Laboratory study of Martian analogs

VIS bidirectional reflectance and VIS-NIR hyperspectral images

To interpret current imaging datasets

To design and operate future remote-sensing instruments

Visible Spectro-Photometry of Dry, Wet and Frozen Mars Soil Analogs

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Introduction

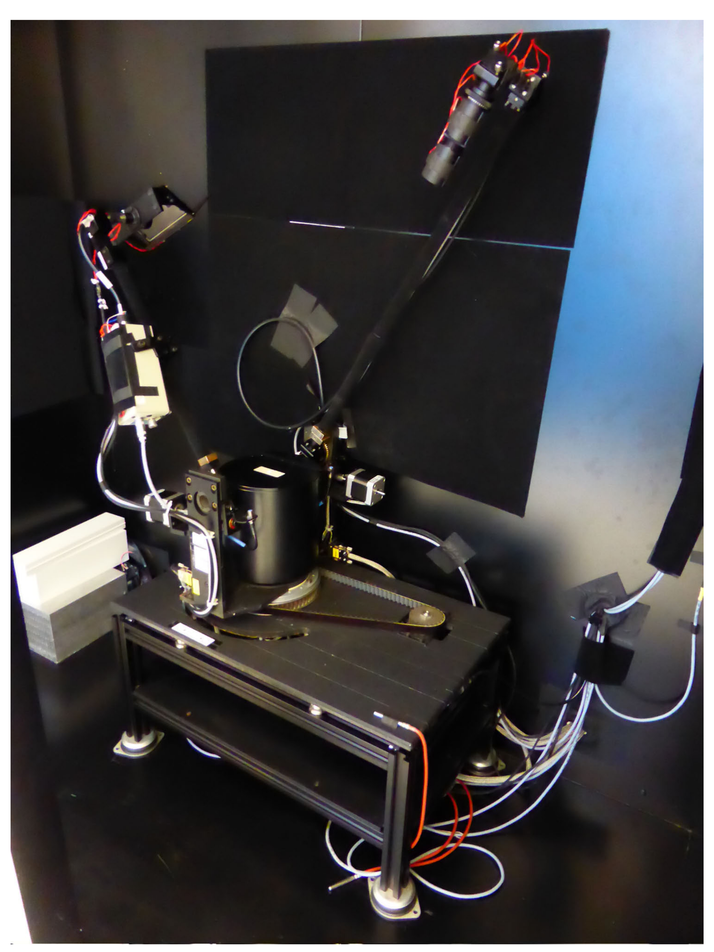
Many observations of the Martian surface rely on the analysis of the solar light scattered by the materials that compose its uppermost layer. A good understanding of this process, through physical modeling and/or laboratory experiments, is thus crucial for detailed analyses of remote-sensing datasets. We report here on a series of laboratory measurements of analog materials, performed to address different questions of prime interest for the Mars remote-sensing community:

- Is it possible to distinguish compositional and textural effects when studying the bidirectional scattering behavior of dry analogs of the Martian surface?
- How reproducible are the bidirectional reflectance curves measured in the laboratory and reported in the literature?
- What changes of color, albedo, and bidirectional behaviour 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?

Our own interest for these questions is essentially motivated by the analysis of images currently returned by the HiRISE and CRISM instruments on board MRO, and by the current development and construction 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 interpretation of the Recurring Slope Linae (RSLs) observed by HiRISE [1].

Methods

Measurements presented here were all acquired in the LaPIA (Laboratory for Photometry of Icy Analogs) at the University of Bern [2]. LaPIA is part of the LOSSy (Laboratory for Outflow Studies of Sublimating Materials) facility. Two instruments were used: the PHIRE-2 (PHysikalisches Institut Radiometry Experiment, v.2) and the SCITEAS (Simulation Chamber for Imaging the Temporal Evolution of Analog Samples)



The PHIRE-2 instrument is a highly accurate and fully automated radio-goniometer that is operated at -30°C in a cold room to acquire measurements with icy samples [2]. It is used to measure the bidirectional reflectance with a high accuracy over wide ranges of incidence, emission and phase angles. Reflectance values were measured inside six discrete bandpasses between 400 and 1100nm.

