



Astronomy literacy concepts

The Essential Principles and Fundamental Concepts
of Astronomy Sciences for Learners of 6 to 12 years old

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La Terre vue de la Lune

The study of astronomy is an important experience that has far-reaching implications for many fields of study. «Astronomical literacy» involves not only knowledge and understanding of the Earth and its interaction with other celestial objects, but also an understanding of the scientific processes used to produce these concepts. Usually, kids are showing a real fascination for space related stories and activities.

USING ASTRONOMY AS A TEACHING TOOL

Astronomy is more a science of observation than an experimental science. We cannot act on the stars, but only observe their appearances, their motions and their configurations in relation to each other.

An awareness of the «things of the sky» favors the emergence of a logical thought, and of an observational thought. For example, with sunlight and the shadows it generates, it will be easy to do some experiments with children of this age. Observations can be asked daily during a month on the Moon's appearance and to take notes of these observations. On the other hand, simulations such as day and night, phases of the moon,... allow to realize some first models and to introduce the concept of the scientific method. For younger age, knowing could be before understanding.

ESSENTIAL PRINCIPLES OF THE SCIENCES OF ASTRONOMY



ASTRONOMY LITERACY CONCEPTS

THE ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS OF ASTRONOMY SCIENCES FOR LEARNERS OF 6 TO 12 YEARS OLD

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THE EARTH AND ITS REPRESENTATIONS

Understand that we live on a round planet named Earth

Understand that we live on a round planet named Earth

We live on a round (spherical) planet named Earth. It is a planet made of rocks and water and wrapped by a layer of air. This layer of air is known as our atmosphere.

The concept of atmosphere / to be distinguished from the vacuum of space

The layer of air above the surface of the Earth is called the atmosphere. These are elements in gaseous form. Most species live by breathing. Clouds and fog can form in the atmosphere. These are made of water vapor and can carry other elements such as seeds or sand. The circulation of layers of air more or less colds induce wind, storms, cyclones.

Associate the Earth with its color seen from Space - The Blue Planet due to its oceans

The Earth is covered to 70% by the oceans. This is why it is called the Blue Planet. Land animals as well as humans live on the continents. Clouds are visible from space.

Understand that a map is a representation of the world: planisphere and globe

You can find representations of Earth in many forms. A globe represents the true shape of the Earth, with continents and oceans. A world map, also called a planisphere, is a flattened representation of the Earth, so it can be seen flat or on a wall. The projection of a sphere on a flat space deforms reality. Hence, several types of planispheres exist.



Manipulate orientation concepts (North / South / East / West / Poles / Hemispheres / Equator)

On the Earth, North and South correspond to the direction of the Poles. East is the direction in which we see the Sun rise, and West the direction in which the Sun sets. They are called the four cardinal points.

On Earth, geographic poles are very close to magnetic poles. Hence, one can use a compass to determine the directions.

Hemisphere is half of a sphere. We define on Earth the North and the South hemispheres that are separated at the Equator. North and south hemispheres experience opposite seasons.

Generally on a map, North is placed on top, South on the bottom. East is then on the right and West on the left.

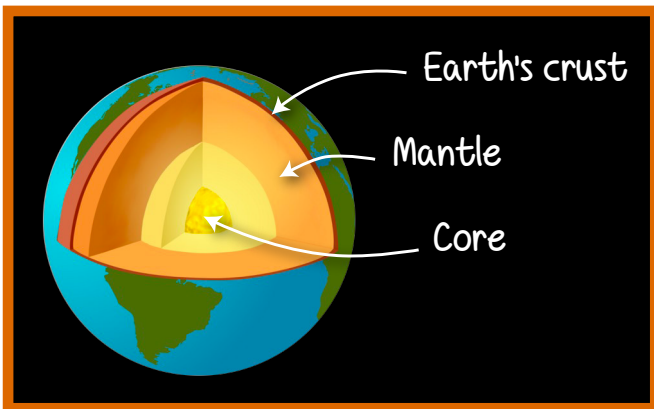
Birth of life on Earth

A billion years after the formation of the Earth, life appeared, first at the bottom of the oceans. At the beginning, the Earth was a huge ball of molten rock. Then it cooled and clouds formed. Rains fell filling the oceans. Thanks to the Sun and the water, plants grew and invaded the continents. Animals also began to leave the water and adapt to life on the continents.

Monkeys appeared 30 million years ago, and the genus Homo, to which humans belong, have inhabited the Earth for 3 million years.



