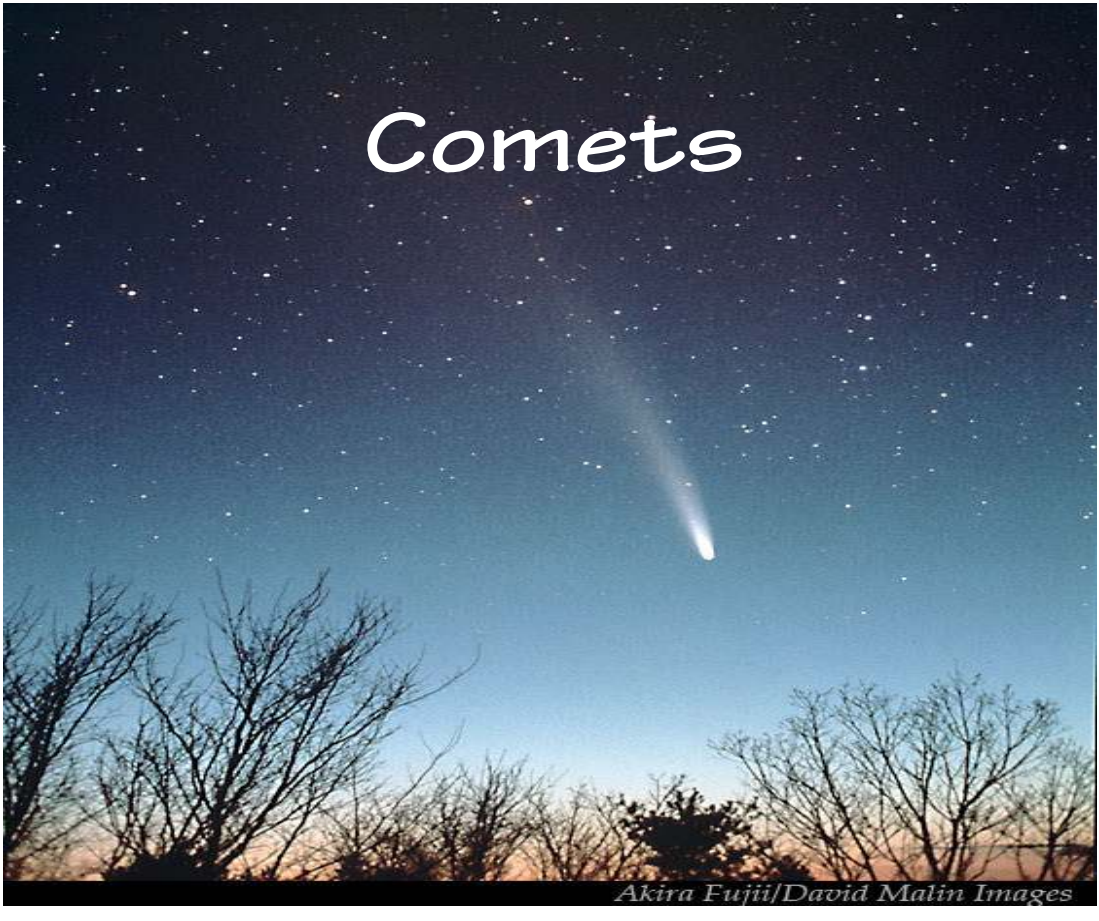
The Universe in my pocket



TUIMP

No. 22

THE UNIVERSE IN MY POCKET

Grażyna Stasińska

Observatoire de Paris

Comet symbol engraved in stone about 3000 years ago. Valcamonica, Italy.

The Silk Book of Mawangdui dates from the 8th century BC and contains descriptions of 29 comets that appeared over a period of several centuries.

The comet of 1401 preceded a great plague in Germany. Image from the Book of Miracles (1552)

Moctezuma looking at the comet of 1519 just before the end of the Aztec empire. Duran Codex, 1581

The announcement that the tail of Halley's comet would sweep over the Earth in May 1910 triggered mass hysteria.

Seeing comets in the sky

From the earliest times, people have been captivated by the appearance of unusual stars, frail nebulae with blond hair, so different from the points of light that are stars or planets. Unlike stars, which have unchanging relative positions, and planets, whose reappearance in the sky is regular, the appearance of comets was completely unexpected - until the 17th century, as we shall see.

Is this why comets in some cultures were associated with evil deities or bad omens? The appearance of comets in the sky was often followed by a meteor shower, which added to their frightening character. Even in the 20th century the approach of comets could cause irrational fears.

Halley's Comet in 1066 in the Bayeux Tapestry (11th century). In the same year the Normans defeated the English at the Battle of Hastings.

Halley's comet in 1301 on a fresco by Giotto from 1305.

Halley's comet in 1531

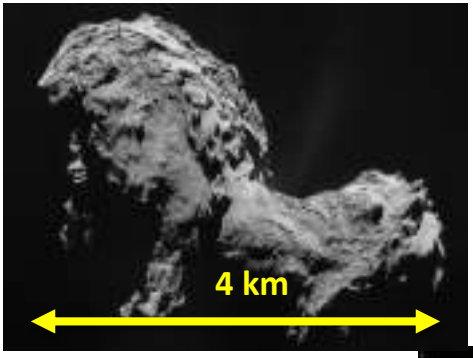
Credit: Science Museum Group Collection

Halley's Comet over London in 1759. Painting by Samuel Scott.

