PLANETARY SCIENCE

Close-up view of an active asteroid

Particle ejections from Bennu could shape the object and send material into space

By **Jessica Agarwal**

Most asteroids are irregularly shaped celestial bodies tens of kilometers in size or smaller that orbit the Sun inside the orbit of Jupiter. They are mostly rocky and have a wide range of compositions. This distinguishes them from comets, which originate further out in the solar system and contain a large fraction of ice that turns into gas when heated by the Sun and leads to the formation of the characteristic dust tail. On page xxx of this issue, Lauretta *et al.* (*1*) found centimeter-sized debris ejected from the surface of the likely ice-free asteroid 101955 Bennu in images taken by NASA's OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer) spacecraft. The cause of this particle ejection remains somewhat puzzling, but the observations show that asteroids are far from being inert bodies.

The notion that asteroids may not be entirely inert came with the 1996 discovery of a comet-like dust tail following the asteroid 7968 Elst-Pizarro (*2*, *3*). Roughly two dozen objects in asteroidal orbits since then were found to be temporarily ejecting dust in large enough quantities to be observable with Earth-based telescopes. Multiple causes have been identified, but the accepted main sources are sublimation of subsurface water ice (*4*) and collisions with other asteroids (*5*). Break-up or internal reconfiguration due to fast rotation may also lead to dust emission. Processes related to electrostatic charging or thermal effects are possible but less likely to induce detectable activity from Earth, unless an object is very close to the Sun (*6*).

Asteroid 101955 Bennu has a diameter of ~500 m and the shape of a "spinning top"—roughly spherical, but somewhat pointed near the poles and bulgy in the equatorial zone (*7*). Bennu is categorized as a near-Earth asteroid (NEA) because it is located between 0.9 and 1.4 times the distance between Earth and the Sun. Bennu is likely composed of materials similar to a certain type of carbon-rich meteorites found on Earth called the CM-chondrites (*8*). Like most asteroids of its size, Bennu is likely a "rubble pile," a collection of boulders held together mainly by their own gravity and with half of the volume empty (*7*).

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The main purpose of NASA's OSIRIS-REx mission is to obtain a sample from the surface of Bennu (in 2020) and return it to Earth for analysis (in 2023). Since the beginning of 2019, the spacecraft has been thoroughly investigating the asteroid in order to pick and characterize the sampling site (*9*).

Lauretta *et al.* found in images from the navigation camera particles traveling in the near environment of Bennu recorded as bright points against the dark sky. The authors identified three major ejection events in early 2019. About 100 centimeter-scale particles per event left the surface from specific locations and at specific times. The three source locations do not seem to have much in common or to be geologically different from the rest of the surface. But all three events took place in the local afternoon of Bennu. The authors also identified a background population of particles. These particles had a variety of trajectories from many different source regions and ejection times. Some particles were launched into interplanetary space, whereas others eventually fell back to Bennu's surface.

Lauretta *et al.* rule out two "standard" processes for asteroidal particle ejection: ice sublimation and rotational disintegration. They also found that electrostatic lofting of particles from the surfaces of airless bodies was inconsistent with their observations. The authors identify micrometeorite impacts, the loss of water molecules embedded in silicate minerals, thermal stress fracturing of boulders, or a combination of these as possible causes of particle ejection. On Bennu, boulder surfaces have 100 K temperature changes at a centimeter-depth scale and on time scales of the 4.3-hour rotation period. Both the meteorite flux and the temperature at 2 cm depth should peak in the local afternoon, which lines up with the timing of the major particle ejections.

The discovery of particle ejections is surprising and may suggest that all asteroids are active at some level. However, previous spacecraft that have visited asteroids have not documented this type of event. Key answers may come from the Hayabusa2 mission by the Japan Aerospace Exploration Agency to the asteroid Ryugu (*10*), which resembles Bennu in terms of shape, density and orbit but likely is composed of different material. Like OSIRIS-REx, Hayabusa2 is characterizing the asteroid in great detail in order to bring back a sample of it in 2020. The presence or absence of activity will provide some additional constraints on the low-level activity of small asteroids.

The Bennu observations leave open a question of how to predict such low-level activity of the many millions of asteroids not targeted for missions. Estimating the amount of debris that is released into interplanetary space is clearly important but very challenging. Depending on the driving process for Bennu's ejections, there may or may not be a continuum between it and "classically" active asteroids. The activity on Bennu shows that an apparently inactive asteroid harbors a complex dynamic of debris reimpacting the surface or feeding the interplanetary dust cloud. This process may have implications for Bennu's evolution. A similar observation was made at comet 67P/Churyumov-Gerasimenko by the European Space Agency's Rosetta mission, which found small outbursts of gas and debris emission through the comet's entire perihelion passage (*11*). Earth-based telescopes did not pick up this activity (*12*). Isolating the detailed processes across different scales that drive activity on asteroids and comets is important to understand the evolution of these bodies and how they supply dust to interplanetary space.

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