Rosetta and Philae at comet 67P/Churyumov-Gerasimenko

June 22 2015, by Hermann Boehnhardt

Fig. 1: A colour image of the Rosetta comet 67P/Churyumov-Gerasimenko shows the two components of the cometary nucleus with grey surfaces. The picture was composed from three images taken by the OSIRIS camera system on 6 August 2014 with the aid of red, green and blue filters from a distance of 120 kilometres. Credit: ESA/Rosetta/MPS for the OSIRIS team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Rosetta has been exploring comet 67P/Churyumov-Gerasimenko since summer 2014. In November 2014, the Philae lander landed on the surface of the comet. The first measurements by the scientific instruments allow conclusions to be drawn about the formation of small bodies in the early phase of solar system formation, cometary activity and the importance of comets for the existence of water on Earth.

Comets are thought to be messengers from the formation phase of the solar system. Formed in the vicinity of the large gaseous planets, some of them were stored in two reservoirs in the solar system during the dynamically very violent clean-up phase of the proto-planetary disk - in the so-called Oort Cloud located at a distance spanning roughly 10,000 to 100,000 times the separation Earth-Sun (=1AU), and in the so-called Kuiper Belt outside Neptune's orbit between 35-50 AU. The vast distance between the reservoirs and the Sun means the comets are deep-frozen (below 100 K) and are therefore considered to be largely unchanged relics from the first 10 to a few 100 million years of the planetary system. Their composition, inner structure and other physical properties should reflect the conditions which more or less prevailed at the time and place where they were formed. Scientists expect there to be a significant proportion of water ice and other types of ice, as well as organic material in comet nuclei. It is possible that collisions led to cometary water contributing to the water in the oceans and in Earth's crust. The organic material in comets was inevitably brought to Earth as well.

The Rosetta mission to 67P/Churyumov-Gerasimenko

After the success of the Giotto probe to Halley's Comet, the European Space Agency ESA decided in 1993 to undertake Rosetta, a scientific mission to a Jupiter-family comet (JFC) as part of the Horizon 2000 programme. The mission's task is to address important scientific issues, as described above (comets and the formation of the planetary system, comets and Earth), with the aid of experimental measurements. In contrast to all cometary probes before Rosetta, which were solely brief fly-by missions with typical local measurement times of only a few hours, the comet was now to be explored over a large part of its orbit around the Sun by means of experiments located on an orbiter. At the suggestion of Helmut Rosenbauer from the Max Planck Institute for Solar System Research and his colleagues, Rosetta was also to deploy a lander on the comet's surface. This would make it possible to undertake the first ever in-situ exploration of the surface layers and the comet's interior.

Nine instrument proposals each were selected for the orbiter and the same number for the lander, supplemented by one experiment which uses instrumental hardware on both the orbiter and the lander for its measurements. The Max Planck Institute for Solar System Research took on the main responsibility for two orbiter instruments (the Osiris camera system and the Cosima dust analyzer), for one lander instrument (the coma gas and soil sample experiment Cosac) and for the whole scientific mission of the Philae lander, and made crucial contributions to a total of three further orbiter (Concert, Miro, Rosina) and two further lander instruments (Romap, Sesame).

