3-μM SPECTROSCOPIC OBSERVATIONS OF ASTEROID 21 LUTETIA USING AKARI SATELLITE.

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Introduction: Asteroids may retain the record of the planetary formation and differentiation processes, because their small size may have prevented them from heating up for a long period of time. Asteroids are also classified into several different types based on its spectral characteristics, which is considered to reflect their chemical compositions. Among them are M-type asteroids. They have high albedos (0.15-0.25) and red-sloped featureless spectra [1]. M-type asteroids have been interpreted to be fragments of the metallic cores of differentiated asteroids [e.g., 2], but two M-type asteroids 55 Pandora and 92 Undina were found to have the evidence of hydrated minerals (i.e., strong 3-μm absorption bands) [3]. Subsequent observations have also indicated that further more M-type asteroids have 3-μm absorption bands [e.g., 4]. The presence of hydrated minerals on M-type asteroids contradicts the interpretation of M-type asteroids as disrupted cores of differentiated bodies, because hydrated minerals are usually caused by aqueous alteration in asteroids. However, if water was present long enough metamorphose high-temperature anhydrous minerals, hydrated minerals may be formed on differentiated bodies [5].

Asteroid 21 Lutetia are categorized as the typical M-type asteroid [1]. Recently, the images of 21 Lutetia has been obtained by European Space Agency's Rosetta spacecraft, and this observation declare that 21 Lutetia may be a remnant planetesimal from the early Solar System based on its geologically complex surface, ancient surface age, and high density [6]. While the spectrum of 21 Lutetia was found to have the 3-μm absorption [4, 7], recent observation showed the shallow or no absorption in 3-μm band [8, 9]. Thus, the presence of 3-μm absorption bands of 21 Lutetia is still unknown. The spectra in the 3-μm band of 21 Lutetia need to be observed. However, the spectra in the wavelength region between 2.6-2.8 μm cannot be easily observed with ground-based telescopes because of the strong absorption of H_2O in the telluric atmosphere. No previous studies have been able to observe the fine structure of the absorption band around 2.6-2.8 μm of hydrated minerals on asteroids using a ground-based telescope yet. Thus, observation in space, which is not affected by telluric absorption, is extremely useful for obtaining data in the wavelength range including 2.6-2.8 μm. The purpose of this study is to investigate the presence of 3-μm absorption band of 21 Lutetia based on the observational results obtained by the Japanese infrared satellite AKARI.

Observation and data reduction: AKARI, the first Japanese satellite dedicated to infrared astronomy, was launched on 2006 February 21 UT, and started observation in May of the same year [10]. AKARI has a 68.5 cm cooled telescope. The Infrared Camera (IRC) [11] is one of the two instruments on board the AKARI satellite. AKARI's liquid helium cryogen boiled off on 2007 August 26 UT, 550 days after launch. During its warm mission phase, the telescope and scientific instruments are kept around 40 K by a mechanical cooler and only near-IR observations (1.8-5.5 μm) are carried out. A grism spectrograph with a 1' x 1' aperture was used for obtaining spectra of the asteroids between 2.5 and 5 μm with a spectral resolution of 0.097 μm/pix [11]. 21 Lutetia was observed in twice as shown in Table 1. The IRCZ4 AKARI IRC observing template get 5 dark, 4 spectroscopy, 1 imaging, 4 or 5 spectroscopy and 5 dark. The near-IR grism (NG) mode of IRCZ4 was used. We use the exposure time of long frame, 44.41 seconds. These data are processed through the IRC Spectroscopy Toolkit for Phase 3 data (version 20090211) with the new spectral responsively (version 20110301). As the observational example in the Solar System using AKARI, there is the detection of parent H_2O and CO_2 of comet C/2007 N3 (LULIN) [12].

21 Lutetia is influenced by the effect of thermal radiation at the longer wavelength range. The thermal radiation effect was removed by using a thermophysical model (TPM) [13]. Literature values [14] are used for TPM parameters as follows: the thermal inertia of 15 $J/m^2S^{1/2}K$, the r.m.s. of the slopes on the surface of 0.6, the fraction of the surface covered by craters of 0.7 was employed for all asteroids observed by AKARI.

