



Right: Phylae was the first instrument that landed on a comet, 67P/Churyumov-Gerasimenko.



Left: Ceres is the biggest asteroid in the Main Asteroid Belt and a dwarf planet. The image shows the enigmatic bright spots on its surface.

Left: The meteorite 'La Concepcion' it weighs more than 3 tons. It is exhibited in the Institute of Astronomy, in Mexico City.

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## The Universe in my pocket



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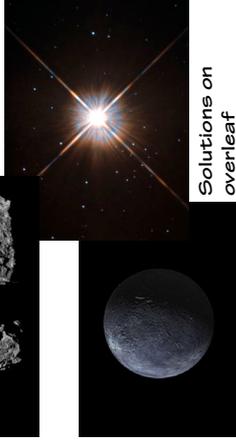


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## Quiz



Do these objects belong to the Solar System?



Solutions on overleaf

## Minor bodies

- **Asteroids** are rocks that orbit the Sun. Their sizes range from one to 950 kilometers. They are mostly found in a ring between Mars and Jupiter, called the main asteroid belt.
- **Comets** are balls of ice and dust that arise from the Kuiper Belt and from the Oort Cloud. Occasionally comets approach the Sun, which melts them. One of the most famous comets is Halley's Comet, which visits us every 75 years.
- **Meteoroids** are rocks that travel through the solar system. If they enter Earth's atmosphere they are called **meteors**, or shooting stars. If they survive to reach the surface of the Earth, they are called **meteorites**.
- **Moons** are bodies that orbit planets or dwarf planets.

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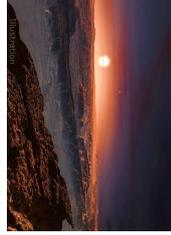
## Other planetary systems

Our Sun is only one of the hundreds of thousands of millions of stars\* that exist in the Milky Way, our galaxy. The Milky Way is just one of the  $10^{11}$  galaxies that exist in the Universe. Thus, how many planetary systems do you expect to exist in the whole Universe?

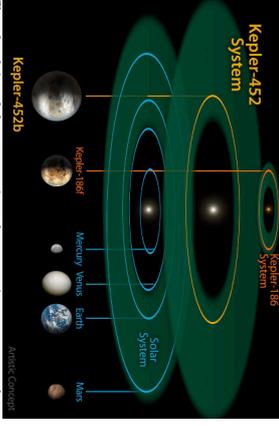
This is a hard question because there are many different types of stars: some of them are very hot while others very cold. Some of them are isolated like our Sun while others are grouped into clusters. We can only imagine that many of the stars in the Universe may have planets around them.

The first exoplanet was discovered in 1988. By the end of 2016, 3540 exoplanets were known!

\* also written  $10^{11} 13$



Artist's picture showing a view of the surface of the planet Proxima b discovered around the closest star Proxima Centauri.



The habitable zone is the region around a star where liquid water can exist on the surface of a planet (because the temperature is neither too high nor too low). The green belts in the image above show the habitable zones in some recently discovered planetary systems.

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## The Sun

The Sun is a star. It lies at the center of the Solar System and contains 99.9% of its mass.

The Sun is an average-mass star. The biggest stars have masses one hundred times larger, while the smallest ones have have masses ten times smaller.

All the heat and light that we receive from the Sun come from its nucleus where the fusion of hydrogen is occurring. The temperature at the center of the Sun is 15 million degrees Celsius.

The magnetic field of the Sun causes a variety of phenomena such as sun spots, flares, storms, and the beautiful auroras occurring on Earth.

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Above: The Sun, seen through different telescopes, each collecting light at different wavelengths (colours). Observing various types of light allows astronomers to study various physical processes.

For example, sunspots are dark in the visible (400 to 700 nm) whereas in the ultraviolet they are bright. Solar flares are bright in the extreme ultraviolet (10 to 100 nm) and X-rays (1 to 10 nm).



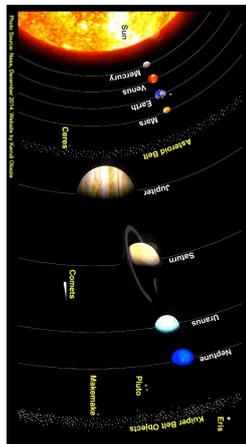
Right: An aurora. It is due to collisions between charged particles from the Sun with atoms in the Earth's atmosphere.

