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Photometric properties and variations across the surface of asteroid (21) Lutetia

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Abstract

We applied the photometric functions of Minnaert and Hapke to multiband, visible-wavelength images of asteroid Lutetia, taken by OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) onboard the European Space Agency's Rosetta spacecraft during a close flyby in July 2010 [1, 2]. The modeled photometric parameters allowed to generate albedo ratio and phase ratio maps for an assessment of the overall light scattering behavior of Lutetia's surface. We also generated color ratio maps of Lutetia to fully investigate the photometric variations across the surface. Further interpretation of photometric parameters of Lutetia is done through the comparison with the available laboratory reflectance measurements and reflectance results for other small bodies in the solar system.

1. Introduction

Studying reflectance from the surface of asteroids and other atmosphereless small bodies provides information about optical properties and other physical properties of the regolith on the surface. Resolved images of the flyby at asteroid (21) Lutetia, returned by the OSIRIS imaging system onboard Rosetta spacecraft, enable us to study its surface reflectance.

In order to understand the surface evolution of Lutetia in the context of light scattering, we modeled the photometric parameters of the surface and scrutinized the photometric variations of regolith on Lutetia.

2. Photometric modelling

We employed two photometric models, i.e. that of Minnaert and of Hapke to model the disk-integrated and disk-resolved data of Lutetia in several filters. In order to extract the disk-resolved brightness, we developed a tool for extracting average intensity associated with geometric viewing angles per facet. The facet is the smallest element on the triangular shape model of Lutetia used in this analysis [3].

The two well-constrained multi-wavelength Hapke parameters of Lutetia are the single scattering albedo (SSA) and the roughness parameter. We calculate the spectral slope of the modeled SSA spectrum is estimated to be (1.65±0.29) % per 100 nm. We found that the best-fit value of roughness parameter of Lutetia ($\theta = 28^{\circ}$) does not vary significantly with the wavelength. The best-fit values of Hapke parameters at 649.2 nm of Lutetia (SSA= 0.226±0.002, B_0=1.79±0.08, h=0.041±0.003, g=-0.28±0.01, θ=28°±1°) are similar to those of average S-type asteroids, particularly the single scattering albedo and the asymmetry factor g.

The modeled Minnaert k parameter of Lutetia at opposition (k_0=0.526±0.002) indicates a flat distribution in the surface brightness without significant limb darkening. No wavelength dependence is found for the Minnaert k value of Lutetia.

3. Comparison with laboratory reflectance measurement

In order to interpret the modeled Hapke parameters, we compare the disk-resolved data of Lutetia extracted from OSIRIS images at λ= 649.2 nm with the reflectance measurements from available terrestrial and extraterrestrial samples in the literature and found best-matches samples by Chromium oxide in the packed state [4] and an Allende meteorite sample [5].

We infer that the close similarity of these samples with the reflectance data of Lutetia is related to the consistency of the material, either by optical or structural properties or both.

4. Photometric variations

We generated albedo ratio maps (Figure 1) and phase ratio maps of Lutetia, using determined Minnaert parameters of the asteroid. The albedo variation on Lutetia is subtle (less than 10%) based on the albedo ratio maps of NAC F82 & F22 filter (649.2 nm) images at small phase angles ($\alpha < 30^\circ$). However, from the albedo ratio maps produced at large phase angle, a larger variation is noted for the so called NPCC region on Lutetia. The phase ratio maps of the asteroid do not display variation over the surface which may be caused by phase function or/and the photometric roughness alteration. This is confirmed by corresponding simulated phase ratio maps.

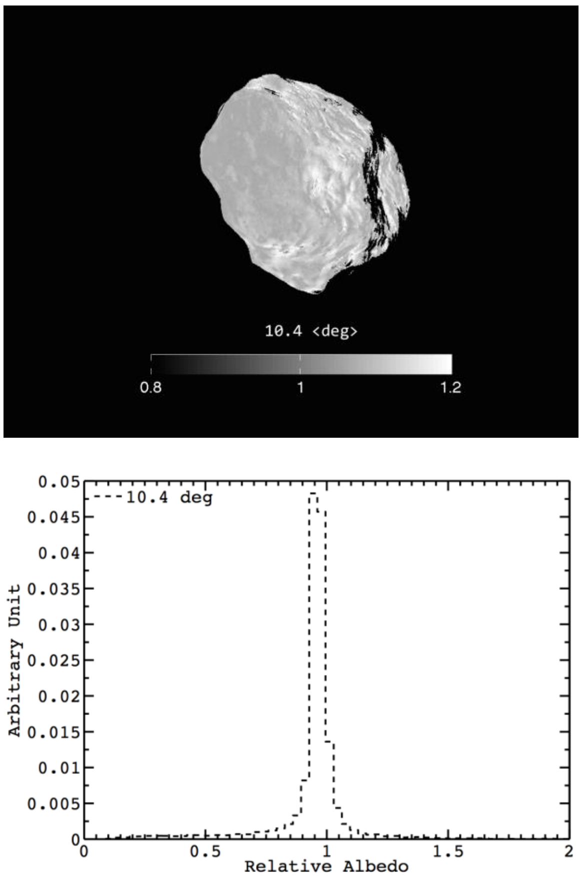

Figure 1: Upper panel displays the albedo ratio map of Lutetia from the NAC F82 image (λ =649.2 nm) at phase angle of 10.4°. Lower panel shows the corresponding weighted histogram of the albedo variations on Lutetia at α=10.4°.

Since the spectrum of Lutetia is featureless, we studied the variation of the spectral slope of Lutetia's spectrum across the surface. Color ratio map of the asteroid was produced using shape model registered images at 931.9-nm and 269.3-nm. The corresponding histogram of the color ratio map shows a symmetrical shape, indicating a rather uniform color variation across the surface. The FWHM of the distribution is 10%. In fact, on a large scale no obvious correlations between the color variations and the geological terrain on Lutetia were found. We note that on a smaller scale color variations are seen, for instance at the landslide location.

6. Summary and Conclusions

The uniform albedo and color contrast of Lutetia suggests two explanations; (a) the subsurface materials of Lutetia are similar to the regolith on surface at least for the reflectance of light, (b) the effect of space weathering is low for Lutetia and the surface is not altered displaying significant and large scale variations in its optical properties.

References

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