REGIONAL PHOTOMETRIC STUDY OF GANYMEDE'S SURFACE

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Introduction: Jupiter's icy moons are at the center of future space exploration missions such as ESA's JUpiter ICy moons Explorer [1] and NASA's Europa Clipper [2]. Ganymede, in particular, will be the primary target of the JUICE mission. Knowledge of its surface is paramount to best plan the mission, help with navigation [3] and understand its geology. In this study, we focus on the photometry of the surface and how we can describe it using the Hapke photometric model [4].

Dataset: This study uses images taken with the Imaging Science Subsystem (ISS) of the Voyager spacecrafts and includes more recent images taken of Ganymede with the LOng Range Reconnaissance Imager (LORRI) of the New Horizons probe. Both datasets were retrieved on NASA's PDS archive [5, 6].

Figure 1: Spacecrafts and instruments used in this study.

Method: A photometric study necessitates two pieces of information: reflectance and geometry. The first can be obtained after radiometric calibration. The second necessitates accurate projections of each pixel. Therefore, the first step of this work is image processing.

Correction of meta-data: We simulated images with SurRender [7], an image renderer developed by Airbus DS allowing the input of custom reflectance models, and using meta-data obtained on NASA's PDS. We compared those simulations to the real images and computed the correction in pointing needed to make them match. The attitude of the moon was also refined by maximizing the correlation between simulations and real images. Additional corrections were needed on the Voyager images for which we also corrected for distortion and distance.

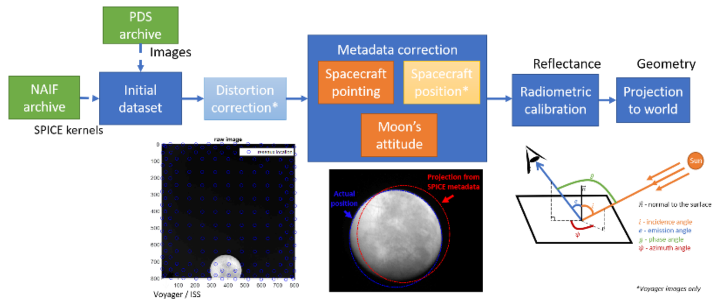

Figure 2: Entire pipeline to extract photometry from images [8]

Photometry: With accurate meta-data and after full radiometric calibration of the images, we can successfully project every pixel onto the moon and compute the observation geometry – incidence, emission and phase angle – for each of them as well as their physical reflectance value. We selected 14 regions to study with varying terrains, albedos and phase coverage.

Model and Baysian inversion: For this study we are considering Hapke direct model detailed in Hapke, 1993 [4]. Six parameters are to be estimated: b, c, ω, θ, h and B0. We have developed an inversion tool using a Bayesian approach based on previous work done on Mars [9, 10]. No a priori knowledge of the parameters were inferred except for their physical domain of variation. This work is detailed in our previous study of Europa [11].

Results: We realized a regional photometric study of 15 areas of Ganymede with very limited dataset of 16 images matching our criteria (see section 1) for which we corrected the metadata (spacecraft position and orientation) and radiometric calibration discrepancies. *Macroscopic roughness*: The macroscopic roughness is the most heterogeneous parameter across the surface (see fig. 2). The variability of $\bar{\theta}$ was also noted in a disk-resolved study by [12]. In our case, the values vary between 4.4° and 40.9° with an average 16.2°. This value is well under the 30° estimated from disk-integrated studies [13, 14] but we are under-sampling the trailing hemisphere with the darkest and presumably roughest areas of the surface so this might just be a bias of our sampling.

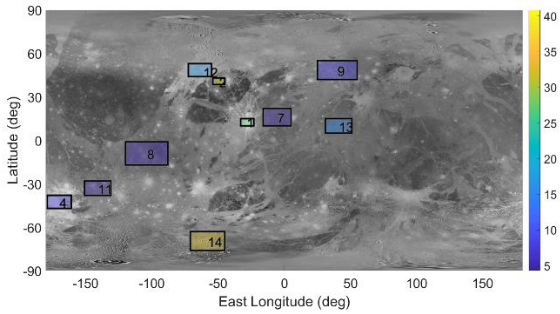

Figure 3: Macroscopic roughness $\bar{\boldsymbol{\theta}}$ over the different regions of interest on Ganymede

Particle phase function: We have found that most of our areas are consistent with a global backscattering behavior of the surface (c<0.5) with two notable exceptions - ROIs #2 and #4 (see fig. 2) – which are forward scattering. Both are in the polar caps region that extends down to latitudes of 40° [15] which are known to have a predominantly forward scattering behavior [12] probably caused by transparent fresh ice particles continuously deposited at polar latitudes by redistribution processes at play on Ganymede.

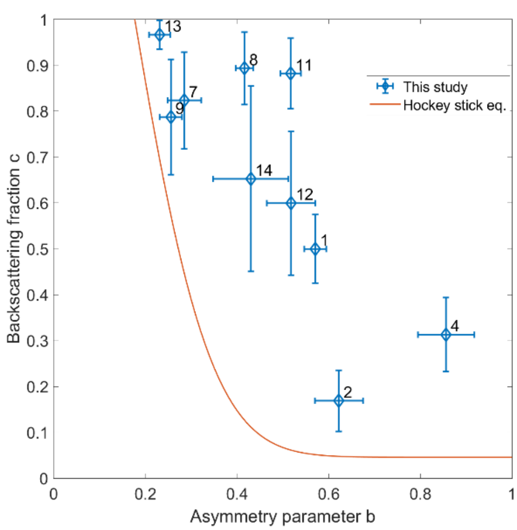

Figure 4: Values of the asymmetry parameter, b and the backscattering fraction, c over the different ROIs superimposed to Hapke's Hockey stick equation curve [16]

We should note, however, that other ROIs are in the polar latitudes and are still strongly backscattering such as ROIs # 9, 12 and 14, although they are a lot less constrained. However, the polar caps are known to be patchy and have a very different thickness over the entire globe [17] which means that it is reasonable to think that some areas would have thicker deposits and exhibit a forward scattering behavior when others would not. Another possible explanation for the forward scattering of ROI$#2 would be the presence of fresh material exposed by the neighboring crater or signs of cryovolcanism.

Conclusion: The preliminary results of this study are very encouraging and show areas of particular interest that could be targeted by future missions. Overall, the general trends of our results are consistent with past integrated photometric studies [13, 14].

We plan to extend this work with more photometric models and additional datasets. We would also like to extend our study to the regions of interest put forth by Stefan et al. [17].

Acknowledgements: This work is supported by a European Space Agency (ESA) research fellowship and has been supported by Airbus Defence & Space, Toulouse (France) as well as the "IDI 2016" project funded by the IDEX Paris-Saclay, ANR-11-IDEX-0003-02.

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