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Estimation of the abundance of organic matter on Ceres from VIR/Dawn data coupled to laboratory experiments

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Abstract

Ceres is the largest object in the main belt and is a wet body with a complex geological and chemical history. Its surface is composed of opaque materials, phyllosilicates, ammonium-bearing minerals, carbonates, water ice and salts. Aliphatic organics, whose origin is still uncertain, have been detected on the Ceres surface by the imaging spectrometer Visible and Infrared Spectrometer (VIR) on board Dawn. Here, using VIR spectra, acquired with a high spatial resolution (< 100m), we analyzed in detail the organic-rich areas around the Ernutet crater, their spectral characteristics, and the associated mineralogy [2]. In addition, we investigated the abundance of aliphatic carbon on Ceres by mixing materials analogue to those identified at the surface of Ceres and compared it to the new high resolution VIR spectra. These new measurements and the experiments show that a large quantity of aliphatic carbon are present on Ceres surface and sub-surface, which likely indicate an internal origin.

1. Introduction

Organic matter directly observed at the surface of a planetary body is quite infrequent due to the usual low abundance of such matter. Unpredictably, the Dawn mission has revealed, thanks to the VIR spectrometer, large area of organic matter at the surface of Ceres, near the Ernutet crater. Observed and characterized by the Dawn mission since 2015, Ceres is a fascinating world. Surface composition (phyllosilicates, carbonates, salts, ice) has revealed a wet body with past hydrothermal activities [1]. The hydrothermal activities on Ceres was certainly very intense, much more than in carbonaceous chondrites and the finding of OM signatures at the surface has raised questions about its origin, composition, and abundance [2,3]. The organic material is mainly localized in the Ernutet region (Fig. 1), but it has also been observed in a few other locations, such as Hakumyi, Inamahari and Omonga craters.

2. VIR/Dawn spectra and region of interest

We have analyzed VIR data taken at LAMO (Low Altitude Mapping Orbit) orbital phases, at a spatial resolution of less than 100 m. Three regions of interest have been identified showing strong absorption features at 3.3-3.5 µm, characteristics of the stretching C-H of aliphatic carbons. Two regions are in the Ernutet crater and one in the Hakumyi area [3] (fig.1).

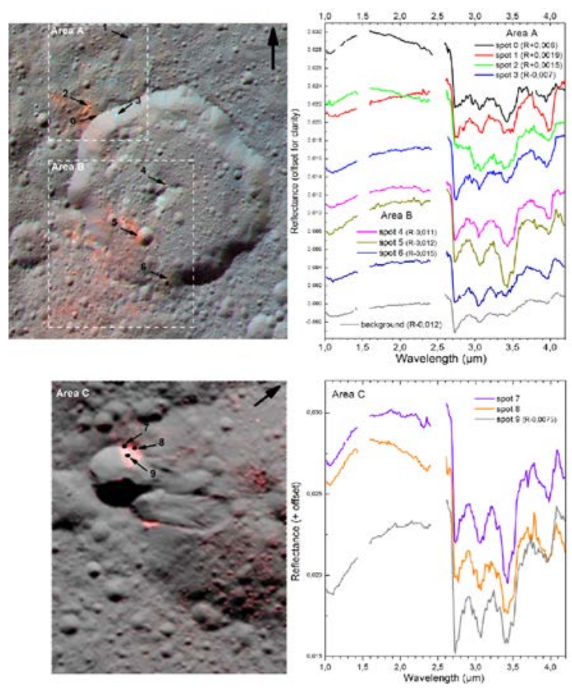

Figure 1: Camera color images of the Ernutet and Hakumyi areas and the localisation of the VIR spectra show on the right panels.

All these regions display signatures of phyllosilicates (2.7 µm) and some of them are richer in carbonate material with the 3.9-4 µm band. Observations of inorganic and carbon materials and their correlation attest to a close relationship of the component at the surface. This intra-mixing could have been produced during the pervasive hydrothermal alteration event [3]. However, sources of carbon inside Ceres and the behavior of the organic during hydrothermal alteration are still under investigation [4].

