The LOSSy laboratory for spectro-photometric characterization of cometary and planetary at the University of Bern

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Introduction

Understanding the interaction of insolation with planetary surfaces is crucial for the interpretation of passive remote-sensing data. Determining the dependence of observed spectro-photometric properties on quantitative properties of the surface, such as composition, grain size and roughness, is very challenging.

In addition to numerical models and simulations, laboratory experiments with well characterized analogues are necessary to link remote-sensing datasets to physical processes.

The photometric analysis of water ice, as a major constituent of the outer solar system bodies, either in its pure form or mixed with minerals and organics is very delicate, because of the dependence of physical processes on enviromental conditions.

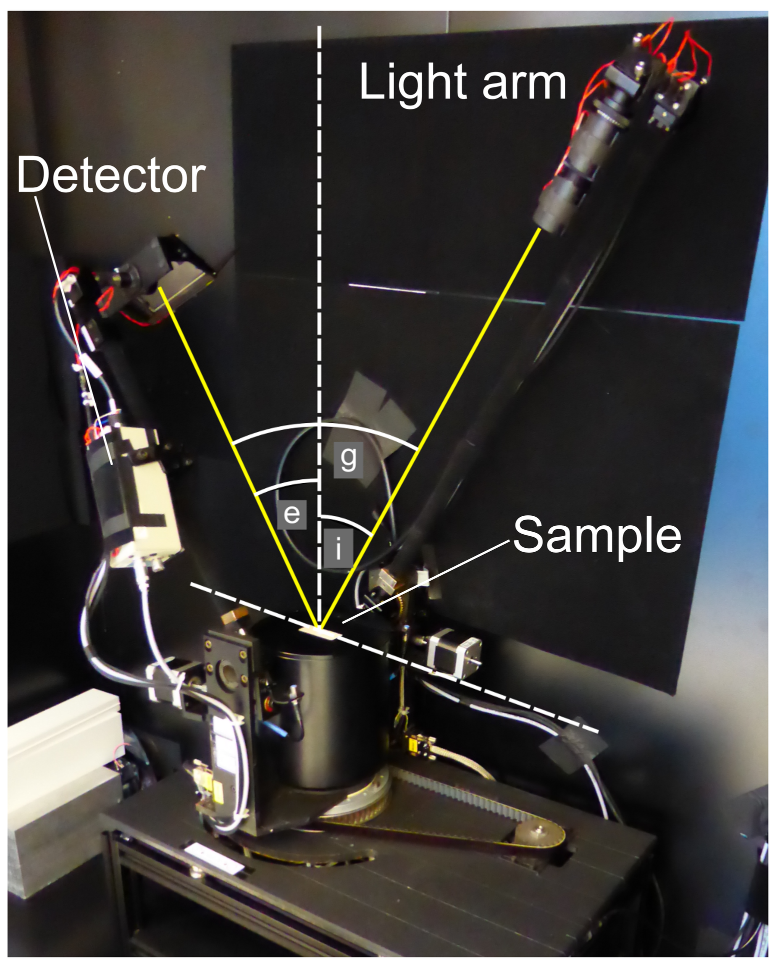
The Laboratory for Outflow Studies of Sublimating Materials (LOSSy, previously called "Planetary Ice Laboratory") at the University of Bern was designed to perform bidirectional visible reflectance measurements and hyperspectral imaging in the VIS-NIR range under different pressure and temperature conditions.

