SPECTROSCOPIC OBSERVATIONS OF DARK MAIN-BELT ASTEROIDS IN THE 2.6-3.1 μm RANGE WITH THE AKARI SATELLITE. N. Okamura[1], S. Hasegawa[2], F. Usui[3], T. Hiroi[4], T. Ootsubo[5], T. G. Müller[6], and S. Sugita[1], [1]Department of Complexity Science and Engineering, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8561, Japan (okamura@astrobio.k.u-tokyo.ac.jp), [2]Institute of Space and Astronautical Science, JAXA, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan, [3]Department of Astronomy, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, [4]Department of Geological Sciences, Brown University, Providence, Rhode Island 02912, U.S.A., [5]Astronomical Institute, Graduate School of Science, Tohoku University, 6-3 Aoba, Aramaki, Aoba-ku, Sendai, Miyagi 980-8578, Japan, [6]Max-Planck-Institut für extraterrestrische Physik, Giessenbachstraße, Garching 85748, Germany.

Introduction: The 3-μm spectra of low-albedo asteroids exhibit a rich variety and contain the absorption bands of hydrous minerals, water ice, and organics, and so on. Thus, detailed characterization of this wavelength range is extremely important. Extensive observation efforts have been made for detecting this 3-μm band feature over the last few decades and have revealed that low-albedo asteroids exhibit wide varieties of spectra shapes, particularly in 3-μm range. For example, distinctive shape absorption band have been observed for many asteroids [e.g., 1-3]. This distinctive spectral shape is considered as the evidence for hydrated minerals [e.g., 4, 5]. Some asteroids categorized as "Ceres-like" show a sharp 3-μm absorption feature [3], while many of the asteroids actually exhibit a shallow and broad absorption about 3 μm and called a "rounded" feature [5].

Hydrous minerals can be detected through absorption bands around 2.6-2.8 μm [5]. However, observation using ground-based telescopes cannot be easily performed due to telluric water. In order to observe the asteroids in this wavelength region with high quality, we need to use satellite-borne telescope. To date, there have been four infrared astronomical satellites for spectroscopic observations, which are IRAS [6], ISO [7], Spitzer [8] and AKARI [9]. Among these four, only ISO and AKARI observed asteroids covering the wavelength range from 2.5-2.85μm. ISO could only observe 1 Ceres in its asteroidal observation campaign [5]. In contrast, the Japanese infrared satellite AKARI observed continuous spectra covering the 2.5-2.85 μm range and observed 33 low-albedo asteroids. In this paper, we analyze the continuous near infrared spectra observed by AKARI and exhibit thirty-three spectra of the asteroids covering 2.6 to 3.1 μm.

Observation and Data Reduction: The AKARI satellite, which has a 68.5 cm cooled telescope, was launched on 2006 February 21 UT, and started observation in following May [9]. The Infrared Camera (IRC) is one of the two instruments onboard AKARI, and is to cover mainly 2-26 μm for both imaging and spectroscopic observations [10]. AKARI's liquid helium cryogen boiled off on 2007 August 26 UT, 550 days after the launch. After the exhaustion of liquid helium, the spacecraft entered a warm mission phase, which is called "the Phase 3". During the Phase 3, the telescope and scientific instruments were kept below 50 K by the mechanical cooler, and only near-IR observations (NIR channel; 1.8-5.5 μm) were carried out. Most spectroscopic observations of asteroids were performed in the Phase 3. Spectroscopic observations were carried out with two or three times for each asteroid to take sufficient redundancy. 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 $\Delta\lambda$ (λ: wavelength) ~0.01 μm [11]. The observation mode utilized IRCZ4, which is designed for spectroscopic observations. Exposure time of each frame is 44.41 seconds and typically eight frames were taken for each target. A spectral analysis was performed using the IRC Spectroscopy Toolkit for Phase 3 data (version 20110301), except for the moving object correction [12]. Most observed asteroid spectra are influenced by the effect of thermal radiation from the asteroids themselves in the longer wavelength range. The thermal radiation effect was removed by using a thermophysical model (TPM) [13]. Literature values [14, 15] are used for TPM parameters.

