WATER ICE ON CERES' SURFACE AS SEEN BY DAWN-VIR: PROPERTIES RETRIEVAL BY MEANS OF SPECTRAL MODELING

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Abstract. Spectral signatures diagnostic of water ice have been detected in localized areas on the surface of Ceres by means of the Dawn/VIR instrument [1] on board the Dawn spacecraft. Here we focus on three craters where water ice signatures are most prominent on the dwarf planet's surface. We take advantage of the Hapke radiative transfer model in order to derive the properties of water ice: abundance, grain size, phase, type of mixture with the average dark terrain of Ceres, and surface temperature.

Introduction. The NASA Dawn spacecraft is in orbit around Ceres since early 2015, acquiring a huge amount of data at different spatial resolutions during the several phases of the mission. The Visible and InfraRed (VIR) mapping spectrometer [1] onboard Dawn, enabled detection and mapping of the main mineralogical phases on Ceres.
The surface of Ceres is mainly characterized by a large abundance of dark component, NH_4-phillosilicates and carbonates. Other mineralogical phases, such as water ice, also exist at local scale.

Dataset and Targets. Water ice has been detected in small areas on Ceres' surface by the Dawn/VIR instrument [1]. The most obvious finding is located in Oxo crater [2]. Further detections of water have been achieved during the Survey mission phase (spatial resolution ~1.1 km/pixel) and High-Altitude Mapping Orbit phase (~400 m/px) [3]. During the Low Altitude Mapping Orbit (LAMO phase, data with increased pixel resolution (~100 m/px) coming from both regions have improved the detection of water, highlighting clear diagnostic water ice absorption features. In this study we focused on spectra acquired in the LAMO phase from three craters where spectral features of water ice as measured by the VIR intrument appear stronger: Oxo (lon=0°, lat=41°N), Juling (lon=168°, lat=35°S), and an unnamed crater (lon=227°, lat=57°N) near crater Messor.

Method and Results. The Hapke radiative transfer model [4] has been applied in order to retrieve the water ice properties.
We consider two types of mixtures: areal and intimate mixing. In areal mixing, the surface is modeled as patches of pure water ice, with each photon scattered within one patch. In intimate mixing, water ice particles are in contact dark terrain's particles, and both are involved in the scattering of a single photon. The best fit with the measured spectra has been derived with the areal mixture for all three cases, which can be improved by a combined areal-intimate mixture (see Fig. 1-3).
The obtained water ice abundance is up to 15% within the field of view in Oxo crater, and in the range 0.15 - 0.25 km^2 in term of surface covered by the icy grains, considering the average ice-rich areas of the craters.
The retrieved grain size is in the range 50-300 μm. Phyllosilicates and carbonates, which are ubiquitous on Ceres surface [5, 6], have been also detected (signature at 2.7 μm, 3.5 μm, 3.95 μm), and modeled in correspondence with the icy regions.
The small relative minimum at 1.65 μm and the Fresnel peak at 3.1 μm are clearly visible, which indicates that water ice is in its crystalline phase.
Water ice is typically detected near the shadows projected by the craters' rims and in scarcely illuminated regions. Surface temperature of ice is in fact retrieved by fitting the temperature-dependent 1.65-μm feature which is deeper for cooler ice [7]. To do this, we rely on optical constants measured at different temperature conditions with sampling steps of 10 K, from 50 K to 150 K [8, 9]: we obtain the best fit with optical contants mesured with a temperature of 150 K (see Fig. 4). Although we have obtained a very good fit we cannot exclude better models with higher temperatures. The value obtained has to be compared with temperature obtained by numerical model based on a 3D finite element method [10], and with temperature as derived by the measured thermal emission [11].
Further analysis are required to study the possible temporal variability of the ice in the time scale covered by the Dawn mission. This, and the properties derived by the spectral modeling, can help constrain mechanisms related to the surficial water ice on the dwarf planet.