Instrumentation

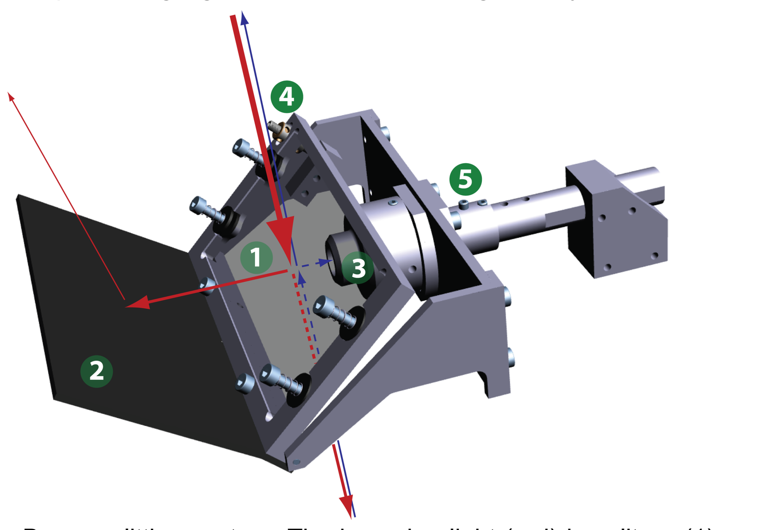
The LOSSy laboratory mainly consists of two different experiments: the PHIRE-2 (PHysikalisches Institut Reflectance Experiment-2) gonio-radiometer and the SCITEAS (Simulation Chamber of Imaging and Temporal Evolution of Analog Samples) thermal vacuum chamber equipped with a hyperspectral imaging system.

PHIRE-2 [1,2] is designed to measure the bidirectional reflectance of cm-size samples at ambient or subzero temperatures (down to 238K) and atmospheric pressure over a wide range of geometries, including opposition. It is equipped with a collimated light source and six different bandpass filters over the 450-1064nm spectral range. The light scattered from the sample is measured with a silicon-photovoltaic sensor. The instrument is fully automatic and optimized for fast acquisition to characterize the potential temporal evolution of icy samples.

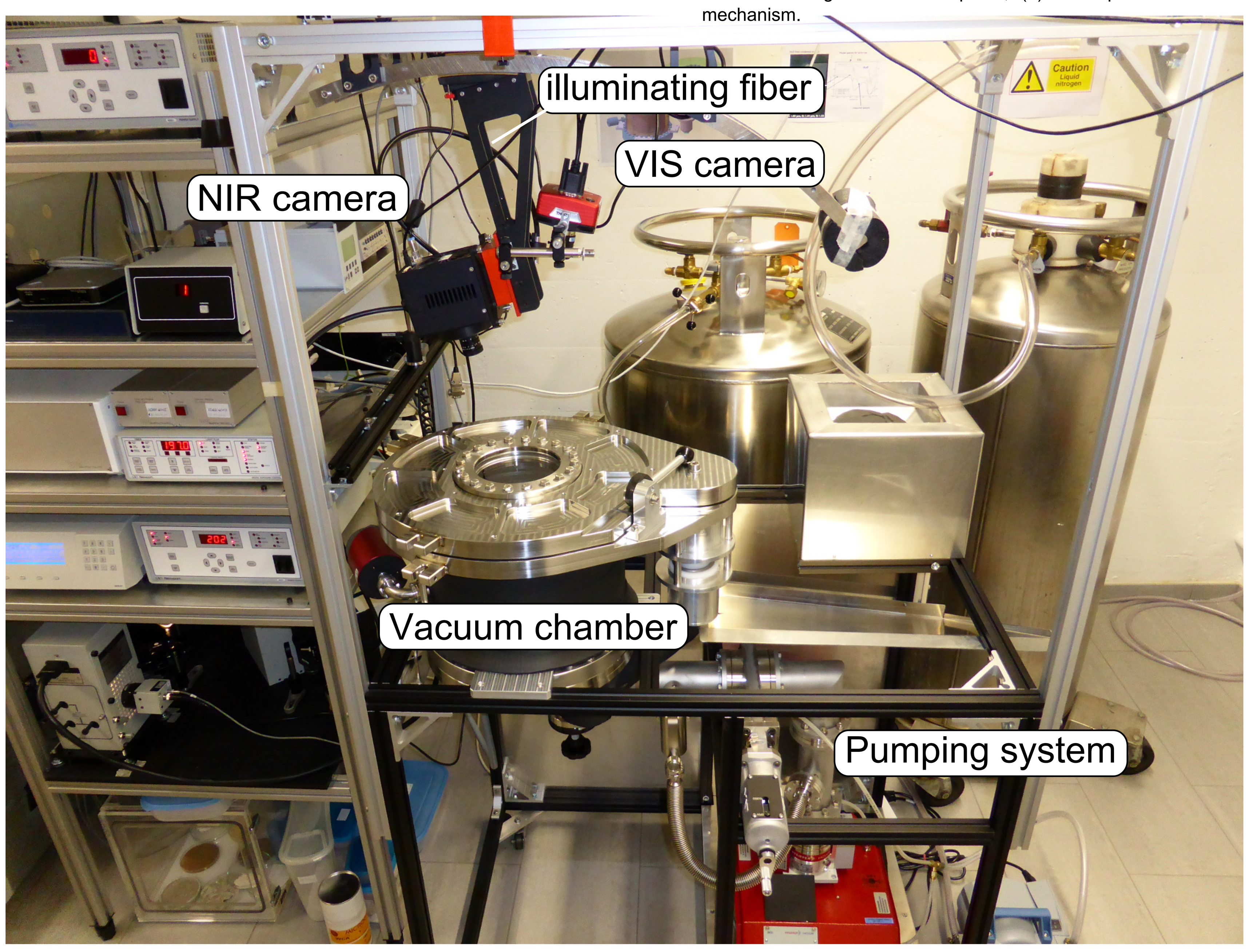
The SCITEAS simulation chamber [3] is used to monitor the evolution of ice-bearing samples subliming under low temperature (170-200K) and low pressure ($<10^{-6}$ mbar) conditions with a VIS-NIR hyperspectral imaging system. Our main interest here is related to the microphysics of the sublimation process, which leads to changes of the surface morphology with time, resulting in changes of its spectro-photometric characteristics.



