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Near-Infrared Asteroid Spectroscopic Survey with AKARI: Dehydration process of C-complex asteroids revealed by spectral features in 2.7 μm band

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Abstract

We conducted a spectroscopic survey of asteroids in the 3 μm band with the Japanese infrared satellite AKARI. 147 pointed observations were performed for 66 asteroids for wavelengths from 2.5 to 5 μm. According to these observations, most C-complex asteroids show clear absorption features (>10% with respect to the continuum) related to hydrated minerals at a peak wavelength of approximately 2.75 μm. Moreover, there is a correlation found between the peak wavelength and the band depth of the 2.7 μm band among 13 C-complex asteroids, which can be understood as the dehydration process. The characteristics of asteroid Ryugu and Bennu can be interpreted in the context of this dehydration process. Our data are released to the public on the JAXA archive (http://www.ir.isas.jaxa.jp/AKARI/Archive/).

1. Introduction

Knowledge of hydrated minerals among asteroids is important for understandings of solar system formation, evolutionary processes, and thermal history. Hydrated minerals 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. Hydrated minerals and water ice exhibit diagnostic absorption features in the 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.

2. 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.

3. 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. 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. 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 solar wind plasma, mutual collisions of asteroids, or decay heat from radioactive isotopes in the rocks.

Recently, two data points of the 2.7 μm band observations were added by the spacecrafts; 162173 Ryugu by Hayabusa2 [7] and 101955 Bennu by OSIRIS-Rex [8]. As shown in Figure 2, the characteristics of Ryugu and Bennu can also be interpreted in the context of the dehydration process found in the main-belt asteroids with AKARI. The size range of this trend has three orders of magnitude. This dehydration process can be considered as a universal phenomenon among C-complex asteroids.

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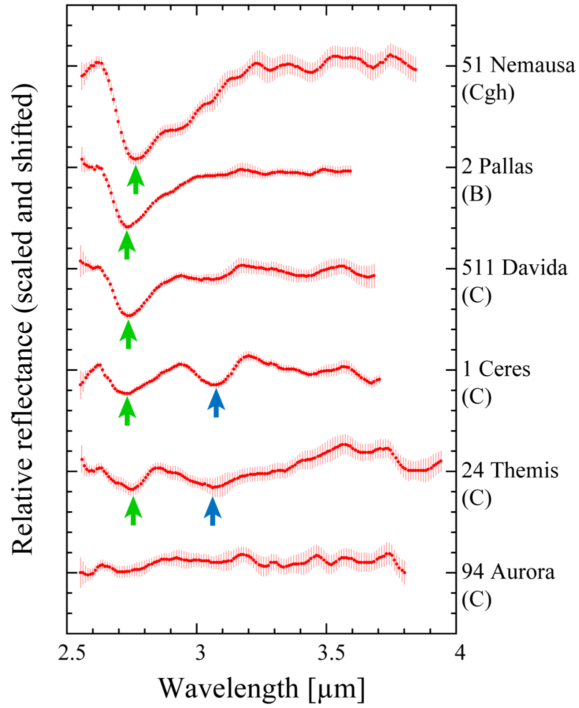

Figure 1: Near-infrared spectra of asteroids obtained from the AKARI observations [5]. The green and blue arrows indicate the identified absorption feature at around 2.7 μm and 3.1 μm, respectively.

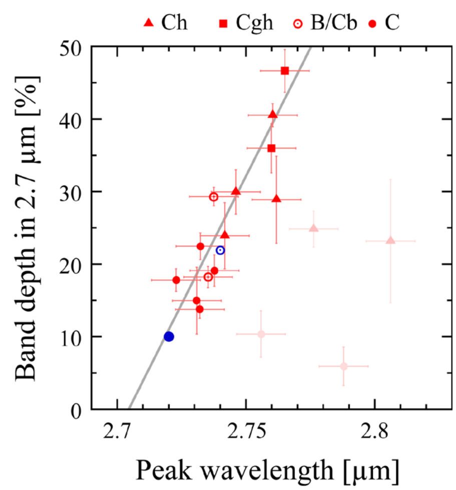

Figure 2: The relationship between the band depths at 2.7 μm against the peak wavelength for C-complex asteroids from [5]. The different marks show differences of subgroups in the types of C-complex based on the Bus-DeMeo taxonomy [6]. Blue filled circle and open circle denote Ryugu [7] and Bennu [8], respectively.