GEOLOGICAL AND COMPOSITIONAL ANALYSIS OF GANYMEDE'S MELKART IMPACT CRATER.

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Introduction: NASA Galileo mission revealed that the surface of Ganymede is characterized by two main types of terrains which are different on the base of albedo, crater density and morphology. These units are defined as dark terrain (low albedo and high density of craters) and bright terrain (higher albedo and much lower crater density). Among the different features located on the surface of Ganymede, impact craters provide information about the impact itself, the substrate characterizing the impact site, as well as the material involved in the impact process. In this work, we investigate the Melkart impact crater, located at 10°S, 186°W on the surface of Ganymede. This represents an example of simultaneous observation acquired by the Near Infrared Mapping Spectrometer (NIMS) [1], obtaining spectra between 0.7 and 5.2 micron, and by the Galileo Solid State Imaging (SSI) camera [2] with relatively high spatial resolution. By combining these data, we study and correlate the geomorphological units with the spectral variation of the crater itself. The results will be also compared with previous works performed on Melkart crater [3].

Melkart impact crater: Melkart is a 107 kilometers crater characterized by a central dome, which is generally thought to be formed by warm soft ice uplifted from several kilometers below the surface, hence representing the lower crust of Ganymede (Figure 1). On the wide central dome, there are a lot of fractures and lineaments that are usually caused by surface stretching. The dome is surrounded by an irregular moat depression and the floor of the crater is both knobby and smooth (i.e. areas that may be refrozen impact melt) [4]. The Melkart crater is partly located between the Marius Regio, which is the dark ancient cratered terrain, and the younger bright grooved and smoothed area. From a compositional perspective, the NIMS spectra map of Melkart revealed a contrast between ice-rich bright terrain (located to the west) and ice-poor dark terrain (located to the east, Figure 2) [4]. A previous spectral analysis identified the different concentration of CO_2 within the impact crater finding that the Marius Regio exhibits a deeper CO_2 absorption band with respect to the impact crater region itself and smoothed terrain [3].

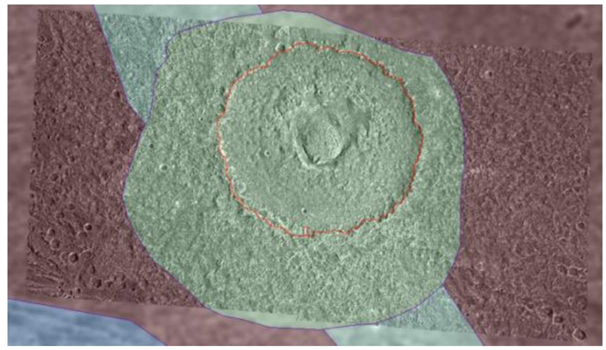

Figure 1: SSI observation G8GSMELKART01 of the Melkart crater (resolution of 186 m/px). From the published Ganymede geological map [5]: the brown unit represents the dark terrain, while the light green represents the bright terrain. Dark green correspond to the crater ejecta extension and the crater rim is outlined in red.

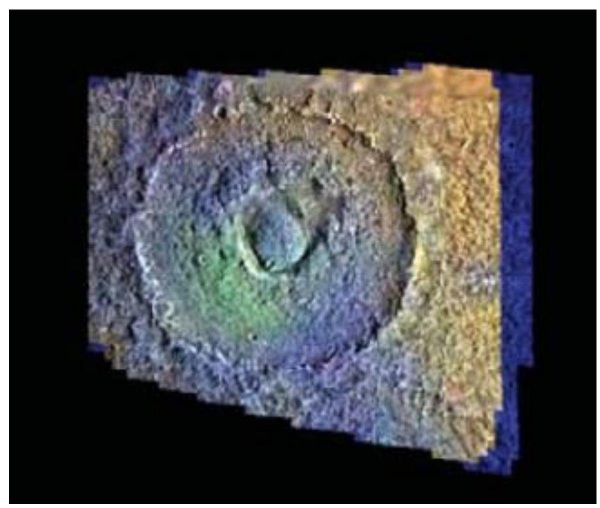

Figure 2: NIMS observation G8GNMELKART01 of the Melkart crater (resolution of 2.7 km/px). The ice-rich areas appear bluish in this false-color view, while the peculiar greenish patch on the west side of the crater floor is of unknown origin, and does not correlate with any observed features in Melkart [4].

Methods: To improve the knowledge of the Melkart impact crater, we performed both a geomorphological and spectral clustering analysis of this area. We investigate the geomorphological characteristic of this crater using the SSI Melkart mosaic in order to perform a higher detailed geological map compared to what available in literature [5]. This underlines the different structures present on the Melkart crater and its closest surroundings. Then, we applied on the NIMS dataset a spectral clustering technique based on a K-mean algorithm that allow us to separate in clusters our studying areas, and characterized each one by an average multi-color spectrum, and its associate variability. Such technique has been extensively validated using different spectral dataset on different areas on Mars, Iapetus, Phobos, Charon and Mercury. [6,7,8,9,10,11,12]. In addition, the relative geographical information of each spectrum is maintained in the process, hence the resulting clusters, can be geolocated on the studied surface and correlations with geographical features can be investigated.