Where do comets come from?

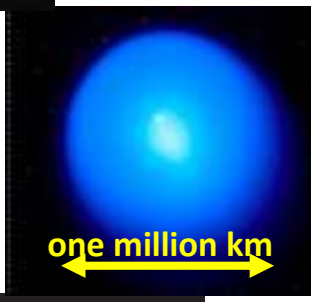
In 1705, the English astronomer Edmond Halley hypothesised that the comet of 1682 was the same one that had been seen in 1531 and 1607. The theory of gravitation developed by his friend Isaac Newton (see tuimp 2) made it possible to explain the comet's reappearance and also to calculate when the next apparition would occur. Halley made the calculat-ions and found that it would be in 1758. The comet appeared in 1759, and was named after Halley. It was a great success for the theory of gravitation.

Halley also suspected that comets come from a 'comet reservoir'. In 1950, Jan Oort showed that this reservoir is located one hundred thousand A.U. (see tuimp 15) from the Sun and probably contains a thousand billion comets. This reservoir is called the Oort cloud.

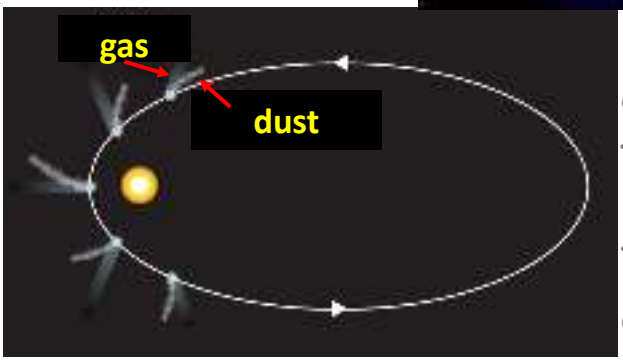


The **nucleus** of comet 67P/Churumov-Guerassimenko taken by the Rosetta probe in September 2014. (ESA)

(Image obtained with the telescope CFH)



The **coma** of comet 17P/Holmes in 2007.



Direction of the tails of a comet according to its position relative to the Sun. They are always opposite to the Sun.

The tail of a comet balloon shows its trajectory.

Comet Hale-Bopp in 1997 with its blue plasma **tail** and white dust **tail**.

(Photo taken by an amateur astronomer)

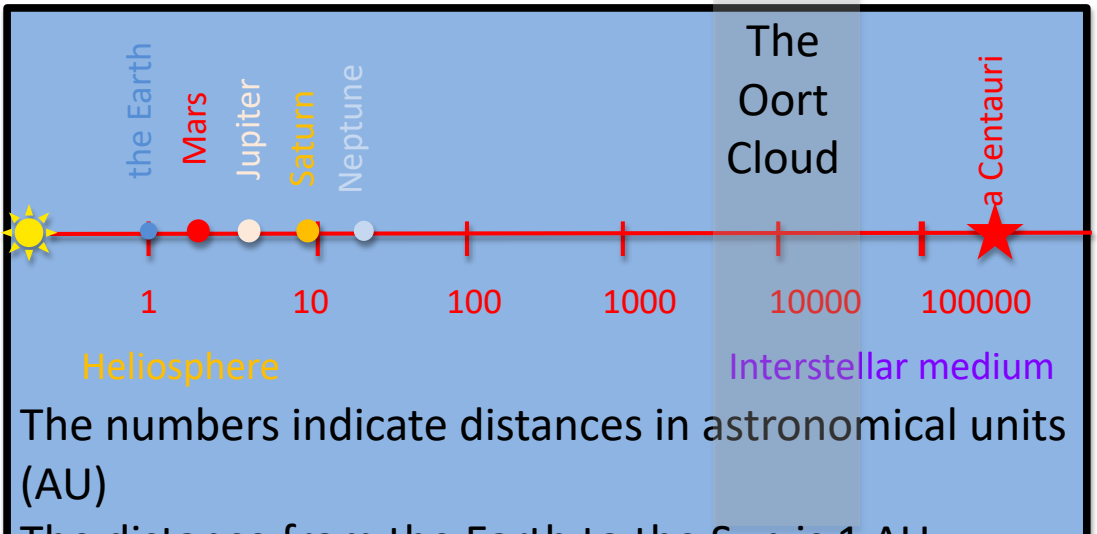
The structure of comets

Today, the nature of comets is well understood. They consist of a solid nucleus a few kilometres in size. This nucleus is made up of ice and rock (dirty ice, as astronomer Fred Whipple used to say).

As they approach the Sun, comets become brighter; the ices evaporate and produce a diffuse atmosphere: the coma, which can be more than a million km in diameter.

