EUROPA CLIPPER PREPARATORY PHOTOMETRY TO CONSTRAIN SURFACE PROPERTIES.

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Introduction: Europa, the target for NASA's upcoming mission Europa Clipper [1], hosts a subsurface salty ocean beneath its ice layer [2]. Europa serves as one of the prime targets for investigating habitability in our solar system [3].

Photometry – the quantitative measurement of reflected and emitted radiation – provides insight into many surface properties of a planetary body, like the compaction state of the upper regolith, the roughness of the surface, the size distribution of particles, the single-particle albedo and the phase function.

We perform a photometric study of Europa [4] to understand its surface properties below the resolution limit of the scientific instruments, providing fundamental parameters for planned and future scientific investigations.

Data: We use data available from five NASA missions, Voyagers 1 and 2 ISS, Galileo SSI, Cassini ISS, and New Horizons LORRI that have examined Europa to get the largest range in viewing geometry, surface coverage, spatial resolution, spectral range, and temporal coverage.

The Galileo Solid State Imager (SSI) dataset's resolution (10s of meters) far exceeds the one from Voyager (100s of meters). We majorly use the Galileo SSI clear filter for generating a plot that depicts the variation of reflected light (I/F) at varying observation geometries. The Galileo clear filter is a broadband filter that covers the peak of solar radiation.

Method: First, we select the images from the Planetary Data System (PDS). Then we carry a radiometric calibration on them using USGS-ISIS3 software. We find that most of the Galileo images need correction for the absolute pointing position and carry that out in all the selected images.

Then we fit the scan of the image to a photometric function. In our case we fit it with the empirical Minnaert function [5], given as

$$I/F = B_0 * \mu_0^k * \mu_1^{k-1}$$

where I/F is the ratio of incident to reflected radiance, B_0 and k are empirical parameters. k is unity for a Lambertian surface and is 0.5 for low albedo surfaces. B_0 is a normalization factor. μ_0 and μ_1 are the cosines of incidence and emission angles. This function has the advantage that it is strictly empirical and offers a simple, two-parameter model for any surface element of Europa that can be used for a variety of practical purposes. These include planning observational sequences and predicting integration times, producing spectrophotometric maps and photoclinometric studies.

Results: Figure 1 (left) shows the full disk image of Europa from Galileo SSI data, over which we took the scan of data. On the right we show the fit of the photometric function to the data.

We see that parameter k that gives us information about the albedo region varies swiftly over differing phase angles for Europa (Figure 2). The variation is steep at higher phase angles which is due to the rapidly changing emission angle after a 90° phase.

Figure 2 shows the variation of the parameter k over a wide range of emission angles. We use images from all the available spacecraft data to generate this plot of variation of I/F over emission angles. We don't show the variation of the normalization factor, B_0 with phase angles here but the variation of B_0 is minimalistic in our analysis.

Future Work: We intend to look at the bright and dark albedo region variation with phase angles for future work apart from fitting the reflectance data to another photometric function that explains the scattering from Europa's surface as lunar like and lambert like.

Acknowledgments: We acknowledge the Planetary Data System, ring nodes for making the Voyagers 1 and 2, Galileo, Cassini, and New Horizons' spacecraft data available.

References: [1] Pappalardo et al., *EGU,* 95(20) (2014): 165-167 [2] Chyba et al. 1998, *Icarus* 134.2 (1998): 292-302 [3] Greenberg et al., *JGR: Planets* 105.E7 (2000): 17551-17562 [4] Buratti et al., *Icarus* 55.1 (1983):93-110 [5] Minnaert, Marcel. *ApJ* : 93 (1941): 403-410.