THE EARTH - SUN SYSTEM



Understand that the Sun is a star

The Sun is a star, a giant sphere of super hot gas. It is 1 million bigger than the Earth. The Sun emits light and energy. It warms us and plants use its energy to feed. The Sun is around 4.5 billion years old.

Understand the difference between stars and planets (and small bodies) - Understand the dimensions - Illustrate the relative sizes of the Earth and the Sun

Stars are huge balls of superhot gas that burn their matter, and thus send light, heat and energy into space. Planets are much smaller than stars, they do not burn their matter and therefore do not send light or heat.

Understand what is a planet

A planet is an object in the Universe that orbits a star. To be called a planet, it must be large enough to have a spherical shape and to have cleared the other rocks in its path. That means that it is the only one that remains on its orbit. There are eight planets orbiting the sun. The Earth is the planet on which we live and the only planet known to date to harbor life.

Understand what is a star

Stars emit light. They are balls of hot, very dense gas. They are made up mainly of hydrogen, which is their fuel. There are stars of different colours: from red to blue. Their colour is related to their size and temperature. These colour differences can be observed at night. However, the flickering that can be observed in the starlight is due to fluctuations in the Earth's atmosphere.

Put the Sun in the center of the solar system

The set of planets and the Sun is called the Solar System. The Sun is at the center of the System, it is so heavy that it attracts the planets around it. Thus, the planets, like the Earth, revolve around the Sun.

Understand the trajectory of the Earth around the Sun

The Earth orbits around the sun, and this path determines the length of a year, 365 days. The Earth's orbit is close to a circle shape with the Sun at the center.

Understand the day/night

The Earth spins. The duration of this rotation defines the duration of a day, and allows alternating the day and the night as it faces or not the Sunlight. The day lasts 24 hours on the Earth.

Understand the seasons.

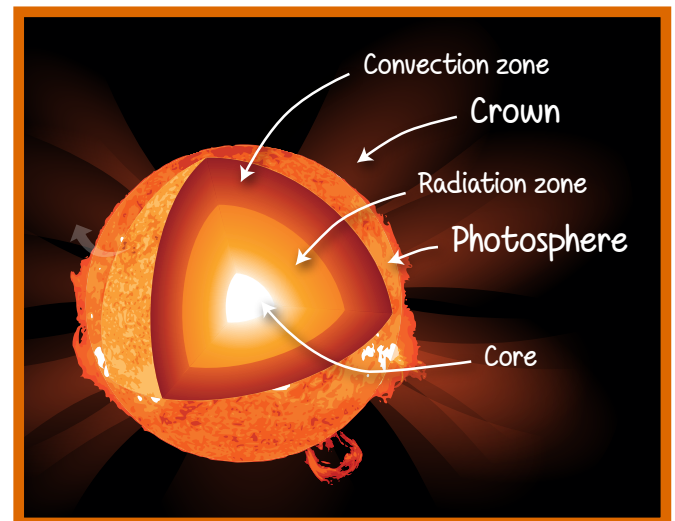
From Europe, we experience four seasons each year: autumn, winter, spring and summer. The seasons are characterized by different weather, day and night length. The Earth spins on itself in a slightly tilted position compared to its movement around the Sun. This tilt is of 23.5 degrees from a straight up vertical position. This causes the seasons on Earth as, through the year, parts of the planet are angled towards or away from the Sun's light. The angle induces more or less light that results in time length and weather variations.

Close to the equator the amount of direct sunlight does not change much during the year, so there is little difference between each season. The extreme cases are at the Pole where it is night 24 hours a day during several weeks in winter, and there is Sunlight 24 hours a day during summer. When one hemisphere experiences Summer the other one is in winter.

Eratosthenes' experiment: first

measurement of the Earth's circumference (and the sundial)

More than 2000 years ago, the Greek astronomer Eratosthenes performed an experiment to measure the size of the Earth, and you can reproduce it. All you need is to have a contact far away on the globe. Everyone takes a stick and plants it in the ground. The shadow of the stick at noon will not be the same size, and this allows us to calculate the size of the Earth.





THE EARTH - MOON SYSTEM

The Moon as a natural satellite of the Earth

The Earth orbits the Sun, but something also orbits the Earth : the Moon!

The Moon is the only natural satellite orbiting Earth. It is four times smaller than the Earth.

Mankind's first step on the Moon was in July 1969.