PHIRE-2 gonio-radiometer. The incidence angle i, emission angle e and phase angle g define the observation geometry.

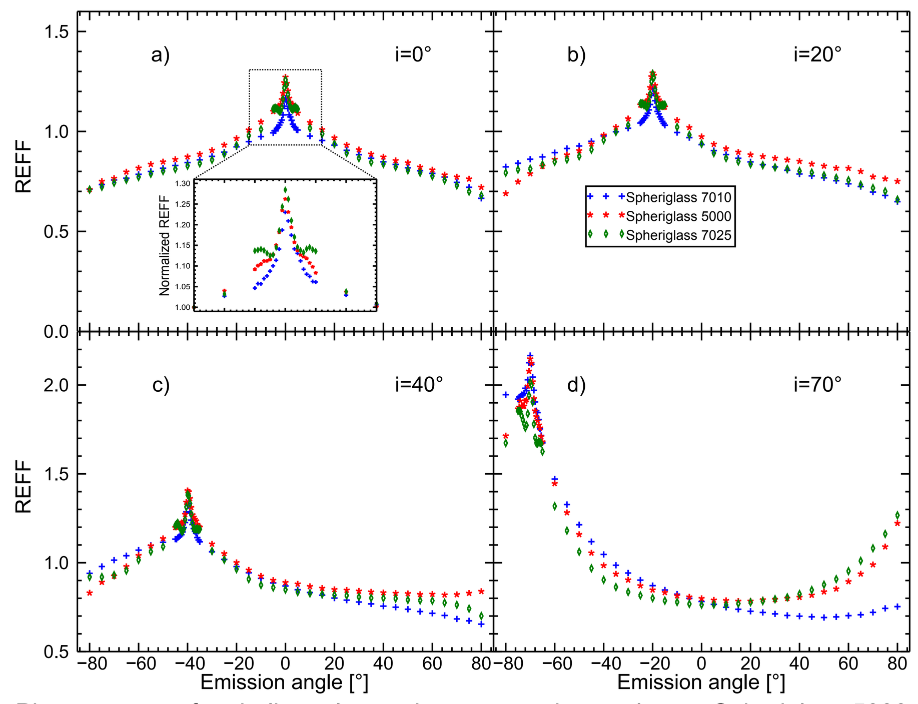


Beam splitting system: The incoming light (red) is split up (1), 50% reach the sample the rest is reflected to the deflection plate (2). The light scattered from the sample (blue) is again spit up, one fraction reaches the fiber (3) the other is transmitted in the illumination direction. A precision screw (4) is used to align the beam splitter, (5) is a quick-release mechanism.



