HANDS IN THE STARS

Encyclopediac dictionary of astronomy for Sign Language Francs (LSF)

/ Under the direction of Dominique Proust /

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Work done with the grant: IAU-OAD TF3 fund project:
2015/12/24 Global Sign Language Universal
Encyclopedic Dictionary

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With the support of

PROLOGUE

Take the stars by the hand

I'm not deaf, just a little hard of hearing! This explanation by the famous Professor[1] Tournesol is a pointer in Herge's work, and one can ask how, in a world of learning which was not much inclined to integrate the deaf community, Tournesol was able to lead the life of a scientist- professor. In the world of education structured almost exclusively for pupils and students able to hear, it's difficult to imagine a young Tryphon Tournesol learning without any problem about ballistics or nuclear physics; we can probably conclude that he wasn't deaf from birth, rather that given his passionate way of speaking, his manner of speech was sufficiently clear to be understood by those around him, even those as inattentive as the Dupon(d)(t)s. Note also that the name *Haddock* was forever screamed out loud by Bianca Castafiore which probably indicate that she had hearing problems in the lower frequencies of the auditory spectrum (Haddock probably being a bass-baritone given his rather large whisky consumption), which didn't stop her hitting a high C sharp in the Jewel Song from Charles Gounod's Faust. However, going beyond this Tintin-esque world, a society that cares for its minorities must make scientific culture accessible to all even the deaf. A lot of people with full faculties would be astonished to learn that a deaf person can appreciate the music of Camille Saint-Saens.

In the world of science in general and astronomy in particular, Sign Language France (LSF) has enabled a remarkable advance in communication, both in the knowledge of deaf culture and by the use of sign language, thus removing any barriers between the deaf and the hearing.

[1] Algoud Albert, *Le Tournesol illustré*, Casterman, 1994.

Dialogue of the Deaf

LSF has its own vocabulary and grammar and can be communicated at an level. However, whereas countries like Sweden have completely integrated it into their culture, France has much further behind on this. In an historical context, the deaf have been marginalised and kept apart in most of the civilised world, and there are very written few accounts that we have concerning them. In spite of the persistent legend attributing the invention of a structured sign language to the Abbe de l'Epee (Charles-Michel), it is quite evident that the communication of ideas by gesture existed well before his time within the world of the deaf, as for example in the cloistered world of the Trappist monks with their rule of silence or with the Indian tribes who used their bodies to communicate over distance.

After the Abbe de l'Epee, LSF suffered much throughout its history. Abbe Sicard, the first director of the National Institute of the Deaf-Mutes founded after Abbe de l'Epee's death, escaped the guillotine in 1793 thanks to the pressure brought by his deaf pupils in defending him. Above all, it was Bebian who created real bilingualism at the Royal Institute for the Deaf-Mutes. However, two schools of thought began to oppose each other, the French maintaining the tradition of hand gestures which a new tendency from Leipzig leaned towards teaching of word and lip reading. Ferdinand Berthier, the oldest member of the deaf professors at the Paris Institute (and himself deaf), forcefully defended sign language at the time when Jules Ferry was introducing compulsory standardised teaching which was based on the premise of positivism and science extolling man's ingenuity in overcoming all problems including deafness. Under these different pressures and in the context of ever increasing industrialisation with its ability to resolve all sorts of problems (hearing aids), the use of sign language progressively disappeared in France. However, Victor Hugo wrote in a letter addressed to Berthier dated 12 November 1845: *What does deafness in the ears matter when one's spirit does the hearing? The only, true, incurable deafness is that of the intelligence*. Between times, sign language enjoyed great success in the USA and Canada thanks to its export by Laurent Clerc, a professor of the Paris Institute.

The coup de grace for sign language was first given at the Paris Universal Exhibition in 1878 where a host of hearing teachers who destroyed all previous practice and culture, this being ratified at the Congress on Milan in 1880. This movement was supported by the Church and the middle classes who were totally opposed to disturbing gestures (as a well know song had it: *You mustn't point your finger at someone*). Moreover, the miniaturisation of prostheses and hearing aids naturally claimed to mitigate any deficiencies of individuals who were carefully kept out of the mainstream of reality. As a result, to this cultural and socio-linguistic world came a change almost by force reducing a community to abject silence. The animosity shown at the Congress of Milan in rejecting any sign language reflected centuries of religious and social prejudice. For example, the well-known adage *"Masturbation makes you deaf"*, the work of a doctor from Lausanne, Auguste Tissot, who was anxious to apply fundamental Calvinistic morals to his patients, was a principal item in the list of misdeeds which particularly victimised the deaf community. In this way, the creation of these rigid and arbitrary social codes allowed the imposition of frustrating and demoralising rules to tens of generations in order to put a moral terrorism into place.

In 1887 the last of the deaf professors were forcibly retired in the course of a memorable ceremony in which the new director of the Institute for Deaf-Mutes gave a brilliant speech: *"Today, miming will leave this Institution, never to come back, and henceforth, the spoken word will reign supreme[2]"*. Of course, the consequence of these measures was one of rapid deterioration in communication. To sanctify the new oral regime, the teachers used cunning strategy, in particular punishing any attempts to use hand gestures, and this situation lasted until the 1970s. This disappearance of LSF for the benefit of oralism would have some dramatic consequences, not only in France, but throughout Europe. A lot of homophomic words can't be seen by a deaf interlocutor the more so if the speaker has an accent, doesn't speak clearly or has a moustache. Very quickly, oralism produced in France a cultural desert a the heart of the deaf community in the same way that so-called "modern" mathematics confused generation of schoolchildren in the 1960s.

Authoritarian regimes were always looking to get rid of minorities in general and the deaf in particular all in the name of eugenics with the Nazis sterilising tens of thousands of deaf woman in Germany between 1933 and 1945. As a result, this isolation of the deaf community gave rise to a reaction normal for the oppressed, that is a resistance movement. In particular, the wish to communicate between youngsters is naturally done by signs. There were therefore two forms of expression, the one based on disciplined oralism imposed by official strictures and the other hidden away using often reinvented signs. Many deaf people who lived through these times testify what a cultural desert they had to live through for so many years. Some intellectuals rose against this ostracism, in particular Henri Gaillard, a journalist and editor of *La Gazette des Sourd-Muets* which openly supported sign language. In 1924m the first Olympic Games for the deaf took place and in 1926 the Salon des Artistes Silencieux was created. The majority of the deaf however had very little hope of passing the level of a CAP (Certificate of Professional Aptitude) and those who graduated

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[2] *Girod, Michel (bajo la dirección de), La Langue des Signes, Editions IVT, 1997.*

could be counted on the fingers of one hand. The unemployment rate reached 30%, mostly affecting the profoundly deaf.

However, sign language had not disappeared everywhere, since from 1817 it became established in the Anglo-Saxon countries, notably by the creation of the Hartford Institute by Thomas- Hopkins Gallaudet and Laurent Clerc. Slowly bu surely, France discovered with what success the deaf were integrated in the USA, Canada, Great Britain and Sweden. At the end of 1970, the expression “French Sign Language” and its initials (LSF) were introduced by the sociologist Bernard Mottez and in 1973 the National Union for the Social Integration of the Hard of Hearing shook up the political classes and finally got some results, in particular the translation of the television news. One had to wait however until 1977 when, as a result of much pressure and the success stories from overseas, the Minister of Health repealed the ban on LSF and 1991 when the National Assembly allowed the teaching of children in sign language (the “loi Fabius”). During this long struggle for recognition of LSF as a separate language, in 1998 a deplorable Minister for Education refused to allow the subject to be studied in its own right. As of today, LSF has finally obtained its identity as a separate language. It is taught in all the regions of France (with variants corresponding to local dialects) although there are still strongholds of oralists notably in the medical world where cochlear implants are much favoured despite the trauma and post-operative risks.

LSF continues patiently to establish itself as a separate language. There are however many hurdles still to overcome, in particular resistance to the deaf in the world of administrative proceedings, the law, medicine, etc. It’s thus regrettable that in thirty hours of learning, it is possible to have a dialogue with a deaf person on general subjects. In the scientific world, it’s interesting to see how easily communication takes place. The examples of the Musee des Art et Metiers and the Cite des Sciences at la Villette are real eye openers as the main exhibitions and conferences are signed by highly competent deaf scientific people.

Listening to well-known deaf people

There have been many renowned deaf people in the worlds of letters, arts and sciences. Among the best know are Pierre de Ronsard, who dedicated his sonnets to Cassandra, Marie and Helene, even though he’d have been hard pressed to respond to their call; Francisco Goya was one of the greatest painters but was unable to hear the criticism of his woks; and Beethoven only heard in his head his *Ode to Joy* from the Ninth Symphony and his final string quarters.

In the world of science, Joseph Sauveur, a French mathematician and physicist, was professor at the College de France in 1686 having been deaf from birth. In spite of his short life, John Goodricke was a deaf astronomer who had a brilliant career. His observations of variable stars such as *Algol* in the Persied constellation, ß Lyre and δ Cephei enabled him to show the family of *Cepheides*, giant cold stars whose periodic pulsing in assocation with their intrinsic luminosity make for a particularly effective calibration of distances. Two of the most important inventions were the work of people linked to deafness. Alexander Graham Bell grew up in a family with a deaf mother and a father who had perfected a system of “visual language” translating sounds by symbols. Professor at Boston for deaf children and having married a deaf wife, Bell developed means of communication between the deaf and the hearing, the most famous of which was the telephone in 1877. The second, Thomas Edison, had only 10% hearing in on ear. To him we owe the invention of a “process of recording and sound reproduction” (the gramophone), as well as the first cinematographic projectors, the incandescent lamp and the improvement of the telegraph. The Edison effect is known as the emission of electrons by heated metals.

Science signs

LSF is a perfectly structured language with its own vocabulary and grammar. It is expressed within precise rules which are linked to basic physical movements. Like every language, it continually evolves and its scientific and technical vocabulary is getting permanently established with new signs such as Numeric, Internet, DVD, Microprocessor, etc.

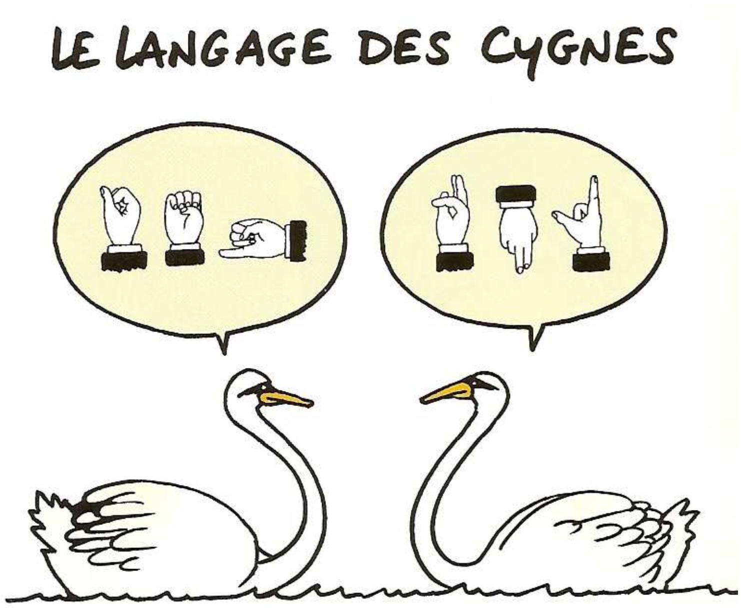
In mathematics, numbers are signed in a sequence of signs: 1,515 is signed as ONE THOUSAND + FIVE HUNDRED + FIFTEEN. Large numbers (millions, billions) have their own signs and operators. For example, the square root sign √ is signed using both hands in an indentical way (see glossary). All quantities are signed whether weight, surface, volume or distance. Pythagoras’ Theorem is signed in a similar way to the oral version such that the hypoteneuse is signed as “the side facing the right angle”. Geometry follows the same rules with the hands firstly describing a perpendicular, a plane or an area. The derivation of a systems of co-ordinates is precisely indicated.

Physics uses a number of explicit signs for each area. Constants are named using the same letter e.g. “c” is the speed of light (SPEED + LIGHT) where c = 300,000 km/s. “Electricity” is signed with the fists facing each other in front of you with the index fingers curving inwards and upwards just like electrodes. “Nuclear energy” uses two signs, the first being a generic sign for all forms of energy and the second symbolising nuclear power. In Chemistry, the elements are signed either specifically or by the chemical symbol.

Astronomy is one of the areas where signing in LSF is both rigorous and at the same time poetic. Signs attributed to the different planets of the Solar System have recourse to their own characteristics. For example, Mercury is very close to the Sun, Mars is red, Jupiter is represented by its famous red spot which has been seen by telescope for centuries, Saturn is known by its rings. The representation of the heavens is helped by the majority of constellations evoking animals or objects which already have a sign e.g. bears (great and Little), swans, fish, whale etc. Mythological names follow legend so for example Orion is a hunter while Centaurus is a being with the body of a man mounted on a horse.

Scientific technology is signed as well with for example computers identified by their model (PC, portables etc). Certain terms are very often found with an equivalent particular sign such as “numeric” which becomes 1-0-1-0-1-0. Medicine and biology have their own very complete and technical vocabularies.

This overview can obviously only give a rough idea of scientific communication in LSF. Facial expression is extremely important whether it’s to express that a mathematical sequence tends to infinity, and is thus “very small” or that the star Vega in the Lyre constellation has a surface temperature of 35,000 degrees and is thus “very hot”. Besides the rigours imposed in scientific language, the signer accompanies (in the musical sense of the term) his words with gestures by which the linking of the signs together relies on their interpretation. This duality interpretership – interpretation transforms the precision of the words to one where there is not only understanding but also feeling. In this way, the association of physical expression with the narrow observance of academic scientific discussion brings a touch of humanity and sharing to an otherwise rough world.



The Language of Swans, taken from La Marque du Chat, Philippe Geluck © Casterman.Courtesy of the author and Casterman Edition.

An LSF astronomical dictionary

The idea of an astronomical dictionary first saw the light of day following a programme broadcast in LSF in the television series “The Eye and the Hand” consecrated to this science, produced by Philippe Quinconneau and Danial Abbou, with the participation of the authors of this dictionary, broadcast in October 2007[3]. Furthermore, since 2000 there have been monthly classes in astronomy organised by the Meudon Observatory in the programme of “Astronomy for All” (AvT) with a goal of sharing knowledge linked to astronomy, astrophysics and related sciences (planetology, climatology, exobiology…) with the general public who have difficulty in accessing the culture of science, These classes bring together at each session some twelve to fifteen deaf participants. If weather conditions permit, observations are made with one of the observatory’s telescopes, having previously selected objects such as the Moon, planets, stars, galaxies etc, and then observing them in the night sky. If the sky is overcast, then a visit to the observatory is made and a specially themed conference with visual back up takes place. These evenings which are much appreciated by the deaf community allow for particularly fruitful exchanges which go beyond formal science and everyone profits from them. For the presenter, they are the occasion of a greater understanding of the world and culture of the deaf, while at the same time continuing the progress in

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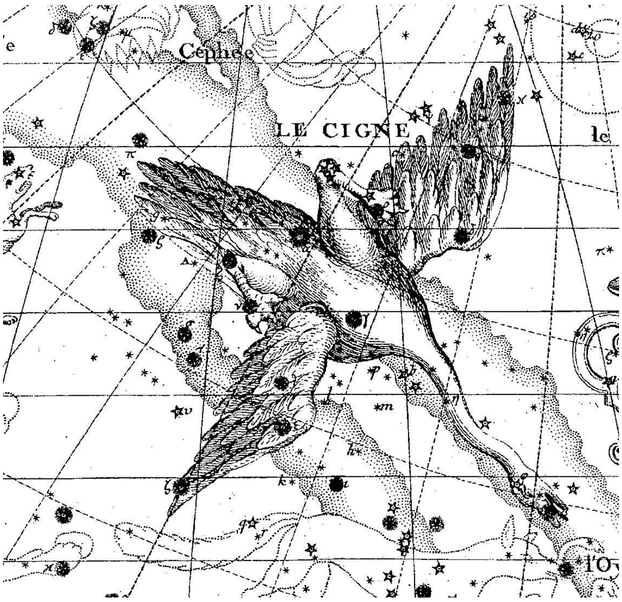
[3] www.france5.fr/oeil-et-main/archives/35220934-fr.php

the practice of signing. The experience so acquired is a t the origins of this dictionary.



Sign language in the heavens: The Swan constellation in Flamsteed's atlas (1776).

This dictionary is the first one to create a detailed link between astronomy and the deaf community. If astronomy is probably the most ancient of the sciences, the difficulties of man’s perception of an immense universe where space and time come into play join up with certain of the concerns of the deaf in a world of sound. As a consequence, the signing of some of the terms essential to astronomy has resulted in the creation of neologisms, in particular for terms borrowed from tradition. As an example, it’s easy to find an equivalent sign for the name of a constellation where it’s a question of animals or objects but where the name of a constellation refers back to the time of Ptolemy and Ancient Greece, this calls for a bit of imagination. Cepheus is represented by the compound sign “Bearded King”, Cassopeia by the sign “Queen” and their daughter, the princess Andromeda by the compound sign “Chained Woman” which is a reference to the myth which shows her chained to a rock having attracted Poseidon’s wrath.

We have been careful to avoid homonyms or paronyms. For example it’s essential to be able to distinguish between Saturn with its ring and a galaxy with its disc. This research into signed equivalents has given rise to long reflection when the astronomical tem is itself of recent appearance and refers to a very complex object. One particular example of this concerns the quasar which is contraction of the English “quasi-stellar radiosource”. We had to wait until the 1960s to understand that a quasar was not a star, even if it appeared to have the same dimensions, but a much further object whose energy burst, identical to that of an entire galaxy, comes from a tiny core. A sign for this that has been put forward by the deaf collaborators on this dictionary goes as follows: “I see a small brilliant source of light in the sky; I open it to see the interior; I am amazed to see the central area of a galaxy enclosed in this space with considerable energy.” Finally, we came up with the compound sign “Same + Galaxy + Energy + Power”.

We have to wait for such constructs to evolve in the hands of the deaf, whether because new knowledge will allow for a better sign language adaptation or because, like all living languages, LSF will tend to be modified over time as compound signs get replaced more simple ones. We are the first to hope for this to take place.

This dictionary has as its aim to bring together the essential components of astronomy and to turn them into an LSF encyclopaedia. For the reader who doesn’t practise LSF, we recommend doing a basic course in parallel. This can be found within different organisations and associations run by deaf teachers. We have wanted to create a work tool aimed at teachers as well as those interested in deaf culture and astronomy.

Each entry is accompanies by a picture of the corresponding sign as well as a commentary explaining the different parameters of each sign. Where the sign refers to antiquity, this commentary also has an etymological slant. The drawings are the work of Carole Marion; movements are represented by arrows in line with the publisher IVT’s long-established conventions. Many of the illustrations come from Wikimedia Commons and these are available freely without the need for a licence.

Words in bold font indicate benchmarks and essential ideas. Technical, geographical and foreign names are in italics. French translation of LSF signs are in SMALL CAPITALS.

Dominique Proust

Dominique Proust is a hearer and is a research engineer at the CNRS and astrophysicist at the Paris-Meudon Observatory. He has studied at The French Academy of Sign Language and at the International Visual Theatre, and is a practitioner of French sign language. He has developed a cultural partnership in astronomy with the deaf community with his programme “Astronomy for All”.

Daniel Abbou is deaf and is a teacher, pedagogue, co-producer and presenter of the weekly programme “The Eye and the Hand” on Channel 5. He is also an adviser on communications at ESAT Jean Moulin (Paris 14). After having been one of the protagonists of the renaissance of sign language in France, he has been a participant in number cultural programmes both in France and overseas as both pedagogue and expert.

Nasro Chab is deaf, and is responsible for LSF conference at the Arts et Metiers Museum and at the Palais de Decouverte, He is a specialist in scientific communication in LSF for the deaf community and has developed an appropriate teaching method for it. He is an active participant in developing sign language overseas where he is frequently invited as an expert.

Yves Delaporte is a hearer and is an ethnologist and research director at the CNRS. He has published many books on the world of the deaf including: « Les sourds, c’est comme ca » (Maison des sciences de l’homme, 2002), «Moi, Armand, ne sourd et muet » (Plon, 2002, with Armand Pelletier), «Dictionnaire etymologique et historique d la langue des signes francaises » (edition du Fox, 2007). He is a keen amateur astronomer.

Carole Marion is deaf and is a professional artist, a graduate of the Ecole des Beaux-Arts de Lyon, former teacher of LSF at the University of Lyon at Bron and teacher of LSF at the Institut Gustave Baguer at Asnieres (92).

Blandine Proust is a hearer and has studied at the French Academy of Sign Language and at the International Visual Theatre. She is a practitioner of LSF most notably in her professional career with a large airline

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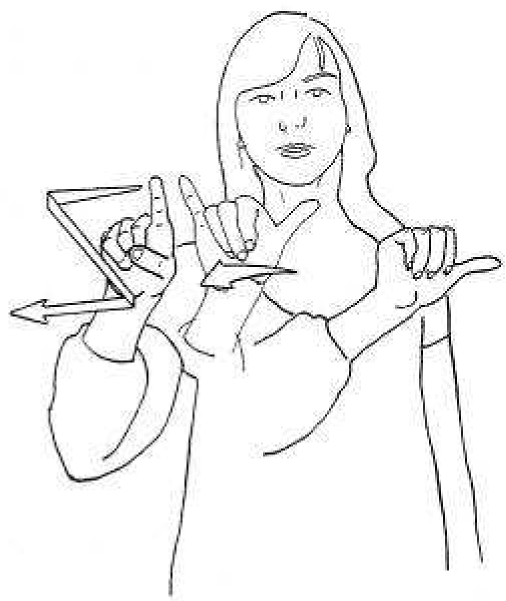
Alphabet

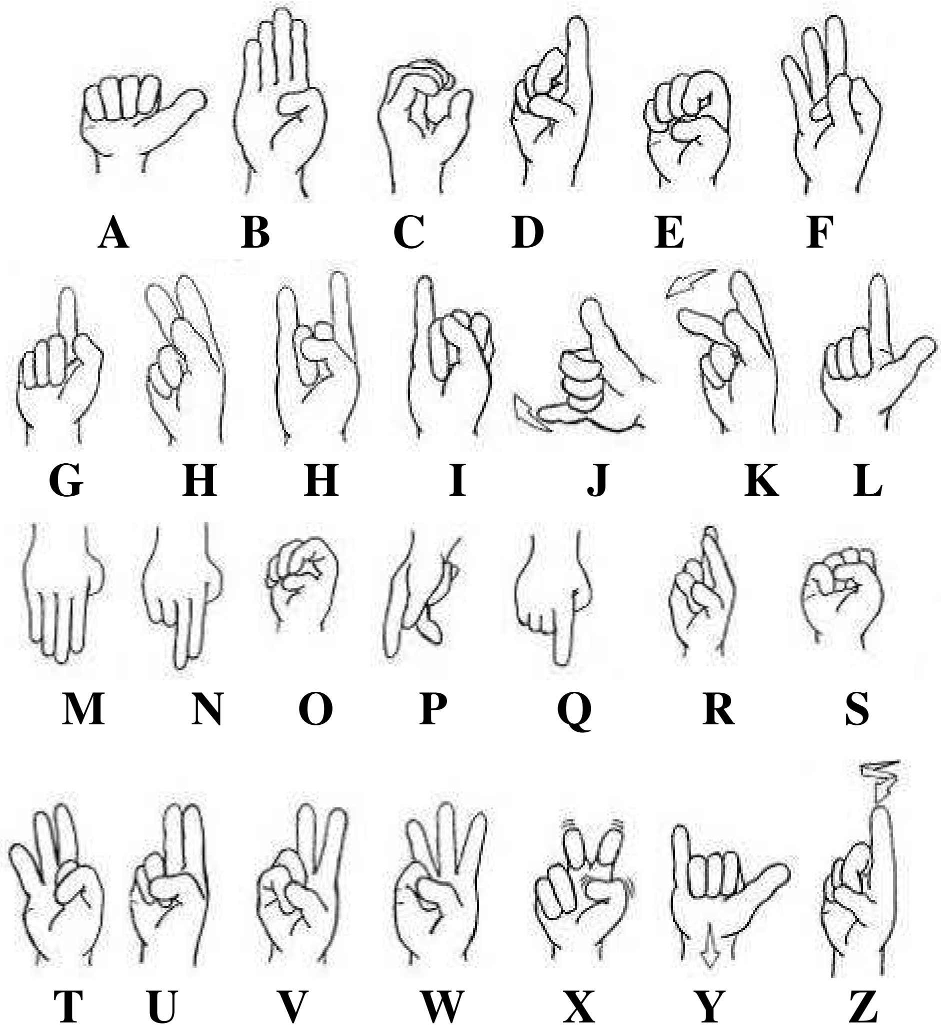
Using Sign Language, Astronomy is expressed through two different but complementary alphabets: the **manual** and the **Greek alphabets**.

The aim of the manual alphabet, also named **dactylology,** is to spell proper names for which no sign yet exists. Several entries in the present dictionary make use of a sign and a spelled name such as Kuiper's belt (see the entry *Transneptunians*) or Halley's comet (see the entry *comet*).

The sign "MANUAL ALPHABET" shows the first two letters of the alphabet, A and B, and continues with a lateral hand movement and an oscillation of the fingers, suggesting a long series.



MANUAL ALPHABET



The manual alphabet.

For many years the **Greek alphabet** has been used. It is represented in French Sign Language with the sign "ALPHABET OF A VOCAL LANGUAGE" (see above) followed by the sign "GREEK" which is represented with a "G", the first letter of the word *greek.*

Each letter designates a star in a given constellation, even when the brightest ones have an Arab name. As an example, the star "alpha" in the Lyre constellation, "α Lyra"», is the beautiful star *Vega.*

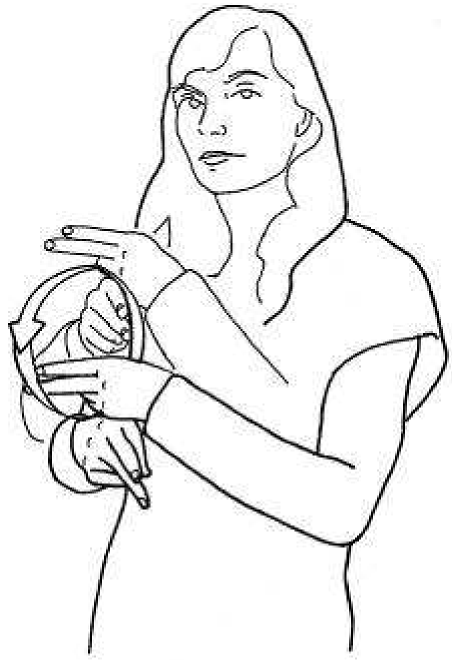
The table below gives the list of 24 greek letters, with their individual name.

GREEK ALPHABET

Letter	Name	Letter	Name	Letter	Name
α	alpha	**ι**	iota	**ρ**	rho
ß	beta	**κ**	kappa	**σ**	sigma
γ	gamma	**λ**	lambda	**τ**	tau
δ	delta	**μ**	mu	**υ**	upsilon
ε	epsilon	**ν**	nu	**φ**	phi
ζ	zeta	**ξ**	xi	**χ**	khi
η	eta	**ο**	omicron	**ψ**	psi
θ	theta	**π**	pi	**ω**	oméga

Artificial Satellite – Spacecraft

A circular movement, made simultaneously by both hands, represents the revolution of an artificial satellite around the Earth or around another planet. The extended index and middle fingers of both hands reproduce the shape of the solar panels which we can see in one of the photos below.



Associated words and expression:
Astronomer - Big Bang - Cosmological Microwave Background - Earth - Eccentricity - Comet - Mars – Moon - Planet - Quasar - Revolution - Satellite (natural) - Saturn - Solar system - Telescope - Titan - Universe - Wavelength.

Artificial satellites are machines built by man and launched into space to send them into orbit around the Earth, around a planet or around a moon. They are distinct from **spacecraft** which are launched into space for a one way journey, such as the *Voyager* spacecraft which left the Earth in 1977, went out of the Solar system several years ago and is now flying towards stars which it will reach in 40,000 years' time.

The first artificial satellite, *Sputnik 1*, was launched by the USSR in 1957. Since then, it has been followed by several thousand civil and military satellites. Many satellites in orbit around the Earth are now inactive, but they continue to orbit and sometimes they fall back down.to Earth The atmosphere protects us by destroying them during their re-entry. However there always remains a risk with big satellites or with those which carry armaments that we cannot rule out that they might fall on an inhabited place or that their fall activates their armaments. There is thus a **pollution of space**.

The spacecraft Voyager. ©NASA/JPL

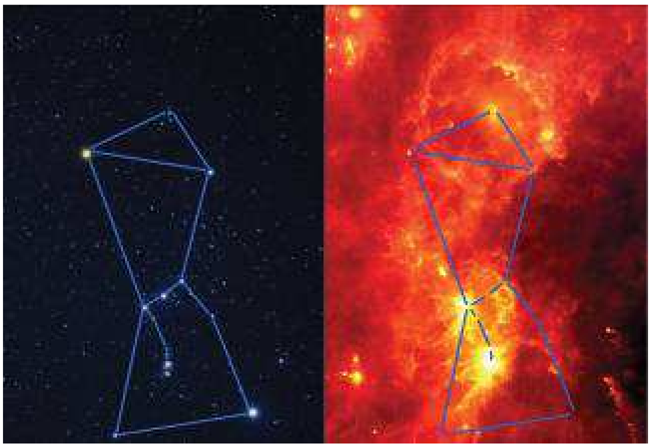
The satellites which revolve around the Earth have highly varied orbits. Some seem fixed over us: these are the **geostationary satellites.** Others have largely eccentric orbits. Others cross over the poles in a vertical orbit, their orbit being **polar**.

Satellite in orbit around the Earth. ©NASA.JPL

The satellite spot5. © CNES

The use of satellites is also highly varied. Some are sent for scientific purposes (observation of the Earth and the universe), others are used for telecommunications (telephone, internet) or for remote detection (meteorology, natural resources, military applications).

Satellites observe the Earth and the universe in all the wavelengths, in particular those which are stopped by the Earth atmosphere such as X-rays. Thanks to them, astronomers can observe the sky without having to worry about weather conditions, in particular clouds. This enables scientists to study the gas and dust of the galaxies, the cosmological brilliance of Big Bang, objects very distant such as quasars, etc. These observations complete those which are carried out on the ground with different telescopes.



The Orion constellation, such as it can be seen with naked eye (left) or observed in the infrared range with a satellite (right). © ESA

Principal satellites and spacecraft

Sputnik 1. 4 October 1957 : first artificial satellite in orbit around the Earth.

Luna 2. 12 September 1959 : first spacecraft crashing on the Moon.

Vostok 1. 12 April 1961 : first human flight around the Earth, with *Yuri Gagarin*.

Mariner 4. 28 November 1964 : first images of the surface of the planet Mars.

Apollo 11. 21 July 1969 : *Neil Armstrong* is the first man on the Moon.

Viking. 1976 : first detailed images of Mars by the two *Viking spacecraft.*

Voyager. 1977 : launch of the two *Voyager* spacecraft which will explore the Solar system.

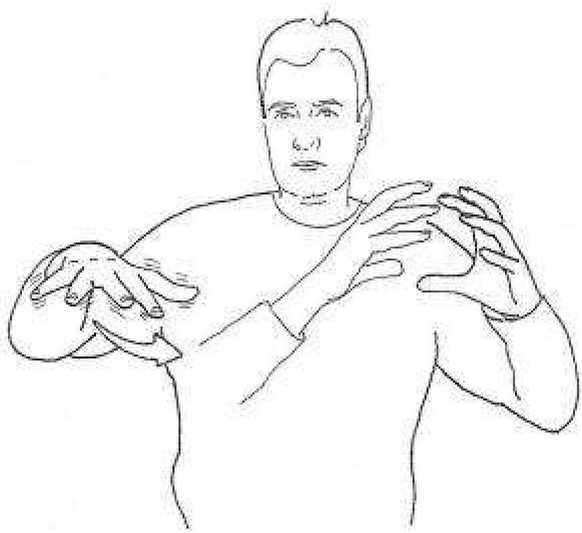
Giotto. 1985 : first images of the nuclei of a comet (*Halley comet*).

Space Telescope. 1990 : launch of the Space Telescope *Hubble*.

Cassini-Huygens. 2005 : images of the Saturn satellite *Titan*.

Asteroids

The concept of an asteroid is expressed with a succession of three signs. The first one shows a large circular area around the Sun represented with a close hand and with the open fingers of the second one. The second sign with the straight index finger indicates that more details will be given, followed by the third one showing STONE / ROCKS. See the etymology of this sign at the entry TRANSNEPTUNIANS.



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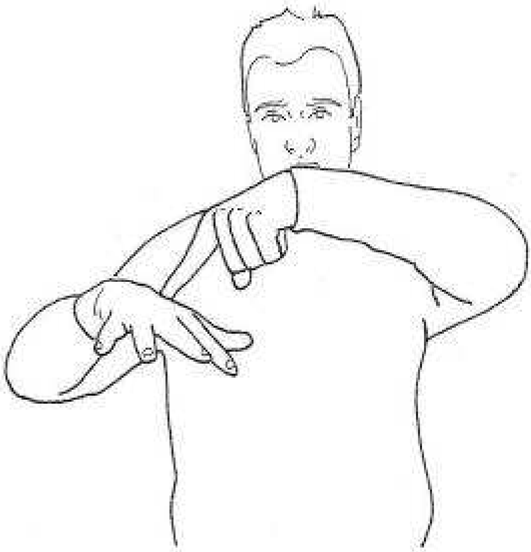

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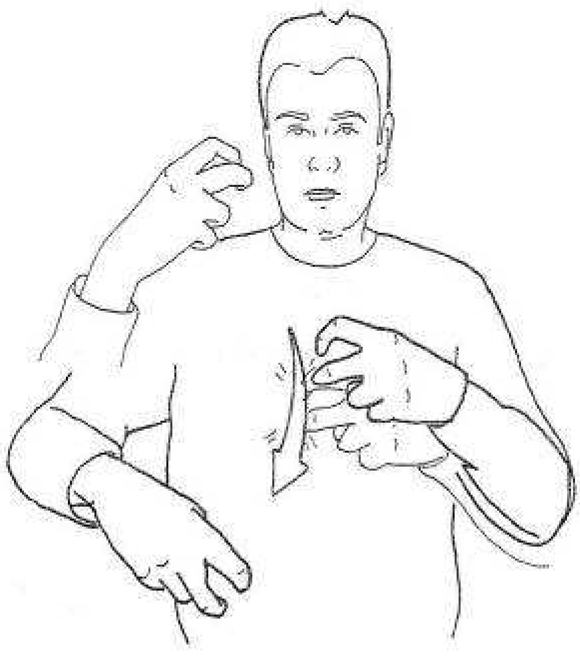

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Associated words and expressions:
Astronomer - Diameter - Earth - Jupiter - Life - Mass - Mars - Moon - Planet - Solar system - Sun.

Asteroids are huge blocks of rocks whose size ranges from a few tens of metres to a few tens of kilometres. They are different from comets as most of the asteroids orbit the Sun in an area situated between the orbits of Mars and Jupiter. They constitute the **asteroid belt**.

This asteroid belt corresponds to an area of the Solar system where the mutual gravitational attraction of the big planets provokes a **gravitational resonance** so that smaller bodies situated in this area cannot merge to make a new planet (see the entry SOLAR SYSTEM). The asteroids are made from the same materials as the nearest planets of the Sun: Mercury, Venus, Earth and Mars. Astronomers consider that two million of such bodies have a diameter less than one kilometre (which corresponds to an individual mass of around twenty billions of tons) while around two hundred have a diameter greater than one hundred kilometres. They orbit the Sun at an average velocity of 65 000 km/h (two times slower than the Earth), with a total mass equivalent to the Moon.

*The asteroid **Gaspra** with a length about 19 km and a diameter of 12 km. © NASA/JPL*

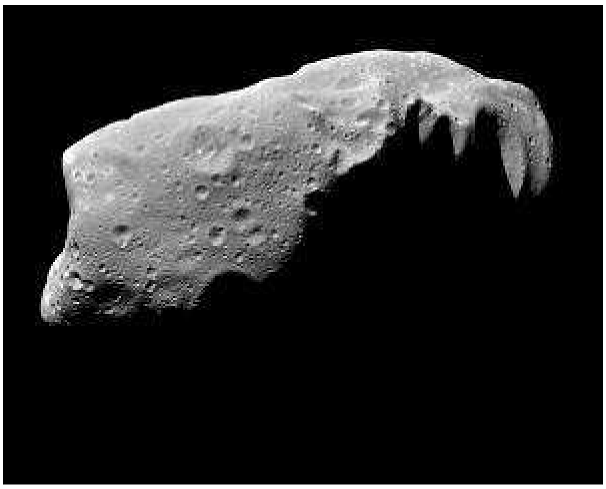
Discovery of the asteroids

In 1788, *Johann Elert Bode* (1747-1826), director of the Berlin observatory, was looking closely at a numerical relationship linking the distances of the planets to the Sun, which had been discovered in 1741 by the German astronomer *Wolf* and formalised by his colleague *Daniel von Tietz* (1729-1796):

$$D = 0{,}4 + (0{,}3 \times 2^n)$$

In this relationship, *n* value is -∝ (minus infinity) for Mercury, 0 for Venus, 1 for the Earth, 2 for Mars, etc. The table below shows the relationships between the values obtained from the Bode's Law and the true distances, the distance of the Earth to the Sun taken as the unity. This table was extended to the celestial bodies discovered after Bode such as the planets Uranus and Neptune as well as the asteroids.

Planet	***n***	**Bode's Law**	**True Distance**
Mercury	-∝	0.4	0.39
Venus	0	0.7	0.72
Earth	1	1.0	1.00
Mars	2	1.6	1.52
Asteroids	3	2.8	2.80
Jupiter	4	5.2	5.20
Saturn	5	10.0	9.55
Uranus	6	19.6	19.2
Neptune	7	38.8	30.1



*The asteroid **Ida**, with a length about 56 km and a diameter of 23 km.© NASA/JPL*

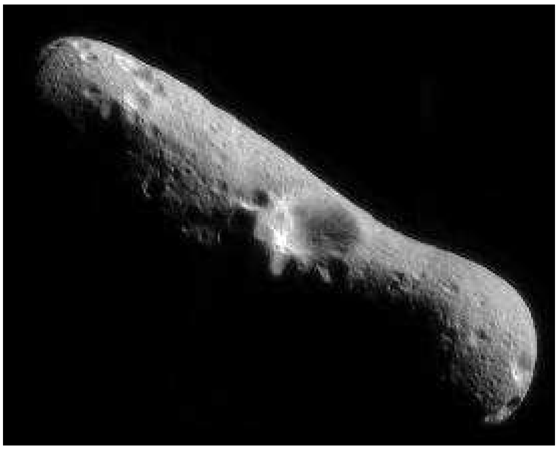
The lack of a planet between Mars and Jupiter (corresponding to $n = 3$) encourages astronomers of the 19th century to search the sky to find a new one. In 1801, *Piazzi* discovered **Ceres**, the biggest asteroid with a diameter of 350 km. Subsequently, new small bodies were discovered, among them **Pallas** (230 km diameter), **Vesta** (190 km), **Juno** (110 km) right down to **Icarus** (700 meters) and **Adonis** (150 meters). The Solar system has a real belt comprising more than 400,000 asteroids. As an example, the asteroid number 4474 is named *Proust* (the author of this text). It has a diameter about 19 km and orbits the Sun every 5.71 years, at a distance from the Sun of between 402 and 554 million km.

Risks for the Earth?

Although the majority of the asteroids quietly revolve between the orbits of Mars and Jupiter, a small number of these objects have a more eccentric orbit. These constitute the **Trojan** family whose respective orbits intersect those of Mars, Earth, Venus and Mercury with a consequent risk of collisions with those planets.

It was probably a ten kilometres diameter asteroid which collided withthe Earth 66 million years ago. It would have caused the formation of the Gulf of Mexico and would have provoked the extinction of the dinosaurs. On 30 June 1908 in the Siberian area of *Tunguska*, a 100,000 tonne asteroid exploded in the Earth's upper atmosphere before colliding with the Earth, flattening all the pine trees on the surface for tens of kilometres all around. Luckily, the   was completely deserted.

If life on Earth was possible thanks to the comets and asteroids, a collision with one of these bodies could be the main cause of life extinction (see the entry LIFE).



The asteroid ***Eros****, a cylinder 33km long and 13km in diameter. The spacecraft NEAR landed on its surface on 12 February 2001. © NASA/JPL*

Astrology

The sign for ASTROLOGY is in fact the former sign for STARS as it was for many centuries and as it still remains today in countries other than France. It consists of pointing with the two index fingers at places on the celestial vault. The creation of two others signs STAR (see the entrances *Star-general* and *Celestial vault*) and the existence of a specific sign ASTRONOMY led to this former sign for STAR BEING KEPT by attributing to it the meaning of "astrology".

Associated words and expressions:
Astronomy - Calendar - Comet - Constellation - Earth - Equinox precession - Planet - Precession - Star - Sun - Zodiac.

It is very wrong to confuse **astronomy** and **astrology**. In ancient times right up to the end of the 17th century, there was a "science of the sky" which consisted of locating the motion of the planets among the **twelve constellations of the zodiac**, in observing comets and stars, in following the eclipses of the Moon and the Sun and in adjusting the calendar. These phenomena were interpreted as tangible signs sent by the gods. In their palaces, kings, emperors and dignitaries had astrologers who made predictions and horoscopes from their observations. This activity was not without risk and astrologers were often executed because their predictions were not realised.

