EXPLORING HYDRATED MINERALS ON ASTEROIDS WITH AKARI. F. Usui[1], S. Hasegawa[2], T. Ootsubo[2], and T. Onaka[3]. [1]Center for Planetary Science, Graduate School of Science, Kobe University, 7-1-48 Minatojima-Minamimachi, Chuo-Ku, Kobe, Hyogo 650-0047, Japan (usui@cps-jp.org), [2]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 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.

Introduction: Water is found in various forms in our solar system and is one of the most important ingredients in the origin of life. It also has vital implications on the exploration of extrasolar planets and provides evidence for the evolution of the solar system, especially its thermal history. Hydrated minerals (any mineral that contains H_2O or OH) are formed in environments where anhydrous rock and liquid water exist together with a certain pressure and temperature, resulting from aqueous alteration. Because hydrated minerals are stable even above the sublimation temperature of water ice, they become an important reservoir to trace the water present in the history of the solar system unless they were reset by a temperature change after formation. The study of hydrated minerals is therefore important for understanding the origin of Earth's water and unravelling of the earliest thermal processes in the solar system. Most asteroids have not experienced sufficient thermal evolution to differentiate into layered structures like terrestrial planets since their formation; thus, asteroids are considered to record the initial conditions of our solar nebula of 4.6 Ga ago. To explore the existence of water in the present solar system, it is indispensable to investigate the presence of hydrated minerals and water ice on various types of asteroids.

Hydrated minerals and water ice exhibit diagnostic absorption features in the so-called 3-µm band (approximately 2.5-3.5 µm wavelength range; e.g., [1]). Features at around 2.7 µm are attributed to hydrated minerals and those at around 3.05 µm to water ice. Many spectroscopic surveys have been conducted in the 3-µm band using ground-based observatories (e.g., [2]), which are severely affected by telluric absorption at around 2.8 µm. Space-borne observations, free from the effect, therefore, offer an excellent opportunity to study and identify the mineral species in asteroids.

Observations: AKARI [3], launched in 2006, is a Japanese satellite mission fully dedicated to a wide range of infrared astronomy. The Infrared Camera (IRC; [4]) on board AKARI has a spectroscopic capability covering 2.5-5 µm continuously with a spectral resolution of R~100, which provide valuable data thanks to its high sensitivity and unique wavelength coverage. We conducted a spectroscopic survey of asteroids in the 3-µm band using IRC [5]. In the warm mission period of AKARI, 147 pointed observations were performed for 66 asteroids in the grism mode for wavelengths from 2.5 to 5 µm. The observed objects comprise C-complex (×23), S-complex (×17), X-complex (×22), D-complex (×3), and V-type (×1) asteroids, all of which are in the main-belt region and have diameters of 40 km or larger.

Results and Discussion: Figure 1 shows examples of the obtained reflectance spectra of asteroids. According to our observations, it is found that most C-complex asteroids (17 out of 22), especially all Ch-, Cgh-, B-, and Cb-type asteroids, have obvious absorption features in the reflectance spectra at around 2.75 µm, which is attributed to OH-stretch in hydrated minerals. Some low-albedo X-complex asteroids and one D-complex asteroid have an absorption feature in the 3-µm band, similar to the C-complex asteroids. Our AKARI results show that only a few S-complex asteroids have an absorption feature with a few percent band depth in the 3-µm band, which is considered to originate from external (exogenic) materials brought to its surface by hydrated impactors or created by solar wind interactions with silicates.

As seen in figure 1, the peak wavelength of the 2.7 µm band feature is concentrated at around 2.75 µm. In particular, C-complex asteroids have a trend between the peak wavelength and the band depth. Figure 2 shows this trend for 17 C-complex asteroids. Except for four outliers (24 Themis at 2.76 µm, 121 Hermione at 2.78 µm, 127 Johanna at 2.81 µm, and 423 Diotima at 2.79 µm), there is a correlation between the peak wavelength and the band depth among 13 C-complex asteroids with the correlation coefficient of 0.88. The correlation should be used with caution because only 13 asteroids comprise this trend; thus, it may be affected by observational bias. Nevertheless, this trend can be understood in terms of the process where hydrated minerals are being heated up and gradually losing water, that is, the dehydration process. The heating energy could be supplied by the solar wind plasma, micrometeorite impacts, or the decay heat from radioactive isotopes in the rocks.

