Where do we come from? – What rocks brought back from an asteroid tell us

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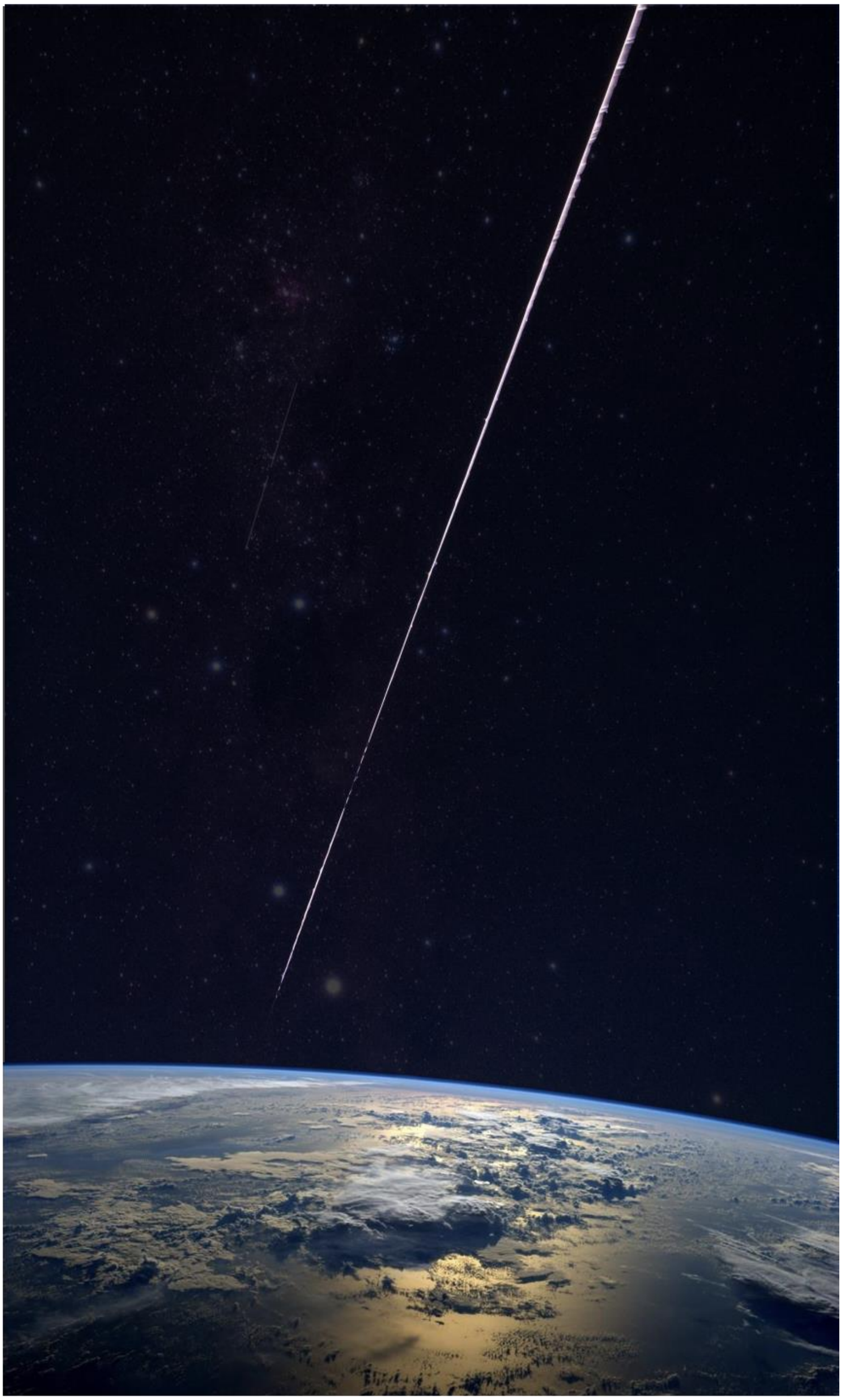

On December 6th, 2020, people saw something bright like a shooting star cross the dawn sky of Australia. It was not an actual star, but instead, the capsule containing samples collected in space by a spacecraft called Hayabusa2.

The Hayabusa2 spacecraft was launched by the Japanese space agency JAXA in 2014,[1] aiming to return samples from an asteroid, which is a small rocky object orbiting around the Sun. After four years of travel, Hayabusa2 arrived at an asteroid named (162173) Ryugu, which was found to have a very dark-colored body with a strange shape like an abacus bead of about 1 km diameter. The spacecraft successfully landed on the asteroid's surface and collected rocks and sands, which were carried back to Earth and finally made a glittering landing on a desert in Australia.

