

Artificial comets

Snowballs with tails

„When they had heard the king, they departed; and, lo, the star, which they saw in the east, went before them, till it came and stood over where the young child was. (Matthew 2:9)“. Despite what the Christmas lights might make us believe, the “Star of Bethlehem” probably was not a comet. Comets are not even stars. But we humans have been interested in comets for millennia. After all, it is very hard to miss a comet that is close to Earth...

In this experiment, we will try and find out more about comets by making an artificial one and observing it in a simulation chamber. Similar experiments were carried out at the DLR as preparation for missions to “proper” comets.

From heralds of evil to objects of research

The many documents on and pictures of comets are proof that people have long been fascinated by comets. The word “comet” (from the Greek *κομήτης*) means hairy or tailed star. Comets were thought to be heralds of important things to come. It was thought, for example, that King Harold’s defeat and death at Hastings in 1066 was foreshadowed by Halley’s Comet. The events of the Norman conquest are depicted in the Bayeux Tapestry.



Depiction of Halley's Comet on the Bayeux Tapestry, around 1070.

About 230 years later, the painter Giotto di Bondone used Halley's Comet as a guideline for his painting "Adoration of the Magi" in the Scrovegni Chapel in Padua. If you want to see Halley's Comet for yourself, you will have to wait until 2061.



Adoration of the Magi, Giotto di Bondone, Padua, 1303.

In 1531, Peter Bienewitz – also known as Apianus – printed a calendar that contained the first scientific representation of a comet's position in relation to the Sun's. In this calendar, Apianus uses his observations of Halley's Comet to show that a comet's tail always points away from the Sun.

However, it was not until 400 years later that L. Biermann presented a scientific explanation for this phenomenon. He explained the directionality of comet's tails with the help of the effect of the fast solar wind (900 km/s). The Sun is a star, a "ball of gas" that constantly releases gas flows from its outer atmosphere – or solar wind – into space. When a comet is close to the Sun, gas particles within its nucleus are discharged and pushed in the opposite direction to the Sun by the solar wind. By the way, the

interaction between solar wind and Earth's magnetic fields is what causes the aurorae or northern and southern lights.



Peter Bienewitz, referred to as Apianus: passage of (Halley's) Comet with the appropriate solar position (Landshut, 1531).



Halley's Comet, photograph taken through a large telescope on 9th January 1986 (by courtesy of Max Planck Institute for Astronomy). The comet is a few hundred million kilometres long. However, its nucleus is a body of ice and minerals about 13 km in size.

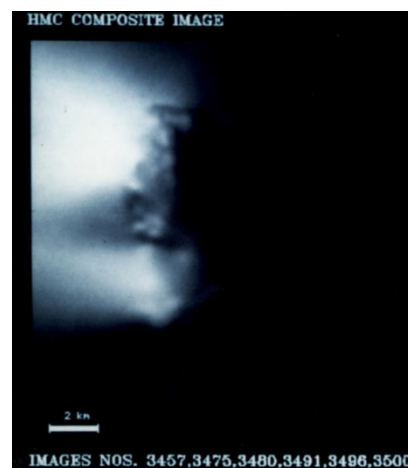
Dirty snowballs

Comets formed about 4.5 billion years ago, at the same time as our solar system. An estimated one hundred billion comets surround our solar system beyond the orbit of our outermost planet, Neptune. These comets make up the Kuiper belt and the Oort cloud. Some comets leave their "parking position" due to collision with other comets or because of the gravitational pull of passing massive objects and hurtle towards the Sun. They circle the Sun in highly eccentric elliptical orbits – if they get that far at all. It can take them anywhere between a few years to a few millennia to orbit the Sun. Halley's Comet takes 76 years to orbit the Sun.

The majority of a comet's existence is spent in a frozen state. Only when they come close to the Sun do they heat up. The ice in the comet is volatilised, water vapour streams out of the nucleus and

drag dust particles along with it: this leads to the formation of a gas and a dust tail. The comet's activity, the emission of gases, begins and ends at a distance of 3 astronomical units¹ between Sun and comet.

Depending on the composition of the comet, an almost spherical coma will develop out of the emitted gas and dust particles and surround the nucleus. The comet also develops its characteristic tail, which can be hundreds of millions of kilometres long and which we can see quite clearly from Earth.