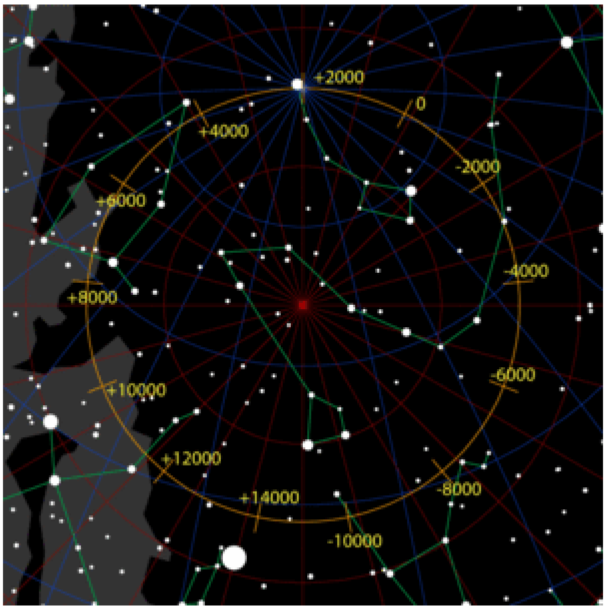
The twelve constellations of the zodiac
During the year, the visible movement of the Sun (although it is actually the Earth which revolves around the Sun) makes it appear traditionally to be crossing the twelve constellations which constitute the zodiac. Here are their names in English and in Latin: the Water Carrier (Aquarius), Fishes (Pisces), the Ram (Aries), the Bull (Taurus), the Twins (Gemini), the Crab (Cancer), the Lion (Leo), the Virgin (Virgo), the Scales (Libra), the Scorpion (Scorpius), the Archer (Sagittarius) and the Goat (Capricornus). In reality, the Sun also passes through other constellations such as Ophiuchus or the Crow.

The symbolism of the twelve constellations of the zodiac (anonymous 17th century treatise).

As the planets are in the same plan of orbit as the Earth around the Sun, they also cross these twelve constellations more or less quickly (according to their distance from the Sun). *Ptolemy*, an astrologer who lived in Alexandria in the year 140, drafted a book called *Tetrabiblos* in which he divided the zodiac into twelve equal regions and to which he gave the names of the twelve constellations (as the complete circle of the zodiac is 360°, every region thus makes 30°). He then established the relationship between the planets and the zodiac which are supposed to influence life on Earth as the planets cross such or such region. Following Ptolemy and until the Renaissance period, astrologers thus associated their observations of the sky and the positions of the planets to help them draw up horoscopes and make predictions. Astronomers gradually realised that these had no serious basis, particularly with the discovery of the Earth's specific movements such as the **Precession of the Equinoxes**.

The Precession of the Equinoxes

The axis of the Earth behaves like a spinning top as it comes to the end of its spin and slowly changes its orientation. At present, it is pointing at the **Pole Star** in the constellation of the Little Bear. But 5,000 years ago, it was Thuban in the constellation of Draco which indicated the North Pole, and in 12,000 years it will be the turn of Vega in the constellation of Lyra to indicate the North. The current pole star (Polaris) will again be at the North in 25,800 years time.
This peculiar movement causes a shift between the constellations of the zodiac and the twelve regions which were associated with them by Ptolemy. So, in reality, the Sun and the planets are no longer in the constellations corresponding to their astrological region.

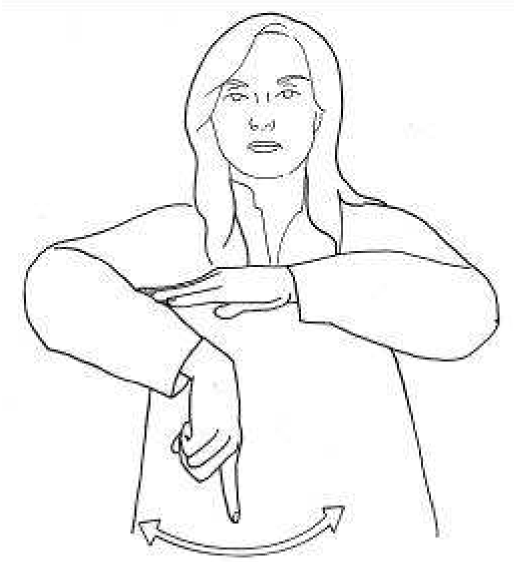


The movement of the North pole for the next milleniums. ©Tau'olunga.

Since the 17th century, astronomers concluded without difficulty that astrology was not based on any serious law and that there was no influence on Earth resulting from the planets except the influences of the Sun (heat and light, flow of particles from solar eruptions) and those of the Moon (in particular the tides). **Astronomy and Astrology thus have nothing in common**. However, we still find horoscopes these days in numerous newspapers. They have no value but bring a lot of money to those who write them. Astronomers have widely shown that astrology has no basis but superstition still seems to have a strong hold.

Astronomical clock

The **astronomical clock** is shown by the sign for CLOCK, which reproduces the motion of a pendulum, followed by the sign ASTRONOMY (see this entry).



CLOCK

Associated words and expressions: Calendar Eclipse - Equinox - Moon (phases) - Planet - Sun - Solstice - Zodiac.

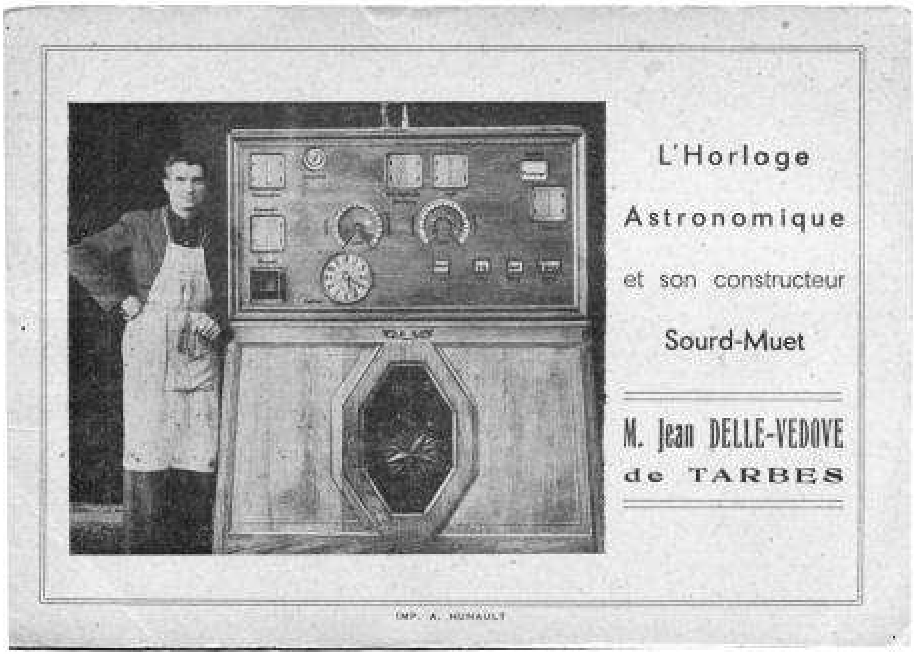
The **astronomical clock** gives us the measurement of as well as the position of planets and stars in the sky. Since the appearance of the first calendars, which were derived from the movements of the Sun and the Moon in the sky, mankind has improved clocks which have become more and more accurate in their measurement of time. These clocks could indicate not only the day and the hour, but also the Moon's phases, the positions of the planets in the zodiac, the Sun's and Moon's rising and setting, solstices and equinoxes, eclipses, etc. These clocks also indicated the dates of the mobile religious feasts, such as Easter. They were very useful information sources for the whole populace which is why they were generally installed in public places such as churches or town-halls.

In France, you can see the main astronomical clocks in the cathedrals of Beauvais, Besançon, Bourges, Chartres, Lyon (Primatial Saint Jean), Saint-Omer and Strasbourg.

The first clock in Strasbourg was built about 1353; a second one, built by *Herlin*, *Dasypodius* and *Habrecht*, replaced it in the 16th century. It was transformed by *Jean-Baptiste Schwilgué* (1776-1856) and is as we see it today. It shows the movement of the planets, the days and the hours with a perpetual calendar, moon phases and the dates of religious feasts.

Automata symbolizing the ages of the life parade regularly throughout the day.

The astronomical clock in Strasbourg cathedral.
© Wysik



Between 1939 and 1950, J-B Delle-Vedove, a deaf cabinet maker in the city of Tarbes, built a wooden astronomical clock which showed sunrises and sunsets, the moon's phases, seasons, the year, the date as well as the main dates of religious feasts. The clock weighs 280 kg, is 2 metres high and contains 92 cogwheels of all sizes.

Astronomical Unit

The astronomical unit (UA) is indicated in Sign language by the letters U and A of the alphabet (see the entry *Alphabet*). During a conference in Sign language, you have to define at first what an astronomical unit is.

Associated words and expressions : Extrasolar system – Earth - Jupiter – Mars – Mercury – Neptune – Planet – Saturn – Solar system - Star - Sun – Uranus - Venus.

An **astronomical unit** (UA) is the average distance from the Earth to the Sun, which is:

1 UA = 149,597,870.691 km

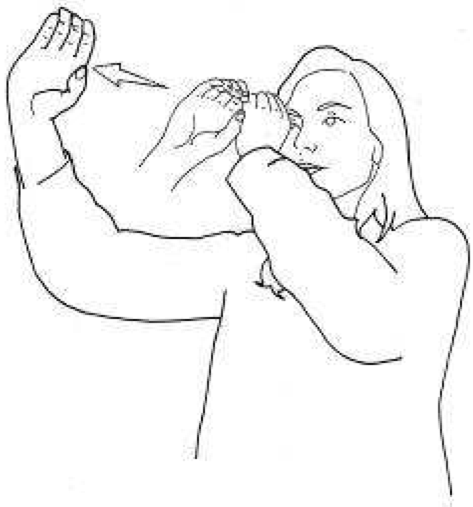
We often round off this distance to 150 million km. This unit is useful in order to express the distance of the planets in the Solar system, as well as in extrasolar systems (planets orbiting other stars). The distance of the planets from the Sun is as follows:

Mercury : 0.39 UA ; Venus : 0.72 UA ; Earth : 1 UA ; Mars : 1.52 UA ; Jupiter : 5.21 UA ; Saturn : 9.52 UA ; Uranus : 19.16 UA ; Neptune : 30.11 UA.

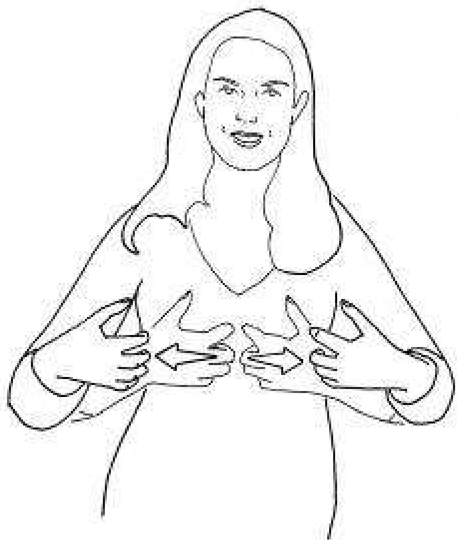
Astronomy - Astrophysics

In the 19th century, the sign for ASTRONOMY was translated by the signs for SUN, MOON, STAR, KNOWLEDGE followed by the sign "to place both hands in a pipe shape in front of the right eye" (Lambert, 1865). This last component has since become the sign ASTRONOMY. To distinguish it from ASTRONOMICAL TELESCOPE, it is followed by the sign for SCIENCE just as it had been preceded by the sign for KNOWLEDGE in the 19th century. For the etymology of SCIENCE, see the corresponding entry.

As astronomy is traditionally the science of the celestial bodies, their movement, time, calendar, etc., the same sign is used for **astrophysics** which is concerned more particularly with the physical, chemical and chronological study (evolution in time) of the planets, the stars, the galaxies and the universe in general.



ASTRONOMICAL TELESCOPE



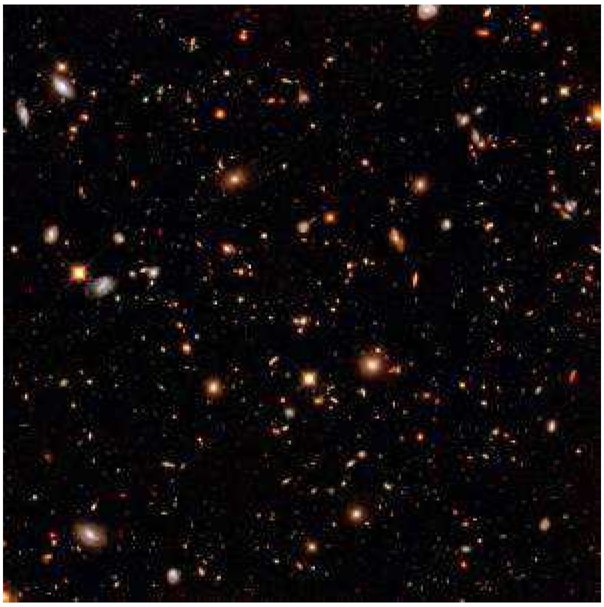
SCIENCE

Associated words and expressions:
Astronomy (history) - Calendar - Celestial mechanics - Celestial vault - Constellation - Earth - Galaxy - Light - Moon (phases) - Photometry - Picture - Planet - Satellite - Solar system - Spectroscopy - Star - Sun - Telescope - Universe - Zodiac.

Astronomy is doubtless the oldest among sciences. It was born with the consciousness of man as soon as he had evolved intellectually enough to notice the regularity of the celestial phenomena such as sunrise and sunset, the moon's phases, the movements of planets on the celestial vault, etc. These phenomena were the basis for the first laws of civilization following the rhythm of the heavens. Throughout history, the importance of astronomy was such that kings, emperors, dignitaries, etc., were accompanied by astronomers whose main task was to make predictions based on the movements of the planets in the twelve constellations of the zodiac. This activity, from which horoscopes derived, constituted **astrology** which is still popular to-day despite it having absolutely no solid basis as has been clearly shown by modern astronomers.

Throughout history (see the entry *Astronomy-history*), astronomers have studied the movement of the Earth, the Sun, the Moon and the planets. They have established sky maps by grouping the configurations of stars into constellations (of which there are 88 in the sky). They have discovered the cycle of the seasons and adjusted the progress of the days by means of calendars. In ancient times, planets were considered as gods but, later, astronomers tried to understand their nature, their origin and to specify their movements. In this way *celestial mechanics* was born. Astronomy allowed a traveller to travel and, for many hundreds of years, it was used by the sailors to navigate. It also allows us to set the exact time with these days a precision of a millionth of a billionth of a second.

Astrophysics is a more recent domain of astronomy. It is essentially interested in the nature and in the history of the bodies which compose the universe: planets, stars, galaxies, etc. Astrophysicists make observations with telescopes all over planet Earth and, for some time now, by means of artificial satellites in orbit around our planet and spacecraft flying in and out of the Solar system.

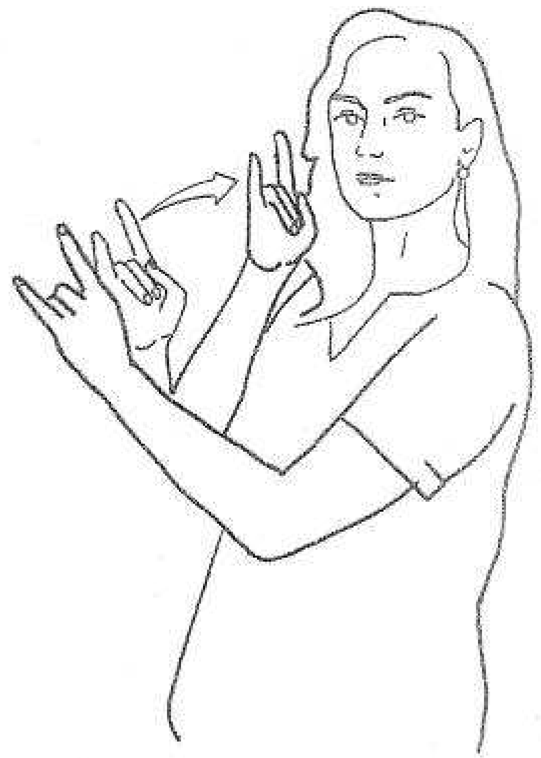


A deep sky field, mixed with stars and very distant galaxies. © NASA/HST

Thanks to the analysis of light which is made by imaging, photometry and spectroscopy, it is possible to know the chemical composition, the movement and the evolution of stars and galaxies, and to be able to go back in time. At present, astrophysicists consider that the universe is about 13.7 billion years old. The biggest telescopes allow us to observe distant galaxies eight billion light years away, in other words to see how the universe was eight billion years ago.

Astronomy (history)

The idea of the history of Astronomy is translated by the sign "HISTORY" followed by the sign "ASTRONOMY". In the first of these, a motionless hand represents the present moment; the other hand moves towards backwards as if on the axis of time, that is towards the past. Both hands have the shape of the letter H of the manual alphabet, the initial of the word *history*. For the etymology of the sign "ASTRONOMY", see the corresponding entry.



HISTORY

Associated words and expressions: Light year - Astronomy - Big Bang - Calendar - Celestial mechanics - Comet - Earth - Eclipse - Ellipse - Galaxy - Interaction (gravitational) - Jupiter - Light pollution - Light velocity - Mars - Moon - Neptune - Planet - Refractor - Satellite - Saturn - Star - Star (binary) - Star (variable) - Sun - Spectroscopy - Solar system - Telescope - Titan - Universe - Uranus - 3K emission.

Since the beginning of time, the universe has always fascinated mankind. The questions of the **how** and the **why** of its origin and its evolution was the justification of the work which allowed astronomy to make its considerable progress over time. Man is born and lives in the universe and it is without doubt that this intimate relationship with the surrounding medium makes astronomy the oldest science, as old as man himself. Until the Renaissance, although man did not use any instruments and observed only with the naked eye, this had the advantage of no light pollution and being able to observe the deep sky everywhere on the Earth, in conditions unthinkable nowadays.

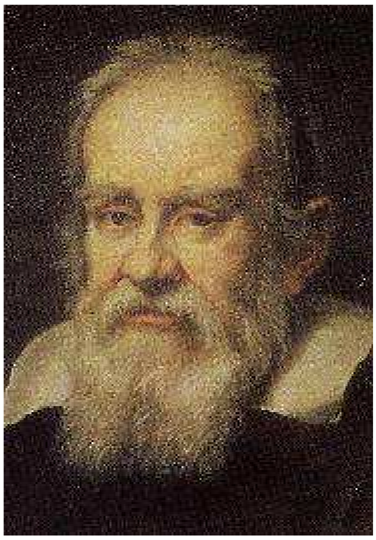
Archaeological research has proved that the civilizations of the prehistory were greatly interested in the heavens. The Moon's phases, the movements of the planets, the alternation of the seasons are at the origin of the first calendars. However, actual knowledge stems from Greek antiquity. In Babylon (800 BC), astronomers already knew how to predict the dates of the eclipses of the Sun and the Moon. *Anaximander* (610-540 BC) placed the Earth in space and the stars at a great distance from it. *Aristarchus* (310-230 BC) was the first to consider that the Earth revolves while in orbit around the Sun. In the 2nd century BC, *Hipparchus* developed the first star catalogue, dividing the stars into six classes according to their luminosity. *Ptolemy* (96-165) proposed a system of the world in which the Earth is at the centre of the universe: this is the **geocentric model**. Although this model was false, it was strongly upheld by the authority of the Church until the Renaissance.

During the medieval period, Arab science brought a large set of fundamental knowledge to astronomy particularly thanks to the development of the mathematics. Among the relevant Arab astronomers, one can note *Al Kindi* (801-873), author of sixteen books on astronomy, or *Al Farghani* (805-880) who studied the movements of celestial bodies. Astronomy was gradually taught in the young European universities but using the geocentric model. One had to wait for *Nicolas Copernicus* (1473-1543) who explained that the movements of the planets are explained by a *heliocentric model* in which the planets revolve around the Sun. This model was disputed by the Church which wanted to give to the man, the creation of God, supremacy in the universe and it was only at the end of the 17th century that the heliocentric model was finally adopted.

Nicolas Copernicus. © Observatoire de Paris

Tycho Brahe


Johannes Kepler


Galileo Galilei

Tycho Brahe (1546-1610) developed catalogues of stars, observed the movements of planets and concluded that comets are distant bodies. His observations of the movement of the planet Mars were used by *Johannes Kepler* (1571-1630) who discovered three laws of celestial mechanics which to-day have his name, one of them attributing an ellipse shape to global orbits. *Galileo Galilei* (1564-1642) was the first to observe the sky using a refractor, invented a few years earlier by Dutch opticians. He observed the craters of the Moon, discovered the four main satellites of Jupiter and, like Kepler, promoted the heliocentric model. In Holland, *Christiaan Huygens* (1629-1695) discovered the rings of Saturn as well as its main satellite Titan, and observed the rotation of the planet Mars. *Jean Dominique Cassini* (1625-1712) was the first director of the Paris Observatory. He measured the distance of the Earth from the Sun and discovered four new satellites of Saturn, whereas *Olaus Römer* (1644-1710) determined the speed of light in the same observatory. In England, *Isaac Newton* (1642-1727) showed that light can be decomposed into various colours (see the entry *Spectroscopy*); he constructed the first telescope and established in 1687 the law of **universal gravitation** in which bodies are submitted to gravitational interaction as a function of their mutual distance. *Edmund Halley* (1656-1742) calculated the orbits of twenty four comets and predicted the return of one of them (see the entry *Comet*).

William Herschel

Urbain le Verrier

Albert Einstein and Marie Curie

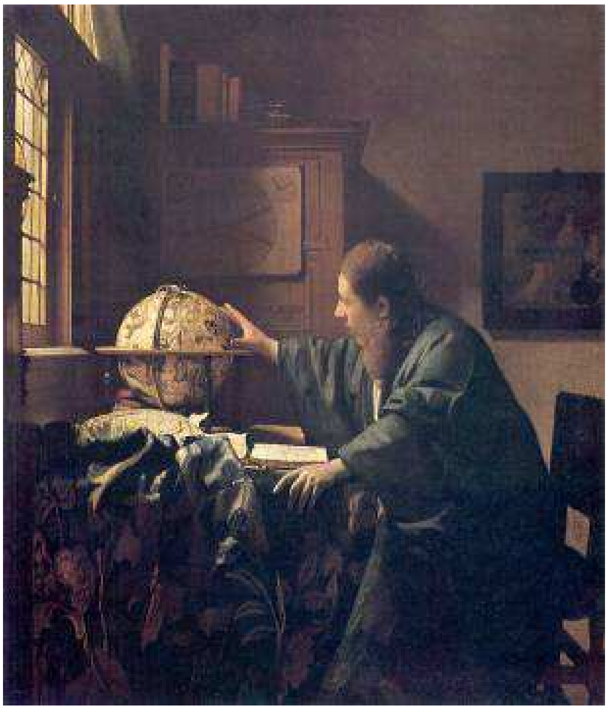
The 18th century brought considerable progress in astronomy. Telescopes allowed the observation of stars, the discovery that their brightness varied (see the entrance *Variable Star*) and that some of them are multiple (see the entrance *Binary Star*). *William Herschel* (1738-1822) discovered Uranus as well as numerous galaxies. *Pierre Simon de Laplace* (1749-1827) studied the formation of the Solar system. In the 19th century, *Urbain Le Verrier* (1811-1877) discovered the planet Neptune by analysing the perturbations that a new planet could provoke on the orbit of Uranus. Technical progress resulted in the first photographic images of the heavens from 1845 and large observatories were built worldwide.

If the universe was considered for a long time to be infinite and eternal, the theoretical works of *Albert Einstein* (1879-1955) changed these old conceptions with the theories of special relativity (1905) and then general relativity (1916) which enabled him to posit that the visible universe began with a Big Bang. It dilated in a global movement of expansion confirmed by the observations of *Edwin Hubble* (1889-1953) using spectroscopic analyses of the light of the galaxies. In parallel, the development of radio astronomy allows us to receive the emissions of celestial bodies in the range of radio waves. The discovery of 3K background radiation confirmed this cosmological model.

Edwin Hubble

Nowadays, the universe is studied on a scale of several billion light years, allowing us to go back very far in the past. With the development of ground and space instruments, we can analyse in detail the structure of planets, comets, stars and galaxies. Basic researches are now possible into the beginning of the universe and the search for extraterrestrial life. It is not possible to detail here the enormous list of discoveries and the progress accomplished in astronomy since the second half of the 20th century. More and more, astronomy has allowed man to find his own origins in the universe as well as allowing him to get to know the immensity of space in which he is evolving.

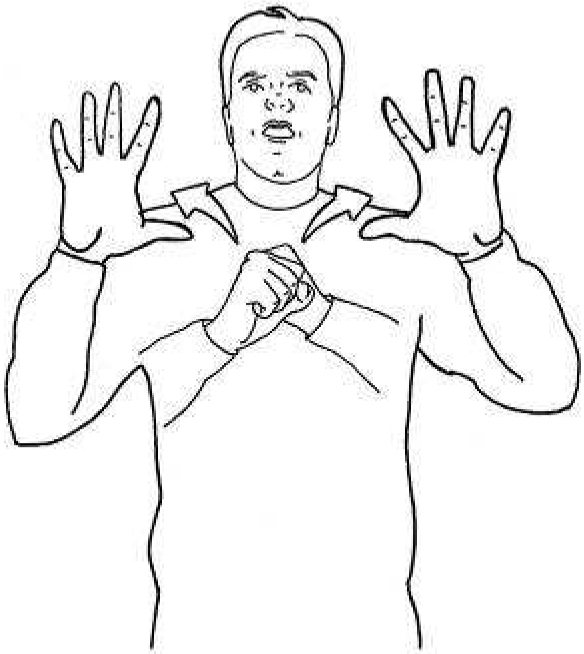
Astronomy (French 16th century tapestry, Göteborg museum).



The astronomer (Jan Vermeer van Delft, 1632-1675, Musée du Louvre).

Big Bang

The Big Bang is represented by the sign for UNIVERSE (see this entry), followed by the sign for EXPLOSION. The fists moving wide apart symbolize an explosion and this is followed by a rapid expansion. This sign, which is different from the standard sign for EXPLOSION by virtue of the distance between the hands, is also used for SUPERNOVA.

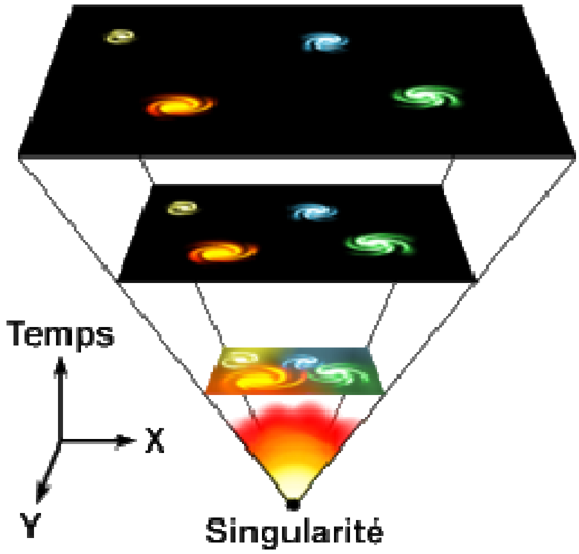


EXPLOSION

Words and associated expressions: Astronomer - Atom - Chemical element - Galaxy - Relativity - Universe (expansion) - Universe (history) - Universe (radiation).

The aim of **physical cosmology** is to analyse the state of matter in the universe by going back into the past to a "beginning", which is the origin of space and time; this is known as the **Big Bang**. The more distant the observed galaxies the younger they are. In the past, the universe was smaller and hotter and the galaxies were thus closer to each other (see the entry *Universe-expansion*). The Big Bang corresponds to the extreme initial conditions of temperature and density where matter was released by way of a hot explosion.

Optical telescopes allow us to see distant galaxies and, consequently, to look back in time. The instruments used on the ground and in space nowadays provide real evidence of a space which was originally hot and dense and of which the beginning was characterised by a **violent cataclysm**. The cosmological radiation and the recession of the galaxies (see the entry *Universe-expansion*) are major arguments in favour of the Big Bang. Furthermore astrophysicists have shown that the abundance of the chemical elements formed at the beginning of the universe such as helium, deuterium and lithium, are quite constant in every direction in the heavens leading to the conclusion that the nuclei of these atoms must have formed at the same time.



The expansion the universe following the Big Bang.

From the solutions of the equations of relativity and the results coming from observations, astronomers have succeeded in redrawing the history of the universe now estimated at 13,8 billion years starting with the Big Bang, this mysterious cataclysm, the physical characteristics of which are still unknown (see the entry *Universe-history*).

Black hole

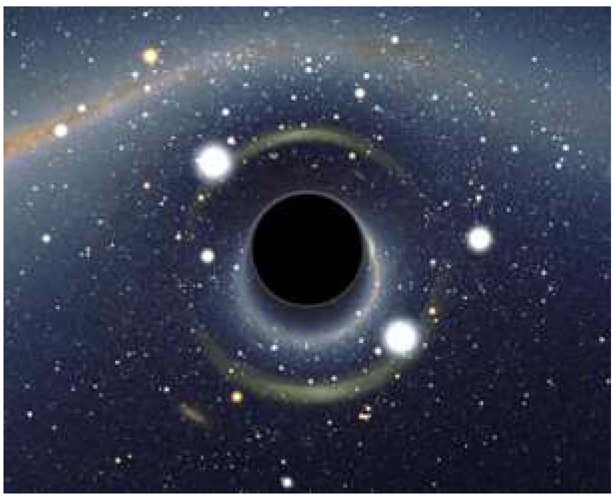
The concept of a black hole is represented in Sign Langage with the sign HOLE followed by the sign BLACK.

Associated words and expressions:
Astronomer - Force (attraction) - Galaxy - Jupiter - Light - Mass - Moon - Neutron (star) - Solar system - Star - Supernova - Universe - Velocity (light).

All the bodies of the universe exercise an attractive force linked to their mass; this is the way the attraction of the Earth maintains the Moon in its place. A rocket which leaves the Earth to explore the Solar system must have a minimal velocity of 11 km/s so as not to be put into orbit or fall back to Earth. This **escape velocity** increases with the mass of the planet: on Jupiter, the escape velocity is 59.5 km/s. What would be then the characteristics of a body for which the escape velocity would be equal to the speed of light (that is 300,000 km/s)? From this old idea of the astronomer Pierre Simon de Laplace (1749-1827) was born the notion of a **black hole** which progress in physics would highlight.

Following *Laplace's* ideas, *Albert Einstein* (1879-1955) showed that if light rays move along a straight line in space, their double nature which is constituted simultaneously with waves and particles (photons (see the entry *Light*)) causes a curvature of their journey when in the neighbourhood of a massive celestial body.

The most extreme case consists of a body with such a mass that it prevents any matter and any light escaping from it. Such a black hole traps and devours anything which passes in its vicinity.



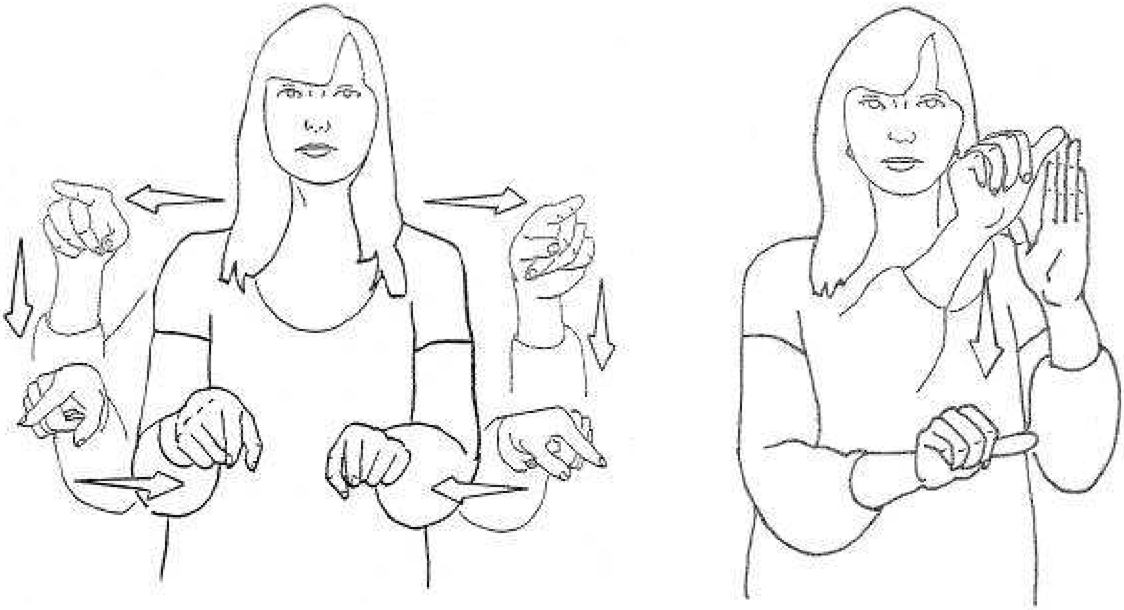
Simulation image of a black hole. The gravity field deforms in arclets the most distant objects. © NASA

Astronomers have discovered that numerous black holes exist in the universe, all of different sizes. The largest are located in the centre of galaxies whereas small black holes result from the total collapse of a massive star after its explosion (see the entry *Supernova*). Within a neutron star, matter continues its implosion until the celestial body has a diameter of no more than a few hundred metres.

Considered as one of the strangest objects of the universe, black holes now have a well established existence although it is actually not possible to observe them directly because no light escapes from them. Theories have resulted in establishing properties which go beyond the realm of classic physics. So "to fall" into a black hole could be a shortcut "to an exit" somewhere far away in the universe. The study of black holes touches on the actual limits of the laws of physics but progress in astronomy will quickly allow us to better understand their nature.

Calendar

The sign for CALENDAR consists of a rectangle drawn in the air which reproduces the shape of the object, followed by the sign for MONTH, the etymology of which was worked out at the end of the 18th century by Ferrand: "we draw on the left hand side lines from top to bottom, to represent months as they appear on almanacs".



Associated words and expressions: Earth - Equinox - Jupiter - Mars - Mercury - Moon (full) - Revolution - Saturn - Solar system - Sun - Star - Star (Christmas) - Venus - Year - Leap Year.

A calendar allows to count the days, to calculate the natural cycles (the Moon, the seasons, etc.) and to mark dates linked to various human activities. Since time immemorial, it has influenced the course of lives in all kinds of way, like allowing us to arrange appointments as well as wishing each other a happy new year.

Fragments du calendrier gaulois de Coligny.
© Wikipedia common

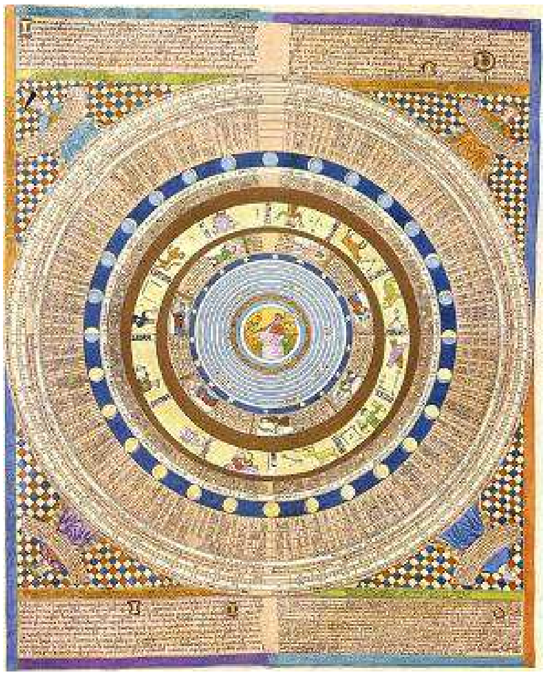
The first calendars were created from the observations of the natural phenomena such as :the succession of day and night, the movements of the Sun, Moon and stars. The cycle of the Moon every 28 days is at the origin of the division of the year into 12 months. The oldest calendar goes back to the time of the Egyptians; it is divided into 12 months of 30 days and completed by an extra 5 days. Later on, numerous civilizations adopted different values, in particular the Greeks who used the lunar year, by inserting 11 days and 6 hours into every year. With its recognition of the leap year, the Roman calendar is closer to the actual calendar. The last deviations in the calendar were corrected by the astronomers of Pope Gregory XIII on

October 4th, 1582 and since that date, the calendar in use corresponds to the revolution of the Earth around the Sun in 365 days 6 hours 9 minutes and 9.54 seconds.

Roman calendar. © Hitman

Every calendar counts years from a point of origin which varies according to tradition. For the Israelites, the starting point is on October 7th 3,761 BC, the date of Genesis; for the Muslims, it is July 16th 622 AD, the date of Mohammed's departure to Medina. Christians count from the birth of Jesus Christ, even though the date is not exactly known as it contains an error of four years (see the entry *Christmas Star*). In the Middle Ages, the new year began on April 1st but in 1569, King Charles IX fixed it on January 1st.

The names of the **days** are connected to the division of the month. Although the Greeks and Romans divided the month into three periods of ten days, we had to wait several centuries to adopt the seven day **week**, the names of which are borrowed from the planets of the Solar system: the Moon for *Monday*, Tiw for *Tuesday*, Woden for *Wednesday*, Thor for *Thursday*, Freya for *Friday* and Saturn for *Saturday* (which is also the day of the Jewish Sabbath). S*unday* is the day of the Christian god (Latin dominicus) and is also the day of the Sun: The names of the **months** are inherited from the Greek tradition: Mars (god of the war), in May (of Maïa, mother of Mercury), in June (of Juno, sister of Jupiter), etc.



Catalan calendar from an atlas of 1375 AD by Abraham and Jehuda Cresques.

The calendar contains **fixed** and **mobile** feast dates. The first are connected to historic events (national days, wars …) and to tradition (Christmas Day). The second are calculated from the date of Easter, fixed in the year 325 AD (at the Council of Nicea) as the first Sunday following the Full moon of March 21st (spring equinox). This is why the date of Easter varies between March 22nd and April 25th, according to the moon's phases. The date of Ascension Day (forty days after Easter) and Pentecost (fifty days after Easter) are thus also variable.

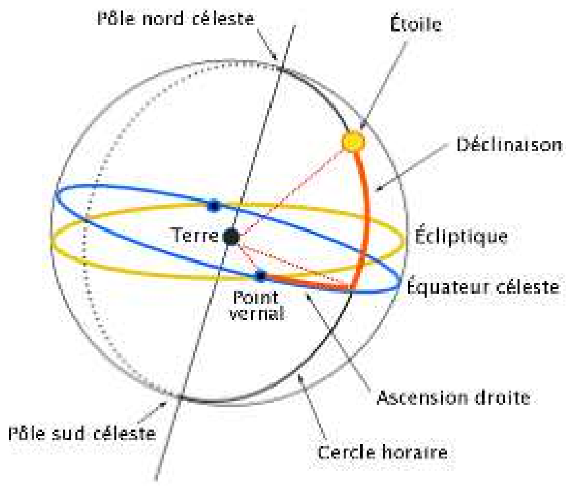
Celestial Coordinates

Celestial coordinates are represented in sign language by making a cross with the two arms. The arm representing the right ascension is horizontal and the second arm representing the declination is vertical.

Associated words: Earth - Ecliptic - Equator - Equinox - Meridian - Zenith.

Ancient astronomers placed stars on a fixed celestial spheres. All celestial objects seemed to be fixed at the same distance from the Earth, as well various planets or stars. This is why we can divide the celestial sphere using meridians and parallels, and then define a zero meridian and an equator which is the plan of the Earth's equator projected onto the sky. So, in the same way as on Eearth when an object is defined with its longitude (horizontal axis) and latitude (vertical axis), the positions of the celestial objects are represented by two coordinates named **right ascension** and **declination**. The first of these corresponds to the horizontal axis, and the second to the vertical one.

Just as the intersection of the Greenwich meridian with the equator is the Earth reference of longitude, which allows us to distinguish between East and West, astronomers nominated a point of origin in the sky of the right ascension which is called the **vernal point**. This is one of two points where the celestial equator (projection of the earth equator onto the sky) and the ecliptic planes cross. The Sun passes by these two points at the two equinoxes.



The celestial coordinates, right ascension and declination. © C.Foellmi.

The right ascension of a celestial body is measured in hours, minutes and seconds of time; the whole circle corresponding to 24 hours, and the right ascension will have a value between 00 hours 00 minutes 00 seconds and 23 hours 59 minutes 59 seconds.

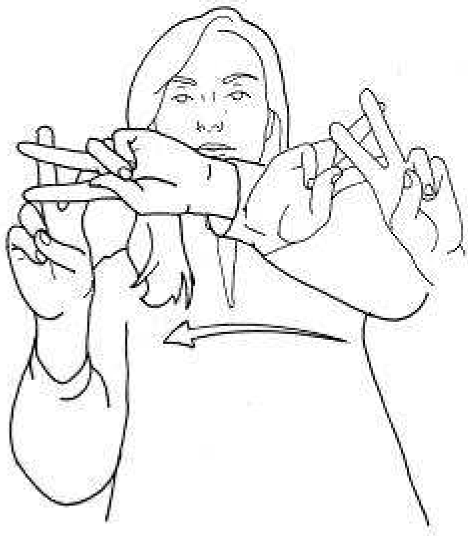
The declination is measured from the celestial equator which is 0 °. It is positive in the north and negative in the south and is measured in degrees, minutes and seconds of an arc, from +90° 00' 00" to -90° 00' 00".

The declination of the polar star is 90° (because at the North Pole, it is at the zenith), while a celestial body seen at the zenith in Paris has a declination identical to the latitude of the city, that is +48° 49', whereas a star at the zenith of Santiago (Chile) has a negative declination of -29°. It is important not to confuse right ascension and declination units. A circle of 24 hours of time (right ascension) corresponds to 360 degrees (declination). One hour of time corresponds to fifteen degrees of angle.

Refractors and telescopes are thus equipped with two circles on each of their two axes, corresponding to the right ascension and to the declination, so allowing us to locate quickly the position of a body on the celestial vault.

Celestial vault

The sign CELESTIAL VAULT is a derivation of the sign STARS which typifies the light of the stars such as they are shown in popular iconography. This sign differs from the one which is used to evoke the stars (see this entry) as distinct bodies. To make the sign CELESTIAL VAULT, the sign STARS is given a motion which represents the curved form of a vault.



Associated words: Comet - Galaxy - Light pollution - Magellanic clouds - Milky way - Star.

