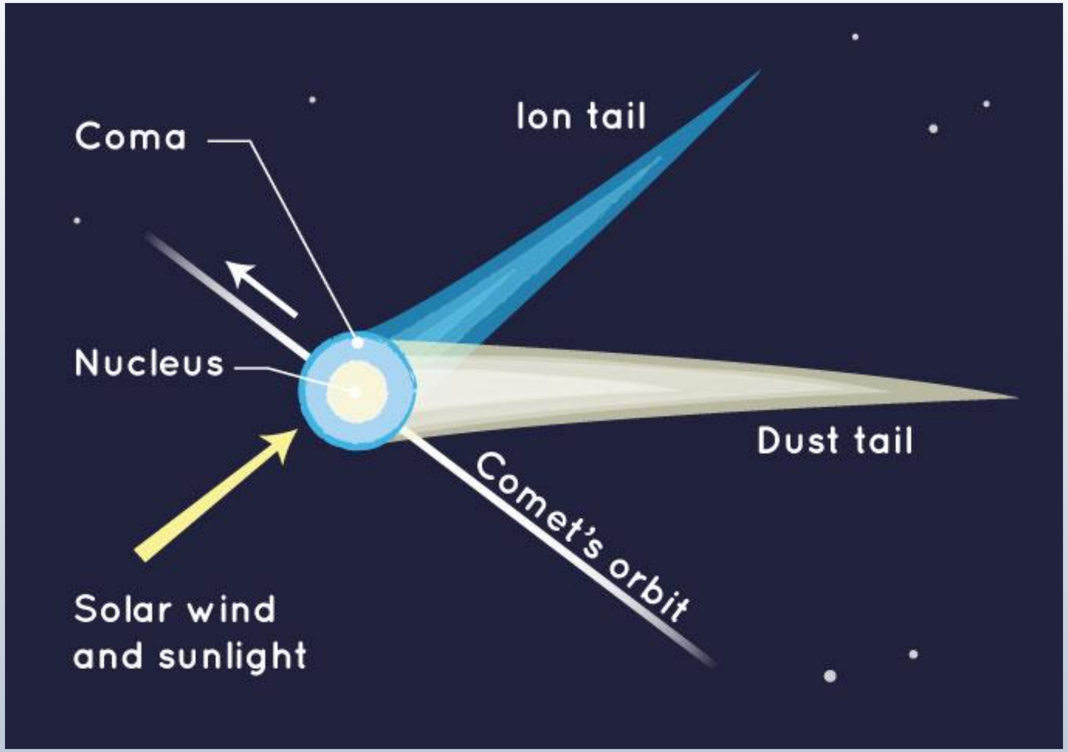
The Observation of Comets

A short history about the observation of comets,
From how it started until today's projects.

Presented by Nóra Halász

What is a comet?



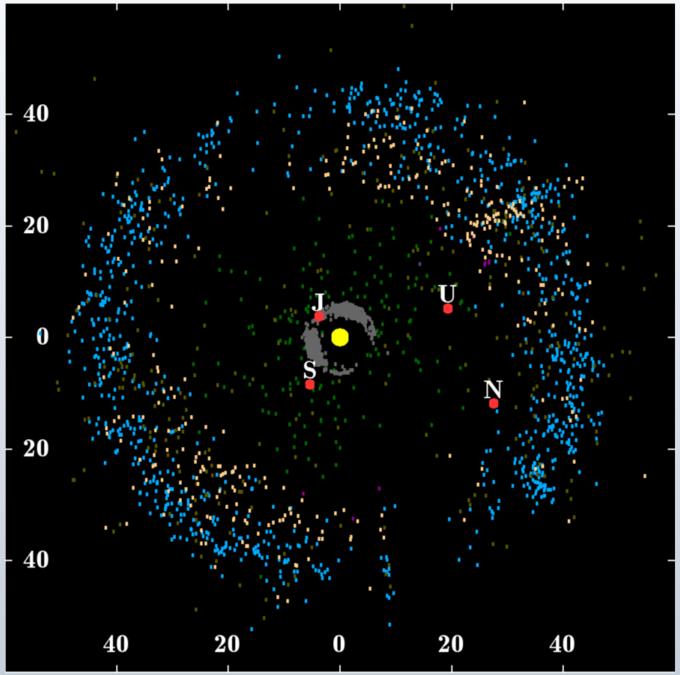
- Comets are frozen leftovers from the formation
of the solar system,composed of dust, rock, and ices.

- Parts:
- Nucleus:
  - tiny frozen part, often no larger than a few kilometers across
  - contains icy chunks, frozen gases with bits of embedded dust
- Coma:
  - A comet warms up as it nears the Sun and develops an atmosphere, or coma.
  - The Sun's heat causes the comet's ices to change to gases so the coma gets larger.
  - The coma may extend hundreds of thousands of kilometers.
- Tail:
  - The pressure of sunlight and high-speed solar particles (solar wind) can blow the coma dust and gas away from the Sun, sometimes forming a long, bright tail.
  - Comets actually have two tails—a dust tail and an ion (gas) tail.

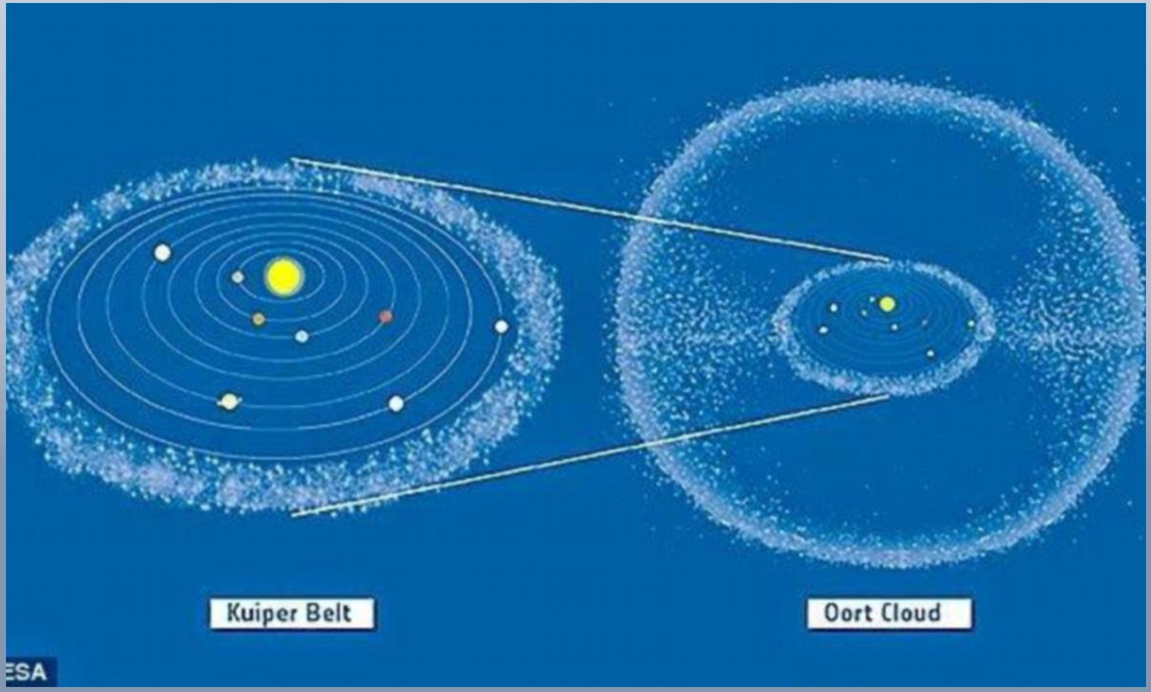
What information can they tell us?

