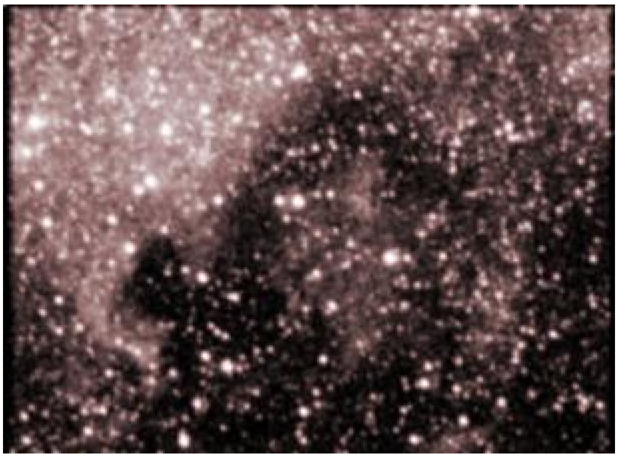
THE EARTH AND THE UNIVERSE



Our planet, the earth, is no more than a small point in a universe full of worlds. Understanding this should fill us with humility and ambition.

With the **humility** of someone who perceives how small we are compared to the cosmos. With the **ambition** to penetrate deeper and deeper into the mysteries which it embodies

By learning about the universe we were able to make precise calendars and guide ourselves in the exploration of the earth.

The knowledge of the nature and evolution of heavenly bodies also brings us the answer to many questions about the origin and destiny of mankind.

Click on next to see the objectives which we propose in this short introduction to the study of the universe or click on the drop-down menu at the side to go directly to our intellectual adventure.

Objectives of this unit

- To understand in a qualitative way the notion of **relative movement**, to a sufficient degree to be able to explain the apparent movement of heavenly bodies as a consequence of the earth's **rotation and translation.**
- To explain in terms of these same movements **the succession of days and nights and the seasons of the year.**
- To know the **components of the solar system** and some of its most interesting properties.
- To understand **the analogous nature among the sun and other stars**, as well as acquiring a notion of its origin, the causes of its energy emission and its probable destiny.
- To explian the night sky as a way of seeing **our galaxy, the Milky Way**.
- To understand the enormous quantity of galaxies which exist in a **universe perceived according to its evolutionary character** .

Does the earth move?

When we are riding a bicycle we clearly see that we are moving with regard to the road. If we are sitting in a car our sensation of movement isn't so clear. **If we are in a train, a really large vehicle, we have the illusion that it is the landscape that is moving, not us.**

Our planet is enormous compared with a train, that is why, although the earth is moving, it seems to us that it is still and the sky around it is moving.
We are going to try to study the earth's movements and how we human beings see them.

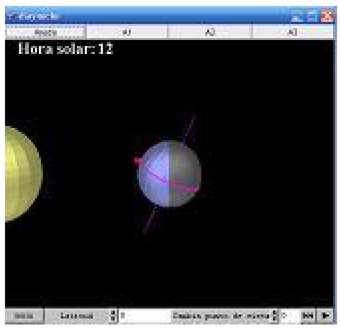
In the following visuals, when necessary the human observer is represented by a red spot: Mr. Smiley

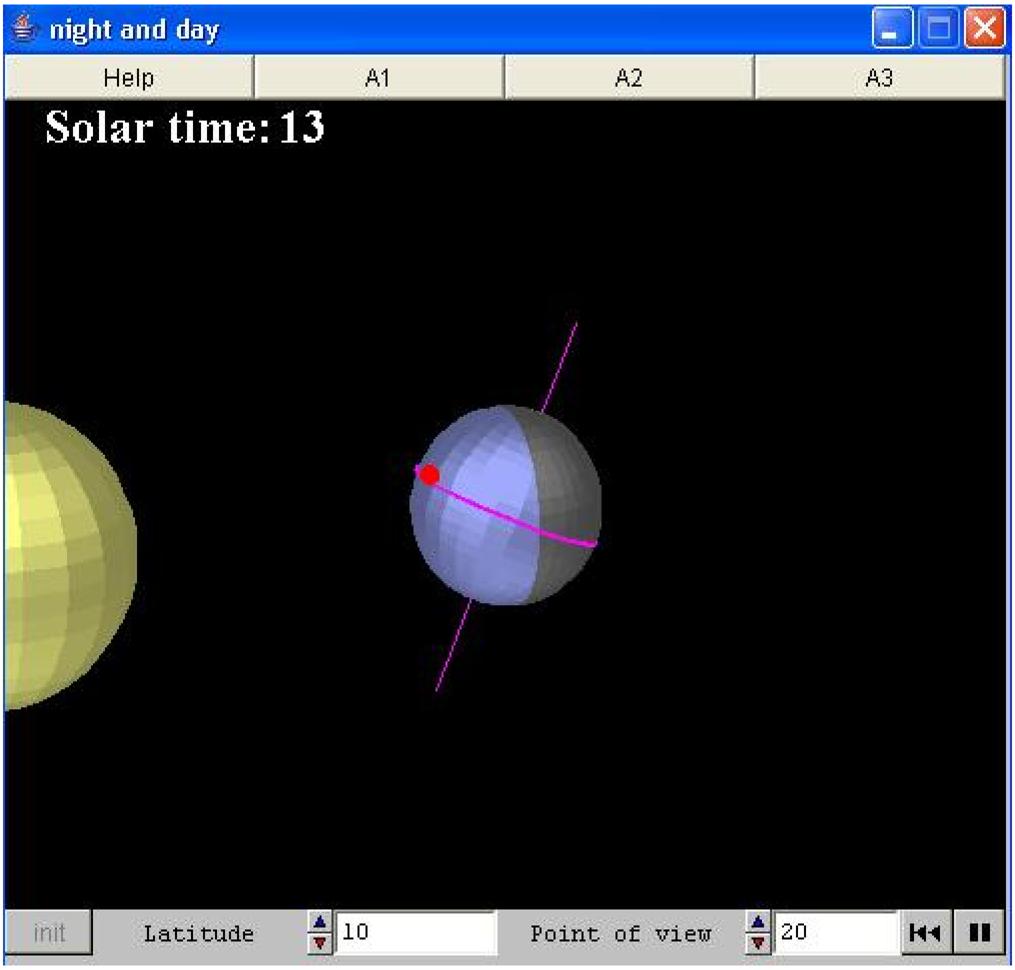
Rotation of the planet

You already know that the earth rotates about its axis.
Have you stopped to think how we know this?

Remember the example of the window of the train.

The daily movement of the sun from East to West is the proof that our planet rotates. To understand this more clearly click on *night and day*.





Help: In this visual, the earth receives light from the sun (on the left).
You can see our planet´s equator and its rotation axis. There is also a red dot that represents an observer, a citizen of the earth.
You can change the point of view with the point of view control.
You can also change the position of the observer with the latitude control.
The other controls start, pause or restart the visual. It is convenient to use the init control after every simulation, when you wish to change the latitude.
The program shows the solar time.

A1: Why is part of the earth dark?
Click on play. What happens to the observer on the surface of the earth? Why?
At what time is it midday? When is it the middle of the night?
At what time does the sun set and when does it rise?
You might want to use the point of view control to answer some of these questions.

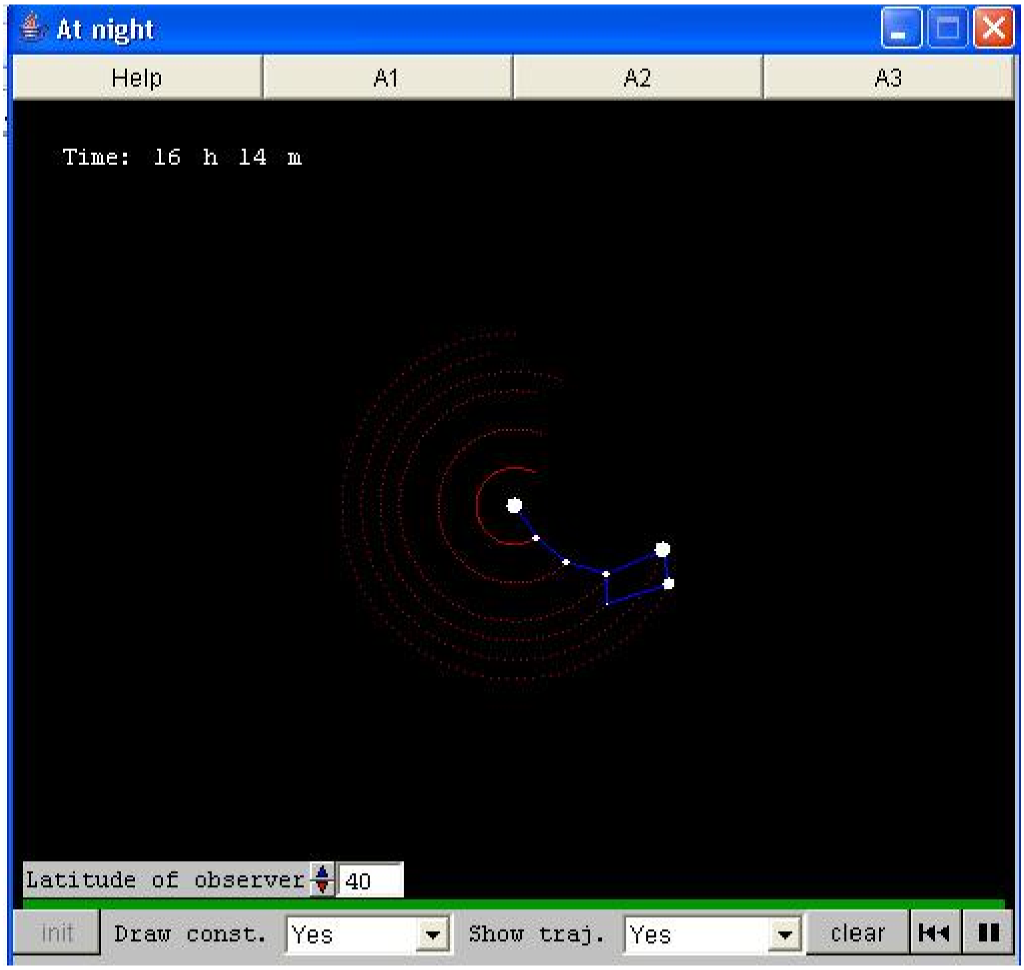
A2: Observe the direction of the earth´s axis and the equator. Do both hemispheres receive the same amount of light?
Further on we will learn that this situation is not maintained all year long.
For now, you should remember that the inclination of the earth´s axis is slightly more than 23º.

A3: Pause the simulation and click on init.
Change the latitude of the observer. What happens then? What is the range of possible values for the latitude?
Place the observer at 40º and click on play. Does this observer experience more time in the sun or less than when he was on the equator?
What about an observer at -40º?

Remember that the observations made here are not true all year long. We will mention this fact again further on.

Does this mean that by night we cannot notice the earth's rotation? Not at all. Haven't you ever noticed that the stars move during the night? Just in case, we are going to explore this movement.

Click on ***at night*** to do so. You will also learn what is special about the **Pole star**, also known as **Polar star** or **Polaris**.