This instrument has been in use for many years but we have recently significantly upgraded it to permit measurements of the bidirectional reflectance at low phase angle, including the exact opposition (g=0°).

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].

The SCITEAS simulation chamber is designed to accommodate the same sample holders as the ones used with the PHIRE-2. Samples are thus easily interchangeable between both instruments.

The closing system of the chamber was optimized for quick and easy sample insertion/removal.

The chamber is cooled by liquid N_2 and evacuated using membrane and turbo-molecular pumps.

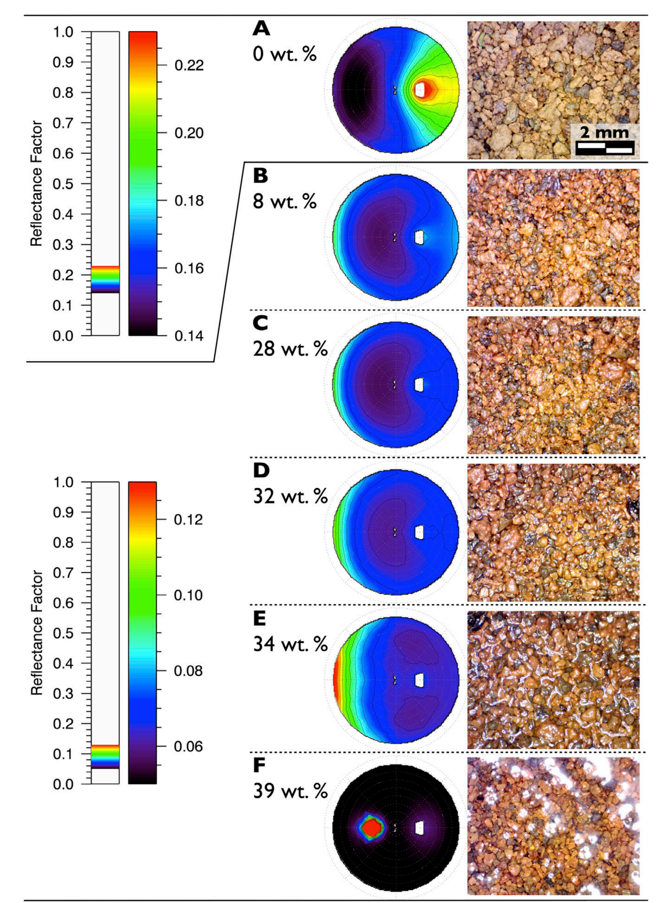
An original imaging system was developed to acquire hyperspectral images of the sample through a large quartz window over the spectral range: 0.4-2.5µm.

Various feedthroughs on the bottom flange of the chamber permit complementary in-situ investigations (temperature) and interactions with the sample.

VIS bidirectional reflectance measurements

Samples were all prepared from two rocky components: the JSC Mars-1 regolith simulant [4] and Hawaiian basaltic sand. Different preparation procedures were used to produce the dry surfaces. The samples were then 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.

Shown below are examples of measurements for surfaces prepared using the JSC Mars-1 analog. Only the data for a constant incidence angle of 30° and a constant wavelength of 650nm are plotted here. Measurements for other samples, wavelengths and incidence angles are reported in [5].

