

EXPLORING THE SPECTROPHOTOMETRIC PROPERTIES OF HOLLOWS FROM MESSENGER MDIS/WAC MULTIANGULAR OBSERVATIONS

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Introduction: The origin and formation of Mercury's hollows represents one of the major open science questions about Mercury surface processes and landforms. Hollows were first identified on MESSENGER (Mercury Surface, Space ENvironment, GEochemistry, and Ranging, [1]) images [2] as tens meters to several km-sized shallow, irregular, flat-floored depressions characterized by bright interiors and haloes and found on crater walls, rims, floors, and central peaks [2,3]. Current proposed hollows formation mechanisms envision hollows as the result of volatiles release from the surface of Mercury through processes like sublimation, thermal desorption, sputtering, micrometeorite impacts and pyroclastic volcanism [2,3,4]. However, a well-established framework explaining their nature and formation is still lacking.

In this work, we analyze a set of multi-angular Mercury Dual Imaging System (MDIS, [5]) wide angle camera (WAC) color images of hollows-hosting Canova (25.62°N, 3.75°W) and Tyagaraja craters (3.89 °N, 138.9°W). Through a photometric modelling approach based on the Hapke and Kasalaainen-Shkuratov models [8] and on the phase-ratio technique, we aim to investigate the spectrophotometric properties of hollows to provide insights on their nature and formation mechanisms.

Methodology. We collected multiple MDIS/WAC images covering the well characterized hollows at Canova and Tyagaraja [6,7] crater in 8 out of 11 filters ranging from 433 nm to 996 nm. Each image was processed through the USGS PILOT web (<https://pilot.wr.usgs.gov/>) interface to apply radiometric calibration and attach the spacecraft pointing and Sun illumination direction information. For all observations in each filter we constructed a sampling grid with a scale of 665 m (Fig. 1A) and we collected the flux and the photometric angles at each sampling point (Fig. 1A, B). This data is then used to invert the basic Hapke model and different version of the Kasalaainen-Shkuratov models (KS1 to KS6 as defined in [8,9]). The best-fitting models at each sampling point are then used to prepare maps showing the spatial distribution of model parameters at both locations. Afterwards, we define regions of interest (ROIs) on the hollows and crater floor material (Fig.

2A,C). Such ROIs are used to compute the median and its uncertainties of the fitted model parameters for both materials. Finally, to better interpret and cross-check our results, we also apply the phase-ratio technique [9,10]. This approach considers the ratio of reflectance between two images taken at different phase angles, which is indicative of both the roughness and texture of the regolith. Low phase-ratio values suggest a smooth terrain while high values are indicative of a rough material [9,10].

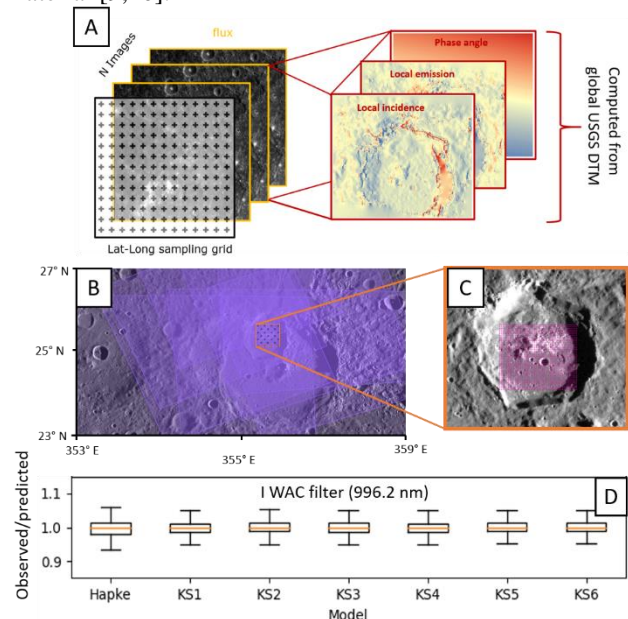


Figure 1 A) Sketch of the MDIS/WAC Canova dataset. B) WAC G-band image coverage (violet, in transparency). C) Area under investigation (pink square). D) Boxplots of the ratio between the observed and predicted flux for each fitted model.

