21 LUTETIA AS A POSSIBLE BINARY SYSTEM. V. V. Busarev[1], V. V. Prokof'eva[2] and V. V. Bochkov[2], [1]Sternberg Astronomical Institute (SAI), Moscow University, Universitetskij pr., 13, Moscow, 119992 Russia, busarev@sai.msu.ru, [2]Research Institute Crimean Astrophysical Observatory, p/o Nauchnyi, Crimea, 334413 Ukraine, prok@crao.crimea.ua.

Abstract: We have analyzed spectra (0.4-0.9 μm) of 21 Lutetia, a target of the ROSETTA space mission, and discovered periodic splitting of them on three nights (4/5, 5/6 and 7/8) in November 2004, at extremely small aspect angle (~43°). It was confirmed by us on 3/4 March 2006. We suggested that Lutetia is a binary asteroid. The colorimetric and frequency analysis of Lutetia's spectrophotometric data (of August-November 2000) [1] and *BVR*-data (of November 2004) [2] led us to conclusions that Lutetia's system consists of a pair of similar in size bodies (40-50 km) at a distance of ~1000-km orbiting around a common center of masses. Furthermore, the components probably are in rotation with periods of ~3-4 hours.

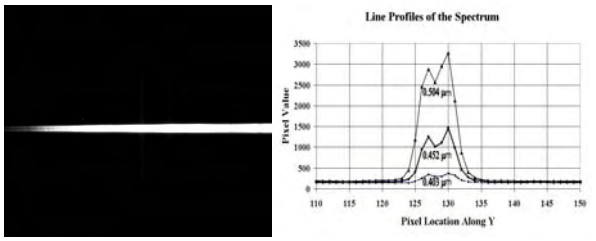
Reflectance spectra of Lutetia's components showed considerable changes in their shapes corresponding to C-S-type bodies at different moments. It does not agree with classification of Lutetia as a classical M-type asteroid.

Spectral Data: Spectral observations of 21 Lutetia were performed by Busarev on 31 August 2000 and 4-8 November 2004 with a spectrograph and ST-6 SBIG CCD mounted on the 1.25-m telescope of the SAI Crimean observatory. The data were reduced in a standard way. "Blue-visible" (0.40-0.71 μm) and "visible-red" (0.63-0.90 μm) parts of the spectra were observed separately at no more than a ten-minute interval. Relative statistical errors of the spectra do not exceed 1-2% within the 0.45-0.80 μm wavelength range and grow up to 8% and 3% at "blue" and "red" ends. A solar analog star, 16 Cyg B [3], was also observed for calculation of the approximate asteroid reflectance spectra. The initial reflectance spectra with the spectral dispersion of about 8 Å/pix were smoothed with a 5-point running box average and normalized to unity at 0.55 μm. The spectra obtained on 5/6 and 7/8 November at favorably small aspect (~43°) and phase (~3°) angles of the asteroid are shown in Figs. 1-5.

The observations of Lutetia on 4-8 November 2004 became a sensation. It was discovered a subtle splitting of the asteroid spectra into two at about 1-2-hour interval. The effect was registered on three nights in November 2004 (4/5, 5/6 and 7/8) and confirmed on 4/5 March 2006 at a considerably bigger aspect angle (~83°) and at a longer interval of time. This means that images of two objects instead of one were observed at the moments on the spectrograph slit. We suppose that no other instrumental, atmospheric or celestial factors could cause the effect. We have made the assumption that the asteroid is a binary system probably consisting of about similar in size components (40-50 km).

Examples of the most clear splitting of Lutetia's spectra on 5/6 and 7/8 November 2004 in the 0.40-0.71 μm region and the line profiles of the spectra at several wavelengths are shown in Fig. 1 (a, b).