This data set, comprising direct observations of absorption features in the 3-µm band, is quite unique. This study will provide important information on whether asteroid features determined by spacecraft exploration

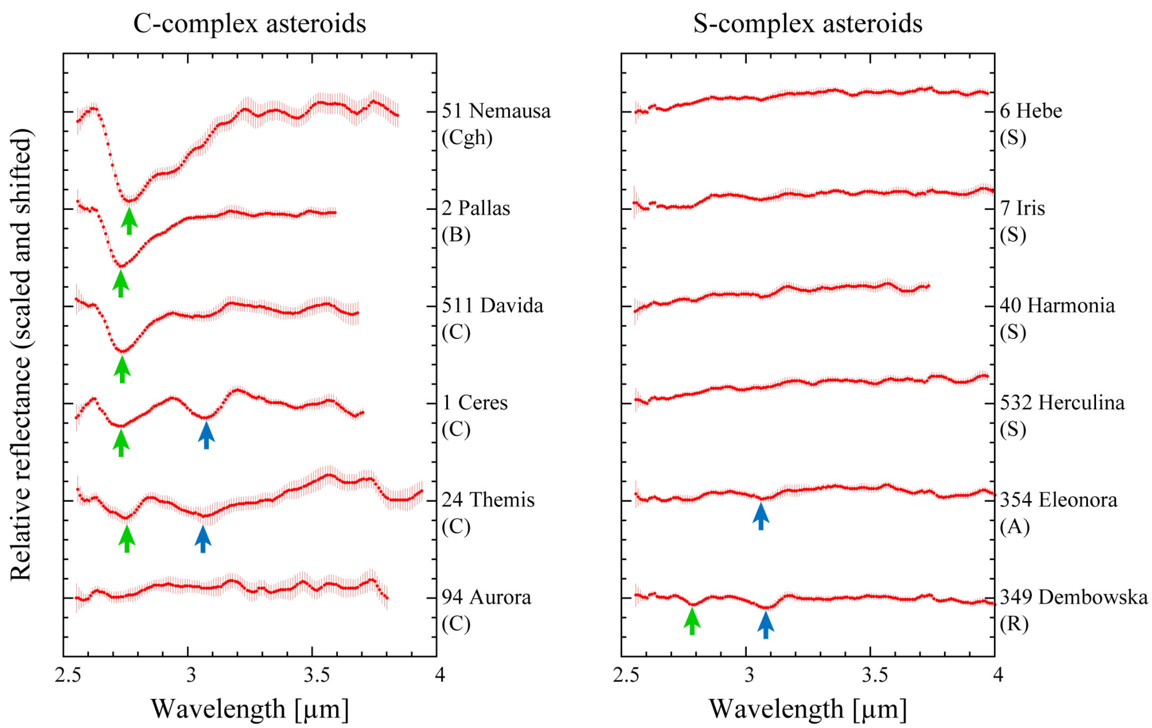

Figure 1: Near-infrared spectra of asteroids obtained from the AKARI observations [5]. This shows 6 examples for both C-complex and S-complex asteroids. The green and blue arrows indicate the identified absorption feature at around 2.7 μm and 3.1 μm, respectively.

(i.e., 162173 Ryugu by Hayabusa-2 and 101955 Bennu by OSIRIS-REx) are universal or exceptional. The catalog of the reflectance spectra of individual asteroids as well as the infrared flux data are summarized in the Asteroid Catalog using AKARI Spectroscopic Observations (AcuA-spec) and open to the public on the JAXA archive (http://www.ir.isas.jaxa.jp/AKARI/Archive/).

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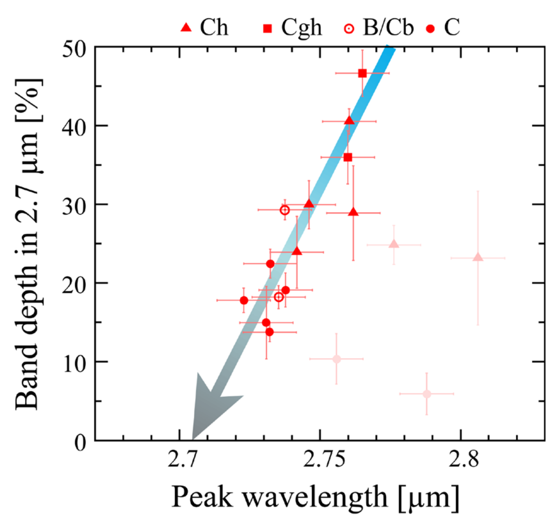

Figure 2: The relationship between the band depths at 2.7 μm against the peak wavelength for C-complex asteroids from [5]. The different marks show differences of subgroups in the types of C-complex based on the Bus-DeMeo taxonomy [6]. The trend of 13 asteroids from top right to bottom left indicated by the arrow can be understood in terms of the dehydration process.