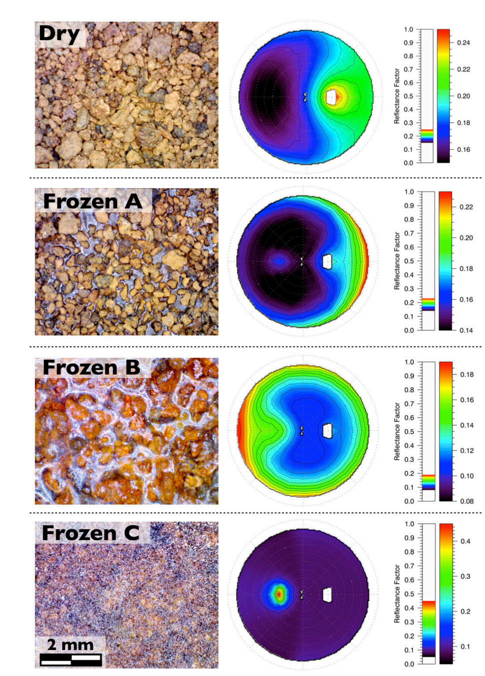


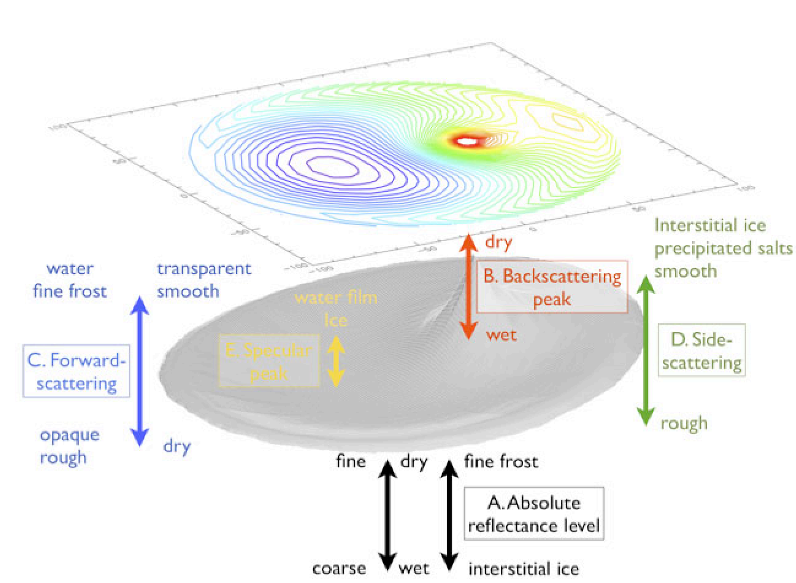
The addition of water strongly influences the overall level of reflectance of the samples but also the shape of the phase function.

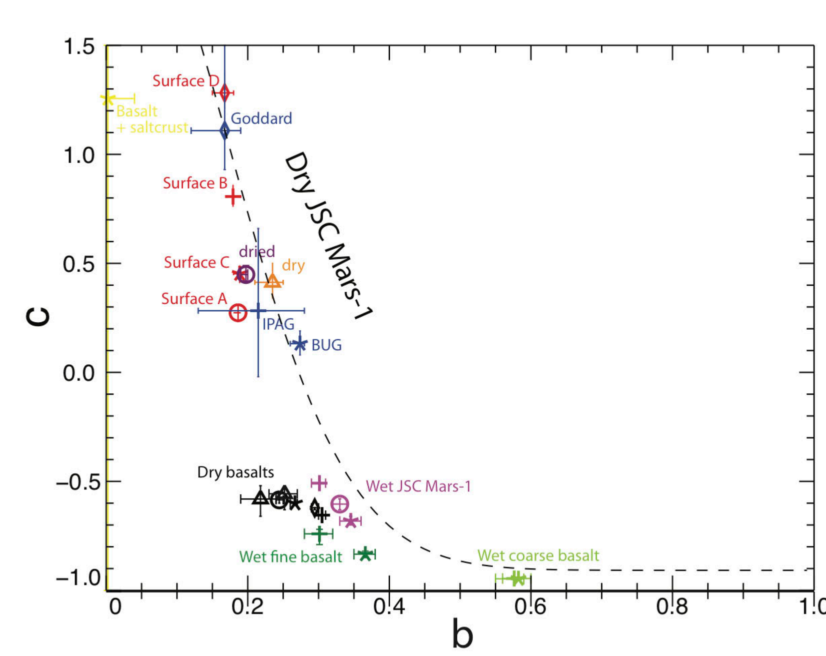
Our observations provide interesting opportunities for putting additional constraints on the presence of liquid water in the Martian regolith from sets of images obtained under different measurement geometries. In particular, it appears that the opposition peak is extremely sensitive to the presence 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.