SCITEAS simulation chamber: Monochromatic light is transmitted by a fiber to illuminate the sample through a quartz window. The chamber is actively cooled by a liquid N_2 circulation system and evacuated by membrane and turbomolecular pumps. A camera system acquires hyperspectral images in the 0.4-2.4µm spectral range. A system for controlled gas inlet is installed but was not yet tested.

VIS bidirectional reflectance

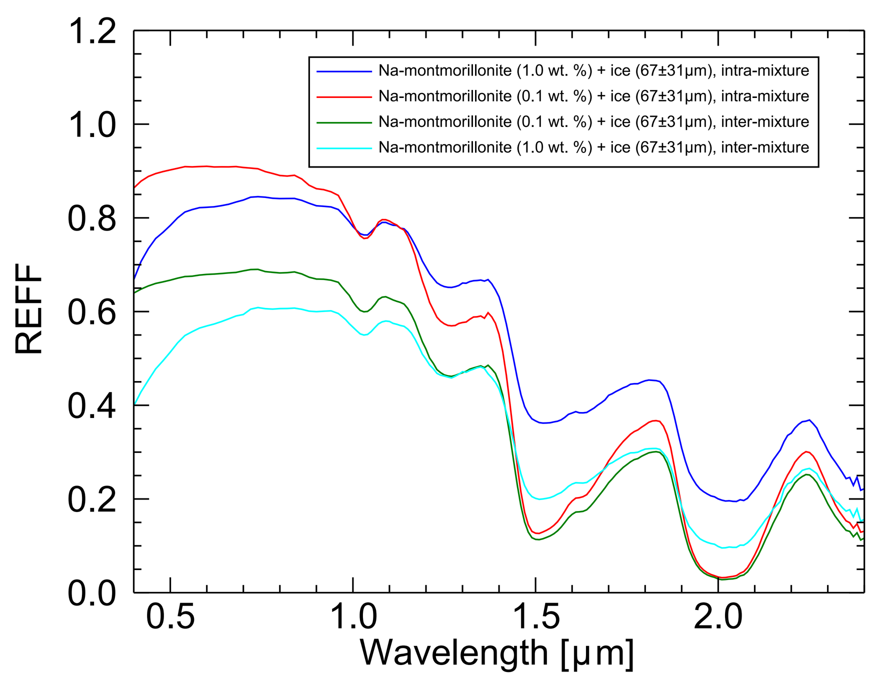


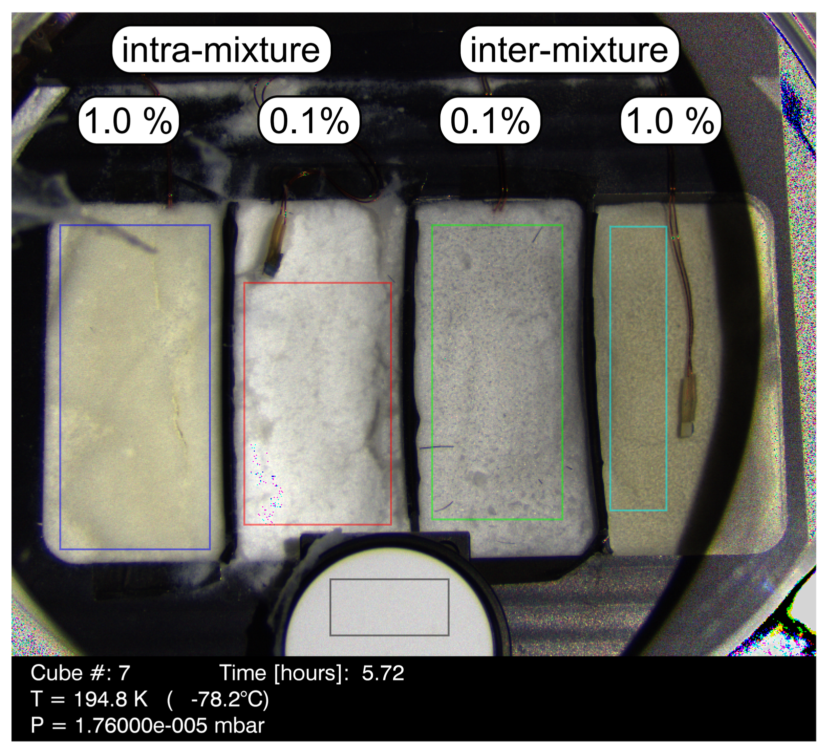
Phase curves of soda-lime glass spheres as an ice analogue. Spheriglass 5000 is the raw (unsorted) material (90% within 0.5-19.3µm), type 7010 is the finer subset (0.5-10µm) and type 7025 the coarser subset (10-19.5µm).

