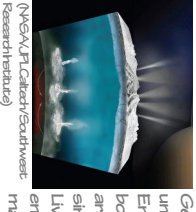
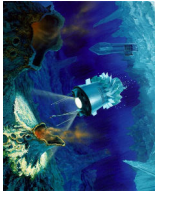


The European Space Agency has scheduled missions to explore not only the surface of the moon Europa, including its geysers, but also its seas. (NASA/JPL)



Geysers emerge from under the ice that covers Enceladus. At the bottom of the sea there are hydrothermal vents similar to those on Earth. Living beings, whose energy sources is geothermal, could develop there. (NASA/JPL-Caltech/Southwest Research Institute)



Enceladus, Earth and Europa, are worlds with seas. Note that on this image the scale is not exact: Enceladus is much smaller than our Moon and Europa is 90% of the Moon's size (NASA).

The Universe in my pocket



Solar System moons

TUIIMP
No. 38
THE UNIVERSE IN MY POCKET

Julietta Fierro
Institute of Astronomy
UNAM, Mexico

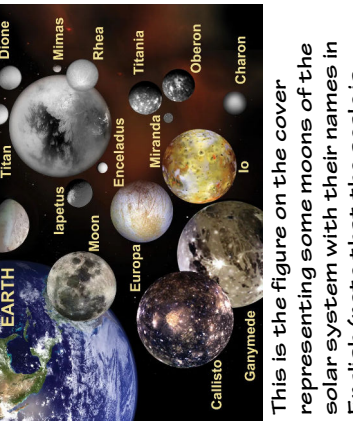
Europa and Enceladus could host submarine life, as it is thought that they also have hydrothermal vents. This life would not necessarily be of the same form as the life that exists on our planet and it would be fascinating to discover it.

Some of the most fascinating satellites in the solar system are Jupiter's Europa and Saturn's Enceladus. Both are covered with cracked ice under which seas exist. On Enceladus, geysers have been observed that contain not only water but also organic matter, which indicates that some kind of life may exist on that world.

On Earth's surface, life thrives on the Sun's energy through photosynthesis. In the deep sea, life gets its energy from hydrothermal vents, a kind of underwater volcanoes, where a great variety of living things can live on geothermal energy.

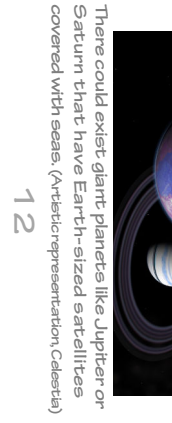
Europa and Enceladus

QUIZ

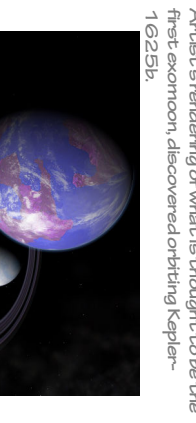


This is the figure on the cover representing some moons of the solar system with their names in English (note that the scale is correct but not the positions). Some of these were presented in this booklet. Do you know which planet they belong to?

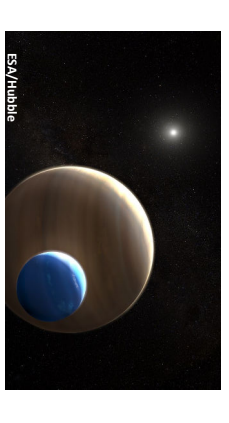
Answers are on the previous page.



There could exist giant planets like Jupiter or Saturn that have Earth-sized satellites covered with seas. (Artistic representation, Celestia)



Artist's rendering of what is thought to be the first exomoon, discovered orbiting Kepler-1625b.



ES/Hubble

Moons on other worlds

With at least 171 satellites in the solar system, imagine the number and diversity of moons revolving around the 5,000 extrasolar planets that have been discovered so far (see TUIIMP 2) — and these only include the nearest stars!

There are even extrasolar planets called 'free floaters' that may have satellites similar to those found in the solar system. Free floaters do not revolve around a star, but they orbit the center of Galaxy as do other stars, along with their planetary systems, satellites, asteroids and comets.

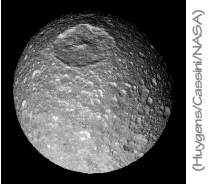
Thus, there is still an immense number of objects for astronomy to discover, sites to explore and fantastic places whose strange conditions are waiting to be unraveled.

Studying the surfaces of satellites tells us about their composition and history. For example, the Earth's moon is covered with impact craters as a result of a constant bombardment by meteoroids that collide with the surface. A satellite with many impact craters usually has a very old surface. If lava emerges from the interior, it covers the craters and erases them; these are the darker and less-cratered areas of our satellite.

On moons such as Jupiter's Europa or Saturn's Enceladus, water emerging from the interior through cracks in the surface cover the craters and freezes. The only satellite with enough gravity to retain an atmosphere is Titan. Its atmosphere is composed mostly of nitrogen and methane.

Enceladus is one of Saturn's 27 moons. It has relatively few impact craters compared to other moons because the water that emerges between the cracks from its subterranean sea tends to cover them with water that freezes and erases them.

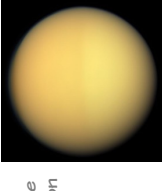
Satellite surfaces



Mimas, a satellite of Saturn, has a surface covered with impact craters. The largest impact left behind a huge crater and a large fracture. If it receives another major impact, Mimas could be split in two.