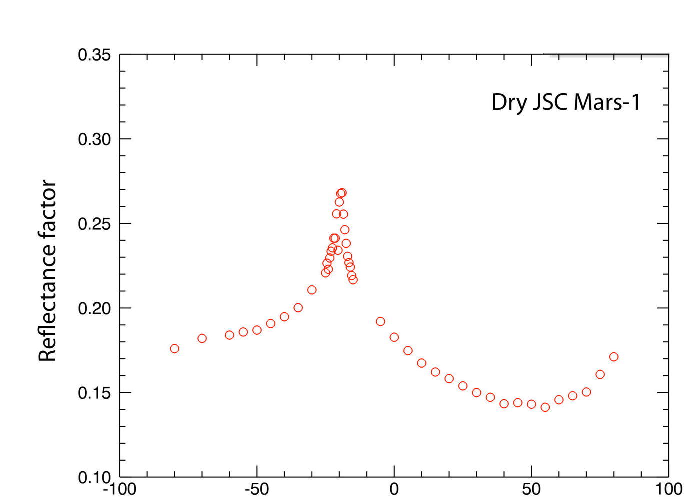
Associations between water ice and minerals can result in very diverse photometric behaviors depending on the state of water ice in the sample. In particular, ice deposited as frost on the surface of the grains results in the appearance of a forward scattering peak whereas samples prepared by freezing surfaces containing liquid water all show a specular peak and a significant side scattering.







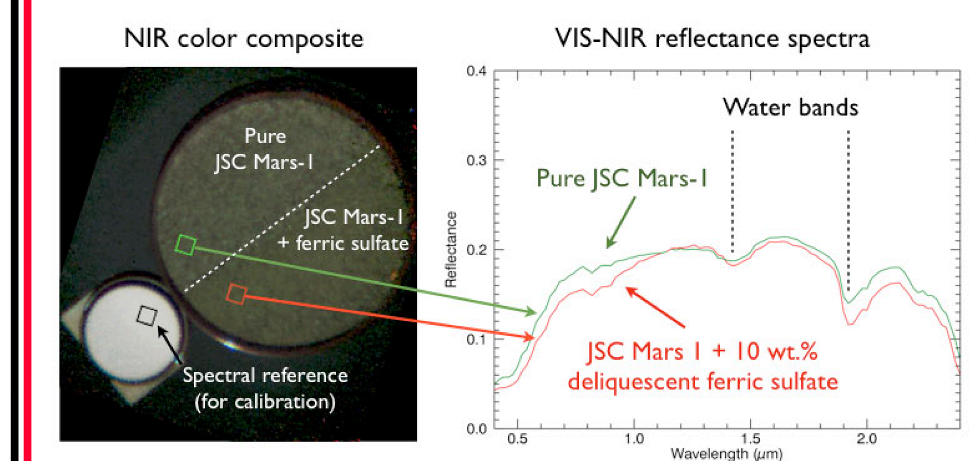
The most characteristic photometric behaviors observed for dry, wet and frozen samples are summarized on the left figure above. The figure on the right shows another summary of results in terms of two of the Hapke coefficients obtained by fitting our data using the Hapke model. The black dashed line represents the «Hockey stick» relation as defined by [3]. Values of these coefficients derived from all measurements performed are provided in [5]. The wavelength-dependence of these coefficients has recently been studied in details by [6].



Recent improvements on the PHIRE-2 instrument now allow us to acquire measurements at low phase angle (down to 0°) and thus study in detail the opposition peak.

