Could the asteroid Ryugu be a remnant of an extinct comet?

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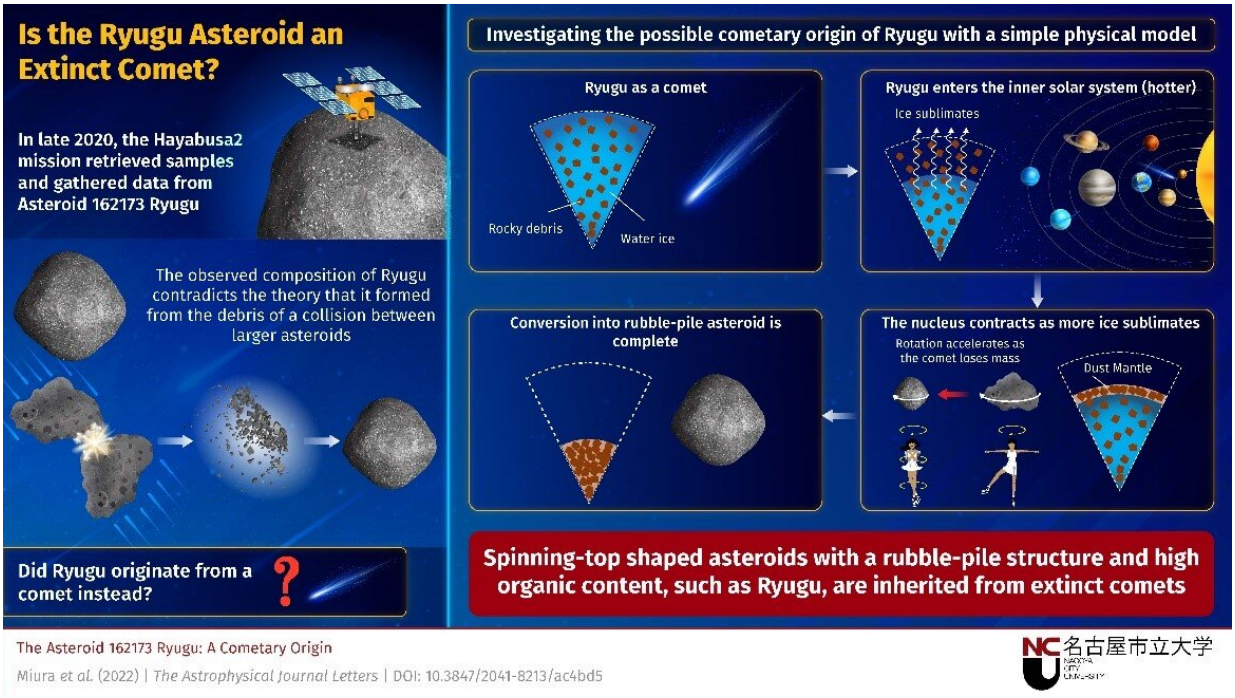

Newly acquired data in the Hayabusa2 mission suggests that the asteroid Ryugu is actually an extinct comet that lost its water ice due to heat from increased solar radiation after getting closer to the inner asteroid belt. Credit: Hitoshi Miura from NCU, Japan

Asteroids hold many clues about the formation and evolution of planets and their satellites. Understanding their history can, therefore, reveal much about our solar system. While observations made from a distance

using electromagnetic waves and telescopes are useful, analyzing samples retrieved from asteroids can yield much more detail about their characteristics and how they may have formed. An endeavor in this direction was the Hayabusa mission, which, in 2010, returned to Earth after seven years with samples from the asteroid Itokawa.

The successor to this mission, called Hayabusa2, was completed near the end of 2020, bringing back material from Asteroid 162173 "Ryugu," along with a collection of images and data gathered remotely from close proximity. While the material samples are still being analyzed, the information obtained remotely has revealed three important features about Ryugu. Firstly, Ryugu is a rubble-pile asteroid composed of small pieces of rock and solid material clumped together by gravity rather than a single, monolithic boulder. Secondly, Ryugu is shaped like a spinning top, likely caused by deformation induced by quick rotation. Third, Ryugu has a remarkably high organic matter content.

Of these, the third feature raises a question regarding the origin of this asteroid. The current scientific consensus is that Ryugu originated from the debris left by the collision of two larger asteroids. However, this cannot be true if the asteroid is high in organic content (which will confirmed once the analyses of the returned samples are complete). What could, then, be the true origin of Ryugu?

In a recent effort to answer this question, a research team led by Associate Professor Hitoshi Miura of Nagoya City University, Japan, proposed an alternative explanation backed up by a relatively simple physical model. As explained in their paper published in *The Astrophysical Journal Letters*, the researchers suggest that Ryugu, as well as similar rubble-pile asteroids, could, in fact, be remnants of extinct comets. This study was carried out in collaboration with Professor Eizo Nakamura and Associate Professor Tak Kunihiro from Okayama University, Japan.

Comets are small bodies that form on the outer, colder regions of the solar system. They are mainly composed of water ice, with some rocky components (debris) mixed in. If a comet enters the inner solar system—the space delimited by the asteroid belt "before" Jupiter—heat from the solar radiation causes the ice to sublimate and escape, leaving behind rocky debris that compacts due to gravity and forms a rubble-pile asteroid.

This process fits all the observed features of Ryugu, as Dr. Miura explains, "Ice sublimation causes the nucleus of the comet to lose mass and shrink, which increases its speed of rotation. As a result of this spin-up, the cometary nucleus may acquire the rotational speed required for the formation of a spinning-top shape. Additionally, the icy components of comets are thought to contain organic matter generated in the interstellar medium. These organic materials would be deposited on the rocky debris left behind as the ice sublimates."

To test their hypothesis, the research team conducted numerical simulations using a simple physical model to calculate the time it would take for the ice to sublimate and the increase in rotational speed of the resulting asteroid due to it. The results of their analysis suggested that Ryugu has likely spent a few tens of thousands of years as an active comet before moving into the inner asteroid belt, where the high temperatures vaporized its ice and turned it into a rubble-pile asteroid.

Overall, this study indicates that spinning top-shaped, rubble-pile objects with high organic content, such as Ryugu and Bennu (the target of the OSIRIS-Rex mission) are comet–asteroid transition objects (CATs). "CATs are small objects that were once active comets but have become extinct and apparently indistinguishable from asteroids," explains Dr. Miura. "Due to their similarities with both comets and asteroids, CATs could provide new insights into our solar system."

Hopefully, detailed compositional analyses of the samples from both Ryugu and Bennu will shed more light on these issues.

More information: Hitoshi Miura et al, The Asteroid 162173 Ryugu: a Cometary Origin, *The Astrophysical Journal Letters* (2022). DOI: 10.3847/2041-8213/ac4bd5

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