CERES SUBSURFACE MINERAL COMPOSITION DETECTED BY SPECTRAL ANALYSIS OF CRATER CENTRAL PEAK MATERIAL (CCP).

A. Galiano[1,2], E. Palomba[1,3], A. Longobardo[1], M. C. De Sanctis[1], F. G. Carrozzo[1], A. Raponi[1], E. Ammannito[4], F. Tosi[1], C. A. Raymond[5], C. T. Russell[6] and the VIR team. [1]IAPS-INAF Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy (anna.galiano@iaps.inaf.it), [2]Università degli Studi di Roma Tor Vergata, Rome, Italy, [3]ASDC-ASI, Rome, Italy, [4]ASI-URS, Rome, Italy, [5]Jet Propulsion Laboratory, Californi Institute of Technology, Pasadena, CA, USA, [6]University of California at Los Angles, Los Angeles, CA, USA.

Introduction: The dwarf planet Ceres is the second target of NASA Dawn mission since March 2015, which acquired images and hyperspectral data of its surface by using the Framing Camera (FC) and the Visible and Infrared Mapping Spectrometer (VIR), respectively. The Ceres surface is mainly composed of a dark component, lowering the albedo, and Mg-phyllosilicates, NH_4-phyllosilicates and Mg/Ca-carbonates, as inferred from the occurrence of absorption bands located at 2.7, 3.1, 3.4 and 4.0 µm in VIR reflectance spectra [1]. Na-carbonates are particularly abundant in crater Occator's faculae [2]. Organics have been discovered in the peak, floor and ejecta of Ernutet crater, and over a large region encompassing the crater, based on an absorption band centered at 3.4 µm diagnostic of the C-H bond [3].

Different from the Ceres surface, the mineralogical composition of subsurface is more uncertain. A mineralogical investigation of Ceres subsurface can be performed by analyzing reflectance spectra of central peak of complex craters. In particular, on Ceres central peaks occur only for craters with diameter larger than 25 km [4], raising from the subsurface as consequence of impact. Material composing the central uplift is termed as *crater central peak material* (ccp): such material is rarely melted or shocked and, since it is geologically isolated within the impact crater, the spectral analysis can provide a preliminary knowledge of Ceres mineralogical subsurface.

VIR data: VIR acquired reflectance spectra of Ceres surface in the wavelength range from 0.25 to 5.1 µm. Since the early approach of spacecraft to the dwarf planet, Dawn performed several mapping orbits, progressively decreasing its altitude from the Ceres surface and acquiring data with increasingly higher spatial resolution. The Survey mission phase was characterized by a spacecraft's altitude of 4400 km and by a spatial resolution of 1.1 km/px; the High-Altitude Mapping Orbit (HAMO) mission phase was performed from an altitude of 1470 km and the spatial resolution of data acquired was 360-400 m/px; finally an altitude of 385 km and a spatial resolution of 90-110 m/px characterized the Low-Altitude Mapping Orbit (LAMO) mission phase.

Selection of ccp and parameters retrieved: A total of 32 craters with a clear peak arising from the floor have been identified from the geologic maps of Ceres [5] and the area of peak has been defined by selecting the minimum and maximum value of both latitude and longitude. The selected area has been spectrally analyzed by using VIR data at high resolution, i.e. data acquired during the HAMO and LAMO mission phases. For each ccp unit, the mean value of 2.7-, 3.1-, 3.4- and 4.0-µm band depths, together with their respective band centers, have been computed [6]. The spectral slope, estimated between 1.2 and 1.9 µm is also a parameter used in the spectral analysis. Furthermore, the elevation of the crater's peak with respect to the ellipsoidal shape model of Ceres has been estimated: by subtracting a tenth of the crater's diameter containing the peak [7] from the elevation, we obtained the estimation of the subsurface depth from where ccp emerged.

Spectral analysis of ccps: The IR spectral slope of ccps results to be negative ("bluer") in the young ccps and positive ("redder") in the older ones. A possible explanation is the fragmentation of peak in finer regolith.

In most cases, the 2.7- and 3.1-µm band depths correlate, as observed for the entire Ceres surface, confirming that Mg-phyllosilicates and NH_4-phyllosilicates exist and are generally connected to each other also in the subsurface (Fig. 1).