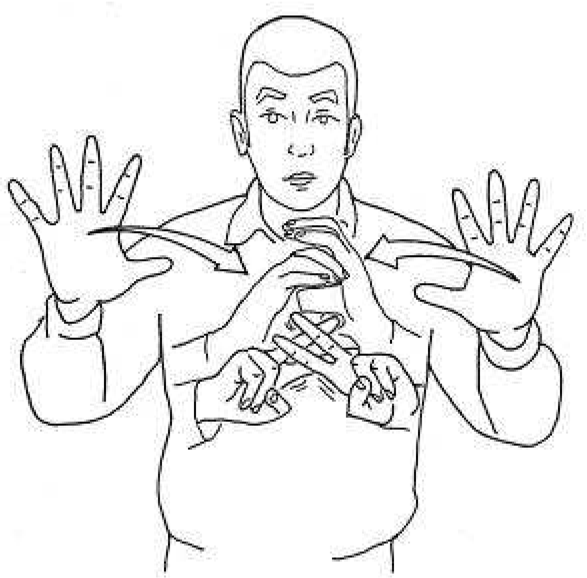
The **celestial vault** is the set of celestial bodies, planets, stars, galaxies, and sometimes comets, which we can observe with the naked eye on a beautiful clear night. The Ancients thought that stars were brilliant nails which punctured a sphere or small holes drilled in an opaque sphere which allowed light to pass beyond it.

The celestial vault is one of most beautiful spectacles that the eye can admire. During a beautiful clear night, we can see simultaneously thousands of stars of different distances, dimensions, temperatures and age. We can also admire the Milky Way which crosses the sky, or some galaxies such as M31 in the constellation of Andromeda (northern hemisphere) or the Magellanic clouds (southern hemisphere).
Unfortunately, the development of cities, industry and, more generally, all human activity have gradually removed this inestimable inheritance because of light pollution (see this entry) which they engender.

A beautiful portion of the celestial vault as seen from the Cordilliera mountains in Chile. © ESO

Cluster (globular)

The notion of a ***globular cluster*** is expressed with the sign STARS followed with open hands that close to represent a spherical nucleus. For the etymology of STARS, see the entry ***Celestial Vault***.



Associated words and expressions: Star - Star (evolution) - Red Giant - White dwarf - Galaxy - Spectroscopy - Lightyear.

Stars are not uniformly distributed in our Galaxy. We can see from time to time, using a small telescope, circular blurs which contrast with the exact appearance of the stars. These regions, whose form is approximately spherical, are named **globular clusters** and are composed of tens of thousands of stars. Several are visible to the naked eye or with binoculars such as the cluster M13 in the constellation of Hercules, the cluster ω (Omega) in the southern constellation Centaurus, or the cluster 47 in the constellation Toucan.

The first globular cluster M22 in the constellation Sagittarius, was discovered in 1665. Subsequently, astronomers observed many of these but often confused them with galaxies. They were called *round nebulae*. This is why the catalogue of Charles Messier (1730-1817) contains 29 globular clusters among 110 objects in total. In the twentieth century, astronomers were able to show that the cluster M54 already observed by Messier, is the furthest in his catalogue at a distance of 87,000 light years. It is associated with a dwarf galaxy. Large telescopes can today observe many globular clusters distributed around other galaxies or in the environment of galaxy clusters, such as the cluster in the constellation Fornax, at a distance of 60 million light-years.

The global cluster 47 in the Toucan constellation. © ESO

Globular clusters are huge spherical agglomerations composed of tens of thousands of stars. They are located at distances ranging from 10,000 to 200,000 light years from Earth and are distributed spherically around the Galaxy. Several hundred of them are known with a diameter ranging between 25 and 400 light years. At such distances, it is difficult to identify individual stars that compose them. However, spectroscopic studies show that the majority of these stars are old. These are red giants and white dwarfs mixed together whose content of heavy elements is relatively low. Globular clusters are approximately the same age as our Galaxy, that is at least ten billion years old..

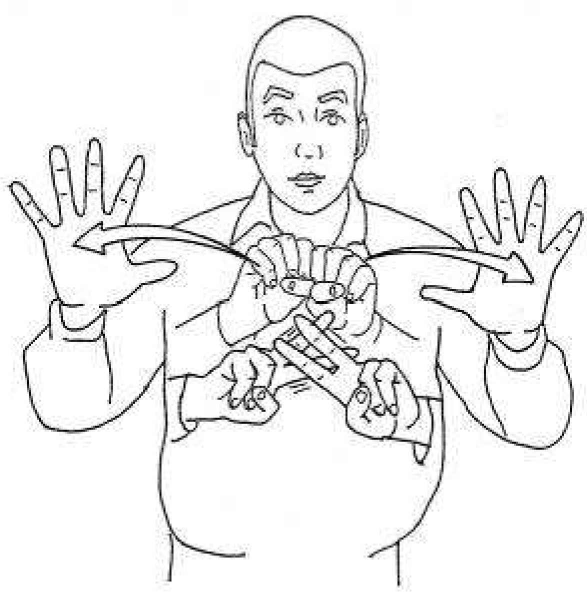
Ten billion years ago, our Galaxy was a huge gas bubble which then slowly flattened into a disc in which were born the tens of billions of stars that we see today. However, residues of this initial bubble remained around the Galaxy and these are the globular clusters, real small satellites in which the stars have slowly evolved.

Global cluster NGC1916. © ESO

Global cluster NGC6397. © ESO

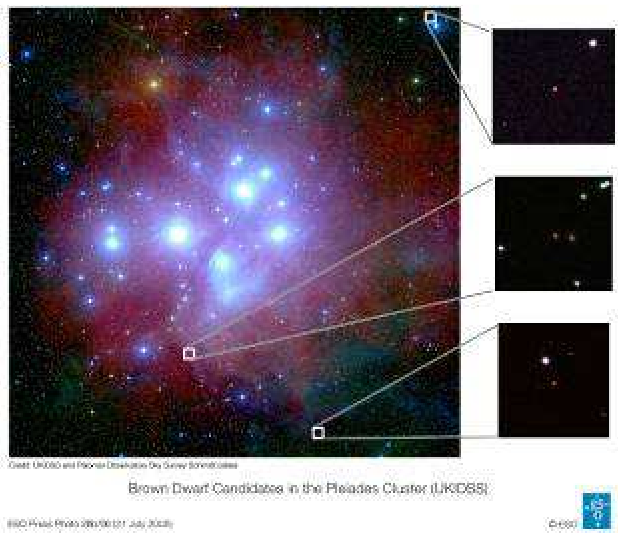
Cluster (open)

The concept of open cluster is expressed with the sign STARS followed by a spreading movement of the hands representing their scattered nature. See the entry ***globular cluster***.



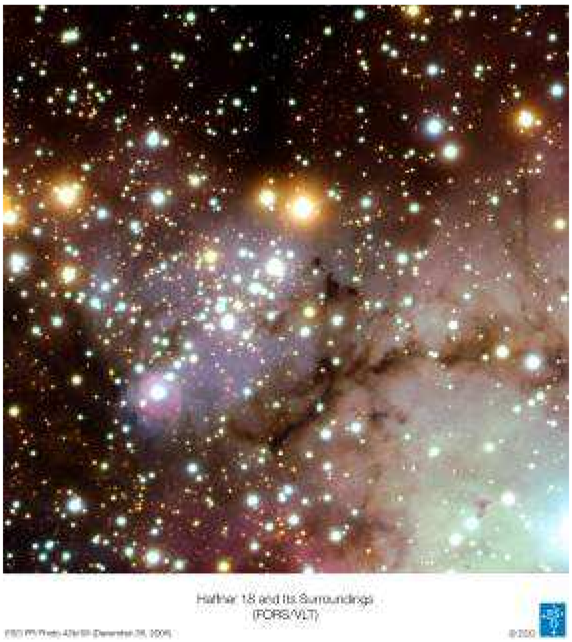
Associated words and expressions: Light year - Star - Star (evolution) - Interaction (gravitational) - Galaxy - Red Giant - White dwarf - Spectroscopy.

Stars are not uniformly distributed in our Galaxy, any more than in any other galaxies. They form more or less concentrated groups or clusters which are known as “open” and “globular” clusters. The first of these have a low concentration of stars whereas this concentration is much greater for the second.



The Pleiads open cluster in the constellation Taurus. © ESO

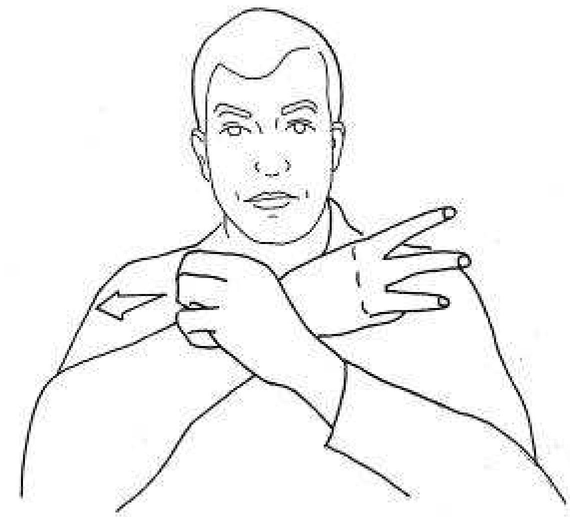
Open clusters are constituted by groups of some hundred to a few thousand stars which are bound together by gravitational interaction. They are situated in the disk of our Galaxy. Their average size is about one hundred light years but each star is distant enough from the others to be able to be individually seen in a telescope. The most brillant ones are often visible with binoculars. Chemical analysis made by spectroscopy indicates that these stars are relatively young. The most famous of these clusters is the *Pleiades* which are easily visible with the naked eye in the constellation of Taurus; Its existence was already mentioned by the Chinese in 2,357 BC. Situated at a distance of about 350 light years, the member stars are "young", with an age of at most thirty million years. Very close to the *Pleiades*, the *Hyades* cluster is distinguished by its resting “V" shape, dominated by the red giant star *Aldebaran*. About 150 light years distant from Earth, its stars are less than a billion years old. It includes all the categories of stars from red giants to white dwarfs and; as with the human population, each has a different "life expectancy" (see the entry ***Star-evolution***).



The open cluster Haffner 18, composed of young stars still mixed in hot gas. © ESO

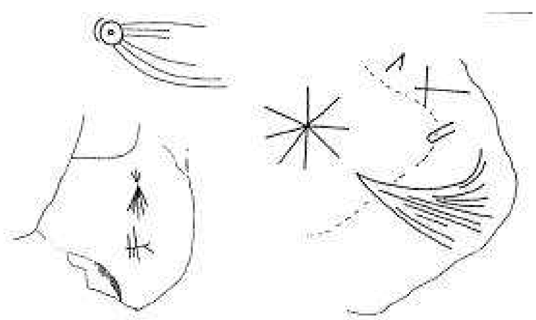
Comet

With the sign COMET, a closed fist represents the nuclei, while the other hand with its four fingers moving away represents the tail. Both hands move together to represent the movement of the comet in the sky.



Associated words and expressions: Earth - Astronomical unit - Ellipse - Planet - Revolution - Sun - Solar system.

The word **comet** comes from a Greek expression meaning "with hairs". For a very long time, we have observed comets from time to time in the sky, as a glittering point followed by a long bright tail. In human history, numerous comets have been recorded. For the ancients, their appearance was the announcement of a famine, a war or other disaster. Nowadays, they are particularly interesting for astronomers. Since they date from the beginning of the Solar system, their chemical analyses allow us to understand how the latter was formed and evolved, in particular thanks to spacecraft which bring back samples of materials and gas to Earth.

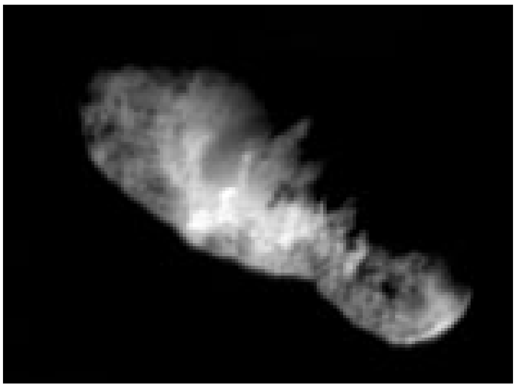


Ancient drawings of comets, engraved on rocks of Easter Island. © DP

The oldest observations for which written records exist date back several millennia thanks to Chinese astronomers. Nowadays, a new comet will be named after its discoverer and there are actually more than 2,000 of them listed.

The Hale-Bopp comet. © Michel Verdenet

A comet is composed of three parts: firstly, the nucleus which is the most brilliant part; then the coma which surrounds the core as an atmosphere and finally the tail which is the long trail we can see in the sky. There are sometimes two tails, as it can be seen on the illustration showing the comet Hale-Bopp. Comets are members of the Solar system. Thanks to the work of Halley (see below), we know that many comets have an orbit and just like planets, they are in revolution around the Sun, but on a much more elongated ellipse. Some comets seem to visit us only once before escaping into the depths of space. It is certain that there are also very many comets in distant planetary systems around other stars.



The nuclei of the comet Borelly. © NASA/JPL

Comet Mac Naught at sunset from Chile. © ESO

The **nucleus** of a comet consists of a big block of rock held together by dust and water ice along with carbon monoxide (CO) and some carbon dioxide (carbon dioxide: CO2). At billions of km from the Sun, where the temperature is of the order of -220°C, nuclei are very difficult to observe because of their small size. The nucleus of the Borelly comet was observed by the spacecraft *Deep Space 1*; it measured approximately 8 km long by 3 km wide.

The **coma** of a comet appears when the nucleus approaches the Sun. The heating warms the ice and a veil of gas escapes with some dust to form a weak atmosphere around the nucleus lit up by the Sun. The coma consists mainly of water and carbon monoxide (CO).

The very fine **tails** are over tens of thousand kilometres long. The most important tail is curved and consists of dust. The other tail, named the "plasma tail", is made up of gas ejected by the nucleus of the comet. Particles projected in all directions by solar activity push away dust and gas molecules which is why **a comet tail is always facing in the opposite direction to that of the Sun**.

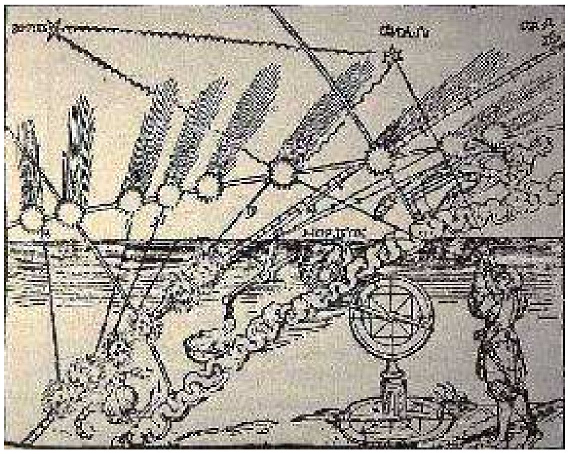
Halley's comet

To sign Halley's comet in sign language, the sign COMET is followed by the name Halley with each letter being spelled out.

Among comets, Halley's comet is the most famous. Its name has become symbolic of this family of objects. It is visible from the Earth every 76 years, when it crosses as close as possible to the Sun, at 0.58 astronomical units (UA), before restarting beyond the planet Neptune at 35.3 UA following a long elliptical orbit. Throughout history, it has been observed at each of its passage near the Earth. The English astronomer Edmund Halley (1656-1742) discovered that it was in fact the same comet which reappeared every 76 years, so we say that **Halley's comet has a 76 year period**.

Halley's comet was observed by the Chinese in 240 BC. It cannot be the star mentioned in St Matthew's gospel, which was observed by the magi at the Jesus' nativity, as it had already passed near the Earth several years before. Visible in 1066, it appears on the Bayeux Tapestry during the Battle of Hastings (**1**). It was reproduced in 1531 (**2**) by the Saxon astronomer *Peter Apian* (1495-1552). It was photographed in 1910 (**3**); and in 1986, the spacecraft *Giotto* approached within 600 km of the nucleus (**4**), this one being 15 km long and 8 km wide. Halley's comet will next be seen in 2061.

1- *The comet Halley in 1066.*

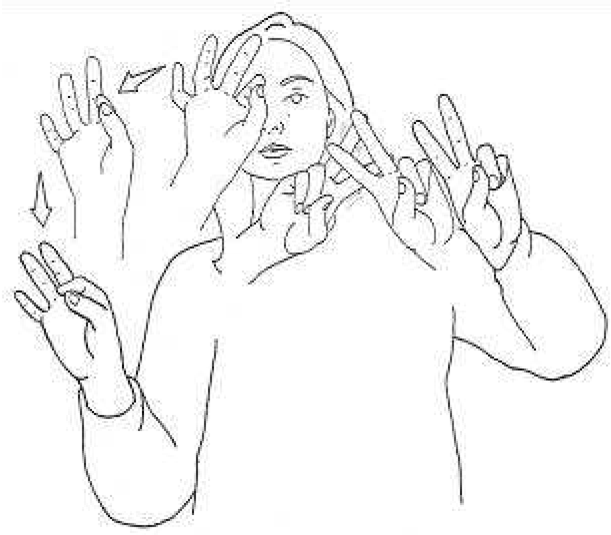


2- *The comet Halley in 1531.*

3- *The comet Halley in 1910.*

4- *The nuclei of the comet Halley In 1985. © ESA*

Constellation

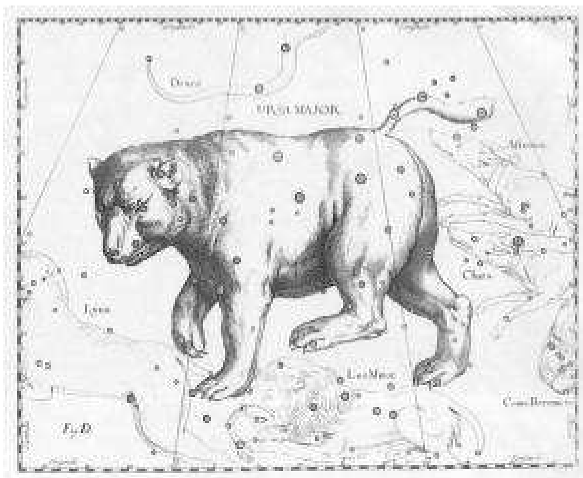


The notion of a "CONSTELLATION" is translated by the sign for a "STAR", which symbolizes rays of light (see the entry *Celestial vault*), followed by a second, third or more identical sign(s), based on precedent depicting the imaginary lines in space that connect the stars of the same constellation.

Associated words and expressions:
Astronomer - Planet - Star - Solar system - Zodiac.

Since the dawn of time, man has tried to take his bearings in the night-sky. He noticed that stars seem to form figures which, with a good dose of imagination, can evoke animals, objects or even people and these are the **constellations**. Every civilization was naturally inspired by its own history and traditions to define its own constellations. As an example, the Australian Aborigines placed in the sky their familiar animals, such the kangaroo or the emu, whereas the Greeks placed the heroes of their mythology, such as Hercules or Orion.

Throughout history, constellations took varied forms and names, but nowadays the division of the sky into constellations has defined once and for all by astronomers. The great majority of them are come from the ancient Greek, but others are more recent, in particular in the southern hemisphere. *Johann Bayer* (1572-1625) was a German astronomer and author in 1604 of a celestial atlas in which new constellations appeared and, for the first time, stars were named using Greek letters. *Johannes Hevelius* (1611-1687) was a Polish astronomer who described twelve constellations, such as the Lynx or the Small Fox. *Nicolas Louis de Lacaille* (1713-1762) was a French astronomer and a geodesist who described fourteen southern constellations during a long stay in South Africa.



The constellation of the Big Dipper, from the Hevelius Uranography (1690).

Nowadays, the sky is divided into 88 constellations, situated in three very precise regions: the northern hemisphere (North), the southern hemisphere (South) and the region of the zodiac including twelve constellations crossed by the orbits of the planets of the Solar system.

The names of the constellations constitute a highly varied group. Many are real animals, mammals (lion, dog, bull), fishes (sea bream, flying fish), birds (eagle, swan) or reptiles (snake, lizard, chameleon). Others are mythical animals (dragon, hydra, unicorn). We also meet figures from Greek mythology (Hercules, Ophiuchus, Orion) and, more recent creations such as tools (compass, ruler, chisel) as well as scientific instruments (telescope, microscope, sextant). Although having no scientific basis, the constellations and their names do not lack a degree of poetry while testifying to their past.

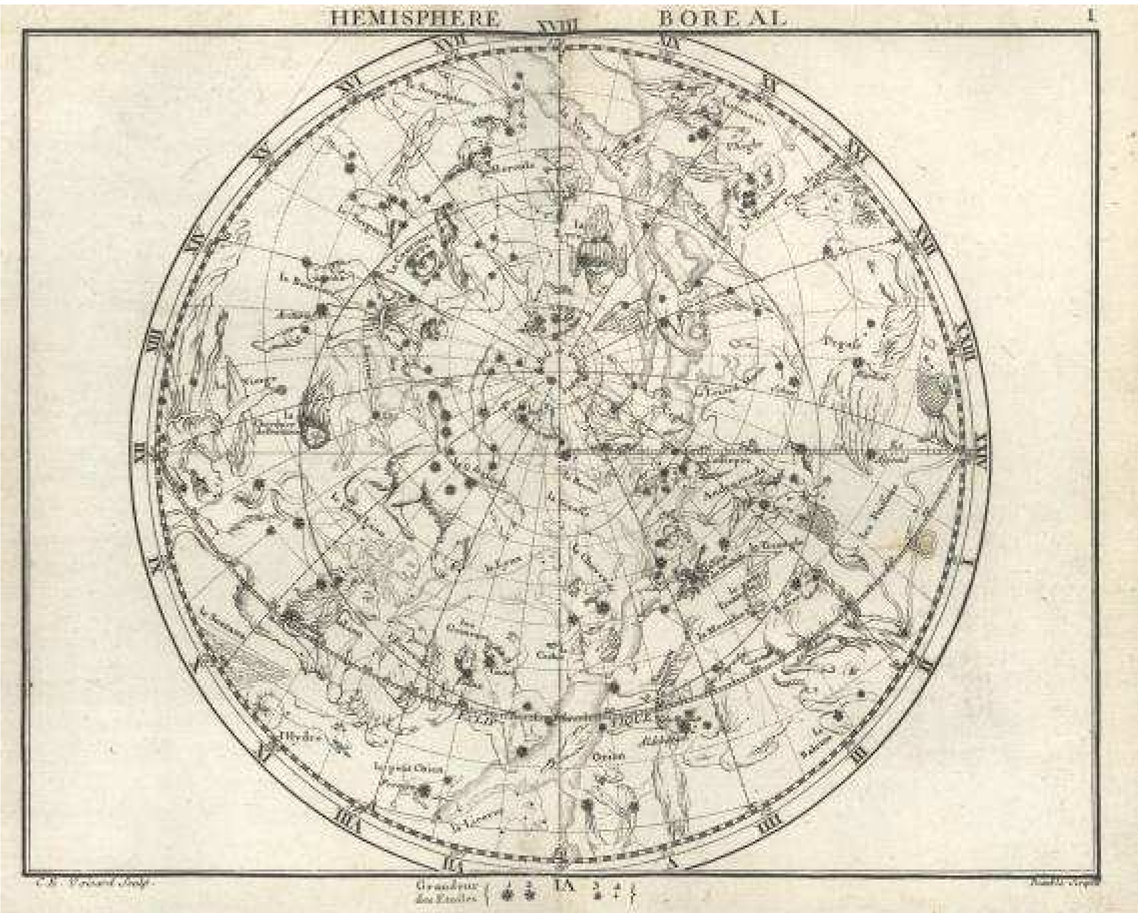
A *portion of a summer sky night in France : the Big Dipper. © M.Verdenet*

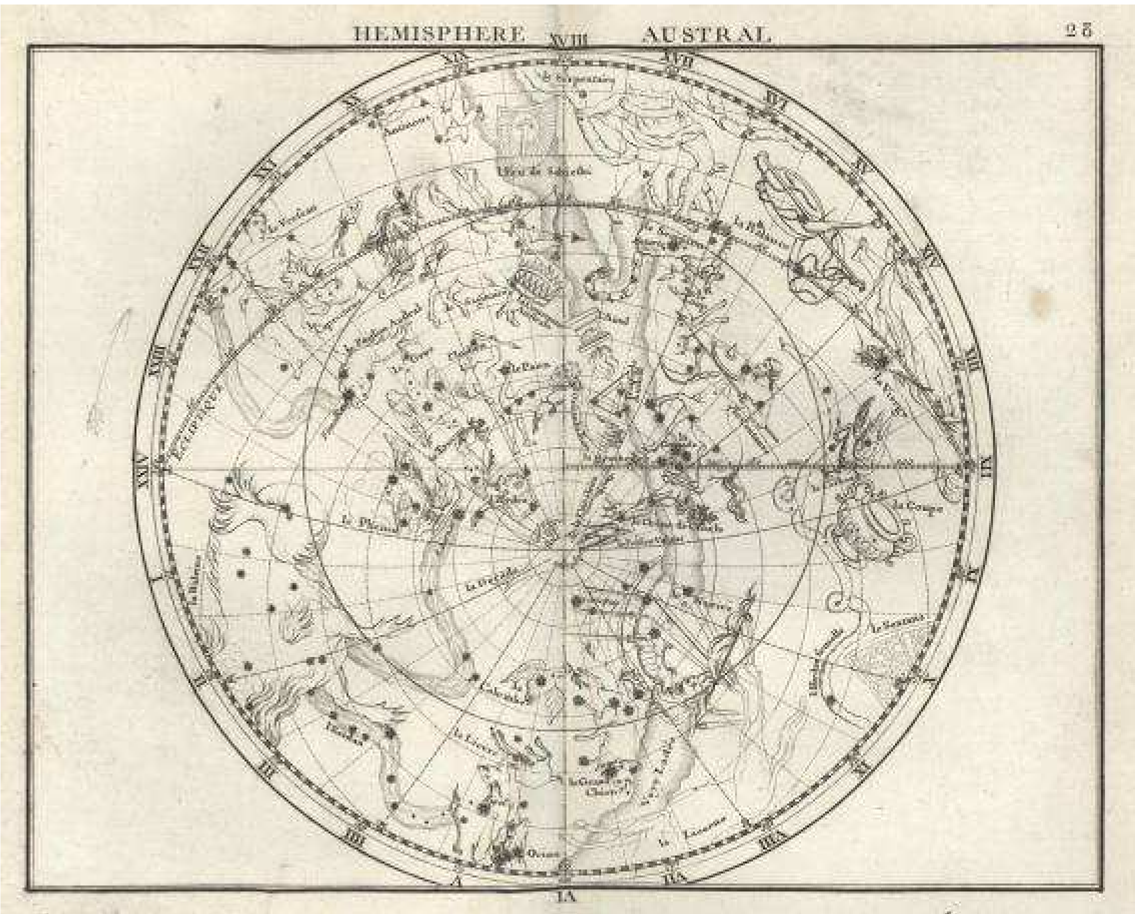
The two celestial maps presented below are extracts from *John Flamsteed*'s atlas (1646-1719). They show the association between the brightest stars of every constellation and the name which was attributed to them: the most brilliant stars of the Big Dipper form the hind-quarters of the animal, etc.

The list of all the constellations and the signs which were attributed to each of them in Sign Language as well as their main stars and curiosities are set out in the Sky Atlas placed at the end of this dictionary.

With this atlas, we can easily locate constellations and stars visible to the naked eye or with binoculars and get to know the main characteristics of the stars (name, temperature, distance and possibly variability or binarity). This is primarily an introduction and readers are greatly encouraged to go to the next level by carrying out observations with a refractor or a telescope.

Next page : maps of the constellations from John Flamsteed's atlas.


HEMISPHERE BOREAL
1
Grandeur des Etoiles


HEMISPHERE AUSTRAL

Diameter

The sign *diameter* is expressed with a rounded hand, representing a circle, and the index finger of the other hand representing the diameter.

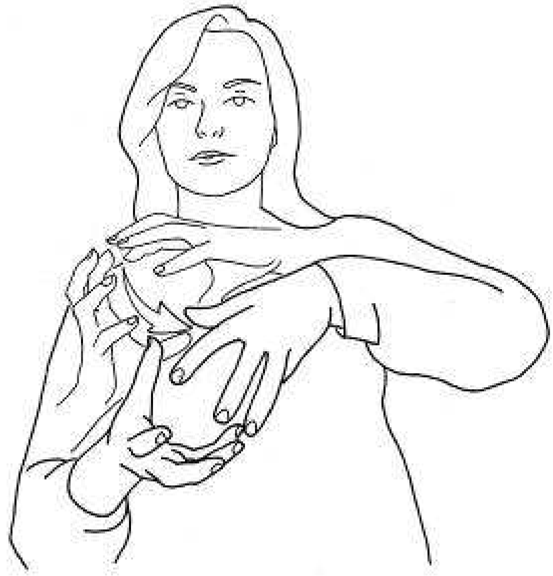
Associated words: Astronomer - Earth - Galaxy - Moon - Planet - Star - Telescope.

The diameter of a circle is the length of the chord which passes through its centre. In astronomy, it is an important quantity. It is used to measure, for example, details of the surface of the Moon (mountains, craters, etc.), or the characteristics of planets, as well as the size of stars and galaxies.

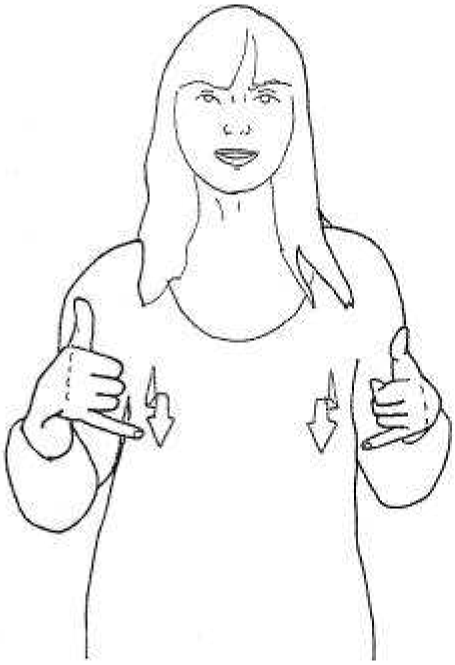
The **apparent diameter** is the diameter of a body seen from the Earth. For example, the Moon, which has a diameter of 3,470 km and which is 384,400 km from the Earth, has an apparent diameter of 30 arc-minutes (or 1/2 degree) and we can hide its disk by holding a one cent coin at arm's length. Using large telescopes, astronomers have succeeded in measuring visible diameters as small as 0,00012 arc-second, which is the diameter of the same coin seen at a distance of 100 km. When we know the apparent diameter of an object as well as its distance, the laws of geometry allow us to calculate its dimensions easily.

Earth

The **Earth** is represented by the sign PLANET, both hands showing a spherical object which rotates on itself while moving in space, followed by the sign HERE. This second component consisted formerly in pointing at the ground with the two index fingers to show the place where we are. These days, it takes the shape of the manual letter I, initial of the french word **ici** (here).



PLANET



HERE

Associated words and expressions: Astronomical unit - Greenhouse effect - Life - Planet - Solar system - Sun - Volcano.

The **Earth** is the third planet of the Solar system. It is actually the only known planet which is inhabited by living forms, belonging to millions of different species. It is also a planet directly threatened by the activity of mankind, a depletion of natural resources, unrestrained pollution, a decrease in the forest surfaces which transform carbon dioxide (CO_2) into oxygen (O_2). In the long term, the increase of CO_2 in the atmosphere will cause global warming by the greenhouse effect and much ecological imbalance. The relationship between man and the Earth shows to what extent the balance of a planet can be quickly weakened by the living bodies which populate its surface. **The Earth is fragile – we must protect it**.

The Earth as seen from space.© NASA/JPL

Distance : The Earth is at an average distance of 149,597,871 km from the Sun. This distance has been adopted to define the **Astronomical unit (AU)**.
Diameter : the equatorial diameter is 12,756 km and the polar diameter 12,714 km : the Earth is slightly flattened at the two poles.
Inclination : its axis is tilted at an angle of 23° 27'.
Rotation : the Earth rotates on itself every 23 h 56 mn and 4 s.
Revolution : The Earth revolves around the Sun every 365.25 days.
Temperature : the Earth shows a large range of temperatures between the different regions according to the seasons. The most extreme measured temperatures are -90°C and +60°C.

Atmosphere:
It consists mainly of nitrogen (N_2) 78 %, oxygen (O_2) 21 %, argon (Ar) 1 % and water vapour (H_2O) between 0 and 7 %. Thanks to this chemical composition, the energy coming from the Sun in the form of light favours "photosynthesis" allowing vegetation to develop by the transformation of carbon dioxide (CO_2) into oxygen (O_2).

The scaled system Earth-Moon. ©Wikipedia/GNU

History of the Earth

The **Earth** was born approximately 4.6 billion years ago along with the other planets (see the entry *Solar system*). During its evolution, it has known several important periods.

Hadean is the first period, which finished 3.8 billion years ago. The Earth's crust thickened while an atmosphere rich in water and in nitrogen was formed as a result of rock vapour. The temperature and pressure were high. Oceans formed with the water vapour when the temperature decreased; the atmosphere was rich in carbon dioxide (CO_2) and in methane (CH_4). These two gases favoured the metabolism of the very first living species.

Archean succeeded Hadean and ended 2.5 billion years ago. During this period, the first rocky formations appeared which combined to form a unique continent. Life developed in the form of multicellular bodies (**eucaryotes**) in the origin of plants, mushrooms and animal species.

Proterozoic ended are 543 million years ago. This period saw the transformation of eucaryotes into bodies equipped with a skeleton. The Earth atmosphere grew rich in oxygen. Continental shields grew until reaching actual continental mass.

The **Paleozoic** (also called the Primary era) ended 250 million years ago. During this period, the single continent began to split up into eight pieces. Life evolved in invertebrate and vertebrate form. The end of the Paleozoic is characterized by the **Permian** era (295-250 million years), a period during which there occured a massive extinction of species, because of important geologic phenomena, maybe as a result of continental movements.

The **Mesozoic era** (secondary era) succeeded the Paleozoic and ended 65 million years ago. Large groups of animals, such as dinosaurs, mammals and birds, proliferated. The Mesozoic era ended with another massive extinction of species, due probably to a violent collision of the Earth with an 8km diameter asteroid.

The contemporary period, the **Cenozoic** (Tertiary and Quaternary eras), is characterized by the renewal and diversification of living species, fishes, mammals, insects, etc. The last link connecting the Cenozoic with the present begins with our distant ancestor hominid who probably appeared approximately 3.5 million years ago.

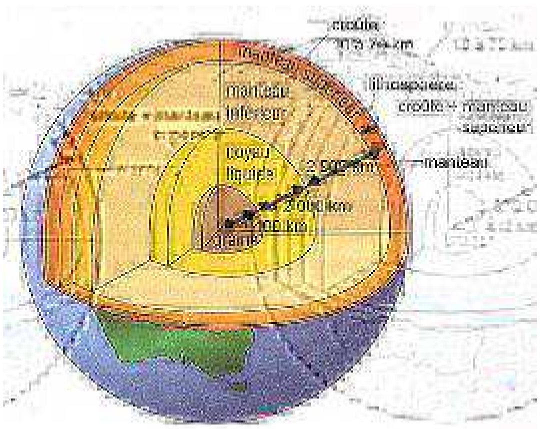
Earthquakes and volcanoes

The slow mutual movements of the tectonic plates provoke violent phenomena. These are **earthquakes** the consequences of which are often catastrophic. Certain countries or certain regions situated on the junction of plates are particularly exposed, such as Japan or California. The inner core of the Earth is extremely hot, the temperature increasing by about 1°C every 30 metres down. At 600 km underground, the temperature is already at 1,500°C; at 3 000 km, it reaches 5,000°C, and, in its centre, it is about 6,000°C. The materials which constitute the Earth core are in fusion, in the form of **lava**, and take advantage of cracks in the crust to escape by chimneys. These are the **volcanoes** which eject this lava along with large quantities of gas and dust at the same time. Volcanoes are found in regions situated at the junction of tectonic plates.

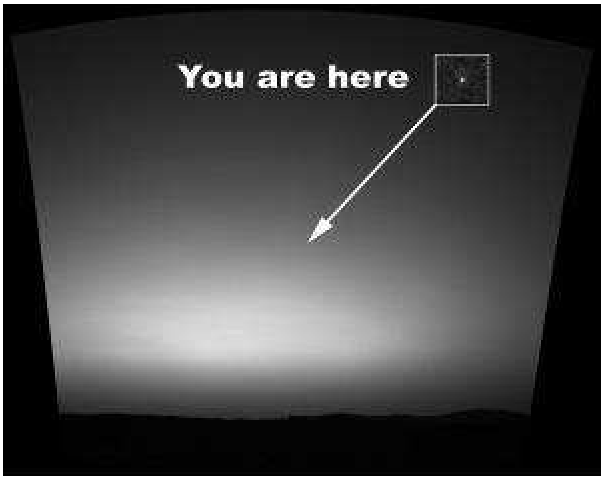
Magnetic field

As the temperature of the core of the Earth is approximately 6,000°C, the nickel (Ni) and the iron (Fe) which constitute it are in the liquid form; they create around the planet a magnetic field which goes at present from the North Pole to the South Pole. We can easily see this by means of a compass. This magnetic field is important, because it protects us from the particles ejected by the Sun during its eruptions (see the entry *Sun*). Samples taken in the ice floe show that this magnetic field changes in time in intensity and in direction. 800,000 years ago, it was inverted, going from the South Pole towards the North Pole.

The Earth is divided into three parts. The **crust** is the thinnest part: it is on average 50 km thick in the continents and 10 km under the oceans. Below this, we find the **mantle** which has a thickness of about 2,900 km. It covers the **core** the thickness of which is 3,400 km. The crust and a part of the mantle form the **lithosphere**, divided into **tectonic plates** which move very slowly. There are seven plates: Africa, Antarctica, Australia, Asia-Europe, North America, South America and Pacific Ocean.



Internal structure of the Earth.© Graines de sciences 1, Le Pommier 1999

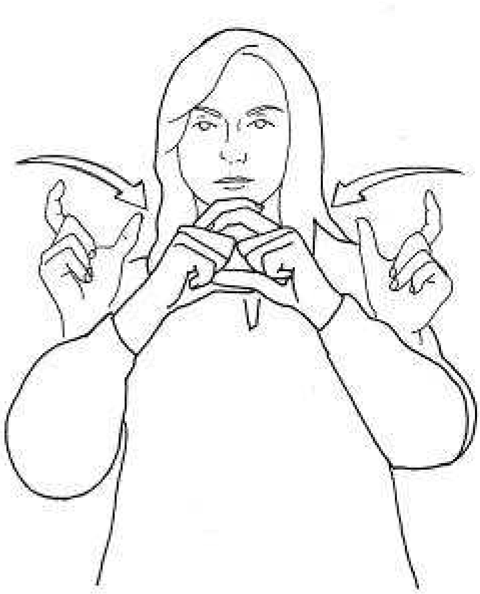


« You are here ». The Earth as a small point in the sky as seen from the planet Mars during sunset. © NASA/JPL

As can be seen from Mars or elsewhere, the Earth is only a small point in space where there live, nevertheless, seven billion human beings. Are we alone in the universe? We are now able to obtain the first images showing **extrasolar planets** the size of the Earth. The following step will allow us to highlight a biological activity. In the reasonably near future, we shall be able to obtain enough fine images enabling us to see the details of the distant planets, and to enable us to know finally if life does or doesn't exist somewhere else (see the entry *Life*). Life appeared on Earth hundreds of million years ago. The most immediate wish that we can have is that we finally become aware of our Earth heritage so as not to destroy too soon the proof that life appeared at least once in the Universe.

Eclipse

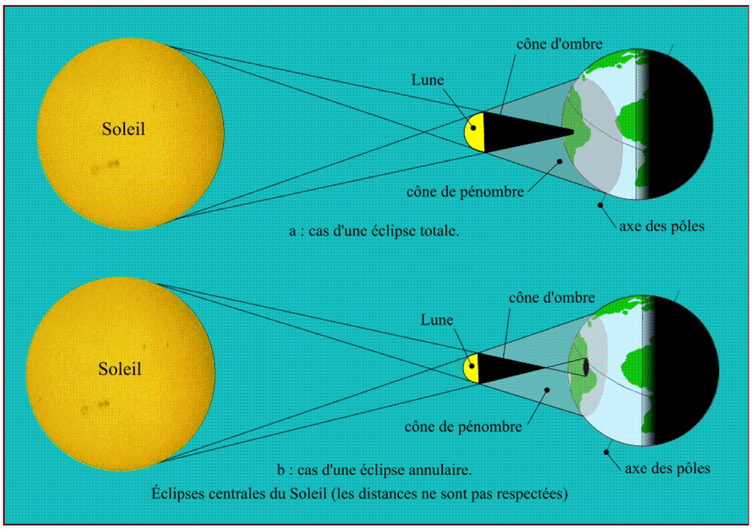
The hands in small crescent shapes represent the disks of two celestial objects. Their superimposition represents the moment of the eclipse. The addition of the sign SUN or of the sign MOON allows us to specify whether it is a solar or lunar eclipse.



Associated words: Diameter - Earth- Moon - Sun.

As seen from the Earth, the diameters of the Sun and the Moon are apparently identical, that is approximately 30 arc-minutes (half a degree). We can hide each of their disks by holding a small coin at arm's length. This is just a coincidence due to the fact that the Sun is enormous (1,390,000 km diameter) but far away (149,597,871 km), whereas the Moon is small (3,473 km diameter) but close to us (384,400 km). From time to time this coincidence allows us to observe solar and moon eclipses. When the Moon passes between the Earth and the Sun, there is a solar eclipse. When the Earth passes between the Sun and the Moon, there is a lunar eclipse. If the alignment of the sun, the earth and the moon is perfect, there is a total eclipse, otherwise there is partial eclipse. The mechanism of an eclipse is explained below.

