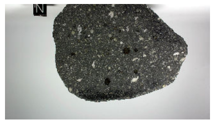
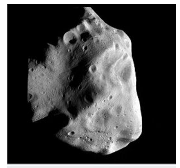
The Universe in my pocket

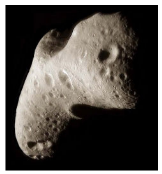
Antonella Barucci
LIRA, Observatoire de Paris - PSL

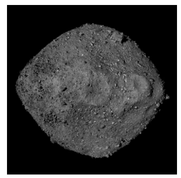
TUIMP No. 49

Which of these objects is not an asteroid?









Answer on overleaf

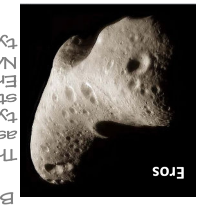
Asteroid mining

Asteroids can contain precious metals such as gold, cobalt, iron, manganese, nickel, platinum, rhodium, tungsten and iridium, among others. From the 1990s onwards, NASA and various private companies have considered mining asteroids with the idea of extracting metals and volatiles.

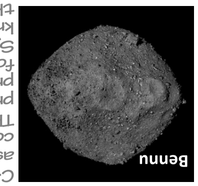
Recently, billionaire entrepreneurs proposed to split water from the asteroids into hydrogen and oxygen and thus create propellent depots in space.

Many companies from the USA, Europe and China showed interest in this ambitious venture. The cost of extraction and returning material to the Earth is under evaluation to determine if asteroid mining is a viable possibility or just speculation.

The M type (metallic) asteroid class contains objects formed mostly of metallic iron and nickel. The asteroid 21 Lutetia, observed by the ESA Rosetta mission during a flyby in 2010, is probably a mixture of metallic and carbonaceous material.

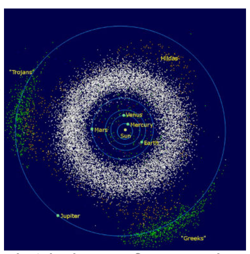


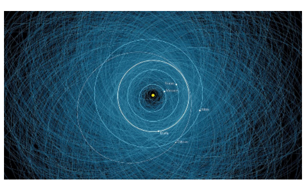
The second most common asteroid class is the S type (silicates) formed of stony materials. 433 Eros, visited by the NEAR NASA mission, is an S-type asteroid.



C-type (carbonacious) asteroids are dark and contain carbon molecules. They are the most primitive (similar to primordial matter that formed the Solar System). About 75% of known asteroids belong to this class. 101955 Bennu is a C-type.

Most asteroids are located in orbits between Mars and Jupiter, a zone called the 'main asteroid belt' and represented in white in the figure. But many others are close to the Earth (Near-Earth Objects) or co-orbital with planets; for example Jupiter Trojans (in green).



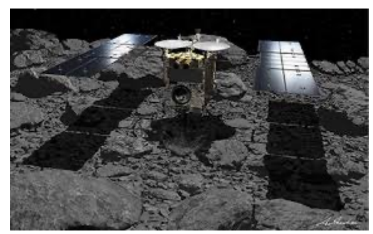


This diagram shows the orbits of 2,200 potentially hazardous objects as calculated by the Jet Propulsion Laboratory Center for Near Earth Object Studies. The orbit of Earth is shown in white. Also shown is the orbit of the double asteroid Didymos, visited by the Planetary Defense DART mission (see pp. 9 and 10).

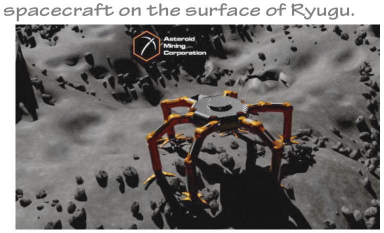
Near-Earth Objects

Near Earth Objects (NEO) are asteroids or comets orbiting the Sun whose closest approach to the Sun is less than 1.3 times the Earth-Sun distance. If an NEO's orbit crosses the Earth's orbit, it presents a collision danger and if the diameter is larger than 140 m, it is considered a Potentially Hazardous object. Some of these pass so close to Earth that they are easy targets for space missions.

The best way to protect the Earth from collisions is to discover all the potentially hazardous asteroids and characterize their orbits. For this many programs are financed by NASA and ESA. Several deflection methods have been proposed, in the event that a collison with Earth seems likely. The simplest one is the 'kinetic impactor', which was tested by NASA's DART mission. In 2022, the spacecraft was crashed into Dimorphos, the moon of the Didimos asteroid, altering its orbit.



An artistic view of the Hayabusa2 spacecraft on the surface of Ryugu.



The robot SCAR-E, developed by the Asteroid Mining Corporation, designed for lunar crater exploration and asteroid prospecting.

Composition

The composition of asteroids can be determined by spectroscopy. Sunlight is absorbed in particular wavelengths depending on the minerals present on the surface. Reflected light carries a spectral signature of the mineral composition of the asteroid's surface.

The composition can also be determined from samples returned to Earth. This was the case for 101955 Bennu (OSIRIS-REx mission) and 162173 Ryugu (Hayabusa2 mission).

Depending on their composition, asteroids are classified into several groups, : C type (carbonaceous), S type (silicates), and M type (metallic).

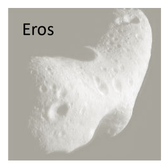
Knowledge of asteroid composition is important to determine where they formed, and gives insight into their evolution.

