EVIDENCE OF SPACE WEATHERING ON THE CI1-CHONDRITE ASTEROID 162173 RYUGU. T. Hiroi[1], R. E. Milliken[1], K. M. Robertson[1], C. D. Schultz[1], K. Amano[2], T. Nakamura[2], H. Yurimoto[3], T. Noguchi[4], R. Okazaki[5], H. Yabuta[6], H. Naraoka[5], K. Sakamoto[7], S. Tachibana[8], T. Yada[7], M. Nishimura[7], A. Nakato[7], A. Miyazaki[7], K. Yogata[7], M. Abe[7], T. Okada[7], T. Usui[7], M. Yoshikawa[7], T. Saiki[7], S. Tanaka[7], T. Fuyuto[9], S. Nakazawa[7], S. Watanabe[10], Y. Tsuda[7], S. Sasaki[11], H. Kaiden[12], K. Kitazato[13], M. Matsuoka[14], E. Tatsumi[15], and Y. Yokota[7], [1]Brown University, Box 1846, Providence, RI 02912, USA, [2]Tohoku University, [3]Hokkaido University, [4]Kyoto University· [5]Kyusyu University, Japan, [6]Hiroshima University, [7]JAXA Institute of Space and Astronautical Science, [8]University of Tokyo, [9]Kanagawa Institute of Technology, [10]Nagoya University, [11]Osaka University, [12]National Institute of Polar Research, [13]University of Aizu, [14]National Institute of Advanced Industrial Science and Technology, [15]Instituto de Astrofisica de Canarias.

Introduction: The Hayabusa2 spacecraft returned samples of asteroid 162173 Ryugu that identified it as similar to CI1 chondrite meteorites. This study compares laboratory reflectance spectra of bulk Ryugu samples with spectra acquired by the spacecraft during the asteroid encounter.

Experimental: Ryugu stone C0002, previously used for physical-strength measurements, was crushed for spectral analysis of a bulk 'powder'. The starting sample was partially contaminated with a glue (glycol phthalate), thus part of the crushed sample was washed with acetone, turning it into a finer powder (<125 µm estimate). Large glue fragments were handpicked from the remaining coarser powder (125-500 µm estimate), and a 'bulk' powder sample was later produced by combining the two powder samples.

Bidirectional reflectance spectra (0.3-2.6 µm) of the samples were measured at the standard viewing geometry of 0° incidence and 30° emergence angles, and biconical FTIR reflectance spectra (0.8-100 µm) were measured at the NASA Reflectance Experiment Laboratory (RELAB). The two sets of spectra were combined at 2.5 µm, and the 0.4-4 µm region is discussed here. Photos and reflectance spectra of the samples are shown in Fig. 1.

Hydration Band Analysis: The OH and H_2O absorption bands near 3 µm (Fig. 1) were analyzed in the same manner as [1]. Natural log reflectance spectra of the powder samples were each fit with a linear (in wavelength) continuum background and sum of Gaussians (in wavenumber) over the ~2.6-3.6 µm wavelength range (variable depending on spectral shape). One of the results (fine powder) is shown in Fig. 2. Because the first two Gaussian bands (labeled

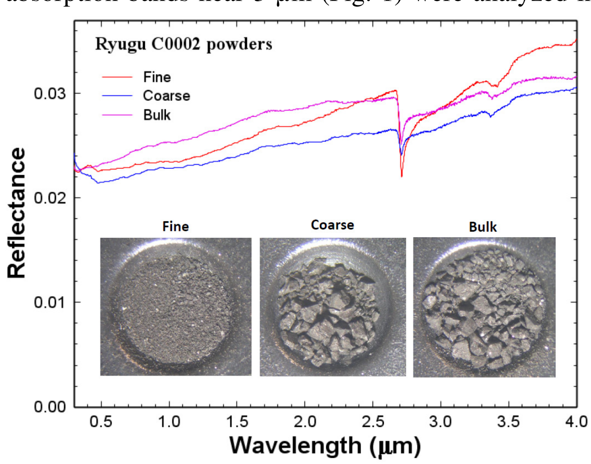

Fig. 1. Reflectance spectra (0.3-4 µm) and photos of Ryugu C0002 powder samples. Cup diameter is 4 mm.