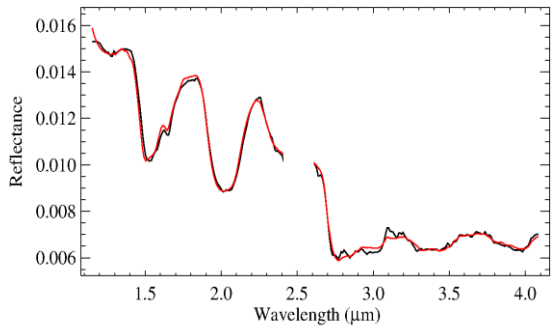

Figure 1. In black the average observed spectra in the Oxo ice-rich areas. In red the best fit obtained with an areal-intimate mixture of water ice (from optical constants [8, 9]) and average dark terrain of Ceres (from photometric analysis [12]) as discussed in the text. Water ice absorption bands at 1.25 μm, 1.5 μm, 2.0 μm, and 3.0 μm are present. The retrieved properties are: abundance 15% and grain size 250 μm. The observed spectrum is an average over an area of 1 km^2, from which we obtain ~0.15 km^2 of pure water ice.

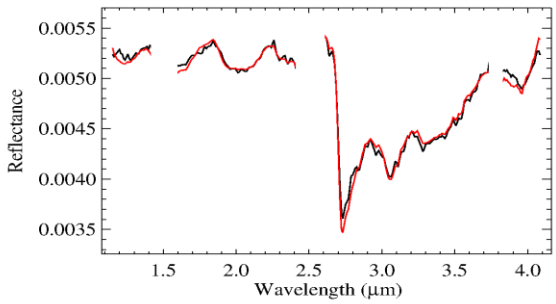

Figure 2. Same as in Figure 1, but for Juling crater. The retrieved properties are: abundance 1% and grain size 300 μm. The observed spectrum is an average over an area of ~25 km^2, from which we obtain ~0.25 km^2 of pure water ice.

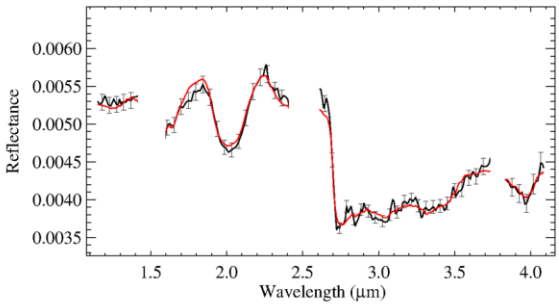

Figure 3. Same as Figure 1, but for the unnamed crater near crater Messor. The retrieved properties are: abundance 5% and grain size 50 μm. The observed spectrum is an average over an area of ~5 km^2, from which we obtain ~0.25 km^2 of pure water ice.

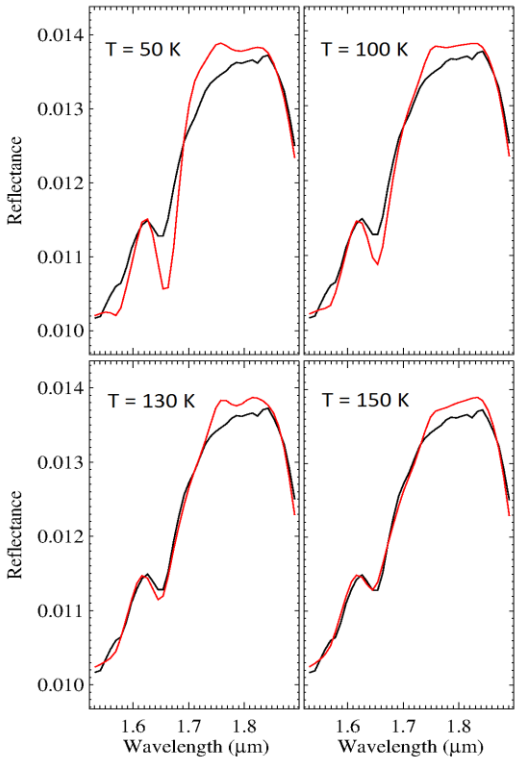

Figure 4. Different best fits of the icy-spectrum shown in Figure 1 are performed by means of optical constants measured at different temperatures [8, 9] with a sampling step of 10 K from 50 K to 150 K. The spectral region 1.5-1.9 μm of water ice is more sesnsitive to temperature changes. The best fit is obtained for optical constants measured at T = 150 K.

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