Main characteristics of the Moon

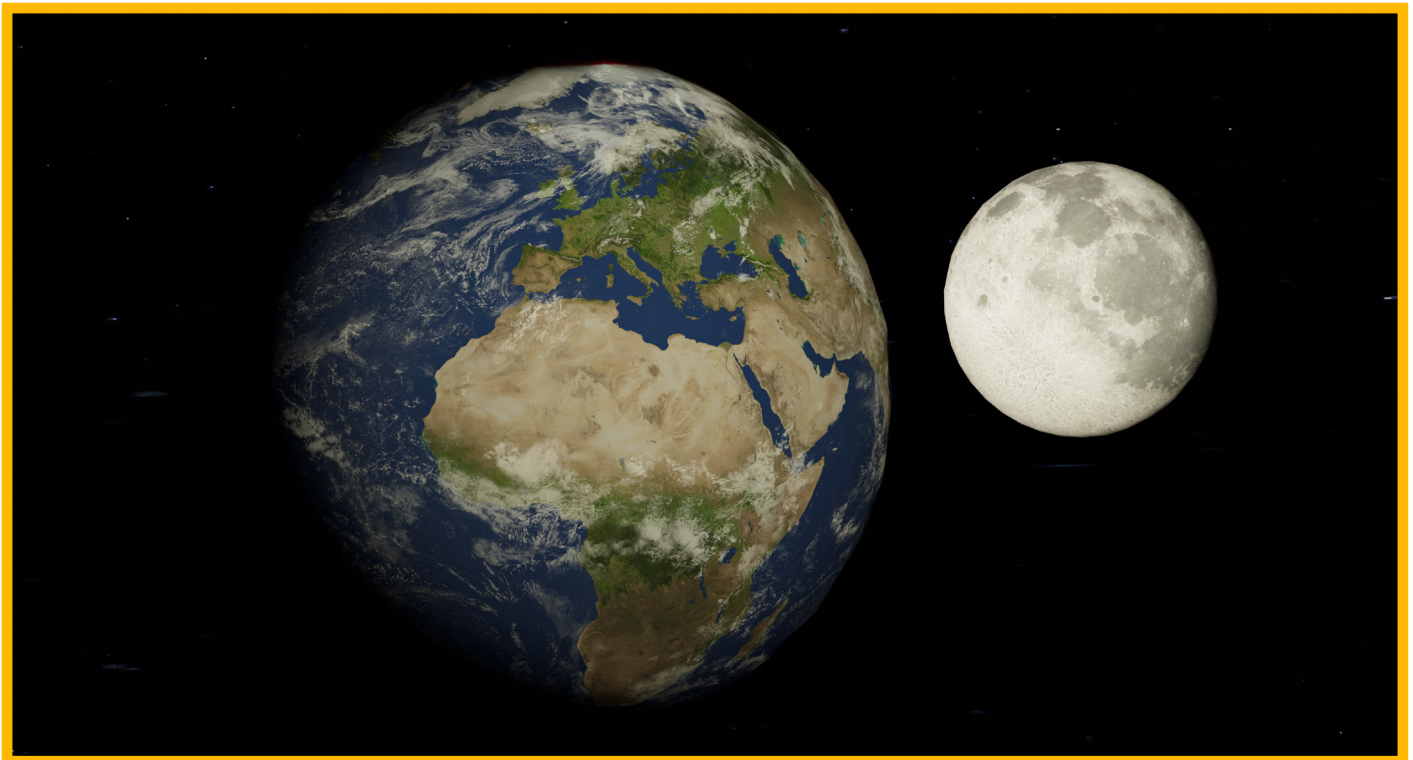
The Moon does not host life, and has no atmosphere, nor water. It is a gigantic spherical rock. When the first humans traveled to the Moon, they left footprints that will never be erased. Indeed, there is no air, therefore no wind.

The formation of the Moon

The Moon would have formed following the collision of a huge asteroid with the Earth a very long time ago (several billion years) when the Earth had just formed. The debris of this collision would have then assembled to form the Moon.

The Moon does not emit light

The Moon is not a star, it does not burn or emit light itself. It simply reflects the light of the Sun.



The trajectory of the Moon around the Earth

While orbiting the Earth, the Moon can be :

- either in front of the sun and we will not see the light it reflects, it is New Moon,
- or behind the Earth, it will be the full Moon,
- or on the sides. We will then see only a part of its illuminated face, these are the crescent moons or the quarter moons.