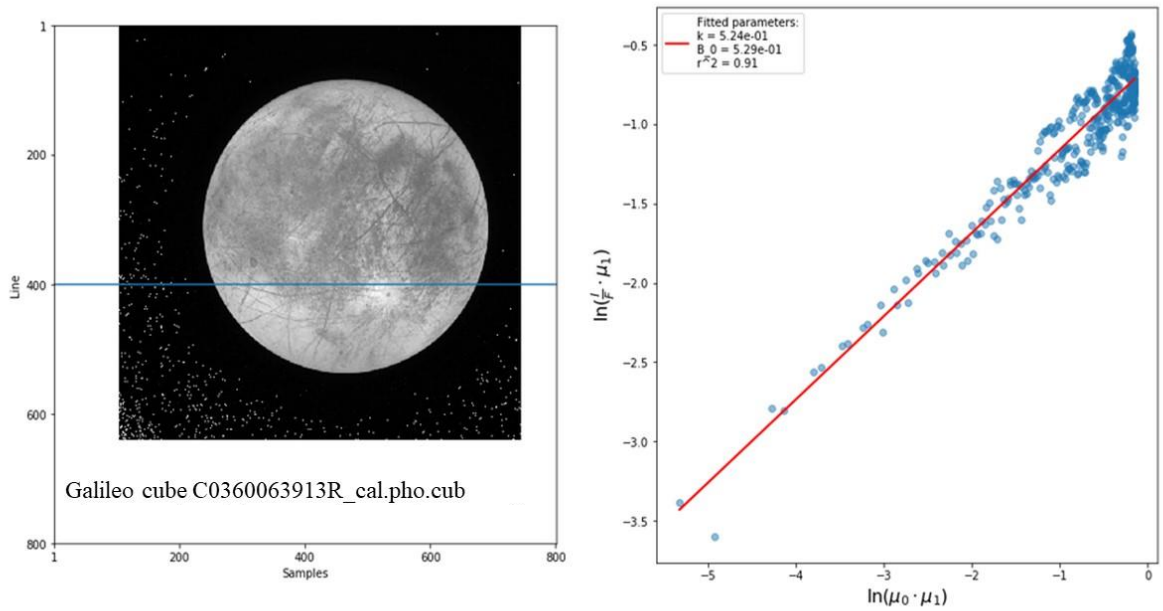

Figure 1: On left we show the full disk image of Europa with the blue line showing the scan of data we took. On right is the data plotted to the photometric function given in the text. We extract the *k* and B_0 parameters at different emission angles.

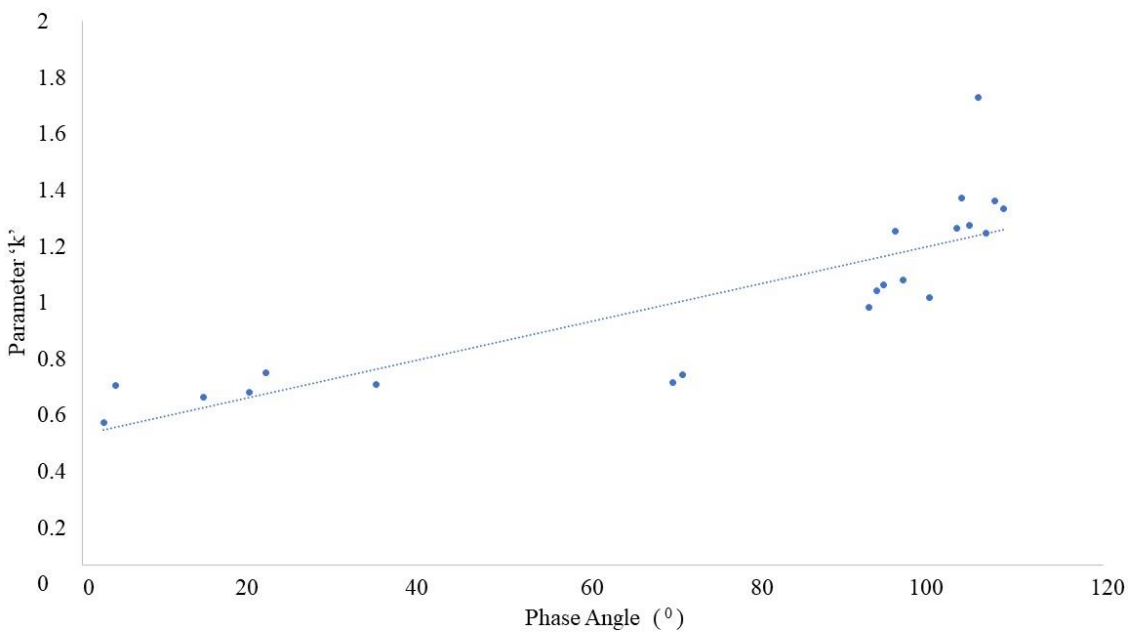

Figure 2: We show here the variation of parameter *k* with phase angle. *k* is unity for a Lambertian surface and 0.5 for a low albedo surface. *k* empirically gives us information about the albedo of the surface. The points here are the data from Voyager 1, 2, Galileo, and New Horizons mission.