

VISIBLE-IR SPECTROSCOPIC DIVERSITY OF RYUGU COARSE GRAINS AND COMPARISON TO SPECTRAL PROPERTIES OF CARBONACEOUS CHONDRITES.

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Introduction: The spacecraft Hayabusa2 explored C-type asteroid Ryugu and brought back representative samples of Ryugu to the Earth in 2020 [1]. We performed reflectance spectroscopy of Ryugu samples to investigate (1) spectral diversity among Ryugu samples and (2) similarities and differences between Ryugu samples and carbonaceous chondrites. These results can also be applied to spectroscopic observations performed by the spacecraft [2,3].

Sample and Analysis: We measured Visible-infrared (Vis-IR, 0.4–18 μm in wavelength) reflectance spectra of 6 and 8 coarse grains (> 1mm in size) collected from the first and second touchdown sites, respectively, and some carbonaceous chondrites. Samples were put into an air-tight cell sealed with a CaF_2 or ZnSe window together with reflectance standards. All the sample handling was performed in a pure- N_2 purged glove-box to avoid atmospheric alteration of the samples. Petrological and mineralogical characterization of the samples including synchrotron X-ray computed tomography and X-ray diffraction analysis was done by other analysis groups in the Hayabusa2 initial analysis “Stone” team [e.g., 4].

IR signature of Ryugu samples compared to hydrated chondrites: All the Ryugu coarse grains have an absorption band at $\sim 2.71 \mu\text{m}$ attributed to Mg-rich phyllosilicates and a reflectance maximum (Reststrahlen band) at $\sim 9.8 \mu\text{m}$ suggesting saponite-bearing phyllosilicate composition. These signatures of phyllosilicates of Ryugu are similar to those of CI chondrites, which is consistent with mineralogical observations of Ryugu samples [e.g., 4]. Ryugu sample spectra show absorption features due to aliphatic compounds (3.4 μm), carbonates (e.g., ~ 3.4 , 3.95 μm), and some samples show an absorption feature at 5.8 μm probably due to carbonyl compounds [5]. Ryugu samples show a sharper 2.7 μm band than CIs, suggesting that they contain little molecular water compared to CIs. Sulfate features are not observed in Mid-IR reflectance spectra of Ryugu unlike CIs [e.g., 6]. Tagish Lake C2-ungrouped chondrite also shows an absorption band at $\sim 2.7 \mu\text{m}$ and Reststrahlen band at $\sim 9.8 \mu\text{m}$. However, IR spectral features due to carbonates are more significant in the spectra of Tagish Lake than those of Ryugu as seen in absorption bands around $\sim 3.4 \mu\text{m}$ and a reflectance maximum at 11.2 μm [7]. CM chondrites also consist mainly of hydrated minerals, however, their spectral shapes around $\sim 3 \mu\text{m}$ and $\sim 10 \mu\text{m}$ are different from those of Ryugu most likely due to the different phyllosilicate composition.

Vis reflectance spectra of Ryugu samples: Ryugu coarse grains have ~ 2 –4% of reflectance in the v-band (0.55 μm) at the phase angle of 30° , which is roughly consistent with those of hydrated carbonaceous chondrites (CI, CM, Tagish Lake, and Tarda). The reflectance spectra of CO and CV chondrites, which are dominated by anhydrous minerals and more chondrule-rich, are brighter than those of Ryugu samples. The IR spectra suggest the compositional link between Ryugu and CI chondrites, however, Vis reflectance spectra of Ryugu are not similar to CI chondrites. Low reflectance Vis spectra without a UV drop (a sudden reflectance decrease towards UV wavelengths) of Ryugu samples are not similar to unheated Orgueil but similar to Orgueil samples heated at 300–400 $^\circ\text{C}$ for 50 hours (or longer) in reduced conditions [8]. The causes of differences between Vis spectra of Ryugu and unheated CIs may be explained by: (1) atmospheric alteration of CIs (e.g., oxidation and water adsorption of CIs [e.g., 9]), (2) different organic composition, and (3) gentle heating experienced by Ryugu.

Vis reflectance spectra of Ryugu particles show some diversity of properties (reflectance, spectral slope, and overall shapes), while IR spectra are consistent among samples. This suggests that the spectral diversity of Ryugu samples are originated from physical properties or orientations of sample surfaces rather than the compositional differences among individual particles.

References: [1] S. Tachibana et al. (2022) *Science* 375:1011–1016. [2] S. Sugita et al. (2019) *Science* 364:eaaw0442. [3] K. Kitazato et al. (2019) *Science* 364:272–275. [4] T. Nakamura et al. (2022) *this meeting*. [5] M. Yesiltas et al. (2021) *Scientific Reports* 11:11656. [6] M. Noun et al. (2019) *Life* 9:44. [7] J. L. Bishop et al. (2021) *Earth and Space Science* 8:e2021EA001844. [8] K. Amano et al. (2020) *Goldschmidt2020 Abstract*. doi:10.46427/gold2020.47. [9] M. Gounelle and M. Zolensky (2001) *Meteoritics & Planetary Science* 36:1321–1329.