The phases of the Moon

Depending on the position of the Earth, the Moon and the Sun, the Moon is not illuminated in the same way and from the Earth only a certain part of this illumination is visible. This is why the illuminated shape of the Moon is not always the same. This phenomenon is called the phases of the Moon. Thus, depending on the position of the Moon in relation to the Earth, we will see different «phases of the Moon». The main ones are Full Moon, New Moon, First Quarter and Last Quarter.

The Moon's synchronization (visible and hidden face)

The Moon orbits the Earth in 27 days. The Moon also spins, in 27 days too! Therefore, from the Earth, we always see the same side of the Moon. It has therefore a «hidden face».

The tides

Twice a day at the level of the coasts, the sea / the ocean withdraws then advances, it is the phenomenon of tide. It is induced by the Moon which attracts the oceans and the Earth in different ways.

Eclipses of the Sun

When the Moon passes in front of the Sun, it sometimes completely masks it. This is called a solar eclipse. It is quite rare and very spectacular. It happens only when the Sun, the Moon and the Earth are perfectly aligned. For a few minutes, on a part of the Earth, it is night in the middle of the day. One sees only a luminous crown: it is the edge of the Sun.

Eclipses of the Moon

Often when the Moon passes behind the Earth, it passes in the shadow of the Earth. Its color changes, and this is called a lunar eclipse. It happens quite often, in the middle of the night, on full moon days, when the alignment between the Sun, the Earth and the Moon are perfect.



THE SOLAR SYSTEM

The planets of the Solar System

The eight planets of the solar system, their name and order.

The solar system hosts eight main planets:

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune

The planets reflect the Sun's light

The planets do not emit their own visible light. It is possible to see, with naked eye, the planets Mercury, Venus, Mars, Jupiter, and Saturn during the night because they reflect the light coming from the Sun. Planets Uranus and Neptune are too far and not bright enough to be seen by naked eye, and require the use of a telescope to be seen. Venus can even be seen during the day, before sunset or after sunrise, depending on its position around the Sun. Venus is commonly named the evening star, the Star of Bethlehem, or the morning star, even if it is not a star at all.

The four inner telluric planets

The planets of the solar system have different colors and composition. The four closest planets from the Sun, (Mercury, Venus, Earth and Mars) and named telluric planets or rocky planets. They have a solid external envelope and are wrapped by a thin atmosphere. They have different colors (Mercury is grey, Venus is yellow, Earth is blue and Mars is red), due to their different composition. The Earth has its own natural satellite, the Moon. Mars owns two natural satellites, Phobos and Deimos. Mercury and Venus do not have satellites. The Earth is the largest rocky planet in the solar system.

The four outer gas giants

The four other planets, Jupiter, Saturn, Uranus and Neptune are farther from the Sun. They are giant, gaseous planets, and do not have a concrete solid envelope. They are way larger than Earth, 4 to 11 times. Their very thick atmospheres have different chemical compositions, making them have different colors. These four planets all have rings surrounding them. Most of them are very tiny and difficult to observe, but Saturn's rings are very easy to see through a telescope or even binoculars. These giant planets have several natural satellites orbiting them, almost 80 in the case of Jupiter and Saturn. The four main satellites of Jupiter can also easily be seen through a telescope.

Mercury

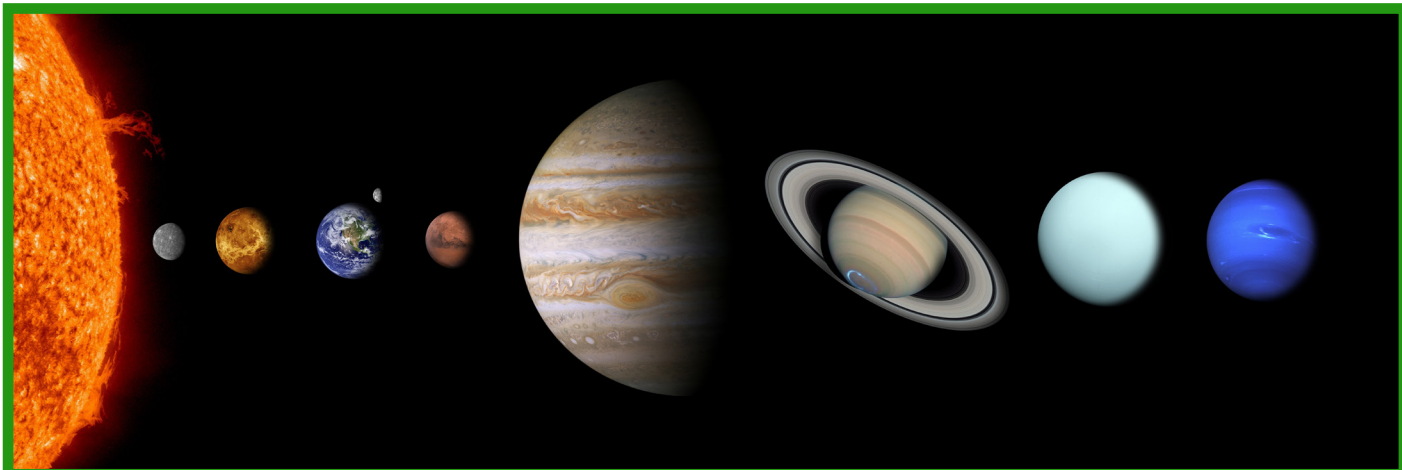
Mercury is the nearest planet to the Sun and the smallest planet of our Solar System. The planet has a rocky surface and is smaller than Venus and Earth. Mercury has no atmosphere and this is why we can see so clearly the craters, as it is for the Moon. It is because there is no erosion from air or water.