Help: If you look northwards at 12 o´clock of a particular night, you will see the Little Dipper as it appears here.

The green line represents the horizon.

The play, stop and rewind controls are used to start and stop the visual and move back in time.

The init control restarts the visual.
You can choose whether to see the constellation or not. You can also choose whether to see the trajectory of the stars during the night.
The clear control clears the trajectories drawn on the screen.
You can select any latitude in the northern hemisphere.

A1: The stars that seem to remain stationary with respect to one another are known as fixed stars.
A constellation is a group of fixed stars with a name.
If you select yes on the draw const. menu, you will see the shape of the Little Dipper, also known as ursa minor.
Other constellations are named after mythological heroes with very interesting stories.

A2: If you look at the stars at night, they seem to be still. However, if you wait enough, you will realise that this is not so. Click on play to see what happens to the Little Dipper as time goes by.
Try to stop it exactly 24 hours after the initial position. What has happened to the stars? How long does it take to get back to the initial position? What is the cause of this phenomenon?
There is a star very near the centre of circular movement. What is its name? Why is it at the centre?
This is the only star in the sky that seems to remain at rest. Why is this fact important?

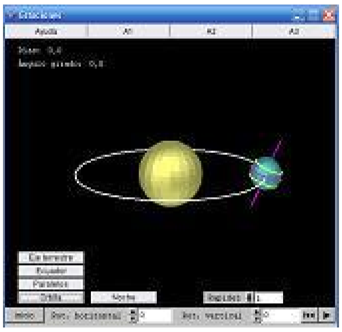
A3: Click on init to restart the visual.
The latitude in Madrid is approximately 40 degrees north. What happens if you decrease the latitude?
Can you see the pole star from the southern hemisphere? What happens when the latitude increases?
The visual cannot go beyond 70 degrees, but can you imagine where the pole star will be when seen from the north pole?

Translation. The seasons

♈	ARIES	♎	LIBRA
♉	TAURUS	♏	SCORPIUS
♊	GEMINI	♐	SAGITTARIUS
♋	CANCER	♑	CAPRICORNIUS
♌	LEO	♒	AQUARIUS
♍	VIRGO	♓	PISCES

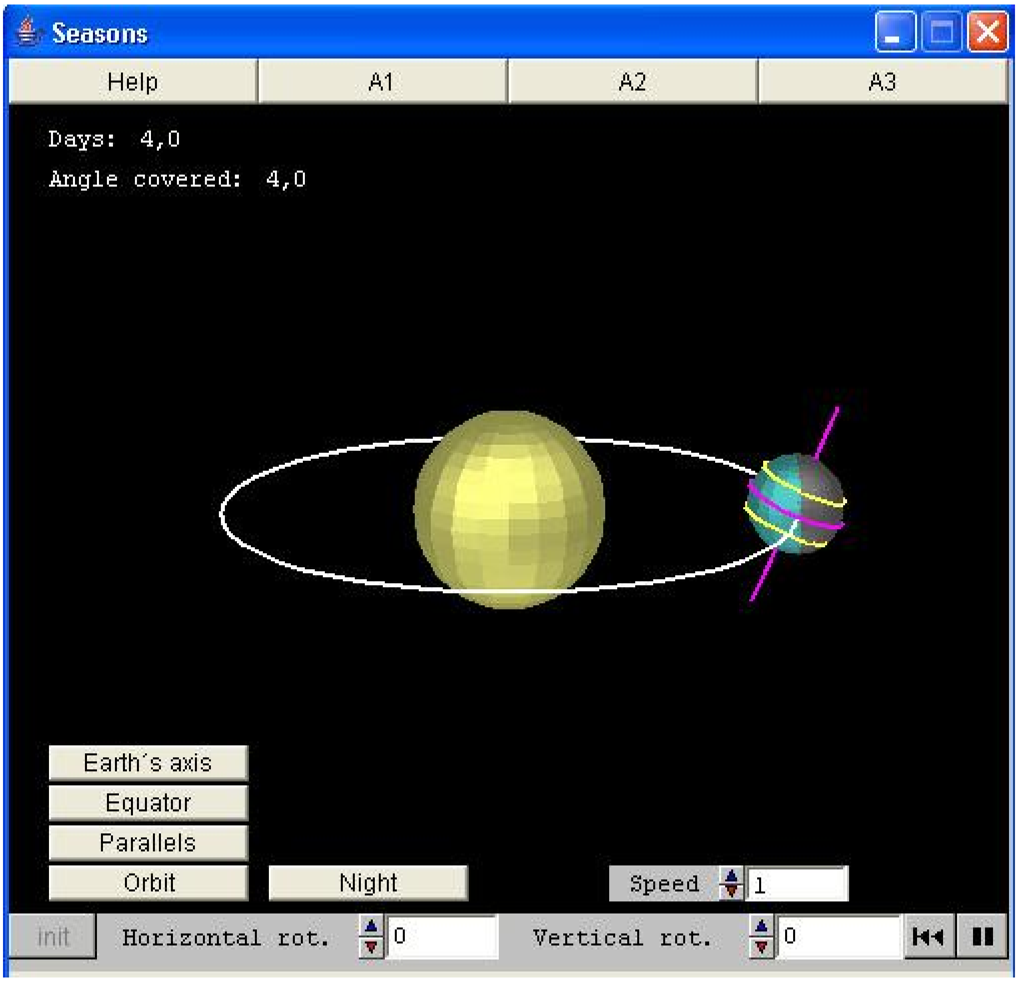
You surely know the signs of the **zodiac**. You even know your own sign. **Yes, we already know that Astrology is a superstition.** It is a lot of nonsense, but it is based on a true fact, related to the movement of translation of the earth around the sun.

Click on *Seasons* and you will see how this movement produces the seasons of the year.



This movement, seen from the earth seem to be the other way round, that is that the sun goes through certain constellations in the sky.

Click on *Zodiac* and you will understand what the zodiac has to do with the annual movement of the earth.



Help: The earth (the blue sphere) moves around the sun.
You can use the appropriate controls to show the earth´s axis, the equator and two parallels of latitude, one in the northern hemisphere and one in the southern hemisphere.
The orbit control allows you to see the earth´s ecliptic, its path around the sun.
The night control darkens the side of the planet that does not receive light directly from the sun.
All these controls toggle on and off.
The horizontal rot. and vertical rot. allow you to change the observer´s point of view.
The speed control changes the speed of the simulation.
You can use start and stop controls to start and stop the simulation.
The init button restarts the visual.
The visual also shows the number of days since the start of the simulation and the angle covered by the planet in its orbit.

A1: You can initially see the sun and the earth. Click on play to start the simulation.
What is the name of this type of motion? Click on the orbit control to show the orbit of the earth in space. What shape does the earth draw?
We already know that the earth also rotates around its own axis. Click on the axis button to show the axis on the screen. Click on equator next. What angle is formed between the earth´s axis and the equator?
Is the equator parallel to the earth´s trajectory? Is it perpendicular to this trajectory?
Check the value of the inclination of the earth´s axis in your textbook.

A2: If the simulation is running, then stop it and click on init.

We will now try to see if the length of days and nights are the same everywhere on the planet.

Click on the night control and observe the north pole. Is it on the dark or the light side or the planet? (Remember: you can use the vertical rot. control to get a better view).

Now use the equator and parallels controls to show the equator and two parallels, one north of the equator, the other south.

Try to figure out which of these two parallels will spend more time on the darker part of the planet.

This situation does not remain the same all through the year, of course. In the following activity, you will see how it changes as time goes by.

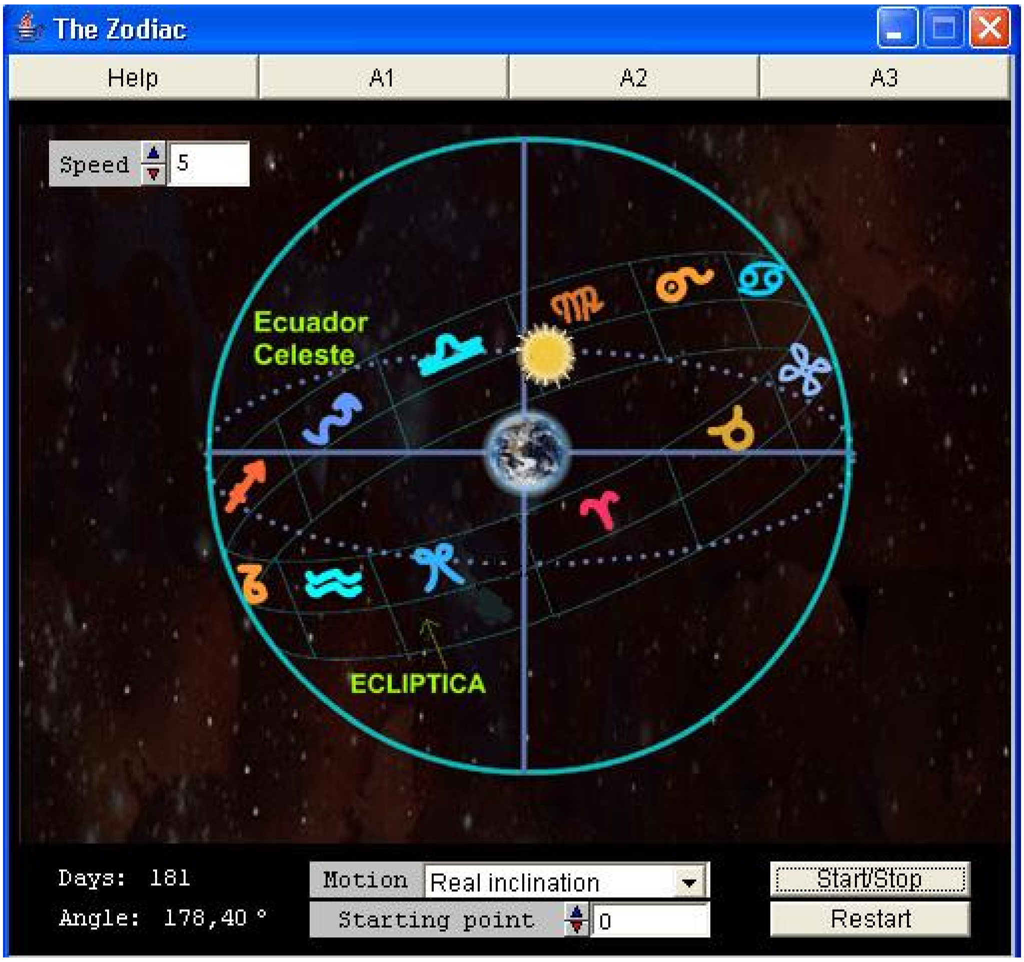
A3: Click on init and set the vertical rot. control to 90º. You have already seen that the north pole is on the dark side of the planet all day long and that daytime in the northern hemisphere is shorter than nighttime.

Click on play and stop the simulation when you see the axis starts to leave the dark side. How many days have gone by? What angle has the earth covered?

Set vertical rot. to 0º and click on init and then on play. Stop the simulation when the angle is equal to 180º. Answer the questions above for each of the hemispheres.

