The Rosetta mission – will it reveal the inner secrets of comets?

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Why are comets so interesting?

Although comets seem quite insignificant in terms of mass compared to planets and satellites, they often look very impressive due to extended comas and extremely long tails of rarified dust and gas. However, one might ask whether it is worthwhile spending about a billion euros sending a spacecraft to a comet. Nonetheless, the small size of a comet nucleus, usually in the order of several kilometers, is one important reason for studying it. While planets, satellites and even asteroids have undergone metamorphic changes due to high internal pressures and temperatures, the material from which comets have been formed are presumed to be much more pristine and unaltered since their formation. Thus comets may be viewed as natural probes that can tell us a lot about the previous conditions in the Solar System. The comet tails and comas exist due to out-gassing from the outer layers of the nuclei. Spectroscopic observations from earth, and spacecrafts have revealed the presence of C, H, O and N as atoms and in various molecular combinations of which water ice (H_2O) is very prominent. Due to the presence of complex hydrocarbons in comets, some even believe that life on Earth may have originated in comets. Close-up images of the comet Halley by ESA's Giotto spacecraft, and of the comets Barely and Wild 2 by NASA's Deep Space 1 and Stardust spacecrafts, have confirmed the so-called "dirty ice model" for comet nuclei. However, we still know little about the morphology of the surfaces and next to nothing about the internal structure and composition of the nuclei.

The comet Halley
Photo:Giotto/ESA

Since most comets have almost hyperbolic orbits, they are assumed to come from the outer edge of the Solar System, the *Oort cloud*, at distances between 10000 AU and 50000 AU (1 AU = 150 mill. km). It is widely debated whether this big reservoir of comets is populated mainly by interstellar material kicked in by passing stars or by material pushed outwards by the outer planets from an inner comet cloud, the *Edgeworth-Kuiper belt*, outside of Neptune's orbit. Since 1992 several hundred very dark objects with radii ranging from a few tens to hundreds of kilometers have been spotted in this belt. Some of these objects could very well be comet embryos that will eventually be perturbed outwards to populate the Oort cloud or inwards to become short-period comets, but most short-period comets are believed to be Oort cloud comets with periods drastically reduced by Jupiter's action.

These are the main issues one hopes the Rosetta mission will shed light on.

The Radio Science Investigations

The Institute of Theoretical Astrophysics (ITA), at the University of Oslo, is co-investigator on the Rosetta Radio Science Investigations (RSI). This experiment will use the radio sub-system on the orbiter to make Doppler measurements for very precise orbit calculations. A two-way S-band or X-band radio link is used to track the spacecraft and measure subtle velocity changes (0.3 mm/s accuracy in X-band) from which the gravity field of the comet nucleus can be extracted. Should Rosetta fly sufficiently close to an asteroid, gravity measurements of the asteroid will also be attempted. When the radio signals on several occasions pass through the solar corona, its plasma contents will be measured from the effect on the signals. Detection of gravity waves will be attempted about the same time as the spacecraft is in opposition to the Sun whose disturbing effect then is minimized. A hydrogen maser on the ground controls the radio transmission. The two different frequencies are used to automatically make up for the delays in the Earth's ionosphere. The spacecraft is equipped with an ultra-stable oscillator that makes it possible to use a one-way link to probe the comet's coma and the interior of the nucleus, should it be penetrable by microwaves. This will give information about the plasma content and particle sizes in the coma as well as the size, shape and interior of the nucleus.

The RSI team at ITA (K. Aksnes, P. H. Andersen, E. Mysen and Ø. Olsen) is mainly interested in accurate orbit computations and gravity measurements. Analytical studies and simulations have been made to investigate the stability of the Rosetta orbiter for different orbit configurations under the influence of the comet's gravity field, out-gassing from the nucleus, and radiation pressure from the Sun. A high-accuracy orbit software is being developed for processing the tracking data on Rosetta. This software incorporates several features of a software, GEOSAT, developed at Forsvarets forskningsinsitutt (NDRE) and used for many years for ultra-precise orbit calculations of Earth satellites and station positioning, based on laser and radio tracking of satellites and VLBI measurements on radio sources in the sky.

The anticipated approach for inserting the Rosetta orbiter is as follows; at first a high orbit will be chosen to enable a global view of the comet nucleus. The period and size of the orbit will then yield the total mass of the nucleus through application of Kepler's third law. At the same time, the shape of the nucleus and its rotation axis and rotation period will have been established by images from the orbiter and from radio occultations by the nucleus. The next step is to lower the orbit which then becomes more sensitive to the asphericity in the gravity field whose low-order coefficients can be measured. The gravity measurements are carried out while the comet is still far enough away from the Sun with little out-gassing. Very little is known about out-gassing from the comet Churyumov-Gerasimenko that is estimated to have an elongated shape of roughly 3 by 5 km dimensions. It is likely that when the comet gets close to the Sun, gas jets on the nucleus will develop and perturb the orbiter appreciably, perhaps enough so that the gas flow can be estimated.