Venus

Venus is more or less the same size than Earth. It has a very thick atmosphere full of clouds. There tends to be strong storms on Venus. The temperature is very high (460 degrees Celsius).

Mars

Mars is the fourth planet from the Sun. It is slightly larger than Mercury, but much smaller than Venus and Earth. Mars has two «Moons» (natural satellites), called Phobos and Deimos. Mars has the highest mountain in the Solar System: Mount Olympus, 25 km high! Humans have sent many robots to explore this planet.



Jupiter

Jupiter is the fifth planet in our Solar System. It is also the largest and heaviest planet in the Solar System. It revolves around the Sun in 12 years. It is mainly made up of gas. It has many bands of clouds on its surface, and a large red spot, which is a huge cyclone. Jupiter has four moons.

Jupiter is visible to the naked eye as a very bright star. If we observe it several nights in a row with binoculars or a small telescope, we will see the Moons revolving around Jupiter. This is what Galileo did in 1610, refuting that everything revolved around the Earth as it was commonly believed in his time.

Saturne

Saturn is the 6th planet from the Sun. It is mainly composed of gas and it is a little smaller than Jupiter. Saturn is well-known for its bright rings.

You can easily see these rings with a small telescope. Most astronomers will tell that it is the best thing to observe in the sky ! Its rings are composed of chunks of ice and dust.

Uranus

Uranus is the 7th planet from the Sun. It has a blueish green color due to clouds of methane in its atmosphere. Contrarily to the other planets that rotate vertically compared to their movement around the Sun, Uranus spins on itself like a wheel around the Sun. Uranus is so far that you cannot see it by eye from Earth, you need a telescope.

Neptune

Neptune is the 8th and the last planet from the Sun. Neptune was discovered by calculation. Uranus movement was strange so scientists deduced there will be another planet. Neptune is deep blue due to the clouds of methane. Neptune is bluer than Uranus. This is due to a component in its atmosphere but

we don't know yet which one. There are very strong winds and storms in its atmosphere as can be seen by the bright clouds and dark spots on its surface.

Distances in the Solar System

If we consider the Sun-Earth distance as a meter, then Mercury is at 38cm, Venus at 72cm, Mars at 1.5m, Jupiter at 5m, Saturne at 9m, Uranus at 19m and Neptune at 30m.

The other objects in the Solar System

The solar system hosts thousands of tiny objects, asteroids, comets, or what we call the trans-neptunian objects, such as Pluto. These objects are all very different, (rocky for the asteroids, icy for the comets), and have different sizes, from the size of a car to the size of the Moon.



THE UNIVERSE

The formation of planets and the life cycle of stars

As everything in the universe, planets and stars have their own life cycle, with a birth, a lifetime, and a death. The lifetime of a star depends on its size.

The birth of a star starts with the collapse of a giant gas and dust cloud. At the center, temperature and pressure will dramatically increase until the star lights up, then the star is born. This spherical star spins and attracts the remaining elements of the dust cloud, forming a disk of debris orbiting it. The planets will form in the dust debris disk.

Scientists are today demonstrating that every star in the universe hosts planets, named exoplanets as they are not part of the solar system.

A star starts its end of life when all the combustible is burnt. There are mainly two different destinies for the stars at the end of their life: if this is a giant star, it could explode as a supernovae or a black hole. Smaller stars like our Sun will inflate and become a red giant star. This process continues until the star becomes a gaseous cloud, whilst the core of the star turns into a white dwarf, smaller than earth and extremely dense.