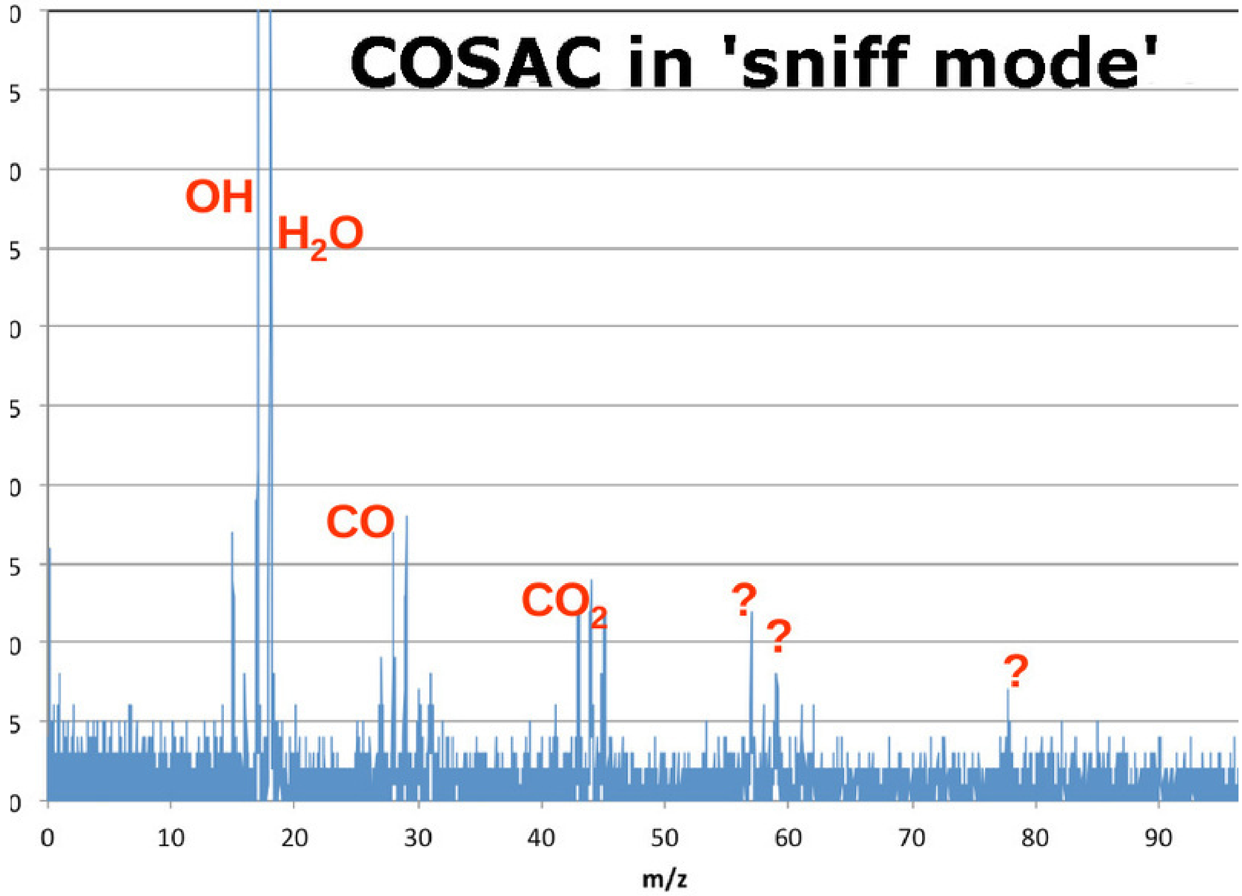

Fig. 2: Cosac mass spectrum, taken during the lander's hopping phase on 12 November 2014. Sniffing mode ("Schnüffelmodus") describes a measurement which allows gas from the cometary coma to be detected. Coma gases identified are labelled in the plot; the question marks denote peaks of organic substances. Credit: ESA/Rosetta/Philae/COSAC/MPS

After a launch delay of one year, which also meant changing the destination comet, Rosetta and Philae set off on their journey of around 7 billion kilometres and roughly 10¼ years to comet 67P/Churyumov-Gerasimenko (67P for short), assumed to be a typical JFC, on 2 March 2004 on board an Ariane 5 rocket. Since adjustment to the cometary orbit could not be achieved by means of rocket engines, so-called gravityassist-fly-bys of Earth (3x) and Mars (1 x) were carried out; as they journeyed through the asteroid belt in the solar system, they were also able to investigate two asteroids, (2867) Steins on 9 September 2008 and (21) Lutetia on 10 July 2010, by means of fly-bys. At the beginning of August 2014, Rosetta arrived at comet 67P at a separation of roughly 100 km and has been carrying out the scientific measuring programme of the orbiter mission close to the comet at heights of between approx. 10 and several 100 km above the surface of the nucleus ever since.