- In the distant past, people were both awed and alarmed by comets, perceiving them as long-haired stars that appeared in the sky unannounced and unpredictably.
- Until the sixteenth century, comets were usually considered bad omens of deaths of kings or noble men, or coming catastrophes.
- We now know that comets are leftovers from the dawn of our solar system around 4.6 billion years ago, and consist mostly of ice coated with dark organic material. They may yield important clues about the formation of our solar system, as they may have brought water and organic compounds, the building blocks of life, to the early Earth and other parts of the solar system.

Where do they come from?

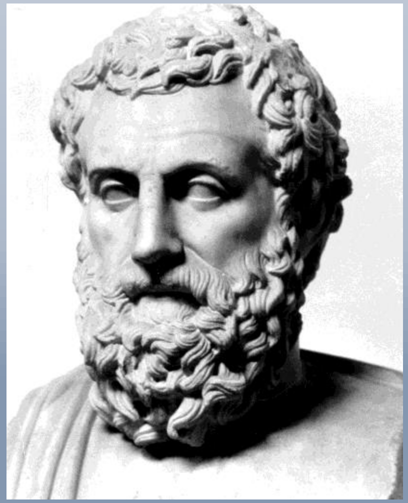


- Gerard Kuiper (1951): a disc-like belt of icy bodies exists beyond Neptune
- Short-period comets: when they are occasionally pushed by gravity into orbits bringing them closer to the Sun. Taking less than 200 years to orbit the Sun, in many cases their appearance is predictable because they have passed by before.
- Long-period comets: many of which arrive from a region called the Oort Cloud about 100,000 astronomical units from the Sun. These Oort Cloud comets can take as long as 30 million years to complete one trip around the Sun.

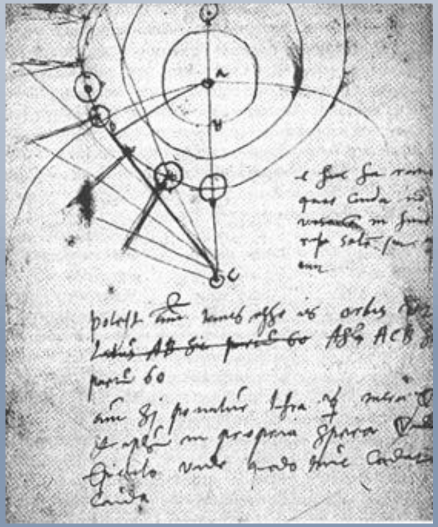


The exploration of comets

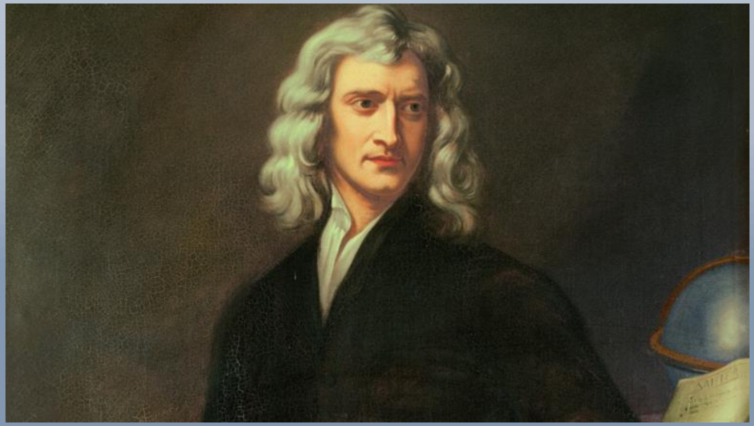
- Chinese astronomers kept extensive records for centuries, including illustrations of characteristic types of comet tails, times of cometary appearances and disappearances, and celestial positions. These historic comet annals have proven to be a valuable resource for later astronomers.
- Aristotle (384–322 BC)
  - first known scientist to utilize various theories and observational facts to employ a consistent, structured cosmological theory of comets
  - He believed that comets were atmospheric phenomena.
  - According to Aristotle, comets must be within the sphere of the moon and clearly separated from the heavens.
- Aristotelian theory on comets continued to be widely accepted throughout the Middle Ages, despite several discoveries from various individuals challenging aspects of it. (For example in the 4th century BC, Apollonius of Myndus supported the idea that comets moved like the planets)

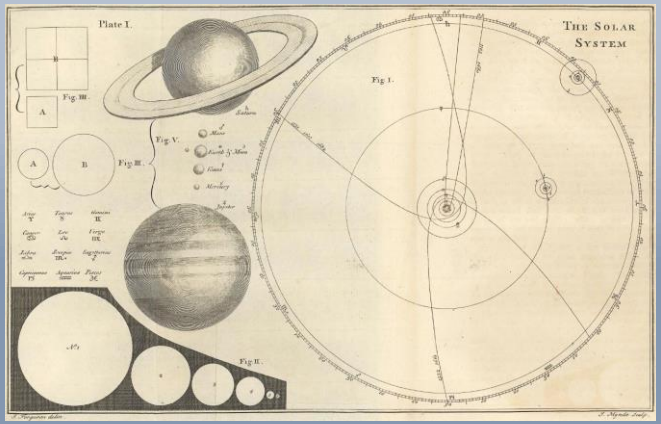


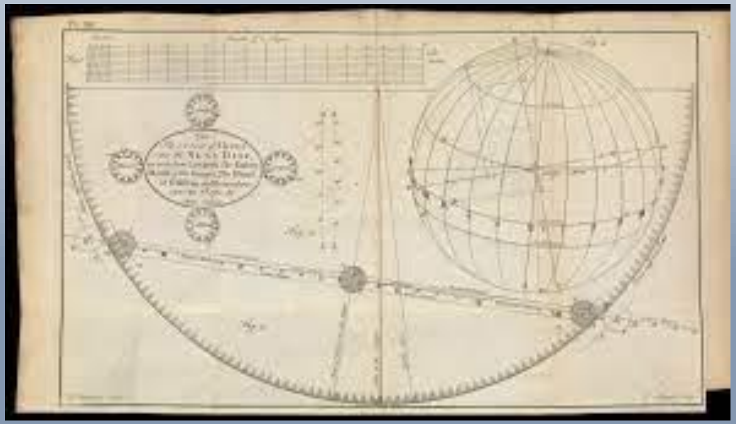
- In the 16th century, Tycho Brahe and Michael Maestlin demonstrated that comets must exist outside of Earth's atmosphere by measuring the parallax of the Great Comet of 1577.
  - Great comet of 1577: non-periodic comet that passed close to Earth
  - On November 7, in Ferrara, Italy, architect Pirro Ligorio described *"the comet shimmering from a burning fire inside the dazzling cloud.,,*
  - On November 8, it was reported by Japanese astronomers with a Moon-like brightness and a white tail spanning over 60 degrees.
- Based on observations in 1664, Giovanni Borelli recorded the longitudes and latitudes of comets that he observed, and suggested that cometary orbits may be parabolic.



