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Photometry of icy planetary analogs: First results of the PHIRE-2 experiment

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Abstract

We have designed and built a gonio-radiometer, PHIRE-2, to measure the photometric properties of analog samples containing water ice. We report here on results from the first measurements campaigns performed with this instrument, focused on the photometry of analogs for Mars Polar Regions and comets nuclei.

1. Introduction

A number of planetary surface observations are based on passive optical remote sensing methods. They hugely rely on the understanding of how the solar light interacts with the solids forming planetary surfaces. Numerical models for surface scattering of light are used to analyze the returned data. Laboratory experiments on analogs are crucial to test these models. Our experimental setup is intended to provide constrains to these numerical models and hence to improve remote data analysis.

The PHIRE (PHysikalisches Institut Radiometry Experiment) was and built at the University of Bern for that purpose [1] and has now been successfully operated for many years [2,3]. We have recently designed and built a second-generation instrument, named PHIRE-2, which among many technical improvements, allows operations at sub-zero temperature. This creates an additional possibility to measure the photometry of analog samples containing water ice.

The main motivations for the construction of the PHIRE-2 gonio-radiometer are the study of comets nuclei, Martian Polar Regions, and Outer Solar System icy satellites and KBO.

2. The PHIRE-2 photo-goniometer

The PHIRE-2 instrument (figure 1) operates in the visible-near IR spectral range (400-1000 nm) and is installed in a large laboratory freezer. Its development was based on the experience gained on the gonio-radiometer PHIRE-1 [1,2,3]. The PHIRE-1 design was modified to permit operations at sub-zero temperatures, increase the signal/noise ratio and stability, and significantly decrease the measurement time.

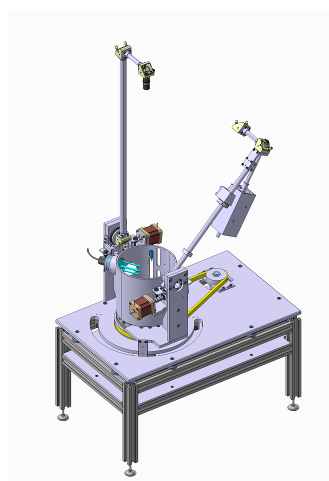

Figure 1: CAD drawing of the PHIRE-2 instrument. The arm with the light source is vertical; the one with the detector is inclined on the right. Thermal and electrical sensors are visible in the sample holder.

The instrument allows measuring the reflectance factor of the sample for emission angle between 0 and 80° and azimuth angle between 0 and 180°. Incidence angle can theoretically be set from 0 to 90° but is limited by the size of the sample. Incidence angles up to 80° can normally be measured without problem. There is also a limitation in the minimum phase angle due to the shadowing of the sample by the head of the detector arm. This limits the phase angle to values larger than 3°. We will implement in the future a second detector system with a beam splitter to make measurements at zero phase angle possible [3].

3. First results

Figure 2 shows some results from the first measurements campaign performed with the PHIRE-2 instrument. We first measured the BRDF of sieved fresh natural snow (200-400 µm) and Lunar JSC-AF1 sample (a dark fined-grained lunar regolith simulant), then contaminated the surface of the snow by increasing amounts of dark mineral dust (only one step is shown in figure 2)

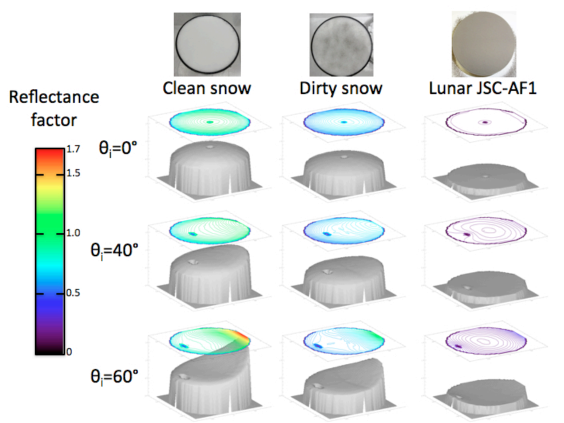

Figure 2: Reflectance factor of fresh snow (left column), lunar JSC-AF1 regolith simulant (right column) and snow contaminated by the regolith simulant (center column). The reflectance factor was measured for emission angles between 0 and 80° and azimuth angle between 0 and 180°. Reflectance surfaces are plotted for three different incidence angles.

In addition to the darkening of the sample as a result of the deposition of dust on top of the clean snow, we note a significant evolution in the scattering behavior of the surface. The clean snow displays a very high value of reflectance factor, reaching 1 at low phase angle, and a strong forward scattering behavior. The regolith simulant JSC-AF1 displays a low reflectance, around 0.2 at low phase angle, and both backward and forward scattering. The contamination of the surface of the clean snow by dark fine mineral dust results in absolute levels of reflectance and shapes of the scattering function that are intermediate between those of the pure end-members. These results represent the first step of a systematic study of the photometry of water ice / minerals / organics mixtures that will help in the understanding of past and future observations of comets nuclei by spacecrafts.

The second measurement campaign was dedicated to the measurement of plausible analogs of Martian soils containing water (liquid and ice) as well as the comparison of the BRDF of H_2O and CO_2 ices, both being encountered on Mars. We observe strong differences between the photometry of dry soils, wet soils and frozen soils. These observations pave the way to the development of photometric fingerprints of these terrains that can be applied to existing and future remote-sensing datasets.

6. Summary and Conclusions

We have designed and constructed an original facility to characterize the VIS-NIR Bidirectional Reflectance Distribution Function (BRDF) and some complementary bulk physical properties of planetary analog samples containing water ice. We report here on the results of two measurements campaigns, focused on comet nuclei and Mars polar regions, which prefigure the future use of the facility in interpreting optical remote-sensing data collected by robotic missions.

Acknowledgements

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References

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