Repeat the analysis for an angle of 270º.

You have just seen how winter, spring, summer and autumn follow each other in the northern hemisphere. What are the corresponding seasons in the southern hemisphere?



Help: This visual shows the apparent movement of the sun during the year.

From our point of view, the earth seems to be the immobile centre of the universe, while the sun moves through different constellations in the sky, which are represented by their symbol in this visual.

The speed control allows you to change the speed of the simulation to adapt it to your reflexes and the computer´s speed.

The motion drop down menu allows you to choose from two different possibilities: you may show how the sun moves through the sky as it is seen from the earth or what the apparent motion would look like if the axis of the earth were perpendicular to the plane of its orbit around the sun.

The starting point control allows you to place the sun anywhere in its apparent orbit, measured from the moment where it crosses the celestial equator (the first point of Aries).

The start/stop control allows you to start and pause the visual and the restart control restarts the visual.

The text at the bottom of the visual shows the days gone by since the sun reached the first point of Aries and the apparent angle covered by the sun on the ecliptic.

A1: What would the apparent motion of the sun look like if the earth´s axis were perpendicular to the plane of its orbit?

To answer this question, select the perpendicular axis option from the motion drop-down menu and click on Start/Stop.

You will then see that the sun would move along the celestial equator, that is to say, it would spend the whole year directly above some place or other on the terrestrial equator.

Click on restart. Now choose the real inclination option from the drop-down menu and click on Start/Stop.

You can now see that the sun is directly above the northern hemisphere during part of the year, and directly above the southern hemisphere during the other part.

A2: The apparent trajectory followed by the sun during the year is called the ecliptic, which is also the name given to the trajectory followed by the earth around the sun.

Click on Restart and Start/Stop to observe that the ecliptic goes through twelve constellations that together are known as the zodiac.

At the beginning of spring (towards the 21st of March), the sun is at the first point of Aries. Do you think it is easy to see this constellation in spring?

What constellation is covered by the sun at the beginning of autumn (right opposite the first point of aries)?

Click on Restart again and make the sun move from one constellation to the next. How long does it take the sun to go through a constellation in the zodiac?

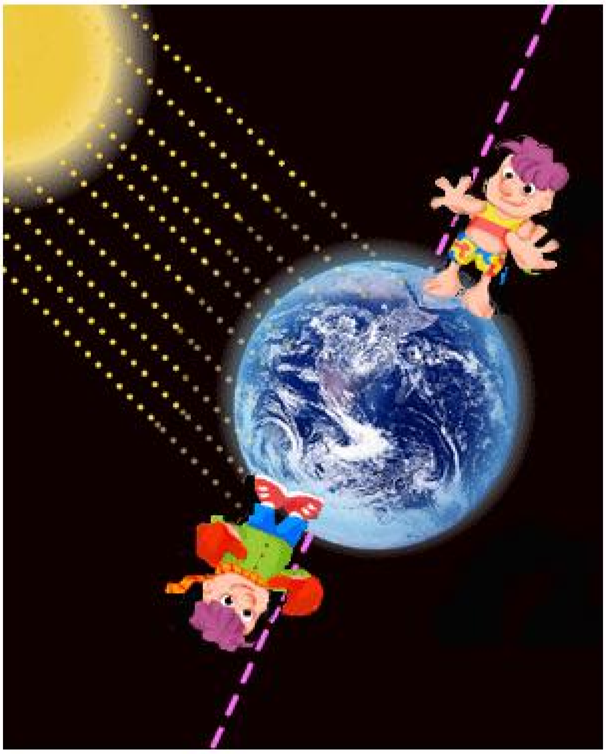
A3: Click on Restart. Try to move the sun around the earth manually by clicking on starting point until it reaches 365 days.

Has the sun covered an angle of 360º? What if you add another day? What is the consequence in relation to the length of a year?

How is this phenomenon related to leap years?

Conclusions on the earth's rotation and translation

The earth's rotation around its axis in 24 hours causes the succession of days and nights. The direction of the rotational axis of the earth points towards the **Pole star** which, for this reason appears to us to be stationary, thus becoming a fixed reference for travellers.



The movement of the earth's translation around the sun lasts a little more than 365 days, making it necessary to introduce a **leap year** (one more day every 4 years).

This movement, combined with the inclination of the earth's axis originates the seasons.

The seasons in the North and South hemisphere are opposite: when it is winter in the North, it is summer in the South and vice versa.

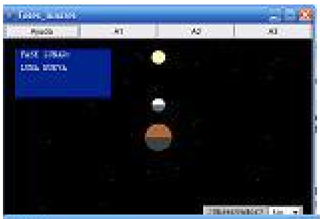
Seen from the earth, it seems to us that the sun is the one that moves during the year, going through the constellations of the zodiac.

The sun and the moon

No, this isn't a magic ring: it is the eclipse of the sun on 3rd October 2005 seen from Madrid, so that really we are seeing the **sun and moon** at the same time. If we had a gigantic torch we could illuminate the side of the moon which is facing us. Drag the mouse over the image to see the effect.

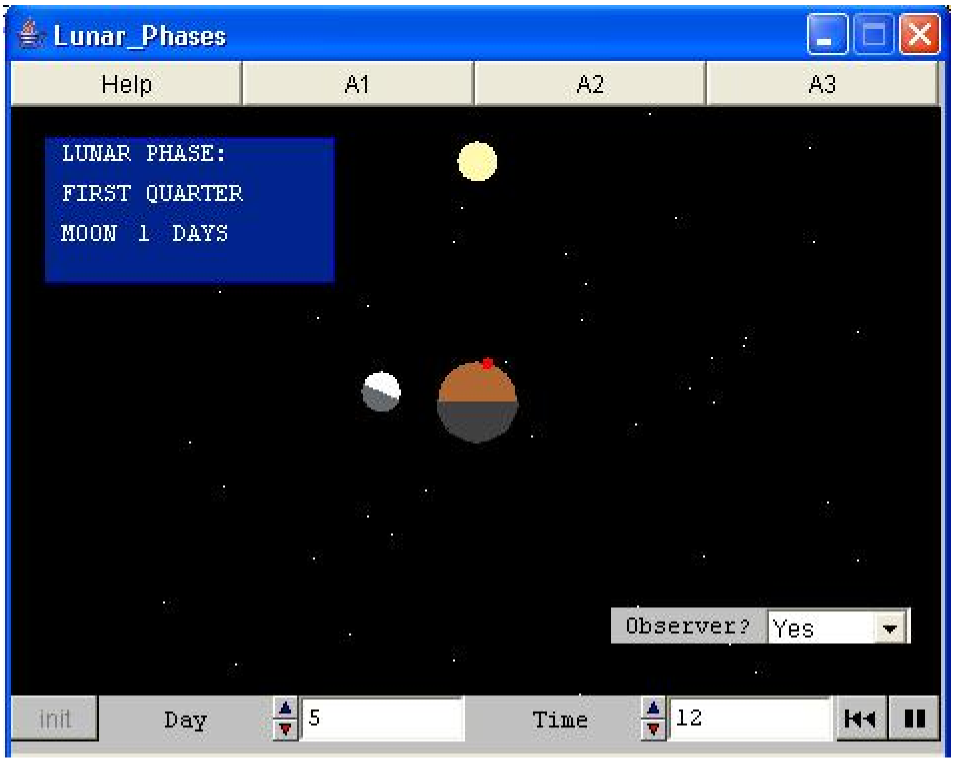
The nature of the sun, a gigantic sphere of incandescent gases, will be referred to later on.

With regard to our satellite, the moon, a rocky sphere about four times smaller than the earth, we are going to concentrate on two important questions:



Its different aspects, seen from the earth.
Click on *Lunar_phases*.

The cause of eclipses like the one in the picture at the top. Click on *Eclipses*.



Help: The visual represents the movement of the moon seen from the earth, as if our planet were fixed.

The yellow circle represents the sun, which seems to be the same size as the moon due to its great distance from the earth. In order to simplify our analyses, we will assume that the sun and the earth are fixed.

We will only consider the earth´s rotation about its own axis.

You can see that the moon has a white part that corresponds to the side illuminated by the sun, and a darker side that corresponds to the side that is not illuminated.

You can use the day control to move the moon along its trajectory. The hour control allows you to alter the position of the terrestrial observer,which can be activated from the observer drop down menu.

A1: What does the computer call the initial phase of the moon?

Click on play. When the name of the initial phase changes, stop the animation and write down the name of the phase and the relative positions of sun, moon and earth.

Repeat the operation until the moon has completed a revolution.

How long has it taken the moon to complete the movement?

What time unit is close to this period?

A2: Click on init to restart the visual. Activate the observer choosing yes from the drop down menu.

What is the time of day for this observer? What will the moon look like to this observer?

Move the moon along its trajectory until it reaches the first quarter and the observer is directly below the moon. What is the time of day for the observer now? What is the shape of the moon for the observer?

Repeat the process for full and third quarter moons. Could this justify the saying that claims that the moon is a lier?

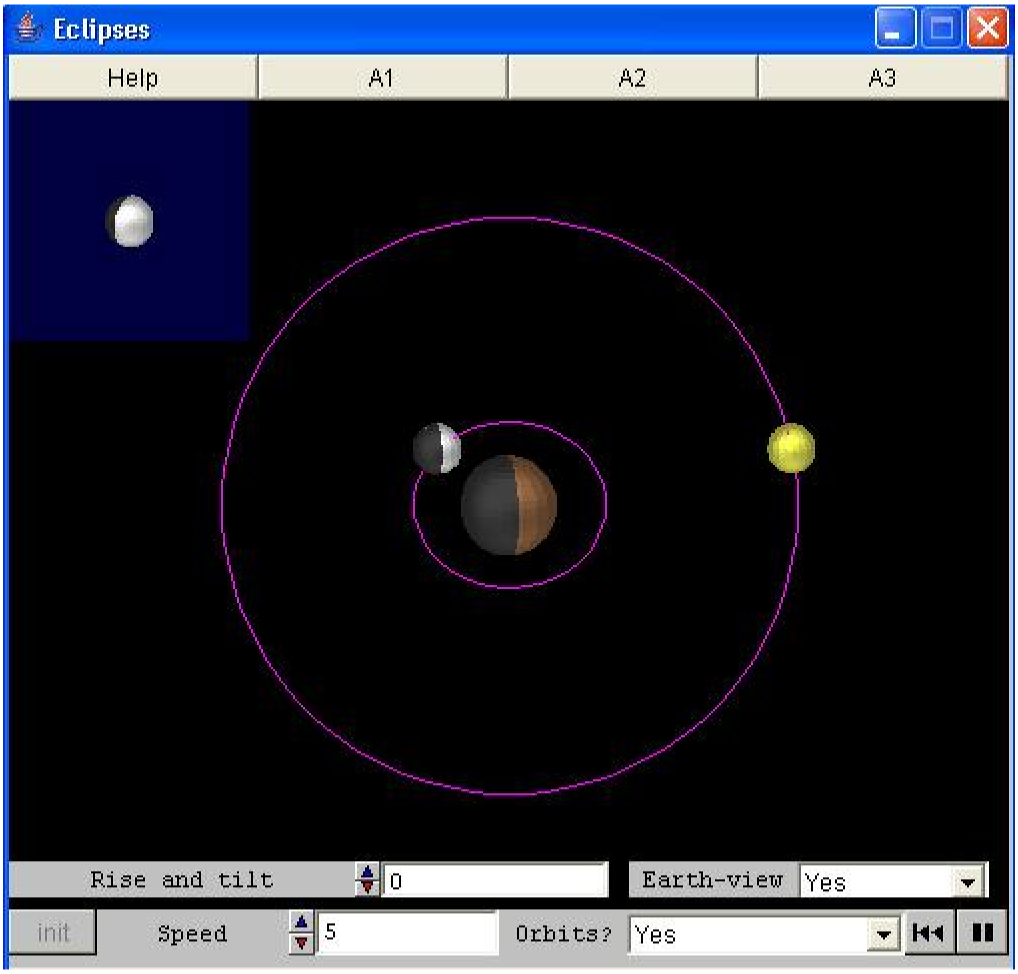
A3: Click on init again. Activate the observer.

