THE ROSETTA SPACECRAFT

Deciphering the Primitive Matter of the Solar System

by William Jones

A small lander is scheduled to touch down on Comet 67P/Churyumov-Gerasimenk Nov. 12, to begin an *in situ* investigation of the properties of the comet. The landing is the result of a 10-year mission conducted by the European Space Agency (ESA), during which the Rosetta spacecraft has traveled 4 billion miles to reach the comet. At a Sept. 30 lecture at the annual International Astronautical Congress (IAC) in Toronto, the principal investigators gave an in-depth and exciting preview of the mission.

Rosetta, named for the Rosetta Stone, discovered in 1799, in Mephis, Egypt, contained inscriptions in three languages, including hitherto indecipherable ancient Egyptian hieroglyphics. The stone allowed French philologist and orientalist Jean-François Champollion, in 1822, to decipher the hieroglyphics, and thereby to begin to understand this ancient script. The ESA Rosetta Mission is aimed at "deciphering" the ancient composition of the Solar System.

Fascination with Comets Through Centuries

Comets have fascinated mankind for thousands of years. A comet is defined as an icy small Solar System body which, when passing close to the Sun, heats up and begins to spew out gas ("outgassing"), displaying a visible atmosphere or coma, and sometimes also a tail, due to the effects of solar radiation and the solar wind upon its nucleus. Comets have, therefore, often been characterized as "dirty snowballs." But Rosetta is likely to change that, as Comet 67P has not yet revealed any ice, but rather a lot of dirt and rock on it.

The first comets were charted by Chinese astronomers over 1,000 years ago. The oldest image of a comet, dating from 185 B.C., was depicted in a "Silk Atlas of Comets," discovered in 1973. But China has been studying astronomy since as early as 2000 B.C., so it is likely that comets were a part of their observations even further back than the Silk Atlas indicates.

Halley's Comet, which can be seen from Earth every 75-76 years, has also fascinated sky-watchers. The appearance of comets was often seen as a sign of things to come, whether for good or for ill, here on Earth. The first recorded sighting of Halley was also by Chinese astronomers, in 240 B.C. The trajectory of Halley's comet was plotted by the Italian physician Paolo Pozzo Toscanelli, in 1456.

But what do we expect to learn by an *in situ* investigation of a comet? Comets fly through space with a speed greater than any spacecraft, spinning as they go. They have been around for a long time, perhaps billions of years. They thus contain some of the oldest material in the Solar System and thus may hold secrets about its origins—and much else. And as the great Ukrainian-Russian scientist Vladimir Vernadsky indicated, in sending a mission to investigate the remote site of the Tunguska meteorite that had exploded over Russia in


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The European Space Agency's Rosetta spacecraft has traveled 4 billion miles to reach Comet 67P/Churyumov-Gerasimenk. The lander, Philae, is expected to touch down on Nov. 12. This is a video animation of Philae separating from Rosetta and descending to the comet's surface.

1906, a study of meteorites and comets, might also tell us something about whether is or has been life elsewhere in the universe.

"The study of comets is a study of the primitive materials of the universe, going back 4 to 6 billion years," said Gerhard Schwemm, head of Planetary Science at ESA at the IAC lecture Sept. 30. "Comets are the only material from pre-solar nebula, and so this is an occasion to do archeology in space." What scientists hope to learn from the mission, Schwemm said, was how comets work, their origin, an inventory of their chemical composition, their role in evolution, and the possible existence of amino acids or any other chemical substance associated with life. "The mission was originally envisioned as a sample return for study in the lab. Then we decided we would take the lab to the comet.

Jean-Pierre Bibring, of the Institut d'Astrophysique Spatiale, and the lead scientist for the Philae lander (named for another famous discovery in Egypt), which Rosetta will carry into the comet's orbit, indicated what we have already learned about the composition of the comet, namely its shape, its dimensions (about 2.5 miles long), its rotation, its albedo (reflection coefficient; darker than coal), mass, density, gravity, thermal properties and the effects of its outgassing.