In March 1986, the probe Giotto gave us the first images of the nucleus of Halley's Comet when it took these pictures from less than 1000 km away.

In 1986, an entire fleet of space probes flew to Halley's Comet to confirm the hypothesis proposed by astrophysicist Fred Whipple that within these huge comets lie relatively small "dirty snowballs" (or "icy dirtballs"). The nucleus is only a few kilometres in diameter.

Recent decades have seen the Stardust and Deep Impact probes fly to different comets and send close ups of their nuclei to Earth. The Stardust probe was even able to send dust from the comet's tail to Earth, where it is currently being analysed in scientific laboratories.

¹ one astronomical unit is the mean distance between the Earth and the Sun = 149.6 Million km



Comet Wild 2 (diameter about 5 km); image taken by NASA probe Stardust on 2nd January 2004 (Image: NASA)

The European probe Rosetta is currently on its way to the comet Churyumov-Gerasimenko, where it will land its daughter probe, the Philae robot, in November 2014. This mission will chart the development of the nucleus into an active comet as it comes closer to the Sun. During your visit to the DLR_School_Lab, you will visit Philae's control centre.

Our experiment

In the DLR_School_Lab, we will make our own comet material and observe it in space-like conditions in our pressure chamber.

Caution! You will be working with liquid nitrogen. It is extremely cold (-196°C). Wear protective gloves and goggles during the experiment!

Getting liquid nitrogen into your eyes can lead to blindness. Make sure it does not come into contact with your skin, as frostbite can occur very quickly!

Only work with your instructors and follow their instructions at all times. It is in your own interest to adhere to these precautions as they ensure your safety.

Artificial comet material

The basis for our artificial comet is slurry of 10 per cent by weight of minerals (olivine) and 1 per cent by weight of carbon black for the colour.

This suspension is then nebulised with the help of a high pressure spray valve and the resultant particles are frozen in

liquid nitrogen. The material forms small, icy particles that look like black snow. It is then transferred from the nitrogen tank to the DLR_School_Lab, where we fill it into our pressure chamber.

Space-like conditions

We use our pressure chamber to simulate the heat, light, temperature and pressure conditions of space. Obviously, we cannot influence gravity. The pressure within the chamber is reduced to 0.4 mbar and the temperature down to -50°C. After we have tilted the chamber (illustration next page), we can turn on our "Sun" – a floodlight. We can adjust the intensity of the light with the help of an aperture: higher light intensity corresponds to the comet being closer to the Sun.

The light that illuminates the comet's surface in our experiment is about as bright as the light of the Sun as seen from the earth. Therefore please do not look directly into the light and use the protective sunglasses!

This is an experiment that takes some time. Therefore all three groups will share the work between them. You will not be able to see any results until after the lunch break. You should have a look at what has become of the comet before the third and final group takes it out of the pressure chamber, or you will miss the most important part of the experiment!

Observe the comet

- > Does the surface change?
 - > Can you observe a tail?
 - > If so: In what way does it differ from your expectations? Why?
- After you have taken the comet out of the chamber, measure the hardness of the surface.
- > What has changed? What consequences should that have for the construction of a comet lander?

...and then we should probably talk about why we even want to know all of this.



Comet Hale-Bopp in 1997 (Image: NASA)



Versuchskammer zur Kometensimulation im DLR_School_Lab Köln

Literature:

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Whipple, F.L. The Mystery of Comets, Cambridge University Press, Cambridge,



After a ten year's journey, the Lander „Philae“ of the Rosetta probe will land on the comet Churyumov-Gerasimenko in November 2014.

DLR at a glance

DLR is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport, digitalisation and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Goettingen, Hamburg, Jena, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

DLR Cologne

Aviation, space travel, transportation, energy and safety are the research areas pursued in the nine research facilities at DLR Cologne. The basis of the research and development carried out on site are the large testing facilities such as wind tunnels, turbine and materials test benches and a high-flux density solar furnace. The 55 hectare/ 136 acre site is home not only to the research and administrative facilities of the DLR, but also to the European Space Agency's (ESA) European Astronaut Centre (EAC). The DLR has around 1400 employees in Cologne.

About the experiment:

Recommended for grade(s): 9 to 13

Group size: 5 to 6

Duration: 50 minutes

Subject matter:

Astronomy
Physics



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