Write down the following questions, and then click on play to try to answer them:

If the moon has reached the first quarter, will the observer be able to see the moon at dawn?

If the moon has reached the third quarter, will the observer see the moon at dusk?

What is the phase of the moon if it is visible all night long?



Help: This visual simulates the movement of the sun-earth-moon system from a geocentric point of view, as if the earth were still.

As the sun is very far from the earth (the visual is not to scale) we see it as small as the moon, revolving around our planet on the plane on which the earth actually revolves around the sun.

The earth-view control shows the moon seen from the earth when it is set to yes, and it allows you to see eclipses when it is set to watch eclipses.

The rise and tilt control allows you to see the system from a different point of view.

The speed control allows you to set the speed of the simulation.

You can choose whether to see the orbits of the sun and moon with the orbit control.

The start, stop and pause are self-explanatory.

The init button restarts the visual. You should use this button after each of the activites, before you go on to the next one.

A1: Click on play. Can you see the sun, moon and earth?

Why do two of these astronomical objects have a darker side? What does the dark side correspond to on earth?

Change the speed control until you can see the animation comfortably.

Select yes on the orbits drop down menu.

How would you define the word orbit? One of the orbits you can see is apparent and the other is real. Can you tell which is which?

A2: Click on init and decrease the speed to 2. Activate the earth-view option by selecting yes and click on play.

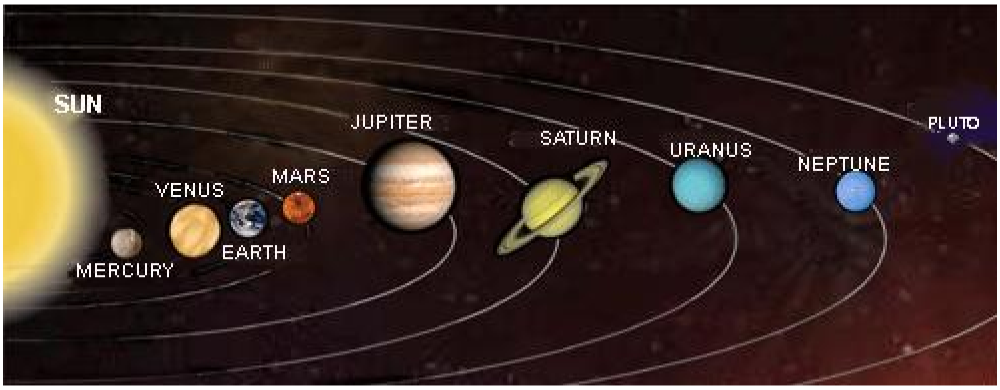
You will see the moon as seen from the earth in the top left corner of the visual. Why is the moon dark at first? What is the phase of the moon?

Try to identify the following different phases: first quarter, full moon and third quarter.

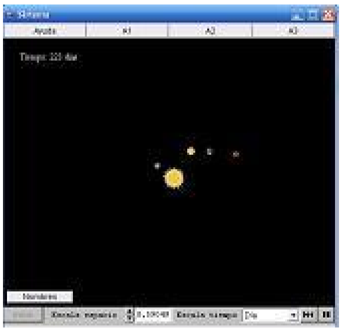
What is the position of the moon during each of the phases?

A3: Click on init and set the speed control to 1. Choose the watch eclipses option from the earth-view drop down menu. Click on play and be patient.
Where is the sun at the beginning of the simulation? There is a moment when the sun is completely behind the moon. This is a total eclipse of the sun.
Let time go by until the full moon is near. What happens then? How would you explain this?
In order to observe other lunar cycles, increase the speed control to 10. Stop the visual whenever you think there could be an eclipse and decrease the speed and click on play.
When is an eclipse of the sun possible? When can we see a lunar eclipse? You will have noted that you do not always get an eclipse when they are possible, why?
In order to understand this point better, wait for a moment when there could be an eclipse of the sun and set the rise and tilt control to 90. Is it clear now?

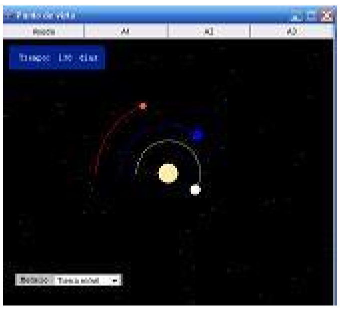
The planets



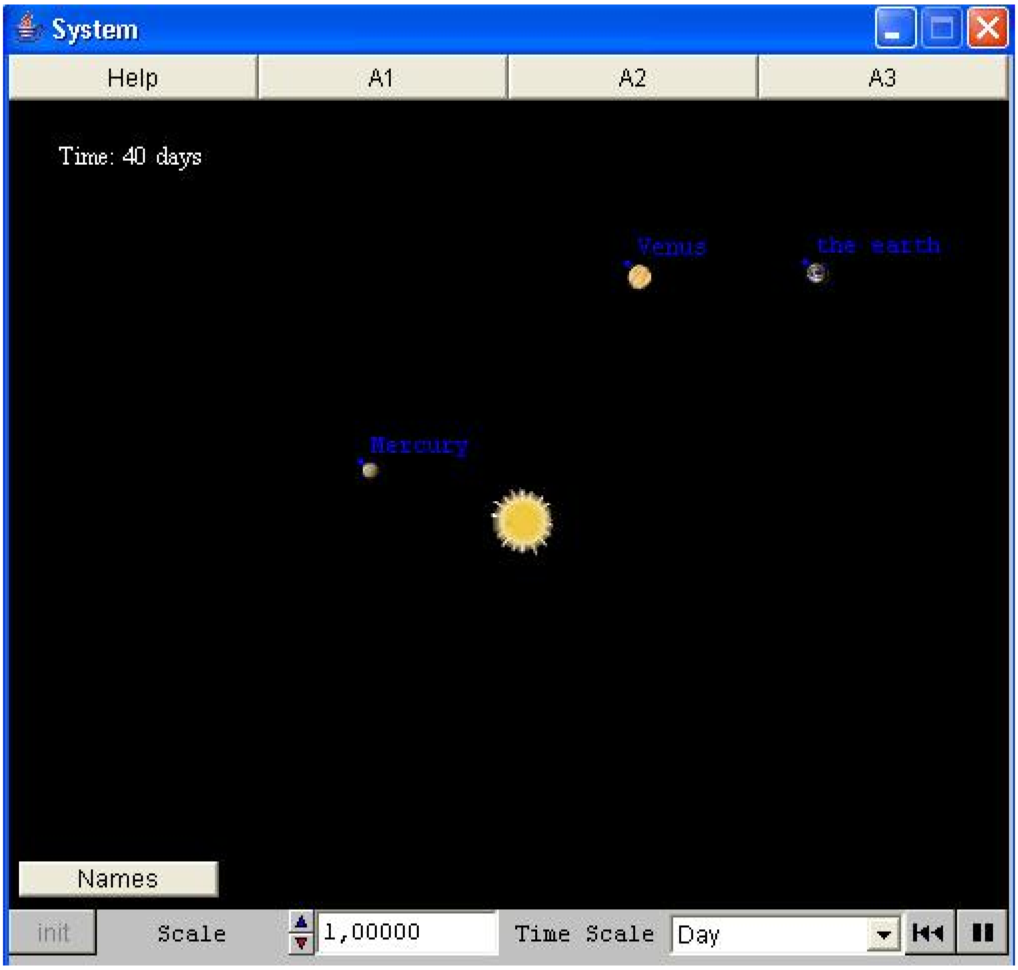
You already know that, **as well as our planet, there are another eight orbiting the sun.**



Up to Mars they are rocky bodies, then there is a series of gigantic planets, mostly formed by hydrogen: lastly there is the smaller frozen Pluto. Until the year 2006, the small and frozen Pluto was considered a planet, but that year the International Astronomical Union reconsidered its classification and Pluto became part of a different category and is now known as a "dwarf planet", together with Ceres and Eris. Click on ***System*** and you will be able to see how they move around the sun.



Clicking on ***Point of view*** you will be able to compare their real movement with the way in which we see them move.



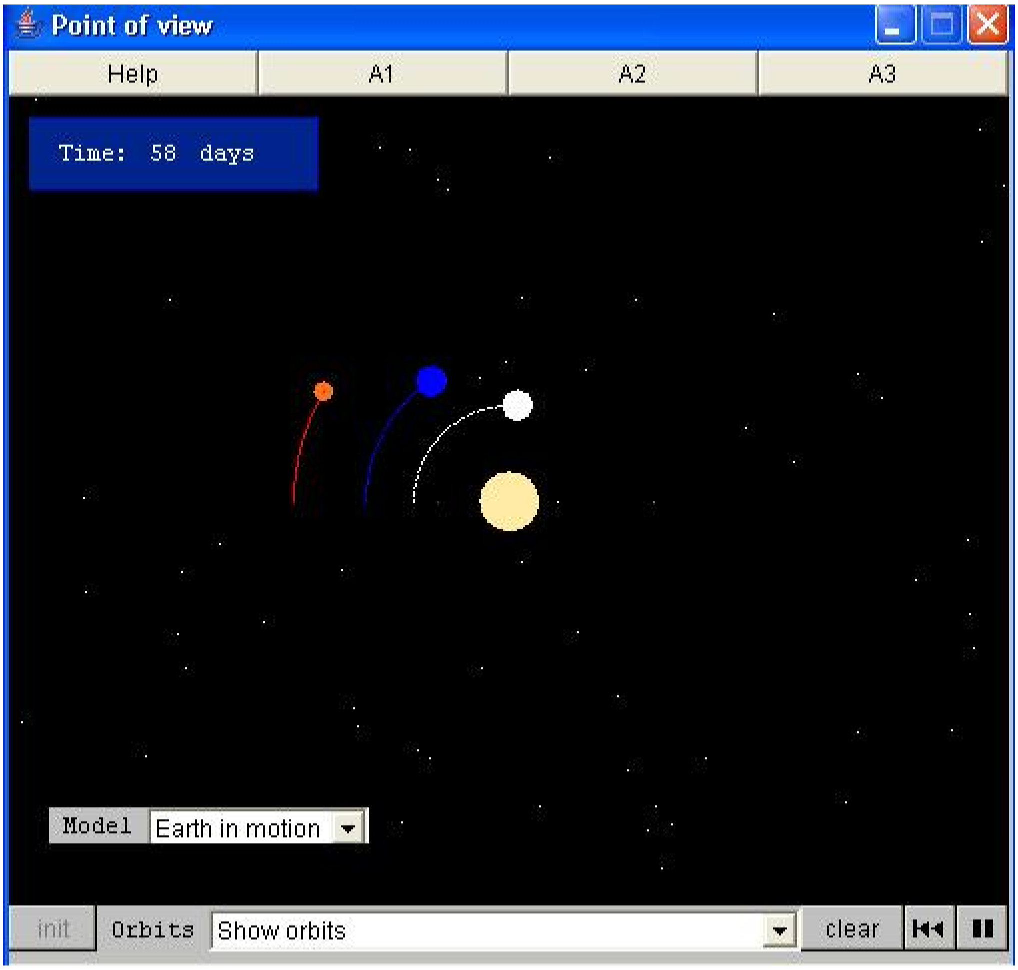
Help: This visual shows the sun and the planets in our solar system. As they do not all fit on the screen, you will need to use the scale control.
You will notice that some planets are slower than others. You can use the time scale control to control the length of the time step.
The name control shows (or hides) the names of the planets.
You can use the start, stop and back buttons to control the simulation. The init button resets the visual.

