Homogeneus units on Ceres inferred by classification of VIR data from the Dawn mission: Preliminary results.

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Introduction: The NASA Dawn mission, in orbit around Ceres since March 2015, acquired a considerable amount of data that improved the knowledge on its chemical and physical properties, surface composition and interior [1]. The orbital mission at Ceres has been divided into several phases based on the altitude of the spacecraft over the mean surface, allowing the mapping of its surface at different spatial resolutions [1]. In particular, a mineralogical mapping of Ceres has been obtained at unprecedented spatial resolution thanks to the Visible and InfraRed mapping spectrometer (VIR) [2]. VIR data revealed a widespread distribution of Mg- and NH_4-phyllosilicates [3] mixed with low-albedo and spectrally featureless materials, and local carbonate-rich areas [4]. Outcrops of water ice have been identified in nine cases, occurring in shadowed regions inside specific craters [5, 6]. Na-carbonates rich areas [4] and organic-rich sites also occur at local scale. The selection of specific spectral parameters, such as depth and position of the main absorption bands, spectral slopes and albedo, permitted the identification of the different compounds at global and local scale. However, it is possible to identify correlations between different spectral parametres, thus defining homogeneous mineralogical surface units. We applied different clustering and classification methods to spectral indices of Ceres, in order to emphasize areas displaying similar spectral characteristics based on all of the spectral parameters already used in previuos papers [3, 4].

Dataset and methods: For this work, we analysed the VIR dataset from the High Altitude Mapping Orbit (HAMO) mission phase, characterized by a nominal spatial resolution of ~386 m/pixel, the best available in terms of coverage and spatial resolution for the VIR spectrometer. VIR is equipped with two channels: the visible which covers the wavelength range ~0.25-1.0 μm, and the infrared, which covers the wavelength range 1.0-5.1 μm [2]. Here we consider only data acquired by the infrared channel, which includes the spectral information most relevant for our analysis. Prior to begin our analysis, VIR data were treated in order to minimize calibration artifact residuals and thermal emission [8, 9], and to perform a photometric correction [10].

Our analysis relies on a total of eight spectral parameters: albedo at 1.2 and 1.9 μm, band depth at 2.7, 3.1 and 4.0 μm, band center at 4.0 μm and spectral slopes between 1.16 and 1.81 and between 1.81 and 2.25 μm. Subsequently, we created a global spectral parameter mosaic for each of these spectral indices.

Our analysis is based on different classification approaches. As a first approach, we applied the K-means unsupervised clustering technique to automatically and non-arbitrarily extracted spectral endmembers [11], afterwards, we use these endmembers to classify the whole dataset, i.e. the entire VIR HAMO coverage of Ceres, by using the Spectral Angle Mapper (SAM) supervised classifier [12]. We then tested an alternative method to specific selected areas, the G-mode unsupervised classification algorithm [13], which allows one to compute the statistical weights of the individual variables.

Results: Preliminary results, based on the classification of specific spectral parameters relative to the entire HAMO dataset, indicate that seven homogeneous classes are appropriate enough to represent the global mineralogy of Ceres. In **Fig. 1**, an example of classification obtained by the SAM method is shown. The map displays the distribution of the different classes across the surface of Ceres, indicating the presence of several homogeneous units whose average values are represented in **Fig. 2**.

Due to original numerical limitations, the G-mode algorithm has been applied only on specific regions of interest. In the area covering crater Occator, the G-mode identifies six hoogeneous classes, of which in particular two classes are representative of bright Na-carbonates-rich faculae. The evaluation of the statistical weights helps one ensure that no particular variable is dominating the classification (**Fig. 3**). A similar result is also obtained by using the SAM method to the same area, without having any information on the statistical weights.

Generally, the displacement of the homogeneous classes reveals a good correlation between homogeneous surface units and specific geologic features. In addition, the classification of spectral parameters is a powerful way to understand whether homogeneous surface units are or are not tightly consistent with units found in the maps of individual parameters. However, although testing different classification methods is needed to verify the numerical robustness of the results, any classification also strongly depends on the number of spectral parameters being used. A natural follow-up will be a global and local classification of VIR-derived spectral parameters in order to strengthen the choice of spectral endmembers.