Solar eclipse



Principle of a solar eclipse. The true size and the distance to the Sun are not represented; the Sun should be 400 times bigger and 400 times more distant. © Patrick Rocher- IMCCE

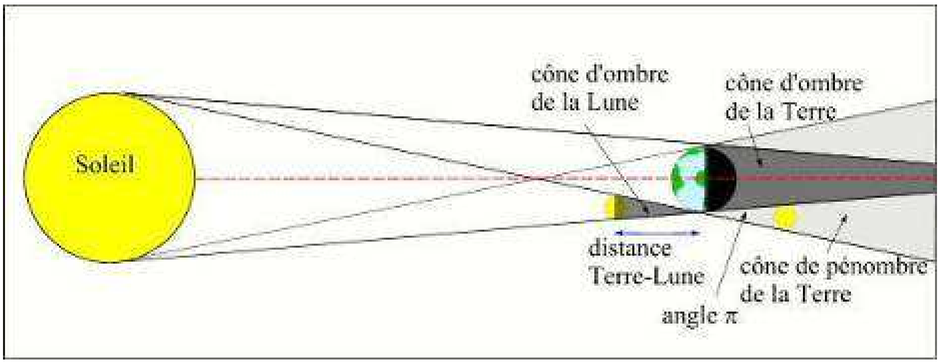
When the Moon is exactly between the Earth and the Sun, it disappears and a shadow is projected onto the earth. As the Moon moves, this shadow also moves on the Earth's surface. Thus, the total eclipse of the Sun on August 11th, 1999 was visible from Canada to India, including the north of France. This phenomenon is extremely spectacular. Night can arise in the middle of day and stars appear in the sky.

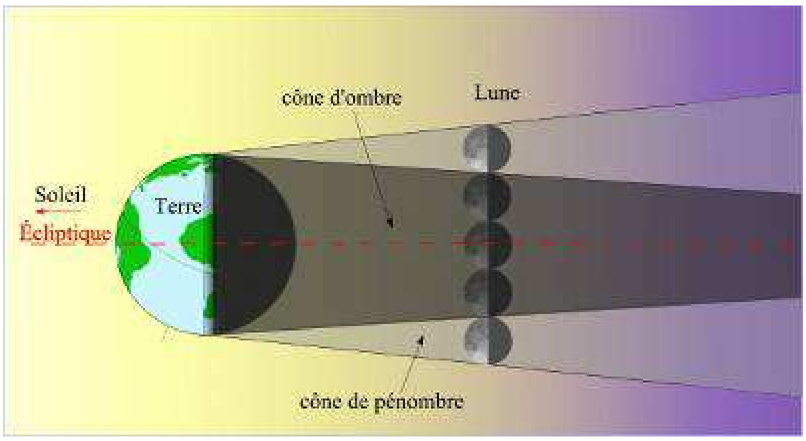
The observation of a solar eclipse is an unforgettable phenomenon, for which it is essential to **take precautions**. Because of the intensity of the sunlight, it is essential to **protect the eyes** by using efficient filters, otherwise there is a risk of blindness.

A total solar eclipse : the Sun is masked by the Moon. © NASA/JPL

The shadow of the solar eclipse of 11 August 1999 projected on the Earth surface as seen by astronauts. © NASA/JPL

Lunar eclipse





Principle of a lunar eclipse. © Patrick Rocher - IMCCE

When the Earth is exactly between the Sun and the Moon, the shadow of the earth is projected onto the moon, offering a magnificent show which gives an idea of the size of the earth as seen from the Moon. The Earth's disk is approximately three and a half times as big as the moon's. Unlike an eclipse of the Sun, an eclipse of the Moon can be observed everywhere on Earth.

The observation of a lunar eclipse doesn't present any danger and can be made with the naked eye.

During a lunar eclipse, the Moon takes on various colours. This is due to the sunlight which crosses the Earth's atmosphere before being projected onto the moon.

A lunar eclipse: the earth's shadow is projected on the lunar disk. © Oliver Stein

Calendar of total eclipses until 2020

From the present moment up to 2020, there will be several total eclipses. Remember that each solar eclipse is only visible in certain places on Earth.

Next total solar eclipses: 22/07/2009; 11/07/2010; 13/11/2012; 20/03/2015; 21/08/2017; 02/07/2019; 14/12/2020. The next total solar eclipse in France will occur in 2081.

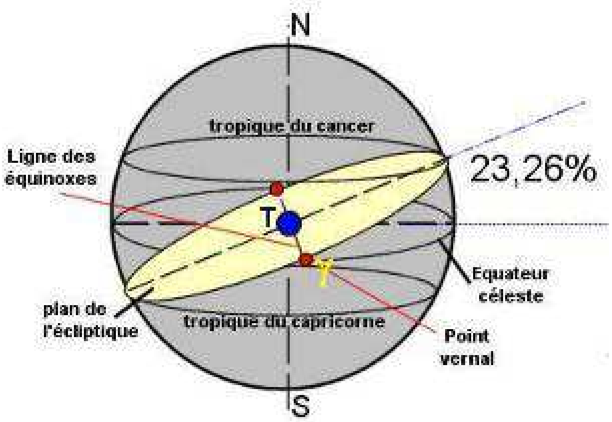
Next total lunar eclipses: 21/12/2010; 15/06/2011; 10/12/2011; 15/04/2014; 08/10/2014; 04/04/2015; 28/09/2015; 31/01/2018; 27/07/2018; 21/01/2019.

Ecliptic

To represent the **ecliptic** in sign language, we first sign **solar system** (see this entry). The hand in a round shape showing the order of the planets then makes a flat shape and draws a wide circle in the same horizontal plane.

Words and associated expressions: Constellation - Earth - Equator - Planet - Revolution - Sun - Solar System - Zodiac.

We see the Sun rise every morning in the East and set every evening on the West. According to the season, it rises more or less high in the sky. These apparent movements of the Sun are in fact the combination of the rotation of the Earth and its revolution around the Sun.
The revolution of the Earth takes 365.25 days, with an inclined axis of 23.5 ° (see the entries **Equinox** and **Solstice**). So, every day, the Sun seems to have travelled approximately one degree eastward. This movement creates a plane on the Earth called the **Ecliptic**. If the axis of the Earth was not tilted, the Sun would seem to remain in the plane of the equator.



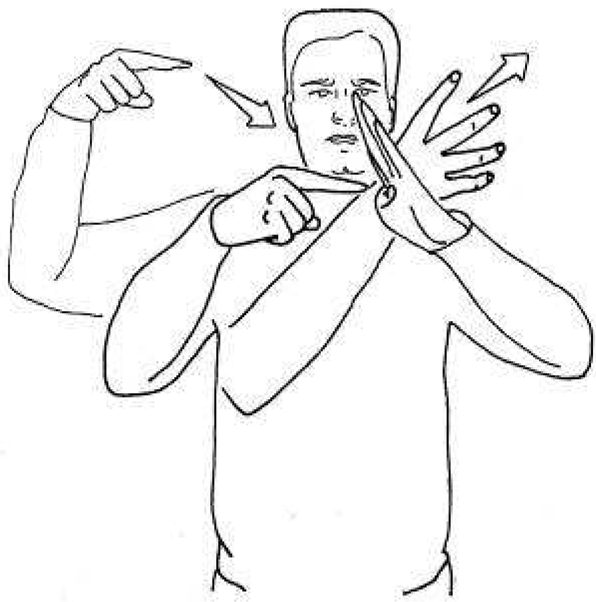
The ecliptic plane. © IMCCE

The planets of the Solar system were created from a disk of gas and dust which turned around the Sun. That is why they have orbits approximately situated in the same plane, very close to that of the ecliptic. They always appear in the same region of the sky, inside which we can see them moving more or less quickly. This region is defined by the constellations of the zodiac.

On the left of the Moon hiding the Sun during an eclipse, we can distinguish three bright points: these are the planets Mercury, Mars and Saturn, aligned in the plane of the ecliptic.© NASA/HST

Electromagnetic spectrum
Spectroscopy

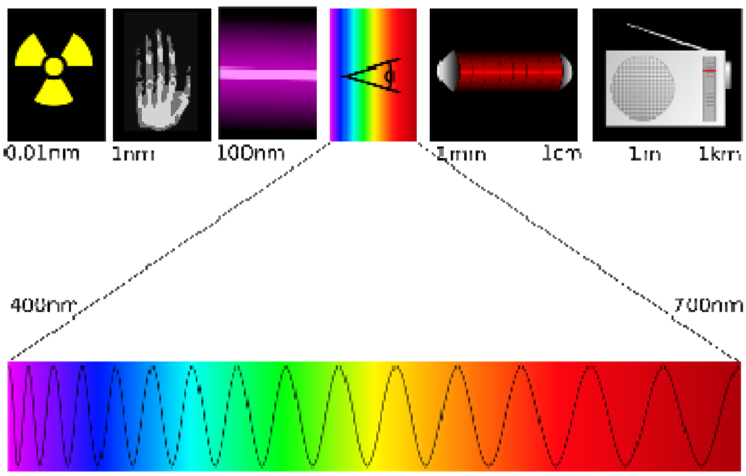
The sign SPECTROSCOPY explains the principle of the decomposition of light with a prism. A tilted hand represents one of the faces of a prism. The index finger of the other hand represents a light beam which, after having crossed the prism, is decomposed into different wavelengths symbolized by the fingers moving away.



Associated words and expressions:
Astronomer - Electron - Chemical element - Galaxy - Infrared - Light velocity - Light - Nuclear reaction - Planet - Radiotelescope - Star - Sun - Ultraviolet emission - X-Ray - Telescope - Universe - Universe (expansion) - Wave - Wavelength.

All the components of the universe produce emissions which can be observable both by the eye (light) as well as being detectable by specialized instruments in the short (X-rays or ultraviolet ray) or the long (infrared and radio emissions) **wavelengths**. All these emissions use a support called **wave** which allows them to travel to the Earth at the speed of light. On the other hand, the wave does not itself move; when we make a string vibrate, each part of the string oscillates but is left in the same place.

In 1666, *Isaac Newton* (1642-1727) discovered that sunlight is decomposed into various colours by means of a prism (see the entry *Light*). These colours correspond to the emission of a light source in various wavelengths. But this wave-range accessible to the eye represents only a quite small part of the electromagnetic spectrum.



The electromagnetic spectrum, from the shortest to the longest wavelengths.

Later, the astronomer *William Herschel* (1738-1822) discovered that the Sun also emits a hot, but invisible radiation which is called the **infrared (IR)**. The same emission brings us the heat of a fire or a radiator. Other emissions were then discovered, in particular **X-rays** (*Wilhelm Conrad Röntgen*, 1845-1923) capable of passing through objects and human tissue, and providing images of the interior, such as the radiograph of the human body. Thus the electromagnetic spectrum includes several specific domains, each having particular properties.

X-rays and a part of the ultraviolet rays emitted from stars and galaxies are stopped by the Earth atmosphere. They are studied by satellites in orbit around the Earth. Telescopes observe radiation emitted in the optical range and a fraction of the infrared radiation with the use of adapted cameras. Radiotelescopes analyse emissions corresponding to radio wavelengths. So, in each range of the electromagnetic spectrum there is a specific device allowing us to understand the nature and the evolution of the various components of the universe.

Spectroscopy

Visible light, the ultraviolet, the visible and the near infrared emissions can be decomposed with the use of a spectroscope to analyse their various properties.

The rainbow, the elementary spectroscope

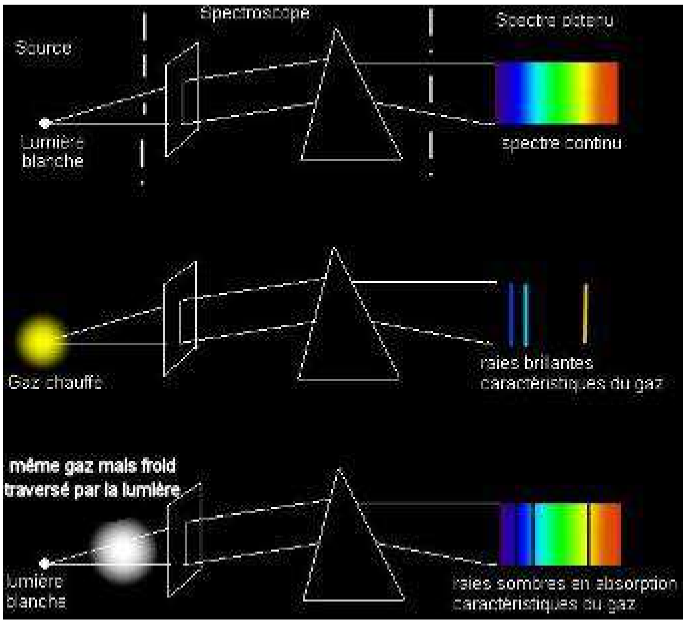
When sunlight crosses raindrops, these have the property of being able to decompose it into a series of coloured bands each corresponding in a precise wavelength. This wavelength is measured in **nanometers** (nm) with 1 nm= 10^{-9} metre (or 0,000000001 metre).

Violet has a wavelength of about 400 nm, and Red 800 nm. Between both colours, we find the main colours, green, yellow, etc.

The rainbow is in fact a spectrum of the Sun, but its fine details cannot be directly analysed which is why astronomers use spectroscopes.

Rainbow.

For a long time, in order to decompose a light beam, physicists used to use a glass prism. Today, spectrographs contain an extremely precise device called a **grism**. The light from planets, stars and galaxies contains a very large quantity of chemical elements starting with hydrogen, helium and carbon, which contribute to the light emission of these bodies with nuclear reactions. The electrons of these elements are excited by heat and "jump" by forming on the spectrum a set of characteristic "lines". These lines allow us to identify the various chemical elements contained in the light source.

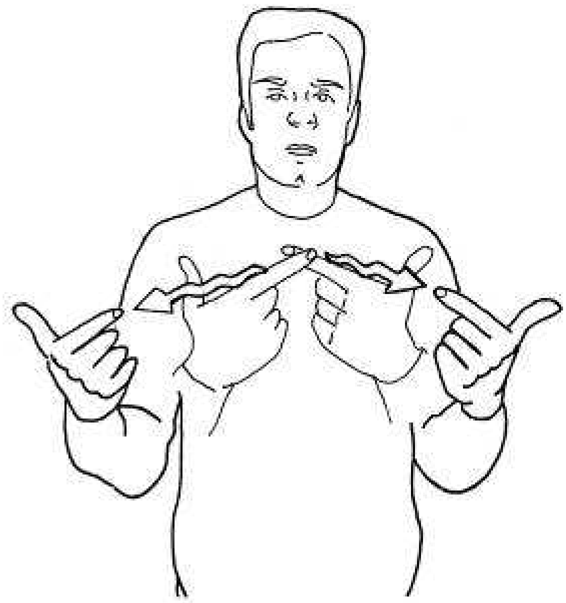


Principle of the spectroscopy. © M.Besnier

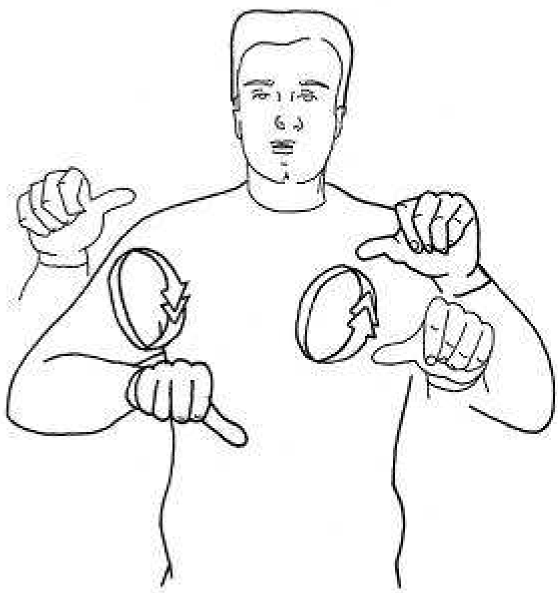
The intensity of these spectral lines allows to know the abundance of the various chemical elements of a planet, a star or a galaxy. Astronomers have shown that a star is old if it has only a small quantity of iron in its atmosphere; conversely, it is young if the latter is abundant. Another property of the spectral lines allows to know the velocity of a body in the universe. Just as a policeman measures with radar the speed of a vehicle whose movement causes a shift of sonic waves called the **Doppler-Fizeau effect** (the horn of a car is higher when it approaches and lower when it moves away), astronomers measure a shift of the light waves when a source is in movement. If the source moves away, the spectral lines are shifted towards the long wavelengths, and vice versa towards the short wavelengths when the source moves closer. It is one of tests which has allowed us to highlight the moving away of the galaxies due to the expansion of the universe. So, thanks to spectroscopy, astronomers are able to know the characteristics of the movements of a body of the universe as well as its chemical composition and its evolution in time.

Elements (chemical)

The notion of chemical elements is translated by the sign ELEMENTS followed by the sign CHEMISTRY. If we wish to evoke a particular element, we point an index finger towards the space in front of you (which indicates that we are going to speak about something in particular), then we specify the chemical symbol of the element in question, for example the sign C for carbon. The sign ELEMENTS is borrowed from the dictionary, where, according to the context, it can also mean "diverse" and "etc.". It was expressed in the 19th century by repeating three times the sign DIFFERENT, formed by both index fingers quickly pulling away from each other. The economy of signs has reduced this composite sign to a single one in which the oscillation of the index fingers replaces the former triple sign. The sign CHEMISTRY represents the products which we pour into a test tube.



ELEMENTS

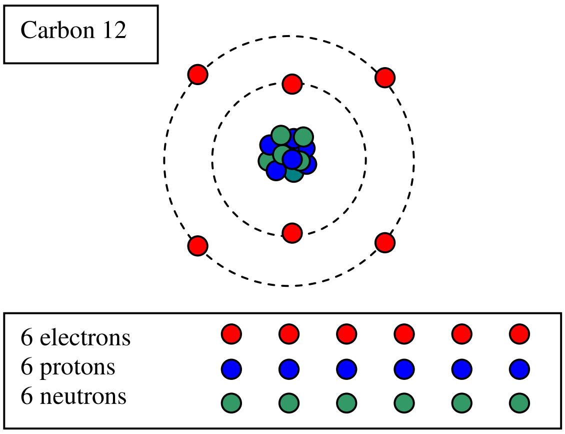


CHEMISTRY

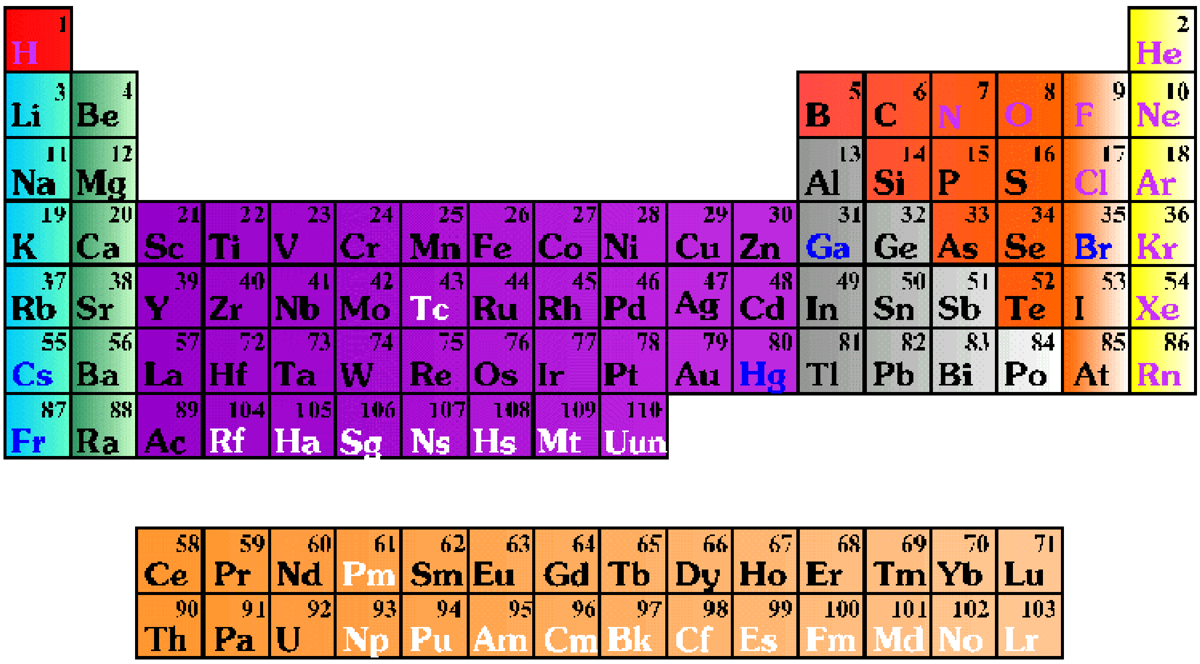
Associated words and expressions: Big Bang - Earth - Electron - Life - Neutron - Nuclear - Proton - Star - Sun - Universe.

In ancient times, the Greeks noticed that items found in nature, for example wood, metal, rocks, leather, water or the air which we inhale, comprised a multitude of components. In their hypotheses on the structure of materials, these latter were deemed to result from the combination of four basic elements: **earth**, **water**, **air** and **fire**. The fifth element, **quintessence**, filled the universe but we could neither see it nor feel its effects. Throughout history, progress made in chemistry has increased the number of known elements which now number 118. Progress in physics and astronomy has allowed us to understand that each of these elements has appeared during the evolution of the universe during the 13.8 billion years which have followed the Big Bang thanks to the nuclear reactions at the core of the Sun and the stars.

The entry *Nuclear* in this dictionary describes two of the main elements present in the universe, hydrogen (**H**) and helium (**He**), but there are many others, among which are some that are also present in living organisms (see the entry *Life*), oxygen (**O**), carbon (**C**), which has the property of being able to bind easily with four other atoms, and nitrogen (**N**). Then come phosphorus (**P**), sulphur (**S**), sodium (**Na**), chlorine (**Cl**), potassium (**K**), calcium (**Ca**) and magnesium (**Mg**). We also find traces of metals such as iron (**Fe**), zinc (**Zn**) and copper (**Cu**).



The list of chemical elements comprises 118 elements of which 110 are classified in increasing order in a famous table of seven lines and eighteen columns. Lines and columns are organized so as to include elements having common characteristics, also represented by the various colours. This is the **periodic table of the elements,** the work of the chemist Dimitri Mendeleiev (1834-1907). We have good reason for thinking that there are no more than 118 elements in the universe of which the last eight are unstable. We find about 90 elements on the Earth which have withstood 4.5 billion years of evolution such as gold (**Au**) and silver (**Ag**). In this table, the figure accompanying every element indicates its **atomic number** which indicates the number of protons of each of the nuclei. The higher the number, the more the element is deemed "heavy". For example, mercury (**Hg**) is much heavier than aluminum (**Al**) for an identical volume. You should not confuse the atomic number with the **atomic mass**, which represents the total number of protons and neutrons of an element. The nucleus of carbon includes 6 protons and 6 neutrons so its atomic mass is 12.



The periodic table of the elements. © Wikipedia.

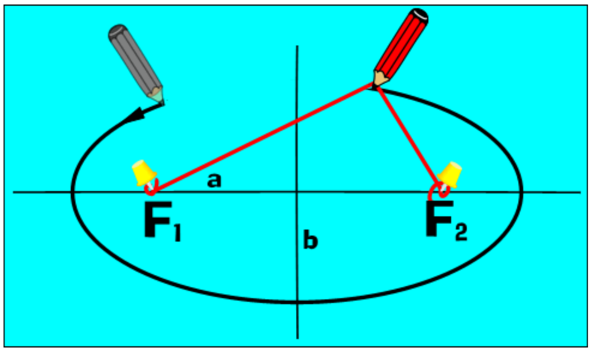
Ellipse

The sign ELLIPSE shows a circle which is stretched.

Words and associated expressions:
Astronomer - Eccentricity - Planet - Sun - Solar system - Earth.

For many centuries, until the work of Nicolas Copernicus (1473-1543), astronomers thought that planets moved around the Earth by following circular trajectories. When the heliocentric model (the sun in the centre of the Solar system) was recognised, Johannes Kepler (1571-1630) discovered that the trajectories of planets around the sun were not circles but ellipses.

An ellipse is a curve on a plane surrounding two focal points such that the sum of the distances to the two focal points is constant for every point on the curve. In the Solar system, the Sun occupies the place of one of the focal points.



La construction d'une ellipse. © Université Laval, Québec.

An ellipse has a main axis (a) and a small one (b). The eccentricity (*e*) of the ellipse is defined by the ratio of these two quantities:

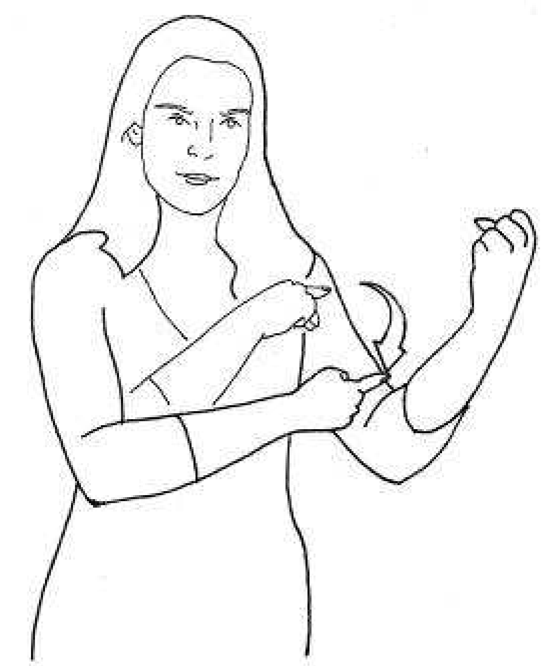
$$e = a/b$$

For a circle, which is a particular sort of ellipse, we have a = b, giving e = 1.

The Earth turns around the Sun by describing an ellipse the eccentricity of which is:
e = 0,0167.

Energy

The sign ENERGY is a symbol of physical strength. An index finger draws the outline of a muscle. The sign applies equally to living bodies as to all working machines.



Words and associated expressions: Light year - Force - Light - Nuclear - Star.

In astronomy as in physics, **energy** is what produces movement, light, heat, etc. Energy is linked to the notion of force. You need to apply force on any system to obtain energy. For example, the water, which is held back by a dam in a mountain, flows into pipes and the resulting force of the stream turns the turbines which supply electrical energy to the valley. In the core of a star, the nuclear reactions which act on the hydrogen atoms to provide helium release enormous quantities of heat which make the star shine.

The unit of energy is the **joule (J)** which is the energy transferred to an object when a force of one newton acts on that object in the direction of its motion through a distance of one metre (see the entrance *Force*).

Example: a 1kg weight in free fall for 1 meter has an energy of 1J.

For historical reasons, astronomers often use another unit of energy named *erg*. We have: 1 erg = 10^{-7} joule. In other words, ten millions ergs are needed to obtain one joule.

In physics, the **kinetic energy** E_c of a body which has a mass *m* and a velocity *v* is:

$$E_c = ½ mv^2$$

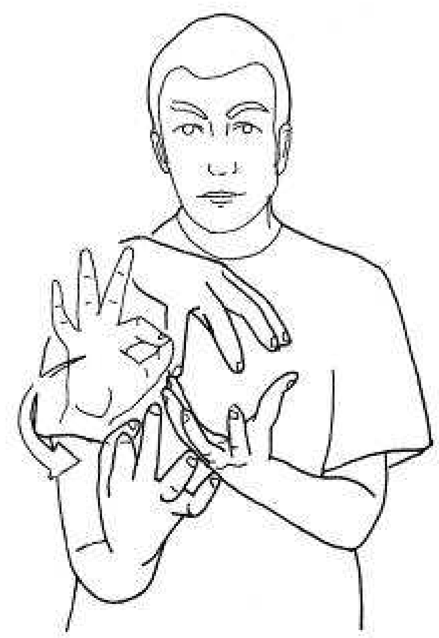
Astronomers often use the famous formula of Albert Einstein (1879-1955) linking a mass *m* and an energy *E*:

$$E = mc^2$$

The term *c* represents the velocity of the light. This formula explains why a small mass can give out an enormous quantity of energy.

Equator

To show the sign EQUATOR, both hands show at first the spherical shape of a planet. The hand in the lower position remains fixed while the other hand takes the shape of a pincer, a symbol of sharpness, to draw the large circle which goes around the planet.



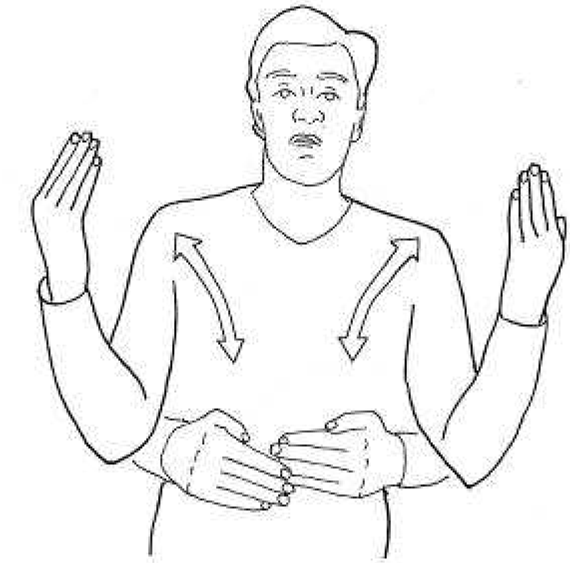
Associated words: Earth - Planet.

The equator is a large imaginary circle which goes round a planet at an equal distance from the North and South Poles. It is perpendicular to the axis of rotation of the planet. The Earth's equator measures 40,075 km.

The red circle represents the Earth's equator. © Wikipedia

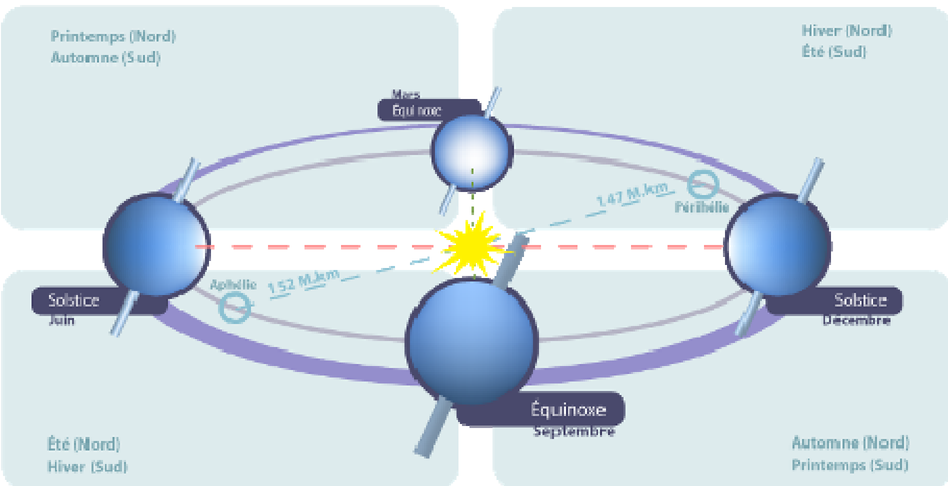
Equinox

The signs DAY and NIGHT are based on the same ideas as the expressions "sunrise" and "nightfall" (see the entry *Solstice*). The: hands rise and move apart (DAY) or move down and come together again (NIGHT). The sign EQUINOX shows a night and a day which are of equal length. To specify which of the equinoxes we are speaking of, we add the sign SPRING or the sign AUTUMN.



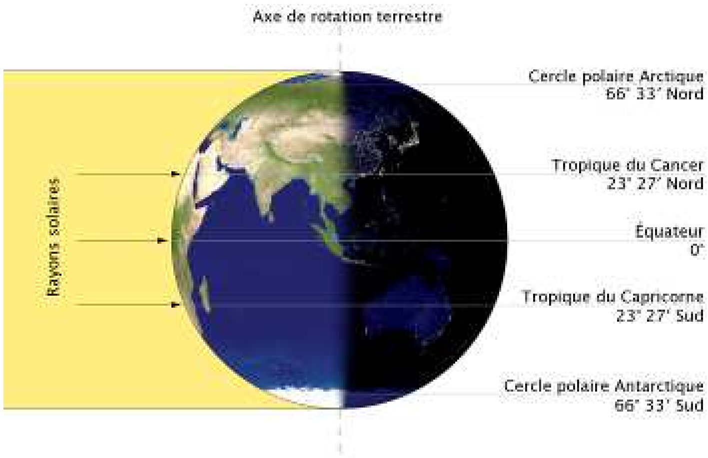
Associated words: Earth – Equator - Revolution - Rotation - Season - Solstice.

As the axis of the Earth's rotation is tilted at an angle of 23° 27', the duration of day and night changes all the year round. These variations are the main cause of the four **seasons**, spring, summer, autumn and winter, which would not exist if the Earth axis was perpendicular to the plane described by the Earth's orbit around the Sun. In Europe, the day lengthens from the winter solstice (see this entry) up to the summer one, before decreasing again until the next winter. Between the solstices, there are two dates when day time and night time are equal; these are the **equinoxes**.



The revolution of the Earth around the Sun. © Wikipedia

Twice during the year, the Sun crosses the plane of the Earth's equator. The sun remains for twelve hours over the horizon before disappearing for the ensuing twelve hours. This equality of the duration of day and night has the name **equinox** and occurs twice a year. The **spring equinox** which in Europe marks the passage of the winter to the spring, takes place on March 20th or 21st according to the calendar. The **autumn equinox** which marks the passage of summer to autumn takes place on September 22nd or 23rd.

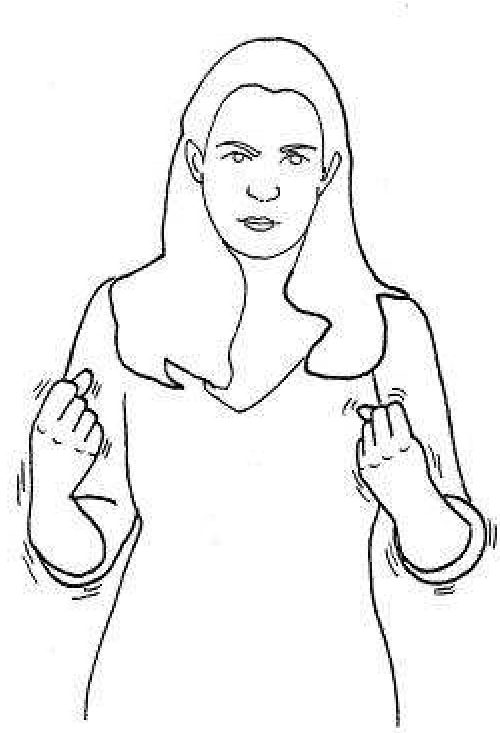


Equality of the day and the night at the equinox. © NASA

In the southern hemisphere, the solstices and the equinoxes are inverted compared with the northern hemisphere. So, in Chile, summer begins in December and winter in June. The spring equinox takes place in September and the autumn equinox in March.

Force or Interaction

The sign FORCE reproduces the attitude of somebody who shows his strength by clenching both fists. In astronomy, this sign can be completed by others which represent one of the four forces of nature: gravitational, electromagnetic, strong nuclear and weak nuclear.



Associated words and expressions:
Attraction - Big Bang - Earth - Electromagnetism - Energy - Galaxy – Moon - Nuclear - Photon - Planet - Sun - Star - Universe.

One of the most surprising aspects of the universe is that all of the matter of which it is comprised such as the planets, stars, galaxies, etc., can be described with the help of only **four forces, also known as interactions:**

- **gravitational interaction**
- **electromagnetic interaction**
- **strong nuclear interaction**
- **weak nuclear interaction.**

Physicists have tried to discover new interactions to better understand certain properties of matter but at present these four interactions are sufficient to explain the evolution of the universe since Big Bang, 13.7 billion years ago. The illustration shows a set of stars and very distant galaxies the history and evolution of which astronomers have studied by means of these four interactions.

A field of stars and the galaxy cluster Cl0053-37. © ESO

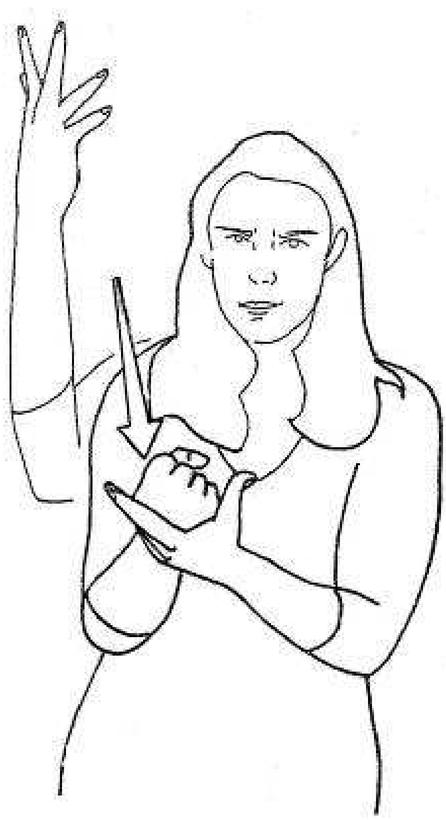
Gravitational interaction.

The concept of gravitational interaction is signed as FORCE followed by the sign INTERACTION. The sign is made from top to bottom as indication of gravity.
This is the most directly noticeable interaction since, on Earth as well as on other planets, the vertical fall of an object is subject to **gravitational acceleration** which in turn creates gravitational interaction.
This attraction explains why we have our feet firmly on the ground wherever we may be on the globe. However, gravitational acceleration changes from one planet to another.
In physics, the units of velocity are m/s or km/s; the unit of acceleration is m/s^2. The value of this interaction is equal to the mass (m) multiplied by the acceleration of gravity (g):

$$F = mg$$

The unit of interaction is the **newton** (**n**):

$$1\text{n} = 1 \text{ kg} \times 1 \text{ m/s}^2$$



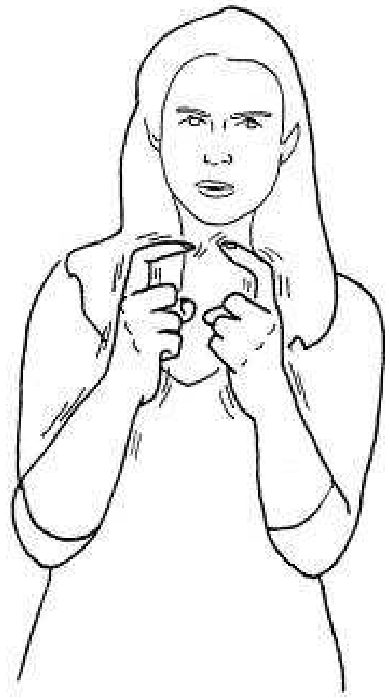
ATTRACTION

On Earth, gravity accelerates at 9.81 m/s^2 but on the Moon it is only 1.63 m/s$^{2;}$ conversely, on Jupiter, it reaches 23.15 m/s^2. A person whose weight is 75 kg on the Earth would weigh 12.4 kg on the Moon, 177 kg on Jupiter and 19 tonnes on the Sun!

This gravitational interaction operates on the Solar system to keep the planets revolving around the Sun, on stars to make them turn in the galaxy, and on the galaxies to make them turn around each other. It is 10^{39} times weaker than a strong nuclear interaction. **It is the weakest of all the interactions** but it acts anywhere where there is matter.

Electromagnetic interaction

The concept of electromagnetic interaction is signed as INTERACTION followed by the sign ELECTRICITY. The latter represents two electric contacts which are in contact to produce a discharge.

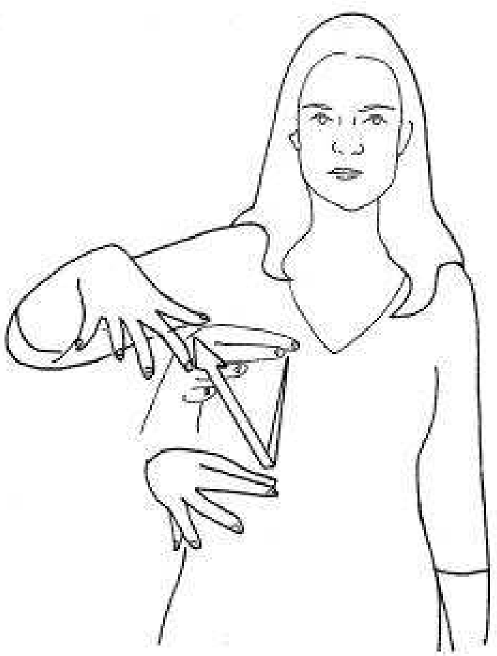


ELECTRICITY

This interaction can be observed in everyday life, for example near an electric line or with a magnet. Like gravitational interaction, it acts everywhere where there is some matter. It is transported by the particles which form light – “photons”. It is 137 times weaker than strong nuclear interaction.

Strong nuclear interaction

The concept of nuclear strong interaction is signed as INTERACTION followed with the signs NUCLEAR (for its etymology, see the corresponding entry) then STRONG.



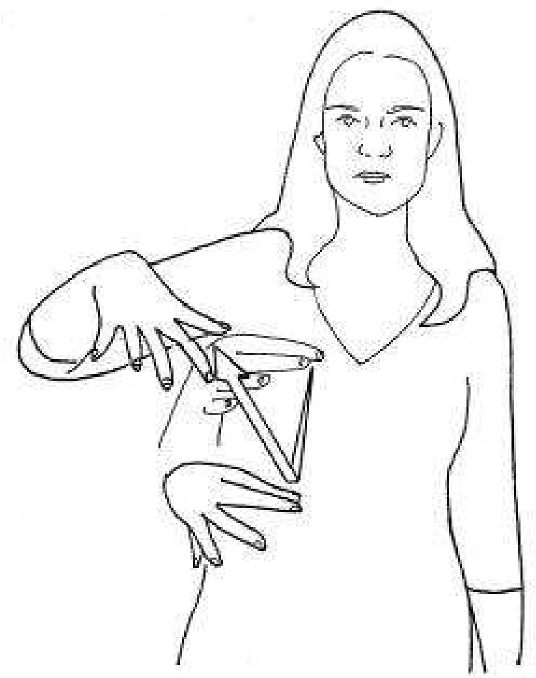
NUCLEAR

STRONG

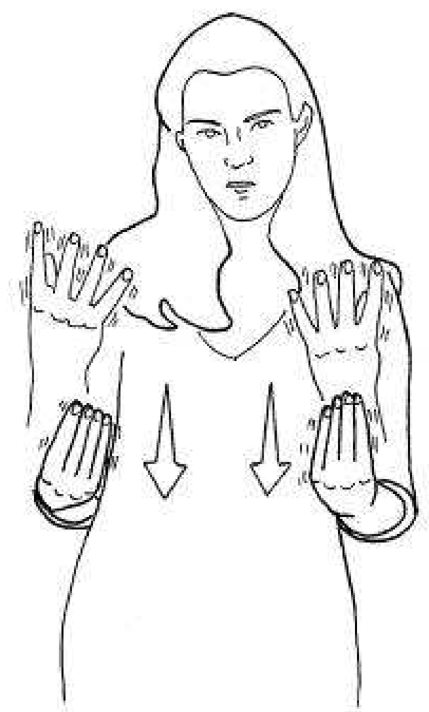
This interaction gathers together the particles which make up the core of atoms and is extremely violent. For example the fission of hydrogen nuclei produces an atom bomb capable of destroying everything. **It is the most intense interaction**, but it acts only inside atoms at a maximum distance of 10^{-15} metres.

