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VIS-IR spectroscopy of mixtures of ice, organic matter and opaque mineral in support of minor bodies remote sensing observations

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Abstract

We investigate the VIS-IR spectral reflectance of mixtures rich in water ice and organics, in support of the interpretation of remote sensing observations of minor bodies from space missions, and to test the ability of radiative transfer models to infer surface composition from VIS-IR spectroscopy.

1. Introduction

The Rosetta mission at comet 67P/Churyumov-Gerasimenko revealed a surface ubiquitously covered with organic-rich materials [1,2,3], mixed with water ice [4] and opaque phases [5,6,7]. Organics and water ice have been detected at local scale also on Ceres' surface [8,9], mixed with widespread phyllosilicates, carbonates and low albedo materials [10]. Following these observations, our goal is now to characterize the spectral reflectance of powders composed of mixtures of water ice, organics and opaque minerals, as analogues of minor bodies' surfaces in the Solar System. Moreover, the proposed mixtures are compared with the outcome of widely used radiative transfer models [11,12] to determine their accuracy in reproducing the observed spectral output and infer compositional properties of the mixtures.

2. Measurements

We present reflectance spectra, in the range 0.4-4.2 μm, measured at the Cold Surface Spectroscopy laboratory at IPAG (Grenoble, France) by means of the SHINE spectro-gonio-radiometer [13]. By using pyrrhotite ($Fe_{1-x}S$) as a darkening agent and kerite [5] as an analogue of cometary and asteroidal refractory organic matter, we experimentally produced binary (ice-pyrrhotite, ice-kerite, pyrrhotite-kerite) and ternary (ice-pyrrhotite-kerite) mixtures stabilized at 173 K. Pyrrhotite and kerite powders of controlled sizes from 63 μm down to sub-μm grains have been used. These have been mixed with water ice particles of 67±31 μm in diameter produced with the SPIPA-B setup [14], as intimate ("salt and pepper", Figure 1) and/or intra-particle (ice grains with embedded refractory sub-μm grains) mixtures.

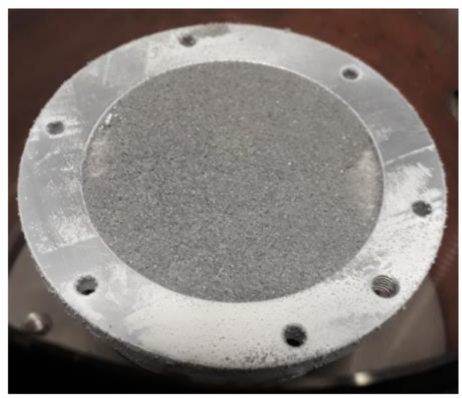

Figure 1: Example of an ice-kerite intimate mixture with 90%-10% mixing ratio.

3. Preliminary analysis

In Figures 2 and 3 an example of a series of water ice-kerite intimate mixtures is shown. For increasing amounts of kerite, a progressive decrease of the reflectance at VIS-NIR wavelengths can be observed, followed by a reduction of the water ice absorption features contrast at 1.2, 1.5 and 2 μm. With large amounts of ice, the band depth of the C-H stretching modes of kerite in the 3.2-3.5 μm spectral range is significantly reduced, because of the low content of organic and superposition with the 3-μm water ice absorption (Figure 3). Interestingly, the intensity of the water ice Fresnel peak at 3.1 μm is hardly affected by the presence of kerite.

For each mixture spectrum of Figures 2 and 3 a preliminary fit with Hapke's model is reported, with the aim to test the possibility to retrieve correct abundances for the two end-members. It can be noted that the different spectra of the mixtures can be modeled with relatively good accuracy. For the ice-kerite intimate mixtures with mixing ratios of 99%-1%, 90%-10% and 70%-30%, the derived amounts by means of Hapke's modeling are respectively 98%-2%, 81%-19% and 57-43%, indicating a reasonable agreement with the actual values.

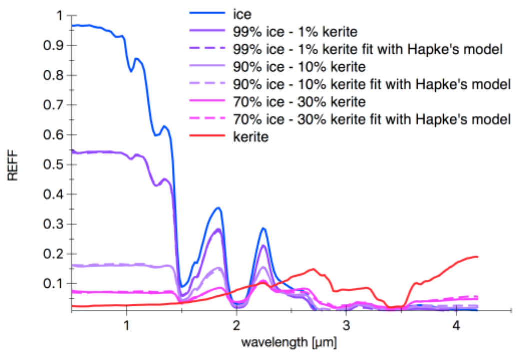

Figure 2: VIS-IR spectra of ice-kerite intimate mixtures (solid lines). Dashed lines indicate the output of spectral fits performed with Hapke's model. For this application, the single scattering albedos [11] of the pure end-members (ice and kerite) have been derived from the corresponding reflectance spectra and used to compute the spectra for the mixtures.

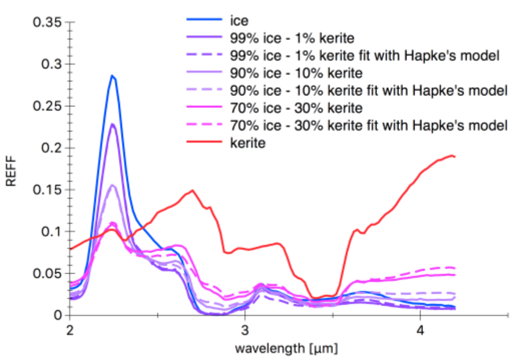

Figure 3: As for Figure 2, zoomed in the 2.0-4.5 µm spectral interval.

A similar approach will be applied to the other mixtures investigated in this study allowing us to characterize systematically their spectral response in terms of end-member abundances, grain size and mixing modality.

The main results of this experimental activity will be presented and discussed in the context of minor bodies remote sensing observations.

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