Tom Lyons

Catching a comet

The Rosetta mission

Key words

comet

spacecraft

gravity

solar system

In 1802, the Rosetta Stone was first displayed at the British Museum, in London. The three scripts inscribed on the stone allowed the modern translation of Egyptian hieroglyphs. Fast forward 200 years to 2004, and the European Space Agency's Rosetta spacecraft is launched on an Ariane 5 rocket: its destination – Comet 67P/Churyumov-Gerasimenko; its goal – to understand more about the origins of life in our solar system.

Rosetta will arrive at Comet 67P in August 2014. In November, it will deploy a probe, called Philae, which will land on the surface of the comet. Rosetta has recently woken up from deep space hibernation but it has not been lazy on its ten year journey to the comet. It has had three Earth gravity assists and one Mars gravity assists on its way and it has flown by asteroid Steins and asteroid Lutetia.

Gravity assist

Gravity assists, also known as slingshot manoeuvres, are used to speed up the spacecraft and to allow it to achieve the correct orbit to rendezvous with the comet. The spacecraft's orbit brings it close to a planet so that it is pulled on and accelerated by the planet's gravity. Momentum is transferred from the planet to the spacecraft – this is essentially an elastic collision. The linear momentum gained by the spacecraft is equal in magnitude to that lost by the planet, though the planet's enormous mass compared to the mass of the spacecraft makes the resulting change in the planet's speed negligibly small. The direction of the spacecraft's orbit is also changed.

The Rosetta Stone, now in the British Museum, was used to decode Egyptian hieroglyphs. Scientists hope that the Rosetta mission will help to decode the history of life in the solar system.

Gravity assist	Launch	Earth-1	Mars	Earth-2	Earth-3
Date	02-Mar-04	04-Mar-05	25-Feb-2007	13-Nov-07	13-Nov-09
Velocity relative to the Earth (km/s)	3.547	3.863	8.809	9.362	9.379
Closest approach to centre of planet (km)	6771	8341	3650	11680	8861

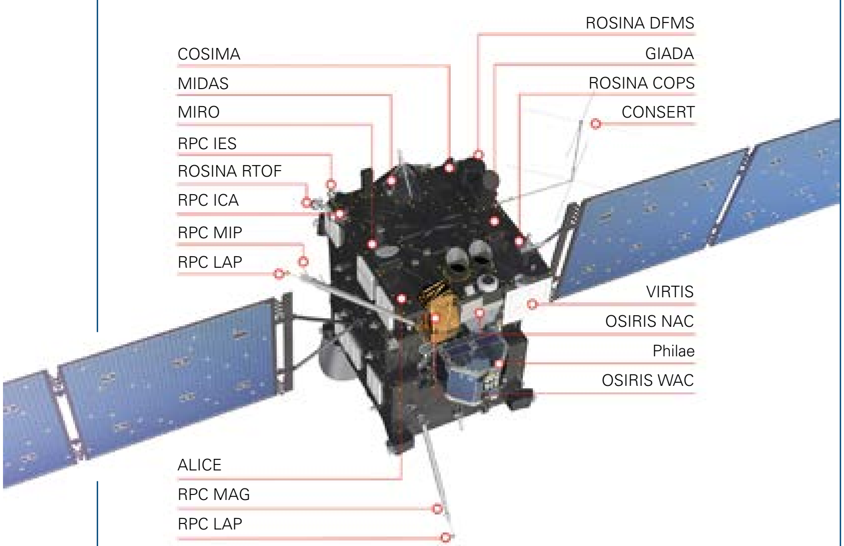
Details of Rosetta's four gravity assist manoeuvres

The table gives the calculated velocities relative to the Earth for the four sling-shot manoeuvres. The declination of the orbit also has to be considered to ensure that the spacecraft achieves the correct orbit to chase the comet. (The declination is the angle at which the comet's orbit crosses the plane of the Earth's orbit.)

All planets have slightly elliptical orbits but most are very nearly circular and they all lie in roughly the same orbital plane. Comets on the other hand have highly elliptical orbits with significant degrees of inclination with respect to the orbits of the planets. Most comets orbit the Sun in a region called the Oort Cloud, at the edge of our solar system, and never come close to the Sun. However, some comets have shorter orbits and, at their closest approach to the Sun, have long tails which can sometimes be seen with the naked eye from the Earth.

Reaching the comet

Once Rosetta has caught up with Comet 67P it will orbit the comet to observe the light emitted from the nucleus and coma (the tail of the comet) and examine gas and dust particles given off by the interaction between the solar wind and the comet. Rosetta has 11 instruments from institutions from across Europe and the United States and the lander has 10 scientific instruments.



Rosetta's instruments

ALICE Ultraviolet Imaging Spectrometer
CONSERT Comet Nucleus Sounding
COSIMA Cometary Secondary Ion Mass Analyser
GIADA Grain Impact Analyser and Dust Accumulator
MIDAS Micro-Imaging Analysis System
MIRO Microwave Instrument for the Rosetta Orbiter
OSIRIS Rosetta Orbiter Imaging System
ROSINA Rosetta Orbiter Spectrometer for Ion and Neutral Analysis
RPC Rosetta Plasma Consortium
RSI Radio Science Investigation
VIRTIS Visible and Infrared Mapping Spectrometer

Philae the lander

How Philae may look after landing on the comet's surface

If successful, the probe Philae will be the first ever to land on the surface of a comet and take in-situ measurements. Scientists will be keen to compare the results with that of other cometary missions and with ground-based measurements of comets.

Philae will actually harpoon the comet so that it is tethered to the surface. This is because the mass of the comet is so low compared to a planet or a Moon that the gravitational attraction between the two is not enough to ensure a secure landing.