Descent onto the cometary nucleus

Philae landed on the surface of the comet on 12 November 2014. The purely passive lander pushed off from the Rosetta orbiter at 08:35 UTC at an altitude of 22.5 km above the surface with a relative speed of 19 cm/s and started its 7-hour descent to the surface of the comet. Its destination was the previously selected landing region J on the smaller component of the cometary nucleus. Despite a large predicted landing ellipse, Philae first touched down at 15:34 UTC only 150 m away from its nominal target. Since the harpoons, which were to firmly anchor the lander to the comet's surface, failed to fire, Philae set off on a tumbling and bouncing excursion of more than 1 km across the surface and only came to rest after almost 2 hours and two further, brief contacts with the ground at the edge of landing region B. The limited battery power then meant that the scientific measurements of the lander had to be implemented and carried out within around two days without any accurate knowledge of the landing site or the attitude of the lander. Despite these unexpected circumstances, the lander team succeeded in operating each instrument at least once, some even several times, for scientific tasks. On 15 November 2014, shortly after midnight, the board computer switched the lander into so-called hibernation mode, as its electric power was running low. This initially meant it was not operating; neither was there any contact to the orbiter, and thus to Earth.

First highlights from Rosetta and Philae

Osiris camera images show a cometary nucleus which consists of two different-sized sub-components linked to each other via a narrow neck region (Fig.1). The sub-components are deemed to be so-called planetesimals which were joined together by collision, probably as the cometary nucleus formed [1]. The neck region is either widened or dissolved by the continuous activity of the comet, a question which the Rosetta mission will follow up by means of further observations. Surface signatures in Osiris images and the range of values for the surface's thermal inertia determined by Miro indicate layers of loose regolith, which deposited in the form of fallback material from the cometary activity [1-3]. At its final landing site, the lander encountered very solid, plate-like surface structures, which can be explained by sintering processes caused by the solar heating and activity of the cometary material. An average density of significantly less than 1 g/cm3 has been determined for the cometary nucleus, which indicates low compaction and a high microscopic and/or macroscopic proportion of voids in the cometary nucleus. Magnetic field measurements made by Romap during the descent show that magnetic fields cannot have played an important role in the formation of the cometary nucleus during the early phase of the solar system.

The Rosina instrument has already been able to detect more than twenty volatile gases in the cometary coma, which vaporize from the ice in the comet's nucleus through solar heating. Water is the main component, followed by carbon dioxide, which can even dominate on the night side of the comet. The D/H isotopic ratio of deuterium to hydrogen in the water gas of 67P is three times the value for oceanic water on Earth. This indicates that comets such as 67P cannot have been the only source for the water on Earth and together with earlier D/H measurements in other comets proves that these bodies must have been formed in a broader span of distances in the solar system and were then mixed in the reservoir of the Kuiper Belt.

The non-volatile or low volatility component of the cometary material, which is released by the activity of the nucleus in the form of dust, for example, consists of silicate and organic compounds. The dust consists of grainy aggregates some of which are held together only very loosely. Cosac probably picked up some cometary dust which was fortunately whirled up during the lander touch down, analyzed it as the lander tumbled across the surface and found a significant carbonaceous and nitrogenous organic content (Fig. 2), which can probably/best be categorized as alcohol, amine, amide and/or aldehyde compounds.

Rosetta and Philae in 2015 and 2016

The year 2014 saw the start of Rosetta's and Philae's scientific missions. The orbiter will accompany and continuously observe the comet on its journey to the point at which it is nearest the Sun in August 2015 and even beyond. An important task here is to decipher the processes which cause and determine the cometary activity. The lander, if it awakes as expected from the hibernation forced upon it by the lack of energy from solar insolation, can play an important role here. It will then be possible to search for amino acids and determine their chirality from soil samples obtained with Philae's SD2 drill. In 2016, if ESA agrees, Rosetta could make an excursion into the cometary tail and investigate the local plasma and magnetic field conditions which generate the interaction between the solar wind and a still weakly outgassing cometary nucleus. Philae will then probably rest on the surface of the nucleus with all its systems already switched off.

More information: "On the nucleus structure and activity of comet 67P/Churyumov-Gerasimenko." *Science* 347 (6220), aaa1044 (2015)
DOI: 10.1126/science.aaa1044

"Subsurface properties and early activity of comet 67P/Churyumov-Gerasimenko." *Science* 347 (6220), aaa0709 (2015) DOI: 10.1126/science.aaa0709

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"67P/Churyumov-Gerasimenko, a Jupiter family comet with a high D/H ratio." *Science* 347 (6220), 1261952 (2015) DOI: 10.1126/science.1261952

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