Detection of 3-μm bands: Two observational data (IDs 1520157 and 1520158) and their average spectrum are shown in Fig. 1. Acquisition of the spectral portion over the wavelength range from 2.6-2.8 μm, where ground-based telescopic observation is extremely difficult, has become possible using AKARI. These spectra seem flat, especially over the 3-μm band range. We compare our spectra with those of previous studies. The spectrum 1520157 is analogous to the 2007 and 2008 spectra in Fig. 1 of [15] over the range of 2.85-3.50 μm within 10% difference. Both of them are blue-sloped in the range of 2.85-2.9 μm and a little red-sloped beyond 3.3 μm. The spectrum 1520158 is analogous to the 2003 spectrum in Fig. 1 of [15] over the 2.85-3.50 μm range within 5%. Both spectra exhibit a shallow 3.2 μm absorption band and a 3.5 μm feature. Additionally, the spectra 1520157 and 1520158 are analogous to the 2007 and 2008 spectra in Fig. A5 of [9] over the 2.85-3.50 μm range within 5% and 10%, respectively. More especially, both the spectrum 1520158 and the spectra in [9] seem to have a shallow absorption band at 3.3 μm.

We investigated the presence of 3-μm absorption band of 21 Lutetia. If the lowest reflectance and error in observation over the wavelength range from 2.55-2.60 μm is higher than the highest reflectance and error in observation over the wavelength range of 2.70-2.80 μm, we consider that absorption band exists, as shown in Fig. 2. Because the green Min (=0.982 at 2.59 μm) is lower than the red Max (=1.00 at 2.72 μm) in Fig. 2, there is no obvious absorption in this region. Thus, the 3-μm absorption band of 21 Lutetia are found to have a very shallow absorption or no obvious absorption. Such observation of 3-μm band will help us understand the nature of M-type asteroids.

Since AKARI has observed other M-type asteroids, we will expand our analyses to other M-type asteroids and investigate the presence of 3-μm absorption band. If there is strong 3-μm absorption, we attempt to match reflectance spectra between the asteroids and minerals (and/or meteorites).

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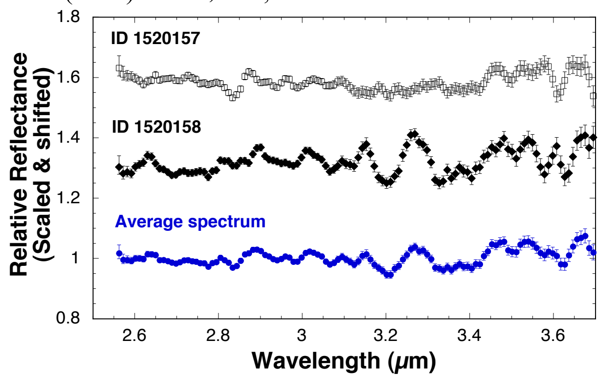

Fig. 1. 21 Lutetia spectra observed by AKARI. 'Average spectrum' spectrum is combined by two spectra (IDs 1520157 and 1520158). The obtained time interval difference between IDs 1520157 and 1520158 is about an hour and a half.

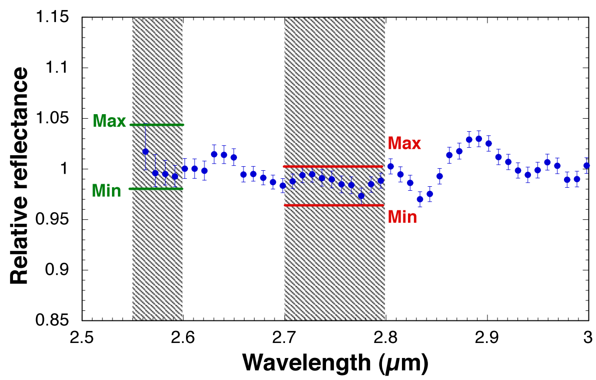

Fig. 2. The criteria for the presence of absorption bands of 2.7-2.8 μm. The green "Max" and "Min" show the highest reflectance and lowest reflectance with error in observation over the wavelength range of the shaded region of 2.55-2.60 μm. Similarly, the red "Max" and "Min" show the highest reflectance and lowest reflectance with error in observation over the wavelength range of the shaded region 2.70-2.80 μm.

Table 1. Summary of observational properties of the asteroids observed by AKARI. The heliocentric distance R_h, the geocentric distance Δ and the phase angle for the asteroids α were obtained by JPL Ephemeris Generator.

Asteroid	ID	Date (UT)	Rh (AU)	Δ (AU)	α (degree)
21 Lutetia	1520157	2008.09.02 17:24	2.2626	2.0242	26.4
	1520158	2008.09.02 19:03	2.2627	2.0235	26.4