(a)



(b)

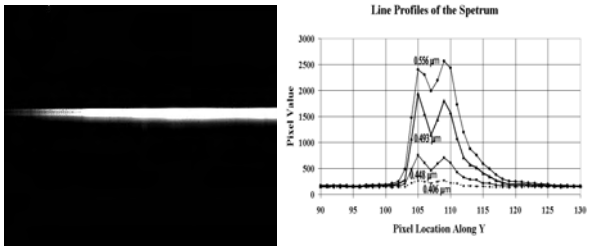


Fig. 1 (a, b). Examples of splitting of Lutetia's spectra obtained on 5/6 November 2004 and 7/8 November 2004: (a) the blue-visible spectrum of Lutetia obtained on 5/6 November 2004 (01:05:33 UT) and its line profiles along Y axis at 0.403, 0.452 and 0.504 μm; (b) the blue-visible spectrum of Lutetia obtained on 7/8 November 2004 (22:40:36 UT) and its line profiles along Y axis at 0.406, 0.448, 0.493 and 0.556 μm.

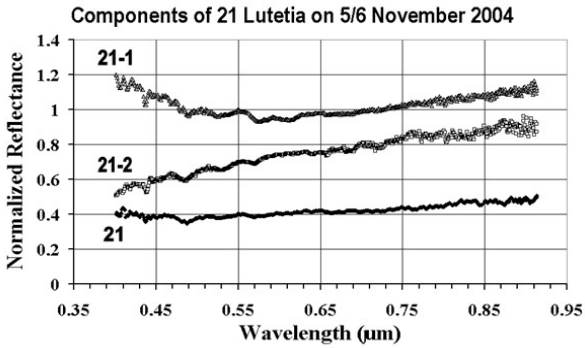


Fig. 2. Reflectance spectra of two components of 21 Lutetia (21-1 – a brighter (bigger?) one; 21-2 – a fainter (smaller?) one) on 5/6 November 2004. The spectra are normalized to unity at 0.55 μm and shifted on the vertical axis for clarity. Curve 21 is an integral reflectance spectrum of Lutetia when the splitting was not observed.

From seeing conditions on the nights (~2-3 arc seconds and, hence, the same cross-width of a single spectrum) we estimated splitting of Lutetia's spectra as ~1". From the line profiles (Fig. 1), a level of the splitting is relatively far from the background and may correspond to about two times

lesser arc distance between the asteroid components than the width of a single spectrum.

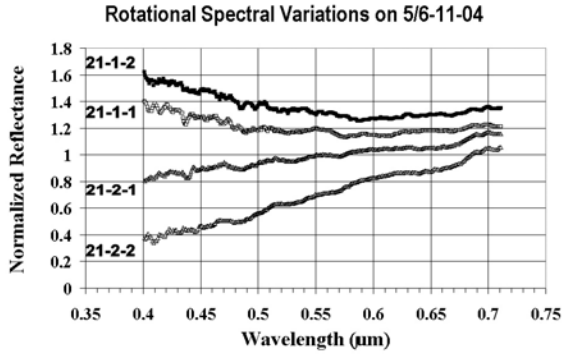


Fig. 3. Consecutive normalized reflectance spectra of two components of 21 Lutetia in the blue-visible region obtained at about 10-minute intervals on 5/6 November 2004: 21-1-1 and 21-1-2 – a brighter (bigger?) one; 21-2-1 and 21-2-2 – a fainter (smaller?) one.

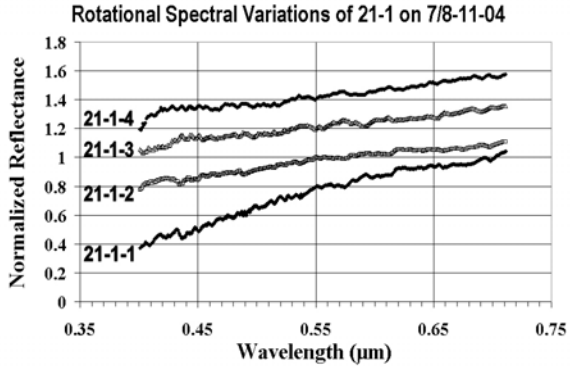


Fig. 4. Consecutive normalized reflectance spectra of a brighter (bigger?) component of 21 Lutetia in the blue-visible region obtained at about 10-minute intervals on 7/8 November 2004.

