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Photometric measurements and calibrations in view of the Cometary Physics Laboratory experiments

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Abstract

As recent space missions to cometary nuclei have provided a glimpse on the complexity of cometary activity, the variety of morphologies present on the surfaces of the nuclei, and have allowed to put stringent constraints on the physical properties of the visited comets. Laboratory experiments and theoretical modelling are now required to further interpret those observations.
We will present the measurements and the results of the photometric modeling of the bidirectional reflectance and reflectance spectra of ice, minerals and organics samples that will be used as part of the CoPhyLab project.

1. Introduction

Over the past 35 years, our understanding of comets has been effectively revised by the different space missions, which have allowed to extensively characterise the coma and nuclei of seven comets [1]. While continuously supported by the results of ground observations, this understanding has been further improved by the multiple laboratory experiments performed concurrently ([2, 3] and references therein).
From March 2014 to September 2016, the instruments of the ESA/Rosetta mission collected a trove of observations of the comet 67P/Churyumov-Gerasimenko, which allowed to study in great details its nucleus, its inner coma and to further investigate the properties of the nucleus' surface as well as the mechanisms of the cometary activities [4, 5].
To provide a more complete picture of cometary processes, the CoPhyLab project [15] seeks notably to further study the optical properties of ices, minerals and organics (e.g. water-ice, pyroxene, coal, paraffin) in a cometary-like environment. We will consider their variations depending of the preparation of the sample, and investigate their temporal evolution.

2. Experiments and data

Over the past decade, the Planetary Imaging Group of the Bern university has developed two instruments and a simulation chamber, that are presently being used in part to contribute to the CoPhyLab project. The radiogoniometer PHIRE-2 [6] is being used to acquire the bidirectional reflectance of the samples. 6 broadband filters are used to illuminate the sample at wavelengths ranging from 430nm to 1070nm. While the incidence arm of the goniometer carries the optic fiber used to illuminate the sample, the emergence bears a 1-pixel Si detector to integrate the reflectance of the illuminated area. This arm may be either equipped with a 45° mirror or with a beam-splitter. While the mirror head is used to measure the reflectance under viewing geometries corresponding to a phase angle ranging from 3° to 180°, the beam-splitter allows to investigate lower phase angle ranges. Additionally, as the instrument is installed within a freezer that can reach 240K, the bidirectional reflectance of icy mixtures can also be measured.
The MOHIS instrument [7] is a spectral imager, that covers the visible and the near-infrared (300-2500nm). The setup of this instrument has been so developped, that it may be easily adapted to a simulation chamber. This instrument will be used on the on-site simulation chamber SCITEAS-2 (see fig. 1), as well as on the CoPhyLab simulation chamber, that will be built in Braunschweig.
Finally, SCITEAS-2 is the next iteration of the simulation chamber presented in [7]. The installed pumps and cooling systems will allow to study the temporal evolution of samples, to be illuminated with a solar simulator, while keeping, within the chamber, at minimum, the pressure down to 10^{-6} mbar and the temperature to 77K.
At the time of this writing, using PHIRE-2 and MOHIS, the measures of the bidirectional reflectance and reflectance spectra of iron oxydes, coal, pyroxene, olivine and serpentine, among others, mixed or not

with water-ice, are underway and the photometric modeling of those measurements has started.

3. Photometric and spectral modeling

We have measured the bidirectional reflectance of pure samples and known mixtures and we are presently using the semi-empirical Hapke photometric model [8] to retrieve the corresponding photometric parameters of the samples. In turn, this modeling will be used in order to characterize the evolution of the surface properties of the samples as they will be left to sublimate in the simulation chambers, based on the reflectance spectra acquired by MOHIS.
We are using an implementation of the Hapke model which contains a surface roughness correction [9], a porosity correction [10], as well as corrections and remarks drawn from laboratory experiments and theoretical considerations [11, 12]. This implementation of the model was used in [13] to model the bidirectional reflectance of comet 67P/Churyumov-Gerasimenko.
The reflectance spectra will also be modeled using the Shkuratov model [14] in order to further compare the retrieved optical properties.

4. Perspectives

As part of the CoPhyLab project, we will investigate the optical properties of ices, minerals and organics samples. We have started to measure the bidirectional reflectances and reflectance spectra of those samples. We have begun to model those measurements using only, at the moment, an implementation of the Hapke model and we will present our results.

Acknowledgements

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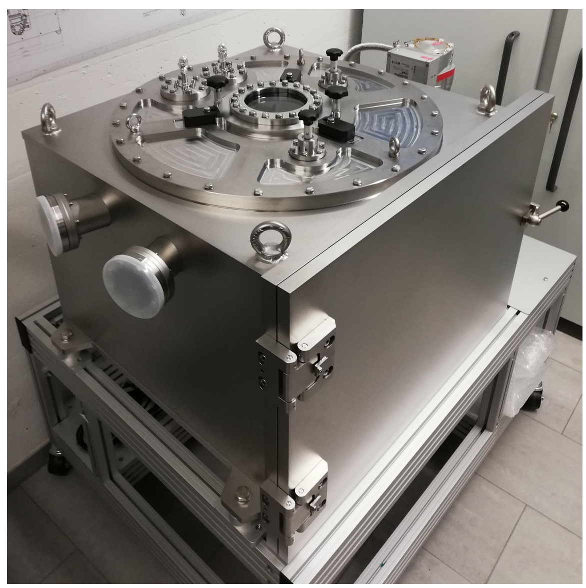

Figure 1: The SCITEAS-2 simulation chamber that will be used in our sublimation experiments.