Analysis Results: In order to examine the accuracy of the obtained spectra, we compared our AKARI spectra and those observed with ground-based telescopes in previous studies. Among our 33 asteroids, the spectra of 21 asteroids were measured over the 3 μm region in previous studies [1, 3, 16-22]. Twenty asteroids show spectra consistent within one sigma of error bars between this and previous studies, but an asteroid 185 Eunike does not exhibit consistency between previous work [20] and this study in the longer than 3-μm. Because the spectral shape over the longer wavelength range depends highly on the method of removing thermal radiation, such a difference may not be real. It is also noted that the discrepancy is within two sigma of error of our observations. Furthermore, considering that some low-albedo asteroids have been proposed to have large regional difference in reflectance spectra [e.g., 23], such discrepancy for a single asteroid between previous and the current studies does not pose a serious question.

Thirty-three typical spectra of the observed asteroids are shown in Figure 1. The spectral portion ranging from 2.6 to 2.85 μm in wavelength has been obtained with high quality by AKARI. Especially, the peak around 2.7 μm related to the hydrous minerals absorption has been clearly observed in asteroid spectra for the first time. Almost all the observed asteroid spectra exhibit absorption band(s) around 2.6-2.85 μm, and their detailed features vary greatly among asteroids.

References: [1] Jones T. D. et al. (1990) *Icarus, 88*, 172-192. [2] Emery J. P. and Brown R. H. (2003) *Icarus*, *164*, 104-121. [3] Takir D. and Emery J. P. (2012) *Icarus, 219*, 641-654. [4] Lebofsky L. A. et al. (1981) *Icarus*, *48*, 453-459. [5] Rivkin A. S. et al. (2002) in *Asteroids III* (eds Bottke Jr., W. F. et al.) 235–253. [6] Neugebauer G. et al. (1984) *ApJ*, *278*, L1-L6. [7] Kessler M. F. et al. (1996) *A&A*, *315*, L27-L31. [8] Werner M. W. et al. (2004) *ApJ Suppl., 154,* 1-9. [9] Murakami H. et al. (2007) *PASJ, 59*, S369-S376. [10] Onaka T. et al. (2007) *PASJ, 59*, S401-S410. [12] Ootsubo T. et al. (2012) *ApJ, 752,* 15. [11] Ohyama Y. et al. (2007) *PASJ, 59*, S411-S422. [13] Müller T. G. et al. (2002) *A&A*, *381*, 324-339. [14] Müller T. G. et al. (1998) *The Universe as Seen by ISO.* (P. Cox & M. F. Kessler, Eds.), *ESA-SP 427,* p.141. [15] Usui F. et al. (2011) *PASJ, 63***,** 1117-1138. [16] Campins H. et al. (2010) *Nature, 464*, 1320-1321. [17] Rivkin A. S. and Emery J. P. (2010) *Nature 464*, 1322-1323. [18] Cruikshank D. P. et al. (2002) *Icarus, 156***,** 434-441. [19] Hiroi T. et al. (2003) *LPS XXXIV,* Abstract #1425. [20] Rivkin A. S. et al. (2003) *Meteorit. Planet. Sci. 38*, 1383-1398. [21] Howell E. S. et al. (2011) *EPSC Abstracts* **6**, EPSC-DPS2011-637-1. [22] Licandro J. et al. (2011) *A&A 525*, A34. [23] Vilas F. (2008) *AJ*, *135*, 1101-1105.

Acknowledgments: AKARI is a JAXA project with the participation of ESA. We thank I. Sakon for cooperating our data reduction.