The Solar System in the Galaxy

The Sun, our hosting star, is one of the billion stars composing our galaxy, the Milky Way. This name comes from our vision of our Galaxy from Earth, this blurred luminous band crossing the night sky. Even if we cannot observe our galaxy from outside, the study of the movement of stars helped us to know its spiral shape. Our galaxy has a supermassive blackhole in its center.

The closest star from the Sun is named Proxima Centauri. If we still consider the Sun-Earth distance as 1m, then this star is at 270 000 km, 4 times the distance Paris- New York City.

The Empty space

The space is mainly empty. Between stars, there is no air. It is not possible to fly. The sound cannot propagate. The temperature is very cold.

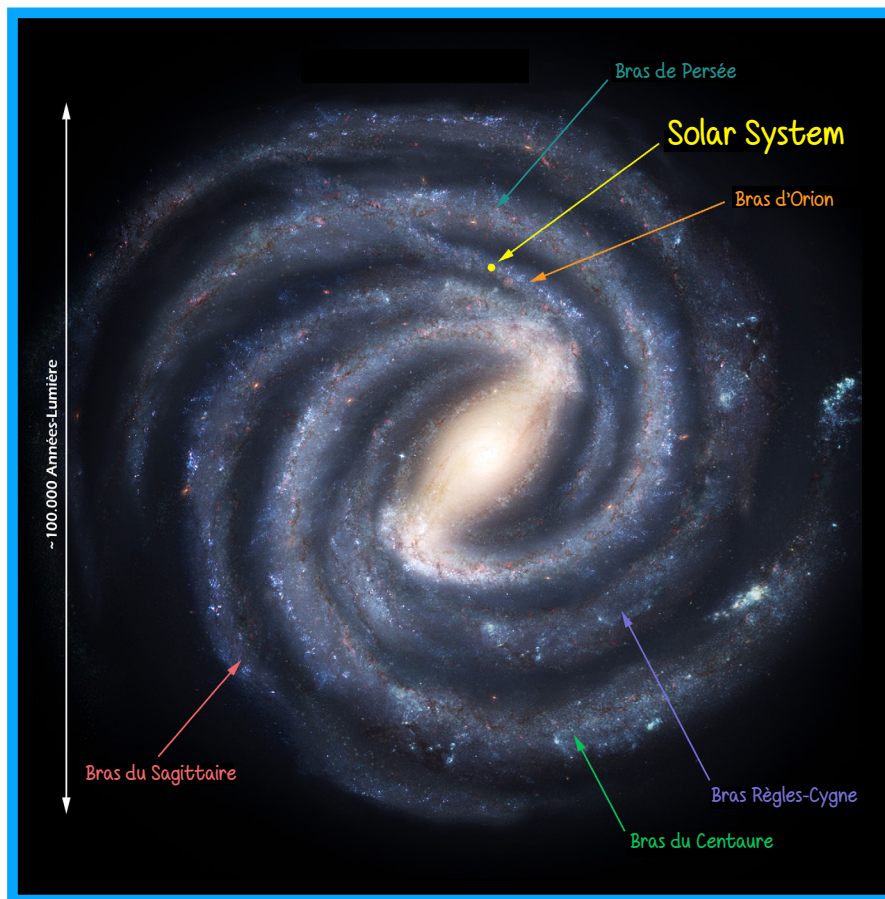
The Galaxy in the Universe

The Milky Way is one over billions and billions of galaxies in the universe. One of the closest galaxies from the Milky Way is the Andromeda Galaxy, visible with naked eye in a very dark night sky. If we consider the Sun-Earth distance as the thickness of a human hair, this galaxy is at 2400 billion kms.

The Big Bang

The Big Bang is said to be the birth of the Universe. This theory tells us that before the Big Bang, nothing was in the universe. The Big Bang is a Giant explosion which gave birth to everything

we know. Of course this is just a theory that has never been proven, and dozens of experiments are going on to try to explain the reality of the birth of the Universe.



The life in the Universe

What makes life possible ? Humans only know life on Earth. Habitability : how life could exist on other planets ?

The Earth is the only habitable planet we know for now. Even if other planets around other stars are found with signs of life, they are not reachable for humans with current technology and would cost such an amount of energy that it does not seem possible.

