SPECTRO-PHOTOMETRY OF MARS SOIL ANALOGS. A. Pommerol[1], N. Thomas[1], B. Jost[1], P. Beck[2], C. Okubo[3], A. S. McEwen[4], M. Massé[5], M. R. El-Maarry[1], [1]Physikalisches Institut, Universität Bern (antoine.pommerol@space.unibe.ch), [1]IPAG, CNRS/Université Grenoble 1, France, [3]U.S. Geological Survey, Flagstaff, AZ, USA, [4]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA, [5]IAS, CNRS/Université Paris 11, Orsay, France.

Introduction: Many observations of the Martian surface rely on the analysis of the solar light scattered by its uppermost layer materials. A good understanding of this process, through modeling and experiments, is crucial to optimize the acquisition and analysis of orbital and in-situ data. The Laboratory for Outflow Studies of Sublimating materials (LOSSy) has been built at the University of Bern to characterize the spectro-photometric properties of planetary analogs with a special focus on those containing volatiles. We give here an overview of the laboratory experiments undertaken with analogs for Mars surface material.

These experiments were motivated by the analysis of data currently returned by the HiRISE and CRISM instruments on MRO, and by the current development at the University of Bern of the CaSSIS imaging system for the Exomars 2016 Trace Gas Orbiter. Of particular relevance for this work is the study of the Recurring Slope Linae (RSLs) discovered by HiRISE [1]. Our experiments were designed to answer the following questions:

- Is it possible to distinguish compositional and textural effects when studying the bidirectional scattering behavior of Mars analogs?
- How reproducible are the reflectance data measured in the laboratory and reported in the literature?
- What changes of color, albedo, and bidirectional behavior would result from the transient presence of concentrated brines in the Martian regolith?
- Can one find unambiguous photometric signatures of the presence of liquid water in regolith analogs, in the bidirectional scattering behavior of visible light?
- What can the bidirectional scattering behavior of icy samples tell us about the physical state of the ice in the regolith?

Methods: Data presented here were all measured in the LOSSy Laboratory at the University of Bern [2] on two different instruments:

- The PHIRE-2 radio-goniometer operated either at -30°C or at ambient temperature was used to measure the bidirectional reflectance inside six discrete bandpasses between 400 and 1100nm over wide ranges of incidence, emission and phase angles. We have recently upgraded the instrument to allow measurements of reflectance at low phase angle, g, including the exact opposition: g=0°.
- The SCITEAS (Simulation Chamber for Imaging the Temporal Evolution of Analog Samples) is a small thermal vacuum chamber in which samples can be exposed to variable conditions of pressure and temperature. The evolution of their surface can be characterized through a large window by a VIS-NIR spectral imaging system. Hyperspectral images in the spectral range: 0.4 to 2.4µm with a resolution of 20nm can be acquired at regular intervals of time (typically 30 or 60min) over a few days.

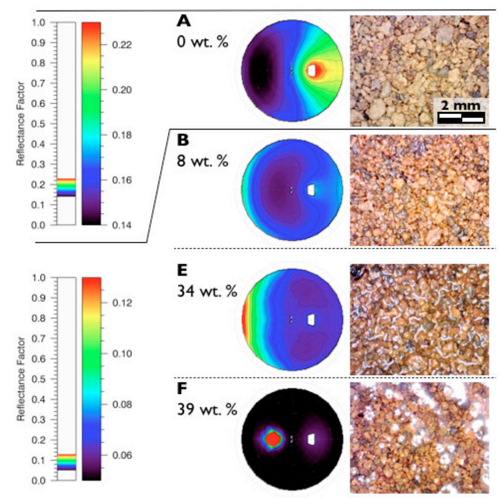

Figure 1: Evolution of the bidirectional reflectance at 650nm of the JSC Mars-1 regolith simulant for increasing amounts of liquid water (four selected steps, A to F). The polar plots represent the reflectance of the surface for various emission and azimuth angles and for a fixed incidence angle: i=30°.

The samples used here were all prepared from two rocky components: the JSC Mars-1 regolith simulant [3] and Hawaiian basaltic sand. The samples were wetted by spraying fine droplets of liquid water over the surfaces. For experiments involving brines, we used ferric sulfate, sodium and calcium chloride as salts. 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 fitted by the Hapke model to retrieve sets of parameters that can be used to reproduce our data and interpolate them to non-measured geometries [4].

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 millimeter-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 (for example: [5]).

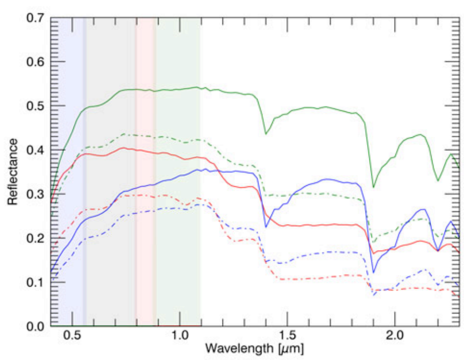

Figure 2: Hyperspectral data for a sample of smectite clay containing substantial amounts of water ice in its bulk. The image on top is a simulated CaSSIS color composite using the NIR, PAN and BLU filters as the RBG channels. The reflectance spectra at the bottom show comparison between the beginning of the experiment (dashed lines) and after 7 hours of sublimation (solid lines) for three different regions of the sample.

The results of measurements on wet samples complement the previous study by [6] 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 placing 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 water. The presence of liquid water also results in the appearance of a forward scattering peak whose intensity depends on the amount of water. However, observations of the Martian surface in the forward scattering direction are more difficult to interpret because of the stronger contribution of atmospheric aerosols to the observed reflectance in this geometry.

In addition to measurements of samples wetted with pure water, we have started to characterize samples wetted with concentrated brine solutions. We would like to complement with new VIS measurements the study performed in the NIR by [7]. We also use these hyperspectral data to simulate the color that would be observed by HiRISE or CaSSIS when imaging such a material to facilitate the comparison with current and future color images of RSL areas [8].

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. We have also characterized by means of hyperspectral imaging, the evolution of ice-bearing clayey soils exposed to low pressure and low temperature environmental conditions representative of the Martian polar regions (Figure 2). These hyperspectral data help in defining the best spectral criteria to distinguish between water ice and hydrated minerals in the near-infrared and the best choice of color channels to map the occurrence of ground ice in the visible

Future observations: At equatorial latitudes, briny water is only stable at the surface in the early morning [9], which prevents its direct observation over RSLs by MRO (which can observe only in the 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 be able to observe the backscattering peak for regions within 25° of the equator where many RSLs are found [1], providing new clues about the possible role of liquid water.

References: [1] McEwen A. S., et al. (2013) Nat. Geo., 7, 53-58. [2] Pommerol, A., et al. (2011) Planet. and Space Sci, 59, 1601-1612. [3] Morris, R. V., et al. (2001) JGR, 106, 5057-5083. [4] Pommerol, A., et al. (2013) JGR, 118, 2045-2072. [5] Johnson, J. R., et al. (2013) Icarus, 223, 383-406. [6] Gunderson, K., et al. (2007) Planet. and Space Sci., 55, 1272-1282. [7] Massé M. et al. (2012) LPSC #43, Abstract #1649. [8] Ojha, L. et al. (2013) GRL, 40, 5621-5626. [9] Gough, R. V. et al. (2011) Earth and Planet. Sci. Let., 312, 371-377.