A1: The visual shows some of the planets. Where are the other planets?
Distances are so large in the solar system, that it is not possible to see them all together. Decrease the value on the scale control and you will see them appear.
When the last planet appears, you will not be able to see the first planets because they are too near the sun. This is what would happen if we were able to see our solar system from the outside, the planets that are near the sun would be invisible due to the light coming from the sun.
Click on Names to see the names of the planets. Do they all have similar sizes?
Use your textbook to find out the size and composition of each of the planets.

A2: Click on init to restart the visual. Do all the planets move at the same speed?
Which planets are slower?

Now you can only see the planets nearest to the sun. See if you can tell how long it takes each of these planets to go around the sun.

A3: Click on init again and decrease the value on the scale control as much as you can. Now you can see the distant planets. Do they seem not to move? That is because these planets are very slow.
Set the time scale to month. Jupiter and Saturn will clearly move, but Pluto will still seem slow. Set the time scale control to year. The planets will all move relatively quickly.
Try to determine the time it takes each of them to circle the sun.



Help: This visual shows the sun (the yellow sphere) and three planets. The white planet is Venus, the blue planet is the earth and the red planet is Mars.
You may choose to observe the system from two different points of view, that is, you may choose to consider the earth at rest or in motion (use the drop-down menu).

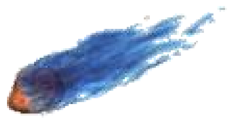
A1: Set the earth in motion in the drop-down menu and watch the visual. What point do the planets revolve around? Which planets move faster?

A2: Leave the earth at rest with the drop-down menu. You will now see the movement of the solar system as it is seen from our planet, because to us it seems that we are at rest. What can you say about the movement of the sun? How about the movements of the rest of the planets?

A3: Observe the orbit of Mars in both models. Can you see any differences in the speed of the planet? Can you explain the origin of this difference? Here is a hint: remember what you see when your car overtakes another car.

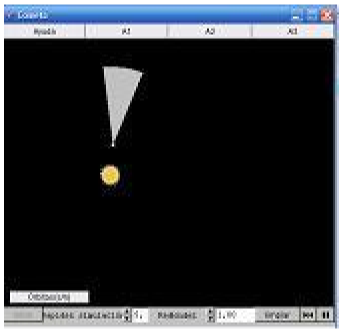
The rest of the solar system

Between Mars and Jupiter, and also beyond Pluto, there are hundreds of thousands of small bodies called **asteroids**.

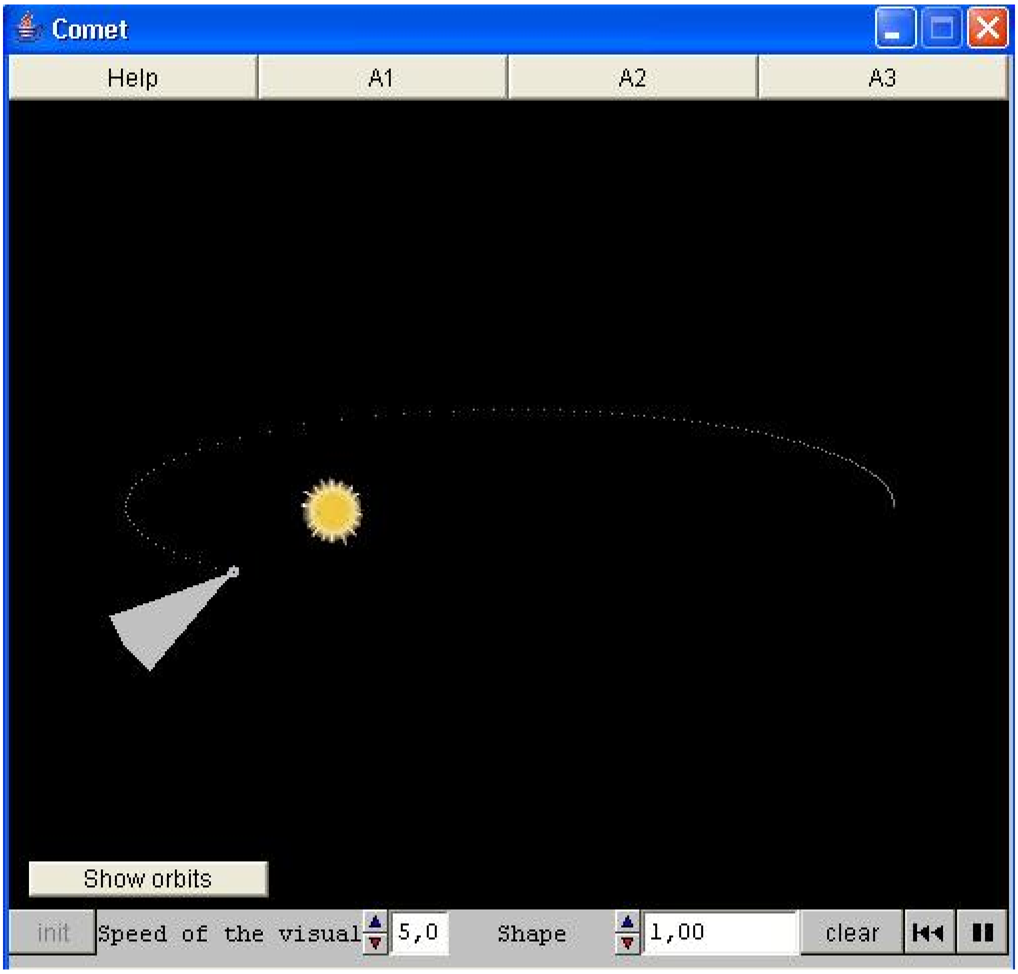


Their diameter varies between a few metres to more than 1000 km.

More spectacular are the **comets**, small bodies, generally less than 100 km. in diameter, formed mostly of ice. When they get near to the sun they unfurl a tail which makes them famous.



We can see how they move by clicking on *Comet*. Today we assume that the comets are the remains left after the formation of the solar system, which makes it very interesting to study them.



Help: This visual shows the movement of a comet around the sun.
You can trace the orbit of the comet by clicking on show orbit. If you click on the control again, the visual will stop drawing the orbit. You can erase it with the clear button.
The speed control allows you to set the speed of the program, so that the visual is not too fast or slow for your computer.
The shape control changes the shape of the orbit making it circular or elliptical. The start and pause control allows you to control the flow of the visual. The init button restarts the visual.

A1: When you first click on play, the comet is an object far from the sun, similar to an asteroid.
What happens when it moves towards the sun?
Taking into account that most of the mass of the comet is just ice, how do you think the tail is formed?
What happens when the comet moves away from the sun?
Observe the direction of the tail. In what direction does it always point? Try to find out why.

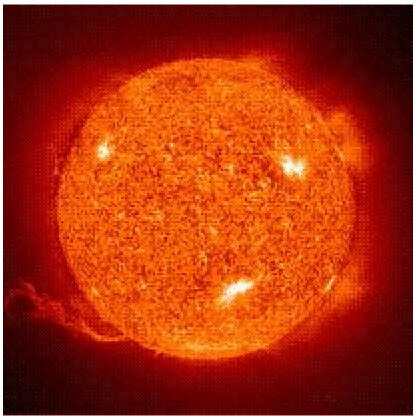
A2: While the comet moves around the sun, watch its speed.
When does the comet move relatively quickly?
Can you justify your observation? Take into account the fact that the sun attracts all the bodies in the solar system.

A3: Click on show orbit. Let the visual draw the complete orbit.
What is the shape of this orbit? Is the sun at the centre of the orbit?

Not all comets have the same kind of orbit. The sun sometimes captures comets which end up moving in orbits which look more like circles.

Use the shape control to change the shape of the orbits. When the orbit is a perfect circle, what happens to the position of the sun? Does the size of the tail change?

Conclusions about the solar system

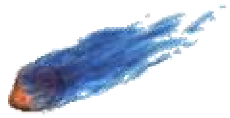


The sun accounts for about 99% of the mass in the solar system.

It is composed above all of **hydrogen and helium** at immensely high temperatures and in a gaseous state.

Nuclear reactions take place in its centre and produce the light and heat that the sun constantly emits.

The planets reflect the light of the sun. The **terrestrial planets** are fundamentally rocky. The **giant** ones have a composition like that of the sun, although without the nuclear reactions. Pluto is more like a very big asteroid than like the other planets



Asteroids are bodies of very varied size, from a few metres to thousands of kilometres. They are different from **comets** in that the latter are mostly made of ice, so that when they come close to the sun, part of the ice evaporates and forms the characteristic **tail**.

What are fixed stars?