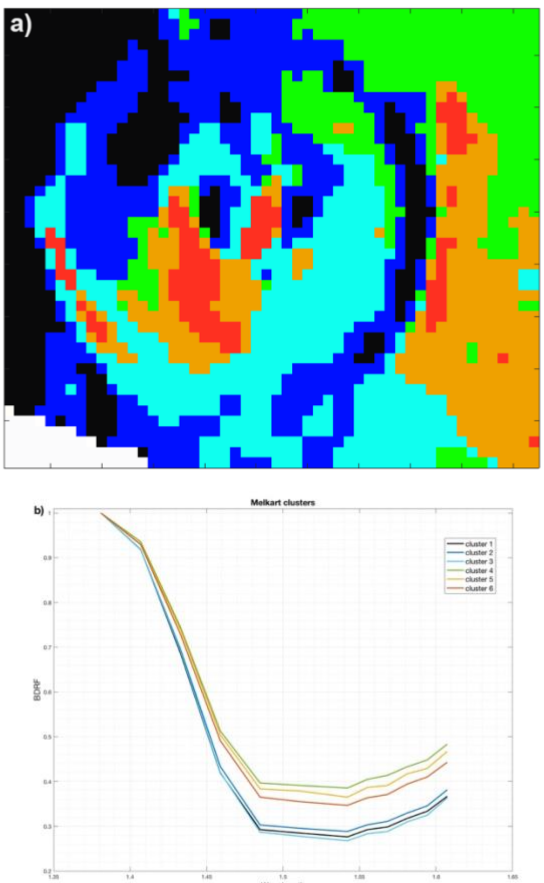

Figure 3: The six clusters identified by exploiting the spectral clustering technique on the NIMS dataset. Each cluster (a) and the corresponding plot (b) is characterized by a unique color.

Results and Future Works: Figure 3 shows the results coming from the spectral clustering technique. This analysis separates the Melkart NIMS data in six different clusters (Fig.3a,b) and the corresponding spectra. We applied the spectral clustering technique on the absorption band at 1.5 micron to understand the behavior of the water ice band depth. As outlined from the spectra, multiple differences appear within the Melkart crater, hence suggesting a much greater variability than the previously reported, i.e. the compositional difference between dark and bright/impact crater terrain [3,4]. Indeed, within the dark terrain, we found 3 clusters (clusters 4, 5 and 6), while within the bright unit we identified 3 clusters (clusters 1, 2 and 3). In addition, we underline that the green patch previously identified in the spectral map (Figure 2) shows a composition similar to the dark terrain one (clusters 5 and 6). By exploiting the presented results, we measure the relative amounts of crystalline and amorphous H_2O ice in the Melkart crater and its closest surroundings.

From the clusters results reported in Figure 3, we use a technique that estimates the relative amounts of crystalline and amorphous H_2O ice based on measurements of the distortion of the 1.5 micron spectral absorption band [13].

Indeed, craters are remnants of cataclysmic events that, by raising the local temperature, melted the ice, which subsequently crystallized. Based on laboratory experiments it is expected that, when exposed to ion bombardment at the temperatures typical of the Jovian satellites, the crystalline structure of the ice is broken, resulting in the disordered, amorphous phase. We therefore expect that the ice in and around the crater is partially crystalline as well as amorphous [13].

The final step is to show maps of the fraction of crystalline ice, overlined onto the Melkart SSI images searching for correlations between crystallinity and geomorphological units. This will provide indirect information about the age of the studied crater.

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References: [1] Carlson, R. W. et al., SSR., 60, 457-502, 1992; [2] Belton, M. J. S. et al., SSR, 60, 413- 455, 1992; [3] Stephan, K. et al., *Science of Solar System Ices*, Abstract #9060, 2008; [4] Schenk, P. *Atlas of the Galilean Satellites;* [5] Collins G. C., et al., (2013), *Global Geological Map of Ganymede;* [6] Marzo, G. et al. (2008), *JGR*, 113, E12009; [7] Marzo, G. et al. (2009), *JGR*, 114, E08001; [8] Pinilla-Alonso, N. et al. (2011), *Icarus*, 215, 1, 75; [9] Dalle Ore, C. et al. (2012), *Icarus*, 221, 2, 735; [10] Pajola, M. et al., 2018. *Planet. Space Sci.* 154, 63-71; [11] Dalle Ore, C., et al., 2018. *Icarus* 300, 21–32; [12] Lucchetti, A. et al., 2018, *JGR*, 123; [13] Dalle Ore, C. et al., (2015), *Icarus*, 261.