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Temperature-dependent VNIR spectroscopy of thénardite and mirabilite

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Abstract

In the framework of the EuroPlanet 2020 Research Infrastructure (RI) programme, we took advantage of the CSS distributed planetary simulation facility at IPAG-Grenoble to perform a series of laboratory measurements aimed to acquire VIS-NIR spectra of anhydrous sodium sulfate (thénardite) and sodium sulfate decahydrate (mirabilite), in three different grain sizes and in a broad range of cryogenic temperatures, representative of real planetary surfaces. These measurements are key to correctly interpret data acquired by spectrometers carried onboard ongoing and future interplanetary space missions aimed at various planetary bodies, particularly the Jovian icy satellites (JUICE, Europa Clipper) and Mars (ExoMars 2020, Mars 2020).

1. Introduction

The surfaces of the icy Galilean satellites Europa, Ganymede and Callisto, dominated by water ice, also show substantial amounts of non-water-ice compounds both at regional scale and at local scale. These satellites will be the subject of close exploration by the ESA JUICE mission and the NASA Europa Clipper mission, which will focus on Ganymede and Europa, respectively.

Among non-water-ice compounds thought to exist on the surfaces of the Jovian icy satellites, hydrated salt minerals have been proposed to exist as a by-product of endogenic processes. In particular, Europa and Ganymede's non-ice material appears to be a complex mixture of sulfate hydrates and other materials [1]. Seasonal cycles of hydration-dehydration at Martian Polar Caps boundaries have also been suggested [2] for Na-sulfates compounds mirabilite and thénardite. Safe detection of these minerals shall rely on laboratory spectroscopic analysis of these materials carried out under appropriate environmental conditions.

2. Laboratory measurements

Following the third call of the Europlanet Transnational Access (TA) 2020 Research Infrastructure programme, our proposal was selected in June 2017. We focused on two sodium sulfates, namely anhydrous sodium sulfate or thénardite (Na_2SO_4) and sodium sulfate decahydrate or mirabilite ($Na_2SO_4 \cdot 10H_2O$). Visible to near-infrared spectral profiles of these compounds were obtained in April 2018 taking advantage of the Cold Surfaces Spectroscopy (CSS) facility at the Institut de Planétologie et d'Astrophysique de Grenoble (IPAG), where such compounds can be measured under cryogenic conditions representative of real planetary surfaces.

These sulfates were first sieved so as to separate them in three different grain size ranges: <50 µm, 75-100 µm, and 125-150 µm. These grain sizes were chosen to: (1) be indicative of typical regoliths known or expected to exist on the surface of the icy satellites, and (2) avoid overlapping between ranges, therefore minimizing particles contamination among the dimensional classes. Each grain size was measured with the SHINE Spectro-Gonio-Radiometer facility [3] in the overall 0.5-5.0 µm spectral range, with spectral resolution increasing with increasing wavelength. For each sample, the overall 80-275 K temperature range was acquired in 12 steps varying from 10 K to 25 K, imposed by time constraints. In particular, at the uppermost temperature, 275 K, and at 140 K, we acquired the spectra both at the beginning (cooling) and during the ramp, to check for any macroscopic physico-chemical changes in the sample.

3. Preliminary results

In the case of anhydrous sodium sulfate (thénardite), our spectral profiles reveal absorption features at 1.9 and ~3-µm, due to an unavoidable hydration of the sample, although this has always been optimally preserved prior to the measurements. On the other hand, the main absorption of sodium sulfate in the considered spectral range is centered at about 4.5 μm, and shows a clear dependence on the grain size, whereas the dependence on temperature is weaker.

The spectral profiles of sodium sulfate decahydrate (mirabilite) are significantly different. Given the high level of hydration of this mineral, here the spectral signatures of the sulfate overlap with the combinations and overtones of the fundamental vibration modes of the water molecule, whose shape and intensity show a marked dependence both on the grain size and on the temperature, with the low temperatures that - similar to what we observed in the past for hydrated magnesium sulfates and hydrated sodium carbonates - reveal a finer structure.

We analyze the spectral behavior of the diagnostic signatures of these two hydrated minerals as a function of both grain size and temperature, deriving trends related to specific spectral parameters such as band center, band depth, band area, and bandwidth.

In Fig. 1, we show an example of spectral profiles of anhydrous sodium sulfate (thénardite), with an average grain size of 125-150 μm, measured in a total of 12 temperature values (coloured curves). Spectral profiles of the same mineral as found in the Reflectance Experiment LABoratory (RELAB) public database at Brown University (black curves) are displayed for comparison.

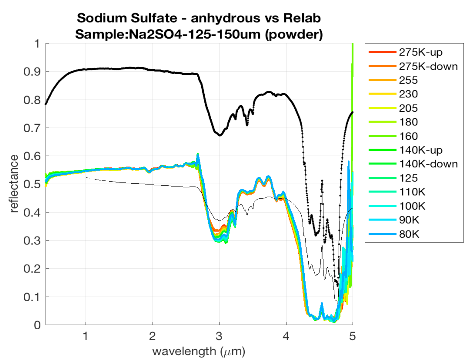

Figure 1: Example of spectral profiles of thénardite measured with the CSS facility at IPAG, in a ramp of cryogenic temperatures indicative of real planetary surfaces. The two black spectra are from Relab, for comparison (bkr1jb638a (thick line), bir1jb638a (thin line)).

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