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Photometry of Mars soils analogs and implications for the identification of wet and frozen soils from orbit

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1. Introduction

A number of observations of the Martian surface rely on the analysis of solar light reflected by the surface. The photometric properties of the materials that compose the uppermost layer of Mars' surface are thus crucial parameters for detailed analyses of the remote-sensing datasets. Whereas laboratory measurements of the bidirectional reflectance of plausible Mars analogs are mostly restricted to volatile-free mineral samples [1], the case of a wet regolith simulant has already being investigated by [2]. These measurements have recently proven to be relevant for the interpretation of some of the most intriguing present-day processes on Mars: the Recurring Slope Linaes (RSLs) [3]. One aim of our work is to complement this pioneer study by using different mineral substrates, varying the amount of water and by investigating a wider range of geometric configurations. Besides the case of wet regolith simulants, we also studied how the reflectance of dry samples is affected by the surface preparation method and the photometric effects of water ice, associated in different ways to minerals.

2. Methods

The photometric measurements were conducted with the PHIRE-2 radio-goniometer [4] operated either at -30°C in a cold room for icy samples or at ambient temperature (+20°C) for ice-free samples. The instrument consists of two mobile arms, one holding a collimated light source, the other a silicon detector. Both arms are rotated to obtain different illumination and observation geometries. The minimum phase angle measured is 5°. Maximum angles are 70° for incidence and 80° for emission, respectively. Relative measurement uncertainties are in the range 0.5 – 2 %.

Samples were all prepared from two mineral components: the JSC Mars-1 regolith simulant and Hawaiian basaltic sand. The samples were wetted by spraying fine droplets of liquid water over the surfaces. Various techniques were used to produce different types of icy samples, for example by freezing wet samples or by letting atmospheric water condense onto cold mineral surfaces. The measured reflectance data were then fitted by the Hapke reflectance model to retrieve sets of parameters that can be used to reproduce our data and interpolate them to non-measured geometries.

3. Results and discussion

The comparison of dry surfaces prepared from the same JSC Mars-1 regolith simulant but with different preparation procedures illustrates the influence of the surface texture at millimetre-scale on the bidirectional reflectance of samples. These effects certainly account for the slight differences seen when comparing measurements of JSC Mars-1 obtained by different teams with different instruments and procedures.

Thee results of measurements on wet samples complement the previous study by [2] and show the strong influence of water not only on the overall level of reflectance of the samples but also on the shape of their phase function (Figure 1). Our observations provide interesting opportunities for putting additional constraints on the presence of liquid water in the Martian regolith from sets of images obtained under different measurement geometries. In particular, it appears that the opposition peak is extremely sensitive to the presence of water, even in low amount. Its absence would thus be a good indicator of the presence of liquid. The presence of liquid water also results in the appearance of a forward scattering peak whose intensity depends on the amount of water. Observations of the Martian surface in the forward scattering direction are however more difficult to interpret because of the stronger contribution of atmospheric aerosols to the observed reflectance in this geometry.

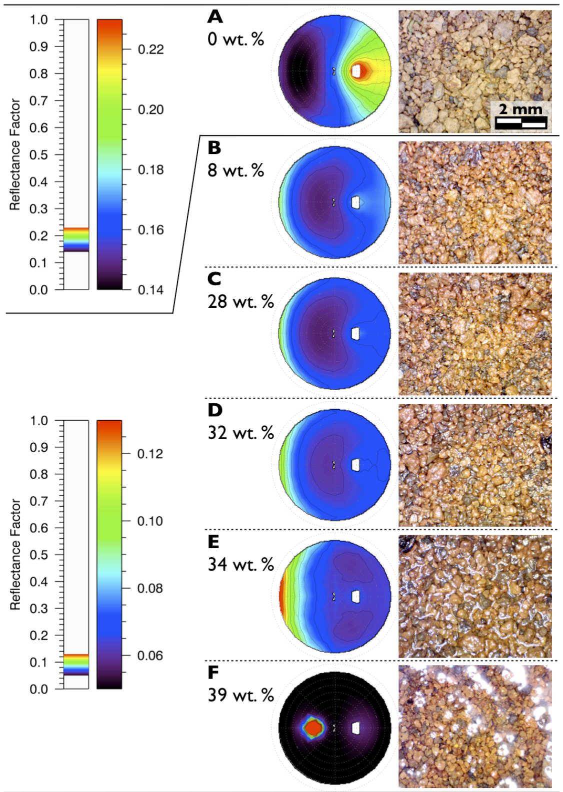

Figure 1: Evolution of the bidirectional reflectance of the JSC Mars-1 regolith simulant for increasing amounts of liquid water. The polar plots represent the reflectance of the surface for various emission and azimuth angles and for a fixed incidence angle: i=30° (see also the 3D representation on figure 2). The white spot on the right of the polar plot is the direction of incidence where no measurement is possible with our current setup.

Associations between water ice and minerals can result in very diverse photometric behaviors depending on the state of water ice in the sample. In particular, ice deposited as frost on the surface of the grains results in the appearance of a forward scattering peak whereas samples prepared by freezing surfaces containing liquid water all show a specular peak and a significant side scattering. The most characteristic photometric behavior observed for dry, wet and frozen samples are summarized in figure 2.

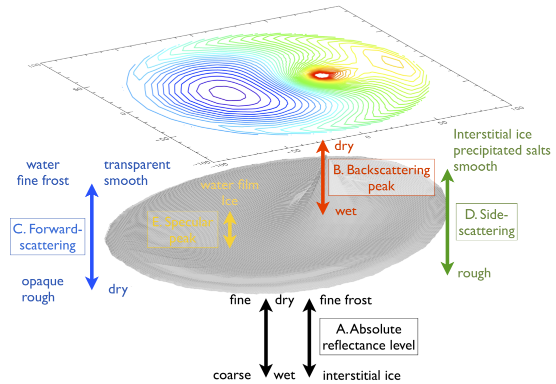

Figure 2: Schematic summary of the various photometric effects evidenced in this study. The 3D surface represents the typical reflectance of a JSC Mars-1 dry sample for incidence: i=30°.

4. Future observations

At equatorial latitudes, briny water is only stable at the surface in the early morning [5], which would prevent direct observation of water over RSLs by MRO (observations in mid-afternoon). The CASSIS camera on ESA's Trace Gas Orbiter will have the capability to observe the surface of Mars at different times of day and will in addition be able to observe the backscattering peak for regions within 25° of the equator, where many RSLs are found [6], providing new clues about the possible role of liquid water.

Acknowledgements

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