- Isaac Newton describes comets as compact and durable solid bodies moving in oblique orbit and their tails as thin streams of vapor emitted by their nuclei, ignited or heated by the Sun. He also pointed out that comets usually appear near the Sun, and therefore most likely orbit it. On their luminosity, he stated, *"The comets shine by the Sun's light, which they reflect,"* with their tails illuminated by *"the Sun's light reflected by a smoke arising from [the coma],,*
- As early as the 18th century, some scientists had made correct hypotheses as to comets' physical composition.





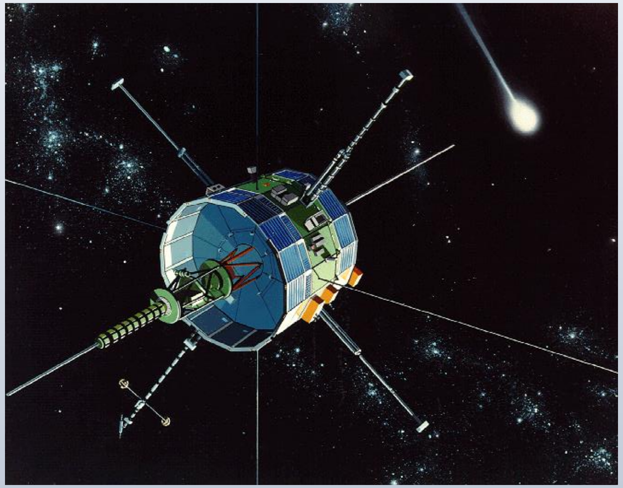


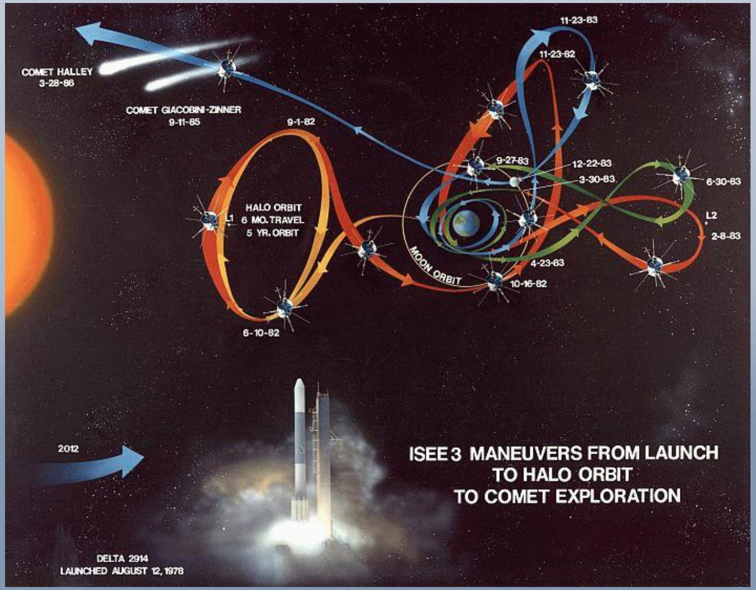
Spacecraft exploration of comets

- The latter half of the 20th century saw a massive leap forward in the understanding of the solar system as a result of spacecraft visits to the planets and their satellites. Those spacecraft collected a wealth of scientific data close up and in situ. The anticipated return of Halley's Comet in 1986 provided substantial motivation to begin using spacecraft to study comets.

International Cometary Explorer (ICE) spacecraft

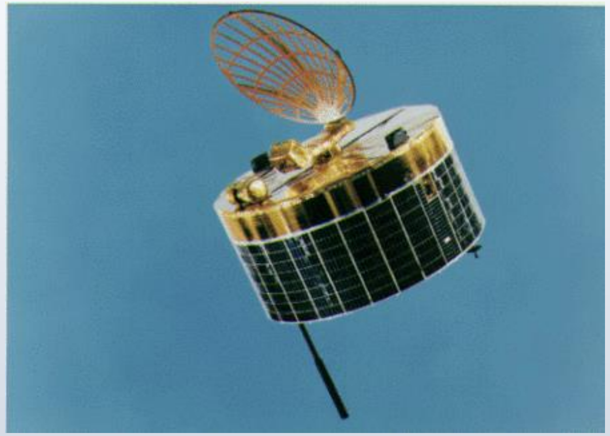
- with Comet 21P/Giacobini-Zinner on September 11, 1985
- The mission consisted of three spacecraft
    - two of them in Earth orbit
    - the third positioned in a heliocentric orbit between Earth and the Sun, studying the solar wind in Earth's vicinity
- The spacecraft was targeted to pass through the ion tail of the comet, about 7,800 km behind the nucleus at a relative velocity of 21 km per second, and returned the first in situ measurements of the magnetic field, plasma, and energetic particle environment inside a comet's tail





Halley Armada

- In 1986, consisted of five spacecrafts
- consisted of two Japanese spacecraft, Suisei and Sakigake (Japanese for “comet” and “pioneer,” respectively); two Soviet spacecraft, Vega 1 and 2 (a contraction of Venus-Halley using Cyrillic spelling); and an ESA spacecraft, Giotto (named after the Italian painter who depicted the Star of Bethlehem as a comet in a fresco painted in 1305–06)aft were sent to encounter Halley’s Comet