Images of asteroids visited by space missions.

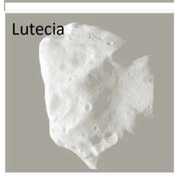
They show different shapes, sizes and morphologies.

152830 Dinkinesh and its satellite Selam as photographed by the NASA Lucy mission. These tiny asteroids of the main asteroid belt are about 700 m and 200 m in diameter.

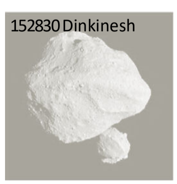
Asteroids encountering the Earth's atmosphere leave a visible trail in the sky. These are called meteors or falling stars. If the object survives through the atmosphere and hits the ground, it is called a meteorite.



All the objects shown here are asteroids described in this booklet ...



...except this one which is a meteorite.



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This booklet was written in 2025 by Antonella Barucci from LIRA (Laboratory for Instrumentation and Research in Astrophysics) of Paris Observatory and revised by Grażyna Stasińska (Paris Observatory).

Cover image: Artist picture of asteroids: probably more than a million in the Asteroid belt between Mars and Jupiter. Credit: 1: NASA/JPL - Caltech, 2: NASA, 4.1 NASA, 4.2 NASA, 4.3: ESA, 6.1: NASA, 6.2: JAXA, 8.1: Wikipedia, 8.2: NASA, 10.1: (http://www.unb.ca/passc/ImpactDatabase), 10.2: NASA DART & LICIACube, 12.1: Akihiro Ikeshita, 12.2: Asteroid Mining Corporation

To learn more about this series and about the topics presented in this booklet, please visit: http://www.tuimp.org

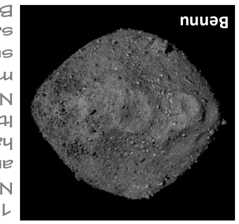
Translation: Stan Kurtz

What are asteroids ?

Asteroids are small bodies of the Solar System formed by accretion from planetesimals (the first macroscopic objects to appear in a protoplanetary disk) about 4.6 billion years ago. They range in size from a few meters up to 1,000 km. They are generally composed of rock and metal, and some contain ice.

When asteroids pass near the Sun they heat up. If an asteroid contains ices, these will vaporize, creating a glowing coma and a tail and consequently the asteroid is said to 'show activity' and is classified as a comet.

Transneptunian objects (at the far edges of our Solar System) are classified as asteroids because when they are discovered they do not show activity, even though they contain ices and are the source of comets.



101955 Bennu is a Near-Earth Object and a potentially hazardous asteroid. It was the target of NASA's OSIRIS-REx mission, which successfully returned samples to Earth. Bennu has a mean diameter of 490 m. It has a roughly spherical shape with a ridge along the equator. Several craters are present on its surface as well many boulders (more than 200 are larger than 10 m). Ryugu has a similar aspect, with its ridge shaped by centrifugal forces. Ryugu is likewise very dark and resembles carbonaceous meteorites.

162173 Ryugu is also a Near-Earth Object and potentially hazardous asteroid. It was the target of JAXA's Hayabusa2 mission, which successfully returned samples to Earth.

Collisions

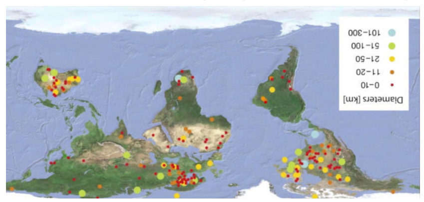
All solar system planets have undergone continuous bombardement since their formation.

A major impact probably formed the Earth-Moon system (see tuimp 027).

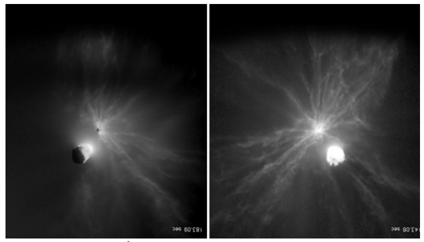
Some prebiotic molecules may have been imported by the impacting bodies, giving rise to proto-life forms.

Earth suffered a mass extinction event some 65 million years ago, when dinosaurs, along with 90% of all other living species, became extinct in a short period of time. There is evidence that this extinction was caused by a collision with an asteroid that provoked an abrupt climate change and affected the global enviroment of Earth (see tuimp 21).

More than 190 craters have been found on Earth with impact structures similar to the Meteor Crater in Arizona.



Global distribution of confirmed impact craters



Images taken by LICIA Cube nanosat just a few minutes after the impact of the DART spacecraft on the Dimorphos moon. The impact changed the moon's orbit and also produced a cloud of dust and boulders around the moon and asteroid.

Why are asteroids so important ?

Studing asteroids provides information on the origin of life on Earth. Current scenarios for the origin of life invoke an exogenous delivery of organic matter to the early Earth. It has been proposed that carbonaceous chondrite matter, in the form of planetesimals down to cosmic dust, could have imported vast amounts of complex organic molecules and water that brought life on Earth.

For example, the analysis of samples from Ryugu showed that water locked in the asteroid's rocks is similar to water found in Earth's oceans.

Analysis of samples of Bennu revealed thousands of organic compounds, including amino acids (molecules that make up proteins) along with nucleo-bases of DNA/RNA. This supports the theory that asteroids delivered these vital life ingredients to Earth when they impacted our planet billions of years ago.