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Visible spectral properties of asteroid 21 Lutetia, target of Rosetta Mission★

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Abstract. Rosetta spacecraft was successfully launched on March 2nd 2004 after its launch postponement in January 2003. Owing to this delay all the original targets, comet and asteroids, have been changed. In particular, on its 10 years journey to the new comet 67P/Churyumov-Gerasimenko, the spacecraft will pass close to the asteroid 21 Lutetia. In this paper we present three visible spectra of 21 Lutetia covering its rotational period. We have not found big surface composition variations and the overall behavior resembles that of a C-type asteroid. However, we discovered two main features which are present on the three spectra at around 0.43 and 0.51 μm probably due to aqueous alteration and porphyrins respectively.

Key words. visible spectroscopy – Rosetta target

1. Introduction

The International Rosetta Mission was approved in November 1993 by ESA as the Planetary Cornerstone Mission in ESA's long-term space science programme "Horizon 2000". Mission Rosetta is devoted to the investigation of the physical and chemical processes which characterised the origin and evolution of the Solar System. Comets and in part also asteroids are the most uncontaminated witnesses of these processes being the most unaltered objects of the Solar System since their formation. The study of the primordial material constituting comets and asteroids is considered of fundamental importance for the comprehension of the origin of our planetary system.

Rosetta has been launched on March 2004, with the final destination of the comet 67P/Churyumov-Gerasimenko which will be reached in 2014. In the course of its 10 year journey to the comet, the spacecraft will pass close also to two asteroids: 21 Lutetia and 2867 Steins. These two targets have fairly different properties. Steins is relatively small, with a diameter of a few kilometres, and will be visited by Rosetta on 5 September 2008 at a distance of about 1700 km. This encounter will take place at a relatively low speed of about 9 km per second. Lutetia is a much bigger object, nearly 100 km in diameter. Rosetta will pass within about 3000 km on 10 July 2010 at a speed of 15 km per second. This will be during Rosetta's second passage through the asteroid belt. The fly-by with the asteroids will provide a global characterisation of the objects, including determination of dynamic properties, surface morphology and composition. However, most of properties of the asteroid targets are still poorly known, so ground-based investigations of these bodies are of fundamental importance to obtain information useful to establish the observational strategies of the spacecraft.

In this paper we will present a spectroscopic investigation in the visible performed with the ESO-NTT of Lutetia. Asteroid Lutetia was discovered on 15 November 1852 by H. Goldsmith. It is 95.5 ± 4.1 km in diameter, as determined by IRAS measurements with an albedo of 0.221 ± 0.020 (Tedesco & Veeder 1992) and a synodic period of 8.17 ± 0.01 h (Zappalà et al. 1984). The taxonomic classification of Lutetia is not yet completely defined: from ECAS data (Zellner et al. 1985) it would belong to the X-complex, it would be an M-type from ECAS and IRAS thermal albedo data analysis (Barucci et al. 1987; Tholen & Barucci 1989) and a Xk-type on the basis of SMASSII spectroscopic data (Bus & Binzel 2002). Finally, Birlan et al. (2004) recently obtained an almost flat, featureless, near infrared spectrum of Lutetia, compatible with a primitive composition, which is also in agreement with a low albedo of 0.09 obtained by Zellner et al. (1977). No absorption features have ever been found on the spectra of Lutetia in these previous works. We present here three spectra of Lutetia covering the entire rotational period of the object in order to determine possible surface composition variations. From our spectra we suggest a primitive composition, typical of C-type asteroids, and we discuss the presence of some absorption features.

2. Observations, data reduction and discussion

We obtained three visible spectra of Lutetia in the range 0.38−0.95 μm on 6th May 2003, with the ESO–NTT at La Silla, Chile. The NTT was equipped with EMMI (ESO Multi-Mode Instrument), used in the low resolution mode with

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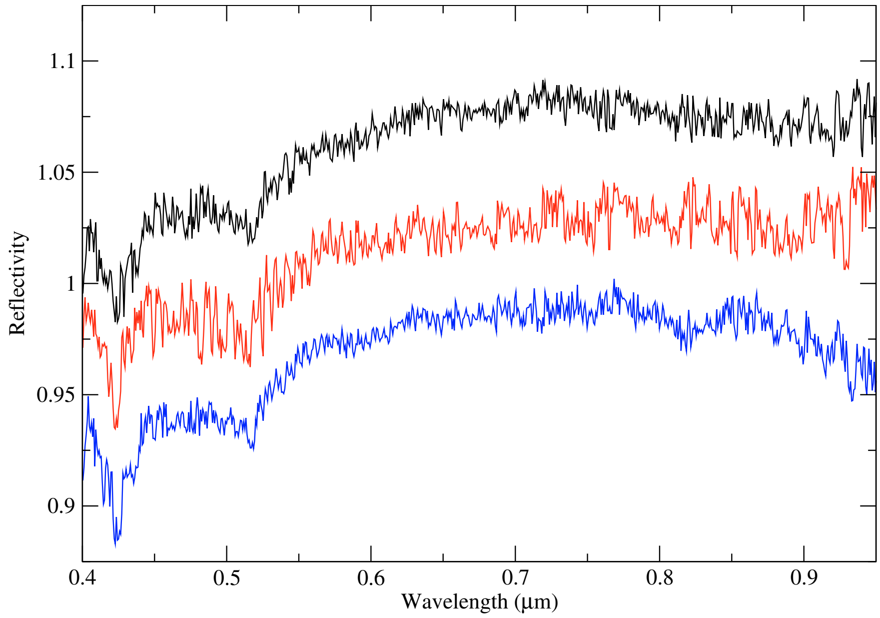

