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Photometric study of Europa with Hapke model

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Abstract

In the context of ESA's future mission JUICE, this work is the start of a broad investigation on the reflectance models of Jupiter's icy moons. It focuses on Europa and Hapke photometric model using images from the LORRI instrument on New Horizons. The parameters are estimated using a Bayesian approach that has been developed for similar work on Mars. We show that it is possible to constrain Hapke parameters on restricted areas of Europa and that they can be fairly different depending on the regions of interest. However, this study shows limitations that we hope to overcome by including more data from other missions such as Voyager.

Introduction

The JUICE (JUpiter ICy moons Explorer) mission from the European Space Agency (ESA) is scheduled to launch in 2022 and arrive at the Jovian system in 2030 to study Jupiter and its icy moons for three and a half years. The spacecraft is being designed by Airbus Defence & Space in Toulouse, France, with a new and innovative navigation system. Any mission to the outer Solar System is challenging considering local radiative and thermal conditions as well as the distance to the Earth. The vision-based navigation algorithm implemented on JUICE will make the spacecraft more autonomous and more precise in its pointing by extracting navigation data from on-board image processing [1]. To offer the best of that algorithm, the spacecraft needs to have a proper knowledge of the photometric models of the moons that will be observed.

Significant work has been done using the Voyager and telescopic observations [2, 3, 4]. But none of these models give satisfying results when simulating images and comparing them to reality. This work aims at studying local photometric properties with the Hapke model [5].

1. Data set

We are using images taken by the LOng Range Reconnaissance Imager (LORRI) on the New Horizons spacecraft. Using [6] we adapted the calibration process to Europa, extracted the measured radiance and converted it to reflectance in REFF units.

$$r = \frac{F_{rad}}{F_{Sun}} \qquad REFF = \pi \frac{r}{cos(inc)}$$

2. Method

2.1 Correction of meta-data

Before anything else, it is essential to correct the images metadata. We have corrected for spacecraft pointing errors as well as moon attitude inaccuracies. To do so, we simulated images using the image renderer developed by Airbus DS, SurRender [7]. Among other things, it allows for custom reflectance model input which is very useful for our study. We used meta-data downloaded on the NASA PDS [8] for the simulations and we compared them to the real images. We then computed the corrections in pointing to make them match using an optimization-based registration function. The attitude of the moon was ultimately refined by computing the optical flow between simulated and real images. The registered movement (fig. 1) was converted to rotation.

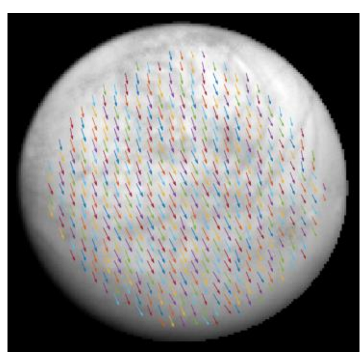

Figure 1: Example of optical flow on image

With accurate meta-data, each pixel was projected onto the moon so the observing geometry – incidence, emission and phase angle – could be computed for all.

2.2 Model and Bayesian Inversion

For this study we are considering Hapke direct model detailed in [5]. Six parameters are to be estimated: b, c, ω, θ, h and B0.

We constrained these parameters in selected areas of Europa using a Bayesian approach that has been used on Mars in the past [9]. No a priori knowledge of the parameters were inferred except for their physical domain of variation. A Monte Carlo Markov Chain algorithm was used to sample the Probability Density Function (PDF) of the a-posteriori solution [9, 10]. The sampling algorithm has been optimized recently [11].

3. Preliminary results

We conducted this local study on nine different zones of interest. Results are rather homogeneous for ω but show some variation for parameters b, c and θ. Fig. 2 shows the distribution for the latter. Since we don't have any data with phase angles lower than 20°, it is impossible to draw any relevant conclusion for h and B0.

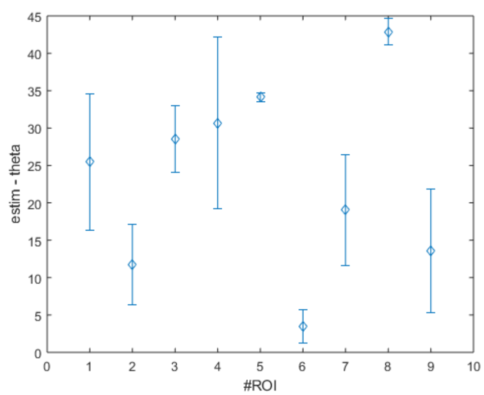

Figure 2: Variation of θ over the different regions of interest

Conclusion

This study shows that we can constrain Hapke parameters on restricted areas of Europa. Thus, local photometric studies should be determined on this moon after additional work. However, we noted that we would need more data to gain confidence in these results and extend the study.

We are working to add data from the Voyager spacecrafts as well as any relevant images from the Cassini and Galileo missions. Because these datasets are very different, each brings its own set of challenges, but we are confident this should help us constrain the photometric properties of Europa and, ultimately, those of Ganymede and Callisto. We will also investigate other photometric models and compare their best fit to fulfill our objective of deriving accurate reflectance models for all three icy moons.

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