Shown here is the example of a dry surface prepared from JSC Mars-1. In the future, we will complement our past measurements on wet and icy samples with new measurements at low phase angle.

VIS-NIR hyperspectral imaging

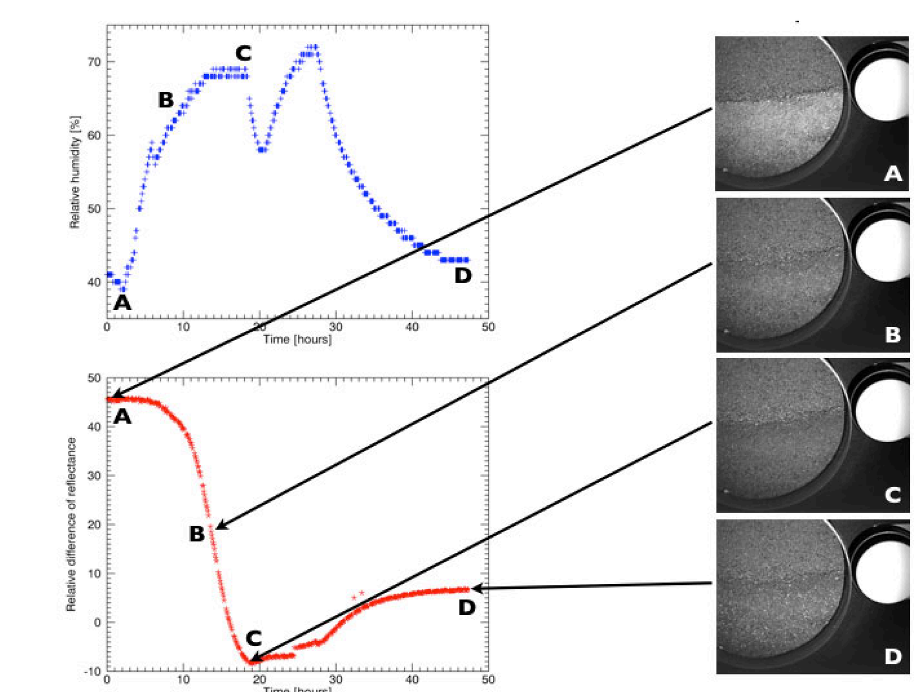


In addition to measurements of samples wetted with pure water, we have started to characterize samples wetted with concentrated brine solutions.

We aim at complementing with the new VIS measurements the study performed in the NIR by [7]. The figure on the left shows an example of hyperspectral measurement of a sample of JSC Mars-1, partially mixed with ferric sulfate.

As the relative humidity in the chamber was increased above 60%, the ferric sulfate became deliquescent and the spectrum of the sample changed in subtle ways, both in the visible and near-infrared ranges.

We 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 [1].



The colour picture on the left shows a sample prepared by freezing a preparation of wet smectite clay. The sample was then inserted into the SCITEAS simulation chamber and hyperspectral images regularly acquired as the ice sublimated in the low temperature / low pressure environment.

The VIS hyperspectral data were then used to simulate the different color composites that would be produced from the four color channels of the CaSSIS imager of the ExoMars Trace Gas Orbiter. Shown of the left is an example of color composite using the NIR, PAN and BGR filters as the RGB channels, respectively.

These data are helpful for helping us defining the exact wavelength range for each of the colour filters and will help us in the future to assess the importance of acquiring images with the different colour filters for various types of targets.

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] Hapke, B., (2012) Icarus, 221, 1079-1083. [4] Morris, R.V., et al. (2001) JGR, 106, 5057-5083. [5] Pommerol, A., et al. (2013) JGR, 118, 2045-2072. [6] Johnson, J. R., et al. (2013) Icarus, 223, 383-406. [7] Massé et al. (2014) PSS, in press.

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http://space.unibe.ch/pig/science/lossy