3. Ceres analogues

3.1. Mixtures preparation and analysis

We used 7 natural end-members as analog material of Ceres' surface: dolomite (grain size < 36 µm) as carbonate, serpentine (20-50 µm) as Mg-phyllosilicate, montmorillonite treated with ammonia (SCa3-NH_4^+) as NH_4^+-bearing phyllosilicate [5], amorphous carbon or magnetite as darkening agent (<50 µm), and coals DECS-16 and 19 (<250 µm) as representative of aliphatic/aromatic carbons. Samples were prepared by mixing together the powder in different wt%, followed by grinding in an agate mortar by hand (5 min) which provided intimated mixing and decrease of the grain size. Analysis were performed from 1.25-25 µm spectral range with a FTIR Bruker Vertex 70v, equipped with Harrik praying mantis accessory, for diffuse biconical off-axis reflectance with incidence angle=45°, emission angle=45°, phase angle 90°, and spectral resolution at 4 cm^{-1}. Infragold was used as reference. The spectrometer optics were under vacuum and the praying mantis accessory was flushed with nitrogen. IR Spectra were extrapolated to Ceres spectral resolution for comparison with the VIR data.

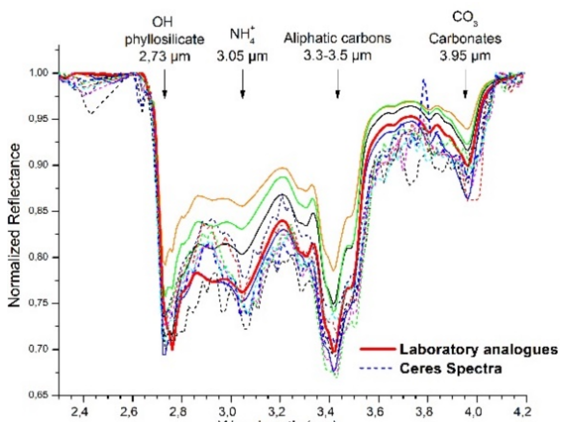

Figure 2: Laboratory IR spectra normalized between 2.5-4.2 µm of five mixtures compared with carbon-rich VIR spectra from CERES around Ernutet and Hakumyi areas. The best laboratory spectral fits are obtained with 14-17.5 wt% of aliphatic carbon.

We found that the IR band depth of the Ceres carbon-rich regions are consistent with mixtures containing up to 17.5 wt% of aliphatic carbon, completed with 21 wt% of dolomite, 17.5 wt% of SCa3-NH_4^+, 14 wt% of serpentine and 30 wt% of magnetite (Fig. 2-red spectrum). Reflectance of the mixtures range between 0.08 and 0.14, which is higher than the reflectance level of Ceres (~0.02 I/F).

3.2. Laboratory analogues issues

We noted an effect of the darkening agent composition on the band depth. The same amount (wt%) of magnetite or amorphous carbon in the mixtures produces a different overall reflectance of the spectrum, and specifically the absorption band depths are modified. Same conclusions are probably also true if using different aliphatic carbon end-members as shown from fitting procedures [3, 6]. Moreover, as shown, for instance, for 67P/ Churyumov-Gerasimenko surface laboratory simulation, the grain size of the different component affects the reflectance, due to the scattering effects of the particles (depending on their composition) [7]. Aggregates or bigger grain sizes for the aliphatic carbon material may be requested to match the low reflectance level of Ceres with magnetite as darkening agent. Laboratory simulations are still under investigations.

Overall, the new VIR data coupled to our experiments highlight that a large quantity of aliphatic carbon is observed in these particular areas on Ceres, up to 17.5 wt% but the choice of the end-member is critical for these estimations. This large quantity suggests an endogenous origin of the aliphatic carbons, in agreement with the mineralogical context [3].

Acknowledgements
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