SPECTROPHOTOMETRY OF REGIONS OF EUROPA

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Introduction: With this study, we are revisiting Galileo's Near-Infrared Mapping Spectrometer (NIMS) data to evaluate the spectral variability of the photometric behavior of selected areas of Europa.

Context: Europa is a very promising target in the search for habitability in our solar system. Its surface is the youngest of the Jovian icy satellites [1]. It appears to be continuously renewed by recent (and possibly ongoing) geological activity. The main driver of this activity is Jupiter's tidal forces which are responsible for the existence of a global water ocean underneath Europa's icy crust [2]. This ocean is thought to be in a direct contact with the rocky mantle [3] creating a potential environment for the emergence of life.

This places Europa at the center of future space exploration with NASA's Europa Clipper mission [4] as well as ESA's JUpiter ICy moons Explorer (JUICE) that will more generally study the Jovian icy moons [5].

To prepare for those missions, it is crucial to get the most out of the data we currently have. Photometry plays a key role in deriving remote sensing science products. As such, photometric correction is often the first step of any remote sensing analysis such as mapping or spectroscopy. In itself, photometry is closely linked to the surface microtexture and can help us better understand its physical state [e.g. 6, 7].

In this work, we are deriving photometric parameters for selected areas of Europa - we analyze their spectral dependency and how that can be translated into physical properties.

Dataset: We are using reflectance data from Galileo's Near Infrared Mapping Spectrometer (NIMS) [8]. This instrument operated between 0.7 – 5.2 μm and produced spectral images across 17 detectors, each containing several spectral channels or bands. In total, depending on the NIMS operating mode, a spectrum can contain up to 408 bands. In addition to the diverse spectral sampling of the instrument, operational issues encountered with some of the detectors and a shift in the wavelengths reference positions over the course of the mission is present in the data.

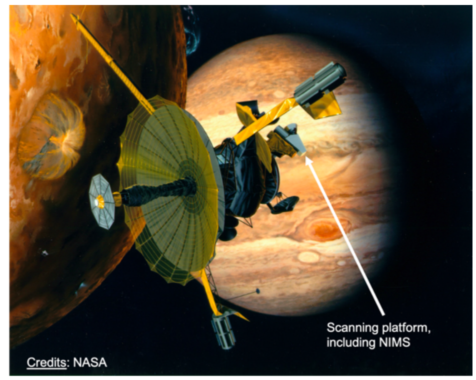

Figure 1: Artist's rendering of NASA's Galileo spacecraft

Calibrated and georeferenced data cubes (g-cubes) archived in the PDS Imaging Node have been stored in a database with relevant information such as longitude, latitude, wavelengths, reflectance value, photometric angles etc. We retrieved the reflectance and geometry information for each NIMS pixel associated with the areas shown on Fig. 2.

Phase angle coverage is very variable across the spectrum with ranges from a few degrees to 80 degrees. We will be favoring spectral intervals with a dense phase coverage.

Moreover, to accommodate the shift in the wavelengths reference over time as well as to maximize our geometric diversity, we will not be looking at specific wavelengths but at 40 nm wide ranges of wavelengths across the spectrum.

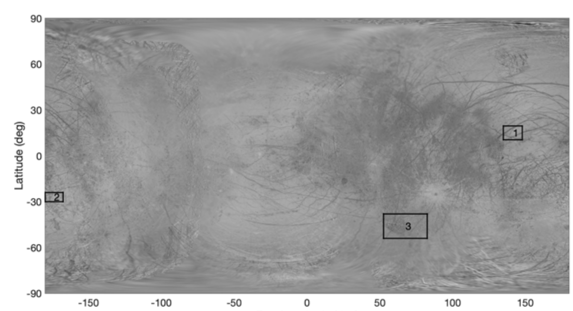

Figure 2: Map of Europa (credits: Björn Jónsson) with studied areas highlighted

Method: For each area we are considering, we estimated a set of photometric parameters for every 40 nm wavelength interval we have defined.