Fig. 1. Spectra of Lutetia taken at intervals of about 2.5 h. They cover the entire rotational period and are offset along the vertical axis for clarity.

the Grism #1 and a slit width of 5″ (the resolving power was about 250), chosen to minimise the differential refraction due to the atmosphere. Notice that for EMMI the contamination of the second order in the red part of the spectrum is of some percents at most. Since this produce an error which is of the same order of magnitude of other sources of errors (e.g. airmass correction), we did not use any order sorting filter. The slit was oriented along the direction of the motion in the sky of the object. Lutetia has been observed during an observational program of near-Earth objects, so for a detailed description of the data reduction we refer to Lazzarin et al. (2004).

Particular care has been paid to the correction for atmospheric extinction, recording spectra of different solar analogs at different airmasses during the night. The solar analogs showed negligible differences: the ratio between the solar analogs' spectra shows a maximum deviation of 5% around 1. The reflectivity has been obtained by dividing the asteroid spectrum by the solar analog's one.

The three spectra of Lutetia have been recorded at intervals of about 2.5 h from each other (every 1/3 of the rotational period), covering the entire rotational period of the object, in order to detect possible surface composition variations. More precisely the UT of observations of the three spectra were: 01:53, 04:48, and 07:29. The airmasses were 1.29, 1.05, and 1.42, respectively. The three spectra, offset for clarity along the vertical axis, are shown in Fig. 1.

On the basis of the ephemeris and pole orientation, the asteroid was observed close to the pole, so the three spectra approximately correspond to the same region of Lutetia. The estimated variation of surface from one spectrum to another is about 15%. The similarity of the overall behaviour of the three spectra is consistent with this observational condition. Moreover, they are compatible with the spectral properties of the average C-type asteroids of Bus Taxonomy (Bus 1999).

This is in contrast with previous works. The photometric observations of Zellner et al. (1985), Barucci et al. (1987), Tholen (1989) are consistent with a X or M-type. More recent spectroscopic observation performed by Bus (1999) indicate an Xk-like composition. Finally, Carvano et al. (2003) obtained a spectrum of Lutetia which is still reddish but not as much as that of previous works. An explanation could be that different surface regions have been observed. For example, Bus observed Lutetia on November 29th 1996 when the direction of the pole axis made an angle of 76 degree with the direction observer-target, namely near the equatorial regions. Carvano et al. (2003) observed Lutetia on June 14th 1999, with an angle of 37 degree, so closer to the pole than Bus (1999).

During our observations this angle was about 17 degree, so our data cover the polar region. Since Lutetia has a diameter of about 100 km, its surface could present some dishomogeneities which could explain the observed discrepancies. However, we would like to point out that there are several different pole solutions in the literature (e.g. Magri et al. 1999, and references therein). We adopted for our discussion the most recent one: $\lambda = 228°$, $\beta = 13°$ (Magri et al. 1999).

Our results are compatible with the findings of Birlan et al. (2004), as shown in Fig. 2. Their data, acquired at an angle from the pole of about 16 degrees, refer to almost the same region we observed. They do not try a classification of Lutetia, but they find a good match between their infrared spectrum and that of the Vigarano meteorite, a CV3 carbonaceous chondrite. This would indicate a primitive composition similar to that of C-type asteroids, but it must be noticed that a flat spectrum, as that one of Birlan et al. (2004), can be connected to different taxonomic types of spectra.

Moreover our spectra show a significant difference with the previous ones owing also to the discovery of some absorption features that could confirm a primitive composition of Lutetia. From Fig. 1 the three spectra clearly show two main