Researchers who first opened the capsule were highly delighted to find as much as 5 g of rock fragments captured in the sample container, which was tens of thousands of times more than the first asteroidal samples returned in 2010 from another asteroid by JAXA’s Hayabusa mission. The samples were as black as Ryugu itself, which made the researchers convinced that they successfully got their hands on the real asteroidal materials.

The Ryugu samples were distributed to researchers all around the world who are normally studying meteorites, which are rocks that originated from asteroids or planets that occasionally fall on Earth and have been of interest in the field of planetary science as tools to investigate materials of the Solar System and the history of their evolution. The researchers who received the samples were excited to analyze them, because unlike meteorites the returned samples are pristine fragments of the asteroid which were neither processed during atmospheric entry nor contaminated on Earth. Another attractive point of the Ryugu samples was that where in space they come from is known.

We know about the parent asteroid, including its location, shape, color, and many other characteristics, which is not the case for meteorites.

The collaborative initial analyses then started in June 2021, which have yielded numerous remarkable findings. The most important finding is that the Ryugu samples are among the most primitive Solar System materials that have been analyzed in laboratories.[2] Previous analyses of meteorites have revealed that they show a wide variety of chemical compositions, reflecting various chemical processes which the parent asteroids or their precursor materials experienced during 4.6 billion years of history of the Solar System. In particular, materials that went through high-temperature processes have lost volatile components such as water to the air. Only a small fraction of the analyzed meteorites have the least fractionated composition similar to that of the Sun, which is the original composition of the entire Solar System. Surprisingly, the composition of the Ryugu materials was classified as this rare group of meteorites, which suggests that they were formed in the cold region of the early Solar System without intense vaporization and have remained chemically unmodified until today.

Another important finding, which is closely related to the first one, is that the samples contain a lot of water. The researchers who observed the Ryugu rocks found that they are composed dominantly of water-containing stones, technically called hydrous minerals. This might suggest that the Ryugu parent body was initially made of rocky grains and frozen water in the cold environment far away from the Sun, which were later warmed up above the melting point of ice and reacted to form hydrous rocks.

The returned samples have told us the history of the asteroid Ryugu, but if we listen to them more imaginatively, they will go on to tell a vivid story about the origin of the Solar System, Earth, life, and humanity.

Researchers have observed a wide variety of materials including gas species and dust grains drifting in cold and diffuse interstellar space, which at some point gather by gravity and eventually evolve into a new star. Some fractions of such materials are not incorporated into the star but start orbiting around it, forming a disk-like structure. In such a disk, the orbiting dust mutually collides and grows step-by-step: dust grows to be pebbles, and then planetesimals (rocky bodies smaller than planets), which finally accrete to form planets like Earth.

Asteroids are important to relate the present Solar System to its evolution history, because they are remnants of planetesimals that were not incorporated into larger bodies, and consequently have maintained original chemical characteristics since they were formed. Thus, studying asteroidal materials enables us to understand the candidate precursor materials from which our Earth was formed. Furthermore, because asteroids are “fossils” of the early Solar System, they tell us about the origin of the Solar System from a viewpoint of materials, including the connection with interstellar materials and chemical processes which accompanied star and planetary-system formation.

Listening to the story that the Ryugu samples tell, we imagine that water on Earth, in the ocean and our bodies, may have been transported by a volatile-rich planetesimal like Ryugu. The water in the planetesimal may have originated from icy dust that was inherited from the precursor of the Solar System. The ice on the dust may have been formed in cold interstellar space long before the birth of the Sun from elements produced by preceding stars and the Big Bang.

“Where do we come from?” is a universal problem that humanity has questioned since ancient times, to which the rock fragments brought back from the asteroid Ryugu may give a hint from the perspective of the origin of materials constituting the physical world that we live in. Researchers are now trying with great excitement to listen to their story more carefully and imaginatively, which may potentially change our fundamental notion of where we are from.

Grammarly was used to correct grammar and spelling.

References

[1]Tachibana, S. et al. Pebbles and sand on asteroid (162173) Ryugu: In situ observation and particles returned to Earth. *Science* **375**, 1011-1016 (2022).

[2]Yokoyama, T. et al. Samples returned from the asteroid Ryugu are similar to Ivuna-type carbonaceous meteorites. *Science* **379**, 786, eabn7850 (2023).

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