Weak nuclear interaction

The concept of nuclear weak interaction is signed as INTERACTION followed by the signs NUCLEAR (for its etymology, see the corresponding entry), then WEAK. In various definitions within Sign Language, the closing together of open hands, as if making a sheaf, symbolizes a decrease and this, alongside a lowering of the hands in front of the body, forms the sign WEAK which thus represents a decrease of physical energy i.e. a state of weakness.



NUCLEAR



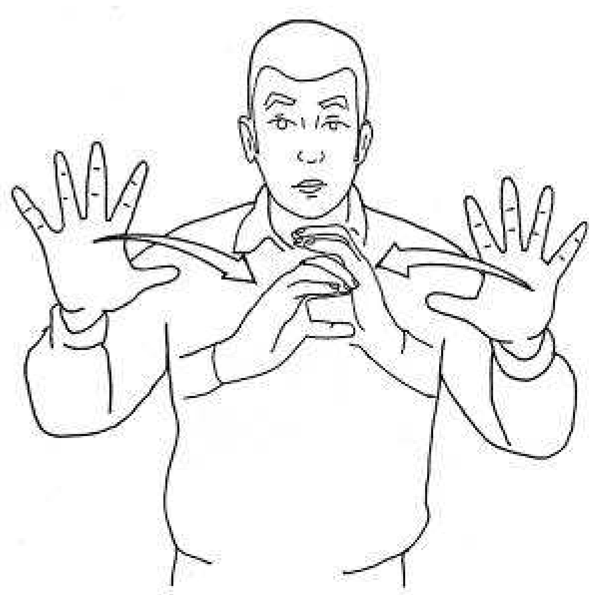
WEAK

This interaction is responsible for certain phenomena of radioactivity and also occurs in nuclear reactions like those that make stars shine. It is 10^{11} times less than a strong nuclear interaction and acts only inside atoms at distances of less than 10^{-18} metres.

Galaxy (cluster)

The concept CLUSTER OF GALAXIES is translated in Sign Language by the sign GALAXY followed by the sign CLUSTER (in the context of a globular cluster). For the etymology of these two signs, see the entries *Galaxy* and *Globular Cluster*.

GALAXY

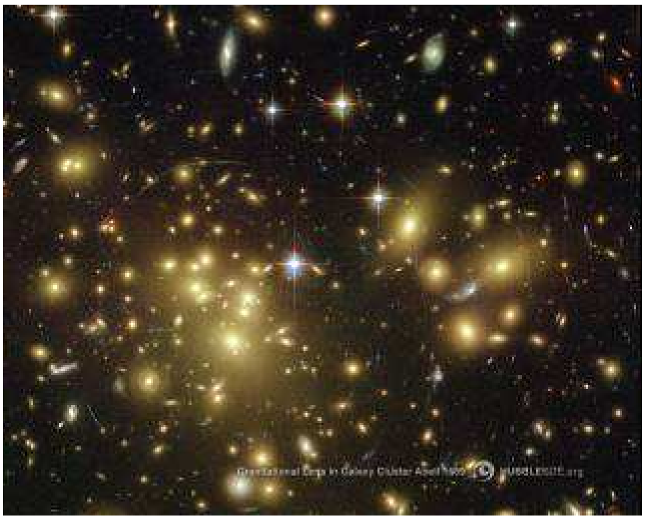


CLUSTER

Associated words and expressions: Big Bang - Cosmology - Galaxy - Galaxy (type) - Interaction (gravitation) - Light - Light year - Local cluster - Local group - Local supercluster - Mass - Telescope - Universe (expansion) - Velocity - X-ray.

In 1784, the astronomer *William Herschel* (1738-1822) noticed that the visible galaxies in his telescope were gathered in vast groups such as that one that he observed in the constellation of Virgo. Later on, the observations of *Edwin Hubble* (1889-1953) showed the extraordinary proliferation of the galaxies as well as their irregular distribution. They are clustered in groups and clusters whereas vast regions of the universe seem empty of matter.

As a contrast with the galaxies distributed remotely in space, numerous galaxies are members of vast associations in which they are gathered together under the influence of gravitational interaction. The two structures most accessible to the telescope are situated in the constellations of the Virgo and Berenice's Hair (Coma Berenices). These concentrations of galaxies form **clusters**, representing probably **the largest physically bound structures in the universe**. Our Galaxy too is a member of a cluster of galaxies named the Local cluster (see this entry).

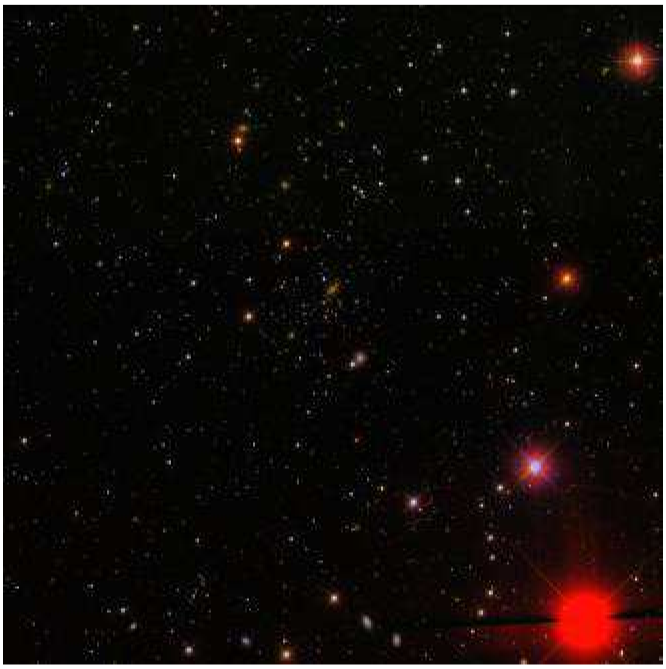


The galaxy cluster Abell 1689. © NASA/HST

Cosmological knowledge suggests that the clusters of galaxies adapted themselves to the initial physical conditions during Big Bang 13.7 billion years ago. The galaxies that are isolated would have "escaped" from a cluster or from a group. The images of the deep sky realized by means of the largest ground based and space telescopes confirm this theory of the clustering of the galaxies.

The observation of galaxy clusters shows that they form part of the general movement of the expansion of the universe (see this entry). So the greater the speed that the galaxies are distancing themselves, the more the cluster is distant. The galaxies of the Virgo cluster are 52 million light years distant and are going further away from us at an average speed of 1,500 km/s. Those of the Coma Berenice cluster, which are 200 million light years distant, are receding at a speed of 7,300 km/s. At more than three billion light years distant, the galaxies of the cluster A1942 are receding at a speed of about 65,000 km/s.

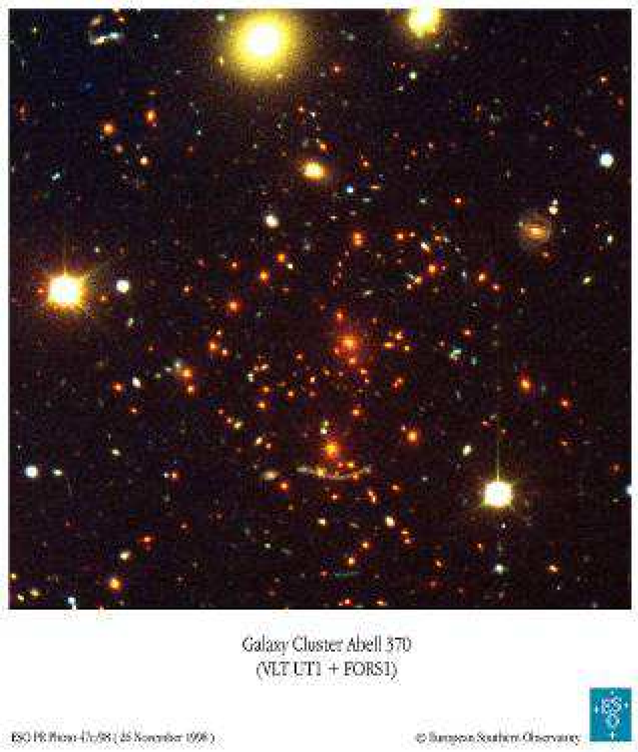
Astronomers have also observed that certain clusters of galaxies have gathered themselves into clusters of clusters named **superclusters of galaxies**, which could reach dimensions of about 150 million light-years. Our Local Supercluster includes our Galaxy, the Local cluster and the Virgo cluster.



Among the stars of the Milky Way, the galaxy cluster A1942 is composed of such distant galaxies that they are only visible as small unresolved dots. © ESO/D.Proust

For the nearest clusters, observations show that the elliptical galaxies tend to be situated towards the centre of the cluster, whereas the spiral galaxies are distributed on their periphery. In the centre of cluster, we often find a huge galaxy called **cD galaxy** which is suspected of being able to absorb the small surrounding galaxies like a glutton.

Finally, the majority of the clusters contain very hot gas whose temperature reaches 10^8 degrees, emitting in the X-rays range. This hot gas, when mixed with colder clouds and the galaxies themselves, gives a great density to the clusters of galaxies, in the order of 10^{15} times the mass of the Sun! In the 1980s, astronomers discovered that this density was capable of diverting luminous rays coming from much more distant galaxies in the same direction, provoking a **gravitational arc** (see this entry). Astronomers observed numerous images of these arcs in galaxy clusters such as A370.



The galaxy cluster A370 with its gravitational arcs. © ESO

Galaxy (evolution)

The evolution of the galaxies is represented by the sign GALAXY followed by the sign EVOLUTION. For the etymology of GALAXY, see *Galaxy-General*. For the sign EVOLUTION, see *Star-evolution*.

GALAXY

EVOLUTION

Words and associated expressions: Angular momentum - Galaxy (cluster) - Light year - Magellanic cloud - Mass - Milky way – Rotation - Universe - Velocity.

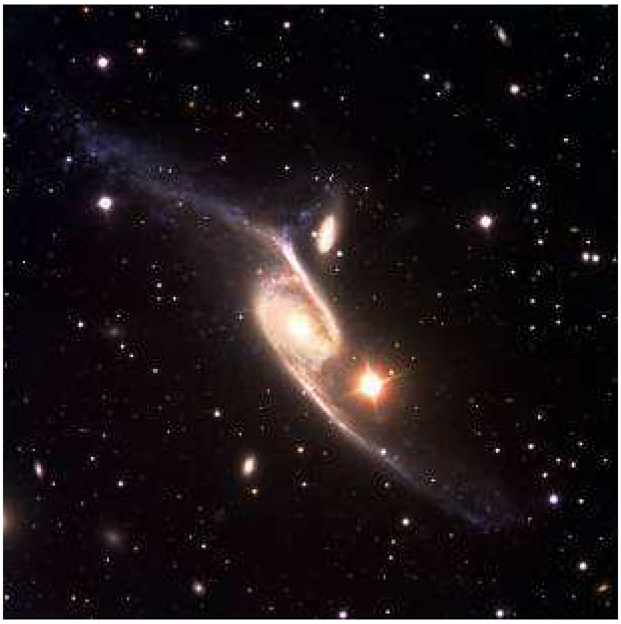
Galaxies do not remain constant during their lives. Like the stars, they evolve from the moment of their formation, both individually and as a function of their environment. They are grouped together in vast structures, known as “galaxy clusters” (see this entry), inside which they undergo collisions and interactions of all kinds.

The morphological variety of galaxies, whether they are elliptical, spiral or irregular (see the entry *Galaxy-type*), reflects the initial conditions of their formation and their evolution. At its origin, a galaxy is formed by the contraction of an immense cloud of gas in rotation which gradually flattens and gives birth to the first stars. This cloud of gas is characterized by its mass and its rotation velocity which is known as **angular momentum**. When this is raised, the resulting galaxy is spiral or lenticular; conversely, an elliptical galaxy results from weak angular momentum.

The galaxy NGC 5128 in the constellation Centaurus at a distance of 14 million light-years. © ESO

Certain galaxies have central regions made up of gas interacting at high temperature which emit in the long wave radio wavelengths. These are **radiogalaxies** such as the galaxy NGC 5128 in the constellation of Centaurus which is formed of two galaxies in collision.

Under the influence of the slow rotation of the galaxies, stars give them back part of the gas which they have made, rich in heavy elements. Conversely, the formation of stars in a galaxy greatly reduces the amount of gas in the environment.
Galaxies were formed at the beginning of the universe with their own characteristics and then evolved at a different pace according to either the quantity of gas which they initially contained, or their isolation or their membership of groups or clusters. The transformation of most of the gas in stars was made quickly in elliptical galaxies and much more slowly in irregular galaxies.



The interacting galaxies NGC 6872 (spiral) and IC 4970 (lenticular) at a distance of 300 million light years. © ESO

The mutual proximity of the galaxies within a group or a cluster strongly influences their evolution (see the entry *Galaxy-cluster*). For example, when the small galaxy IC 4970 collided with the galaxy NGC 6872, the effects of gravitation on the gas of the latter resulted in a strong increase in star formation.

Galaxy (general)

The sign GALAXY starts as a spherical nucleus with the arms then surrounding it in a horizontal plan. Separated and oscillating fingers symbolize the countless stars which compose the arm of a galaxy allowing us to avoid any confusion with an object surrounded with a disk, such as Saturn.

Associated words and expressions: Light year - Local group - Magellanic cloud - Milky way - Nebula - Rotation - Solar system - Star - Sun - Universe (expansion) - Velocity.

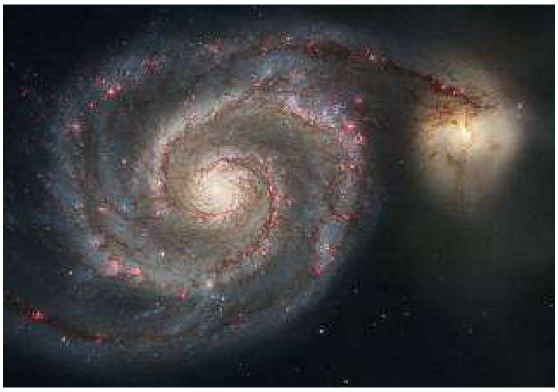
The **galaxies** are immense flattened objects where stars are born, live and die immersed in vast clouds of gas and dust. The best known is the Milky Way in which our Sun and the Solar system are situated. We can easily admire the Milky Way on a beautiful starry night.

The first galaxy mentioned in the history of astronomy was observed in the constellation of Andromeda by the Arabic astronomer Al Sûfi in the year 964, then by Simon Marius in 1612. The first observation with an instrument was made by Charles Messier (1730-1817), who established a list including 104 "diffuse objects" in which the Andromeda galaxy has the number 31, and is named Messier 31 (or M31). William Herschel (1738-1822) discovered more than 2,000 "nebulas" which complete Messier’s list while his son, John Herschel, published a list of 5,079 objects. In 1888, astronomers listed 7,840 "misty objects". By 1908, they had recorded 15,000 galaxies, the majority of which constitute the *New General Catalogue* (NGC) and the *Index Catalogue* (IC). Thus the Andromeda galaxy (M31) is also NGC 224. Nowadays, the galaxies number in the hundreds of millions thanks to the images obtained with large ground-based or space telescopes.

The spiral galaxy M31 in Andromeda and the elliptical galaxy M32 situated below. © Observatoire de Paris

We had to wait for 1920s to be certain that some of these "nebulas" were galaxies (from the Greek word gala "milk"), immense disks composed of stars bathed in gas and dust, rotating very slowly and situated very far from our Milky Way. Their real nature had been suspected in the 19th century, in particular since the discovery, in the 1850s, of the spiral structure of many of them. The expression "universe-island" gives a good idea of their large dimensions and the immense distances which separate them.

Dimensions – Galaxies have very variable morphologies and dimensions (see the entry *Galaxies-types*). The Large and the Small Magellan Clouds, easily visible with the naked eye in the southern hemisphere, have dimensions of respectively 22,000 and 10,000 light years, whereas our own Galaxy (the Milky Way) has a diameter of 100,000 light years. In the constellation of Andromeda, M31 attains 150,000 light years, whereas M32 measures only 3,500 light years.



The galaxy M51 in the constellation Canis Venaticorum. © NASA/HST

Distance – Galaxies are sprinkled in space at immense distances. The Magellan Clouds are our neighbours at a distance of 169,000 light years whereas M31 is situated 2,800,000 light years away. The galaxies which constitute the Local Group are tens of millions of light years apart but large telescopes are capable of detecting up to eight billion light years!

The galaxy NGC 4565, seen from the side. © ESO

Rotation – Galaxies turn on themselves, which explains the structure of their spiral arms which wind gradually. Our Galaxy, the Milky Way as seen from the position of the Sun, has a velocity rotation of 220 km/s and it makes a complete rotation every 220 million years. Moreover, galaxies tend to distance themselves from others because of the general expansion of the universe; but, locally, gravitational interaction can make them move closer. So M31 is approaching us at a velocity of 275 km/s and will collide with the Milky Way in four to five billion years.

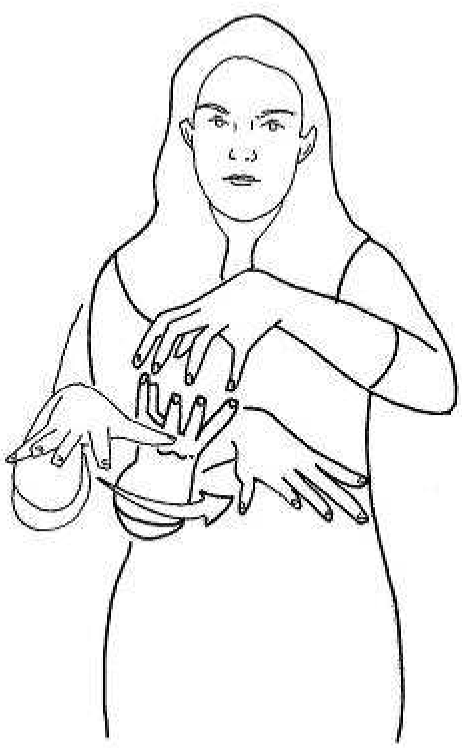
Mass – Galaxies have very different masses according to their morphological type. Composed of billions of stars, gas and dust, our Galaxy is 150 billion times the mass of the Sun, M31 twice this, whereas small galaxies have masses of between a hundred million and a billion times that of the Sun.

Origin of the galaxies

In general, galaxies are born from an immense cloud of gas in rotation, which collapses slowly on itself while forming stars. If there is a lot of remaining gas, this mixes with the stars to give the spiral arms which result from a larger rotation velocity near the centre than on the periphery. So, about ten billion years ago, our own Galaxy would have evolved from a gigantic bubble of gas to become the flat disk we can see today.

Galaxy (structure)

From the sign GALAXY (see the entry *Galaxy-general*), we can describe the structure of these objects, for example specifying that they are in rotation with a speed expressed in km/s, or to indicate their mass as a function of the Sun which is chosen as the unity and which can be from several million to several thousand billion times its mass.



GALAXY

Words and associated expressions: Dust - Galaxy (evolution) - Galaxy (type) - Gas - Mass - Milky way - Rotation - Star - Sun - Universe - Velocity.

The galaxies were formed several billions years ago and have never stopped evolving right up to our epoch (see the entry *Galaxy-evolution*). They consist of a mixture of stars, gas and dust, the whole being activated by a slow movement of rotation. They belong to three main different families: the ellipticals (E), the spirals (S) and the irregular (I) (see the entry *Galaxy-type*).

Structure - Spiral galaxies are formed of a central bulb in the shape of an egg, surrounded by a disk endowed with arms, unlike elliptical galaxies. There is a difference between the stars of spiral and elliptical galaxies. We find in the spiral arms of the former a larger quantity of hot young stars or those coming to maturity like the Sun, whereas the latter are richer in old evolved stars.

The superb spiral galaxy M101 in the constellation of the Great Bear (Ursae Majoris). © NASA/HST

Stars of spiral galaxies are bathed in vast clouds of gas (essentially hydrogen) and of dust (essentially carbon) whereas elliptical galaxies are relatively lacking in them. It's the stars that make the galaxy shine. The cohesion of a galaxy is also assured by the fragments of "dead stars" as well as "dark matter" whose nature and localization are not actually well known at present.

Rotation - The galaxies are all in rotation since the cloud of gas from which they are formed started rotating. The central regions turn faster than the outside ones. At the level of the Sun, our Galaxy has a velocity of 220 km/s. Nearby galaxies have an average velocity of between 40 and 300 km/s. The periods of rotation increase as we go from the ellipticals towards the spiral bulbs, graduating between 5 million (ellipticals) to 80 million years (spirals). These periods of rotation are much greater for the arms of the spiral galaxies. From our Sun's position, it takes our Galaxy 220 million years to complete a rotation.

Elliptical galaxy in the galaxy cluster Abell S740.
© NASA/HST

Mass - It is extremely difficult to know exactly the mass of galaxies if only because of the uncertainty which concerns their dimensions, their halo, and the quantity of dark matter. This uncertainty increases with the largest objects but the huge elliptical galaxies have a mass greater than 10^{13} times that of the Sun. The masses most usually adopted are the following (always expressed in solar masses): huge elliptic galaxies: 10^{13}; large spirals: 3×10^{11}; our Galaxy: 1.5×10^{11}; small spirals and irregular: 10^{10}; small ellipticals: 10^{6}.

Galaxies represent the intermediate stage between the stars and the universe. They contain the first, without which life would not exist, and are contained in the second, without which nothing would exist.

Galaxy (type)

The idea of a “type” of galaxy is shown in Sign Language by the sign GROUP, followed by the sign GALAXY.

GROUP

Associated words and expressions: Astronomer - Distance - Ellipse - Galaxy (cluster) - Light year - Magellanic cloud - Milky way - Star - Telescope.

In the 1920s, the observations of astronomers such as *Edwin Hubble* (1889-1953) with large telescopes established once and for all the immense distances which separate galaxies (M31, the big and closest galaxy to the Milky Way, is situated at a distance of 2 800 000 light years) as well as their structure. According to their morphology, astronomers have identified three fundamental classes of galaxies: **spiral**, **elliptic** and **irregular**. The first category contains two subclasses of spirals, “**normal” spirals** and “**barred” spirals**; the second category includes **lenticular galaxies**. Irregular galaxies have no symmetry.

The elliptical galaxy NGC 1132 with its bright nuclei. © ESO

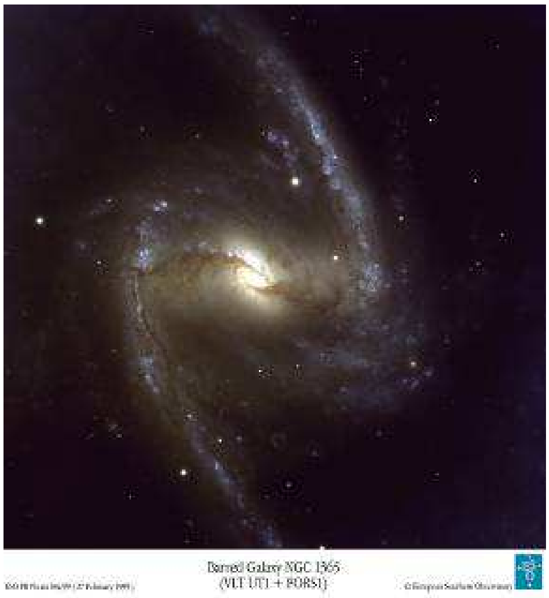
The magnificent lenticular galaxy M104, called « sombrero » because of its shape. © ESO

Elliptical (E) and lenticular (S0) galaxies

The **elliptical** galaxies (E) have no spiral arms, but do have a vast bulb. They are classified in several groups E1, E2, etc., according to the more or less spherical structure of the bulb. Their low flattening is due to a particularly slow rotation. Some of them have a small surrounding disk: these are **lenticular** galaxies, the type of which is S0.

In Sign Language, an elliptical galaxy is shown with a big bulb having the shape of an ellipse (see this entry).

The spiral galaxy NGC1232. © ESO



The barred spiral galaxy NGC 1365. © ESO

Spiral galaxies (S)

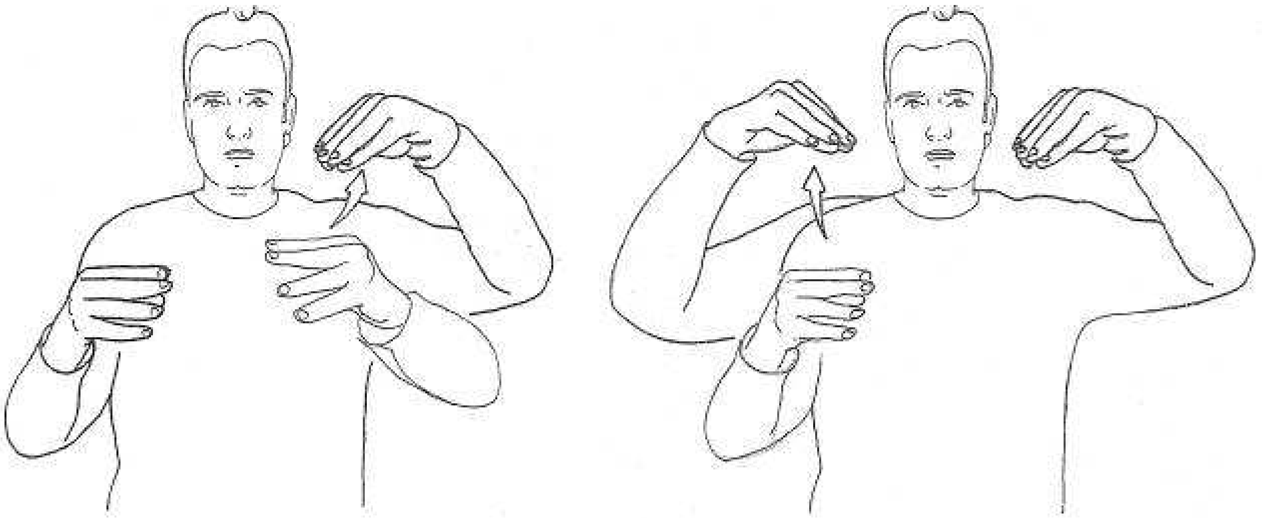
Spiral galaxies form the first category of the discovered galaxies because of their luminosity. This is essentially due to young stars concentrated in the spiral arms, as well as from hot gas (hydrogen) in the dense regions favourable to the development of stars. We also find old stars with low mass uniformly distributed in the disk of the galaxies. Unlike the ellipticals, spiral galaxies show, for the visible part, a very flattened structure, a real pancake of stars around a small central bulb. According to the “opening” of their spiral arms, they are classified in various types, Sa, Sb, Sc, etc. Astronomers distinguish two kinds of nuclei: when this is spherical, the galaxy is called **spiral**, but when it presents an elongated shape, galaxies having this characteristic are known as **barred spirals**. These are also divided into several groups, SBa, SBb, SBc, etc.

SPIRAL GALAXY

Irregular galaxies (Irr)

To the regular galaxies, elliptical or spiral, we have to add the **irregular** galaxies of which the two **Magellanic clouds** constitute a good example.

The « cosmic bird » formed by the collision of two irregular galaxies. © ESO

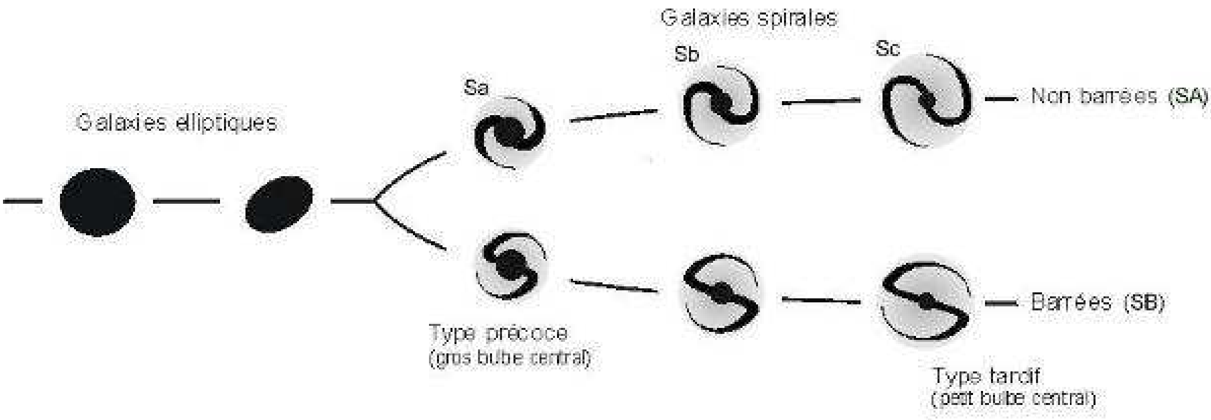


IRREGULAR GALAXIES

Galaxies types are distributed as follows: 69 % spirals, 28 % elliptical and lenticular, and only 3 % irregular. The most massive galaxies are of E and S0 types. The spirals have masses between 30 and 300 billion times that of the Sun, or between 0.2 and 2 times the mass of our Galaxy (gas and dust not included). Galaxies are not uniformly distributed in the universe: they gather in groups and in clusters (see the entry Galaxy-groups and clusters).

Hubble's tuning fork

In the 1930s, *Hubble* proposed a classification of all the galaxies according to their morphology. This classification is named Hubble’s "tuning fork", because of the shape of the diagram. Bars are one of essential motors in the evolution of galaxies; they exist in 2/3 of spiral galaxies.



The classification of galaxies, or Hubble's "tuning fork". © Observatoire de Paris

This "tuning fork" was considered for a long time as representing the diverse phases of the evolution of the galaxies without our knowing very much in which order this evolution occurred. Some astronomers thought that an elliptical galaxy evolved towards a spiral, whereas others thought the opposite. We now know that galaxies come together to form groups and clusters of galaxies inside which we find that elliptical galaxies are in the majority, and that often in the centre there is a a very big "cannibal" galaxy which can have absorbed and digested its neighbours over time. Spiral galaxies are situated outside the cluster. Being more distant from each other, they are less at risk of colliding and, therefore, were not able to lose their spiral arms in order to become ellipticals.

By means of the index and of third fingers stretched out and separated horizontally, we can represent in Sign Language a tuning fork on which we can place the various types of galaxies.

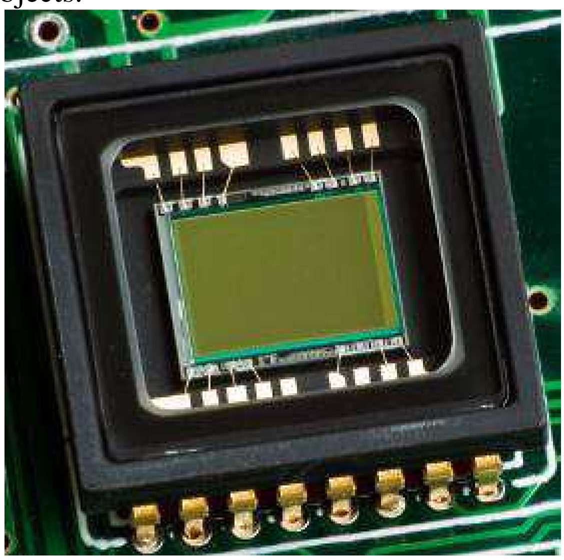
Imaging

Astronomical imaging is indicated by the sign IMAGE which can be followed by the sign ASTRONOMY (see this entry). We can also specify colour by means of the signs for blue, red etc., according to which filters are being used. In the 19th century, the sign IMAGE, which referred to illustrations in schoolbooks, was a square drawn in front of you by both open hands. Under pressure from the gestural world, it has evolved into its current sign.

Associated words and expressions:
Astronomer - Comet - Earth - Electron - Galaxy - Light - Magnitude - Photon - Planet - Star - Universe.

The study of the components of the universe, planets, comets, stars, galaxies, etc., is done by means of telescopes. With the appearance of photographic techniques, astronomers have adapted and improved these to create images that are essential documents for the understanding, structure and evolution of these objects.

For a long time, astronomers only had their eyes to work out the characteristics of a celestial body. From the end of the 19th century, they used photographic plates; then developed new techniques, such as the electronic camera which appeared in the 1960s. Today, the acquisition of the image of a celestial body, a star or a galaxy, is done by means of a camera, the detector of which is a CCD (Charge Coupled Device). A rectangle contains hundreds of millions of sensors among whom each of which transforms photons received into electrons, their number indicating the quantity of light received by this sensor. In this way we are able to recreate the image from digital information.



CCD detector with charge transfer.

Images of the Orion constellation in three different wavelengths : visible, red and infrared. ©ESA/ISO

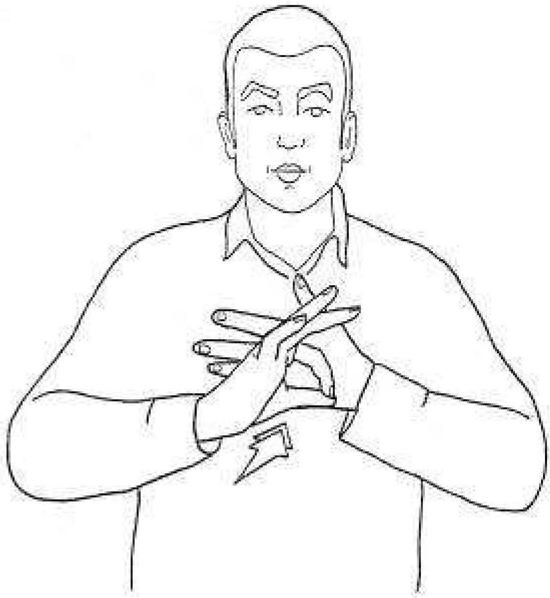
Light is collected either just as it is seen or by interposing filters which allows us to measure its intensity in other wavelengths. In this way, we can get the characteristic magnitudes in the short (B or "blue") or the large (R or "red") wavelengths. These magnitudes have direct applications in the study of the evolution of stars and their environment. Thus, the infrared domain allows to study the gas and dust of our Galaxy as shown by these images of the constellation of Orion.

CCD image of the galaxy M51 in the constellation of the "Hunting dogs" (Canes Venatici) obtained with the Hubble Space Telescope. ©NASA/HST

Image of a deep stellar field with stars and galaxies mixed, obtained with the 2.20m telescope of ESO at La Silla (Chile). © ESO

Jupiter

In the sign JUPITER, an open hand represents the surface of the planet, whereas the other hand in the shape of rounded tongs represents the famous “red spot”.



Associated words and expressions: Moon - Ring - Satellite - Solar system - Spacecraft - Volcano.

Just as the god *Jupiter* dominated the other gods of Antiquity and used thunder and lightning to assert his power, the planet Jupiter is the biggest in the Solar system. It is very brilliant in the sky and a pair of binoculars is sufficient for observing it as a small disk accompanied with its four main satellites.

Distance : Jupiter is at an average distance of about 778,412,000 km from the Sun.
Diameter : 143,000 km, which is eleven times the Earth’s diameter.
Mass : it is 318 times greater than our planet ; a man weighing 75kg on Earth would weigh about 177 kg on Jupiter!
Inclination : its axis is only 3° 6' inclined (23° 27’ on Earth) .
Rotation : a small telescope is sufficient to show that the planet is very much flattened at the two poles, in a 1/16 ratio. This flatness is due to its very rapid rotation: a day on Jupiter lasts only 9 h 53 min.
Revolution : a Jupiter year lasts 11 Earth years and 315 days.
Temperature : around -120°C.
Atmosphère : This would be more than 50,000 km thick and consists of hydrogen (H_2) 86 %, helium (He) 13 %, methane (CH_4), ammonia (NH_3) and ethane (C_2H_6). The smallest instruments allow us to observe immense dark bands parallel to the equator, formed by ice crystals of ammonia, with winds reaching 360 km/h. The magnetic field of Jupiter is fourteen times as intense as that of the Earth.

Jupiter as seen by the spacecraft Voyager. © NASA/JPL

The famous **red spot** is an immense anticyclone, observed by astronomers since the beginning of the 19th century. It is oval in shape, is 40,000 km in length and rotates in approximately six days, with winds of more than 400 km/h. In a world so restless, it is not very probable that we can find any form of life.

The red spot of Jupiter. © NASA/JPL

The four main moons of Jupiter. From top to bottom : Io, Europe, Ganymede, Callisto. © NASA/JPL

Jupiter has several very fine **rings**, invisible from the Earth and composed of dark dust. They were discovered by the spacecraft *Voyager 1* in 1979.

Jupiter is accompanied by 63 moons of which the four biggest, of a similar size as the Moon, were discovered by Galilee (1564-1642) in 1610. A pair of binoculars are sufficient in size to observe them and spot their movement around the planet.

An active volcano on the surface of the satellite Io. © NASA/JPL.

Spacecraft have allowed us to analyse in detail the surface of these four main moons. **Io** is the closest to Jupiter with several volcanoes in eruption ejecting some sulphur dioxide (SO_2) on its surface which is why it appears to be yellow in colour. **Europe** is covered with a crust of ice covering large areas of water. There are few craters on its surface. **Ganymede** shows some very dark regions, as well as very numerous craters and crevises. **Callisto**'s surface includes a very big lake about 3,000 km wide.

The four main moons have the following characteristics:

Name	**Distance from the planet (km)**	**Diameter (km)**	**Duration of revolution**	**Discovery**
Io	421,800	3,642	1d 18 h 27 mn	Galileo (1610)
Europe	671,100	3,122	3d 13 h 13 mn	Galileo (1610)
Ganymede	1,070,000	5,262	7d 3 h 43 mn	Galileo (1610)
Callisto	1,883,000	4,821	16d 16 h 32 mn	Galileo (1610)

Life (in the universe)

In the sign **life** attested since the beginning of the 19th century, the rise of hands on the breast symbolizes the sap which irrigates an alive body. Hands have the shape of the letter "V".
The concept of **exobiology** (search for the life in the universe) is expressed with the successive signs SEARCH, LIFE and UNIVERSE.

LIFE

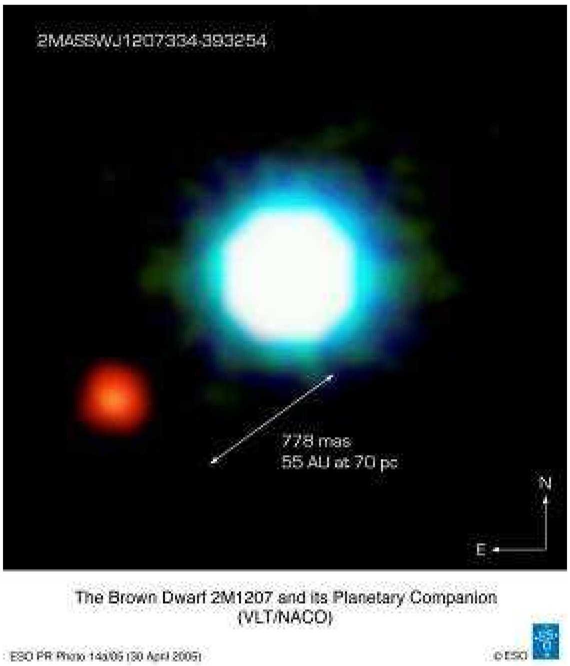
Associated words and expressions:
Astronomy - Astrophysics - Chemical element - Earth - Eclipse - Exoplanet - Interaction (gravitation) - Light year - Mars - Planet - Radiotelescope - Satellite - Solar system - Star - Telescope - Universe.

The universe provides all the conditions favorable to the development of the life. The laws of nature allow the stars to make all the chemical elements, in these to assemble in **molecules**, and in the molecules to multiply with the help of the nucleic acids in **macromolecules**, then in **cells** and in alive organisms. So is understandable, after 4.5 billion years of evolution on the Earth, the very large variety of the alive species. But because the observable universe seems to show everywhere the same physical characteristics as the Earth and its environment, it is quite natural to wonder if life exists somewhere else.

On the Earth, organisms live in the marine ocean depths at more than 4 000 meters deep, where the pressure can reach more than 1 000 times the atmospheric pressure. In these depths, ascents of lava under the Earth's crust warm the water at temperatures higher than 70°C. Such organisms can live and reproduce at very important temperatures and pressures. The biologists so discovered hundreds of unknown species, capable of adapting themselves to these extreme conditions.

If the exploration of the Solar system leaves not much hope to find the life on the nearby planets of the Earth (in particular Mars), we detected more than 3000 **exoplanets** around stars. The observations are made with ground-based telescopes, and in space with satellites. These can measure the small oscillations of a star connected to the gravitational interaction exercised by the planet, or the tiny modification of the brightness of a star, when a planet just passes in front by producing an eclipse.

A number of these exoplanets present favorable conditions of temperature to allow the life to develop; we have now to detect an atmosphere and the presence of water on their surface as well as the signs of a biological activity, such as the carbon monoxide emission (CO_2) and methane (CH_4).



The planetary companion of the star 2M1207. © ESO

The astronomers thus look if the life can develop on other planets, even if these have physical characteristics very different from the Earth. In the 21st century, the search for the extraterrestrial life became a « real », called **exobiology**. This one is connected not only to the chemistry and to the biology, but also to the progress of the astronomy and the astrophysics. It collects the most recent scientific disciplines, which concern as well the study of the origins and the evolution of the alive, than the detection of planets around stars.