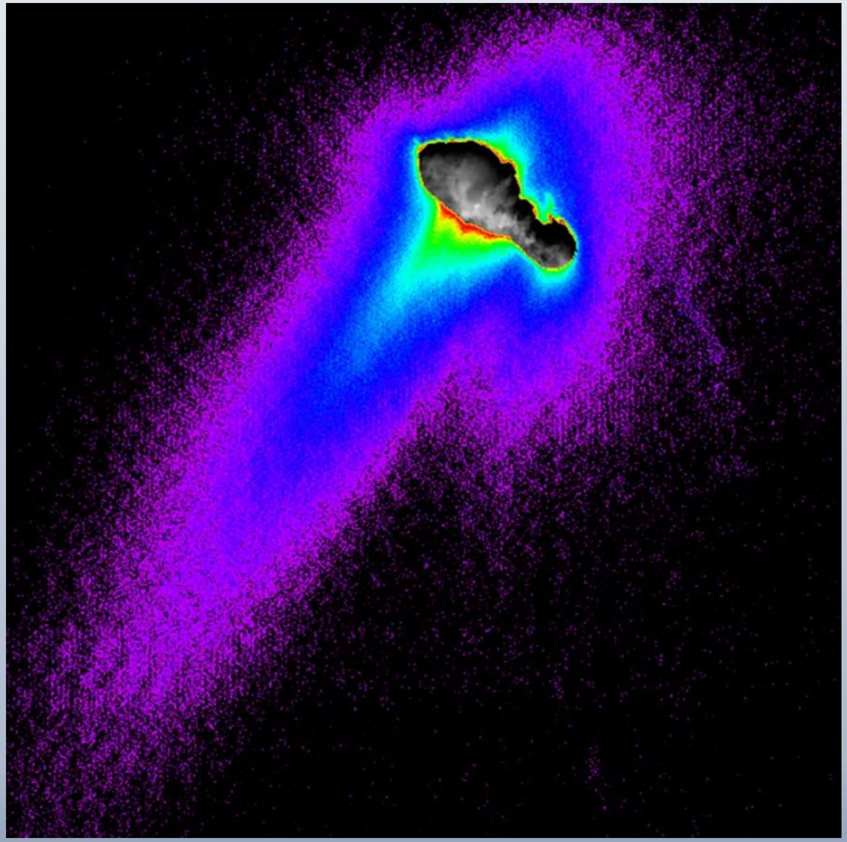


What could these spacecrafts measure about Halley’s comet?

- One of them flew through the Halley coma and made numerous measurements of the coma gas and dust composition, plasma and energetic particles, and magnetic field environment.
- Another one returned the first picture ever of a solid cometary nucleus, and one of the pictures clearly showed a peanut-shaped nucleus about 16 by 8 km.
- And lastly, one of them carried infrared spectrometers designed to measure the temperature of the Halley nucleus. They found quite warm temperatures between 47 and 127 °C . That surprised many scientists who had predicted that the effect of water ice sublimation would be to cool the nucleus’s surface; water ice requires a great deal of heat to sublimate. The high temperatures suggested that much of the nucleus’s surface was not sublimating.

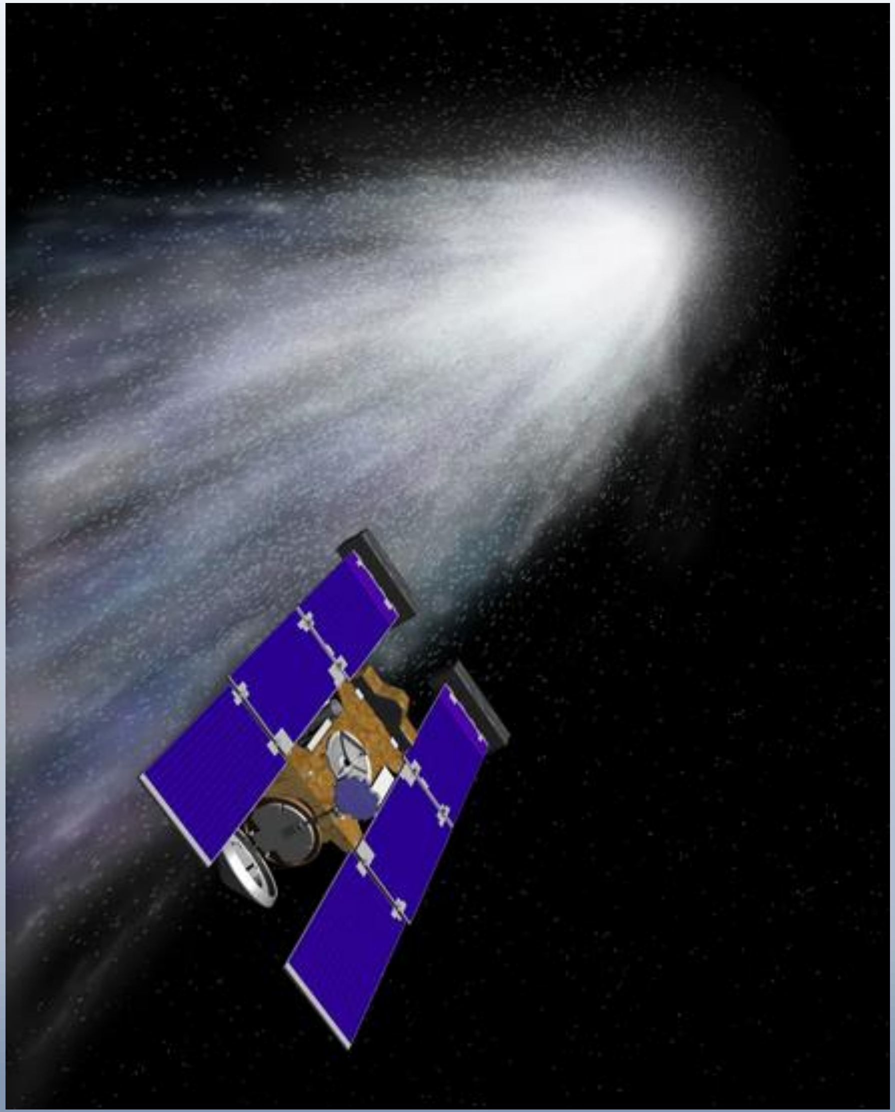
Deep Space 1

- 1988, NASA, a spacecraft designed to test a variety of new technologies
- was retargeted to fly past the comet 19P/Borrelly on September 22, 2001
- Images of the Borrelly nucleus showed it to be shaped like a bowling pin, with very rugged terrain on parts of its surface and mesa-like formations over a large area of it.



