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Asteroid 21 Lutetia at 3 μm: Observations with IRTF SpeX

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Abstract

We present observations of asteroid 21 Lutetia collected 2003-2008 using the SpeX instrument on the NASA Infrared Telescope Facility (IRTF) covering 2-4 μm. We also reevaluate NSFCam observations obtained in 1996 [1]. Taken together, these show deeper 3-μm band depths (~3-5%) in the southern hemisphere of Lutetia, and shallower band depths (≤ 2%) in the north. Such variation is consistent with observations at shorter wavelength by previous workers [2,3], who observed hemispheric-level variations from C-like spectra to X-like spectra. It is also consistent with Rosetta's reported non-detection of an OH band in Lutetia's northern hemisphere [4]. While the shallowness of absorption bands on Lutetia hinders identification of its surface composition, goethite appears plausible as a constituent in its southern hemisphere [5].

1. Background

It has been difficult to reach a consensus on the composition of the asteroid 21 Lutetia. It was one of the original members of the M asteroid class, and thought likely to be either akin to iron meteorites or enstatite chondrites [6]. However, decades of more in-depth observations have interpretations that are difficult to reconcile with those analogs (particularly iron meteorites).

For instance, Lutetia's radar albedo is similar to that of the C and S asteroids rather than what is expected of a metal-rich surface [7]. Polarimetry of Lutetia also shows a surface unlike high-metal asteroids like 16 Psyche [8]. An extension of the Tholen taxonomy to 2.5 μm by Howell et al. [9] found Lutetia grouped with the C asteroids, with only its high albedo precluding a reassignment. Most pertinent to this presentation, observations in the 3-μm region in 1996 found Lutetia to have an absorption interpreted as due to hydrated minerals [1], though this has not been confirmed [10,11]. Visible-near IR (0.5-2.5 μm) spectral slope differences have been seen on Lutetia and attributed to compositional variation on its surface [2,3].

Interest in Lutetia increased when it was announced as a flyby target for the Rosetta spacecraft, and Belskaya et al. [12] compiled the current state of knowledge about Lutetia before Rosetta's July 2010 flyby. Here we present additional 3-μm spectra using SpeX on the NASA Infrared Telescope Facility (IRTF) and another look at the 1996 observations.

2. Observations and Results

Table 1 shows the UT dates, and sub-solar and sub-Earth coordinates on Lutetia for the midtimes of the IRTF observations. The 1996 observations used NSFCam, as described in [1]. The new observations used SpeX in long wavelength cross-dispersed (LXD) mode, covering the 2-4 μm region. The data were reduced using Spextool and additional IDL routines, as in previous recent work [13].

UT Date	SE Lon	SE Lat	SS Lon	SS Lat	Note
9/29/96	227.6	+3.3	223.4	-17.8	NSFCam
9/30/96	316.0	+3.3	311.8	-18.1	NSFCam
3/2/03	124.9	+85.5	160.5	+65.9	Spex
3/31/07	358.5	+67.3	71.5	+85.2	Spex
12/23/08	~117	-77.6	~105	-67.3	Spex
7/10/10	---	---	---	+46.6	Rosetta

Table 1: Observational circumstances for IRTF Lutetia spectra and the Rosetta encounter.

The three Spex spectra and the 1996 NSFCam data are shown in Figure 1, thermally corrected and offset from one another. The NSFCam data were shown as an average when previously published [1]. Band depths in the 3-μm region vary from nearly 10% for 29 September 1996 (measured from an extrapolated continuum) to 1-2% (perhaps consistent with zero) for 2003 and 2007.

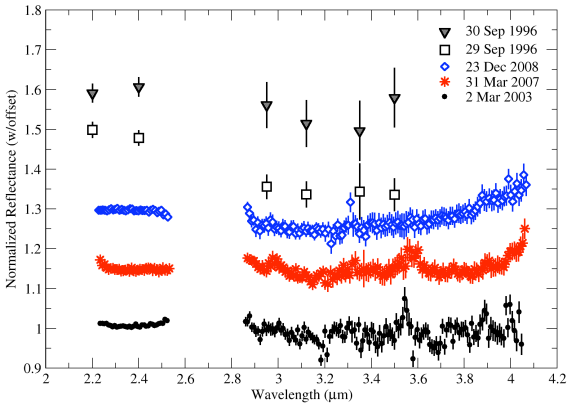

Figure 1: Lutetia's spectral shape in the 2-4 μm region is qualitatively similar in the 5 spectra shown here. The apparent band depth varies from ~15% on 29 September 1996 to < 2% in 2007. The high-frequency structure present in the 2003 and 2007 data is due to unremoved artifacts, and we interpret the overall band shape to be like the 2008 spectrum.

4. Discussion

Figure 2, adapted from Carry et al. [14], shows the fraction of Lutetia's surface visble from Rosetta, with the sub-solar positions of the IRTF observations included. Interestingly, none of the three observations showing deeper 3-μm bands were visible from the high northern latitudes observed during the Rosetta flyby. Both SpeX and NSFCam data from the southern hemisphere show evidence of a 3-μm band, and the data are consistent with compositional variation on Lutetia's surface. The observations of Birlan et al. [10,11] were also centered at high northern latitudes, consistent with their interpretations of little or no absorption in the 3 μm region.

The band shapes seen in the southern hemisphere are not typical of the 3-μm bands seen in C-class asteroids or carbonaceous chondrites: they do not have the triangular or "checkmark" shape seen in objects like Pallas (interpreted as CM-like phyllosilicates) [15], nor the well-defined minima seen in Ceres or Themis interpreted as brucite and ice, respectively [16,17]. Instead, the spectrum appears to step down into the 3-μm band, which is shallow but broad and has no identifiable substructure. Simple mixing models suggest space-weathered goethite can qualitatively match Lutetia's spectrum, but detailed models and consideration of the plausibility of space-weathered goethite are only beginning.

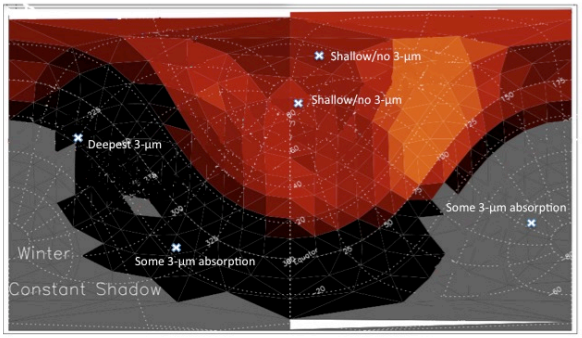

Figure 2: Adapted from Carry et al. (2010), this figure shows the portion of Lutetia visible from the Rosetta spacecraft (shades of red) and the sub-solar positions during the IRTF observations. The three observations with the deepest 3-μm bands largely cover areas unobservable by Rosetta.

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