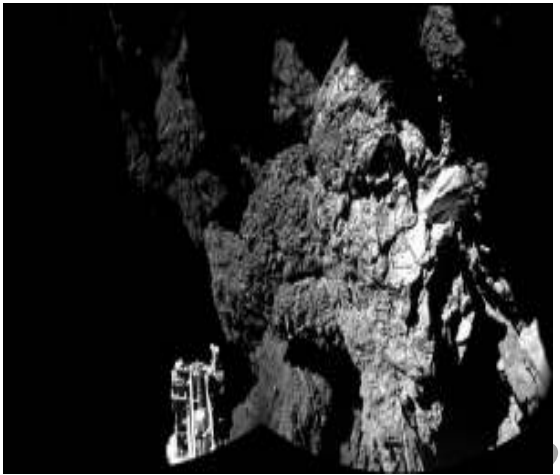
Even closer to the Sun, the solar radiation pressure and the solar wind become significant. A tail of gas and dust appears. This tail does not follow the comet's trajectory - unlike the case of a balloon comet (see opposite). The dust responds to the radiation pressure but the gas is affected by the magnetic field of the solar wind, so the two tails are distinct.

Distances to the Sun of the planets, the Oort Cloud and the nearest star, α Centauri.



The numbers indicate distances in astronomical units (AU)
The distance from the Earth to the Sun is 1 AU.

Molecules in the atmosphere or on the surface of a comet can be identified directly by taking a sample with a space probe and analysing it with a mass spectrograph.



The Philae lander in 2014 after being dropped off on comet 67P/ Churyumov-Gerasimenko by the Rosetta probe after a 10-year journey (Credit ESA).

Comets, the memory of the Sun

In 1982, Mayo Greenberg put forward the idea that comets are aggregates of interstellar dust that were not incorporated into the planets when they formed. The comets remained in the most remote and coldest regions of the solar system, and hence they would have retained the chemical composition of the molecular cloud in which the Sun was formed.

The chemical composition of cometary ice can be revealed by spectroscopic analysis of comets (see tuimp 2) or by direct analysis (see opposite page). Water and many carbonaceous molecules such as carbon monoxide and dioxide, methane, methyl alcohol, formaldehyde, etc. are found in comets. These molecules are also found in the clouds of the interstellar medium, suggesting that Greenberg's hypothesis was correct.

The oceans cover 71% of the Earth's surface and contain 1.4×10^{18} tonnes of water.

A comet 5 km in diameter has a mass of 5×10^{11} tonnes. Assuming a duration of one billion years, it would have taken 3 impacts per millennium to fill them.

Comets impacting the young Earth (artist's view)

The great Geyser in Iceland

The idea that all the water in the oceans was brought by comets or asteroids is not shared by all scientists. For example, some believe that it came from geysers, similar to those we see today, which drew water from the Earth's interior.

Earth, water and comets

When the Earth was formed, its temperature rose so high that water evaporated and escaped into space. But where does the water in the oceans come from?

For more than thirty years, work has suggested that water was brought by comets that hit the Earth. However, analysis of comets has shown that the water they contain is not identical to the water in the oceans: it is richer in deuterium. Moreover, while the first calculations gave a sufficient number of cometary impacts, recent work contradicts this. Carbonaceous chondrites from the asteroid belt between Mars and Jupiter appear to be a better candidate.

In 2011 it was discovered that the water from comet Hartley 2 resembles that of the oceans. It is now thought that a combination of the two sources was involved. But there are also other hypotheses.

Artistic representation of a comet impact by Ben Crowder.

Sample of a carbonaceous chondrite.

Comet 67P-CG photographed by the European probe Rosetta.

Current research points to two possible sources for the origin of 'molecules of life' on Earth: an extraterrestrial source (comets and carbonaceous chondrites) or a terrestrial source (the ocean floor). The debate is not clear-cut and it is possible that both sources contributed these organic molecules.

Comets and life

Half of the mass of comets is made up of 'organic' molecules. These are molecules containing carbon and hydrogen, which are found in living organisms. If they encounter a favourable environment, such as water, they could give rise to living cells.

The hypothesis that life on Earth came from elsewhere - panspermia - has been put forward by some thinkers for over 2000 years. With the discoveries of the chemical composition of comets and asteroids, and experiments on the strength of organic molecules and their ability to form complex compounds, this idea is being taken seriously by scientists. The 'seeds' of life could be spreading in space, carried by dust, asteroids and comets.

Comets inspired many painters and poets

Captions on overleaf

Veru: stylized comet in the book of comets (Flanders, 1587)

Painting by the Anglo-American painter Peter W. Rogers (2017)

Halley's Comet by Yamaji artist Karen Comegain (Australia 2009)

In space float the planets
And wander the comets,

Poem
Eve, 11 years old (France)

Comets. Pastel by Maria Clara Eimmart, German astronomer (ca. 1700)

Comet Yakutake over San Xavier del Bac Church in Arizona.
Painting by American astronomer Jim Scotti (1996)

The Universe in my pocket No. 22

This mini-book was written in 2021 by Grażyna Stasińska and revised by Dominique Bockelée-Morvan (both from Paris Observatory).

Cover image: Comet Bennett, 1970.
Credit: Akira Fujii/Davidmalin.com.

To find out more about this collection and the themes presented in this mini-book you can visit
http://www.tuimp.org