Rosetta tracks debris around comet

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Ever since its approach to and arrival at Comet 67P/Churyumov–Gerasimenko, Rosetta has been investigating the nucleus and its environment with a variety of instruments and techniques. One key area is the study of dust grains and other objects in the vicinity of the comet.

Earlier this year, an analysis of measurements from GIADA – Rosetta's Grain Impact Analyzer and Dust Accumulator – and images from the OSIRIS camera revealed hundreds of individual grains, either bound to the comet's gravity or flowing away from it. These included small grains as well as much larger chunks, with sizes ranging from a few centimetres to two metres. Lumps up to four metres in size were also identified by NASA's EPOXI mission in the environment of Comet 103P/Hartley 2 after its flyby of this comet in 2010.

A new study based on OSIRIS images has now built on these previous detections of cometary chunks, using dedicated observations to perform a dynamical study and determine, for the first time, the orbits of four pieces of debris, the largest of them half a metre in size, in orbit around 67P/C-G.

"Previous studies were based on a handful of images of a given field, and this was sufficient to detect chunks of material and say that they are moving. However, to determine their trajectories and demonstrate whether they are truly bound to the comet, we need dozens of images taken over an extended period of time," explains Björn Davidsson, an OSIRIS scientist at Uppsala University, Sweden, and lead author of the paper reporting the new results.

To follow the motion of the cometary debris in fine detail, the scientists monitored a patch of the sky with the OSIRIS wide-angle camera (WAC), which has a field of view of 12 x 12 degrees – over 700 times the area of the full Moon as seen from Earth. Observing over a thirtyminute interval on 10 September 2014, they obtained 30 images, one every minute, with an exposure of 10.2 seconds each.

Incidentally, these observations were performed just a few hours before the manoeuvre that would place the spacecraft on its first bound orbit around the comet. At that time, Rosetta was 30 km away from the comet centre.

When Davidsson and his collaborators later inspected the images, they identified four debris pieces with sizes ranging between 15 and 50 centimetres, making their way against the stellar background in the sequence of images. The chunks appear to move very slowly, with velocities of a few tens of centimetres per second, and are within four to 17 kilometres of the comet.

"This is the first time that we could determine the individual orbits of such pieces of debris around a comet. This information is very important to study their origin, and is helping us understand the mass loss processes of comets," says Davidsson.

It seems that some of these chunks may have been accompanying the nucleus of 67P/C-G for quite a while.

Four image NAVCAM mosaic of Comet 67P/Churyumov-Gerasimenko, using images taken on 10 September when Rosetta was 27.8 km from the comet. Credit: ESA/Rosetta/NAVCAM

In fact, three of these pieces appeared to be bound to the comet's gravity, moving on elliptical orbits, in agreement with what the scientists had expected. However, the paths covered by the grains over the 30-minute long monitoring were too short to enable a unique determination of their orbits, so they cannot exclude that these three chunks are in fact on unbound, hyperbolic orbits.

As for their origin, the chunks might date back to the last time that the comet reached its closest point to the Sun, the perihelion passage in 2009, when they were driven away from the nucleus by very strong sublimation processes. But since the gas drag was not sufficient to free them from the gravity of the nucleus, they lingered in the realm of the comet rather than dispersing into space.

"This study proves that comets can eject such large chunks of material and that these may also remain bound for long stretches of time as the comet swings around the Sun," says Davidsson.

On the other hand, one of the pieces of debris is definitely following a hyperbolic trajectory, which will see it soon depart from the comet's surroundings.

"The outbound trajectory of the fourth lump was a surprise: it suggests that the cloud of debris these objects belong to, bound to the comet since its last perihelion, had already started to dissolve in September 2014, when the comet was 3.4 AU (about 500 million km) from the Sun," he adds.

This is likely the result of increased activity, causing outgassing from the nucleus and pushing the chunk away from the comet's gravity.

One of the three bound lumps also has an interesting trajectory that appears to cross the comet's nucleus, hinting that it might have been ejected shortly before the observations.

The trajectory of the outbound chunk (identified with the letter 'B' in the paper) found around Comet 67P/C-G. The chunk is seen moving against the background of fixed stars. This sequence shows ten consecutive images taken with the OSIRIS wide-angle camera (WAC) on 10 September 2014. The images span 1.9 x 2.1 degrees, showing a portion of the full WAC field of view. Each image was taken with an exposure of 10.2 seconds, with 60 seconds between the beginning of each exposure. Transient point sources are also visible, likely due to cosmic rays, while the long streaks visible in certain frames are caused by dust grains that happened to be close to Rosetta during the exposure. Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

This possibility is as intriguing as it is puzzling, since the comet was still at a very large distance from the Sun at the time for sunlight to cause enough sublimation and release such a large chunk of material from the nucleus surface.

More sets of similar images were collected after last September, and they are being analysed to identify and study the trajectories of other chunks as the comet got closer and closer to the Sun. However, it will be virtually impossible to recover and identify the same chunks in later images.

As far as Rosetta is concerned, the lumps of cometary material detected by Davidsson and colleagues are too sparse to pose any hazard to the spacecraft operations.

But what about much larger lumps of cometary material, several tens of metres across? Such satellites have been detected around many asteroids and other small bodies in the solar system. Is there any evidence for similar 'companions' of Comet 67P/C-G?

Ivano Bertini from the University of Padua, Italy, led a study to look for such satellites around the comet, reporting their results in another paper tto be published in *Astronomy and Astrophysics*. The team used images that were taken with the OSIRIS narrow-aperture camera (NAC) in July 2014, prior to arrival at the comet, to inspect the comet's large-scale surroundings at high resolution.

After careful examination of these images, the scientists found no evidence of satellites around 67P/C-G. The upper limits set by these measurements indicate that no chunks larger than six metres were found within distances of 20 kilometres from the nucleus, and none larger than a metre at distances between 20 and 110 kilometres from the nucleus.

Finding such a large satellite around the comet could have brought additional information to constrain the formation of this curiously shaped body. However, the analysis of Bertini and collaborators does not exclude the possibility that 67P/C-G might have had such a companion in the past, that could have well been lost given the harsh events that characterise a comet's life.

More information: "Search for satellites near comet 67P/Churyumov-Gerasimenko using Rosetta/OSIRIS images." dx.doi.org/10.1051/0004-6361/201525979

"Orbital elements of the material surrounding comet 67P/Churyumov-Gerasimenko ", dx.doi.org/10.1051/0004-6361/201525841

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