Results and discussion: The performance of our correction is shown by the box-plots in Fig. 1D. On the y-axis we report the ratio of the observed vs predicted flux for the I (996.2 nm) band. We plot only 1 band for clarity, but the others give similar results. The fitted photometric models allow to reproduce the observed flux values with an error below 10% at 3σ , which is comparable with the radiometric accuracy of the MDIS/WAC datasets. The median Hapke parameters for hollows and the crater floor material ROIs are shown in Fig.3. We highlight that hollows at both locations show consistent parameters. They are characterized by a higher c than the crater floor and a lower θ , implying

a more backscattering and smoother material, rich in holes, vesicles or fractures that serve as scattering centers [11,12]. Phase ratio images of both sites, displayed in Fig. (2B, D) result in lower values for hollows with respect to the crater floor material, confirming a smoother surface.

Conclusions

We analyzed a set of multiangular MDIS-WAC images in 8 WAC filters showing hollows on the floors of Canova and Tyagaraja craters on Mercury. These observations were used to fit several photometric models, obtaining photometric correction with accuracies higher than 10% at 3σ . Among these models, we relied on the Hapke one to investigate the photometric properties of hollows. Both locations are characterized by young hollows, made of relatively small, coalescing depression. Therefore, our model parameters are indicative of the scattering properties of the hollow walls and haloes. Since the floors are relatively small sized at these locations, their contribution is not significant. We found that both the Tyagaraja and Canova hollows have similar Hapke parameters, and that they are more backscattering and smoother than the crater floor material. The latter result is also independently confirmed by the phase-ratio analysis. The increase hollow backscattering is consistent with a volatile-release mechanism, where the removal of a volatiles phase from the hollow walls leaves holes that serve as additional scattering centers. In addition, this is also consistent with the proposed scarp retreat growth mechanism, where i) the walls progressively weaken as they get more and more devolatilized, ii) then crumble and collapse towards the hollow floor, leaving a smooth depositional lag near the wall [13]. In this scenario the floor would be made of a mass-wasted, blocky material, implying a rougher surface. Therefore, the removal of such blocks from the walls implies that these would be made of a smoother material. In addition, the emplacement of a halo made of finer particles would also result in smoother hollow walls. In summary, our analysis provides new evidence that support hollows as the result of the release of a volatile from the surface, which occurs through scarp retreat and emplacement of a bright halo of fine material. This spectrophotometric characterization will be also useful for future investigations of hollows with high-resolution DTMs, color images and spectra from the SIMBIO-SYS [14] instrument onboard BepiColombo.

Acknowledgements: This study is supported by the BepiColombo ASI-INAF contract n° 2017-47-H.O.

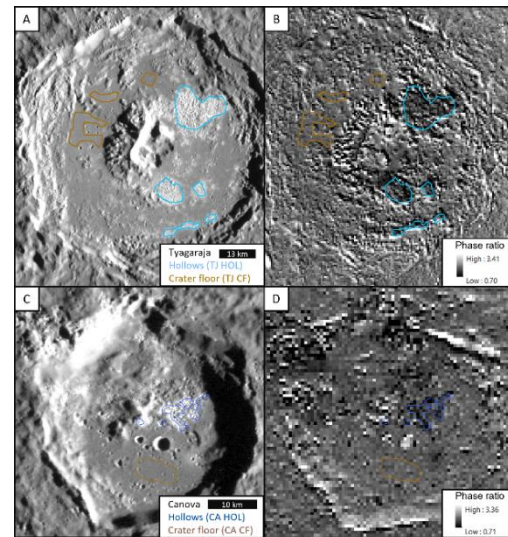


Figure 2 A) Global mosaic of Mercury showing Tyagaraja crater. The blue and brown areas represent the Canova hollows (TY_HOL) and the crater floor material (TY_CF) ROIs, respectively. B) Phase-ratio image of Tyagaraja. C) MDIS/WAC image of Canova crater. Lightblue and gold areas are the Canova hollow (CA_HOL) and crater floor material (CA_HOL) ROIs, respectively. D) Phase ratio image of Canova crater.

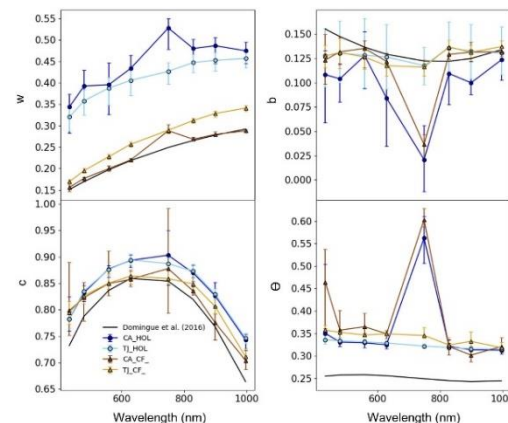


Figure 3 Hapke parameters for the Canova and Tjagaraya hollows (blue and light blue markers and lines) and crater floor material (brown and gold markers and lines) and for the average Mercury (black lines).

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