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High spectral resolution / low-temperature IR study of carbonates

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Introduction

The determination of surface properties of Solar System rocky bodies is a fundamental step in the interpretation of remote-sensing data from planetary missions. Estimating the surface temperature from remotely sensed spectroscopic data data is generally performed by applying models and inversions to infrared spectra. Such models have been used in the past to estimate the surface temperature of planetary bodies like Mars and Ceres (e.g. Pollack et al., 1990; Tosi et al., 2016). In some specific case, namely water ice, the absorption bands in the near infrared range have been calibrated in position (Fink and Larson, 1975; Grundy and Schmitt, 1998; Mastrapa et al., 2009) and their shift with respect to laboratory P-T conditions can be used to infer the surface temperature of icy satellites if these are relatively free from contaminants, or of ice outcrops on smaller bodies (see e.g. Raponi et al., 2018, for Ceres). Other non-water-ice materials can be in principle used as temperature proxy, useful for an independent estimation of the surface temperature of rocky bodies. Phyllosilicates for example are characterized by diagnostic OH absorption bands in the 1-2.8 µm-region, and these have been detected on Mars (Bibring et al., 2005; Ehlmann and Edwards, 2014) as well as on asteroids (De Sanctis et al., 2015; Hamilton et al., 2019; Kitazato et al., 2019) by telescopic and space missions. Nevertheless, the absorption of water hiddens or strongly affects the structural OH absorption in the IR, thus other non-hydrated materials are needed in order to be related to temperature changes. Carbonates, also detected on bodies such as Mars (Ehlmann et al., 2009) or Ceres (De Sanctis et al., 2016) are good candidates for such a study, because they are characterized by a number of absorption bands that may be little to no affected by water; in particular the bands at 3.4-4 µm are outside the broad 3-µm water band. In previous laboratory studies carbonates reflectance spectra in the IR have been acquired at room temperature (Harner et al., 2015). In other laboratory studies a correlation between band position and temperature change has been showed for 3.4 and 4-µm bands (De Angelis et al., 2018) regarding the natrite, although measurements were carried out at low spectral resolution.

Methods

In this work we studied the IR spectral reflectance of a number of different carbonates, in the 3.2-4.6-µm range, at high spectral sampling and resolution, in a wide temperature range from 270 K down to 60 K. This set of measurements is part of a larger project, which aims at investigating also other classes of anhydrous minerals at high spectral resolution, in order to identify other valuable temperature proxies that can be useful in the interpretation of remote-sensing data from current and future planetary missions. We acquired spectra on six different types of carbonates, namely: calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), magnesite ($MgCO_3$), siderite ($FeCO_3$), natrite (Na_2CO_3), malachite ($Cu_2(CO_3)(OH)_2$). These materials cover a wide range of carbonates with different cations (Ca^{2+}, Mg^{2+}, Fe^{2+}, Na^{+}, Cu^{2+}) thus allowing studying also the band variability due to the different chemical environment. Spectra were acquired with the setups of the Cold Surfaces Spectroscopy (CSS; https://cold-spectro.sshade.eu) facility at the Institut de Planétologie et d'Astrophysique de Grenoble (IPAG); measurements were performed with the SHINE Spectro-Gonio-Radiometer facility (Brissaud et al., 2004) equipped with a simulation chamber to control the sample temperature. The spectral sampling was 3 nm, corresponding to a spectral resolution < 8 nm. This facility uses a monochromator as a light dispersion element. All spectra were acquired at standard conditions of illumination (i = 30°) and emission (e = 0°). Spectralon and Infragold (Labsphere ©) were used as reference targets.

The materials have been analyzed in the form of fine powders, each mineral having been ground and dry-sieved at grain size below 50 µm.

Preliminary results and Conclusions

Spectra of a dolomite sample are shown in Fig.1. Several changes can be seen in the spectra as the temperature is lowered from 270 to 60 K. In Fig.1A the overall 3.2-4.6 µm-spectra are shown. The reflectance level at continuum becomes higher for wavelengths beyond 3.5 µm; below 3.3 µm a decrease of reflectance could be related to some minor amount of water contained in the sample, or to frost condensation in the chamber. In Fig.1B a closeup on the first minimum of the carbonate 3.4-µm band is shown. The position of the first minimum, located at about 3.31 µm at 270 K, seems to shift towards shorter wavelengths as the temperature decreases, by roughly 6-7 nm. In Fig. 1C a closeup on the 4-4.2-µm region is displayed. A very weak band, that is quite unrecognizable at 270 K, becomes clearer and definite as the temperature decreases to 60 K, located at 4.15 µm.

All these subtle changes in spectral bands positions as well as small bands appearing at low temperatures could be in principle detectable by high-resolution spectrometers.

Future work will deal with the detailed spectral analysis of band parameters of all the carbonate samples, as well as with the investigation of other anhydrous materials.

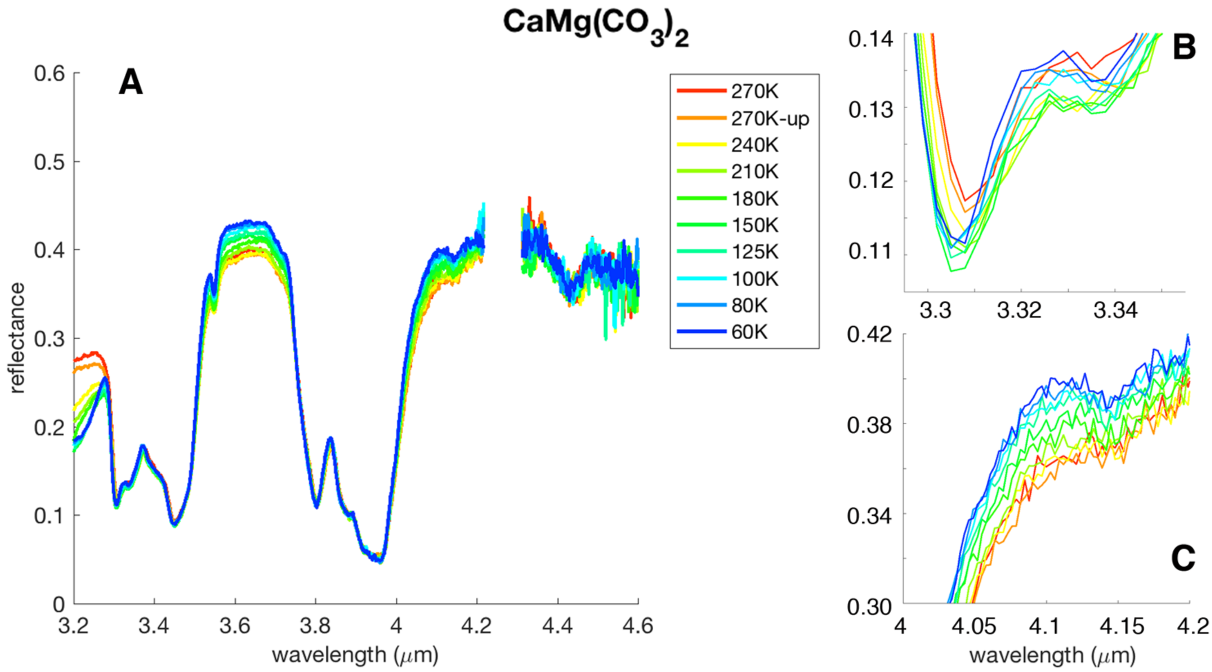

Fig.1. IR spectra of dolomite in the 3.2-4.6 μm range, at temperatures in the 270-60 K range.

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