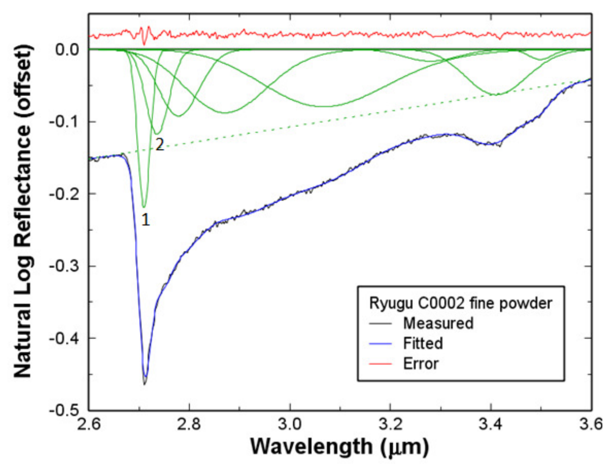

Fig. 2. Gaussian fitting of C0002 fine powder spectrum.

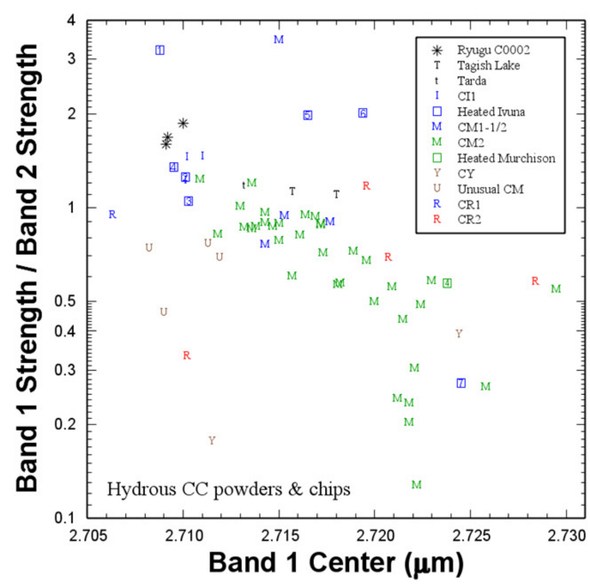

Fig. 3. Band 1 center vs. Band 1 / Band 2 strength ratio of C0002 powders and other carbonaceous chondrites [1].

as 1 and 2 in Fig. 2) are believed to be characteristic of carbonaceous chondrite classes [1], their Band 1 centers and Band 1 / Band 2 strength ratios are plotted in Fig. 3 alongside other C chondrites. All Ryugu C0002 powders plot very close to unheated CI1 chondrites and Ivuna samples heated up to 400°C. This result is consistent with previous studies of Ryugu being most similar to unheated CI1 chondrite [*e.g.*, 2].

Comparison with ONC-T and NIRS3 Data: Shown in Fig. 4 are weighted linear combinations of the C0002 fine and coarse powder spectra that best match the average spectra representative (but different) areas of Ryugu acquired by ONC-T and NIRS3. Most of the ONC-T band reflectance values, overall spectral shape, and NIRS3 2.7 µm absorption band strength can be matched reasonably well.

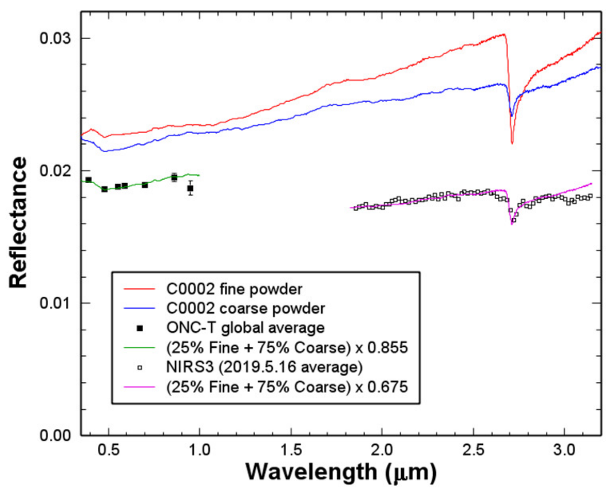

Fig. 4. Comparison of C0002 powder spectra with ONC-T and NIRS3 data.

