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Spectral clustering on Hermean hollows located on pyroclastic deposits

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Abstract

By means of the Mercury Dual Imaging System (MDIS [1]) onboard the NASA MESSENGER mission (Mercury Surface, Space Environment, GEochemistry, and Ranging [2]) the Hermean surface has been imaged both in colours and with unprecedented spatial scales. Indeed, the MDIS instrument was equipped with a multiband Wide Angle Camera (WAC) that could observe the Mercury surface up to 11 filters (in the 0.43 – 1.01 µm range) and with a monochromatic Narrow Angle Camera (NAC) that returned images of multiple Mercury's areas with resolutions of 10s to 100s meters.

We here decided to make use of the wealth of multiband WAC imagery to study the hollows located in proximity to two previously identified pyroclastic deposits [3] inside the Tyagaraja crater (a 97 km wide crater, centered at 3.89°N, 148.9° W in the Tolstoj quadrangle) and the Lermontov crater (a 166 km wide crater, centered at 15.24°N, 48.94° W in the Kuiper quadrangle). Hollows are shallow, irregular and rimless flat-floored depressions characterised by bright interiors and halos with bluish colours, often found on crater walls, rims, floors and central peaks [3-5]. The main aim of this work is to assess similarities and differences between the Visible spectra of the hollows located in Tyagaraja and Lermontov craters and to compare them with the spectral properties of the neighbouring pyroclastic deposits.

The resolution for each datacube used, as well as the multiband filters used for each observations are presented in Table 1. All images have been photometrically corrected with Hapke methods following [6], using the parameters derived in [7], i.e. incidence angle of 30°, emission angle of 0° and phase angle of 30°. On the photometrically corrected

	Tyagaraja	Lermontov
Resolution (m)	383	266
Filters used (µm)	0.4332	0.4332
	-	0.4799
	0.5589	0.5589
	0.6288	0.6288
	-	0.6988
	0.7487	0.7487
	0.8284	0.8284
	-	0.8988
	0.9470	0.9470
	0.9962	0.9962
	1.0126	1.0126

Table 1. The resolutions and filters used for the two MDIS cubes used in this work.

full datasets we applied a statistical clustering based on a K-means partitioning algorithm developed and evaluated by [8]. This makes use of the Calinski and Harabasz criterion [9] in order to find the intrinsically natural number of clusters, hence making the process unsupervised. Such technique has been extensively validated using different spectral data sets on different areas of Mars [8,10,11], Iapetus [12,13], Phobos [14], and Charon [15] as well as on other Herman hollows [16,17]. On both datasets, each of the identified clusters is characterised by an average multi-colour spectrum, and its associated variability. 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.

For the specific case of the Tyagaraja crater (Fig. 1A), a natural number of 10 clusters was identified (Fig. 1B); instead, 11 clusters were identified on Lermontov crater. As it is possible to see from Fig. 1B-C, the clustering technique separates the different spectral trends between the pyroclastic material,

located both inside and outside the crater and the hollow deposits. Clusters 8 and 9, i.e. those associated with the hollow fields, show distinct shallower/bluer spectra with respect to those associated with the pyroclastic deposits (clusters 3-5) and the surrounding dark terrains (clusters 0-2). The clusters unrelated to hollows are all characterised by distinct steeper/redder spectral slopes, typical of the pyroclastic deposits observed on Mercury [4]. Instead, clusters 6 and 7 of Fig. 1B are transitional deposits where hollows' halos intermix with the pyroclastic deposits.

We point out that hollows' spectra present a distinctive, wide absorption band (0.558-0.828 μm) that was already observed on other different hollows (all unrelated to pyroclastic deposits) located inside the Dominici, Velazquez and an Unnamed crater [16,17]. This suggests that despite being located on different hosting terrains, hollows present a similar composition.

Eventually, the same spectral trends characterising the Tyagaraja crater are observed both on the pyroclastic deposits and the hollowed terrains of the Lermontov crater as well, with the main difference that the Lermontov pyroclastic deposits show steeper spectral slopes than the Tyagaraja's ones.

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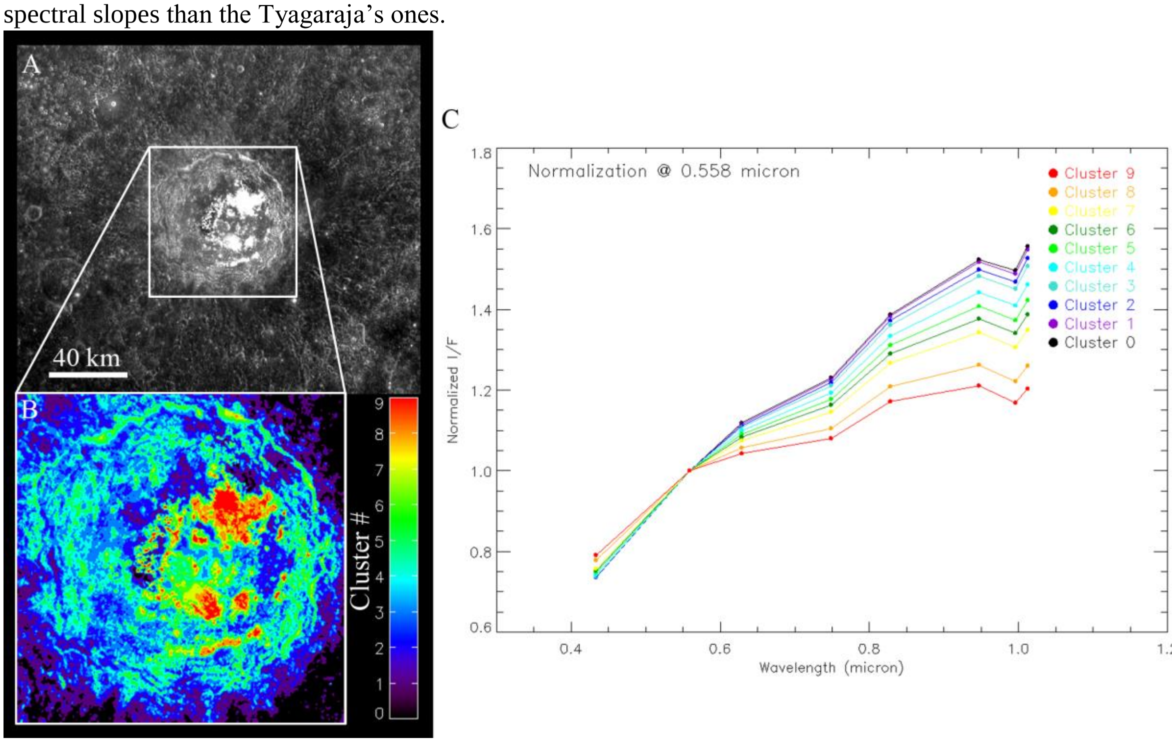

Fig. 1: A) The MDIS WAC image (EW1009232936D) of the Tyagaraja crater. B) The 10 clusters identified on the dataset. C) The average I/F normalised spectra (at 0.558 μm) of the clusters identified in B. Colours refer to B.