The astronomers also try to detect artificial signals coming from other civilizations by means of huge radiotelescopes, as that of Nançay, in France; conversely, messages travelling at the velocity of light were sent from the Earth, with the same instruments. The distance constitutes a big obstacle for possible communications: if a civilization distant by 30 light years receives our message, it will have already 30-year-old informations, and the answer will require so much time to reach us.

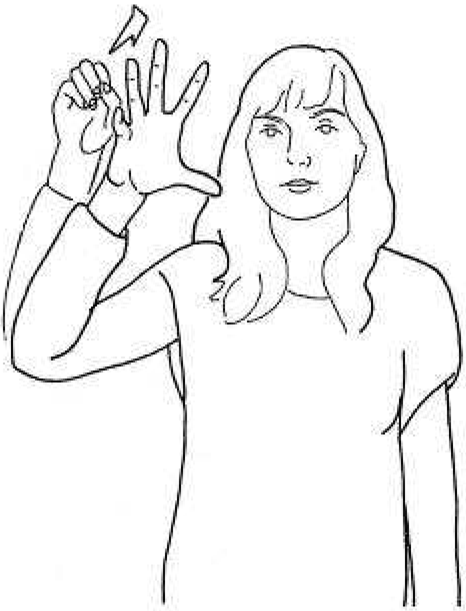
The **SETI** program (Search for ExtraTerrestrial Intelligence) began in 1992. It uses radiotelescopes to collect possible messages from an extraterrestrial civilization. The chosen frequencies are located in the field of the decimetric wavelengths. To analyze the obtained data, the SETI@home association suggests to the voluntary Internet users, using simply the background of their personal computers, with a supplied program of signal processing. Several million volunteers on all the Earth participate in this large project.

The radiotelescopes of the « Very Large Array » in the New Mexico desert. ©NASA/JPL.

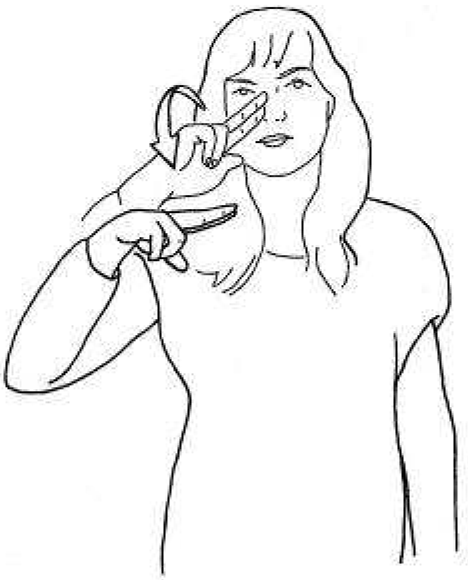
Conversely, the researchers send testimonies of the life on Earth by means of the same radiotelescopes, in the form of simple messages, as we make it with the radio. Also, spacecrafts such as *Pionneer 11* and *12* launched from the Earth carry a plate representing a man, a woman and the description of the Solar system aimed to possible extraterrestrial civilizations.

Light pollution

Light pollution is represented by the sign LIGHT (see this entry) followed by the sign POLLUTION. This second component is a recent derivation of STINK which is why the hand leaves the nose with a movement of rejection; the hand takes the form of the letter "P" of the manual alphabet, the initial of the word POLLUTION.



LIGHT



POLLUTION

Associated words and expressions: Earth - Light - Milky-way - Planets - Star - Temperature.

Over the course of time, all human activity, in particular the development of cities, roads and factories, has multiplied light sources spreading in the direction of the sky which represents a waste of energy and makes observations of stars and planets more and more difficult.

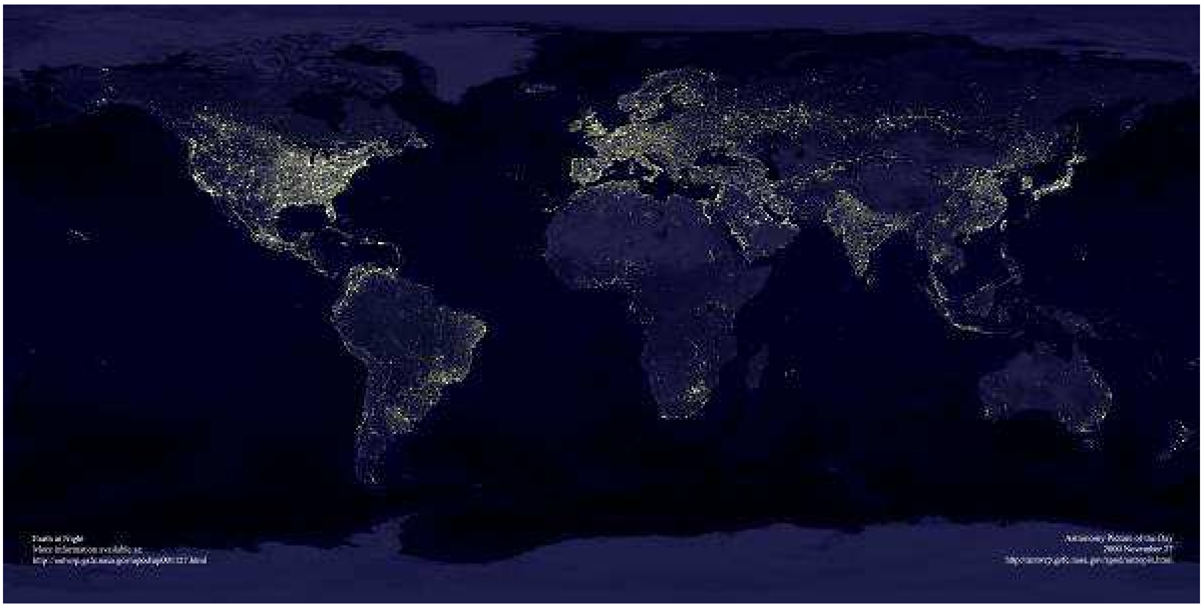
Light pollution is the light emitted towards the sky by projectors, lampposts and all badly controlled light sources. In France, we waste 35% of the energy used by approximately nine million lampposts. These are often not covered by lampshades and as a result lighten up the sky in a useless fashion. As a result, we don't see in towns anything other than the most brilliant stars and we have to go to the countryside to finally see the Milky Way such that we have arrived at a point that very few people nowadays know anything the heavens.

L'Opéra by Ludwik Delavaux (1868-1894).

Besides the nuisance for astronomy, light pollution is responsible for disturbances in the animal world (insects and other night-animals) and vegetable (growth and reproduction of plants). Worse still, it can modify in mankind the secretion of regulating hormones which could thus be at the origin of the increase of certain cancers. Just as the Earth is being put in danger by the release of carbon dioxide (CO_2) into its atmosphere (increasing average temperatures), and by the wasting of water, the abusive use of artificial fertilizers and pesticides, etc., light pollution represents a tremendous wasting of energy and a danger for the cultural heritage which a beautiful starry sky represents.

The light pollution on Paris as seen from Meudon astronomical observatory. © Juan Quintanilla/ Observatoire de Paris

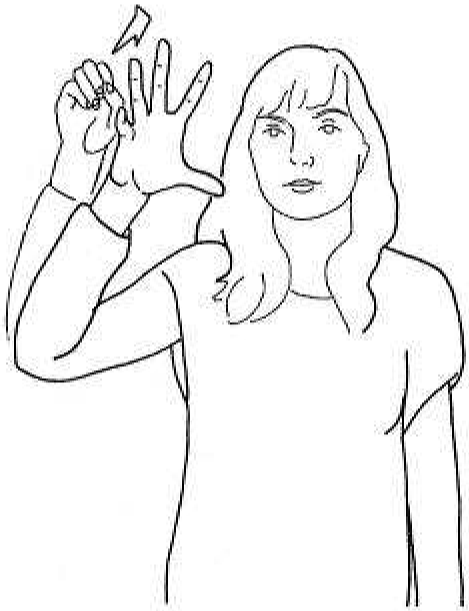
There are numerous web sites dedicated to the night sky protection from light.



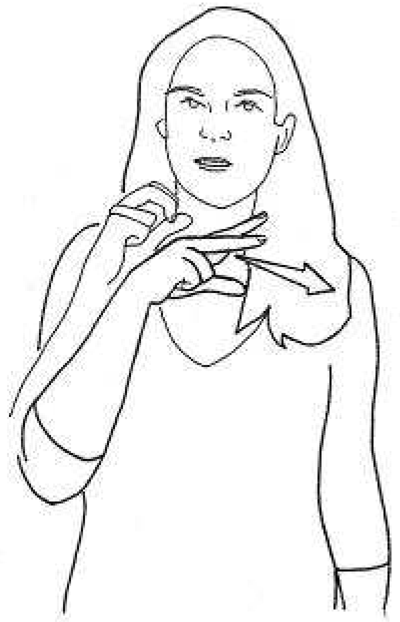
Satellite image of the Earth, showing the light pollution in three main zones: North America, Europe and Japan.© NASA.

Light (speed)

The speed of light is represented by the sign LIGHT, with the hand thrown forwards and opening just as a light source projects its beams. It is followed by the sign VELOCITY (speed), which imitates an object thrown at high speed.



LIGHT

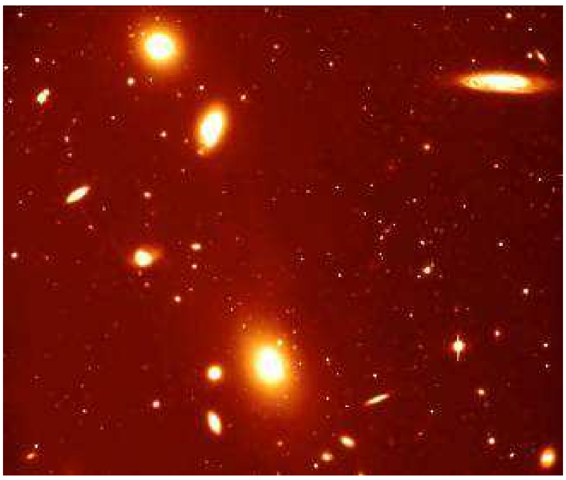


SPEED

Associated words and expressions: Galaxy - Galaxy cluster - Planet - Relativity - Spectra - Star - Sun - Universe - Wave - Wavelength.

Light is defined as the totality of waves of the **electromagnetic spectra** (see this entry) which the eye is capable of seeing in a domain of wavelengths ranging from 400 to 800 nanometres (a nanometre = 10^{-9} metres, that is 0,000000001 metres).In 1669, *Isaac Newton* (1642-1727) set out a theory on the nature of white light which he thought of being an assembly of particles. This idea came to an end in the 20th century when physicists demonstrated that the wave aspect of light reflected the collective behaviour of particles named **photons**, which move at the speed of light. So, the light which we receive from the Sun is made up of photons that left it eight minutes earlier.

Light that results from all the constituents of the universe travels in space at a speed of 299,792 kilometres per second. Thanks to this, we can know both the physical as well as the chemical nature of the planets, as well as those of the stars and galaxies, such as they were when the beam of light left its host to travel to us. We can know, for example, the nature of galaxies which composed a galaxy cluster such as ACO 3341 several hundred million years ago, which is the length of time that the light has taken to reach us. Light thus brings us innumerable messages from the past, from the closest to the most distant.

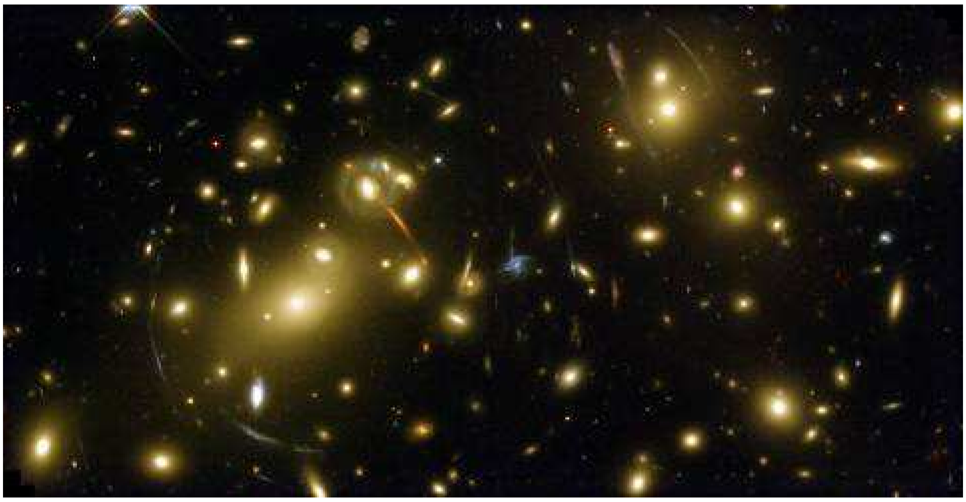


The galaxies of the cluster ACO 3341. © ESO

Light has surprising properties which were highlighted by numerous physicists, in particular *Albert Einstein* (1876-1955). For example, if a traveller could move at a speed near to that of light close to a beam of light, he would notice that the speed of this beam would be the same as if it were measured from the ground (see the entry *Relativity*). We cannot thus add or subtract our own speed from that of light which is a **constant**.

Another property demonstrated by *Albert Einstein* is that if rays of light move in a straight line in space, they are bent by gravitational attraction when they pass near a massive body, a star or a galaxy. This is why the rays of light resulting from a very distant galaxy, which have to cross a cluster of galaxies (see this entry) to reach us, produce a **gravitational arc**. The analysis of the light of this arc by means of spectroscopy provides us with information which l allows us to know the distance of this distant galaxy.

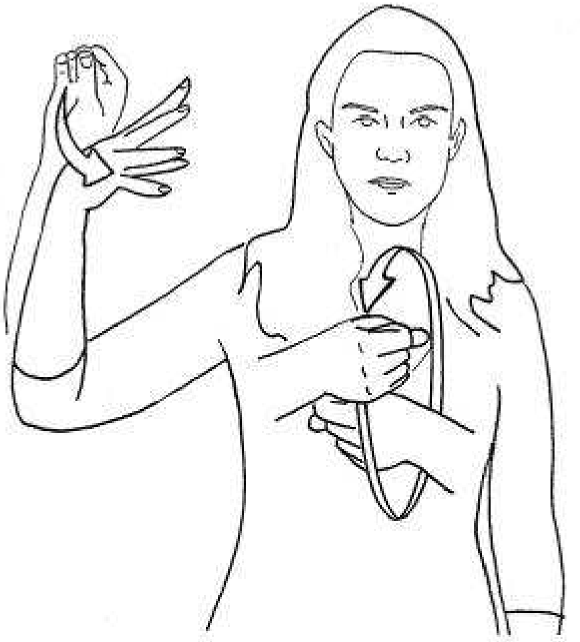
It is because all the components of the universe emit light that it is possible to know the past and the evolution of the bodies which constitute it.



Gravitational arcs in the galaxy cluster A2218. © NASA/HST

Light-year

The concept of a light-year is expressed by the sign ***year*** followed by the sign ***light*** (q.v.).. The sign ***year*** reproduces the movement of rotation of the Earth around the Sun and was already being used in institutions for deaf children at the beginning of the 19th century. In order to avoid the repetition of the composite sign LIGHT-YEAR during a conference in astronomy, we can adopt the alphabetical abbreviation A-L.



Associated words: Astronomy - Distance - Earth - Galaxy - Jupiter - Moon - Particle - Planet - Photon - Star - Sun - Telescope - Velocity.

In astronomy, the light year is a much easier to use than the kilometre to measure very large distances. Photons, particles which compose light, move at a velocity of about 300,000 km/s in a vacuum. A light year thus represents the distance travelled in one year by these particles.

Because one year includes 365 days and because a day has 24 hours and because one hour has 60 minutes and because one minute has 60 seconds, a light year is worth:

$$300\,000 \text{ km/s} \times 60 \text{ seconds} \times 60 \text{ minutes} \times 24 \text{ hours} \times 365 \text{ days, giving:}$$

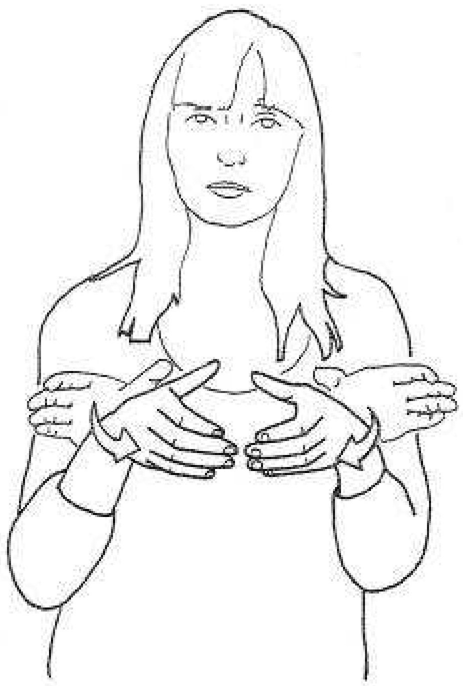
1 Light-year = 9,460,800,000,000 km

The Moon is thus 1.25 light-seconds from the Earth; the Sun is at eight light-minutes; the planet Jupiter at one light-year; and the pole star at 300 light years. As a result, we see this star such as it was 300 years ago which is the time that its light has taken to reach us. The most distant galaxies currently being observed with the largest telescopes are eight billion light years distance from our planet.

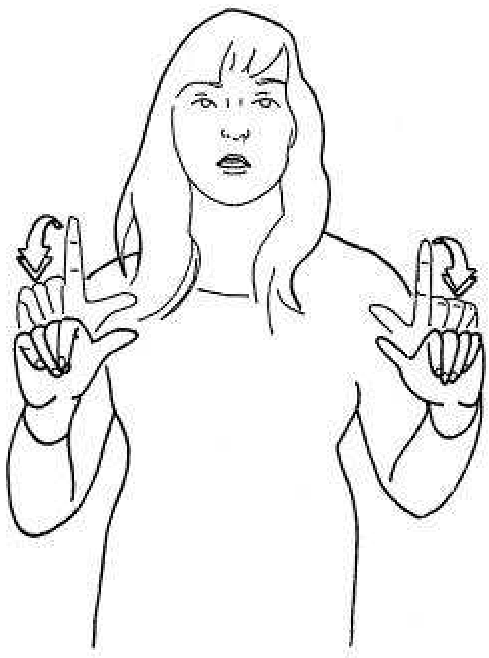
Local group, Local cluster and Local supercluster

The *Local group* of galaxies to which our Milky Way belongs is represented in Sign Language by the sign GALAXY (see the entry *Galaxy-General*) followed by the sign GROUP and finally with the sign HERE. In this context, "HERE" means "LOCAL" and is formed by the joining of the two letters "L" and "A" ("là" meaning "HERE" in French).

The *Local cluster* of galaxies, a structure larger than the local group, is indicated by the sign GALAXY followed by the sign CLUSTER (entry GLOBULAR CLUSTER), and finally by the sign LOCAL.



GROUP



LOCAL

Associated words and expressions: Galaxy (type) - Interaction (gravitation) - Light year - Magellanic Clouds - Milky Way - Radiogalaxy - Sun - Solar System - Telescope - Universe.

The organization of the universe looks like a Russian doll (*Matriochka*) where smaller ones fit into others in order of size. The Solar system is a part of our Galaxy (the Milky Way), which itself belongs to the **Local Group of Galaxies**. This is situated on the periphery of a bigger structure, the **Virgo Cluster of Galaxies,** which is a cluster of galaxies situated towards the constellation of Virgo, with which it constitutes the **Local Cluster of Galaxies** (see the entry **Galaxy-cluster**). Finally, the Local Cluster is also a member of a larger structure, the **Local Supercluster of Galaxies**.

The "Matriochkas", Russian dolls which fit into one another. © Wikipedia

The « Matriochka » of the universe.

- The **Earth** is in the **Solar System**.

- The **Solar System** is in the **Milky Way**.

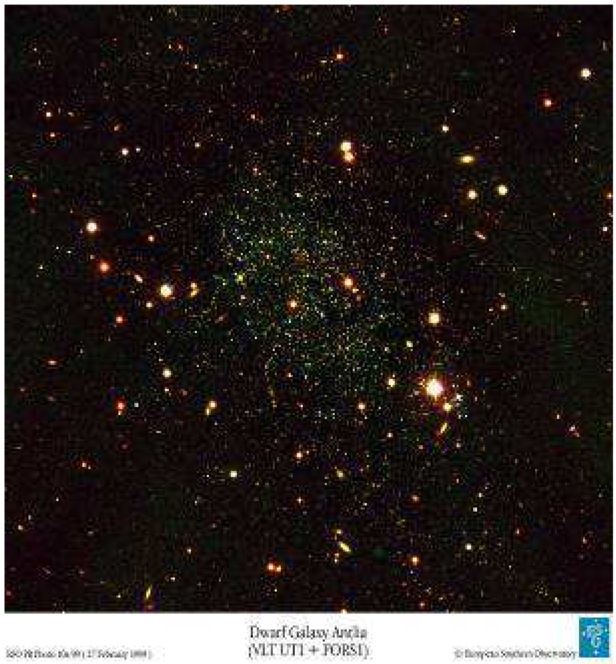
- The **Milky Way** is in the **Local Group**.

- The **Local Group** is in the **Local Cluster**.

- The **Local Cluster is in the Local Supercluster**.

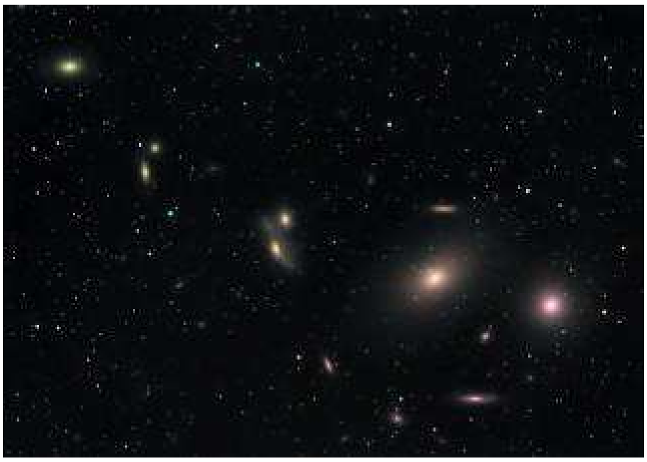
- The **Local Supercluster** is in the **universe**.

The **Local Group,** to which our own Galaxy (the Milky Way) belongs, has a diameter of about ten million light years and contains the principal types of galaxies (see the entry *Galaxy-type*). The Milky Way and the galaxy M31, situated at 2.8 million light years in the constellation of Andromeda, are the two most important ones. We also find the spiral galaxy M33 in the constellation of the Triangle, at a distance of three million light years. Several elliptical dwarf galaxies are members of the Local Group such as M32 in Andromeda at a distance of 2.3 millions light years, as well as nearby dwarf galaxies, such as the one situated in the constellation Antlia ("the Pneumatic Pump"), at 3.75 million light years. The two Magellanic Clouds, easy to observe with the naked eye in the southern hemisphere, are also members of the Local Group.
All the galaxies which constitute the Local Group are bound together by gravitational force. Thus the galaxy M31 is getting closer to us at the rate of 300 km/s and will collide with the Milky Way in five billion years time.



Dwarf galaxy of the Local Group, situated in the constellation of the "Pneumatic Pump". © ESO

The Virgo cluster of galaxies is between 50 and 70 million light years distant. It consists of about 2,000 galaxies some of which are easily observable with a small telescope. We find the various types of galaxies there: spiral, elliptical and irregular. Its mass is estimated to be 10^{14} times that of the Sun.
The Virgo cluster of galaxies is a part of an even larger structure in which it occupies: the centre: **The Local Supercluster**. This includes several thousand galaxies, such as the radiogalaxy of Centaurus, which is situated at a distance of 14 million light years from the Sun.



The Virgo cluster of galaxies. © NASA/HST

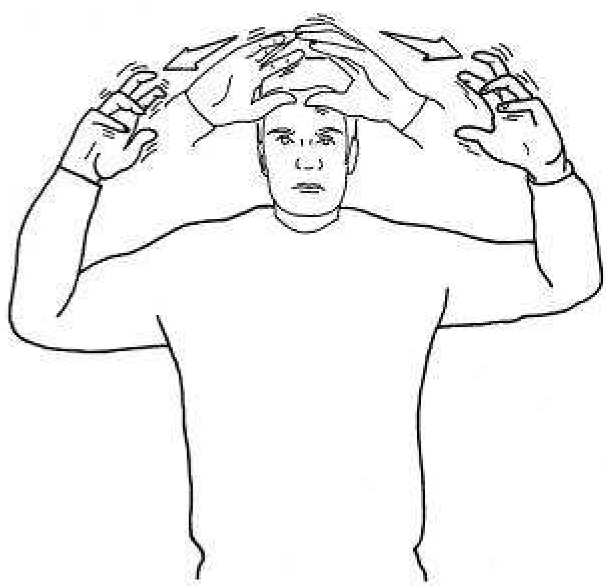
The radiogalaxy of Centaurus. © ESO

The universe contains numerous superclusters of galaxies, such as that of **Coma** (Berenice's hair) situated beyond the Local Supercluster at a distance of 300 million light years. Observations indicate that these superclusters could be interconnected by immense filaments tens of millions of light years in length, composed of individual galaxies.

A part of the Coma (Berenice's hair) Supercluster of galaxies. © NASA/HST

Magellanic clouds

The **Magellanic clouds** are represented by the sign CLOUD, a shaking of the fingers which refers to the multitude of the stars which make them up. This can be followed by one of 2 signs, BIG or SMALL. Moreover, to avoid any ambiguity, we can then spell the name “Magellan” or reduce it to its initial letter “M”.



Associated words and expressions: Astronomer - Diameter - Distance - Equator - Galaxy - Light year - Local group - Mass - Milky way - Star - Sun - Supernova.

Tradition attributes the observation of these two nearby galaxies of the southern hemisphere to the sailor *Fernando de Magellan* (1480-1521). In reality, they were known to all the old civilizations situated South of the equator. With the naked eye, they appear as two pieces of the Milky Way which have become detached. They are actually two small galaxies situated in the neighbourhood of our own Galaxy. We can tell the **Small Cloud** and the **Large Cloud** apart by their size. Astronomers have observed a long moving belt of gas which connects both Clouds to the Southern Pole of our Galaxy, proving that there is a real interaction. Both Magellan Colds are a part of the Local Group (see this entry).

The **Large Magellanic Cloud** is an irregular galaxy (see the entry : *Galaxy-type*) situated in the Dorado constellation at a distance of 173,000 light years from Earth. Its diameter is 22,000 light years. It rotates on itself at a velocity of 70 km/s and is approaching our Galaxy at a speed of 275 km/s. Its mass is ten billion times that of the Sun.

The Large Magellanic Cloud. © ESO

The appearance of a supernova on February 23rd, 1987 allowed us to confirm its distance. There are three populations of stars in the Large Cloud. The presence of hot and young stars (less than a billion years old) proves that, in this small galaxy, there is intense stellar activity. We find also older stars from one to three billion years old along with a group of stars formed more than ten billion years ago.

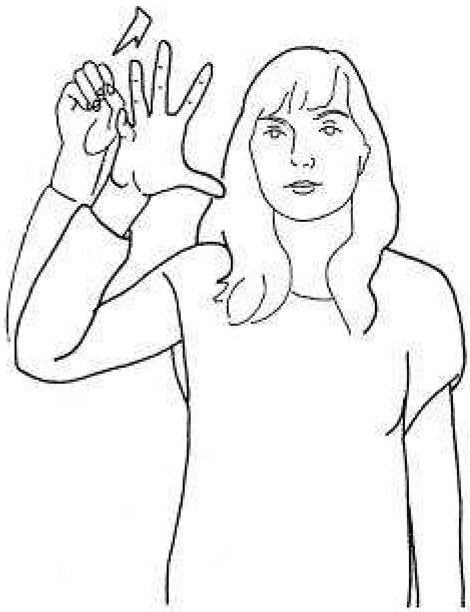
Situated in the Tucana constellation, the **Small Magellanic Cloud** has a more complex structure than that of the Large Cloud. Astronomers have observed that it appears to be “facing” us, so its shape is difficult to study. Less massive than the Large Cloud, it is however richer in gas which is about 20 % of its total mass. Its diameter is 10,000 light years and it is 196,000 light years away from us. It has a mass of two billion times that of the Sun.

The Small Magellanic Cloud. © ESO/Stéphane Guisard

Details of the Large and Small Magellanic Clouds observed with the Hubble Space Telescope. © NASA/HST

Magnitude (photometry)

The concept of "magnitude", associated with the measure of the brightness of a celestial body, is expressed with the sign LIGHT, possibly followed by the letter "M" (initial of the word magnitude) and by a numerical value.

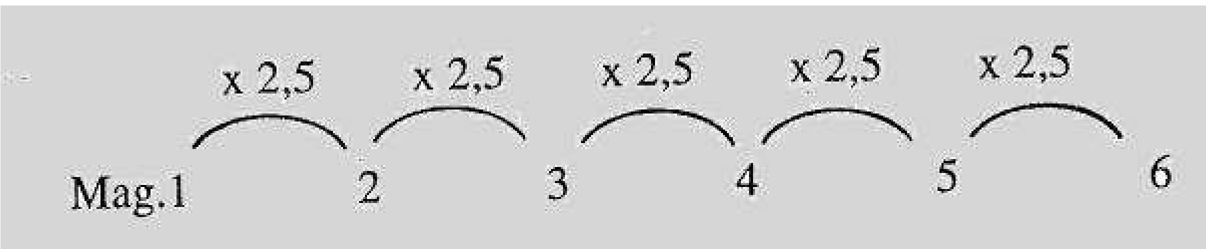


LIGHT

Associated words and expressions:
Astronomical unit - Colour - Constellation - Earth - Galaxy - Light - Light year - Parsec - Planet - Solar System - Spectral type - Spectroscopy - Star - Temperature - Universe.

The **visual magnitude** of a star, a planet or any other bright object of the universe is a measure of the quantity of light received on Earth. This quantity is greater or less in the same way as a 100 watt bulb emits more light than a 40 watt one at the same distance.

The Greek astronomer *Hipparchos*, who lived in the 2nd century BC, established a catalogue of 1,024 stars visible with the naked eye. According to the "intensity" of their brightness, he classified them into six categories, from the most brilliant (magnitude 1) to the weakest (magnitude 6). Nowadays, the term of *visual magnitude* describes the brightness of a star, so that a star of magnitude *n* is 2.5 times as brilliant as a star of magnitude *n+1*; in mathematics, this ratio is called a *logarithmic scale* as shown below :



The magnitude scale.

So, a magnitude 1 star is 2.5 times as brilliant as a magnitude 2 star; it is 2.5 × 2.5 (= 6.25) times more brilliant than a star of magnitude 3, and so on. A star of magnitude n is thus a hundred times more brilliant than a star of magnitude n+5. Astronomers attributed magnitude 0 (zero) to the star *Vega* of the constellation of the Lyre so that celestial bodies more brilliant than *Vega* have a negative magnitude. The following table gives the magnitude of some bodies in the Solar system and of the twenty most brilliant stars with the name of their constellation:

Sun	-26.73	Vega (Lyrae)	0.0	Betelgeuse (Orion)	0.8
Full Moon	-12.6	Capella (Auriga)	0.1	Antares (Scorpio)	0.9
Venus (maximum)	-4.4	Procyon (Canis Minoris)	0.3	Spica (Virgo)	1.0
Mars (maximum)	-2.8	Achernar (Eridanis)	0.5	Pollux (Gemini)	1.1
Sirius (Canis Majoris)	-1.6	Agena (Centaurus)	0.6	Fomalhaut (Pisc Austr)	1.2
Canopus (Carina)	-0.7	Altaïr (Aquila)	0.7	Deneb (Cygnus)	1.3
Rigel (Orion)	-0.3	Aldebaran (Taurus)	0.8	Mimosa (Crux)	1.3
Arcturus (Bootes)	-0.1	Acrux (Cux)	0.8	Regulus (Leo)	1.3

In the Solar system, the magnitude of a planet or a comet gets weaker and weaker the further we go away from it. Stars, the distance of which to the Earth can be considered more or less invariable at the scale of our measuring instruments, keep approximately the same magnitude.

Astronomers also use **absolute magnitude**, which corresponds to the brightness of a star situated at a distance of 10 parsecs. The parsec is the distance of about 150 million kilometres which separates the Earth from the Sun (astronomical unit) seen under an angle of 1 arc second. At a distance of 10 parsecs, the Sun would be just visible to the naked eye with a visible magnitude of 5.3.

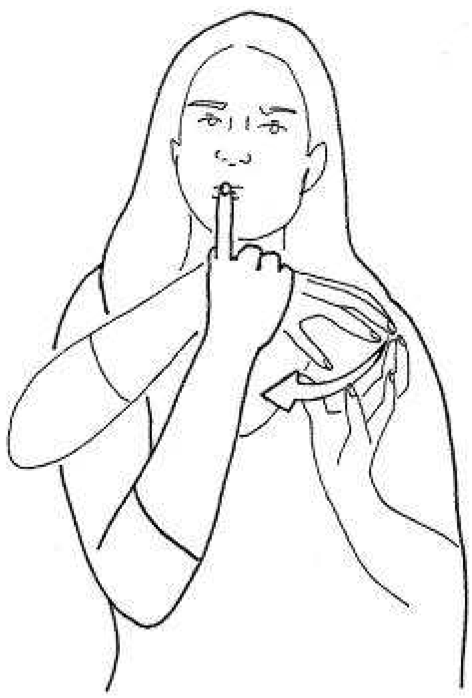
Photometry

All the components of the universe emit radiation in all wavelength ranges from ultraviolet to infrared, including the visible. We measure the luminous intensity of a celestial body through various filters and thus deduce from it the colour, temperature, spectral type (of a star) and many other characteristics. This method is named **photometry**, and is a precious tool which completes the information supplied by spectroscopy to enable us to know the structure and evolution of a star or a galaxy.

The M42 Orion nebula, a nursery of new born stars at a distance of 1,500 light years, and visible with the naked eye. Its visual magnitude is about +5. © ESO

Mars

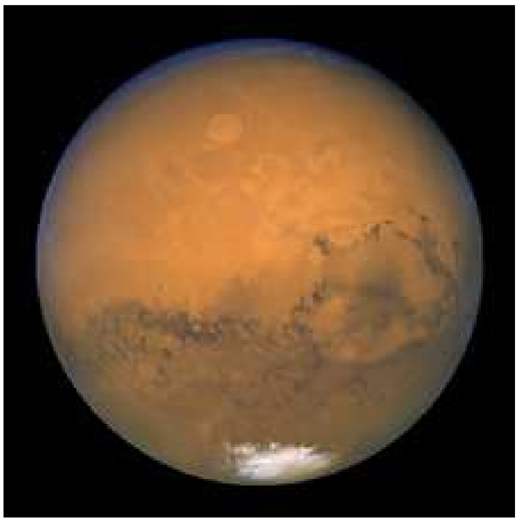
The name of **Mars** in Sign Languge uses its popular name: PLANET followed by RED.which is referenced to the colour of lips. For the etymology of PLANET, see the entry EARTH. (Note that the sign for the month of March ("Mars" in French) is completely different. It doesn't refer to the planet but to period of abstinence during Lent.)



Words and associated expressions:
Astronomer - Crater - Ellipse - Earth - Planet - Satellite - Solar System - Star (binary) - Volcano.

The **planet Mars** is one of the five planets visible to the naked eye. Numerous civilizations associated its red colour (the colour of blood) with the theme of the war. This is why it has the name of the Roman god of the war: *Mars*. Its apparent movement through the sky was the object of long and meticulous observations by the Danish astronomer *Tycho Brahé* (1546-1601). By analyzing the measures of Brahé, the German astronomer Johannes Kepler (1571-1630) noticed that the movement of Mars around the Sun is not a circle, but an ellipse. It is the same for all bodies which revolve around a celestial body more massive than them, whether planets, moons or binary stars.

Distance : Mars is at an average distance of 227,936,600 km from the Sun.
Diameter : With a diameter of 6,804 km, Mars is smaller than the Earth.
Inclination : Its axis is almost identical to that of the Earth : 25° 19' ; Mars has both a summer and a winter.
Rotation : Mars rotates in 24 h 37m 22 s ; a day on Mars is almost identical to that on Earth.
Revolution : Mars is revolves around the Sun in one year and 322 days.
Temperature : on the surface of Mars, the temperature can be as low as -140°C in winter, but can reach +20°C at the equator during its summer.



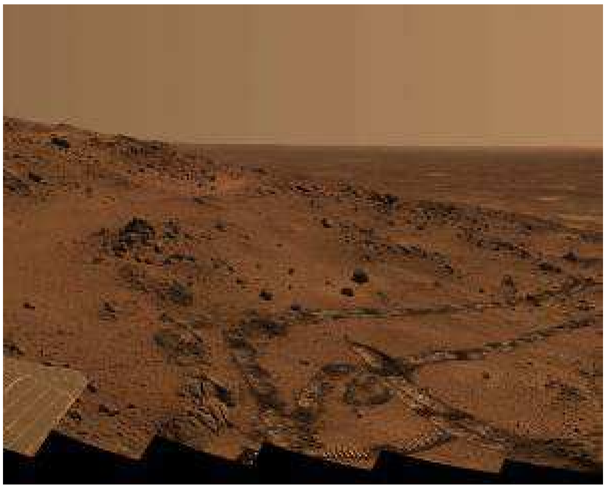
Mars observed with the Space Telescope. North is up. © NASA/JPL

Atmosphere: Mars is has a **very thin atmosphere**, approximately 150 times less dense than that of the Earth. It is essentially composed of carbon dioxide (CO_2 - 95 %) and with nitrogen (N_2 - 3 %). You cannot breathe on its surface without a breathing apparatus. Nevertheless winds blow and raise very big dust clouds.

The similarities between the Earth and Mars are numerous. That is why astronomers thought for a long time that both planets were identical, and supposed that "Martians" could exist. Observations made with refractors in the 19th century seemed to show straight and dark lines, which were called **canals**. For these reasons, Mars was of particular interest to astronomers. Space exploration has shown that these canals do not exist; they are only optical illusions due to the imperfections of old instruments.

Martian soil is of red colour because of the iron oxide (Fe_2O_3) which is on its surface. Thanks to spacecraft launched from Earth and vehicles which were landed on Mars, we now have a good knowledge of the Martian terrain. It is divided into **two very different regions**. The northern hemisphere is rather flat, covered with silicon oxide (oxidized sand) and volcanic rocks. Conversely, the southern hemisphere is formed of **high plateaus** with many craters. In the past, there was some water on the surface of Mars, and there was possible an ocean covering the northern hemisphere. There are also **old river beds** and **dried up streams** going down from the hills.

One of the two **polar caps** is very noticeable for its white colour at the bottom of the picture above. Both polar caps are formed mostly of iced water along with ice-cold carbon dioxide. The ice is about ten metres thick.



The surface of Mars with the tracks of the wheels of the robot vehicle. © NASA/JPL

Old dried up streams on Mars. © NASA/JPL

There are **volcanoes** on the surface of Mars. The tallest, *Olympus Mons* (Mount Olympus) is the highest mountain in the Solar System, with a height of 25,000 m (Mount Everest on Earth is 8,827m). The diameter of this volcano is 600km. The volcanoes on Mars are not active; the most recent lava flows dating from two million years ago.

Future space missions will teach us by digging into the Martian soil where the planet's water went to and if forms of life remain under ground.

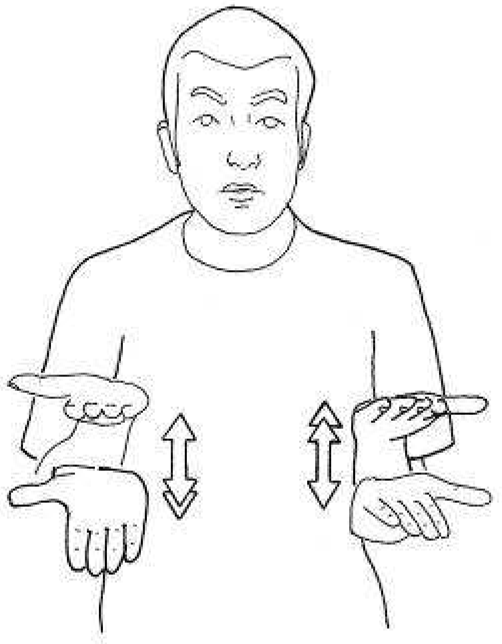
The volcano Olympus Mons. © *NASA/JPL*

Mars is accompanied by two very small satellites which are possibly asteroids which the planet captured. Their names, **Phobos** and **Deimos**, are those of the horses hitched to the chariot of Mars, the god of the war. They have the following characteristics:

Name	Diameter (km)	Distance from the planet (km)	Revolution every:	Discovered by
Phobos	22	9,385	7h 29m	Hall (1877)
Deimos	13	23, 450	1d 6h 17m	Hall (1877)

Mass

The idea of **mass** is associated with that of weight. In Sign Language, we represent "mass" with the sign TO WEIGH, while specifying whether we are talking about a "heavy" or a "light" body.



Associated words and expressions: Atomic mass **-** Attraction - Element - Earth - Interaction - Jupiter.

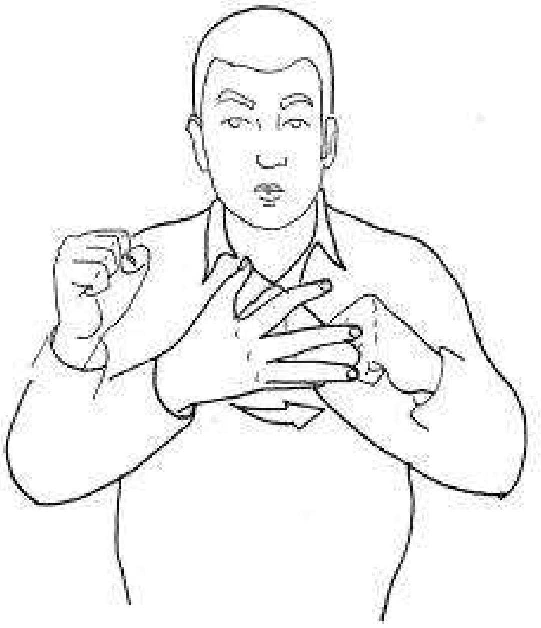
Mass is a specific property of a body, bound both to the quantity and nature of its matter. One kilo of feathers and one kilo of lead both weigh the same but you need a much bigger quantity of feathers than lead to arrive at such a balance. This is linked to the nature of feathers which are composed of a lot of carbon, the atomic mass of which is 12 (6 protons and 6 neutrons, see the entry *Elements*) as well as other lighter elements whereas the atomic mass of lead is 207.