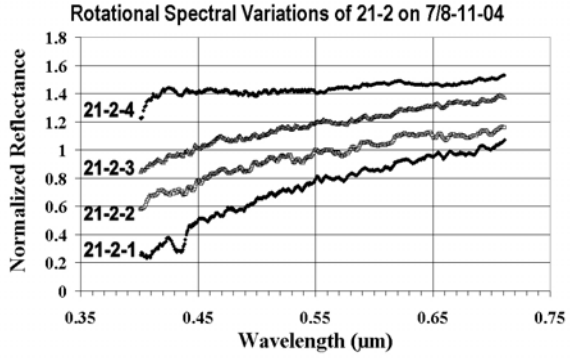


Fig. 5. Consecutive normalized reflectance spectra of a fainter (smaller?) component of 21 Lutetia in the blue-visible region obtained at about 10-minute intervals on 7/8 November 2004.

We have preliminary designated a slightly brighter (and possibly bigger) component as 21-1 and a fainter (and possibly smaller) one as 21-2. From the forked spectra of Lutetia we extracted spectra of both components and calculated the reflectance spectra presented in Figs 2-5. As seen from the figs, shape of the reflectance spectra is changing quickly with time (and, then, with rotation of the components) and is similar to that of C- or S-type bodies at different moments of the observations. Interestingly, when the spectral splitting was not observed, Lutetia's integral spectral reflectance was similar to spectrum of an M-asteroid (curve 21, Fig. 2).

Interpretation of observational results: Binarity of 21 Lutetia was first suggested on the basis of the frequency analysis of its *BVR*-data of November 2004 [2]. According to the analysis, the most pronounced periods of variations in the *V*-, *B*-*V*- and *V*-*R*-values are $0.^{d}70$ (16.8^{h}) and $3^{d}.20$. We came to conclusion that a previously known period of $0.^{d}3405$ ($8.^{h}172$) [4] was probably taken mistakenly for a rotational period of Lutetia, since it is not confirmed by convolutions of our *B*–*V* and *V*–*R* color data of the asteroid. A periodic 1-2-hour splitting of Lutetia's reflectance spectrum could be explained as a result of synchronous rotation of irregular in shape asteroid components with a period of 3-4 hours. This may happen when the line connecting centers of the bodies is perpendicular to the line of sight. Probably, the interpretation is confirmed by found $0.^{d}1238$ ($2.^{h}97$) period of oscillations in the synthetic color indexes $\Delta m_{1\text{-}2}$ and $\Delta m_{1\text{-}3}$ (obtained from the selected synthetic bands 0.40-42 μm (1), 0.50-51 μm (2) and 0.58-0.62 μm (3) in spectrophotometric data [1]) characterizing changes in the asteroid reflectance spectrum and by a close $0.^{d}1223$ ($2.^{h}94$) period in the *B*-*V* color indexes [2]. The discovered ~1" splitting of the asteroid spectra may correspond to ~1000-km distance between its components (at semi-major axis a= 2,4369 AU of Lutetia's orbit). However, we understand that the estimated distance was restricted by our seeing conditions.

Shape of Lutetia's component reflectance spectra at the smallest aspect angle (~43°) changed quickly with rotation of the bodies and was similar to that of C or S type asteroids at different moments (Figs. 2-5). At the same time, Lutetia's integral reflectance spectrum was similar to that of an M-asteroid. This contradicts classification of Lutetia as a classical M-type asteroid. The components may be conglomerates of materials with very different content (hydrated silicates, igneous silicates and/or metals). Probably, it is confirmed by identification of a 3-μm absorption band of bound water [5] and a 0.44-μm absorption band of serpentines [6, 7] in Lutetia's reflectance spectra.

References: [1] Bochkov V.V., et al. (2003) *Astron.& Astrophys. Trans.*, *22*, 621–624. [2] Prokof'eva V. V., et al. (2006) *Sol. Sys. Res.*, *40*, 468-476. [3] Hardorp J. (1980) *A&A*, *91*, 221-232. [4] Michalowski T. (1996) *Icarus*, *123*, 456–462. [5] Rivkin A. S., et al. (1995) *Icarus*, *117*, 90-100. [6] Busarev V. V., et al. (2004) *Vernadsky Inst.- Brown Univ. Microsimp. 40th*, Abstract #15. [7] Busarev V. V., et al. (2004), in *The new ROSETTA targets* /L. Colangeli, et al., eds., Kluwer Acad. Publishers, 79-83.