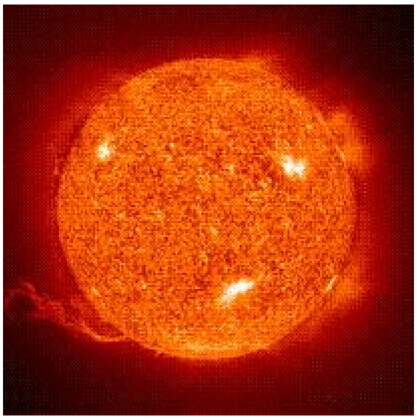
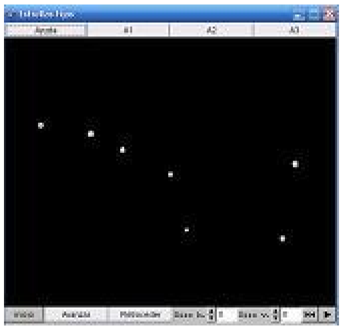


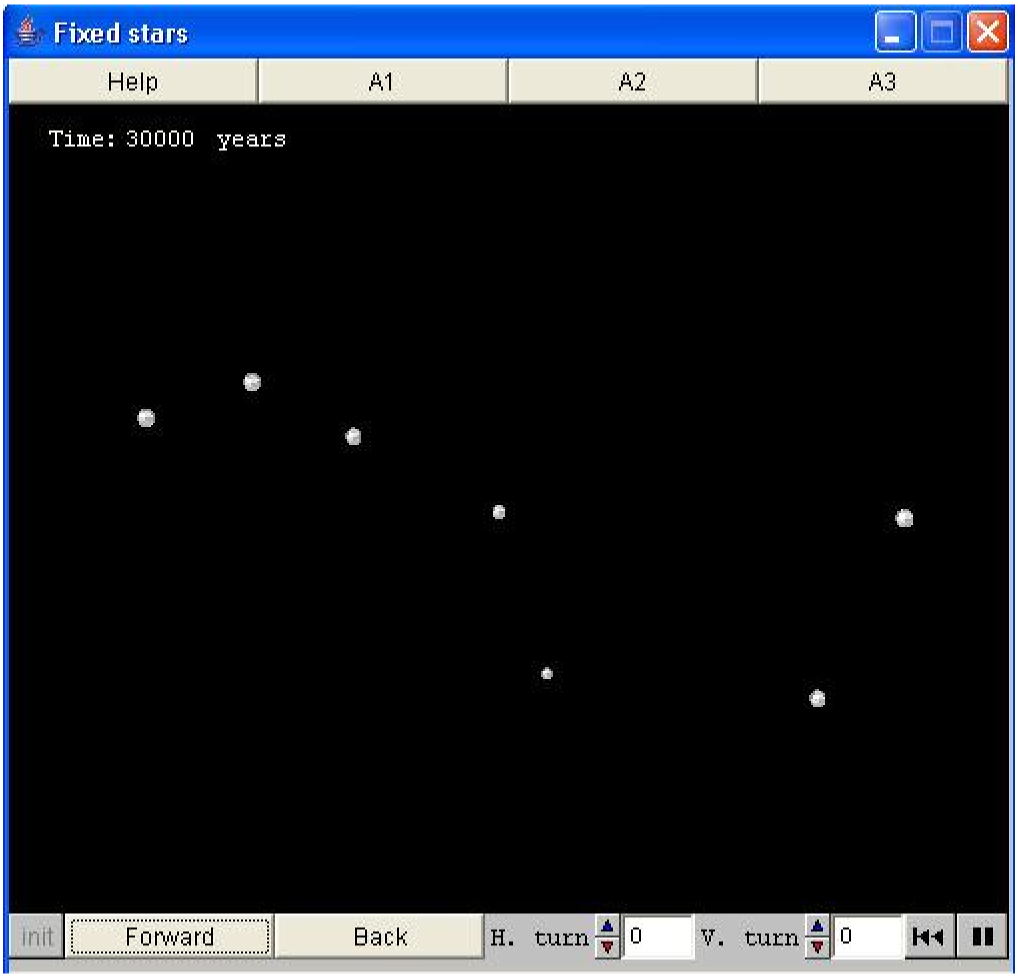
Image of the **sun** taken from the **SOHO** satellite.

Today we know that **the sun is no more than a star which is near to us. Like it, the stars we call fixed stars are large gaseous spheres, of which 99% is hydrogen and helium.** In their centre there is a continuous nuclear reaction, much more powerful than our hydrogen bombs, which maintains its surface at a temperature of thousands of degrees.

Fixed stars are distributed randomly in the sky making groups we call constellations. Now let's ask some questions:

Are all the stars the same distance away? Are they all alike? Are the so-called fixed stars really immobile? To be able to answer these questions, click on ***Fixed stars***





Help: This visual represents the Big Dipper as it seen from our planet at present.
The h. turn and v. turn allow you to rotate around the constellation, to see how it would be seen from other points in the universe.
The forward button sets the time flow towards the future, and the back button sets it towards the past.
The init button restarts the visual.

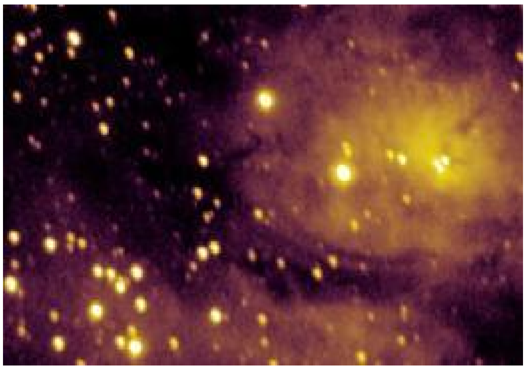
A1: Initially, you will be looking at the Big Dipper as it is seen from our planet. Click on h. turn a few times. This makes the observer move around the constellation without moving towards it.
What happens when you have turned 90 degrees?
Think about what you have observed. The change in our point of view shows the distances between the stars from a different point of view. Taking this into account, do you think that all the stars in the Big Dipper are at the same distance from our planet?
Click on init. Use the v. turn control until you reach an angle of 90 degrees. Do you think you can classify the stars in the Big Dipper according to their distances to the earth?

A2: Although stars are really suns, that is, great masses of incandescent gas, from our point of view they are just twinkling dots.
Do all the stars shine with the same intensity? They do not. To represent this effect, the visual has made some of the spheres bigger.
The difference may be due to different distances from our planet, so the more distant ones would appear weaker. It could also be due to the fact that some stars are actually brighter than others.

Compare the results from the previous classification according to distances with a classification according to intensity. You will easily be able to tell whether any star is brighter than another.

A3: Click on forward and then on play. What happens as time goes by?
Will our descendants see a similarly shaped constellation in 100000 years?
Click on init, and then on back. When you click on play you will be moving towards the past. How do the stars move now?
What was the shape of the Big Dipper 100000 years ago?
What is your conclusion about so-called fixed stars?

Life and death of the stars

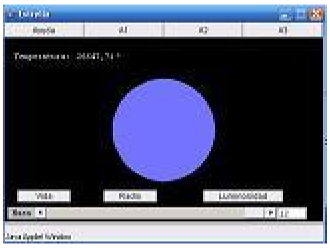


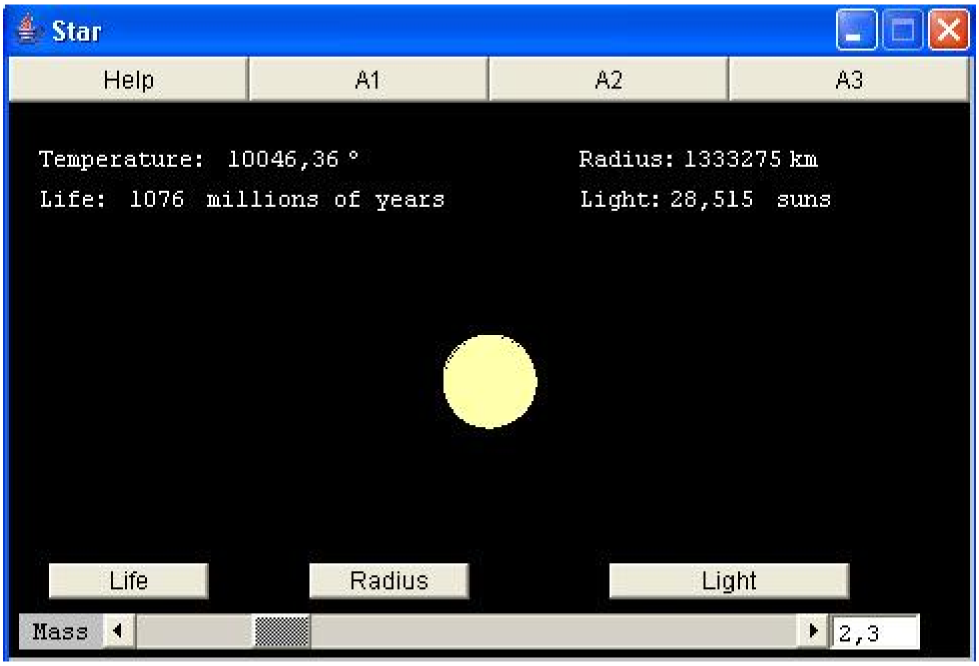
The stars are born in clouds of gas called **nebulae**, like the one we see on the left. Its matter condenses and heats up until a group of stars is born from the same cloud.

Our sun was born, probably together with other suns, about 5000 million years ago in a cloud similar to this one and it will continue to shine for many more millions of years.

When there is no more hydrogen left in the nucleus, the stars like the sun lose their outer part as in the photograph on the right, and shrink to small and very dense bodies called **white dwarfs** (can you see it in the centre of the cloud?).

Between their birth and their death, the stars emit light and heat.
What do the differences from one to another depend on? To find out click on *Star*





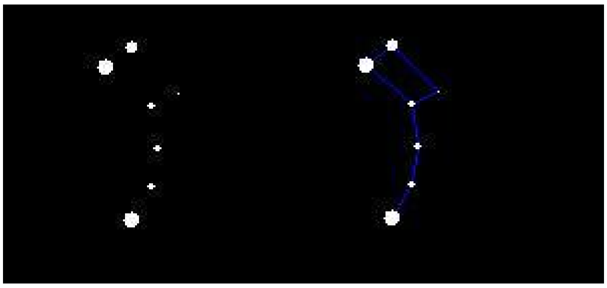
Help: This visual allows you to have an idea of the main properties of a star during its normal life, that is, not during its birth or its death.
You can control the mass of the star with the mass scroll bar. The mass is measured in sun masses, that is, the unit is the mass of the sun.
You can always set the temperature on the suface of the star, its size and its colour.
The life control shows or hides the length of the normal life of the star.
The radius control shows or hides the radius of the star in kilometres.
The light control shows or hides the light intensity of the star compared to that of the sun.

A1: By changing the mass of the star, you can see changes in the temperature of the surface and the colour of the star. What colour are the coolest stars? What about the hottest ones?
Which stars are cooler, the small stars or the large ones?
If you see a blue star, is it larger or smaller than the sun?

A2: Click on the light control and observe the variation of the light of the star while you change its mass.
If a star has a mass double that of another star, is it also twice as bright? Is it not much brighter? If you are not sure, test a star with 4 sun masses and then change the mass to 8. How much brighter is the star now?
In order to understand why massive stars are brighter you must pay attention to two factors: the temperature and the radius.
Click on radius. You will note that as the mass increases the radius and the temperature increase as well. Therefore, it is not surprising that they are much brighter than the smaller stars.

A3: Which star will live longer, a large one or a small one? Click on life and change the mass to find out.
You might find the answer surprising, but you may be able to explain the cause if you take into account the relation between the quantity of light emitted by the star. Do you think you can come up with the correct explanation?

Conclusions on the stars



The heavenly bodies we know as **fixed stars** are suns which are so distant that we see them as points of light. They are called that because, due to the great distance that separates them from us, they take thousands of years to move in a clear fashion to a terrestrial observer. This is why we group them into **constellations** like the one in the picture (Little dipper), which are seen as changeless over the millenia.

The stars are born in clouds of dense cold gases, which heat up as they condense. They normally are born in groups.