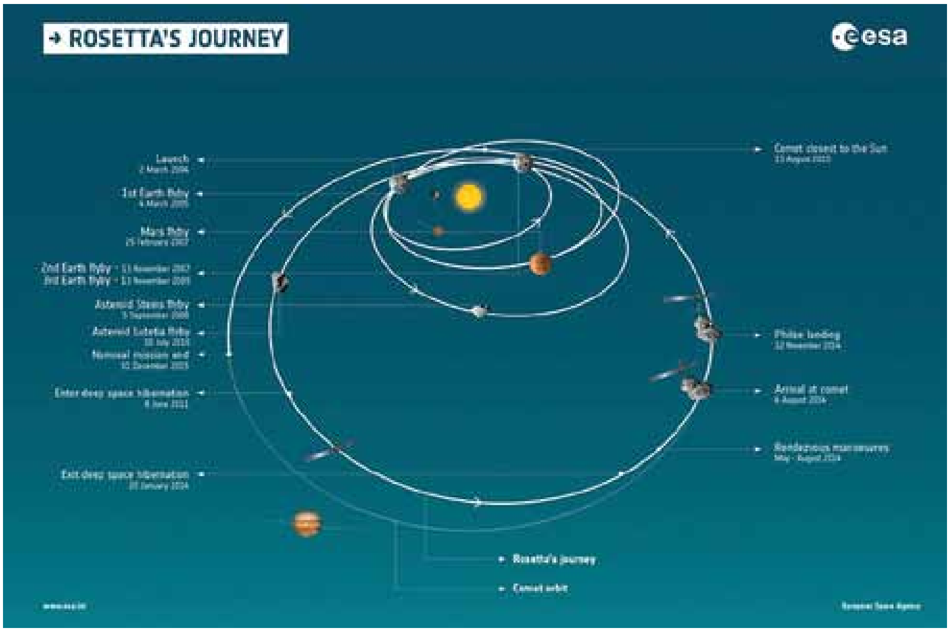
What scientists hope to attain from the *in situ* investigations is information about the comet's internal structure, its magnetic field, its mechanical, electrical, and thermal properties, its elemental composition, including its isotopic and molecular composition, its organic chemistry and any indications of chirality (molecular left- or right-handedness), a factor which may indicate signs of microscopic life.

"Right now we don't see any ice," Bibring said. "We see a crust of organic material with a specific chemistry from when the Solar System was formed. There may be chirality and the thermal properties are colder than we thought. We will drill, take samples and analyze the composition and chirality. This will be the first time that these are measured in space," Bibring said.

A Complicated Mission

Rosetta, which was launched in March 2004, went into orbit around the comet on Aug. 6, 2014. At the time of the IAC conference in Toronto, the orbiter was 18.6 miles from the landing site. The Philae lander is designed to deploy from the main spacecraft and descend to the body of the comet from an orbit of 22.5 km (14 mi) along a ballistic trajectory. It will touch down on the comet's surface at a very slow speed, about 1 meter per second, and will take about 7 hours in its descent. There is 10-20 times less gravity on the comet (the escape velocity is only around 0.5 m/s), so that if the lander bounces a bit, it could be thrown back into space. Therefore its legs have been designed to dampen the initial impact to avoid bouncing. Upon contact, it will deploy two harpoons to anchor itself to the surface to keep it from being thrown back into space. Philae carries a suite of instruments,

FIGURE 1
Rosetta's Journey



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including a drill that can penetrate 23 cm (9 in) beneath the surface.

Two sites have been chosen as potential landing sites, one primary and one for backup, after the number of potential sites was narrowed down from 10, with more information about the comet becoming available as the orbiter approached it. The choice of a landing site has not been an easy matter. The comet's surface is extremely corrugated, with a slight bend in it, making some people think it looks like a duck. There was even a suspicion that the comet had thus resulted from the collision of two different bodies that had fused together, although that hypothesis has been more or less abandoned. The choice of a site had to take consideration of the topology—the existence of boulders, its slope, as well as the amount of sun which would shine at the location, since the Philae lander will be solar-powered. "The site is not ideal for landing," Andrea Accomazzo, the flight director for Rosetta, told the IAC participants at a Late Breaking News update on Oct. 3, "but none are." It is a dusty area and therefore perhaps not so hard and the slope there is only 30°.

As the comet gets closer to the Sun and heats up, it will also increase its outgassing, which could alter Rosetta's trajectory, or kick up dust from the comet which could interfere with Rosetta's optical sensors. Presently the comet spews out water vapor at the rate of one-third of a liter per second, but the rate will increase 100 to 1,000 times as the comet approaches the Sun.

These problems are, of course, compounded by the fact that, at that distance, it takes 30 minutes to send or receive messages between Earth and the satellite. Rosetta will remain in orbit around the comet for at least one year, monitoring the work of the lander as long as the Philae continues operating, and taking its own measurements of the comet. What are the chances of a successful landing? None of the scientists reporting on this very ambitious mission have offered an answer. "Just keep your fingers crossed," Stephen Ulamec, Philae's landing manager, told the audience.