Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.30627

Vibrational electron spectroscopy of nanoscale organic matter in Ryugu

CHRISTIAN VOLLMER[1], JOHANNES LIER[1], DEMIE KEPAPTSOGLOU[2] AND QUENTIN M. RAMASSE[2]

[1]Institut für Mineralogie, Universität Münster
[2]SuperSTEM Laboratory

The molecular constitution of organic matter (OM) within returned samples of JAXA´s Hayabusa2 mission is of paramount importance to understand the evolution of terrestrially unaltered organics on water-rich asteroids [1]. Synchrotron-radiation spectroscopy and electron microscopy on minimally processed Ryugu OM show that differences exist compared to other extraterrestrial samples, such as more dominant aliphatic bonding [3] and a higher heterogeneity [4]. In this work, we analyzed Ryugu OM by monochromated "ultra-low-loss" (vibrational) electron energy loss spectroscopy (EELS) in a dedicated aberration-corrected scanning transmission electron microscope ("SuperSTEM"), operated at 60 kV in low-dose conditions to reduce beam damage on carbon-based materials [5]. We investigated two types of Ryugu samples: polished particles embedded into epoxy and pristine particles pressed into indium foils. We acquired spectrum images in the "ultra-low" energy loss region (<0.5 eV) with extremely high energy resolution (~0.01 eV), which has been applied to extraterrestrial materials only very rarely up to now [6,7]. A very rich "vibrational EELS" spectrum with numerous identifiable bands directly comparable to phonon modes known from conventional IR spectroscopy techniques can be mapped at the nanometre scale, confirming the presence and variability of intact functional groups inferred from core-loss analyses. In particular, the distribution of the "1000 cm^{-1}" (= ~0.12 eV) Si-O stretch and the "3000 cm^{-1}" (= ~0.4 eV) C-H stretch modes can be mapped across these vibrational spectrum images. These investigations further demonstrate that Ryugu OM is a highly complex material whose evolution and origins can be traced from interstellar to parent body environments.

Acknowledgements: We acknowledge JAXA for the loan of Ryugu samples, the DFG for funding within project VO1816/3-1, and EPSRC for support to SuperSTEM (EP/W021080/1).

References : [1] Nakamura T. et al. (2022), *Science* 379, p. eabn8671. [2] Yabuta H. et al. (2023), *Science* 379, eabn9057. [3] Ito M. et al. (2022), *Nature Astronomy* 6, 1163. [4] De Gregorio B. et al. (2024), *Nature Communications* 15, 7488. [5] Vollmer C. et al. (2024), *Nature Communications* 15, 778. [6] Vollmer C. et al. (2020), *Meteoritics & Planetary Science* 55, 1293. [7] Laforet S. et al. (2024), *The Astrophysical Journal Letters* 963, L45.