Direct model: For this study, we are considering Hapke's direct model detailed in [9] and [10]. Six parameters are to be estimated: b, c, ω, $\bar{\theta}$, h and B_0.

Bayesian inversion: We chose to use Bayesian approach to constrain these parameters and have a more comprehensive view of the solutions. No a priori knowledge of the parameters was inferred except for their physical domain of variation. We sampled the posterior Probability Density Functions (PDFs) with a Monte Carlo Markov Chain algorithm that we have used in previous studies [11, 12, 13].

Results: We analyzed the different parameters over our three areas of study. Results were very heterogeneous in terms of accuracy across the spectrum but photometric parameters do vary.

Figure 3 shows the variation of the single scattering albedo. It is by far the most constrained parameter across the spectrum. We can see variations that are consistent with the known spectrum of Europa in the infrared and notable absorption lines.

Figure 4 shows the example of the macroscopic roughness estimation between 700 nm and 5 μm for ROI#1 in the leading hemisphere.

Even though with naïve theoretical considerations we would expect a constant roughness - independent of wavelength - we found here that $\bar{\theta}$ seems to become more important with higher wavelengths. This could mean that the dominant scale of roughness varies with wavelength. Moreover, chemistry of the area could play a role with, for instance, the presence of certain inclusions that would influence the photometric behavior in preferred wavelengths. Some effects of spatial and / or spectral resolution may also come into play.

We also see a tendency to more forward scattering (decrease of backscattering fraction c) with wavelength.

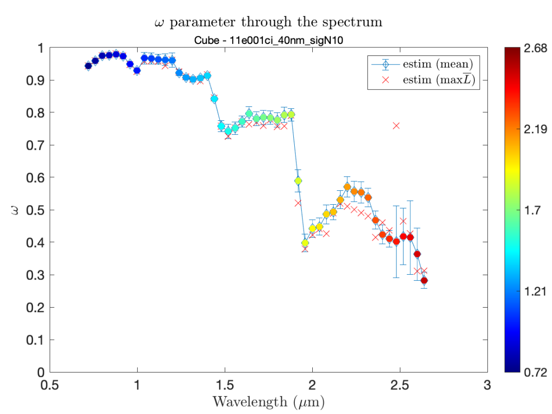

Figure 3: Spectral evolution of the singles scattering albedo for ROI#1 estimated via mean of posterior distribution (blue) and maximum likelihood (orange)

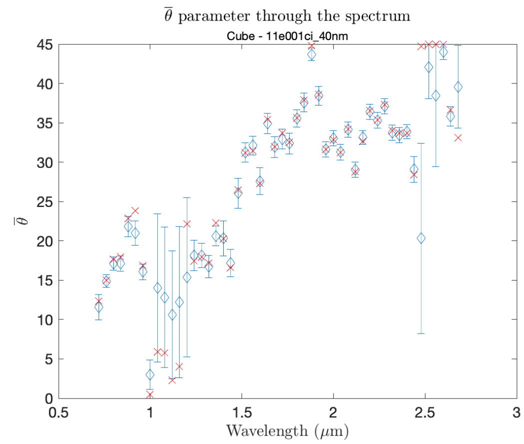

Figure 4: Spectral evolution of the macroscopic roughness for ROI#1 estimated via mean of posterior distribution (blue) and maximum likelihood (orange)

Conclusion: We are able to locally study the spectroscopic dependence of the Hapke parameters and provide precise corrections for given areas at several wavelengths. These corrections can have different applications in remote sensing data products such as spectroscopy and mapping. A complementary study has been carried out with the same dataset to constrain the chemistry of selected regions of interest and we plan to implement such photometric corrections to help better constrain the purely spectroscopic behavior of these regions [14].

We plan to extend this work to more areas where the dataset allows it and assess the wavelength dependency of other photometric models as well [e.g. 15, 16].

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