The luminosity and temperature of the stars increases rapidly with their mass. The hottest stars appear more blueish to us and have a shorter life than the reddish stars with a smaller mass and lower temperature.

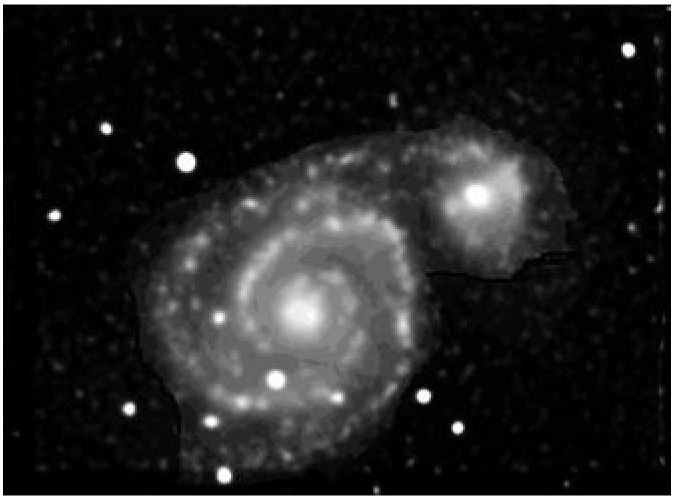
The Milky Way

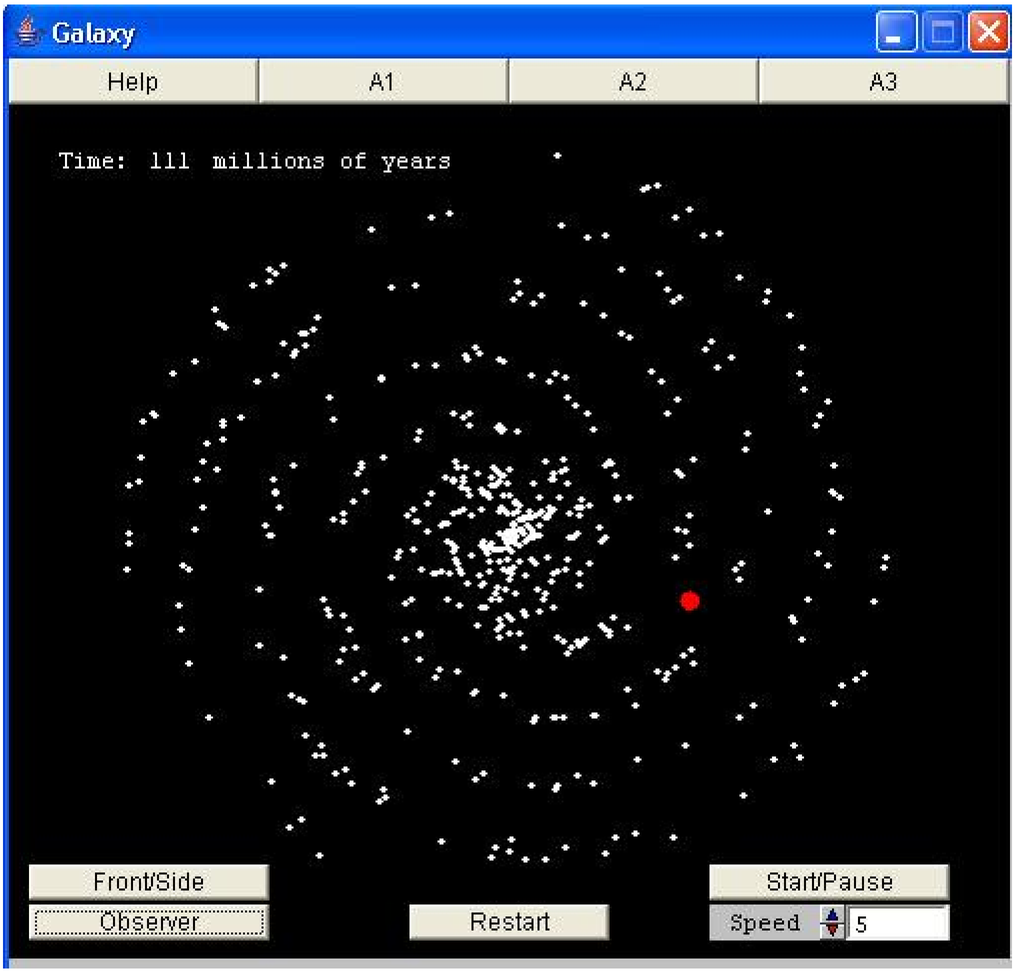
On a dark night, without a moon and away from large cities, we can perceive among the stars in the sky a whiteish strip: **the Milky Way.** Using binoculars we can discover that it is made up of innumerable stars. **What does this strange accumulation of heavenly bodies mean?**

For centuries this was a question without an answer. At the beginning of the 20th century an ingenious astronomer called **Shapley**, suggested that the universe had the shape of a disc. So that the Milky Way was the result of looking at the disc in profile from the side.

Everything changed when **Hubble** showed that the cosmos was full of island-universies like ours, which we now know as **galaxies**. On the right we can see the photograph of a galaxy similar to ours.

To see the characteristics of our galaxy, click Galaxy





Help: Initially, the visual shows a frontal view of the galaxy. Although our galaxy is formed by hundreds of thousands of millions of stars, this simulation shows only 500.
The front/side control allows you to choose between the frontal and side view of the galaxy.
The observer control shows the position of our solar system in the galaxy.

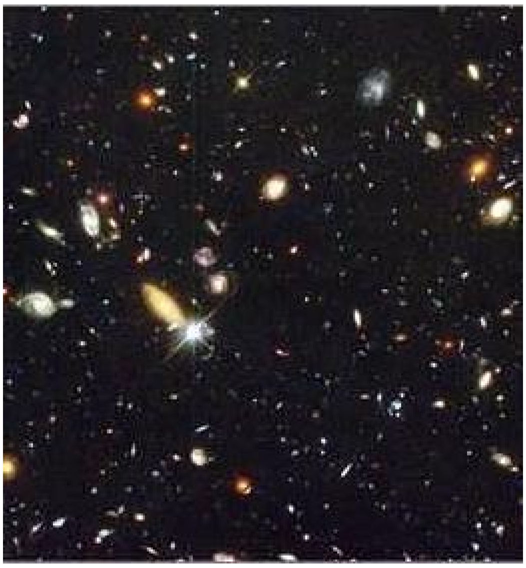
The play/pause allows you to set the visual in motion and to freeze the image.
The restart control restarts the visual.
The speed control allows you to adapt the speed of the simulation to the speed of your computer.

A1: The galaxy is made up of a core and spiral arms. Can you see these elements in the visual? Where are there more stars, in the core or in the arms?
How many spiral arms can you see?
Click on Front/side. Is the galaxy more or less flat? If not, where is the thickest part?

A2: Click on restart and then on observer.
Can we say that our sun is at the centre of our galaxy?
Click on front/side again. Imagine a galactic equator that divided the galaxy into two equal halves. Would the sun be near this equator?
This might have helped you understand the way se see our galaxy. When we look along the direction of this equatorial plane, the galaxy looks like a long milky strip with countless stars on it. During the winter, it is thinner and weaker because we are facing the outside of our galaxy at night.
In the summer we are facing the core, so the strip is thicker and brighter.
If you look at the sky in the direction perpendicular to the galactic equator, you will see the few stars that are above or under the sun.
Can you imagine what the sky would look like if the sun were at the centre of the galaxy?

A3: Click on restart, observer and play/pause.
How does our galaxy move? Try to find out how long it takes the sun to complete a revolution. Can you guess what kind of animals lived on earth one revolution ago?
Click on Front/Side and watch the movement for a while. Why does our sun disappear from time to time?

Other galaxies

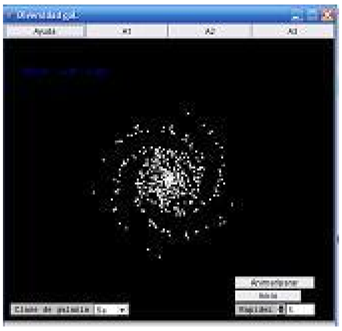


How many galaxies are there in the universe? Nowadays, we believe that the Cosmos **was born 13.700 millions of years ago** in a great explosion (the **Big Bang**) of all the matter which was concentrated in a single point.Therefore, we cannot see beyond 13700 millions light-years (which is the distance travelled by light in 13700 million years).

There are about 100.000 million galaxies in the known universe. In this photograph taken by the Hubble Space Telescope (named after E. Hubble, who discovered galaxies) we can see a tiny fraction of them.

Are the galaxies all the same?

In the same photograph we gan guess that this is not so. In any case, to get an idea of their variety, we can click on *Gal. diversity.*



Help: You will learn about the variety of galaxies in the sky.
This visual offers a drop-down menu that allows you to choose among the different types of galaxies.
Once you have selected a galaxy, the computer carries out the relevant calculations (this may take a while) and shows the type of galaxy selected.
The Play/Stop control sets the visual in motion or stops it.
The Restart control resets the visual.
You can adjust the speed of the simulation with the speed control.

A1: Inspect the Sa, Sb and Sc types of galaxy (you might have to wait a bit for the computer to carry out the calculations). What do these types of galaxies have in common? What are the differences? Observe the differences in the core-arm ratios to answer the question.
What type of galaxy is the Milky Way?

A2: Now choose E0 on the drop-down menu. What is the difference between this galaxy and spiral galaxies? Why do you think these galaxies are known as elliptical? Now test types E4 and E7. What do you think the numbers 4 and 7 stand for?

A3: Choose an Sb galaxy like our own and click on Play/Stop. Wait for the galaxy to complete a revolution and stop the animation.
Now choose E4 on the menu. What are the similarities and differences between the motions of elliptical galaxies and spiral galaxies?
Does the movement of an elliptical galaxy look like the movement of any part of a spiral galaxy?

Conclusions on the galaxies

The suns with their possible planetary systems and nebulae form island-universes of thousands of millions of heavenly bodies called galaxies. There are galaxies of very different types, but the most characteristic are the **spiral** and the **elliptical** ones. The latter are similar to the nuclei of the spiral ones, but without their typical arms.

Our galaxy, the Milky Way, is of the spiral type and forms a disc which is about 100.000 light years in diameter (that is, the light takes, 100.000 years to cross it). The thickness of the disc is about 10.000 light years. This difference in size explains why when we look along the disc we see many more stars than when we look in another direction.

Today we think that the universe was born about 13.700 million years ago in an enormous explosion known as the Big Bang. For this reason, the largest sized universe which we can observe measures 13.700 million light years. In this space there are about 100.000 million galaxies of all types.

What have we learned?