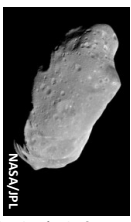
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Titan, the largest satellite of Saturn, is the only moon in the solar system that has an atmosphere.

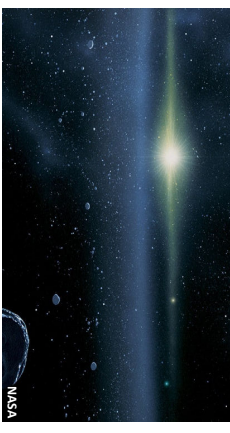
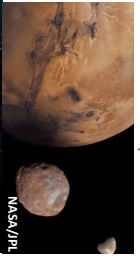
Io of Jupiter

One of the most fascinating satellites is Io, which orbits Jupiter. On this moon there are always active volcanoes. They produce lava flows and their volcanic plumes can reach 300 km in height. Some of their particles travel into space and form a ring of dust around Jupiter known as 'Io's torus'. It is shaped like a doughnut. The interiors of Jupiter's large satellites are molten. One might think that they should be frozen because the surface temperatures are about -160°C due to the distance to the Sun. But the tidal forces generated by Jupiter attract the near side more than the far side. Thus, the interior of these satellites alternately stretches and shrinks as they revolve around themselves, and its temperature increases. If the interior is rocky, as is the case for Io, it becomes lava. If it is icy, it creates underground seas.

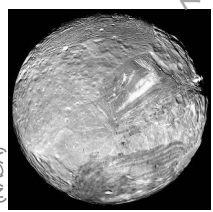


Most of the satellites are irregularly shaped. For example, the asteroid Ida has a small oblong moon called Gaepira.

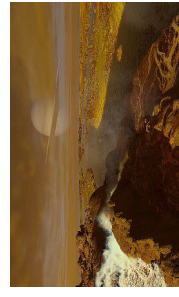
The two moons of Mars are trapped asteroids.



Thousands of asteroids are in the Kuiper belt; a few escape, and are later trapped by more massive objects and become their satellites.



Miranda, one of Uranus' satellites. (NASA/JPL)



Artist's rendering of Titan showing its atmosphere and seas of liquid methane. (NASA)



The second largest satellite in the solar system is Saturn's Titan. In this image it is shown compared to the sizes of the Earth and the Moon.

Answers to the quiz on the last page

- Earth: Moon
 - Jupiter: Europa, Io, Ganymede, Callisto
 - Saturn: Titan, Rhea, Enceladus, Iapetus, Dione, Mimas, Tethys
 - Neptune: Triton
 - Uranus: Titania, Miranda, Oberon
- (The moons whose names appear in gray are not mentioned in this booklet)

A small experiment ...

... that you can do to understand how tidal forces heat the interiors of some satellites. You will need a rubber band or a deflated rubber balloon. Put the rubber band in a refrigerator for a few minutes so that it cools down a bit. When you take it out, place it on your forehead and you will feel how cold it is. If you now take each end with each hand and stretch and loosen it many times and place it back on your forehead you will feel how it warmed up. This is how the tidal forces of Jupiter heat the interiors of Io by stretching and loosening it.

Titan and Miranda

After Ganymede the largest satellite in the solar system is Titan. Some scientists think it resembles the newly formed Earth, before the appearance of life. Titan is a very cold place with seas of liquid methane - which would be a gas on Earth. Titan's atmosphere is so dense that it keeps these seas from evaporating. It also has mountains covered in solid methane. Some scientists believe it also has mountains covered in water ice. Miranda is a satellite of Uranus that has a very strange and unique surface made of terraces, depressions, ridges and fractures that do not seem to fit together properly. This might be the result of a collision of Miranda with another satellite. The scattered pieces were brought together again by gravity, but in a different arrangement.

The Universe in my pocket No. 38

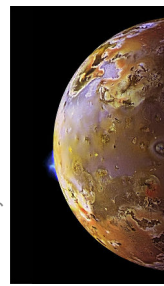
Julietta Fierro, from the National University of Mexico, wrote this booklet in 2022, with the participation of Grażyna Staśnińska, from the Paris Observatory.

Credits: ESO, NASA, Space, Universe Today, Wikipedia.

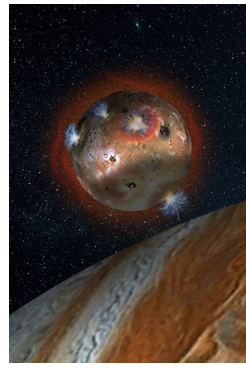


To learn more about this collection and the topics presented in this booklet you may visit <http://www.tuimp.org>.

Translation: Stevan Kurtz
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Artist's rendition of Io, with some of its volcanoes erupting. (SwRI/Andrew Blanchard/NASA)



Io is covered with sulfur-rich volcanic lava, which gives it an orange color. A 300 km high volcanic plume is visible at the upper edge. (NASA/JPL/Arizona State University)

What you will discover

The solar system, in addition to planets, has at least 171 satellites, also called moons, which move around the planets, except for Mercury and Venus, which do not have any moon. Most of them are irregular, like huge rocks. Others are spherical, similar to the terrestrial Moon, some are smaller than our satellite and others larger. In this booklet you will discover some properties of several notable moons such as those orbiting Jupiter, Saturn and Uranus. You will notice that in the study of the solar system, geophysics and astronomy work hand in hand. Geophysics studies the Earth, a rocky planet with a molten core and volcanoes, covered with deep oceans that are filled with living creatures. Astronomy studies all the celestial bodies of the Universe.