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Shape/size/spin of Lutetia from ground-based observations

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Abstract

The ESA/NASA mission Rosetta will encounter main belt asteroid (21) Lutetia on 2010 July 10. Prior to this encounter, we had imaged Lutetia with large ground-based telescopes equipped with adaptive optics (AO). Using our KOALA algorithm [2, 6], we combined more than 300 images of Lutetia, together with 50 optical lightcurves, to derive Lutetia's physical properties. We released a shape model constraining Lutetia's volume and orientation to help mission planners prepare for the flyby [3, 4]. We will discuss our results compared with the high spatial-resolution images acquired by Rosetta.

1. Introduction

Knowing the spin state, size, and approximate shape of an asteroid months before its flyby is fundamental for mission teams: from the estimated size, a rough mass can be estimated and used for flight dynamics, and the sequence of observations depends highly on the spin state and shape of the asteroid (observable regions).

Reciprocally, *in situ* measurements can be used to test ground-based observations and methods. For instance, the spin and overall shape derived by lightcurve inversion techniques for (951) Gaspra were consistent with the gross size and shape properties observed during the Galileo-mission flyby [7], although details of the local topography were not (and were not expected to be) correct in detail.

2. Observations

We acquired images of the apparent disk of Lutetia over 5 epochs in 2008-09 using the NIRC2 camera at the Keck II telescope. We also acquired images at the ESO VLT with NACO in June 2007. In total, we used more than 300 images to measure the apparent size and shape of Lutetia. We show some examples of these images in Fig. 1.

We also used the 32 optical lightcurves gathered by Torppa et al. [8], plus 18 additional observations acquired mainly from the Pic-du-Midi 1-m telescope and from amateurs (listed in the acknowledgments and thanks to them).

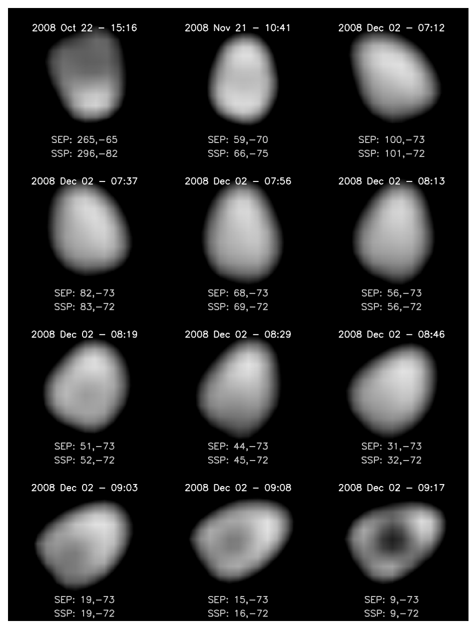

Figure 1: K-band images of Lutetia acquired with Keck II during 2008. For each frame we report the observing date and Sub-Earth Point (SEP) and Sub-Solar Point (SSP) coordinates (longitude λ, latitude β). Variations in the surface brightness in these images is not real, but are consequences of the deconvolution process.

3. KOALA

We derived the physical properties of (21) Lutetia using our **K**nitted **O**ccultation, **A**daptive optics, and **L**ightcurve **A**nalysis algorithm [KOALA: 2, 6]. This algorithm derives the spin properties and shape (including the size) of an asteroid by a combined inversion of three data modes: chords from stellar occultations[1], contours from disk-resolved images and photometry from optical lightcurves.

4. Spin and Shape

The shape of asteroid (21) Lutetia is well described by a wedge of Camembert cheese as is visible in Fig. 2. The shape model we derived suggests the presence of several large concavities on the surface of Lutetia, presumably resulting from large cratering events.

The spin coordinates lie within 5° of ($\lambda = 52^{\circ}$, $\beta = -6^{\circ}$) in ECJ2000. This implies a high obliquity of 95°, Lutetia being tilted with respect to its orbital plane, similar to Uranus. At the time of Rosetta flyby, Lutetia's northern hemisphere will be in constant sunlight (summer), while regions below -35° latitude will be in constant shadow (winter). Therefore, extreme southern latitudes of Lutetia will not be observable from Rosetta in optical wavelengths, preventing precise shape reconstruction and size determination.

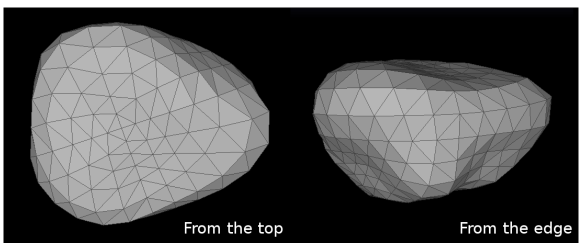

Figure 2: Two views of our shape model of Lutetia.

5. Size and Density

We find Lutetia's dimensions to be $124 \pm 5 \times 101 \pm 4 \times 93 \pm 13$ km, the large uncertainty on the smallest axis being due to the unfavorable geometry of AO observations (far from Lutetia's equator). Coupled with two recent mass estimates [1, 5], this leads to a density ranging from 3 to 5 g/cc, with an uncertainty of about 1 g/cc. Such a large uncertainty range is due to the lack of precision on the dimension of the short axis, and on the mass estimates (which differ by 25%).

Unfortunately, the solar illumination during the Rosetta flyby will have the southern hemisphere in constant darkness, hindering the size estimation from Rosetta. The next opportunity to observe Lutetia's shortest dimension, impacting its volume determination, will occur in 2011 July, one year after the Rosetta flyby (SEP_{β} of +31°). During this time, observations using large telescopes equipped with adaptive-optics will allow refinement of Lutetia's short dimension and thus improve the volume determination. This ground-based support will be essential to take advantage of the high-precision mass determination resulting from the spacecraft deflection.

[1] unavailable in the case of Lutetia

6. Summary

We determined the spin, size, and shape of (21) Lutetia from ground-based imaging and photometric observations. We predicted the geometry of the flyby and found that Lutetia's southern hemisphere will remain unobserved from Rosetta at optical wavelengths, hindering the size (hence volume) determination. The Rosetta flyby of (21) Lutetia provides a unique opportunity to test our KOALA algorithm, a powerful new tool in the field of remote sensing.

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