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Classification of Dawn/VIR data reveals homogeneous surface units on Ceres surface

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1. Introduction

The NASA Dawn spacecraft [1] orbits around Ceres since March 2015, and is now completing the second extended phase of the mission. The large amount of data acquired by Dawn are fundamental in understanding the chemical and physical properties undergoing on Ceres surface [2]. Dawn's payload is made up of three instruments: the Framing Camera (FC) [3], the Visible and InfraRed mapping spectrometer (VIR) [4], and the Gamma Ray and Neutron Detector (GRaND) [5]. VIR is a key instrument for deciphering Ceres surface mineralogy at unprecedented spatial resolution [4]. The spatial resolution depends on the altitude of the spacecraft over the mean surface, which changes from one phase to another. The main Dawn mission phases at Ceres, in the two-year period 2015-2016, were: Survey (1.1 km/pixel), High Altitude Mapping Orbit (HAMO) (0.38 km/px), and Low Altitude Mapping Orbit (LAMO) (0.095 km/pixel) [1]. After LAMO, the mission was extended to perform a first extended mission phase in 2016-2017, which was divided in a number of sub-phases where the altitude of the spacecraft raised back to ~19,500 km. In 2018, the Dawn spacecraft was finally injected into an elliptical orbit to perform the second and last extended mission phase (XM2). The combination of broad coverage and varying pixel resolution allow both a global analysis and a local study of features of interest. In particular, several VIR-derived mineralogical maps have been produced [6, 7]. The global mineralogy of Ceres is consistent with a large abundance of a low-albedo, carbonaceous chondrite-like spectral endmember, mixed with Mg- and NH_4-bearing phyllosilicates [6, 7] and Mg-carbonates, whereas Ca- and Na-carbonate-rich areas have been identified at the local scale [8]. Outcrops of water ice have also been identified in about ten cases, mainly occurring in shadowed regions inside specific craters [9, 10], as well as at least one organic-rich material unit [11]. Here, we considered VIR data acquired only in the HAMO phase, and we applied clustering and classification methods to define homogeneous compositional units on Ceres surface.

2. Dataset description

The VIR spectrometer acquires data in two distinct channels: the visible channel (0.25 - 1.07 µm), and the infrared channel (1.02-5.1 µm) [4]. The HAMO dataset represents an optimal trade-off between coverage and spatial resolution (~380 m/pixel obtained at broadly regional scale). For this study, we used only VIR data acquired in the infrared channel range, which includes the main absorption bands observed on Ceres. In particular, we selected the 1.0-4.2 µm range, the date were corrected for thermal emission [12] and instrumental artefacts [13], and then corrected for the instantaneous illumination and observation geometry [14]. On the other hand, the 4.5-5.1 µm spectral range was systematically used to perform surface temperature retrieval.

3. Analysis and preliminary results

We applied different clustering and classification methods to VIR-derived spectral indices of Ceres, to emphasize areas displaying similar spectral characteristics based on all of the spectral parameters already used in previous published papers [6, 8] (Fig. 1). First of all, we considered the K-means unsupervised clustering technique to automatically and non-arbitrarily extract spectral endmembers [15]. Then we used 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 [16]. We selected ten spectral parameters: reflectances at 1.2 and 1.9 µm, spectral slopes computed between 1.16 and 1.81 µm and between 1.81 and 2.25 µm, band depths at 2.7, 3.1 and 4.0 µm, and band centers at 2.7, 3.1 and 4.0 µm, respectively (Fig. 1, upper ten panels).

We first generated global mosaics for each of these spectral indices, which become inputs for our spectral classification. Prior to K-means clustering, we normalized each spectral parameter by its mean value in order to compare different spectral parameters spanning substantially different ranges. We also considered an alternative method to specific selected areas, namely the G-mode unsupervised classification algorithm [17], to compute the statistical weights of the individual variables for specific regions of interest. The classification of VIR-derived spectral parameters for the entire HAMO dataset, indicates that seven homogeneous classes are appropriate enough to represent the global mineralogy of Ceres. In Fig. 1, bottom panel, an example of classification obtained by means of the SAM method is shown. In this presentation, each homogeneous surface unit is marked by a different color, which allows us to display the distribution of the outcome of the classification. A proper selection of spectral parameters, such as band depth and position of the most diagnostic signatures, along with spectral slopes and albedo, demonstrates the existence of substantially different mineralogical units at both regional and local scale. We can then investigate the degree of correlation existing among the spectral parameters, thus identifying those variables that are most important in driving the classification.

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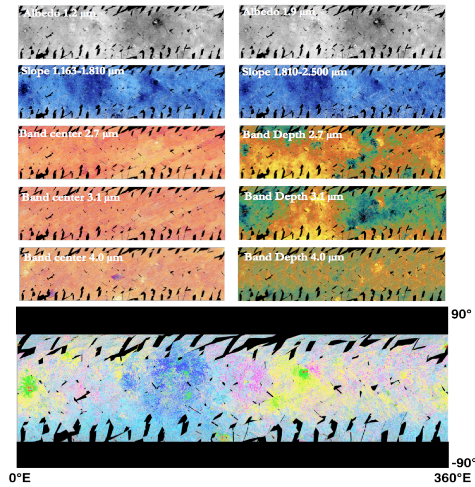

Figure 1: Top: VIR-derived maps of the considered spectral parameters. The meaning of each mosaic is written in white color in the upper left corner. **Bottom:** Result of the K-means unsupervised clustering technique applied to the spectral indices shown in the top panels. Each color corresponds to a homogeneous surface unit resulting from the classification of all of the diagnostic spectral maps considered above.

References

[1] Russell, C.T. and Raymond, C.A., 2011, SSR. [2] Russell, C.T., et al., 2016, Science. [3] Sierks, M. et al., 2011, [4] SSR De Sanctis, M.C., et al., 2011, SSR. [5] Prettyman et al., 2011, SRR [6] Ammannito E. et al., 2016, Science. [7] De Sanctis, M.C. et al., 2015, Nature. [8] Carrozzo, F.G., et al., 2017, Science Adv. [9] Combe, J.-Ph., et al., 2016, Science. [10] Combe, J.-Ph., et al., 2018, Icarus. [11] De Sanctis, M.C., et al., 2017, Science. [12] Raponi, A., et al., 2017, Icarus. [13] Carrozzo, F.G., et al., 2016, RSI. [14] Ciarniello, M., at al., 2017, A&A. [15] Tou and Gonzalez, 1974, Addison-Wesley Pub. Comp. [16] Kruse, F. A., et al., 1993, Remote Sens. Env. [17] Coradini, A., et al., 1977, Comput. Geosci. 3, 85-105.