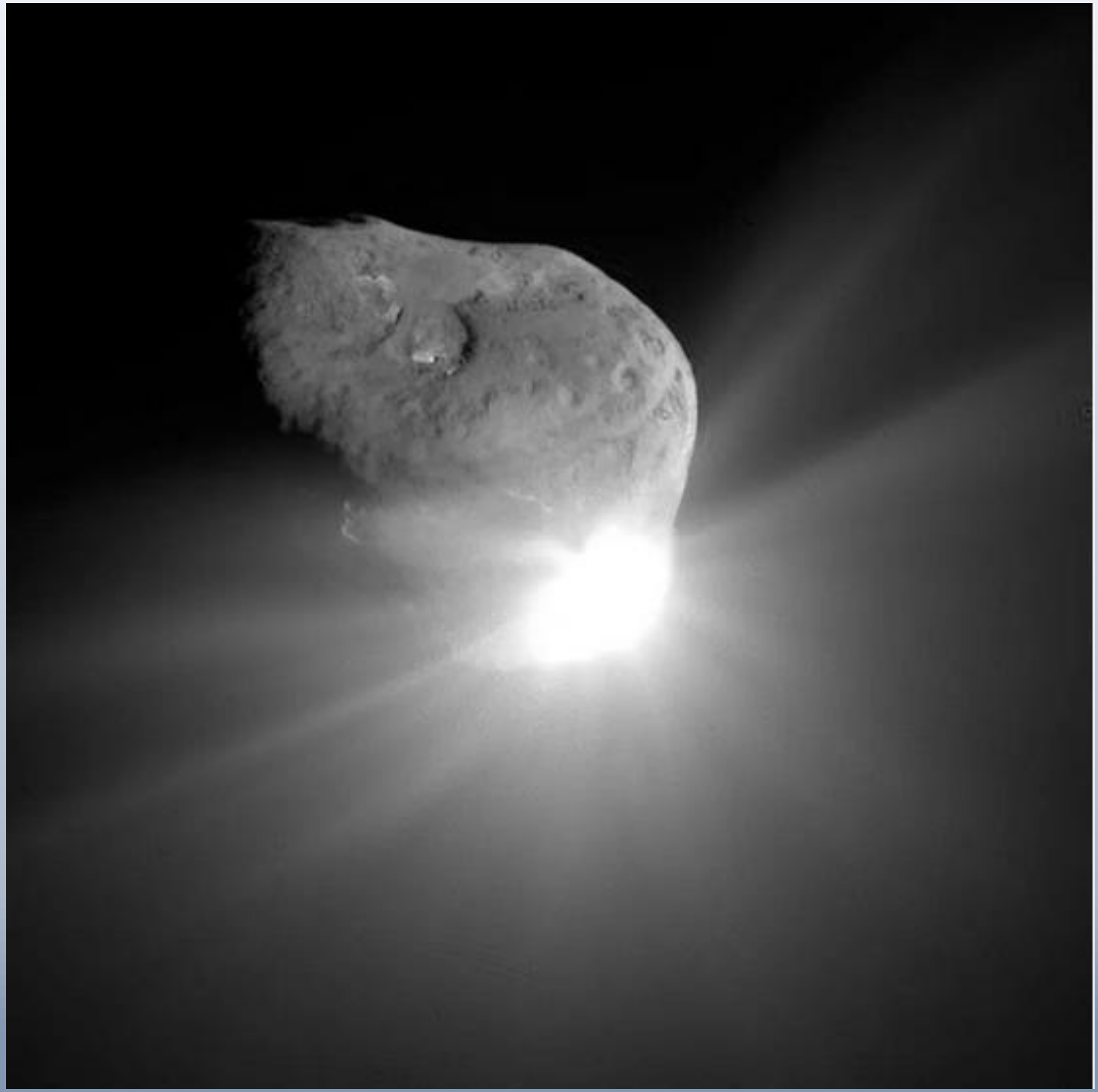
Stardust

- The NASA Stardust mission was launched in 1999 with the goal of collecting samples of dust from the coma of Comet 81P/Wild 2.
- At a flyby speed of 6.1 km per second, the dust samples would be completely destroyed by impact with a hard collector. Therefore, Stardust used a material made of silica (sand) called aerogel that had a very low density, approaching that of air. The idea was that the aerogel would slow the dust particles without destroying them, much as a detective might shoot a bullet into a box full of cotton in order to collect the undamaged bullet. It worked, and thousands of fine dust particles were returned to Earth in 2006.
- Perhaps the biggest surprise was that the sample contained high-temperature materials that must have formed much closer to the Sun than where the comets formed in the outer solar system. That unexpected result meant that material in the solar nebula had been mixed, at least from the inside outward, during the formation of the planets.



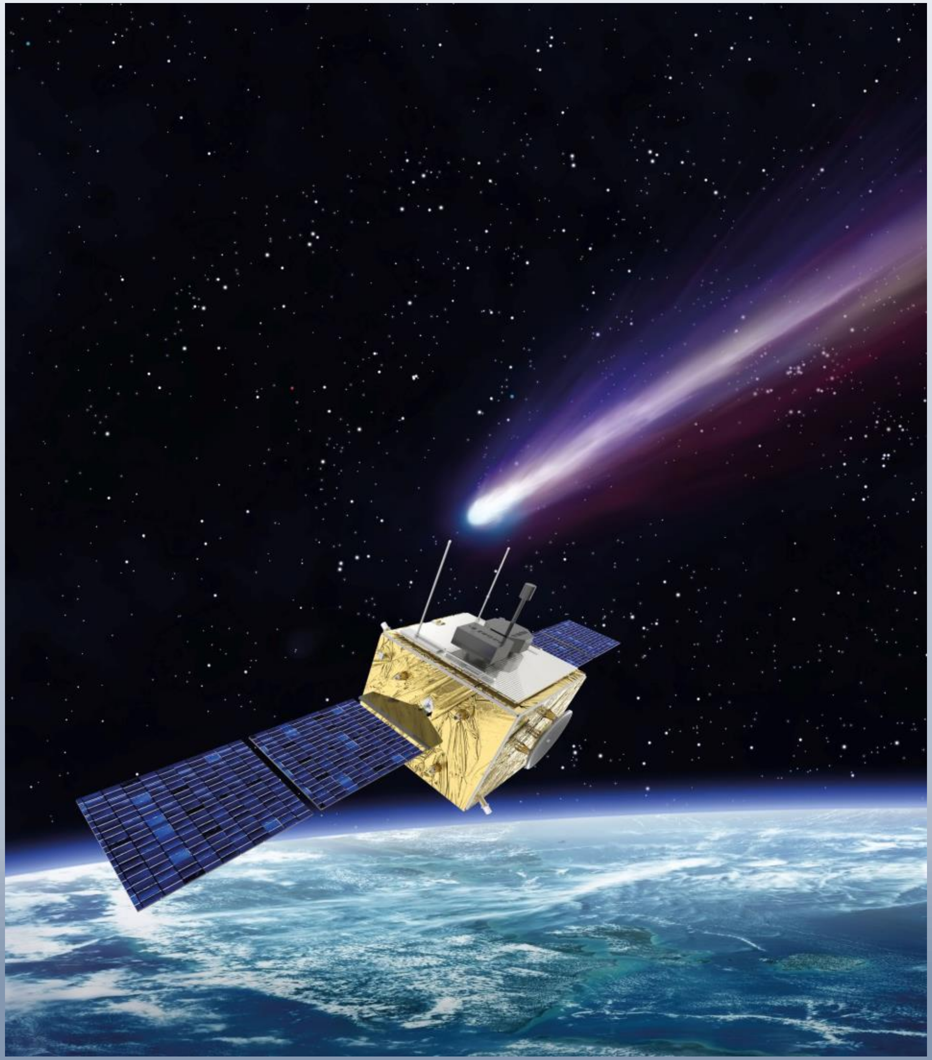
Deep Impact

- In 2005, NASA
- This mission consisted of two spacecraft, a mother spacecraft that would fly by Comet 9P/Tempel 1 and a daughter spacecraft that would be deliberately crashed into the comet nucleus. The mother spacecraft would take images of the impact. The daughter spacecraft contained its own camera system to image the nucleus surface up to the moment of impact. To maximize the effect of the impact, the daughter spacecraft contained 360 kg of solid copper. The predicted impact energy was equivalent to 4.8 tonnes of TNT.
- The impactor produced the highest-resolution pictures of a nucleus surface ever, imaging details less than 10 metres in size.



