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SHADOWS: spectrogonio radiometer for bidirectional reflectance studies of dark meteorites and terrestrial analogues

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Abstract

A new spectrogonio radiometer SHADOWS is designed for the spectral bidirectional reflectance study of dark surfaces. Its official delivery as an European simulation facility within the Europlanet 2020 RI program is set late August 2017. This abstract presents a general description of the instrument, and some of its measurements modes. Test spectra measured with the instrument's prototype on challenging dark surfaces (Spectral Black, Metal Velvet and Vantablack) are then presented.

1. Context

Reflectance spectroscopy (sometimes combined with polarimetry) can provide information on surface chemical and physical properties. Ground-based instruments or onboard space missions have and will perform spectroscopic measurements of planetary and small bodies surfaces, such as asteroids or comets. The limits of this method depend on the instrument spectral resolution, detector sensitivity and on the surface illumination and albedo. Many solar system surfaces, particularly primitive objects (C- and D-type asteroids, cometary nuclei), are extremely dark (a few percent of reflectance in the visible). Analogue materials can be challenging to analyze in the laboratory due to the limited power reflected by the targets. The laboratory spectrogonio radiometer SHADOWS will simulate the geometrical and thermal conditions of observations of small bodies and planetary surfaces, and will be able to measure surfaces with reflectance lower than 1% with a high signal to noise ratio.

2. Instrument overview

SHADOWS (Spectrogonio radiometer with cHanging Angles for Detection Of Weak Signals) is the IPAG new spectrogonio radiometer, specially designed to record bidirectional reflectance spectra on low albedo surfaces and on small samples, that will be available as an European facility within the framework of the Europlanet 2020 RI program. SHADOWS design is based on the current IPAG spectrogonio radiometer SHINE [1,2] but with a radical change in illumination spot size dedicated to allow reflectance measurements of dark samples. In addition, small (and therefore precious) samples can be studied, since only 10 to 100 mg of material is needed. The spectral range covered, from 0.35 to 5µm allows studies of minerals, organic or ices spectral signatures. The instrument will be installed in a cold room for analysis from room temperature to -40°C. A low-temperature environmental cell can be inserted in the goniometer in order to perform reflectance measurements on samples down to 50K. The source, its stabilization device, the modulator and the monochromator produce a modulated monochromatic light. A bundle of 8 ZrF_4 multimode optical fibers leads monochromatic light from the instrumentation table. At the output of the fiber, this monochromatic light is focused on the sample surface using a spherical mirror. The goniometer part of SHADOWS consists of two arms, one sending the monochromatic light on the sample and the other holding two detectors (visible and near-infrared) that collect the reflected light. The incidence, emergence and azimuth angles can be changed to simulate a variety of observation geometries and characterize the angular dependencies of the reflected spectrum. Figure 1 represents the goniometer part of SHADOWS, showing the illumination and detection arms.

The modulated incident light and two lock-in amplifiers, one for each detector, synchronized with the modulation frequency, isolate the reflected light signal from the thermal infrared background.

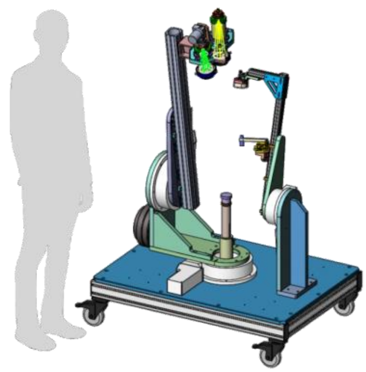

Figure 1: 3D representation of the SHADOWS goniometer. The table with the instruments for modulated monochromatic light generation and the optical fibers connecting them to the instrument are not represented. The total height is about 170 cm.

3. Spectropolarimetry

Light becomes polarized when reflected on a surface. The amount of polarization depends on the chemical and physical characteristics of the surface, as well as on the illumination/observation geometry. For spectro-polarimetry measurements, one has to minimize the polarization of the incident light on the sample as it induces measurement errors. To reduce parasite polarization from the incident light, the optical fibers are bent to induce more light reflections at the core-clad interface and thus mix the polarizations. This solution offers the best results for the whole instrument spectral range and do not affect significantly the incident flux. A rotating polarizer can be installed across the light path on the incident arm but reduces light intensity by over a factor 2. The instrument allows the operator to conduct spectra measurements with unpolarized or fully-polarized incident light, as well as to measure the polarization of the reflected light, with polarizers placed in front of the detectors. Spectra can be recorded for different angular positions of the polarizers and the polarimetric spectrum is automatically calculated. SHADOWS can be used for phase angle dependent polarimetric spectra, such as inversion angle analysis.

4. Control software and automated routines

A control-acquisition software has been specially written to control SHADOWS for automatized spectral measurements, as well as spectral-BDRF measurements. Additional routines involve, among others, the automated control of the cryostat of the environmental cell, making SHADOWS able to perform step-by-step temperature dependent spectral measurements over several hours without any interruption or manual operation.

5. Schedule and expected results

All the instrumentation table (source, stabilizator, monochromator, modulator, optical fibers) and signal analysis is already set, as well as the control program. In May 2017, the goniometer part of the instrument will be finished and installed in the cold room. The first spectra, calibrations and performance tests will be conducted during the following weeks. The official delivery is set to the 31st August 2017. The instrument prototype was used to record spectra on reference and challenging dark surfaces, such as Metal Velvet, Spectral Black or Vantablack (Figure **2**). We expect even higher S/N ratio and photometric accuracy with SHADOWS, as some optical characteristics and several components have been optimized to get the best S/N compromise.

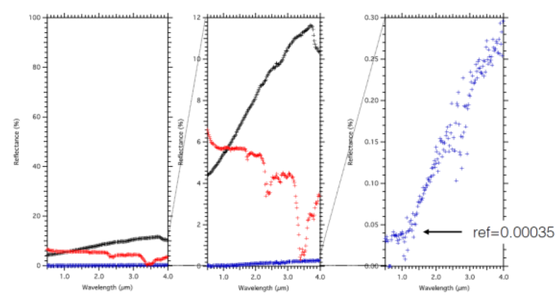

Figure 2: Reflectance spectra of Metal Velvet (black curve), Spectral black (red curve) and Vantablack (blue curve) obtained with the instrument prototype, at incidence angle 0° and measurement angle -30°.

References

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