Organic Functional Group Analysis of Asteroid Bennu Samples by Infrared and N-*K*-Edge Partial Fluorescence Yield X-Ray Absorption Spectroscopies

*Yoko Kebukawa[1], Hikaru Yabuta[2], Mutsumi Komatsu[3], Minako Hashiguchi[4], Toru Matsumoto[5], Hiroki Suga[6], Hiroshi Naraoka[7], Yuma Enokido[8], Kanako Sakamoto[8], Tomohiro Usui[8], Shogo Tachibana[9]

1. Institute of Science Tokyo, 2. Hiroshima University, 3. Saitama Prefectural University, 4. Nagoya University, 5. Kyoto University, 6. Japan Synchrotron Radiation Research Institute, 7. Kyushu University, 8. JAXA/ISAS, 9. The University of Tokyo

The OSIRIS-REx mission returned samples from the carbonaceous asteroid Bennu, enabling comparison with Ryugu and aqueously altered carbonaceous chondrites. Although Bennu and Ryugu share many mineralogical similarities, differences in organic chemistry have been reported [1,2]. To characterize organic functional group chemistry, we conducted micro-FTIR and partial fluorescence yield N K-edge X-ray absorption near-edge structure (PFY-N-XANES) analyses on intact Bennu particles and their insoluble organic matter (IOM).

FTIR spectra of Bennu show typical hydrated chondrite features, including silicates, OH, carbonates, and aliphatic C–H, closely resembling Ryugu. Bennu samples exhibit slightly higher CH_2/CH_3 ratios than Ryugu [3,4] and CM/CI chondrites. Bennu IOM displays strong aliphatic C–H along with C=O and aromatic C=C features. Higher CH_2/CH_3 ratios in IOM compared to intact samples suggest preferential loss of short-chain, CH_3-rich compounds during solvent extraction and acid treatment.

PFY-N-XANES reveals three nitrogen bonding states: (A) imine/pyridinic N (N=C), (B) nitrile/pyridinic N, and (C) pyrrolic N/amine/amide/ammonium species (N-C,H). Intact samples show substantial heterogeneity, whereas IOM is more homogeneous and enriched in N-heterocycles. Compared to CI and CM chondrites [5], Bennu exhibits greater diversity in nitrogen functional groups. Differences between intact samples and IOM indicate that single-bonded nitrogen (N-C,H) is partly associated with soluble or acid-labile fractions.

Overall, the diversity of organic functional groups in Bennu is consistent with its rubble-pile structure and heterogeneous aqueous alteration history [6].

References:
[1] Lauretta D. et al. (2024) *Meteorit. Planet. Sci. 59*, 2543–2486.
[2] Glavin D. et al. (2025) *Nat. Astron. 9*, 199–210.
[3] Yabuta H. et al. (2023) *Science 379*, eabn9057.
[4] Kebukawa Y. et al. (2024) *Meteorit. & Planet. Sci. 59*, 1845–1858.
[5] Kebukawa Y. et al. (2025) *Goldschmidt 2025*, Abstract doi:10.7185/gold2025.30315.
[6] Mojarro A. et al. (2025) *PNAS 122*, e2512461122.

Keywords: Asteroids, Bennu, Organic matter

