REFLECTANCE SPECTRA OF CARBONACEOUS CHONDRITES MEASURED UNDER ASTEROID-LIKE CONDITIONS: IMPLICATIONS FOR HAYABUSA2'S NIRS3 INSTRUMENT Y. Nakauchi[1], D.Takir[2], C.A. Hibbitts[3], K.R. Stockstill-Cahill[3], J.P. Emery[4], L.L. Corre[5], T. Iwata[6], and K. Kitazato[1], [1]University of Aizu (Aizu-Wakamatsu, Fukushima Pref. 965-8580, Japan; nakauchi@u-aizu.ac.jp), [2]SETI Institute, [3]JHU-Applied Physics Laboratory, [4]University of Tennessee, [5]Planetary Science Institute, [6]Japan Aerospace Exploration Agency.

Introduction: Japan Aerospace Exploration Agency (JAXA)'s Hayabusa2 is cruising towards the near-Earth Apollo asteroid (162173) Ryugu, a carbonaceous asteroid [1]. Hayabusa2 will arrive at Ryugu this summer. NASA's OSIRIS-REx spacecraft is also planned to reach asteroid (101955) Bennu, another carbonaceous asteroid [2], in 2018. These two primitive targets are expected to contain water and/or organics. The study of carbonaceous chondrites is important to constrain the meteorite analogs for these primitive targets, and to provide important input on the petrological and geochemical environments in which these primitive asteroids were formed. Studying carbonaceous chondrites is also important for sampling and landing site characterization and selections. Furthermore, the study of carbonaceous chondrites will help place the analysis of the returned sample from primitive asteroids in a broader context.

Since it is not possible to return samples from every small body, the information obtained from remote sensing data (ground-based or space-based) such as reflectance spectra is important to characterize the surface composition of these bodies. It was reported, for example, that the integrated area of the 3µm band is sensitive to the amount of hydrated minerals and/or water content [3]. The previous studies used reflectance spectra of carbonaceous chondrites measured in ambient conditions to drive spectral parameters, such as, band center, band depth, and band area. [4] showed, however, that ambient conditions can affect the calculation of spectral parameters of the 3-µm band due to the contamination of adsorbed water. The study of [4] focused only on CM and CI carbonaceous chondrites. Here we expend that sturdy to include other carbonaceous chondrites typed, such as, CV, CO, CR, etc.

Experiment: In this study, we used 10 new carbonaceous chondrite samples: Allende (CV3), Felix (CO3), Al Rais (CR2), MIL15328 (CR2), Murray (CM2), Banten (CM2), Crescent (CM2), Alais (CI1), Essebi (C-ungrouped), EET83226 (C-ungrouped). We got these samples as a loan from various colleagues and laboratories (please see acknowledgements). The sample powders were not sieved. MIL15328 and EET83226 are finds from Antarctica. Their weathering grade are B and A/B, respectively.

The reflectance spectra of carbonaceous chondrites were measured in the Laboratory for Spectroscopy under Planetary Environmental Conditions (LabSPEC) at the Johns Hopkins University Applied Physics Laboratory. Samples were placed in a copper sample holder and retained in place with a 1 mm-thick MgF_2 window. A diffuse gold reflector and a powder Spectralon standard, both mounted immediately below the sample holder were used as the IR and VNIR reflectance standards, respectively. A thermocouple embedded in the sample provided an accurate temperature measurement. We obtained biconical reflectance (i = 15˚, e = 45˚) from 0.4µm to 5.5µm. Spectra were initially collected at room pressure and temperature. Then the chamber was evacuated to high vacuum (10^{-6} to 10^{-7} Torr), the samples were heated from room temperature up to ~373K to remove adsorbed telluric water, and spectra were again acquired.

Results & Discussion: Under vacuum and at elevated temperature, the shape of reflectance spectra around the 3-µm band, which is related to the presence of water molecules, significantly change (Fig. 1). This change is attributed to the removal of the adsorbed water in samples. The absorption feature at 2.7 µm, which is mainly related to the presence of structural hydroxyl group, and the absorption feature around 3.4-3.5 µm, which is related to C-H stretching of aliphatic organic compounds, became more pronounced. These trends are consistent with the previous study of [4]. CI meteorites showed the most significant 3-µm band change, more likely because they have abundant clays and FeO/oxyhydroxide materials [5].

