Rosetta readies for its close rendezvous with a comet

Once it drops its lander, the spacecraft will tag along as dusty, icy comet circles the sun

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Very soon, on November 12, a spacecraft called Rosetta will sidle up to a comet, steady itself and drop a 100-kilogram robotic lander toward the hunk of rock, dust and ice. The lander, named Philae, will drift through space, tugged only slightly by the gravity of the comet, commonly called 67P. Mission scientists will be holding their breath for what could be several anxiety-filled hours to see if Philae lands where and how it's supposed to.

The exercise — the first attempt to set a lander on a comet — is as nerve-racking as landing on Mars or the moon, with some added challenges. Comets and other small space rocks have much less gravity than planets or moons, which is why it will take Philae close to seven hours to float to comet 67P's surface. Then there's the comet's speed: Rosetta will drop the lander toward 67P as the comet shoots through the solar system at 55,000 kilometers per hour.

Add to that a comet's unpredictable nature: At any moment and without warning, 67P might spew out jets of gas and dust. Such eruptions could blow the spacecraft off course or skew the lander's trajectory so it hits a boulder or misses its mark.

Early in the mission, scientists estimated that Philae had a 70 to 75 percent chance of successfully touching down on the comet, officially known as 67P/Churyumov-Gerasimenko. They made that prediction when they thought the comet was shaped like a potato. In July, Rosetta began sending pictures of 67P, indicating it looks more like a rubber duck — two masses connected by a thin neck. The new shape adds a bit more uncertainty to Philae sticking its landing.

A busy machine

The comet lander Philae is named after an island in the Nile where two ancient obelisks helped archaeologists decipher hieroglyphics. The lander is equipped with 10 instruments designed to take panoramic pictures of comet 67P's surface and investigate its chemical composition.

The potential payoff of this mission is worth the hazards and the nail-biting, says Matt Taylor, Rosetta's project scientist at the European Space Agency's Science and Technology Center in Noordwijk, the Netherlands. Comets, along with asteroids, are thought to be the oldest, most pristine relics of the early solar system. We can't go back billions of years to the birth of the sun, Taylor says, so exploring comets and asteroids may be the best option for learning how the solar system evolved. Studying their geology and chemistry could give clues to how the planets became what they are today and whether comets brought water and other ingredients for life to Earth.

Cometary close-up

Rosetta's rendezvous with the comet, which is currently traveling between the orbits of Mars and Jupiter, has been a long time coming. The mission was first conceived in the late 1970s. By late 2002, when ESA was preparing to finally launch Rosetta, disaster struck. As part of a separate mission, the same type of rocket that was set to carry Rosetta exploded three minutes after liftoff. That rocket failure delayed Rosetta's launch, closing the window to the original target of the mission, 46P/Wirtanen. Over the next few months, scientists scrambled to find another comet that would be at the right place in the solar system at the right time. 67P fit the bill.

Rosetta finally launched in 2004. Ten years later, on August 6, the spacecraft began orbiting 67P, and its 11 instruments started scrutinizing myriad characteristics of the comet (*SN: 9/6/14, p. 8*). Those instruments, plus the cameras and sensors on the Philae lander, are designed to map 67P, determine what it's made of and observe how its chemistry might change as it swings around the sun.

A long road

More than 30 years since its conception, the Rosetta mission hit a major milestone — catching up with comet 67P — in August. The next big steps are getting the lander Philae to 67P's surface and staying with the comet through 2015.

Rosetta's history

Late 1970s/early 1980s Rosetta mission proposals developed

December 11, 2002 Rocket failure postpones Rosetta launch

March 2, 2004 Rosetta and Philae launch

September 5, 2008 Flyby and imaging of asteroid Steins

July 10, 2010 Flyby and imaging of asteroid Lutetia

August 6, 2014 Rosetta arrives at comet 67P

November 12, 2014 Philae deploys to surface

August 13, 2015 67P and Rosetta make closest approach to sun

December 31, 2015 Proposed mission end date

Credit: ESA, ATG Medialab

As 67P approaches the sun, its ice transforms directly to water vapor and other gases, which, along with dust, shoot outward. These jets collide with other particles from the sun to form two tails. Unlike Halley's comet and its showy run in 1986, 67P's tails won't be visible to the naked eye. But Rosetta will have a front-row seat on the action. As the comet's tails grow, Rosetta will give scientists their most detailed look at a comet and the changes it goes through.

Already, Rosetta's high-resolution photos have shown scientists that 67P looks different than other comets explored with spacecraft. It may even be two comets merged together with a surface that's a mountain climber's dream.

