UNIQUENESS AND SIMILARITY OF ORGANIC MATTER IN THE ASTEROID RYUGU AND CARBONACEOUS CHONDRITES REVEALED BY INFRARED TRANSMISSION SPECTROSCOPY.

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Introduction: JAXA's Hayabusa2 mission returned the surface samples from the carbonaceous (C-type) asteroid Ryugu. The first touchdown samples and second touchdown samples were separately stored in the sample container chamber A and chamber C, respectively [1]. Fourier transform infrared (FTIR) spectroscopy is a nondestructive technique for functional group chemistry and structures which is suitable for both organic and inorganic compounds. As a part of the Hayabusa2-initial-analysis organic macromolecule team, infrared absorption spectra from the intact Ryugu particles and extracted insoluble organic matter (IOM) were obtained using FTIR microspectroscopy, to understand the nature of organic matter in Ryugu.

Methods: Several samples were analyzed in parallel in the team, in Japan (Yokohama National Univ., YNU) and in France (IPAG, Grenoble and Orsay-lab teams) to increase the robustness of the analysis. The aggregates in chamber A (A0108 and A0106) and chamber C (C0109) were analyzed as intact Ryugu particles. IOM was obtained after solvent extraction followed by HF/HCl demineralization from the aggregates A0106 and C0107 (Hiroshima U) [2]. During drying, most IOM was precipitated, but there was a little left suspended (sticky phase). The samples were pressed between two diamond windows and then FTIR measurements were performed on the diamond windows in transmission mode.

Results and Discussion: The organic features shown in the FTIR spectra of the Ryugu intact particles (Fig. 1) were aliphatic C-H stretching at 2960 cm^{-1} (CH_3 asymmetric), 2930-2925 cm^{-1} (CH_2 asymmetric), 2855-2850 cm^{-1} (CH_3 and CH_2 symmetric) and aromatic C=C stretching (~1600 cm^{-1}). Carbonyl C=O stretching modes (~1700 cm^{-1}) were not always visible. Extracted IOM displayed these organic peaks more clearly. In addition, C=O at 1660 cm^{-1} newly appeared, which may be assigned to unsaturated ketones/aldehydes or amides.

There was no significant difference between the samples from surface and interior of a mm-sized grain (A0108-58) from the A0108 aggregate. Moreover, both in the case of intact particles and extracted IOM, the IR absorption spectra of chamber A and chamber C were almost identical, but some local heterogeneity exists.

The Ryugu IOM had the highest CH_2/CH_3 with the highest aliphatic CH/aromatic C=C ratios compared to IOM from unheated carbonaceous chondrites [3], indicating that it is rich in long chain aliphatic moieties. We also observed possible N-H features at 3350 cm^{-1} and 3180 cm^{-1} in the Ryugu IOM. The N-H absorption was previously detected from reflectance IR measurements of intact Ryugu particles by JAXA curation [4,5], but the peak positions were ~80-90 cm^{-1} lower than the Ryugu IOM.

Overall, the FTIR organic signatures of the Ryugu samples generally agree with CI chondrites but some differences do exist. The high CH_2/CH_3 ratios, aliphatic-rich, and N-rich nature of Ryugu organic matter might indicate primitiveness and freshness of the Ryugu particles. The differences between Ryugu and carbonaceous chondrites could be attributed to modification of organic matter in carbonaceous chondrites due to long preservation on the Earth, which Ryugu samples escaped.

References: [1] Tachibana S. et al. (2022) *Science* 375: 1011–1016. [2] Yabuta H. et al. (2022) *53rd Lunar and Planetary Science Conference*, Abstract #2241. [3] Kebukawa Y. et al. (2011) *Geochimica et Cosmochimica Acta* 75: 3530–3541. [4] Yada T. et al. (2022) *Nature Astronomy* 6: 214–220. [5] Pilorget C. et al. (2022) *Nature Astronomy* 6: 221–225.

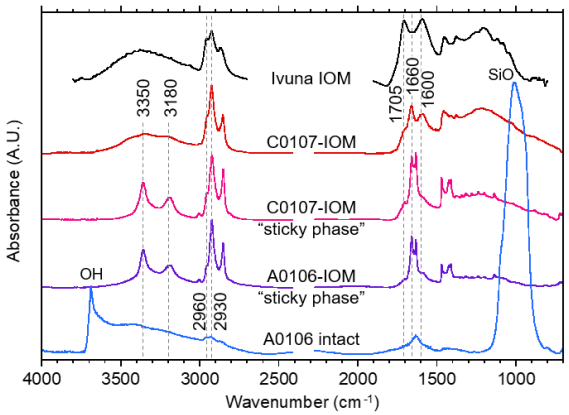

Fig. 1: Typical micro-FTIR spectra of the intact Ryugu grains and IOM. Ivuna IOM is from [3].