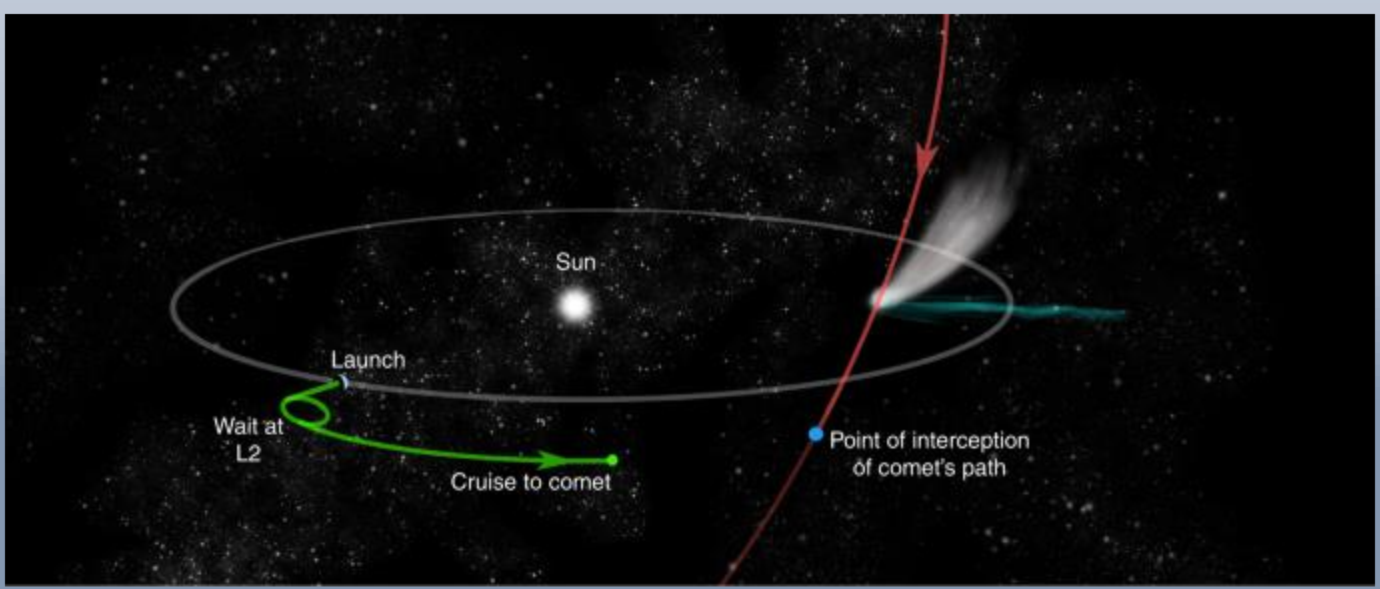
Comet interceptor

- Project of ESA (The European Space Agency)
- In the past, ‘new’ comets have only been discovered a few months to years before they pass through their closest approach to the Sun, which is too short notice to plan, build and launch a space mission, and for it to travel to the specific object before it moves away from the Sun again.
- Comet Interceptor is different because it will target a comet visiting the inner Solar System for the first time – perhaps from the vast Oort cloud that is thought to surround the outer reaches of the Sun’s realm. As such, the comet will contain material that has not undergone much processing since the dawn of the Sun and planets. The mission will therefore offer a new insight into the evolution of comets as they migrate inwards from the periphery of the Solar System.



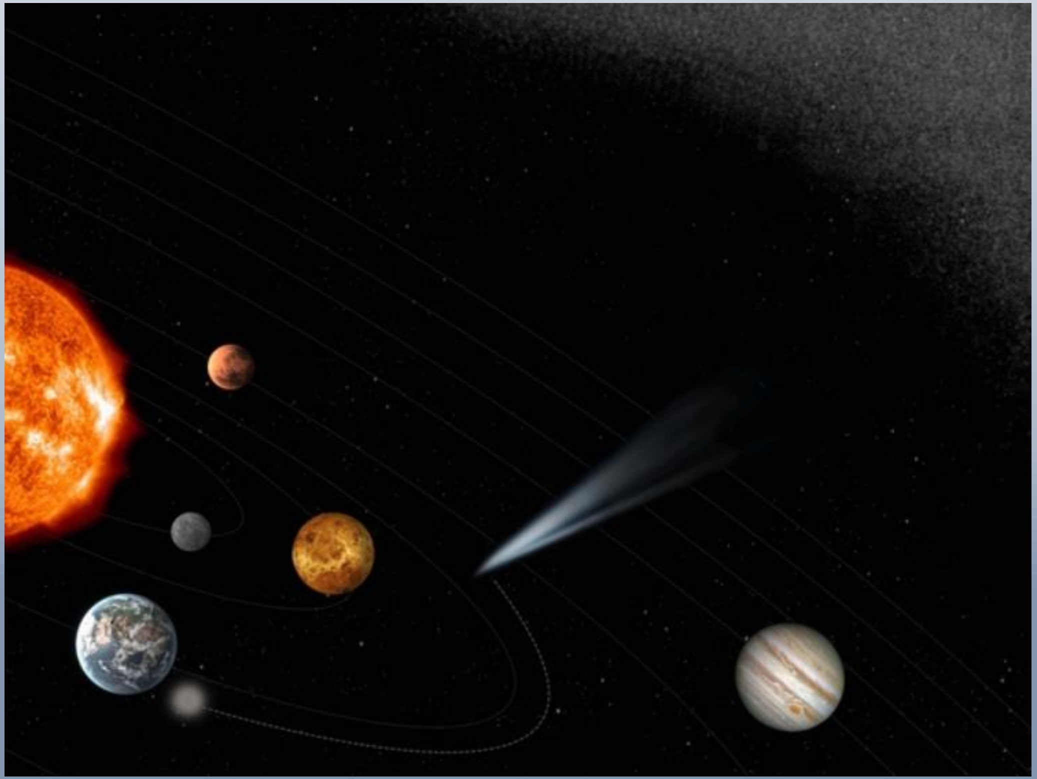
How will this mission work?

- The mission will travel to an as-yet undiscovered comet, making a flyby of the chosen target when it is on the approach to Earth's orbit. Its three spacecraft will perform simultaneous observations from multiple points around the comet, creating a 3D profile of a 'dynamically new' object that contains unprocessed material surviving from the dawn of the Solar System.
- *"Pristine or dynamically new comets are entirely uncharted and make compelling targets for close-range spacecraft exploration to better understand the diversity and evolution of comets,"* said Günther Hasinger, ESA's Director of Science.



