LABORATORY REFLECTANCE MEASUREMENTS OF ICE AND DUST MIXTURES. APPLICATION TO PERMANENTLY SHADED REGIONS ON THE MOON AND MERCURY.

Z. Yoldi[1], A. Pommerol[1], O. Poch[2], B. Jost[1] and N. Thomas[1], [1]Physikalisches Institut., University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland (zurine.yoldi@space.unibe.ch), [2]Université Grenoble Alpes, CNRS-INSU.

Introduction: Some polar craters of the Moon and Mercury host permanently shaded regions (PSRs), i.e. areas that do not receive the light of Sun for geologically long periods of time. Because of the lack of atmosphere on these two bodies, PSRs on their surfaces can reach very low temperatures (<120 K) and cold-trap volatile components. A variety of techniques have been employed to search for volatiles that may be trapped in PSRs and to characterize them. At present, there is a general agreement on the presence of water ice trapped in PSRs on Mercury, whereas the detection of water ice on the Moon is yet inconclusive. An overview of the detection timeline of Lunar and Mercurian PSRs, as well as of the techniques used to identify possibly trapped volatiles is given by Lawrence in [1]. Some of those techniques, such as laser altimetry, focus on the detection of ice through the potential changes that its presence can cause on the reflectivity of the surface. Laser altimeters in orbit around the Moon (Lunar Orbiter Laser Altimeter, LOLA [2]) and Mercury (Mercury Laser Altimeter, MLA [3]) have already detected such variations in reflectance and for both bodies, the possibility of finding ice mixed within the regolith is explored [4, 5]. In order to help with the interpretation of laser altimetry observations in term of the presence and concentration of water ice, we conducted a laboratory study of the bidirectional reflectance distribution function (BRDF) of intimate mixtures of ice and JSC1-AF [6]. The study included measurements at zero phase angle (comparable with the data provided by LOLA and MLA) that could also be used to calibrate the reflectance models employed to invert the measured spectra. We showed how, in the visible range, dust can mask large quantities of ice (specially at small phase angles), hampering its detection by laser altimetry. As from 2019, the NASA's mission Lunar Flashlight [7] will measure the reflectance of the south polar PSRs at strategic wavelengths for water studies: 1.4, 1.5, 1.84, and 2.0 μm [8]. In order to check whether the masking of the ice by the dust is reproduced in the near-infrared (NIR), and to help with the future interpretation of the new observations, we have measured the reflectance spectra of ice and JSC1-AF mixtures in that wavelength range.

Methods: We have produced intimate mixtures of lunar soil simulant JSC1-AF with two different sizes of spherical-shaped ice grains in different mixing ratios. The fine-grained ice (a.k.a. SPIPA-A) has an average diameter of 4 μm and the coarse-grained ice (a.k.a. SPIPA-B) one of 70 μm. Details on the ice production and the mixture preparation are provided in [6]. All the reflectance measurements have been performed with the Simulation Chamber for Imaging the Temporal Evolution of Analogue Samples (SCITEAS) [9], a setup designed to acquire hyperspectral cubes from 0.355 to 2.5 μm at low temperature and pressure conditions.

Results: Figure 1 shows the reflectance spectra of intimate mixtures of SPIPA-B and JSC1-AF mixed in different proportions. The vertical lines show the wavelengths at which Lunar Flashlight will operate [8].

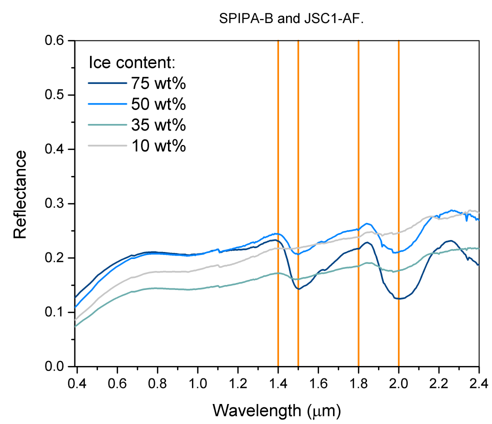

Figure 1: Reflectance spectra of intimate mixtures of SPIPA-B ice and JSC1-AF. Different colors correspond to different percentages of ice within the sample. The orange vertical lines indicate the spectral bands of Lunar Flashlight.

Figure 1 shows a drop in the reflectance in the first stages of ice addition; in the NIR, the sample containing 35 wt% of ice appears approximately 50% darker than the sample containing 10 wt% of ice. This behavior is partially explained by the presence of relatively large ice particles, which, when present in low percentage, increase the optical thickness of the sample. At larger ice concentrations the surface scattering counteracts the optical thickness, thereby the sample containing 50 wt% of ice appears brighter than the ones containing less ice. However, the strength of the darkening depends not only on the size of the ice but also on the properties of the dust [10]. Often, modeled reflectance spectra of icy intimate mixtures published in the literature assume a linear increase of reflectance with the augmenting content of ice within the mixture (e.g. [8]). This is true if the effective scatterer sizes of the end-members are similar, but cannot be generalized [6]. Without knowledge of the properties (i.e. size and shape) of the soil and ice that compose a mixture, numerical models for the inversion of reflectance data should be used with caution.

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