We calculated the integrated 3-µm band area and band depth at 2.9 µm using the methods of [6]. Fig. 2 shows a good correlation between the integrated 3-µm band area and band depth at 2.9 µm [6]. This correlation can be applied to estimate water content in asteroids [7]. However, carbonaceous chondrites subgroups cannot be differentiated in this plot.

[8] used the reflectance ratios at 2.5 µm, 2.8 µm and 3.0 µm to separate meteorite types. Their scatterplots could separate CI and CM chondrites, but CM and CR could not be separated. They used meteorite spectra that were acquired under ambient conditions, and therefore were affected by adsorbed water. Fig. 3 showed the scatterplots of the reflectance ratios at 2.5 µm, 2.8 µm and 3.0 µm using our study's spectra, which were measured under heated and vacuum conditions. We found that CM and CR types can be separated in our scatterplots. On the other hand, CI, CM and C-ungrouped could not be separated. From this result,

we suggest that this parameter is related to the primitive property of the carbonaceous chondrites.

Conclusion: In this study, reflectance spectra of carbonaceous chondrites, including new CIs, CMs, COs, CRs, CVs and C-ungrouped were measured under vacuum and while heated to remove adsorbed water. The shape of the absorption band around 3 µm changed under vacuum and elevated temperatures in all carbonaceous chondrites. Using these spectra, we found a good correlation between the 3-µm band area and the 2.9-µm band depth. Although these parameters may be used to estimate water abundance in primitive asteroids, the meteorite types cannot be separated. On the other hand, the scatterplots of new reflectance ratio at 2.5 µm, 2.8 µm and 3.0 µm can be used to separate primitive carbonaceous chondrites and other meteorites.

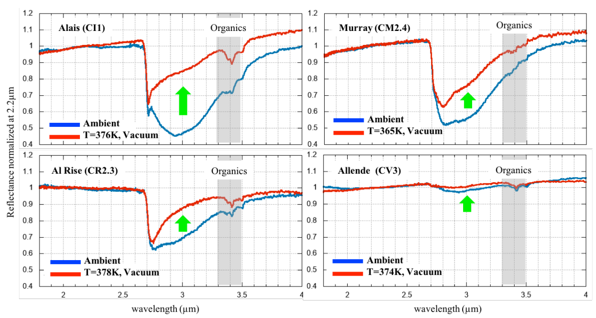

Fig. 1) Example of reflectance spectra of carbonaceous chondrites: All spectra were normalized at 2.2 µm. (Blue line) The spectra were measured under ambient conditions. (Red line) The spectra were measured under vacuum and heated conditions. The green arrows indicate the amount of adsorbed water around the 3-µm band. CIs are characterized by adsorptive surfaces.

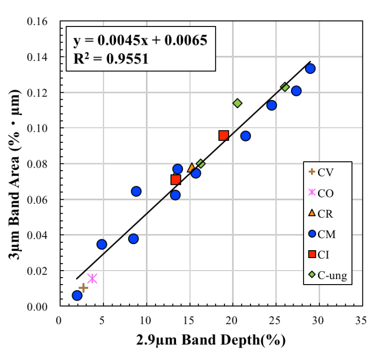

Fig. 2) We found a good correlation between the 2.9µm band depth (BD) and 3µm band area (BA). In this plot, we combined data from this study and the study of [3]. The continuum (R_C) was linear.

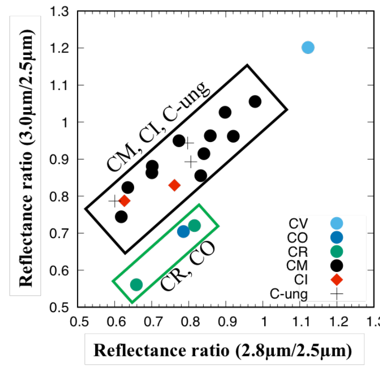

Fig. 3) Scatterplots of reflectance ratio at 2.5µm, 2.8µm and 3.0µm. The black diagonal quadrangle cover the area of CM, CI, and C-ung chondrites. The green diagonal quadrangle covers the area of CR and CO chondrites.

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