The mass of a body allows us to know the strength of attraction that it exercises and consequently its weight which you get by multiplying this mass by the acceleration of gravity at a given point (see the entry *Interaction*). We should not confuse **mass**, which has an absolute value, with **weight** which has only a relative value which varies according to its location.

Mass is measured by comparison with a standard. We measure the mass of the planets by comparing them to the Earth. The mass of Jupiter is 318 times that of the Earth. We measure the mass of stars and galaxies in comparison to the Sun. The mass of M31 (the galaxy of Andromeda) is 300 billion times that of the Sun.

Mercury

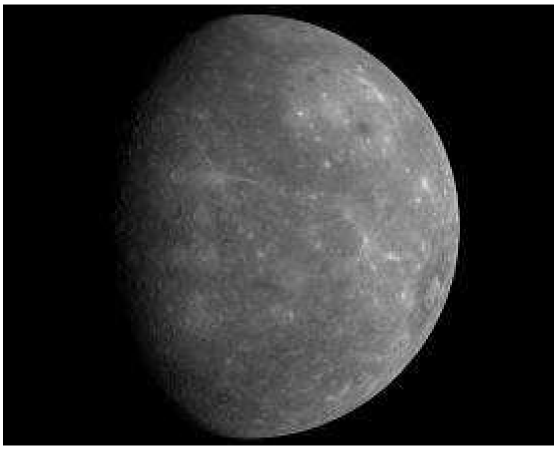
The sign MERCURY shows a planet (represented here by a closed fist) illuminated by light projecting from the Sun, represented by the other fist which opens wide.



Associated words and expressions: Crater - Moon - Phase - Solar System - Sun - Telescope - Venus.

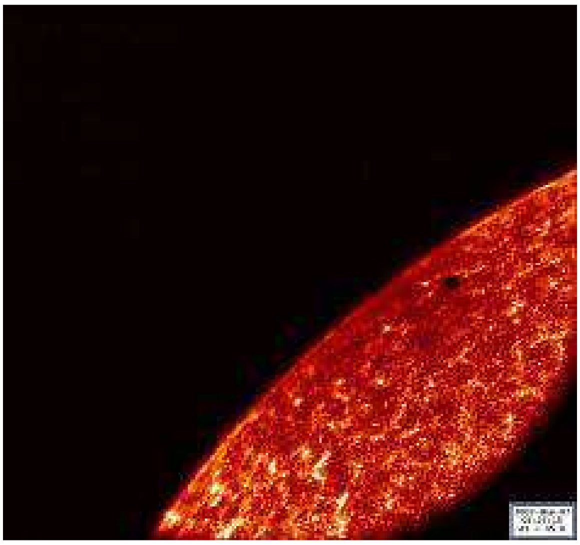
Among all the planets, Mercury is the closest to the Sun and is thus only visible in the morning shortly before sunrise or in the evening shortly after sunset. Flooded in the light of the Sun, it is difficult to spot. Because of the velocity of its movement in the sky, the former Greeks gave it the name of *Mercury*, god of travellers and messengers.

Distance : Mercury is 57,900,000 km from the Sun.
Diameter : 4,880 km.
Mass : its mass is only 0.05 times the Earth's.
Rotation : the rotation of Mercury is very slow: the duration of a Mercury day is 58 days and 15 hours.
Inclination : its axis is inclined by only 7°.
Revolution : Mercury revolves around the Sun in 88 days.
Atmosphere : the atmosphere of Mercury is a very thin gas layer composed by potassium (K - 31 %), sodium (Na - 25 %) and oxygen (O_2 - 10 %).
Temperature : because of the lack of atmosphere, there is a large variation of temperature, from +178°C on the sun-lit side, to -180°C on the dark one. There is a similar phenomenon on the Moon.



The planet Mercury © NASA/JPL

Relief : Mercury's landscape is rather flat which is an indication of important volcanic activity in the distant past. As with the Moon, a large quantity of craters cover its surface.



Mercure in front of the Sun disk on 7 May 2003.
© NASA/JPL

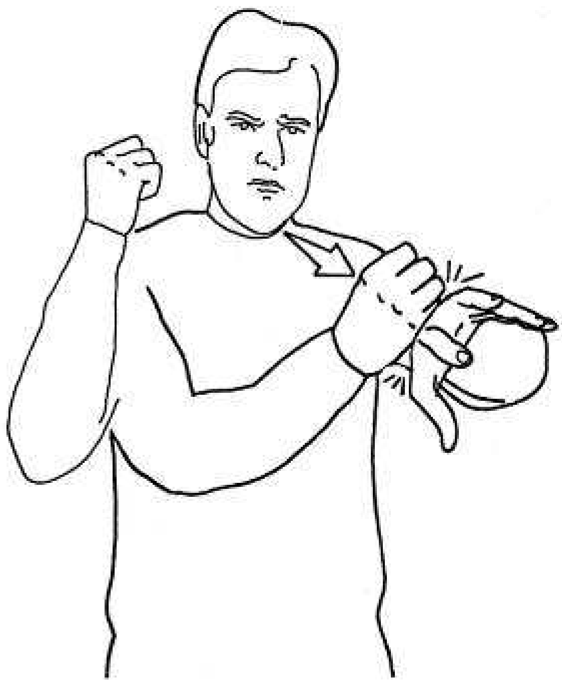
As Mercury is closer to the Sun than the Earth, it sometimes passes between these two celestial bodies. It is then possible to observe it as a small black spot moving on the solar disk, **but do not forget to protect your eyes from the light of the Sun**. The last passage of Mercury in front of the Sun occurred on 9th May 2016.

As Mercury is lit from face-on or from the side, it shows similar phases as Venus and the Moon, with quarters and crescents (see the two entries *Venus* and *Moon*) observable with a small telescope.

Like Venus, Mercury has no moon.

Meteorite (Meteor)

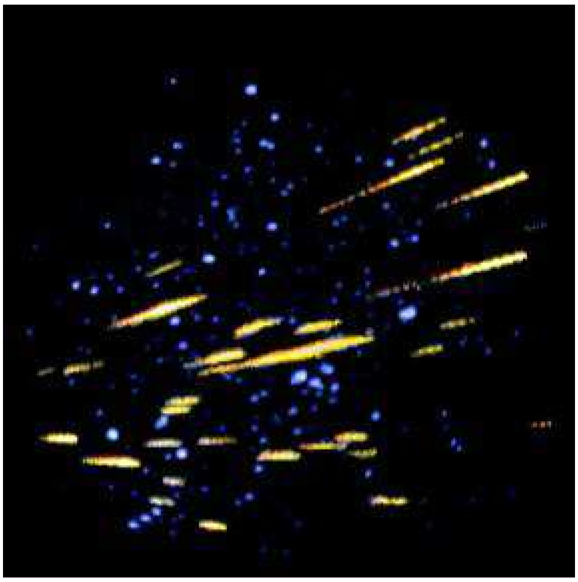
The sign METEORITE shows a solid object, more or less round in shape, represented by a closed fist, which collides with the Earth, represented by the other open hand.



Associated words and expressions: Comet - Earth - Moon - Planet - Planetesimal - Revolution - Solar system - Sun.

The formation of the Solar system ended approximately 4.5 billion years ago. The different planets were formed by the agglomeration of planetesimals and dust (see the entry *Solar system*) but, as in any construction, there were fragments in the form of rocks, pebbles and dust, which are also in orbit around the Sun, and which the Earth meets during its revolution.

When they penetrate into the high layers of the Earth's atmosphere, meteorites undergo intense friction. This causes them to heat up very quickly and emit light visible from the ground; these are the famous **shooting stars**. While the great majority of specks of dust are destroyed in this way, larger pebbles can reach the ground and the bigger they are, the greater the damage that they can cause.
Meteorite showers thus represent a permanent danger for astronauts during their stay on the Moon or on the planets which do not have enough dense atmosphere to create a protective screen. However, even on Earth, we are never completely shielded from a meteorite fall.



A « meteorite shower » Perseids in August 1995.
© NASA/JPL

Every year during its revolution around the Sun, the Earth crosses the same clouds of fragment and dusts some of which are the remains of comets whose trajectory crossed the orbit of our planet. The most remarkable showers of shooting stars, which are visible every year at the same time, have been given names. The **Perseids** (around 12th August) reach us from a point apparently situated in the constellation of Perseus. There are also the **Quadrantids** (around 3rd January) which appear to come from the constellation of Bootes, the **Leonids** (17th November) from Leo, the **Geminids** (14th December) from Gemini, etc.


A fragment of the Allende meteorite. © DP

In spite of the Earth's atmosphere, numerous meteorites reach the ground. On 8th February 1969, a meteorite fell on the village of *Pueblo de Allende* in the North of Mexico, fortunately without any victims. More than two tonnes of rock were found, in the form of thousands of fragments, the biggest of which weighed more than 100 kg, and which were distributed over an area of 300 km^2.


The Meteor Crater in Arizona. © NASA/JPL

In the past, large quantities of meteorites formed craters on the Earth. The *Goss Bluff* crater, in the centre of Australia, is five kilometers in diameter. The meteorite which created it, more than 140 million years ago, had to weigh several hundred thousand tonnes. Today it is a sacred site of the Australian aborigines.

Approximately 50,000 years ago, a forty metre meteorite weighing 300,000 tons fell in Arizona, digging a crater 1,200 meters in diameter and 170 metres deep. We think that several tons of meteorites reach the Earth's surface every day.

Meteorites are divided into various types. The most common belong to two main families. **Chondrites** are constituted by a mixture of silicates, iron and nickel. They are the same age as the Solar system. The *Allende meteorite* is carbon rich and is a **carbon chondrite**.

Siderites are mainly comprised of iron and nickel. They are particularly dense and would have escaped from planets during their formation.

Milky Way

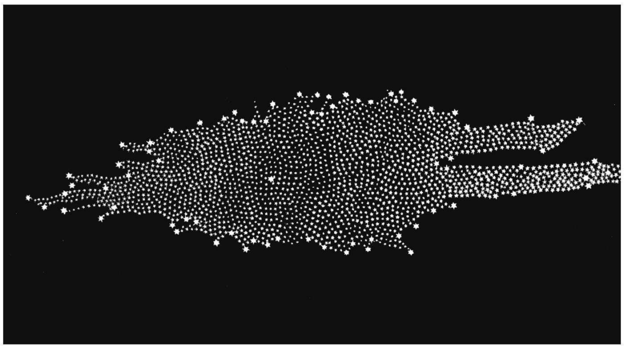
The hands reproduce the shape of the immense arch that the Milky Way traces above our heads. The spaced fingers symbolize the multiplicity of the stars that compose it

Related words and expressions: Globular cluster - Light-year - Astronomer - Constellation - Star - Galaxy - Local group - Wavelength - Magellanic Cloud - Sun - Solar system - Telescope - Earth - Black hole.

The Solar System is part of an immense galaxy that a beautiful summer night in the Northern Hemisphere, allows to observe from the inside, in the form of a broad band of diffuse stars in the sky: it is the **Milky Way** . Crossing the constellations of Perseus, Cephaeus, and Cassiopeia, the Milky Way is particularly brilliant in the Swan, and then divides into two branches, descending towards Scorpio and Sagittarius. In the Southern Hemisphere, it crosses the Centaur, the Southern Cross, the Sails and the Hull, to ascend to the northern hemisphere through the Great Dog and Orion. It is easy to see that the Milky Way is irregular, more or less broad, more or less brilliant, but that it follows almost a great circle of the celestial sphere. In a modest instrument, there are thousands of stars.

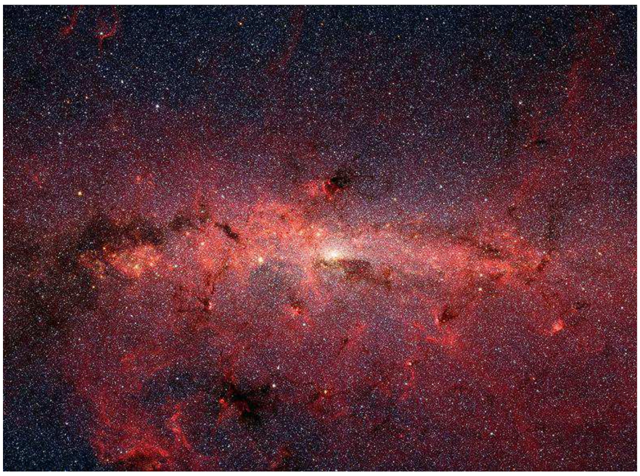
History

The origin of the name Milky Way goes back to the ancient Greeks who thought to see the drops of milk that Hercules child dropped from the breast of Juno. In 1610, Galileo (1564-1642) concludes that it consists of a myriad of stars. In the eighteenth century, astronomers issued a number of ideas about its nature. In 1755 Emmanuel Kant (1724-1804) provided an explanation of the Milky Way in the Theory of Heaven: a systematic arrangement of stars around a plane. In 1785, William Herschel (1738-1822) counted the stars visible in his telescope, and concluded that millions of stars nearly equally spaced form a very thin layer. We



Structure of the Milky Way by William Herschel, 1785.

must wait until the twentieth century to know both the real dimensions and the different characteristics: the **Milky Way** is **our galaxy**; it is also called the Galaxy, with a capital "G".

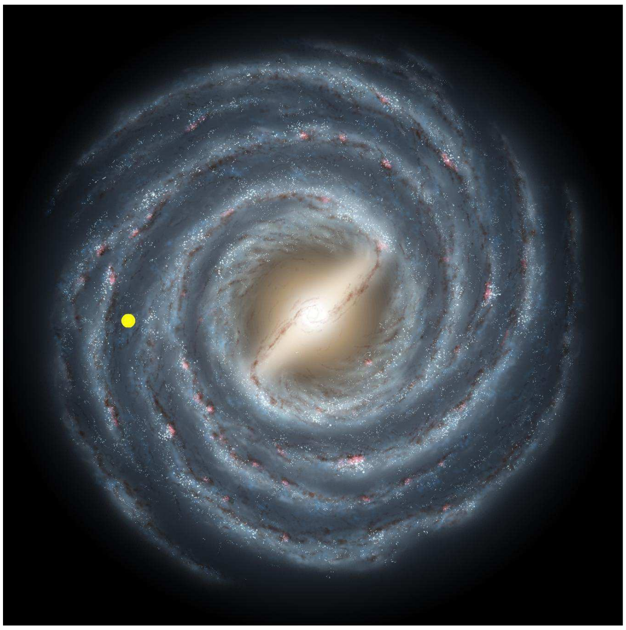


The Milky Way observed by the infrared satellite Spitzer. © NASA

What does our galaxy look like?

As the Earth is inside the Galaxy, it is difficult to know its shape and structure; Similarly, a walker in the forest can have no idea of the shape of the forest if he/she does not have a map. The work of astronomers has shown that our Galaxy resembles the galaxy M83 located fifteen million light years in the constellation of the female Hydra. The Sun is about 2/3 of its radius. Seen from Earth, the center of the Galaxy is in the direction of the constellation of Sagittarius. The numerous measurements made at the telescope now allow us to represent our galaxy "from the outside" with good precision.

Galaxy M83. © ESO



Model of our Galaxy. The yellow point marks the position of the Sun. © NASA/JPL

Identity card

Our Galaxy is a flat disc with a spiral structure (see Galaxie entry).

Diameter: 100,000 light-years.

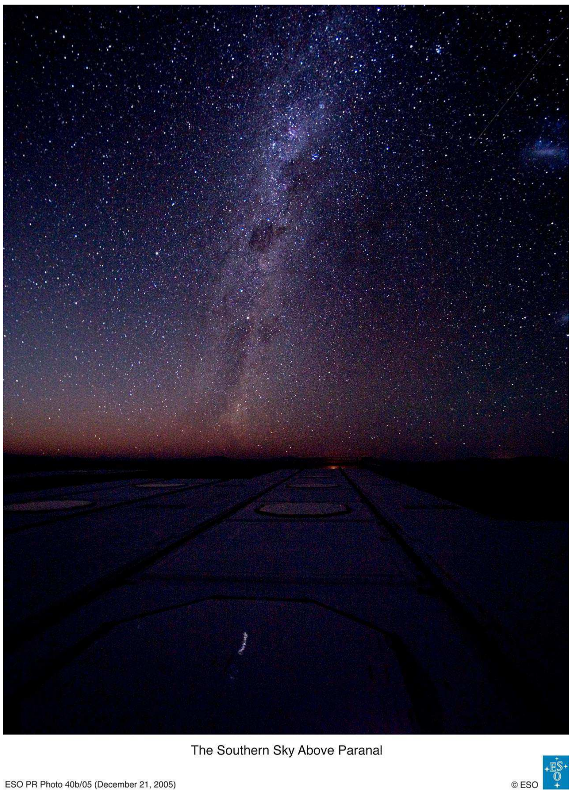
Thickness: 1800 light-years.

A large **bulb** rich in matter, 19,000 light-years in diameter and 3,000 light-years thick, occupies the central regions. The **center** emits strong X-radiation, in the infrared and radio wavelengths. It consists of a core of 1.5 billion kilometers of radius only, containing a black hole. As it approaches the center, the temperature reaches 10,000 degrees.

A dense gas **disc** where the stars born is located at 10,000 light years from the center.

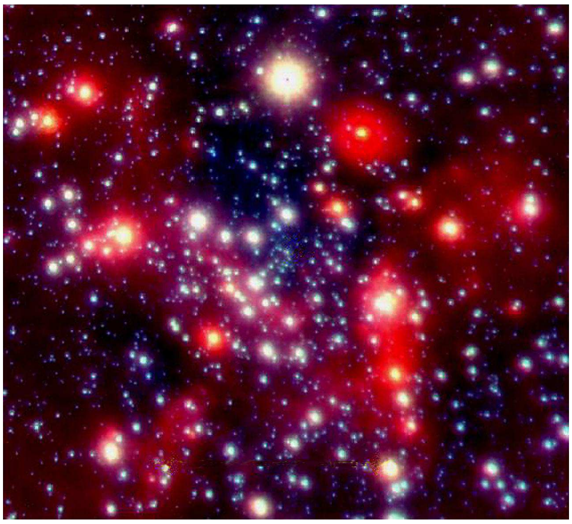
The **Galaxy is rotating** and performs a turn on itself in 220 million years, at a speed of about 220 kilometers per second. The Solar System turns 27,200 light-years from the center of the Galaxy.

The Galaxy contains about 200 billion stars, as well as gas and dust, distributed mainly in the spiral arms.



Milky Way at Paranal Observatory, Chile. © ESO

Astronomers estimate that the mass of the Galaxy is about 600 billion times that of the Sun. Ten billion years ago, the Galaxy was an enormous sphere of gas that began to turn on itself and flattened to become the disk we see today. The spiral arms are a consequence of this rotation. From this ancient gas bubble, there remains a vast halo containing globular clusters as well as gas from ancient missing stars..

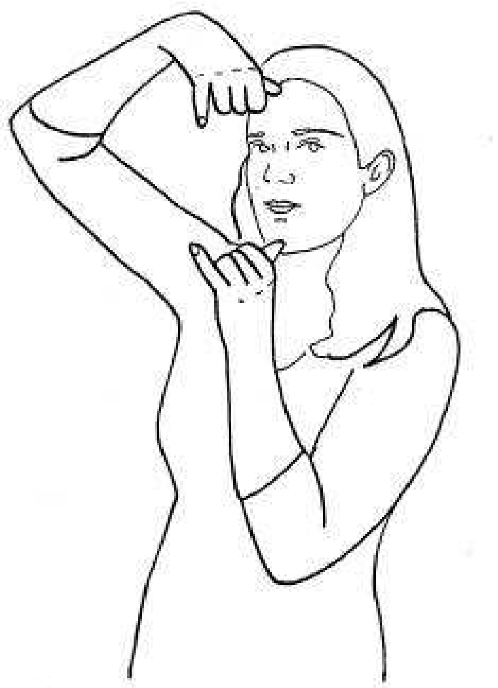


Center of our Galaxy. © ESO

Our Galaxy is accompanied by a dozen small galaxies, the two Magellanic Clouds being the most brilliant (they are visible to the naked eye in the southern hemisphere). It is part of the Local Group (see this entry) which gathers about thirty nearby galaxies.

Moon

According to popular iconography which attributes human traits to the Moon, the face is used to represent the lunar disk. In the 19th century, a flat hand dividing the face into two represented the quarters of the Moon. In the current illustration, both hands make a horn shape to represent the lunar crescent.

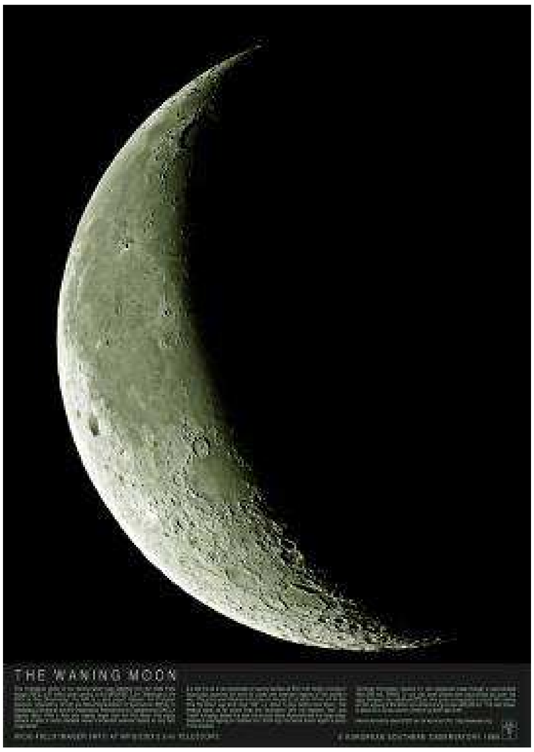


Words and associated expressions: Calendar - Earth - Eclipse - Gravitationnal interaction - Mars - Planet - Revolution - Rotation - Satellite - Sun.

The Moon offers an unforgettable spectacle of which we never grow tired. With a small refractor or a small telescope, we can observe craters, plains, faults and mountains for which the illumination changes with the Moon’s phases. The Moon is the natural satellite of the Earth; it is the only other world on which the man has set foot. It has always fascinated civilisations, inspired numerous poets, and many calendars have been established from its cycle. The crescent moon is one of the symbols of Islam.

The Moon plays a major role in the evolution of the Earth by its gravitational action on our planet. Although this action is lesser than the corresponding one that the Earth has on the Moon, it is the cause of the oceanic tides and of a part of the seismic activity and it also contributes to the Earth atmospheric circulation. As the duration of its own rotation is identical to the duration of its revolution around the Earth, the Moon always presents the same face towards us.

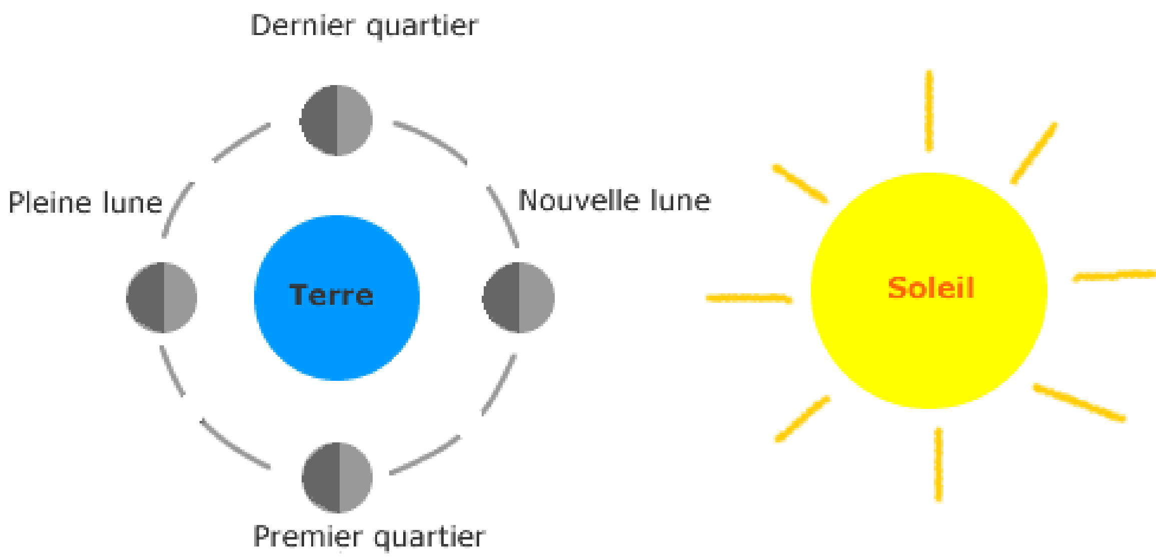
Distance : The Moon orbits the Earth at an average distance of 384,400 km.
Revolution around the Earth : The Moon's revolution around the Earth lasts for a period of 27 days 7 hours 43 minutes and 11,5 seconds.
Diameter : 3,475 km, which is barely more than a quarter of that of the Earth.
Mass : The mass of the Moon is 1/81 of that of the Earth. The **gravity** on its surface is approximately a sixth of that of the Earth: a man who weighs 75 kg on the Earth would weigh no more than 12,4kg on the Moon.
Atmosphere : The Moon has no atmosphere.
Temperature : The lunar soil is capable of absorbing 93 % of sunlight which is why the temperature of the Moon varies between +100°C when its surface is lit by the Sun, and -150°C when it is plunged into night. The Moon has an extremely low magnetic field compared with that of the Earth.



Un croissant de Lune. © ESO

The phases of the Moon

According to its position with regards to the Earth and to the Sun, we see the Moon shining partially or totally: after the **new Moon** (when it is not shining). The main phases are the **first quarter**, the **full moon** (the shining disk is circular) and the **last quarter**. The cycle of these four phases, called the **synodic cycle**, takes 29 days, 12 hours, 44 minutes and 2.8 seconds.



The phases of the Moon.

Map of the principal Moon areas, visible with binoculars

The surface of the Moon

The surface of the Moon is very rugged. We can distinguish vast dark areas, which are incorrectly called **seas**, covered with basalt of volcanic origin. The ground is riddled with a multitude of **craters** due to the multiple impact of meteorites. The biggest, the crater *Clavius*, has a diameter of 200 km and is also streaked with numerous faults and cracks, easily observable with a small telescope. Several important mountain ranges are also visible, among which are the *Montes Roots* which peak at more than 8,000 metres. It does not seem that there is any trace of water on the surface of the Moon.

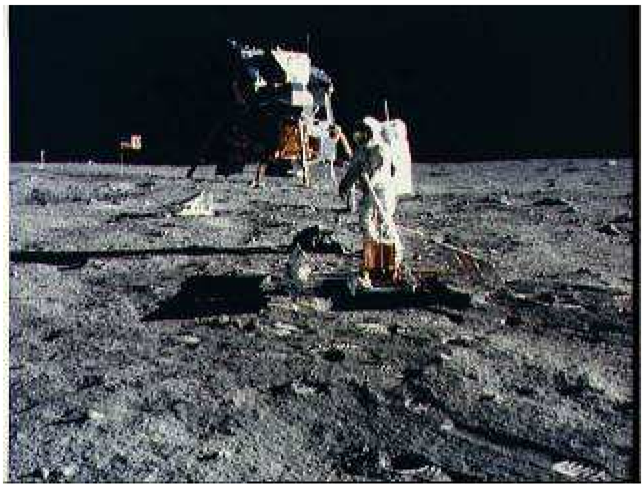
The Moon came into being about five billion years ago, when the Earth collided with a planet of the size of Mars. This explains why we find the same materials on the Moon and on the Earth, although in different proportions. More than 4.5 billion years ago, the surface of the Moon was covered with a hot liquid magma which cooled to form a crust about forty kilometres thick on average. This crust is covered with a layer of dust called *regolith*, the average thickness of which is four metres in the "seas", but which can reach fifteen metres thick on the plateaux.

Eclipses

When the Moon passes exactly between the Sun and the Earth, there is a **Solar eclipse;** when the Earth is aligned between the Moon and the Sun, there is a **Lunar eclipse**. In both cases, they are spectacular phenomena (see the entry *Eclipse*).

Man on the Moon

The Moon is the only celestial body other than the Earth where man has been. Neil Armstrong and Edwin Aldrin landed on its surface on July 21st, 1969. To this day, twelve men have walked on the Moon. They have brought back to Earth 380kg of rocks and have left a whole series of scientific instruments, among which are the reflectors which allow us to make measures of distance by laser telemetry between Earth and the Moon, with a precision of a few centimetres.


Neil Armstrong on the Moon. © NASA/JPL

Neptune

The planet **Neptune** is represented by the sign PLANET followed by an inclined very thin ring. For this second part of the sign, the hand makes a pincer shape which in sign language is the symbol of thinness.

Associated words and expressions: Earth - Observatory - Planet - Pluto - Ring - Satellite - Solar System - Uranus - Telescope.

Neptune is the most distant planet of the Solar system, Pluto having been displaced in 2006 to become the most representative of the family of "small planets". Neptune was observed for the first time by the German astronomer *Johann Gottfried Galle*, on 23rd September 1846, from the calculations based on the perturbations of the orbit of Uranus, made by *Urbain Le Verrier* (1811-1877) at the Paris Observatory. Neptune can be observed with a small telescope.

Distance : Neptune is 4,498,253,000 km from the Sun.
Diameter : it has a diameter of 46,300 km, much bigger than the Earth.
Mass : its mass is 17.26 times greater than that of the Earth.
Inclination : its axis is slightly more inclined than the Earth's at 29°.
Rotation : the length of a day on Neptune is: 15 hr 6 min 36 sec.
Revolution : Neptune orbits the Sun every 164 years and 343 days.
Temperature : the average temperature on Neptune is -220°C.

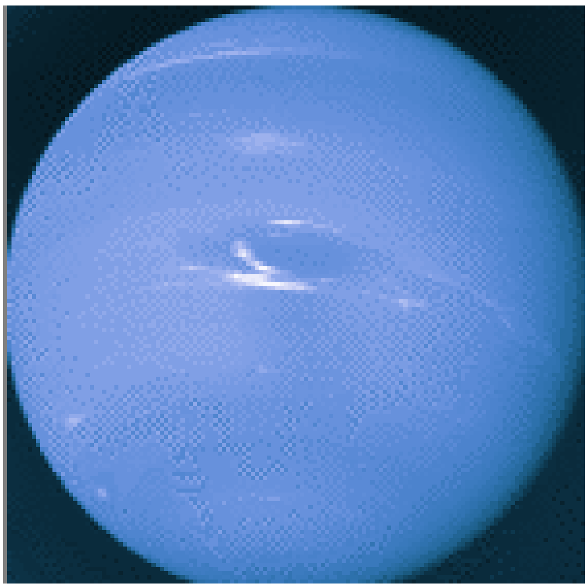


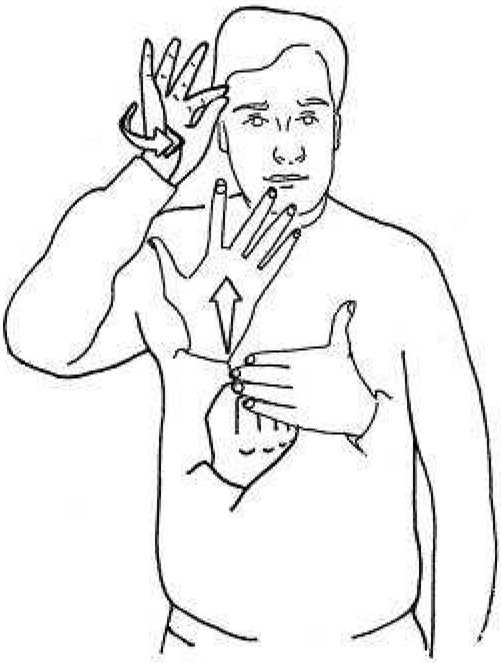
Image of Neptune taken by the spacecraft Voyager II, on 20th August 1989. © NASA/JPL.

Atmosphere : The atmosphere of Neptune, which is more than 8,000 km thick, is similar to that of Uranus. It mainly consists of hydrogen (H_2 - 84%), helium (He -12%), methane (CH_4 - 2%), ammonia (NH_3) and ethane (C_2H_6). Clouds form long bands in regions close to the equator. Winds can reach 2.000 km/h, and we have observed gigantic thunderstorms.
Rings : Neptune is surrounded by very thin dark rings. They were discovered in 1984 and their nature is still mysterious.
Moons : Neptune is accompanied by at least thirteen moons. **Triton** has an inverse orbit: it turns the other way from the general direction of revolution of all the moons of the other planets. Two bigger satellites have the following characteristics:

Name	**Diameter (km)**	**Distance to Neptune (km)**	**Duration of revolution**	**Discovery**
Triton	2,707	354,800	5d 21h 2mn	Lassel (1946)
Néréide	340	5,513,400	359d 21h 9mn	Kuiper (1949)

Nova

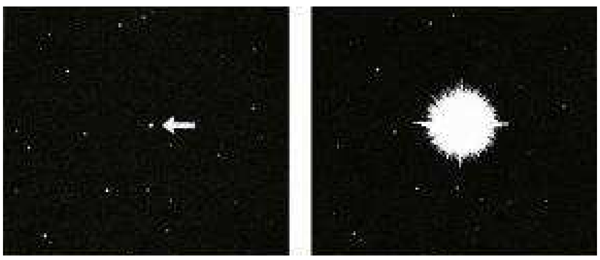
A nova, a star appearing suddenly in the sky, is shown with the sign STAR followed by the sign NEW. In the 19th century, the second part of the definition, "to make as if the fingers of the right hand burst out of inside the left hand" (abbé Lambert, 1865), has a sense of "springtime" in that it symbolizes the growth of vegetation. This meaning is then extended to any phenomenon presenting a character of newness. For the etymology of STAR, see the entry *Star-general*.



Associated words and expressions:
Astronomer - Black hole - Galaxy - Globular cluster - Light year - Magnitude - Neutron star - Nuclear (reaction) - Star - Star (binary) - Star (evolution) - Star (type) - Sun - Temperature - X-ray.

The word **nova** (plural *novae*) is an abbreviation of Latin *nova stella*, "new star". It indicates stars which appear suddenly in the sky. In the distant past, astronomers supposed that a nova was a star which was being born. Numerous novae were observed during the course of history. For example, a star appeared in the constellation of the Eagle on 8th June 1918. This was "the star of victory" for the combatants of the first World War. Although 1,500 light years from us (so that this really occurred in the Carolingian period), it became as brilliant as the star *Sirius*. Today, it is a weak magnitude 11 star which has the name *V603 Aql.* More recently, a nova was observed in the constellation of the Swan. It reached magnitude 1.7 on 31st August 1975 becoming four million times more brilliant than its initial brightness. At the end of December, 1975, its brightness had fallen again to magnitude 10 (see the illustration which shows its light curve) and it now has the name *V1500 Cyg*. Nowadays, dozens of novae are discovered every year.

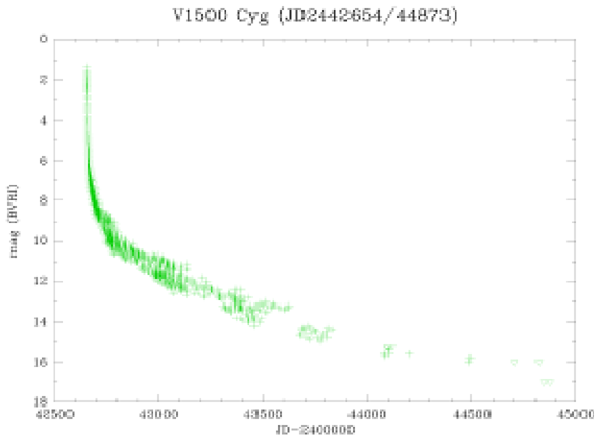
Certain novae have the peculiar property in that they reappear from time to time as in the case of *RS Oph*, in the constellation of Ophiuchus, that was discovered in 1901 but reappeared in 1933, 1958, 1967 and 1985: this type of object is called a **recurrent nova**.



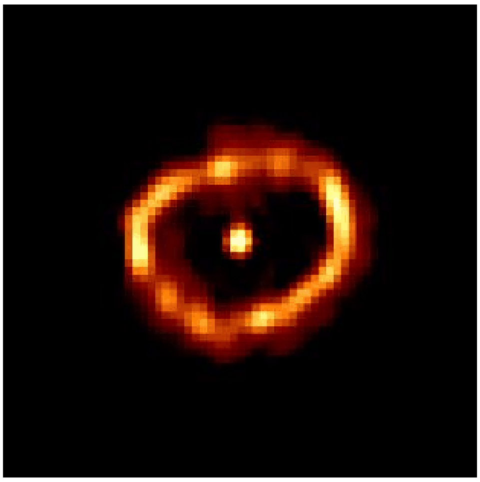
Appearance of the nova RS Oph, in the Ophiuchus constellation.

Modern telescopes allow us to understand the phenomenon at the origin of novae. **A nova is not a new star, but a binary star** composed of a red giant accompanied by a white dwarf (see the entry *Star-type*) rich in carbon and in oxygen. An important flow of hydrogen escapes from the giant under the

gravitational attraction of the dwarf, forming a ring of gas around the latter.
This is sufficient for re-activating the nuclear reactions by releasing an enormous quantity of energy, more or less what the Sun burns in 10,000 years. The ring of matter is observable in the images obtained with the use of large telescopes on Earth or in space.
The nova phenomenon is not specific to our Galaxy; we also observe it in globular clusters and in nearby galaxies.
More precise observations, in particular in the X-rays emission range, indicate that in certain binary stars, the white dwarf would be a neutron star or even a black hole.



The decrease in light emitted by the nova of the Swan 1975, observed over 2,500 days. "Holes" in the light curve correspond to the periods when the constellation of the Swan was unobservable in France. © AFOEV

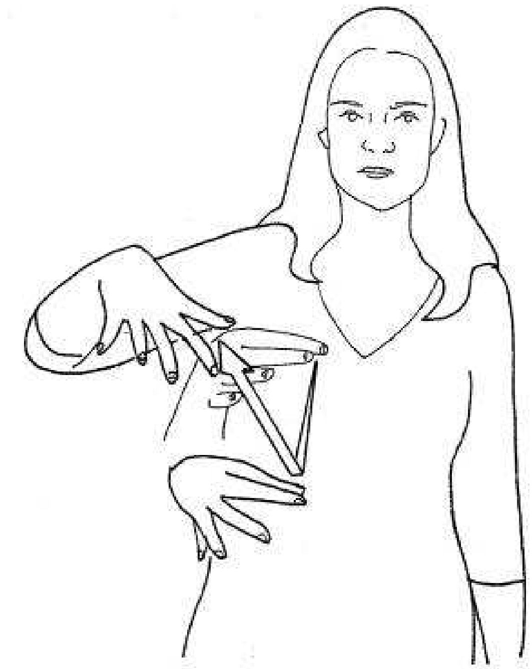


Ring of matter escaped from a nova. © NASA/HST

The recurrent nova Z Cam in the constellation of the Giraffe. © NASA/HST

Nuclear (reactions)

The polysemic sign ATOMIC / NUCLEAR shows several images: the intensity of downward movement evokes the fall of an atom bomb; the open hand which goes up represents the cloud which it causes while the hand with the pincer shape indicates the small size of an atom.



Associated words and expressions et expressions: Cosmic rays - Earth - Element - Energy - Nova - Solar system - Star (evolution) - Sun - Supernova - Velocity of the light.

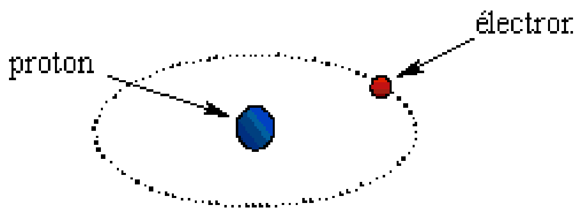
Nuclear physics describes the reactions of atoms in a star's core where the temperature reaches fifteen million degrees and where the density is very high. Stars are mainly made of hydrogen (H) (see the entry *Star-evolution*). In the central regions of the star, hydrogen is transformed into helium (He). This is the **nuclear reaction** which releases an enormous quantity of heat and energy, such as a gigantic atom bomb the explosion of which would be continuous. In this way, a star such as the Sun can shine and disperse its energy into space over several billion years.

The nuclear reaction hydrogen – helium

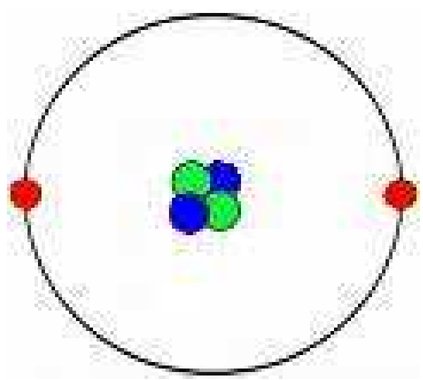
Among all the atoms present in the nature, **hydrogen** is the simplest. It is made up of a proton of positive electrical charge (+) and an electron turning around it with a negative electrical charge (-). In the core of a star, four atoms of hydrogen (four protons and four electrons) interact, but when a proton and an electron merge, they produce a neutron without electrical charge (loads "+" and "-" nullify):

proton + electron = neutron

A new atom is formed, consisting of two protons, two neutrons and two electrons; this is **helium**.



A hydrogen atom.



A helium atom (neutrons are represented in green).

A star such as the Sun shines over several billion years by t**ransforming its hydrogen into helium**, a part of which is again recycled into hydrogen.

The quantity of energy ***E*** obtained is computed using *Albert Einstein's* (1879-1955) well-known formula by multiplying the mass **m** of matter with the square of the speed of light (***c***):

$$E = mc^2$$

This very simple formula explains how an atom bomb can destroy everything on a large surface with only a small quantity of hydrogen. The Sun is thus an enormous nuclear reactor using hydrogen to make the energy which it needs.

