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Spectral investigation of Ceres analogue mixtures for in-depth analysis of ccps

A. Galiano (1), F. Dirri (1), E. Palomba (1,2), A. Longobardo (1), B. Schmitt (3), P. Beck (3).
(1) INAF-IAPS, Rome, Italy (anna.galiano@inaf.it), (2) SSDC-ASI, Rome, Italy, (3) Université Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France.

Abstract

The dwarf planet Ceres is an airless cratered rocky body with complex craters on its surface. The analysis of VIR data of the material composing the central peak (termed as *crater central peak material*, ccp) revealed a moderate correlation between the spectral slope and the age of crater's formation [1]. Different hypotheses were proposed to explain the trend of spectral slope in ccps, including variation in composition and/or in grain size. To better understand such spectral variation, Ceres analogue mixtures, characterized by different composition and grain size, were produced and analysed. An opposite trend to what expected was observed from the results, revealing a bluer slope at decreasing grain size.

1. Introduction

Ceres was investigated by the NASA/Dawn spacecraft from March 2015 to October 2018 [2]. The VIR (Visible and Infrared Mapping Spectrometer) spectrometer [3] onboard Dawn acquired hyperspectral data of the surface, revealing absorption bands at 2.7-, 3.1-, 3.4- and 4.0-µm in reflectance spectra, suggesting a surface made of Mg-phyllosilicates, NH_4-phyllosilicates, Mg/Ca-carbonates and a dark featureless component [4]. Central peak of complex craters (ccp) is representative of the subsurface mineralogy and the reflectance spectra of 32 ccps were analyzed, investigating a subsurface depth included between 110 m and 22 km [1]. Ccps spectra show the same absorption bands observed in the surface, suggesting a mineralogy similar to the crustal layers, even if an increasing abundance of phyllosilicates is evident at increasing depth in the subsurface [1]. Furthermore, younger ccps show a negative (bluer) spectral slope (estimated between 1.2 and 1.9 µm) and older ccps are characterized by more positive (redder) slope. Moderate correlation between the spectral slope and the age of crater's formation suggests a variation of the peak with time [1]. The variation of spectral slope with the age of craters could be linked to grain size and/or composition. A more accurate investigation of this spectral trend was performed by producing Ceres analogue mixtures, characterized by different grain size and/or composition. Then, to better simulate the Ceres environment, heating process was applied on mixtures.

2. Experimental procedure

The mixtures were prepared and analyzed at the laboratory "Cold Surface Spectroscopy Facility" at the Institute de Planétologie et Astrophysique de Grenoble (IPAG). The mixtures were produced with the four end-members suggested to compose the Ceres surface, i.e. dolomite, antigorite, NH_4-montmorillonite and the graphite as dark component. Each end-member was first ground in a pestle and mortar, then the selected grain size (0-25, 25-50 and 50-100 µm) was obtained with an automatic sieving system. The end-members were mixed by varying their abundance and six mixtures were obtained: Mixture #1 (grain size 0-25 µm), Mixture #2 (50-100 µm), Mixture #3 (50-100 µm), Mixture #3a (50-100 µm), Mixture #4 (50-100 µm). Since the Mixture #4 (50-100 µm) is, spectrally, the most similar to Ceres mean spectrum, it was heated in oven at about 120-160 °C and the Mixture #4_h was obtained. The bidirectional reflectance spectra of laboratory mixtures were acquired at room temperature (290 K) in vacuum chamber, with an incidence angle *i* of 0° and an emission angle *e* of 30°. The spectral range of laboratory measurements of mixtures extends from 1.0 to 4.0 µm, comparable with the VIR data. The reflectance spectra of laboratory mixtures are compared with the Ceres mean spectrum in Figure 1. Given the similarity between the spectrum of Mixture #4_h and the Ceres mean spectrum (obtained by VIR data), this mixture was reproduced at grain size of 0-25 µm and 25-50 µm and heated in oven for about two hours at 100-120 °C. The reflectance spectra of the three samples of Mixture #4_h (grain size 0-25, 25-50 and 50-100 µm) were acquired in vacuum chamber both at cold and at room temperature (from 180 to 300 K).

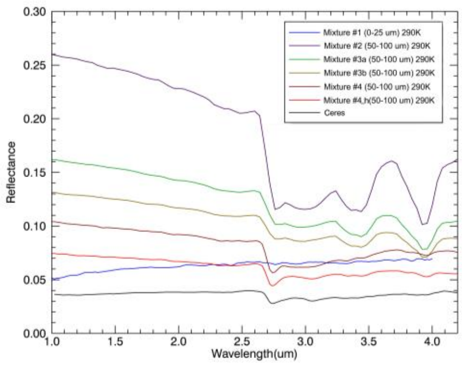

Figure 1: Bidirectional reflectance spectra of laboratory Ceres analogue mixtures compared with the mean spectrum of Ceres surface acquired by VIR.

3. Spectral parameters

The spectral slope of laboratory mixtures was taken into account in this work, estimated between 1.2 and 1.9 µm. Such parameter could be related to variation in composition and/or grain size. Absorption bands were also considered, since bands could be affected by grain size and temperature of sample, as well as by composition. Therefore, spectral parameters as Band Center (BC), Band Depth (BD) and Full Width Half Maximum (FWHM) were retrieved after the spectral continuum removal [5]. The BC is the band minimum in continuum-removed spectra and the BD is $1-R_{bc}/R_c$ where R_{bc} and R_c are the reflectance and the continuum at the BC, respectively [6]. The FWHM is the width of isolated band at half the height between the BC and the spectral continuum.

4. Spectral analysis of Mixture #4_h

The 2.7 and 3.1 µm BD of Ceres Mixtures #4_h decrease with increasing grain size at both room temperature and for cold temperatures, following the trend of end-members responsible of such spectral bands (i.e. antigorite and NH_4-montmorillonite). The carbonate bands, located at 3.4 and 4.0 µm, are also weaker at increasing grain size. Contrarily to previous laboratory experiments [7], the spectral slope is bluer at decreasing grain size.

5. Discussion

On the basis of these results, mixtures composed by fine grains are blue-sloped and coarse size of grains produce a redder spectral slope. Younger ccps, which are characterized by bluer spectral slope [1], could be composed by fine grains, melted by the impact. Differences in composition could also explain the blue slope observed in younger ccps, in particular cases as Haulani: elevated percentage of carbonate generates a negative spectral slope, as can be observed in the spectrum of Mixture #2 (which contains 57% of dolomite). Furthermore, and probably the most likely explanation, the variations in spectral slope could be related to different size of end-members composing the peak. In particular, the presence of dark component in fine size and therefore dispersed in a coarser mixture could produce a blue slope in the spectrum [7]. Anyway, the spectrum of Ceres analogue Mixture #4_h is not totally coincident with the mean Ceres spectrum, since it is brighter and redder than the mean Ceres: improvements in the Ceres analogue mixture need to be performed.

Acknowledgements

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