgments: The authors acknowledge the Centre National d'Etudes Spatiales (CNES) for its continuous support. We are grateful to the Grand Accelerateur National d'Ions Lourds (GANIL, Caen, France) for the time allocated on the ARIBE beamline for ion irradiation experiments under the proposal P1377.

References: [1] Wargnier et al (2023a), *A&A*, 669 [2] Wargnier et al. (2023b), *MNRAS*, 524, 3 [3] Wargnier et al. (2024), *Icarus,* 421 [4] Miyamoto et al. (2021), *EPS*, 73, 214 [5] Pieters and Noble (2016) [6] Takir et al. (2022), I*carus*, 371 [7] Wargnier et al. (2025), *A&A*, *accepted* [8] Potin et al. (2018), *AO*, 57, 28

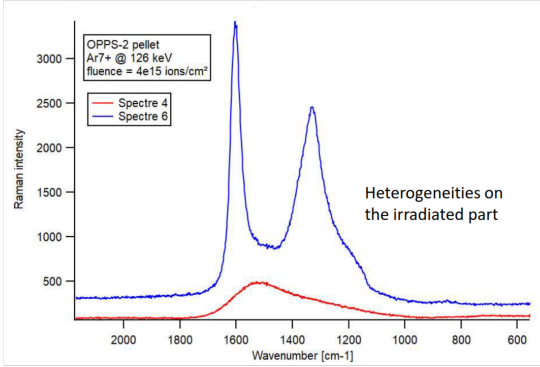
Keywords: Phobos, surface, asteroids, space-weathering

Fig. 1



Reflectance spectra (normalized at 3.1 µm) of DECS-19 in the 3.0 - 4.0 µm region.

Fig. 2



Raman spectra of OPPS Phobos simulants on two different regions of the sample