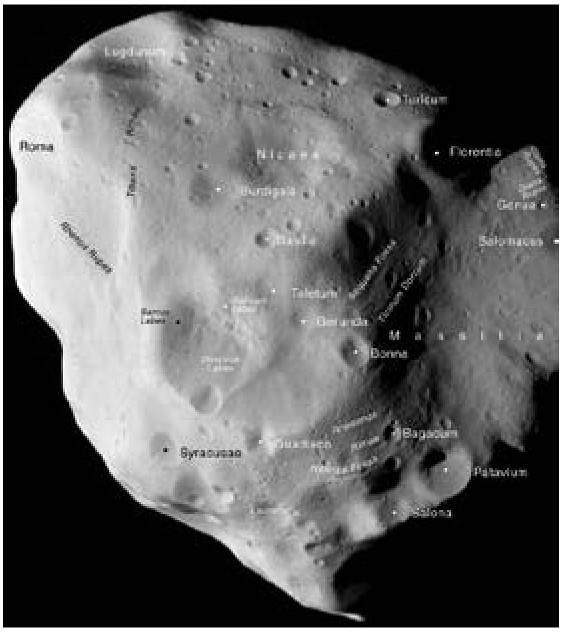
We can use Newton's law of gravitation to calculate the force F with which the comet will attract the lander Philae. Mass of Comet 67P $M = 3\times10^{12}$ kg approx.; mass of Philae m = 100 kg approx.; comet radius r = 2000 m; gravitational constant $G = 6.67\times10^{-11}$ Nm^2/kg^2.

$F = GMm/r^2 = 0.005$ N. This is roughly the weight of a 0.5 gram mass on the Earth (about the same as a paperclip) and far too small for the comet to hold on to the lander.

Ancient evidence

Comets and asteroids are the oldest objects in our solar system. They can provide information on what the solar system was like as it was forming, 4.5 billion years ago. Comets are also known as dirty snowballs because they are made up from a lot of ice, some silicates, carbon, hydrocarbons and a few more complex molecules, such as amino acids. Amino acids have also been called 'the building blocks of life'. It may be that life on our planet was seeded by a comet (or comets). It is also possible that the water on our planet originally came from the impacts of comets on the surface of the Earth.

Rosetta's flyby of the asteroid Lutetia has proved important in studies of the make-up of asteroids. Discovered in 1852, Lutetia was one of the first objects to be classified as an M-type (metallic) asteroid but subsequent measurements of the light reflected from the asteroid suggested more similarities with carbonaceous or C-type asteroids. Rosetta's flyby in 2010 allowed scientists to map the surface of the asteroid. It was found to have many large impact craters and several hundred large boulders on its surface. It was found to have a high density, suggesting a metallic core covered with a more rocky exterior.



Rosetta's map of the asteroid Lutetia which it flew past in July 2010

Rita Schulz, like other scientists working on the Rosetta project, gives public presentations about her work.

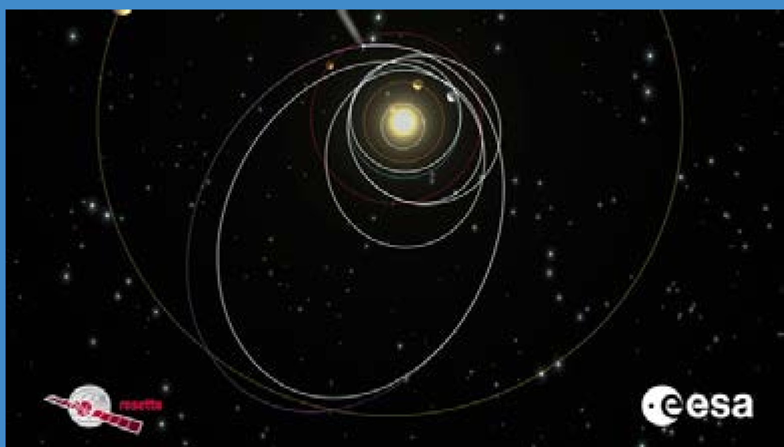
"This is a crucial step in understanding the asteroid belt," said Rita Schulz, one of ESA's Rosetta Project Scientist. "Having seen several members of the belt in the past that were all different in their own ways, we have now found a large and rather primordial body. Clearly, there is still much more to investigate before we understand the belt fully.

"The excellent scientific results of Rosetta's two asteroid encounters (Lutetia and Steins) also show how important it is – when possible – to add asteroid flybys to any mission," she added.

Rosetta mission: key dates

Event	Nominal date
Launch	2 March 2004
First Earth gravity assist	4 March 2005
Mars gravity assist	25 February 2007
Second Earth gravity assist	13 November 2007
Asteroid Steins flyby	5 September 2008
Third Earth gravity assist	13 November 2009
Asteroid Lutetia flyby	10 July 2010
Enter deep space hibernation	8 June 2011
Exit deep space hibernation	20 January 2014
Rendezvous manoeuvre	May 2014
Arrive at comet	August 2014
Start global mapping	August 2014
Lander delivery	November 2014
Closest approach to the Sun	13 August 2015
End of mission	31 December 2015

Spacecraft Operations Manager Andrea Accomazzo and his colleagues are jubilant when Rosetta reactivates after deep space hibernation in January 2014.



Look here!

An animation showing the journey of Rosetta including gravity assist fly-bys and its rendezvous with the comet: *bit.ly/1dkf1ky*

Tom Lyons has worked as an engineer on space satellite systems and as a physics teacher. He is now based at the National STEM Centre in York.