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The Solar System is composed of the Sun and of all the bodies travelling around it: planets, dwarf planets, moons, asteroids, comets, meteors, ...

Almost 225 objects in the Solar System have sizes bigger than 1 000 kilometers: the Sun, the four gaseous planets and the four earth-like planets, five dwarf planets, and around 12 moons and trans-neptunian objects.

The other constituents (asteroids, and dust particles) are much smaller.



## The planets

The first official definition of a planet was given only in August, 2006 by the International Astronomical Union (IAU). With this definition **Pluto** 'stopped' being the ninth planet.

A planet is a body that:

- 1) orbits the Sun,
- 2) has enough mass to be rounded by its own gravity, and
- 3) has cleared its neighborhood of minor objects.

Objects that satisfy 1) and 2) but not 3) like **Pluto** or **Ceres** are called **dwarf planets**.

The Solar System contains **eight** planets: **four earth-like planets** (Mercury, Venus, Earth and Mars) and **four gaseous planets** (Jupiter, Saturn, Uranus, and Neptune).



**90482 Orcus** is a Trans-Neptunian object

YES



**67P/Churyumov-Gerasimenko** is a comet in our solar system

YES



**Pluto** is a dwarf planet of the solar system

YES



**Proxima Centauri** is the closest star to our Sun

NO



**Andromeda** is a galaxy with many solar systems

NO

## Solutions

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The cover image is an artist's representation of the Solar System with its star (the Sun), eight planets, and 130 moons, comets, asteroids, rocks, and dust particles. Credit: NASA. The other images are mostly from NASA, ESA, and the Hubble archives.

**The Universe in my pocket No. 4**

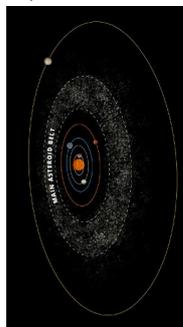
This booklet was written in 2016 by Gloria Delgado Inglada from the Instituto de Astronomía, UNAM (Mexico) and revised by Stan Kurtz from the Instituto de Radioastronomía Astrofísica, UNAM (Mexico).

## Zones in the Solar System

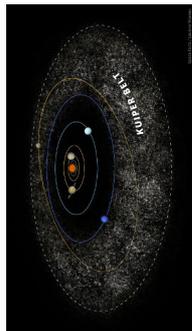
**The Main Asteroid Belt** contains billions of asteroids. These bodies formed at the beginning of the Solar System and were trapped in this annular region by Jupiter's gravity.

**The Kuiper Belt** contains hundreds of thousands of comets and other bodies, such as Pluto.

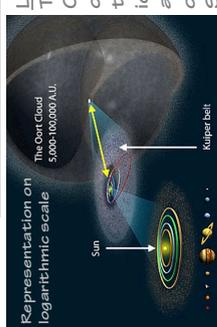
**The Oort Cloud** is a cloud of small bodies at the edge of the Solar System. It is so far away from us and so big that Voyager 1 (a spacecraft launched in 1977) will take hundreds of years to reach it, and thousands of years to leave it. At the speed of the light (300,000 kilometers per second), it takes one year to travel from the Sun to the Oort Cloud.



Left: The Main Asteroid Belt, between Mars and Jupiter.



Right: The Kuiper Belt is located beyond the orbit of Neptune.



Left: The Oort Cloud contains trillions of icy bodies at the edge of the Solar System.

Our Solar System formed around 4600 million years ago. We know this from the study of meteorites and radioactivity.

It all began with a cloud of gas and dust. A nearby supernova explosion probably perturbed the calm cloud, which then started to contract due to gravity, forming a flat, rotating disk with most of the material concentrated in the center: the protosun.

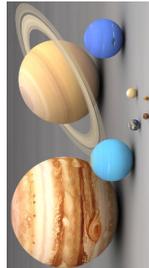
Later, gravity pulled the rest of the material into clumps and rounded some of them, forming the planets and dwarf planets. The leftovers resulted in comets, asteroids, and meteoroids.

## Formation of the Solar System

Balls representing the different planets of the Solar system. In each image the relative sizes of the planets have been respected.



Left: Earth, Venus, Mars, Mercury.



Right: Jupiter, Saturn, Uranus, Neptune, Earth, Venus, Mars, Mercury.



Left: The Sun, Jupiter, Saturn, Uranus, Neptune, Earth, Venus, Mars, Mercury.