Scientists have yet no idea if life appears easily or not. Is this a very common thing that occurs when all elements and favorable conditions are present ? Or is this a difficult process that appears by hazard on Earth (and maybe in a few other places in the Universe) ? We do not know ! Hence, aliens are not known even if they have a huge place in human fantasy since humans knew that other planets exist.



ASTRONOMY IN OUR DAILY LIFE

The calendar (year, month, leap year)

A calendar is a way of organizing time. This is done by naming a period of time like days, weeks, month, year. Day and year are related to astronomical facts. Day is the time that Earth spins on itself, and a year is the time that the planet orbits around the Sun. The lengths of the month are related to the cycle of the phases of the Moon. However, its length of 29.5 days does not fit on the 365.25 day of the year ($12 \times 29.5 = 354$). So, it is necessary to add more days, which is why several months have more than 29 days. Several calendars exist in the world.

Days of the week (to be adapted with each language country)

In English, some days of the week are named according to celestial bodies. Saturday is named in reference to Saturn. Sunday is the Sun day, and Monday refers to the Moon.

Natural / artificial satellites

A satellite is a small object orbiting a bigger object like a planet, a dwarf planet or big asteroid. One could differentiate natural and artificial satellites. Natural satellites are body rocks that arrived to rotate around the planet through the evolution of the Solar system. Artificial satellites were sent by humans to rotate around a planet (see the section sending satellites into space). All the planets in the solar system except Mercury and Venus have natural satellites. Thousands of artificial satellites rotate around the Earth.



Gravity

Gravity is the name we give to the force that pulls things to the center of Earth as we experience. It is why we stick on the ground. All objects interact within each other through gravity even across space. This force results in attraction between bodies. Hence it is the force that bound Earth and Moon, or the planets of the Solar System with the Sun. It contributes to what makes the lightest bodies rotate around the heavier object.

Observing the sky (naked eyes, binoculars, amateur and professional telescope)

Human beings have been observing the sky for ages. Ancient temples or alignment of prehistoric stones show that humans are interested in what happens in the sky for a very long time.

A scientist observing the universe is named an astronomer or an astrophysicist. An astronomer is working with an observatory, on earth or a satellite. Observatories are often placed on the summit of mountains, or in the middle of the desert, where there is no light pollution and where the good weather with no clouds is favorable for observations.

With the telescope's instruments, astronomers study the planets, the stars, the galaxies. They record spectra or pictures.

Shooting stars and Meteors

Shooting stars are fragments of asteroids, the size of a grain of sand or a small pebble. When they enter the Earth's atmosphere, they burn and emit light. This is the shooting stars phenomenon. Some of them are large enough to not burn entirely and fall down on Earth. We name them Meteors.

Constellations - Bright stars - Northern star

A constellation is a figure pictured by humans when they were observing the night sky, without instruments or binoculars. Constellations often picture figures of mythology. These are made by considering stars as points, and link them together, as a drawing game. In fact, these stars are very far from each other and are not bound.

Ursa Mayor and Ursa Minor are two constellations in the northern sky, visible during the whole year. Each one is made of seven main bright stars, and several other tiny stars.

The North Star in the Northern Hemisphere is the brightest star in the Little Dipper constellation. It can be seen with the naked eye and points north. Because of the Earth's rotation, during the night all the stars move across the sky, except this one. This is because this star is aligned with the Earth's axis of rotation (see the Season definition).



ASTRONOMY IN OUR DAILY LIFE

Astronomy / astrology

Astronomy is a science based on facts. Researchers explain how they derive their theories and observations. They make their calculations public. They can be verified and tested by anyone. Before a new concept is accepted as true, it is verified and tested by many other researchers.

It should not be associated with astrology that is now well identified as a mix of beliefs. Astrology believes that there is an influence of the position of the planets on human life. Moreover, to the fact that none of the ideas believed by astrology have not been proven, the concept is often based on positions of the stars that are not correct. Scientists show that astrology is not based on verified facts - what it is understood and accepted by most. However, astrology is still popular, like many other superstitions, as some people think it helps them to release stress on uncertainties of life.

Light pollution

Light pollution is the excessive and prolonged use of artificial light. It results in the brightening of the night sky. It has serious environmental consequences for humans, fauna and flora. It impairs our vision of stars, planets and galaxies. The many bright lights in cities contribute to light pollution. As a result, the stars can no longer be seen from brightly lit places. Most children in big cities can see very few stars and cannot experience the Milky Way, our own galaxy.