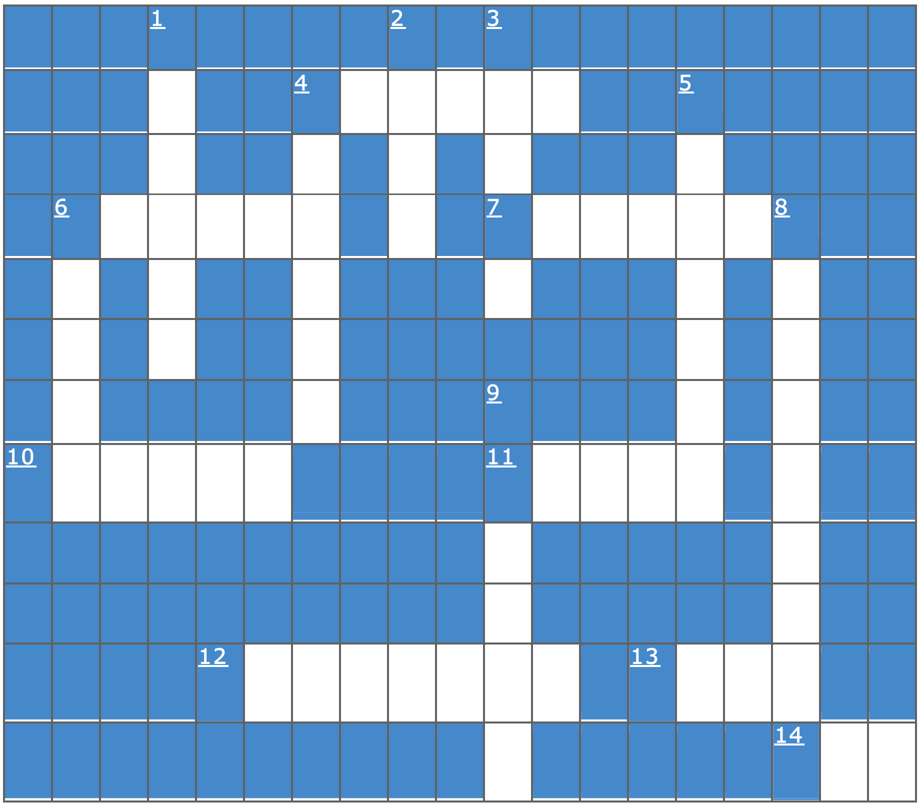
After studying this unit, you should know that:

- **By observing the sky we can understand the movement of the earth in the universe.**
- The succession of the days and the nights and the change in the seasons are consequences of this movement.
- The earth is only one of the planets in the solar system and the moon, the sun, the asteroids and the comets are our companions in the solar system.
- Our sun is just another of the stars which inhabit our galaxy.
- The spiral galaxy where the sun and the Milky Way are is just one of the thousands of millions of galaxies in our expanding universe.

If you want to check that you have understood all this, click on the control to start our evaluation exercises. Evaluation

Put your cosmic vocabulary to the test

Complete the crossword. On each number there are clues to its contents. The check control tells us if we have done it correctly or not.



Across

4. A natural part of a year.
6. A heavenly body that orbits around the sun.
7. When one celestial object moves into the shadow of another.
10. (Verb) To spin.
11. A star that does not appear to move during the night.
12. (Two words, no spaces) The name of our galaxy.
13. The satellite that orbits the earth.
14. What the stars are made of.

Down

1.A group of thousands of millions of stars.
2. The main magnitude on which the properties of stars depend.
3. An astronomical object that has a tail sometimes.
4. The planet with rings.
5. The largest planet in our solar system.
6. A very distant and small planet.
8. The state of the universe.
9. The shape of our galaxy.

Check you capacity to relate concepts

Planets, asteroids and comets

The spiral galaxias

The blueish Stara

The red Stara

The seasons of the year

The hours of the day and night

The fixed stars

The constellations of the zodiac

The eclipses of the sun

The eclipses of the moon

Can move very fast, even though they do not seem to.

Are the hottest and least longevous.

Look like the milky way.

Are crossed by the sun during the year.

Are caused by the inclination to the earth´s axis and its translation around the sun.

Can only take place during a new moon.

Put together have a total mass which is way below that of the sun.

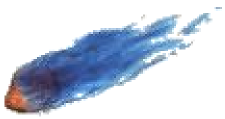
Change depending on the season.

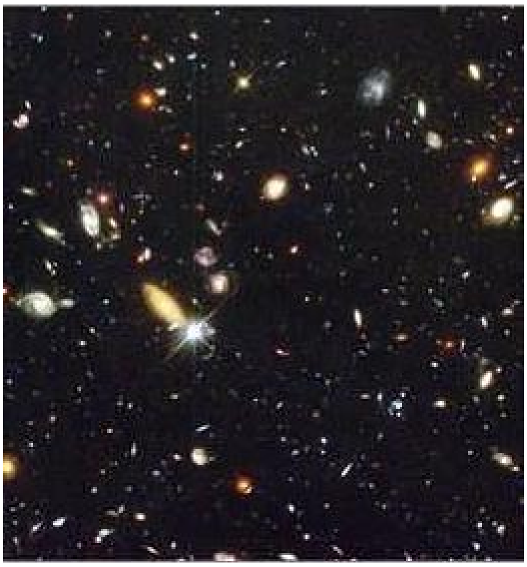
Can only take place during a full moon.

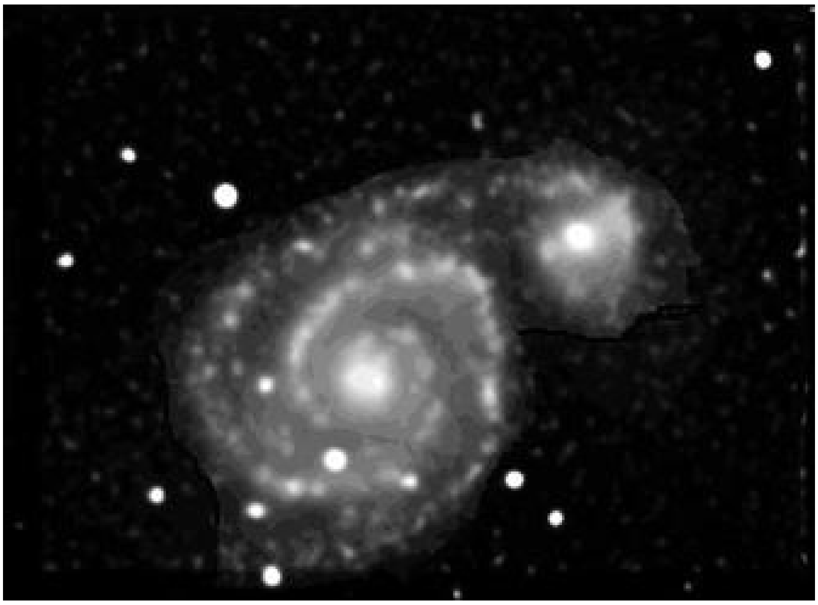
Are cooler, but they live longer.

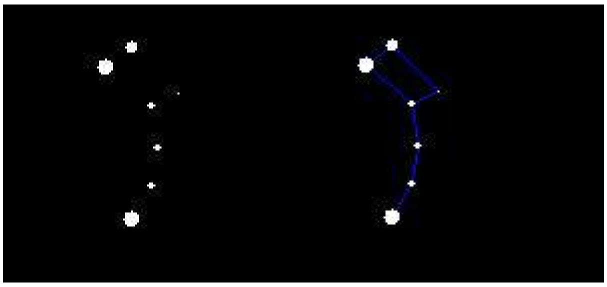
Match the pairs

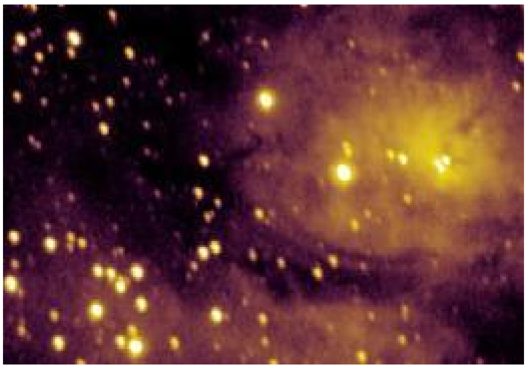
Find the correct definition for each image











This is a comet

This is the solar system

This is a nebula

This is a galaxy

This is a galactic cluster

This is the set of constellations crossed by the sun

This region is a birthplace of stars

This is an asteroid

This is a constellation

This is a solar eclipse

Choose the correct answer

1. Why does night fall in Barcelona before it falls in La Coruña?

A. Because it is further east, and the earth rotates eastwards.

B. Because it is further north, and night falls earlier in the north.

C. Acutally, this is only true in the summer. During the winter it is the other way round

D. This is false. Night falls at the same time everywhere.

2. What is the Milky Way?

A. A nebula made of gas from dead stars which forms a ring around the solar system.

B. A spiral galaxy that is close to our own and which we see as a cloud.

C. A mithological creature that gave the gods milk.

D. The spiral galaxy that we see around us, the galaxy that contains the sun.

3. When it is summer in Spain, in Australia...

A. It is also summer. The seasons are the same everywhere.

B. It is winter, because Australia is in the southern hemisphere.

C. It depends on whether we are in a leap year.

D. It is autumn, because it is further east, and the seasons arrive days earlier.

4. Why is the Polar Star important to us?

A. Because it is the brightest star in the sky.

B. Because it appears to be fixed in the sky during the night.

C. It has never really been important to human beings.

D. It is just a tradition, people have always spoken about the Polar Star.

5. How large do we think the known universe is?

A. About 13,700 million light years, which is the distance travelled by light since the universe began to exist.

B. It is infinite, the observable universe has no beginning or end in any direction.

C. About 4700 millions of years, which is the age of the sun.

D. This question does not make sense from the point of view of science, and it has never been asked.

6. Is it true that a comet's tail is opposite to its velocity vector?

A. False, the tail always points towards the earth.

B. Yes, it is. The tail is made of matter that the comet leaves on its trail.

C. False, the tail always points away from the sun.

D. Yes, it is. The tail behaves like the streak created by a jet engine.

7. What are fixed stars?

A. Stars that are upon a sphere which is at a fixed distance from us.

B. Stars that remain in the same point forever.

C. Stars that are so far away that it would take millenia to notice their movement with the naked eye.

D. Stars that move at the same speed in a constellation. This makes them seem fixed.

8. Is it true that giant planets like Jupiter have a composition similar to that of the sun?

A. Yes, it is. The main difference is that they do not have enough mass to start the nuclear reactions.

B. No, it is not. The sun is made of hidrogen and helium, while planets are always rocky.

C. No, it is not. All planets have a composition similar to that of the earth.

D. Yes, it is. That is why they emit their own light.

9. Is it true that fixed stars are all immobile and at the same distance from us?

A. They move, but they remain at the same distance from us.

B. It is true, all the stars are on a sphere known as the "sphere of fixed stars".

C. They are immobile, but at different distances from us.

D. No. The stars move as the centuries go by and they are at very different distances from us.

10. What is the difference between a solar and a lunar eclipse?

A. During a lunar eclipse, the moon moves into the earth's shadow, while during a solar eclipse, the earth moves into the shadow of the moon.

B. There is no difference. These are just two different names for the same phenomenon.

C. During a lunar eclipse, the moon enters the shadow of the earth. During a solar eclipse, the sun enters the shadow of the earth.

D. During a luntar eclipse, the earth's shadow covers the moon. During a solar eclipse, the sun covers the moon.