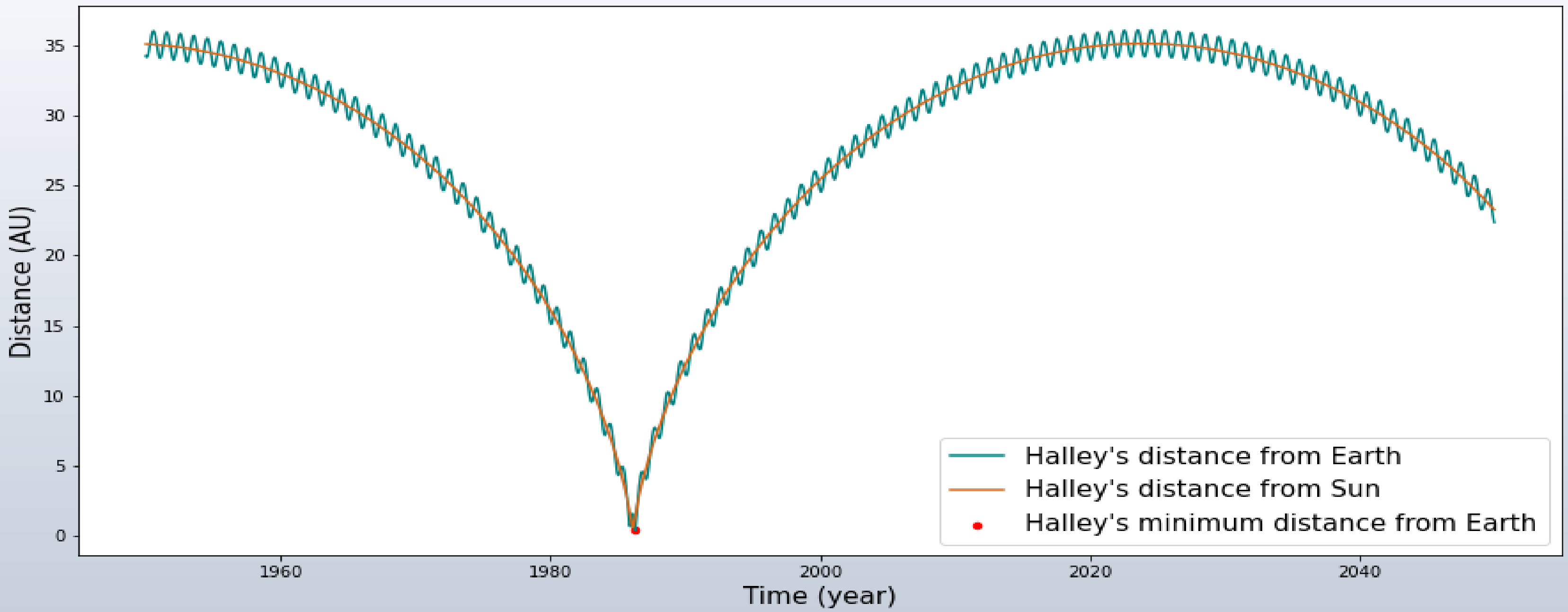
When will Comet Interceptor spacecrafts launch?

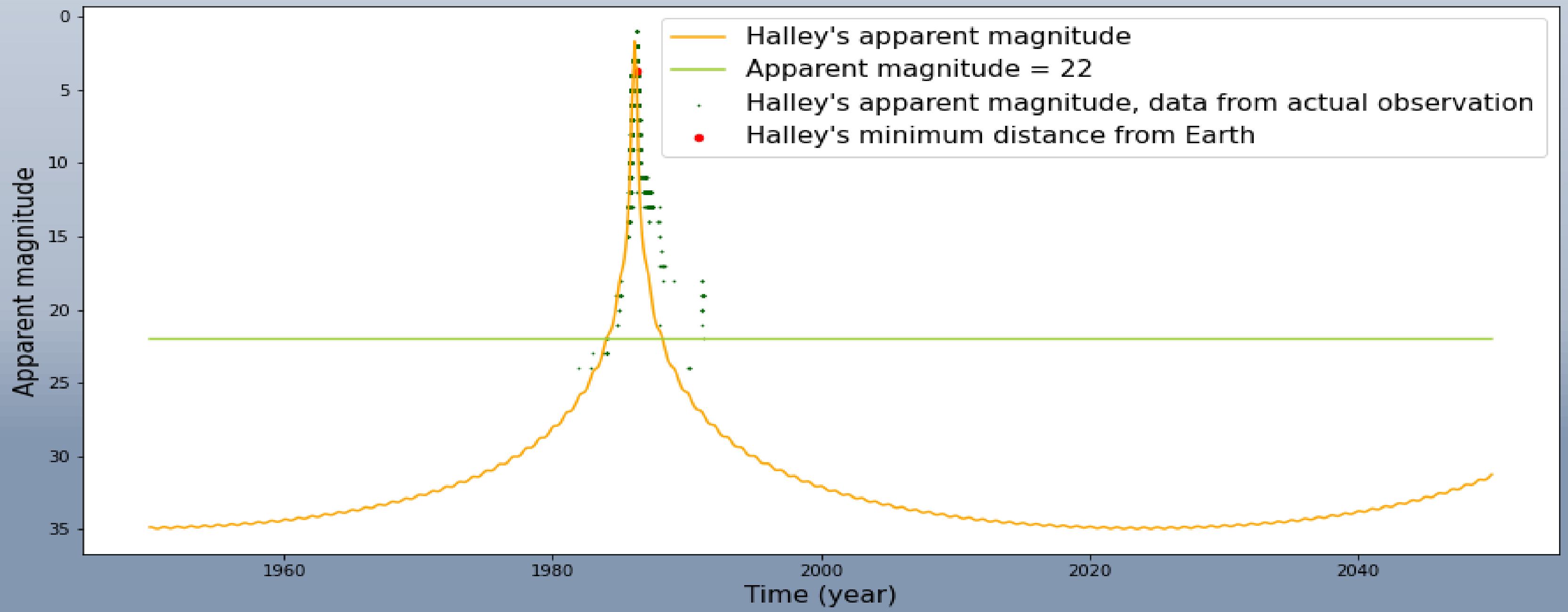
- It is a fast-mission, where the ‘fast’ refers to the implementation time, with a total development duration from selection to launch readiness of about eight years.
- Comet Interceptor is foreseen for launch in 2028.