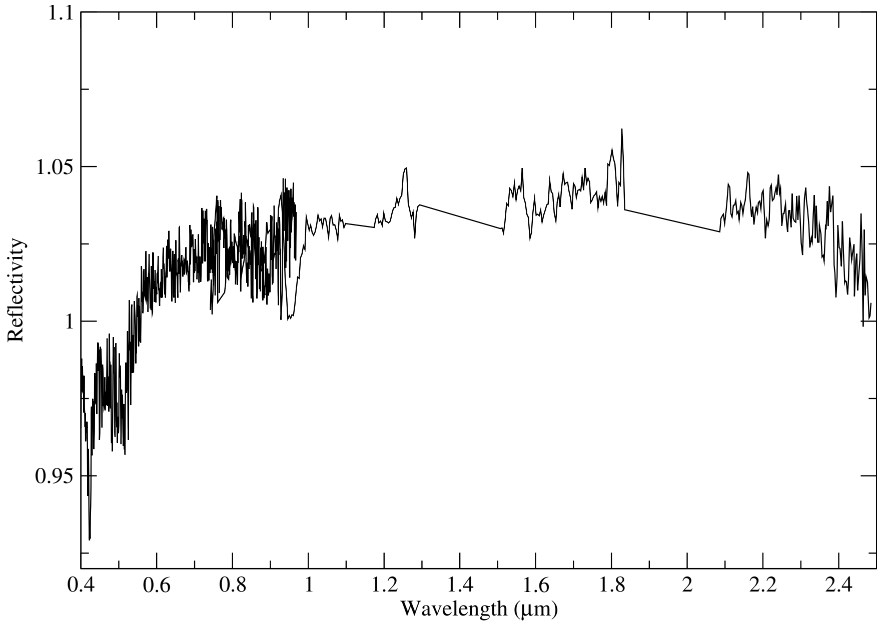

Fig. 2. Average visible spectrum of Lutetia from this work, connected to the NIR spectrum of Birlan et al. (2004). The connection has been possible since the two spectra present an overlapping region.

absorption bands around 0.43 μm and 0.51 μm. We are convinced that these features are real, because they cannot be due for example to bad removal of telluric absorptions, as no telluric absorptions are present at those wavelengths. We exclude also instrumental effects, because the features only appear in the spectra of Lutetia but not in those of the other objects observed during the same night. Moreover, the features are present in all the three spectra and they are irrespective of the particular solar analog chosen for the reduction.

The spectrum on the bottom of Fig. 1 shows two other fainter absorption features: one around 0.6 μm and one between 0.80−0.85 μm. However, they are close to the S/N level and further investigation would be needed for a sure confirmation. We stress that all these features are not present in the spectrum of Bus (1999). The one at 0.51 μm could be present in the spectrum of Carvano et al. (2003), but it has a poor S/N ratio (it also starts at 0.5 μm), so our detection remain the first sure identification of this band.

The 0.43 μm band is the most widely known as due to a ferric iron spin-forbidden absorption present in minerals, such as phyllosilicates (in particular jarosite), which are the result of aqueous alteration activity (Vilas et al. 1993). This process seems to dominate the mid and outer belt, that is the region between 2.6 and 3.5 AU defined by Vilas et al. (1994) as aqueous alteration zone, populated essentially by C-type asteroids (and asteroids belonging to the subclasses B, F and G). They are low-albedo (p_V of about 0.05) asteroids, considered to be primitive. The aqueous alteration is also responsible of several other bands in the visible region (at 0.60−0.65 μm, 0.70 μm and 0.80−0.90 μm), attributed to charge transfer transitions in oxidised iron (Vilas et al. 1993, 1994; Vilas 1994; Barucci et al. 1998). From Fig. 1 the 0.43 μm band is clearly evident on the three spectra, while an absorption band around 0.6 μm and another one between 0.80 and 0.85 μm are present only on the spectrum on the bottom of the figure.

Another absorption band is evident on the three spectra, centered around 0.51 μm. A similar feature has been detected on some spectra of Mars, and attributed to crystalline iron oxides (Bell et al. 1989; Soderblom 1992). This feature has been found only on another asteroid (1998 BY1), a Jupiter Trojan, by Jewitt & Luu (1990), and it is very similar to that one present on our spectra of Lutetia. As already mentioned, this band is present on all three spectra and absent on all the other spectra of asteroids recorded that night. Jewitt and Luu attributed this band to porphyrins, carbon rich compounds indicative of a primitive composition.

We have inspected several porphyrins spectra taken from RELAB (`http://www.planetary.brown.edu/relab/rel_pub/`) and we found that they have a band at about 0.535 μm. The difference with our measured wavelength could be due to several effects, like composition variations, grain sizes effects, etc. In addition, porphyrins show a band around 0.41 μm, which is also compatible with that present on our spectra (may be blended with the ferric iron 0.43 μm band), and another band at 0.577 μm which is however not seen on Lutetia. We conclude that other observations are needed to confirm the presence of this material on Lutetia.

3. Conclusions

In this paper we discuss the visible spectra of 21 Lutetia, target of the Rosetta mission. We have obtained three spectra covering the entire rotational period of the asteroid. Our results can be summarised as in the following:

- There is a good match between our spectra of Lutetia and the average C-type taken from Bus-taxonomy (Bus 1999).

Letter to the Editor

- Our classification is at variance with those obtained by Zellner et al. (1985), and by Bus & Binzel (2002) (M-type and Xk-type respectively), but in agreement with the recent result of Birlan et al. (2004).
- We have found absorption features on the three spectra due probably to aqueous alteration products and/or porphyrins. The most evident is the 0.43 μm band. Another band, rare among asteroids, at about 0.51 μm, present on all three spectra, could be also attributed to porphyrins.
- Other two minor bands have been identified on one of the three spectra around 0.6 μm and between 0.80 and 0.85 μm. The presence of aqueous alteration material on Lutetia would be consistent with a C-type classification of the object. However, other observations of the object are needed to confirm its classification and the identification of the absorption bands.

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