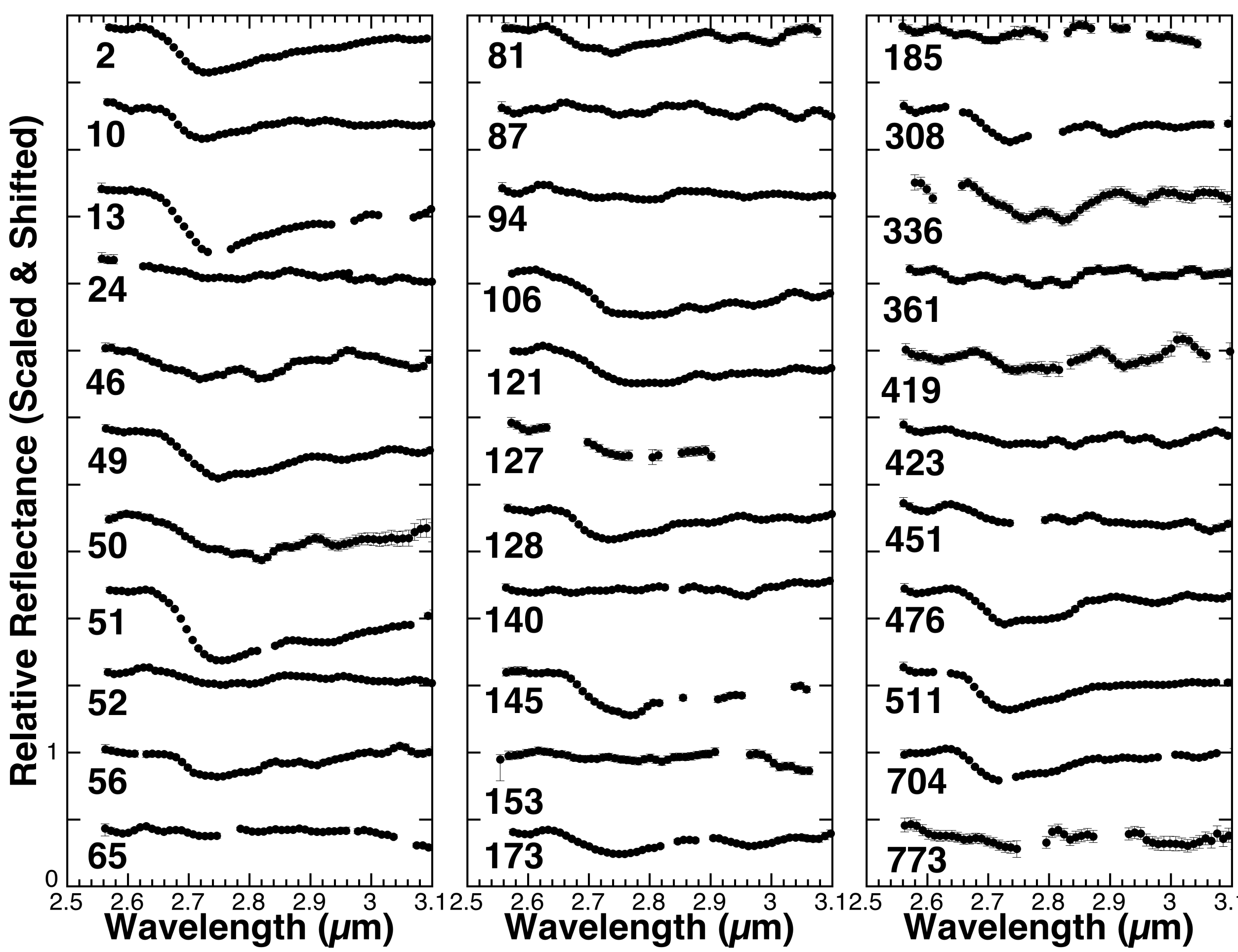

Figure 1. Thirty-three reflectance spectra of asteroids observed with AKARI. The number shown for each spectrum in this figure is its asteroid number.