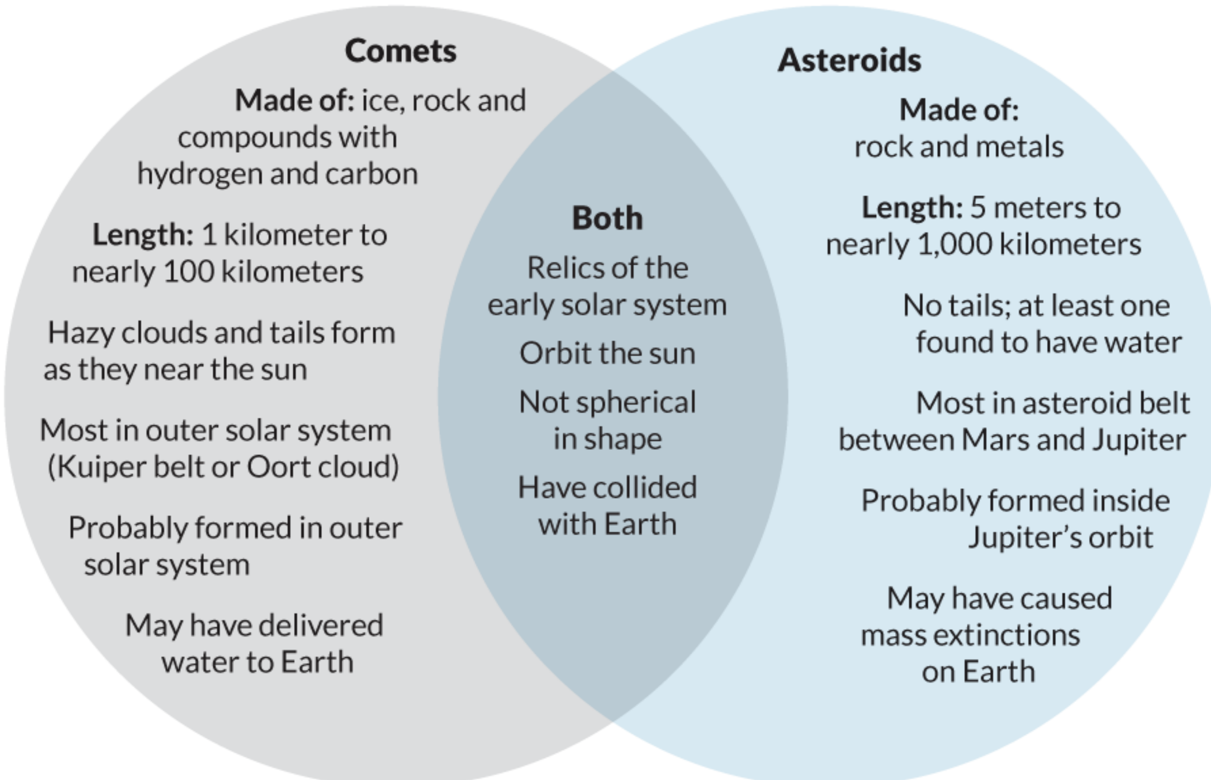
"The team really hit the jackpot with this comet," says Donald Brownlee, a planetary scientist at the University of Washington in Seattle. Seeing a duck-shaped comet with house-sized boulders, craggy craters and 150-meter-high cliffs "really knocks your socks off," he says. The bath-toy shape and rugged surface indicate that the comet has had an interesting life history, one scientists are eager to learn about. But first, they've got to get their instruments down to the comet's surface.

"This very particular shape of the comet doesn't make it easy to land," Philae project manager Stephan Ulamec of the German Aerospace Center in Cologne said at a September 15 news conference. But the team has confirmed that it will attempt to set the lander down in November on a sliver of flat land on 67P's small lobe, or head. The spot is flanked by cliffs, crevices and a few boulders.

It is also covered in carbon-rich dust, according to Rosetta's measurements, which makes mission scientists extremely happy with the site, says lead lander scientist Jean-Pierre Bibring of the Université Paris-Sud in Orsay, France. The lander, he explains, can immediately start testing the comet's surface and drill deeper to look for traces of ice and complex carbon-based compounds, which are among the major requirements for life.

Ice and certain complex carbon compounds are also some of the characteristics thought to distinguish comets from asteroids, the other early inhabitants of the solar system.

Rethinking space rocks



SOURCE: NASA

"At first glance, comets are fundamentally different from asteroids, the way ice cream is different from a cookie," says NASA scientist Claudia Alexander, based at the Jet Propulsion Laboratory in Pasadena, Calif. Most asteroids appear to be made of rocky materials and no water. Comets, however, seem to be icier. These distinctions are thought to explain where comets and asteroids originated as the solar system formed.

