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Digging into the mantle and flying over the Solar System: Let us bring back samples from unexplored worlds

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Sample return missions from Solar-System celestial bodies have provided solid new geochemical evidence from unexplored worlds and have made outstanding contributions to our understanding of the Solar System [e.g., 1]; (1) Lunar rocks showed that the Moon had a magma ocean during its early evolution and contributed to develop the crater chronology (Apollo, Luna, and Chang'e 5), (2) The large-scale dynamical mixing in the Sun's protoplanetary disk was indicated by returned cometary grains (Stardust), (3) Collected solar wind particles showed that the Sun's oxygen isotopic composition is different from the Earth, Moon, Mars, meteorites, and cometary grains (Genesis), (4) S-type (stony) asteroids are parent bodies of ordinary chondrites, the most common meteorites in the terrestrial collection (Hayabusa), and (5) C-type (carbonaceous) asteroids contain water and organics and could have delivered volatiles to the proto Earth [e.g., 2] (Hayabusa2). A new sample will be back from pristine B-type asteroid in 2023 (OSIRIS-REx), and sample return missions from a Martian moon and Mars are planned (MMX and Mars Sample Return). These sample return missions were/will be made possible by the engineering development. Close collaboration between engineers and scientists is a key for the success of scientific explorations and was indeed critical for the Hayabusa2 sample return mission [e.g., 3-6].

The Earth's mantle is still one of the unexplored frontiers in geoscience even in the era of sample return missions from space. Direct sampling of mantle materials that record the dynamics, origin, and evolution of the Earth system will make enormous contributions to geoscience. This presentation will overview sample return missions from Solar-System bodies, focusing on the JAXA's Hayabusa2 mission that returned surface samples from C-type asteroid (162173) Ryugu, with expectations of sample return from the Earth's mantle.

[1] Longobardo A. (ed.) (2021) Sample Return Missions: The Last Frontier of Solar System Exploration. Elsevier. [2] Yurimoto H. et al. (2022) This meeting. [3] Tachibana S. et al. (2014) Geochem. J. 48, 571. [4] Sawada H. et al. (2017) Space Sc. Rev. 208, 81. [5] Okazaki R. et al. (2017) Space Sci. Rev. 208, 107. [6] Tachibana S. et al. (2022) Science. doi.org/ 10.1126/science.abj8624.