However, upon closer inspection, there are noticeable differences between the NIRS3 and C0002 spectra near ~2.7 µm. The NIRS3 spectrum shows weak absorption bands at 2.65 and 2.81 µm which are absent in C0002 spectrum. These subtle features may be due to uncertainties in processing of the NIRS3 data or, if related to real surface features, indicative of additional components on the asteroid surface that are not present in the Ryugu sample measured here.

There is also a slight but distinct difference in the 2.7 µm band center position. The NIRS3 spectrum shows the band center at ~2.72 µm, but the model C0002 powder spectrum (solid circles) shows the band center at a shorter wavelength near 2.71 µm (Fig. 5). When the C0002 powder spectral data near the 2.7 µm band center are artificially shifted by 6 nm toward the longer wavelength and then resampled for the NIRS3 resolution (open circles), the resulting model spectrum yields a better matches with the NIRS3 spectrum. This 6 nm shift is consistent with the band center position

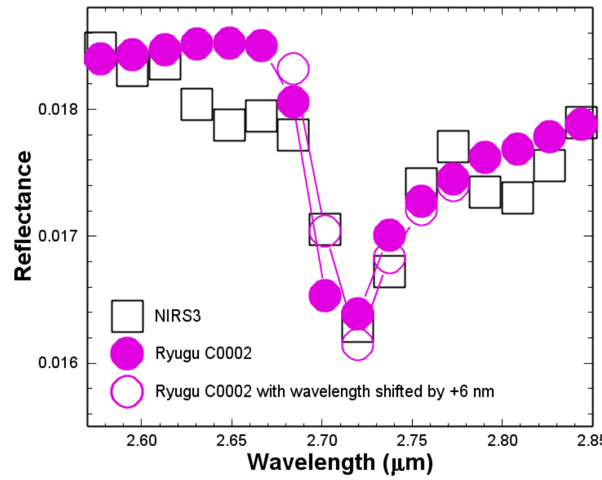

Fig. 5. Matching the 2.7 µm band spectrum between the model C0002 powder spectra and the NIRS3 spectrum in Fig. 4.

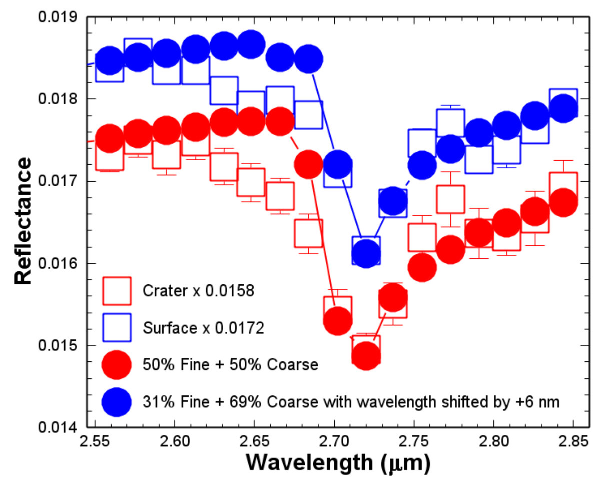

Fig. 6. Same matching attempt as in Fig. 5 with NIRS3 data for an artificial crater and its surrounding surface.

difference between materials at the artificial crater site on Ryugu and those in the surrounding area [3] as shown in Fig. 6, and such a shift can result from space weathering [*e.g.*, 4].

Summary and Discussion: If the C0002 powder samples represent the average material of asteroid Ryugu excavated by the impact experiment, space weathering by solar wind may explain a shift of the 2.7 µm band to slightly longer wavelengths, consistent with the band position observed by NIRS3 at a global scale for the undisturbed optical surface.

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References: [1] Hiroi T. et al. (2021) *Polar Sci. 29*, 100723. [2] Yokoyama T. et al. (2022) *Science* 10.1126 /science.abn7850. [3] Kitazato K. et al. (2021) *Nat. Astron. 5*, 246-250. [4] Lantz C. et al. 2015. *A&A 577*, A41.