The Earth: our fragile raft in space

Does life exist on other planets ? In astronomy, planets are found that orbits around stars. Other planets exist in the Solar System. For now, none of them showed evidence to sustain life on them.

Humans need air with oxygen and a temperature between 0 and 40 deg to live. These conditions do not exist on the other planets and Moons of the Solar System. The exoplanets found around other stars are very very far from us (the closest, Proxima b, is at a distance of 40 000 milliard de km - the light takes 4.2 year to go there).

So humans, animals, plants, mushrooms,.. only live on Earth and we should take care of our environment.



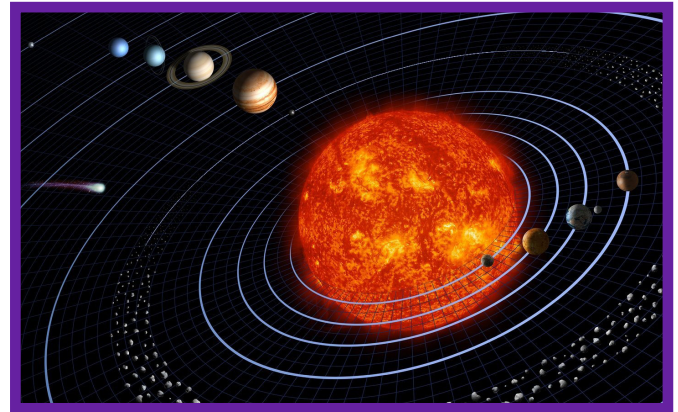
WORKING IN ASTRONOMY OR SPACE SCIENCES

The scientific process

This is the main method of research used by scientists to study and learn. When a question is raised or when a problem is identified, the method could be detailed as : gathering data of this problem (observing and experimenting), then an hypothesis can be formulated and then tested. Example of an experiment by a baby: observe objects falling on the ground when they are not hold, hypothesis : when the object is not hold, it always falls, Test : take and drop object again and again.

Astronomers at work

Several professionals work for astronomy projects. Researchers are dedicated to study physical problems, raise questions and define theories or observations and hence better understand space. Most of them are also teaching at the University. Engineers and technicians work on building and maintaining the instruments and the telescopes used for the observations or to send satellites and probes to space using rockets. Several specialities are needed : electronics, mechanics, optics (for the mirrors and the lenses), informatics,... Administratives professions are needed to maintain the laboratories and enterprises structure.



Sending satellites into space

Rockets launch satellites into space and put them on orbits around the Earth. The satellites get their energy from solar panels. Antennas allow communication with the Earth. Satellites allow people to communicate with each other or to take measurements of the universe or the earth. For example, weather satellites take pictures of clouds and predict the weather.

Sending probes on Solar System bodies

Space probes are sent up to explore the solar system. These robotic spacecrafts are not orbiting Earth like satellites but they are sent in deep space and transmit their findings back to Earth through radio waves. They could be sent close to the Sun, planet, moon or asteroids of the solar system. The space probe can carry a second smaller one for release into an atmosphere or a lander craft to touchdown the surfaces. Among all the information they gather, probes took very nice pictures that are available for all on the internet or books.

Sending humans into space

Before humans were sent into space, dogs and monkeys were first sent. In 1961, Yuri Gagarin was the first person to fly in space for just under two hours, orbiting the Earth. The first woman in space, Valentina Terechkova, flew in 1963 to spend three days in orbit around the Earth.

Living in the Space station

The space station is in orbit around the Earth. Since 2000, it has been constantly manned by astronauts who stay for a few months. The station circles the earth 16 times in one day. Everything inside the station is weightless. In space, without the force of gravity, nothing has any weight. When you drop something, it floats. Hence, everything needs to be attached in the station. To move around, astronauts use handles to hold on to. To maintain their muscles, astronauts have to do a lot of sport.

Living humans on other bodies (Moon, Mars,)

No human lives on other body. Several humans were sent on the Moon between 1969 and 1972. Since then, no other humans have landed in extraterrestrial rocks. Several programs have now their objective to install a base on the Moon and to send humans on Mars. The difficulties come from several aspects: humans need to live air with the composition and temperature of the earth's atmosphere, water and food that does not exist elsewhere. A group of humans that plan to live on another object needs to bring or to create on site these needs. Moreover for Mars the trip is already quite long, at the minimum 6 months and the mission will last at least 2 years. The distance could create difficulty to communicate with Earth (around 15 minutes for a message to travel between the two planets - so 30 minutes to wait for an answer) and bring the humans to feel loneliness and far from Earth.

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