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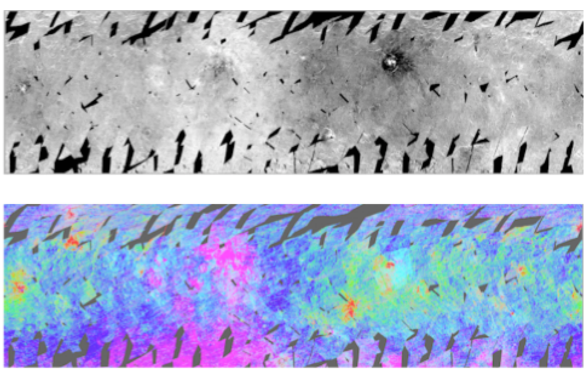

Figure 1: *Top: Ceres albedo map @1.2µm obtained in the HAMO mission phase. Bottom: Results obtained by applying the SAM classifier to the VIR-derived spectral parameters during the HAMO mission phase.*

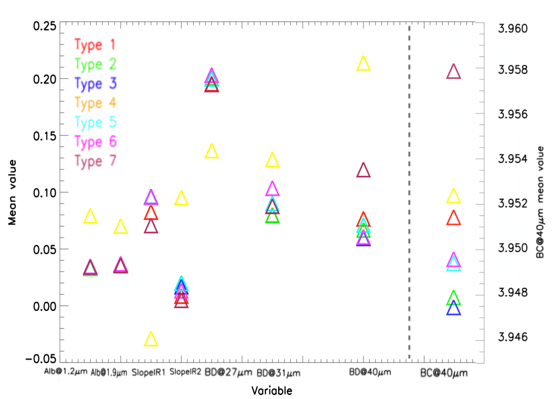

Figure 2: *Average values of the 8 spectral parameters (variables) obtained by applying the SAM classifier to the global mosaic of Ceres (Fig. 1). Each color corresponds to a different homogeneous class, using the same color code displayed in Fig. 1 (bottom).*

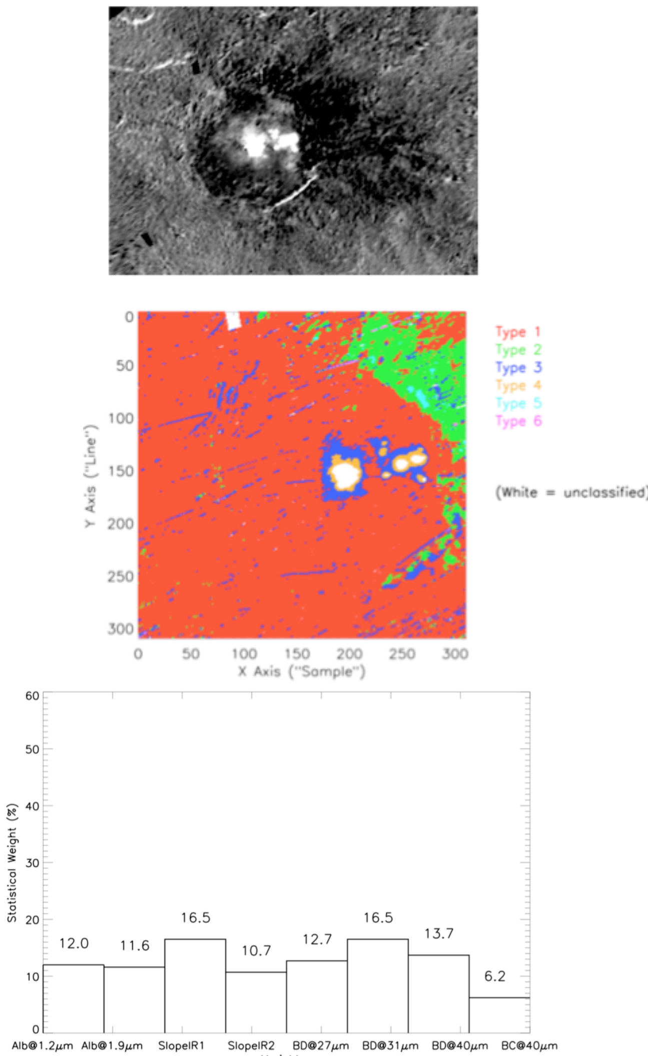

Figure 3: *Top: Occator albedo map at 1.2 µm. Center: G-mode results relative to the Occator crater area. Bottom: statistical weight of the single variables, obtained by G-mode algorithm.*

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