Scientists think that around 4.6 billion years ago, the solar system started to form as a giant cloud of gas and dust collapsed inward and coalesced. Most of the material got pulled into the center of the cloud to form the sun. The rest condensed into a handful of huge rocks that became planets plus smaller bodies that became comets and asteroids.

In that scenario, asteroids probably formed between Mars and Jupiter, where it was too hot for water and other ices to survive. Comets, on the other hand, probably condensed farther out in this embryonic cloud where it was considerably cooler and ice could persist and start to attach to clumps of gas and dust.

If comets formed far out in the Kuiper belt or Oort cloud, where there was a lot more ice, they could have ferried a lot more water to Earth than did asteroids from the inner solar system.

Rosetta and Philae will give scientists a chance to virtually “get their hands on” the comet’s ice, says Alexander. That could help them figure out pretty quickly whether comets like 67P brought water to Earth billions of years ago.

The first question: What type of water is on 67P? If it is the same H_2O that makes up Earth’s oceans, then perhaps 67P and similar comets brought that water to Earth. But if 67P, like most comets studied so far, contains a larger amount of the heavy hydrogen isotope called deuterium than does water found on Earth, then the idea that comets brought most of the water here is less likely.

That opens the door for the paradoxical idea that asteroids were the main source of our planet’s water. Scientists have recently found at least one asteroid with water. For example, the asteroid Ceres (actually large enough to be considered a dwarf planet) orbits the sun on a path between Mars and Jupiter, but it spouts off water vapor, sort of like a comet.

To confuse matters further, Rosetta’s observations indicate that 67P has characteristics of an asteroid. The comet, for example, isn’t covered in surface ice. Instead, its water appears to be stored deeper within its core.

These observations hint that comets and asteroids aren’t as radically different as scientists had thought. Instead, they may fall on a continuum with rocky, dry asteroids on one end, really icy comets on the other and everything else in between, Alexander says.

Getting warmer

When a comet gets close to the sun, a lot of its ice turns to vapor, and dust comes shooting out of its core. The comets with shorter orbits around the sun — 67P takes a brief 6.5 years — could eventually lose all of their ice and vapor leaving only rock and dust. Of course, scientists can’t really understand the long-term fate of 67P and other comets until they figure out the chemistry of what happens as a comet swings close to the sun on its elliptical orbit.

“We have theories about what happens to a comet as it gets closer and then moves away from the sun, but we do not understand how a comet really works,” says retired ESA scientist Gerhard Schwehm, one of the original leaders of the Rosetta mission.

That’s because scientists have never been able to stay with one for very long. All the previous comet missions have been flybys, lasting a few hours. If Philae sticks its November landing, it could work on the surface of 67P until March 2015, when the sun’s heat will become too hot for the lander to function. Rosetta will stay with 67P through August, when the comet reaches its closest point to the sun at a distance of 185 million kilometers. But Rosetta won’t give up there. It will continue orbiting the comet until at least December 2015.

Spending a year or more with 67P will give scientists a chance to track how the sun’s heat changes the comet’s composition over time. To do this, Philae will first identify the elements and compounds that make up the comet’s surface. These materials may have survived unchanged for billions of years and could give scientists clues to what materials were available when the solar system started to form.

Scientists are most interested in molecules containing carbon and hydrogen (*SN: 11/1/14, p. 7*), which could have existed even before the birth of the solar system. Investigators are also looking for amino acids and other building blocks of life that may have been brought to Earth by comets. Past missions have found both kinds of materials on comets before (see sidebar above, “Comets visited by spacecraft”). If they exist on 67P, they could add more evidence for scientists’ ideas that comets delivered the ingredients for life to Earth.

However, because scientists have never studied a comet while it faces the sun’s intense heat, they cannot be sure if these molecules are primordial or if they formed later, after being cooked by the sun. There are hints to support both origin stories. Rosetta’s observations could tell scientists if some of the molecules they see on the comet predate the solar system, or if they are created in reactions from the sun’s heat.

The comet’s chemistry could also have implications for places far beyond Earth, says Edward Young, a geochemist at the University of California, Los Angeles. “Establishing the link between these primitive building blocks of planets and our own planet will go a long way toward helping us understand whether rocky planets with at least as much water as Earth are the norm, or not,” he says.

That’s a lofty goal, one that hinges on a spectacular landing and the final 14 months of Rosetta’s 10-year voyage.

READY FOR TOUCHDOWN The Rosetta spacecraft and its lander Philae are ready to make history in a risky rendezvous with comet 67P/Churyumov-Gerasimenko.
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