VISIBLE COLOR VARIATION OF BOULDERS ON 162173 RYUGU. E. Tatsumi[1], S. Sugita[1], S. Kameda[2], R. Honda[3], T. Kouyama[4], Y. Yokota[5], N. Sakatani[5], C. Honda[6], T. Michikami[7], M. Tomokatsu[8], M. Yamada[9], H. Suzuki[10], Y. Cho[1], M. Matsuoka[5], M. Hayakawa[5], K. Yoshioka[1], K. Ogawa[11] H. Sawada[5], F. Vilas[12], D. Domingue[12], L. Le Corre[12], S. Sasaki[12], T. Nakamura[14], T. Hiroi[15], [1]Univ. of Tokyo (eri@eps.s.u-tokyo.ac.jp), [2]Rikkyo Univ., [3]Kochi Univ., [4]National Inst. of Adv. Industrial Sci. and Tech., [5]ISAS/JAXA, [6]Univ. of Aizu, [7]Kindai Univ., [8]Nagoya Univ., [9]Chiba Inst. Tech., [10]Meiji Univ., [11]Kobe Univ., [12]Planetary Science Institute, [13]Osaka Univ., [14]Tohoku Univ., [15]Brown Univ.

Introduction: Observations by the Telescopic Optical Navigation Camera (ONC-T) onboard the Hayabusa2 spacecraft revealed that the Cb-type asteroid 162173 Ryugu is covered by numerous boulders. These boulders may be fragments of cratering or disruption of its parent body [1]. The variation in visible color of the boulders [2] could reflect the thermal and chemical condition of the parent body. Thus, it is important to closely examine and categorize the color of the boulders.

Observations: These multi-band observations by ONC-T/Hayabusa2 were conducted at altitude of ~20 km on 3 July and at altitude of ~5 km on 20 July using 7 color filters (ul: 0.40 μm, b: 0.48 μm, v: 0.55 μm, Na: 0.59 μm, w: 0.70 μm, x: 0.86 μm, p: 0.95 μm), corresponding to a resolution of ~2 m/pix and ~0.6 m/pix, respectively.

Calibrations: The calibrations were conducted from both preflight and inflight observations [3-5]. Due to the problem in the previous flat-fields, we used the updated flat-fields described in [6].

The largest boulder "Otohime": Otohime sits at the south pole, and its size is ~140 m (Fig. 1). Otohime is a unique boulder, showing both sharp cliff-like and moderately sloped faces. Otohime displays distinctive color features as well. The visible color of Otohime changes from face to face. Figure 1 shows the Otohime's color variation especially in spectral slope. The cliff-like faces have bluer spectra and the moderately slope faces display relatively redder spectra, similar to Ryugu's average spectrum (Fig. 2). The cliff-like sharp faces could have formed by a recent impact or a landslide, thereby showing relatively fresher surfaces. Thus, the color of material on Ryugu may become redder with exposure to the space environment, as expected with space weathering effects. Another cause for this color difference could be grain size variations. The moderate slope faces could be covered by finer-grained regolith, causing a redder spectral slope [7].

Colors of large boulders >40 m: Next, we analyzed the relatively large boulders (>40 m) resolved by the lower resolution images. Figure 3 shows the color slope distribution of boulders in the ul-v and v-p color space. We measured the spectra in several im-

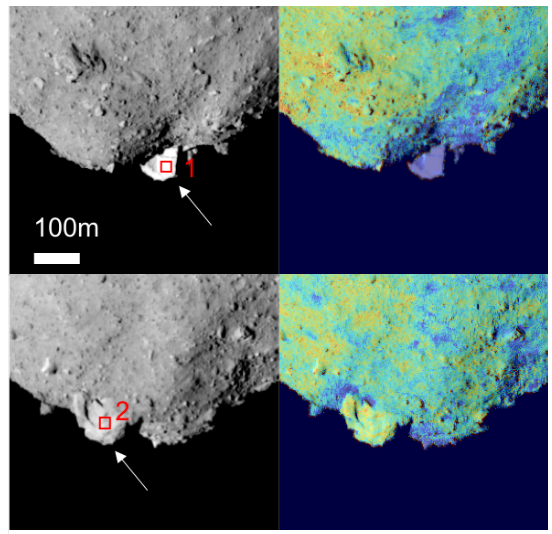

Fig. 1. The Otohime boulder on the south pole. I/F images (left) and spectral slope images (right). Otohime boulder is indicated by arrows. Spectrally blue regions are shown in blue color in spectral slope images.

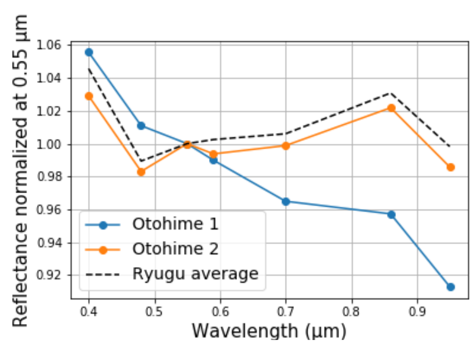

Fig. 2 Visible spectra of Otohime boulder in different faces (the spectra are normalized to R=1 at 0.55 μm). The regions of interest (ROIs) are shown in Fig. 1. The cliff-like face (ROI1) shows a blue spectrum.

ages to see the effect of illumination conditions, although the phase angle did not change. The spectral properties of Otohime's cliff-like, blue face is distinct from the color properties of other large boulders across Ryugu's surface.