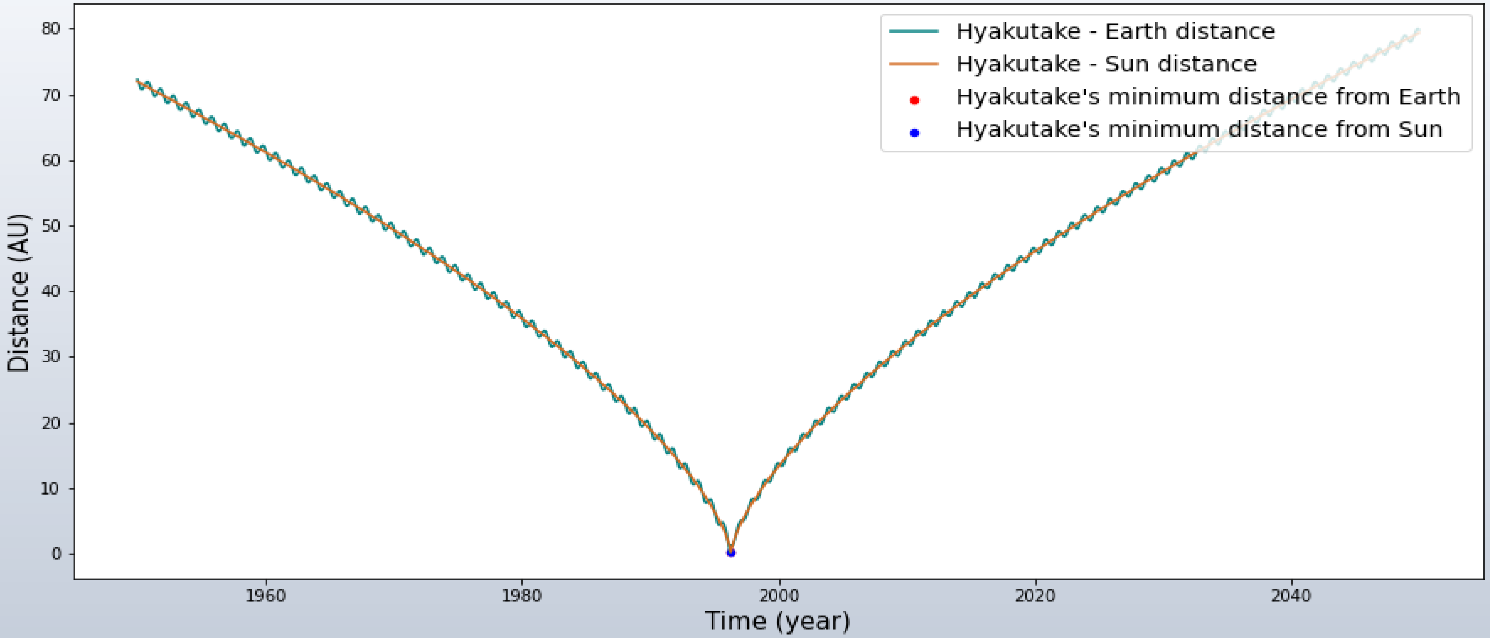
Simulation showing how the Comet Interceptor will help with the observation of comets

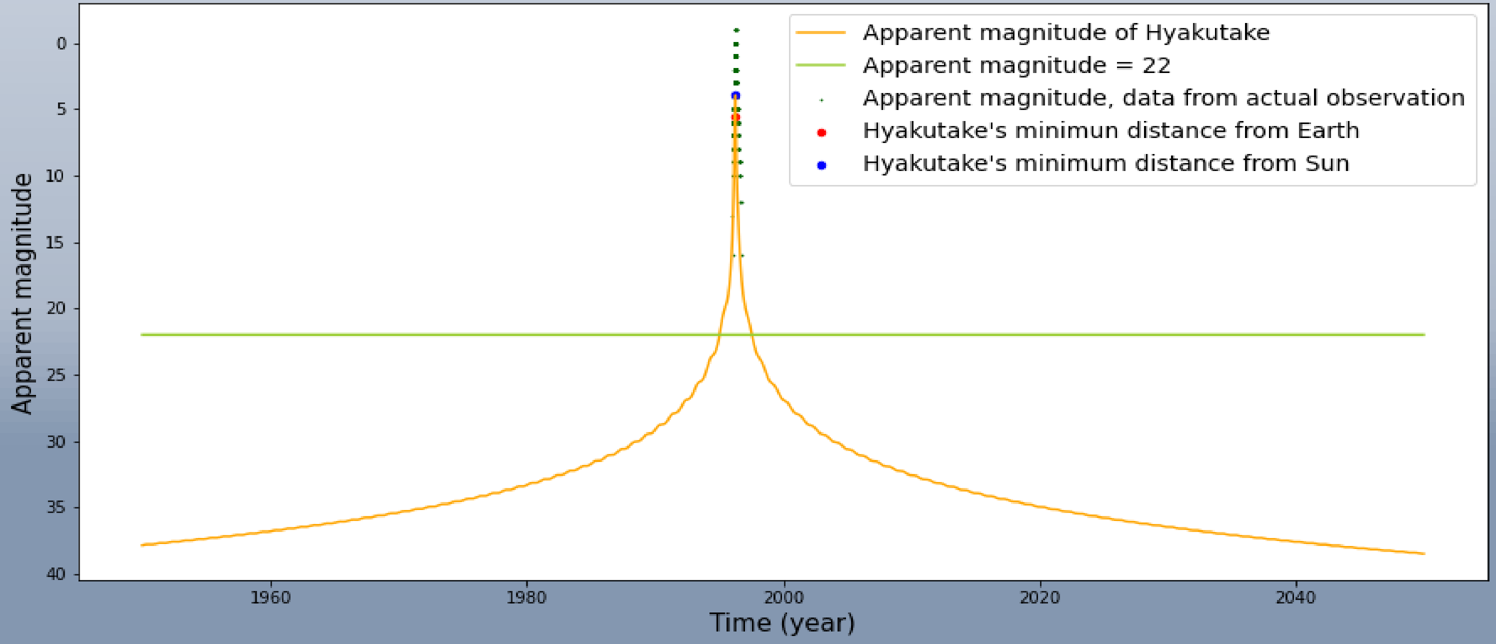
- As part of my BSc thesis, I made a simulation showing when the Comet Interceptor spacecraft will be able to detect a comet based on its apparent magnitude.
- As we have already discussed, building a spacecraft takes quite long time, which could not be carried out in the time interval when a comet is detectable. In the simulation it is shown when a comet could be detected by a sensor which can see its magnitude below 22, and how it is in comparison with actual observation data.
- This simulation uses the Kepler orbits part of the Skyfield documentation, which is written in python.
- So far it has made calculations with comets Halley and Hyakutake, and we plan to expand it to other comets as well as hypothetical ones, to make projections about how for example a comets's luminosity index or its path can change the date of detection. With these calculations we can also determine how long a comet can be observed before and after it reaches its closest point to Earth, which is shown in the next two slides.





Halley's comet was closest (according to this model) to the Earth in 1986. April 14. Before that, its magnitude was smaller than 22 since 1984. January 5. until 1988. March 21, which is 830 days before and 707 days after its path's closest point to Earth.





Comet Hyakutake was closest to the Earth in 1996. March 18. Before that, its magnitude was smaller than 22 since 1995 . January 20. until 1997. July 30, which is 423 days before and 499 days after its path’s closest point to Earth.

Sources

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