The figure on the left shows a series of PHIRE-2 measurements of glass spheres acting as an ice analogue. Around opposition geometry the angular resolution is increased to monitor subtle features of the opposition effect, while at large phase angles this would give no information benefit and elongate the acquisition time. Measuring at high incidence angle (>40°) allows to retrieve information about backward/ forward scattering behavior and highlight roughness effects caused by shadowing.

Sublimation experiments

The figure below shows a colour composite and spectra from samples of ice particles made up different mixtures of water and phyllosilicates (Na-montmorillonite). The two samples on the left are made of an "intra-mixture": the phyllosilicate is thoroughly mixed with water inside the ice particles at different concentrations. The samples on the right are made of an "inter-mixture": the phyllosilicate is coating pure water ice particles. The sublimation of the water leads to the formation of dry mineral mantles whose texture largely depends on the type of mixture and on the concentration of the phyllosilicate. We are studying the effect of these surface textures, also including other cometary components (olivine, organics) on the scattering of light.





Applications & Outlook

The main purpose of our cometary analog dataset acquired with PHIRE-2 is its use in the analysis of data to be measured by the OSIRIS and VIRTIS instruments on board Rosetta. The combined use of PHIRE-2 and SCITEAS allows us to monitor changes in bidirectional reflectance induced by sublimation under simulated space conditions, by regularly exchanging the sample between the two instruments.
Further applications of the SCITEAS system are the simulation of HiRISE colour images with icy samples for a better understanding of physical processes on Mars. Furthermore, hyperspectral images of Martian analogue samples will help in simulation CaSSIS images (a camera still under construction to be launched toward Mars on the ExoMars TGO, Thomas et al., this conf.)
Another field of interest lies in the simulation of surface conditions on Jovian and Saturnian satellites namely Europa and Enceladus, whose surfaces are composed mainly of water ice.

	PHIRE-2	SCITEAS
Operating temperature	-35 to +25°C	-100 to +25°C
Operating pressure	ambient atmosphere	$<10^{-6}$mbar to ambient atmosphere
Optical range	450-1064nm	400-2500nm
Optical concept	Bandpass filters	Monochromator
Light source	250W tungsten-halogen	100W tungsten-halogen
Illuminated FOV	0.3-2.0cm	15cm
Spatial resolution	none	1392 x 1040 px (VIS) 320 x 256 px (NIR)
Observation phase angle	0-150°	fixed (~20°)
Energy input	< 5µW/cm^2	~5W/cm^2 (thermal IR)

References

[1] Pommerol, A., et al. (2011) Planet. and Space Sci, 59,1601-1612. [2] Jost, B., et al. (2013) Icarus, 225,352-266. [3] Pommerol, A., et al. (in prep), Spectro-photometric characterization of the sublimation of icy planetary analogs; first results of the SCITEAS experiments.

Acknowledgements

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