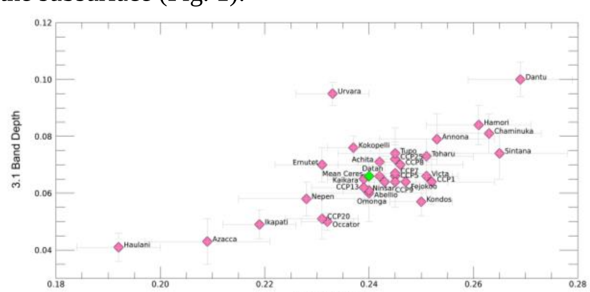

Figure 1. Scatterplot of 2.7- vs 3.1-µm band depths relative to Ceres ccps, highlighting that Mg-phyllosilicates and NH_4-phyllosilicates exist also in the subsurface.

The 3.4- and 4.0-µm bands, which are associated to carbonates, do not show a similar trend. The 3.4-µm band depth correlates with both the 2.7- and 3.1-µm band depths, whereas the 4.0-µm band depth is weakly related to the spectral features diagnostic of phyllosilicates. The mineralogical composition of ccps is similar to the average surface composition of Ceres, even though some differences occur in ccps located at high latitudes (the maximum latitudes observed in this work are 70°N in northern hemisphere and 60°S in southern hemisphere) and at ccps emerged from deeper layer of the subsurface (the maximum excavation depth is about 22 km).

Spectral parameters as a function of latitudes. The 2.7-µm band depth is larger in ccps located at poleward latitudes, as well as the 3.1-µm band depth. This trend can be interpreted as a different content of phyllosilicates close to the poles. The 4.0-µm band depth is, contrarily, independent of the latitude.

Spectral parameters as function of depth. By comparing spectral parameters with the excavation depth, it can be observed that the 3.1 µm band is stronger in ccps coming from the deeper part of crust. The trend is weaker for the 2.7 and 4.0 µm band.

The ccp of Dantu emerged from a depth of about 22 km below the surface (that is one of the deepest excavation depth among the analyzed ccps): the highest abundance of NH_4-phyllosilicates is on the peak (Fig. 2), suggesting a vertical gradient in its concentration.

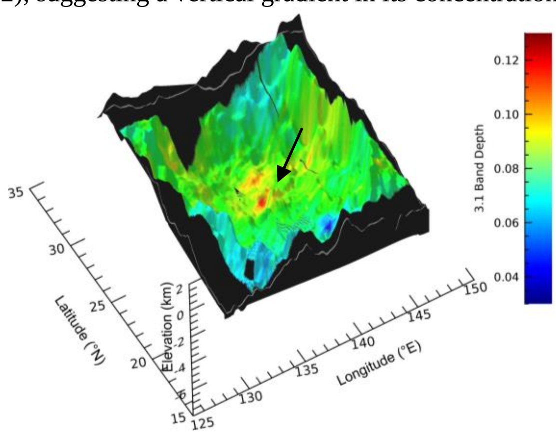

Figure 2. Three-dimensional image of Dantu crater, where the ccp is marked by a black arrow. The distribution of the 3.1-µm band depth is displayed with a rainbow color bar, allowing one to note that the highest abundance of NH_4-phyllosilicates (red color) occurs in Dantu's peak.

Carbonatic composition in ccps. Carbonate minerals composing most of the ccps are Mg- and Ca-carbonates. In Ernutet, Haulani and Ikapati ccps, the occurrence of Na-carbonates is suggested, observed as pure minerals and mixed with Mg/Ca-carbonates. The excavation depth of these ccps is between 6 and 9 km.

Conclusions: 32 ccps have been spectrally analyzed, in order to gather mineralogical information on the subsurface of Ceres. Older ccps are characterized by higher ("redder") spectral slope, possibly explained as a fragmentation of volume of rock composing the peak. The subsurface deposits closer to poles are richer in Mg-phyllosilicates and NH_4-phyllosilicates, while at increasing depth in the subsurface, a higher abundance of NH_4-phyllosilicates is observed. Carbonates are globally diffused in the shallow subsurface of Ceres, even though the occurrence of Na-carbonates has been observed in peaks emerged from depth as large as 9 km.

References: [1] De Sanctis M. C. et al. (2015) *Nature, 528,* 241–244. [2] De Sanctis M. C. et al. (2016) *Nature, 536,* 54-57. [3] De Sanctis M. C. (2017) *Science, 355,* 719-722. [4] Hiesinger H. et al. (2016) *Science, 353.* [5] Mest S. C. et al. (2016) *LPSC XLVII*. [6] Galiano A. et al. (2017) *Advances in Space Research*. [7] Pan C. et al. (2015) *J. Geophys. Res. Planets, 120,* 662-688.