Color variations in small boulders: We examined color variations in small boulders using the higher resolution observations acquired at ~5 km altitude, Figure 4 compares the normalized color spectrum of the small boulders with the Ryugu's average spectrum, showing the variation in the reflectance upturn at the ul(0.40 µm)-band. The boulders indicated with white arrows show less upturn in ul-band. This ul-upturn appears to be independent of the spectral slope. Suggesting that there may be at least two different processes that have or are modifying the surface; one that affects the spectral slope and another that affects the ul-band upturn.

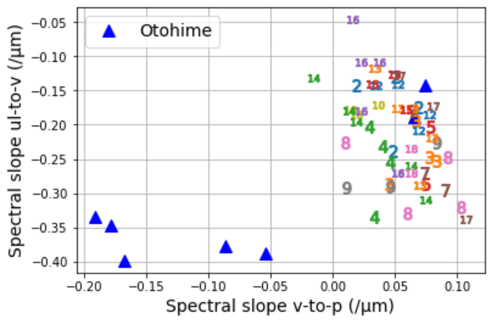

Fig. 3 The color distribution of boulders >40 m. Boulders are numbered in descending order. Some parts of Otohime show similar spectra to other boulders.

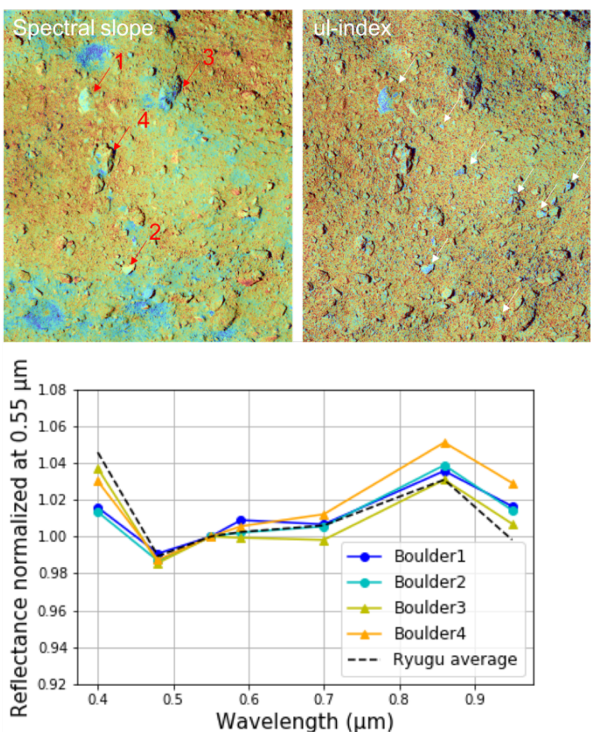

Fig. 4. Spectral slope and ul-index maps for higher resolutions images taken at altitude of ~6 km (top). Several boulders with less ul-upturn are shown by white arrows. Four examples of boulder spectra are shown in the bottom panel; two have less ul-upturn (●).

Discussions: We found visible color variations for boulders on Ryugu. Prominent variations are found in the spectral slope and ul-upturn. If the spectral slope variations are induced by space weathering, then possible counterparts in the meteoritic samples can be discussed. Figure 5 shows laser irradiation experiments, simulating micrometeorite bombardments, for dehydrated CI and CM chondrites [8,9,10]. Although many dark carbonaceous chondrites are known to have a bluing response [11], these meteorites redden in response to irradiation. This is commensurate with our spectral observations of fresh versus older boulder faces. The ul-upturn may correspond to the degree of aqueous alteration [12] or/and the presence of carbon contents [13].

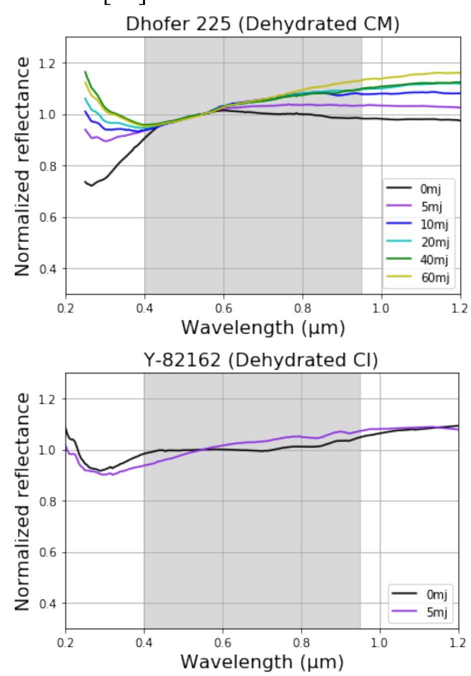

Fig. 3 Laser irradiation experiments on dehydrated CM (Dhofar 225) and CI (Y-82162) chondrites.

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