When a star has exhausted its reserves of hydrogen, new nuclear reactions transform the helium into successively beryllium (Be), carbon (C), oxygen (O), silicon (Si), etc. (see the entry *Element*). Thus from the moment of their formation, stars have "made" all nature's elements from the lightest (hydrogen, helium) up to the heaviest (lead, mercury, uranium...), including iron or gold.

Thousands of stars in the region of the Southern Cross. Each of them "makes" nature's elements with a chain of nuclear reactions. © ESO

The various chemical elements only exist thanks to the stars which make them. On Earth, they result from the formation of the Solar system 4.6 billion years ago from an immense disk of gas and dust. Without their presence on our planet, life would probably not have developed here.

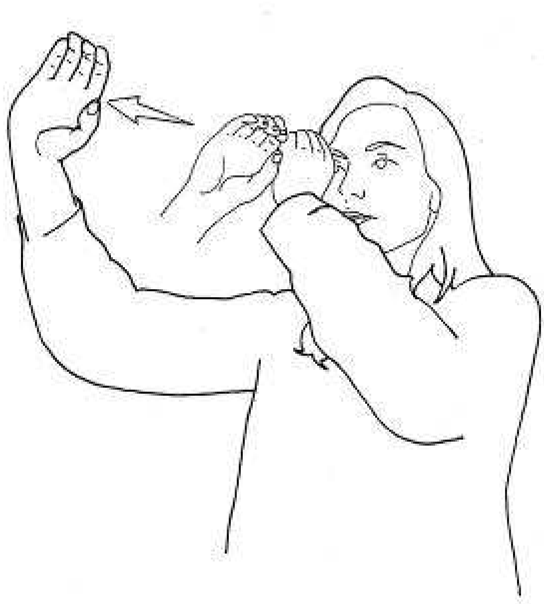
*The simplest nuclear reaction, the one which transforms hydrogen into helium, takes place by the formation of a particle, the **neutron**, without any electrical charge (the opposite electrical charges of the proton and the electron nullify). To explain this nuclear reaction in Sign Language, we first specify the nature of the hydrogen atom, then we indicate why four of them are needed to obtain an atom of helium.*

*If **e** is an electron, **p** a proton and **n** a neutron, we can more clearly explain it:*

*Four atoms of hydrogen react: **p - e**, **p - e**, **p - e**, **p - e***
*Two neutrons form: **p + e = n**, **p + e = n**, which leaves **p - e**, **p – e***
*This then forms an atom of helium: **e - pnpn - e***

Observatory

An OBSERVATORY is represented in sign langage by the sign REFRACTOR, followed by the sign DOME.

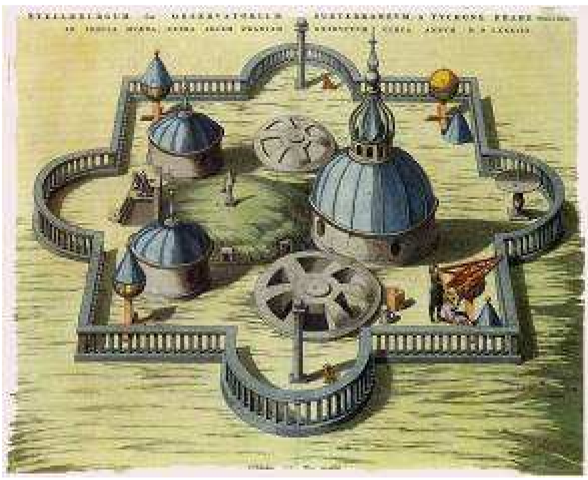


REFRACTOR

Associated words and expressions:
Astronomy - Cosmic rays - Cosmology - Earth - ISO satellite - Moon - Planet - Radiotelescope - Refractor - Star - Sun - Space Telescope - Telescope - Universe.

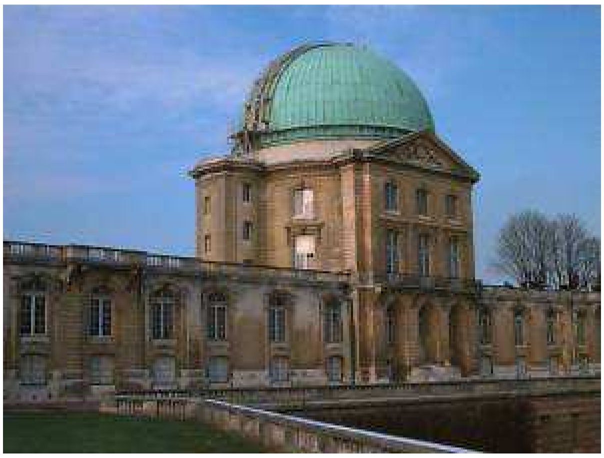
From earliest times up to the present day, mankind has observed the sky in order to understand where the Earth is situated in the universe, what is the nature of the planets and the stars which surround us, and finally what are mankind's origins. For these reasons, they settled in places favourable for observing the sky and built specially adapted buildings there, **Observatories**.

An old observatory: Tongariki in Easter Island, where according to the tradition, the huge statues keep watch over the inhabitants and observe the stars. © DP

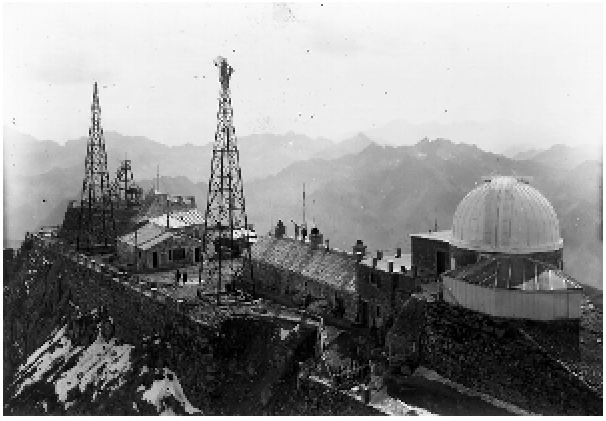


The Tycho-Brahe observatory "Uraniborg", constructed on the island of Hven in the north of Denmark.

Everywhere on Earth, the various civilizations had their observatories and their astronomers who wanted to know the secrets of the universe and the origins of man. Improvements in instruments led gradually to the construction of places specifically dedicated to observation, such as the observatory of the astronomer Tycho-Brahe (1541-1601) in Denmark.

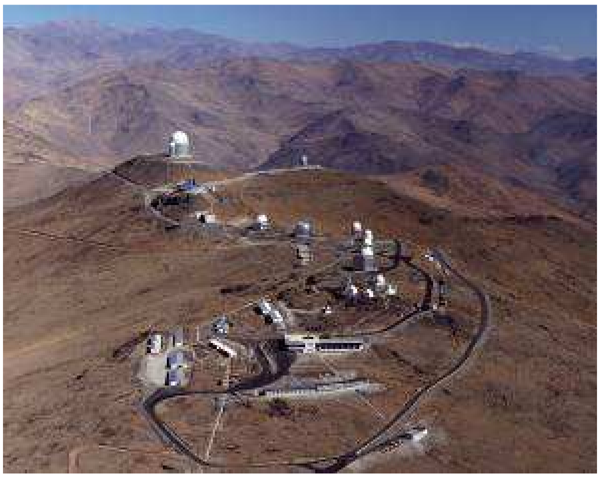


The dome containing the great refractor of Meudon observatory, constructed on a former chateau near Paris during the 19th century. © Observatoire de Paris.



The Pic du Midi observatory in the Pyrenees mountains in 1937. © IMCCE

Little by little, observatories grew in size and got closer to towns such as Meudon, near Paris, until street lighting, industrial development and pollution forced astronomers to work in the most isolated places of Earth where the sky is at its the purest. Observatories are now built on high mountains such as the *Pic du Midi* in the Pyrenees mountains.



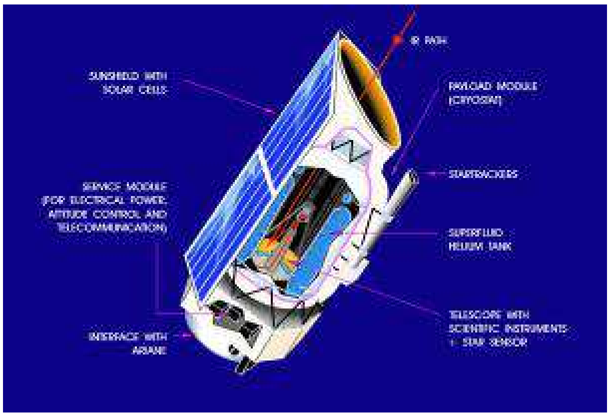
View of the domes on the European Southern Observatory (ESO) at La Silla in the Chilean Andes mountains. © ESO

The four domes of the Very Large Telescope of the European Southern Observatory (ESO), installed on the Paranal Mountain in Chile. Each dome contains a 8.20m diameter telescope. © DP

To have the best weather conditions, modern monitoring observatories are now constructed in the most remote places on Earth, in particular in the Chilean Andes, where the European community has an impressive battery of instruments up to the huge telescope (the VLT) of the European Southern Observatory (ESO). Several other observatories have also been built in the same region. Very large observatories exist also in the United States, China, and Russia, as well as on islands such as Hawaii and the Canary Islands, the oceans playing the role of regulator of the weather conditions.

Control room of a telescope (with astronomer Dominique Proust observing with the 3.60m ESO telescope in Chile).

With the progress of science and related techniques, astronomers have built different kinds of observatories over the past few years, among them the Space Telescope or the ISO Satellite which are in orbit around the Earth. They can observe the universe without having the problems linked to the Earth's atmosphere (turbulence, clouds, etc.).



Details of the ISO observatory (Infrared Space Observatory), in revolution around the Earth. © ESA/ISO

Certain observatories are dedicated to the observation of the sky in the infrared and radio wavelengths, notably with the use of radiotelescopes, such as the one at Nançay in Sologne (France). Finally, recent work in cosmology has resulted in the construction of very specialized centres, intended to detect high energy particles such as cosmic rays. These days, urban observatories are laboratories where scientists prepare and analyze observations made elsewhere, design and build their various instruments and carry out their research.

Parsec

There is no specific sign for **parsec.** The letters PC, a transcription of the common abbreviation *pc*, suffice. They are preceded by the letter K for *kiloparsec* (*kpc*) or M for *megaparsec* (*Mpc*).

Words and associated expressions : Astronomical Unit - Earth - Light-year – Solar system – Sun.

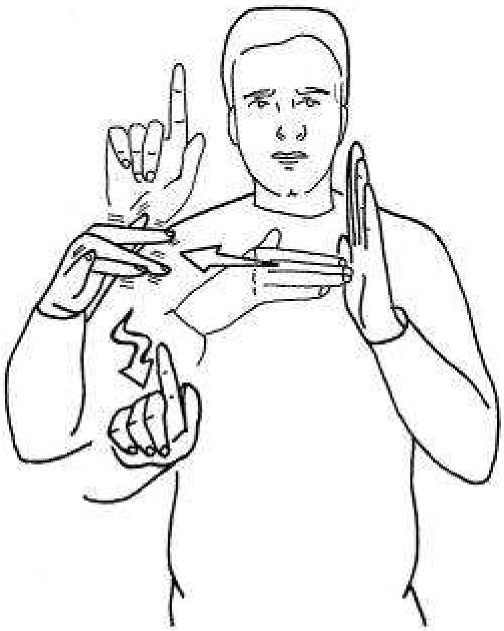
In astronomy, large distances are often expressed in light years (q.v.). However, for calculations, it is often much more practical to use the **parsec** which comes from the contraction of the words **par**allax and **sec**ond. We know that the distance of the Earth to the Sun is 149.6 million km. If we move away from the Solar system, we see the Earth getting closer to the Sun, until the visible distance between them is not more than one arc-second (1"). At this point, we are 30.85 trillion km distant, which is the definition of 1 parsec:

1 parsec = 3.26 light-years

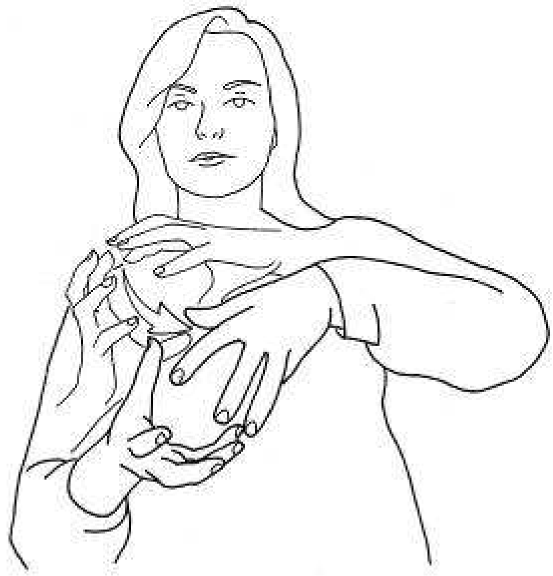
In order to measure the distance of galaxies, we use the **kiloparsec** which is 1,000 parsecs, and the **megaparsec** which equates to 1,000,000 parsecs

Planetary nebula

The concept of **planetary nebula** is translated with the composite sign GASEOUS NEBULA, followed by the sign PLANET. The sign NEBULA represents the material in movement which escapes from the surface of a star and it is followed by the sign GAS. This second component is formed by the manual letter “G” represented simultaneously with the movement of the letter “Z”, respectively the initial and final letters of the word *gaz* (*gas* in french). For the etymology of the sign PLANET, see the entry Earth.



NEBULA

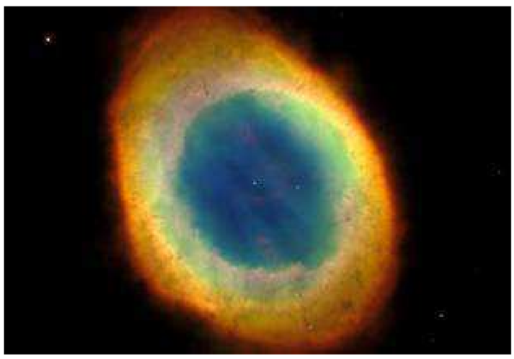


PLANET

Associated words and expressions: Dimension - Distance - Earth - Light year - Nuclear (reactions) - Planet - Star - Star (type) - Star (evolution) - Sun – Supernova - Telescope - Temperature.

It happens frequently that stars are surrounded with a ring, or with a bubble of material. In a small refractor or a telescope, they often seem to appear as a small disk looking like a planet. This led *William Herschel* (1738-1822) to name them **planetary nebulae**. This name has been maintained by convenience, although we know today that these objects have in reality nothing in common with the planets.

Unlike a massive star, which becomes a *supernova* at the end of its life, a “normal” star, which can reach ten times the mass of the Sun, begins to dilate when, having finished the combustion of its hydrogen, it starts to burn the helium of its central regions (see the entry *Star-evolution*). The helium is transformed into carbon while the central temperature of the star can reach tens of millions of degrees. By dilating, it becomes a *red giant* which, put in place of the Sun, would extend up to the

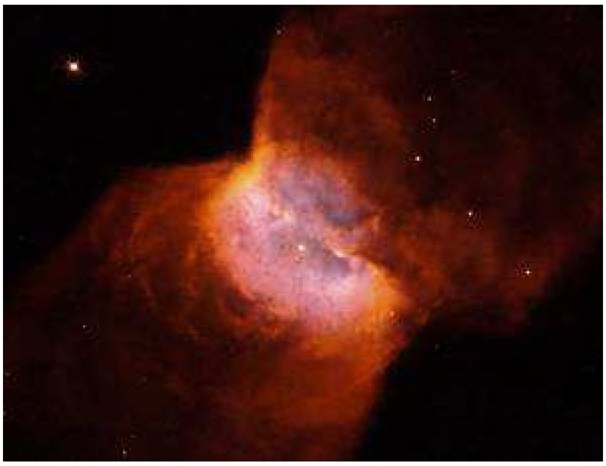


The planetary nebula M57 and its central star in the Lyre constellation, at a distance of 2,300 light-years. © NASA/HST.

orbit of the Earth. In this movement of expansion, the star ejects a part of its external layers in the form of a shell of matter while, under the effect of its own weight, it begins to implode to become a white dwarf.

Seen through a telescope, planetary nebulae are spectacular. We can make out the central star which has contracted and whose ejection of particles creates the shell of matter. These can survive only 12,000 years on average, before being gradually diluted in space, enriching it with chemical elements made during the star's life. These elements can be recycled to give birth to new stars, each one of which can be surrounded by planets.

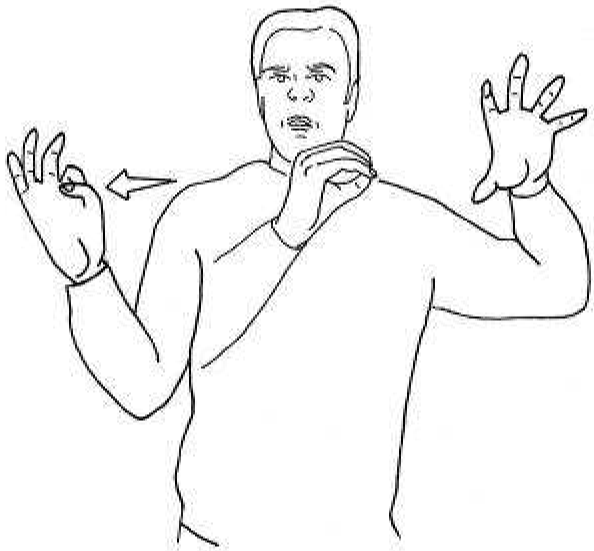
The planetary nebula M27 in the Vulpeculae constellation, discovered by the French astronomer Charles Messier (1730-1817) in 1764. It is 1,250 light-years distant from us. © ESO



The planetary nebula NGC 2346 in the Monoceros constellation at a distance of 2,000 light-years. Its diameter is approximatively 0.3 light-years. © NASA/HST

Pluto

The planet PLUTO is represented in sign language by reference to its small size and its location beyond the limits of the Solar system. An open hand represents the Sun whereas the other hand in the shape of the letter "O" represents Neptune, the most distant planet. The same hand moves away while taking the shape of pincers symbolising an object of small dimensions.

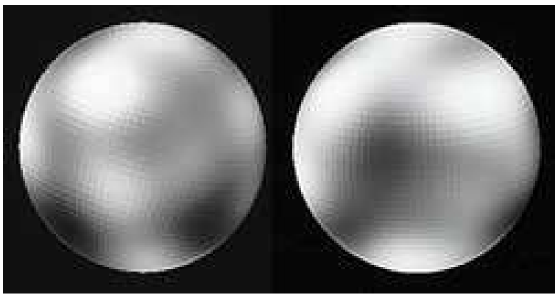


Associated words and expressions:
Asteroid - Earth - Eccentricity - Jupiter - Moon - Planet - Satellite - Saturn - Solar system - Titan.

The planet **Pluto** was discovered by the American astronomer *Clyde Tombaugh* on February 18th, 1930. It was considered as the most distant planet of the Solar system until 2006, when the discovery of other bigger and more distant planets brought the International Astronomical Union to modify its classification and to remove Pluto from the list of the main planets. Moreover Pluto is smaller than the Moon, smaller as well as the four main satellites of Jupiter and smaller than Titan, the large satellite of Saturn. It presents other anomalies compared with the planets: the plane of its orbit is tilted by 18° compared with the plane of the Solar system, and this orbit has a strong eccentricity of 0.2. At the distance from Pluto, the Sun appears as no more than a bright star.

Distance : Pluto is 5,906,451,000 km from the Sun.
Diameter : its diameter is 4,600 km, which is 2/3 that of the Moon.
Mass : its mass is only 1/10 of the Earth's.
Inclination : its axis is less inclined than the Earth's : 17°.
Rotation : the planet rotates slowly. A Pluto day lasts 6 days 9 hours and 17 minutes.
Revolution : Pluto orbits around the Sun about 248 years and 31 days.
Temperature : -229°C.
Atmosphere : Unknown. The surface is probably completely frozen, with rocks, water ice and methane (CH_4)..
The observation of Pluto needs a large telescope because it only appears like a very faint star.

Pluto and Charon ©ESA/NASA



Images of Pluto with the Hubble Space Telescope. © NASA-JPL

Satellites: Pluto is accompanied by a big satellite, **Charon**, whose diameter is half that of Pluto: we thus have a double planetary system. Just as with the Moon and the Earth, Charon always presents the same side turned to Pluto. Charon has the following characteristics:

Name	Diameter (km)	Distance from the planet (km)	Duration of revolution	Discovery
Charon	604	19,570	6 d 9 h 17 mn	Christy (1978)

Two small satellites, **Nix** and **Hydra** were discovered in 2005 with the Space Telescope. Their diameter would be only 50 and 62 km respectively.

Power

In mathematics, the symbol for POWER is written over a term or an expression. In Sign Language, this graphic symbol is reproduced in the air. This is the way that, for example, 10^3 is shown by the sign "ten" followed by the higher-placed sign "three" We then make the sign "SMALL THICKNESS" (index finger and thumb moved closer to each other) at the place where we have just placed "three".

The power of a number or of an expression indicates how many times this number or this expression must be multiplied by itself. So the "power 2" of a, which we also call its **square**, is the number x such as $a \times a = x$ or $a^2 = x$.

The "power 3" of b which we call its **cube** is the number y such as $b \times b \times b = y$ or $b^3 = y$.

Thus the square of 2 is 4, the cube of 3 is 27, etc.

In astronomy, the numbers are often immense so it is more practical to note them by means of powers. For example, one thousand billion km (1,000,000,000,000 km) is written 10^{12} km.

Surfaces and volumes in Sign Language.
A surface or a volume is expressed in Sign Language by specifying at first that it is a surface or a volume, then by indicating the value without using the powers.

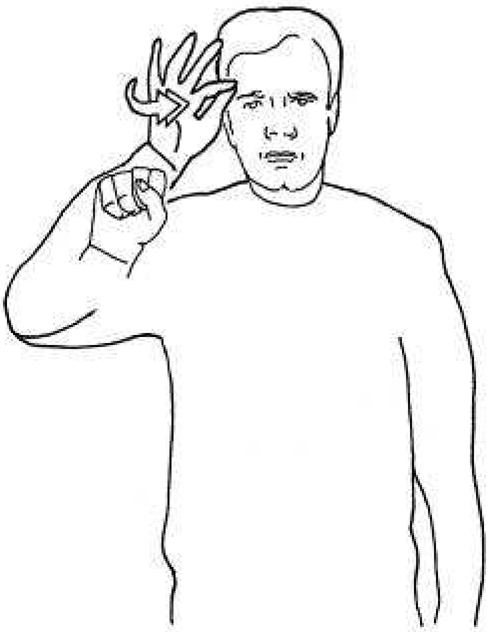
For a crater of 600 km^2, we make the signs CRATER + SURFACE + 600 + KM one after the other.

For an asteroid of 18 km^2, we make the signs ASTEROID + VOLUME + 18 + KM again consecutively

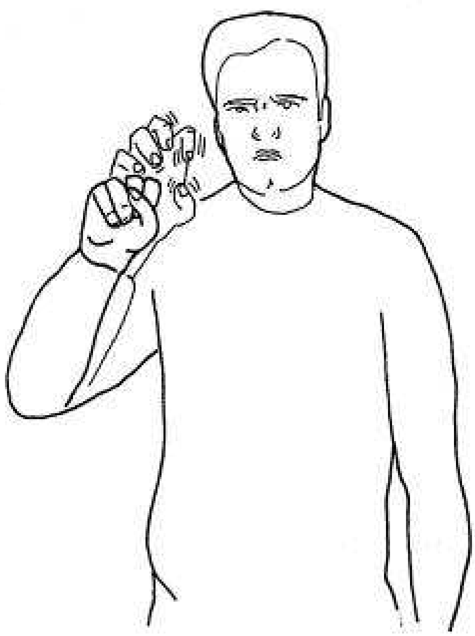
The fact of having specified initially that we are talking about a surface or about a volume makes it unnecessary to use km^2 or km^3, the sign for kilometres being sufficient in itself.

Pulsar

The sign PULSAR is composed by the sign for STAR followed by the sign BLINKING. For the etymology of STAR, see the entry *Star-general.*



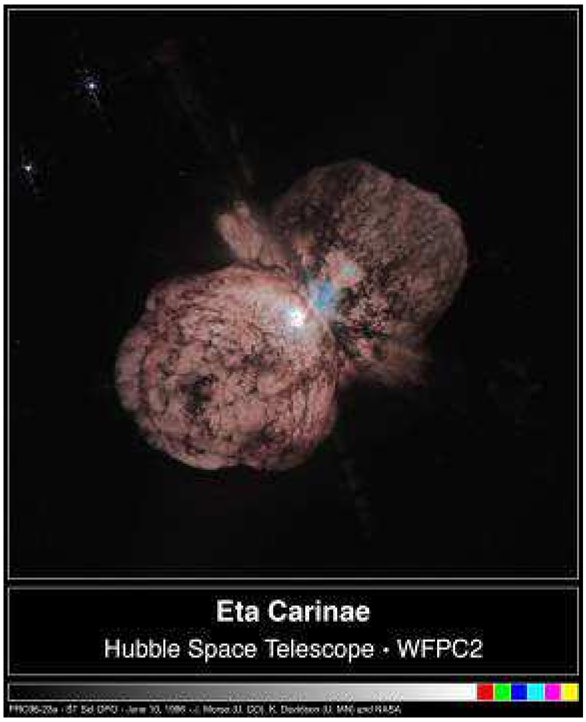
STAR



BLINKING

Associated words and expressions: Astronomer - Diameter - Electron - Neutron - Light-year - Nuclear (reactions) - Proton - Star (type) - Sun - Supernova.

The entry *Supernova* describes how a massive star finishes its life with a spectacular explosion. Such a star, the mass of which is at least thirty times greater than that of the Sun, becomes a very brilliant supernova ejecting the main part of its material into space, whereas the central material of the star collapses. Protons and electrons merge then to form neutrons (see the entry *Nuclear reaction*). The star has a diameter of only around 19 km with a density such that a thimble of material can weigh tens of tons: it is a **neutron star**.



The star η in the constellation Carina in the southern hemisphere is about 8,000 light years away. It had approximately 100 times the mass of the Sun and exploded in 1843 becoming a supernova. © NASA/HST

During this movement of collapse, the star begins rotating on itself faster and faster, reaching tens of revolutions per second. Under the action of the magnetic field, it emits a signal in the shape of a paint-brush, like a lighthouse for boats. This pulsation is at the origin of the name **pulsar**, contraction of the English expression "pulsating star" (vibrating star). The first pulsar was discovered in 1967 and the regularity of its signals led the astronomers to think at that time that they could result from a distant civilization.

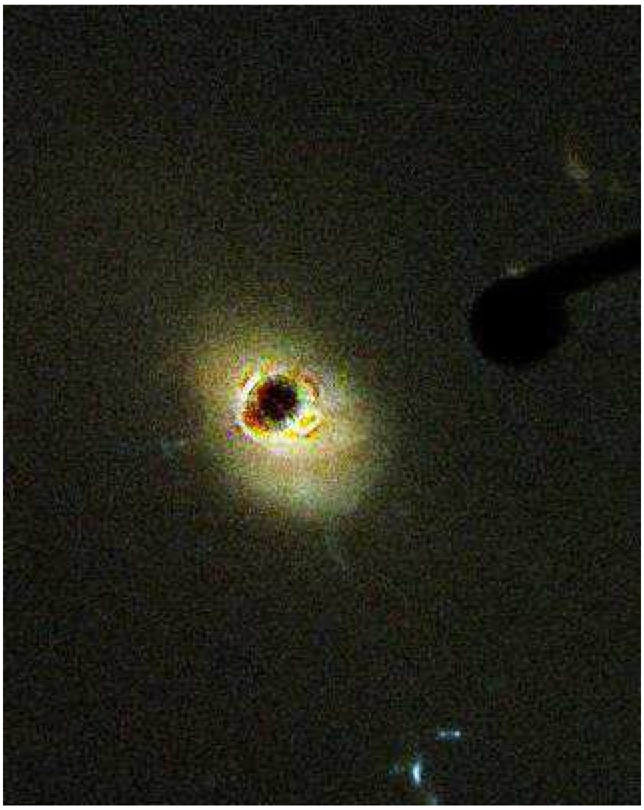
Composite visible and X-ray image of the centre of the supernova of the Crab showing the gas in whirlwinds, and the brilliance of the pulsar. © NASA

Quasar

Due to its small dimensions and to its tremendous energy of radiation, a quasar is represented by the sign NUCLEUS followed by the sign POWER which is made with a large movement. With hands in the shape of horns, the sign POWER is a reference to the defences of animals renowned for their strength such as, wild boar or elephants.

Associated words and expressions:
Astronomer - Black hole - Earth - Electron - Galaxy - Light year - Radiotelescope - Spectroscopy - Solar system - Star - Universe.

In the 1960s, when radio telescopes became sensitive enough to detect radio emissions coming from the depths of the universe, astronomers associated these emissions with stars, galaxies, etc. However, a lot of these sources do not correspond to clearly identified objects. For example, a powerful radio source in the Virgo (Virgin) constellation, catalogued with the number 3C273, has the shape of a small blue star with a curious rectilinear jet. Thanks to spectroscopy, astronomers noticed that these emissions result from extremely distant sources to which they give, by contraction of the English expression "quasi stellar source", the name **quasar**.

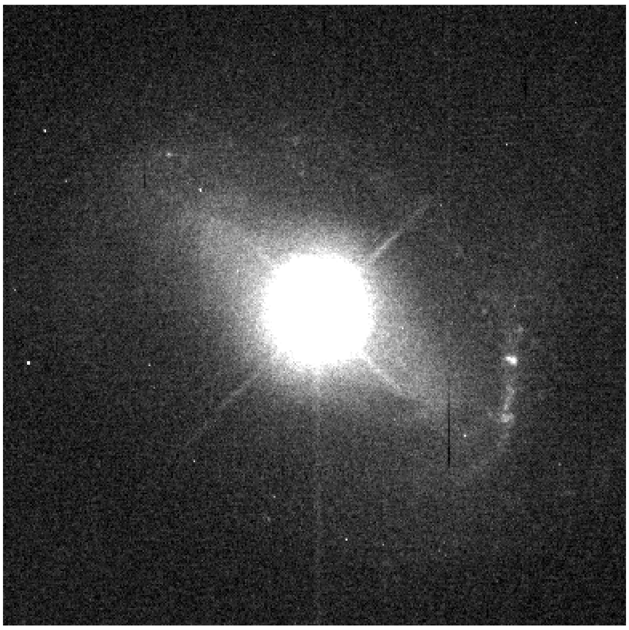


The quasar 3C273 in the Virgo (Virgin) constellation. © NASA/HST

The study of the shift of the spectral lines of the quasar 3C273 (see the entry *Spectrum*) shows that it is 1.85 billion light years distant from the Earth. In spite of its small size, it is an object possessing an enormous power of radiation in the radio domain for an almost pin-point optical aspect.

These days we are aware of several thousand quasars, the distance of which from the Earth can reach several billion light years; in other words, the light which reaches the Earth today left before it was formed.

The radio emission of quasars is a **synchrotron type emission**: these are electrons which describe a spiral trajectory around the strength lines of a magnetic field. We can thus observe very fine jets on scales of hundreds of light years.



A brilliant quasar in the core of a galaxy.
© NASA/HST

A quasar is generally hosted in the core of a good-sized galaxy. By itself, it often outshines more than one thousand galaxies similar in size to our own, but its own size being no greater than that of the Solar system! Its emission interacts with the central regions of the galaxy by provoking movements of matter at speeds of of some thousands or tens of thousands of kilometres per second. According to work based on high-resolution observations made with telescopes, the centre of a quasar would consist of a very massive black hole and what we can see is the emission emitted by matter falling into the black hole.

A quasar (up-right) in the vicinity of the galaxy NGC4319. © NASA/HST

Quasars remain mysterious objects.
Astronomers have often posed questions about their formation, knowing that they were fifty times more numerous five or six billion years ago but .we are able to observe them throughout the history of the universe. Computer simulations show that collisions between galaxies can lead, in a several hundred million year time scale, to their complete merging, leading us to the inference that very strong interactions of the central gas would give rise to extremely active nuclei from which quasars are formed.

Radiotelescope

The RADIOTELESCOPE is represented by the sign RADIO which reproduces the pressing of the big buttons on old transmitters, followed by the making of the shape of a directional antenna dish.

Associated words and expressions:
Astronomer - Diameter - Earth - Galaxy - Light - Planet - Star - Telescope - Universe - Wavelength.

Radiotelescopes allow us to observe the universe in the range of the radio wavelengths. The various components of the universe, planets, stars, galaxies, etc., emit in all those wavelength ranges (see the entry *Spectrum*), from X-rays, which are stopped by the Earth's atmosphere, to the large wavelengths identical to those of the broadcasting radio stations.

To be able to study the nature and the evolution of the various elements of the cosmos, Astronomers use telescopes to analyze light. Radio observations enable us to complete the necessary scientific information, which is why they also use **radiotelescopes**.

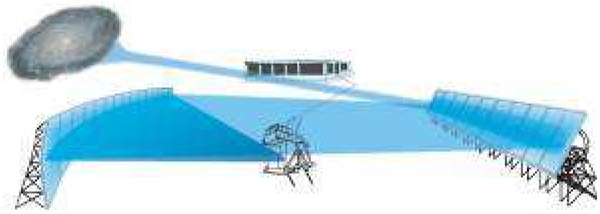
Electromagnetic waves from a source in the universe arrive on a concave metallic large surface which plays the role of a mirror of a telescope. They are then concentrated in a point (we say that they are "focused"), then amplified and handled numerically to obtain a scientifically usable signal.

The 30 meters IRAM radiotelescope installed at Pico Veleta, in the south of Spain. © CNRS/INSU

It is important to specify that these r**adio waves emit no sound**. In order for an acoustic signal to be transmitted, you need a surrounding atmosphere, whereas broadcast emissions coming from the cosmos are propagated in empty space before being received on the Earth.

The Nançay radiotelescope.

Situated in France near the city of Bourges, the Nançay radiotelescope is operated by the Paris Observatory. It is one of biggest instruments in the world, consisting of a mobile antenna 200 metres long, revolving around a horizontal axis, and a fixed antenna of 300 meters. A reception module is mounted on rails to receive the radio emissions from space while compensating for the rotation of the Earth.



The Nançay radiotelescope and its combination of antennas allowing the reception of emissions from space. *© Observatoire de Paris.*

The Arecibo radiotelescope

On the island of Puerto Rico, scientists have installed a radiotelescope in the old crater of extinct volcano. This is the Arecibo radiotelescope which has a diameter of 305 metres.

The Arecibo radiotelescope in Puerto Rico. *© NASA/JPL.*

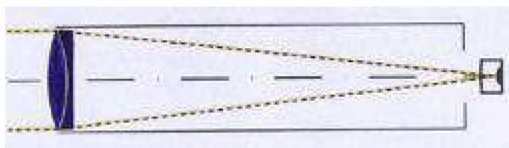
Refractor

The sign REFRACTOR represents the classical shape of the optical instrument used to observe sky objects.

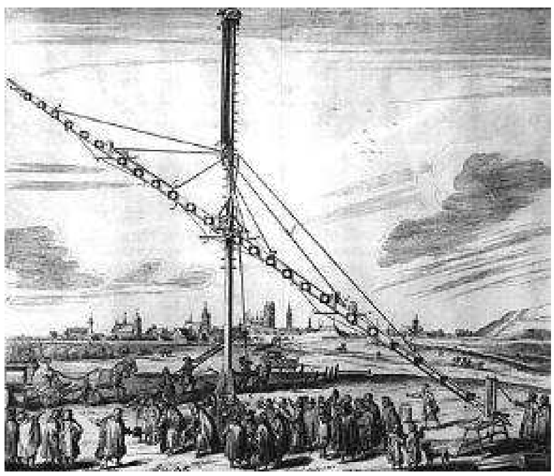
Words and associated expressions: Earth (rotation) - Focus - Jupiter - Moon - Satellite - Telescope - Venus.

The astronomical **refractor** was the first instrument which allowed us to get closer to objects in the sky thanks to its ability to enlarge. We don't know exactly who invented it but it is almost certain that by 1585 clever optician, probably in the Netherlands, discovered that by using two lenses, it was possible "to see closer". By pointing it towards the sky, *Galileo* (1564-1642) discovered the craters of the Moon, the phases of Venus and the four largest moons of Jupiter.

An astronomical refractor consists of a long tube at the end of which is placed an objective. This plays the same role as a magnifying lens. It concentrates rays of light to a single point, the focus. At the focal point, a system of lenses allows the enlargement of the image just like a microscope. The largest refractors have tubes 15 to 20 metres long. The largest objective is one metre in diameter at Yerkes-Chicago observatory USA, while there is one of 0.91m at Lick observatory in California. The big refractor of Meudon (France) is the third largest in the world with an objective of 0.83m diameter.



Optical principle of an astronomical refractor.

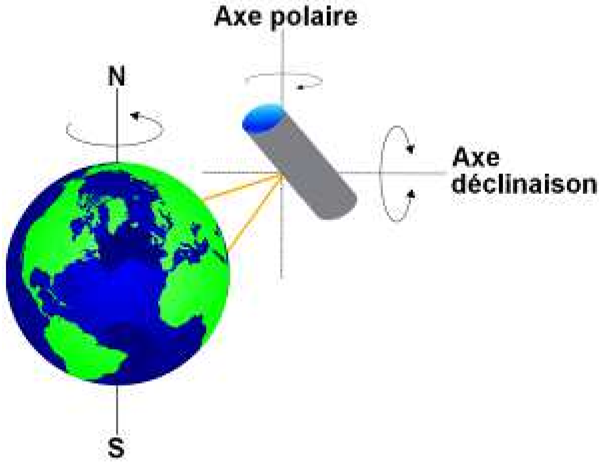


The refractor of the German astronomer Johannes Hevelius (1611-1687) constructed at Danzig.

Because of the disproportionate length of the refractors, astronomers gradually replaced them with telescopes. These are more compact and can have bigger diameters.

The difference between a refractor and a telescope is the absence of a mirror for a refractor. In a refractor, light crosses glass lenses to give enlarged images, whereas telescopes reflect light on to curved mirrors.

Small refractors sold in the commercial market are positioned on a horizontal and a vertical axis which is known as an **azimuthal mount**. The largest refractors are built on **equatorial mounts** in which one of the axes is parallel to the axis of rotation of the Earth, allowing the instrument to rotate and compensate for the movement of the Earth, by means of a motorized "clock drive"..



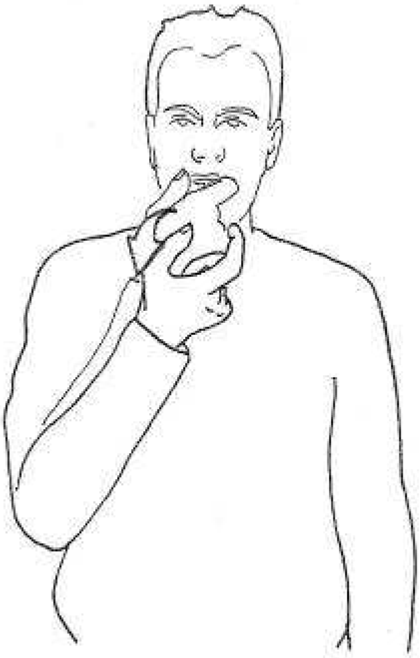
Principle of the equatorial mounting.


The 38cm refractor at Paris Observatory.
© Observatoire de Paris

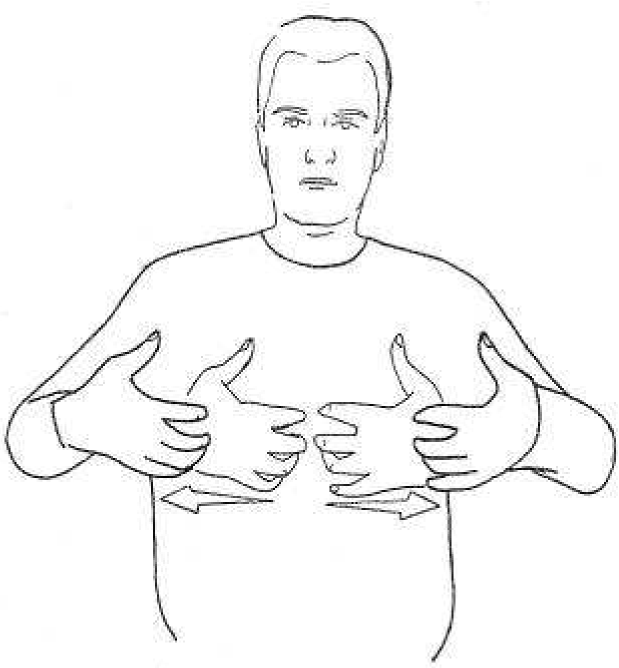

The great refractor of Meudon Observatory in 1877.
© Observatoire de Paris

Relativity

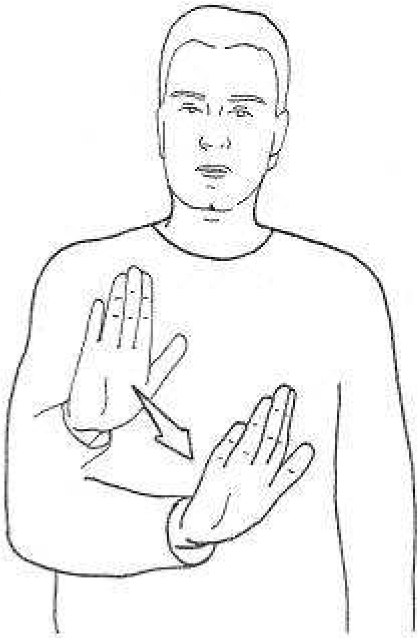
The **theory of relativity** is signed with a compound: LANGUAGE followed by SCIENCE and CHARACTERISTIC. The first of these components is the sign attributed by the deaf to Einstein in reference to a famous photograph of Einstein roguishly sticking his tongue out. The idiomatic sign conventionally translated by CHARACTERISTIC has multiple meanings: "it's his, it's all his, it is typical of him". It comes from the old sign for "him/his" just as it was used in the 19th century. For the etymology of SCIENCE, see the corresponding entry.



1- EINSTEIN



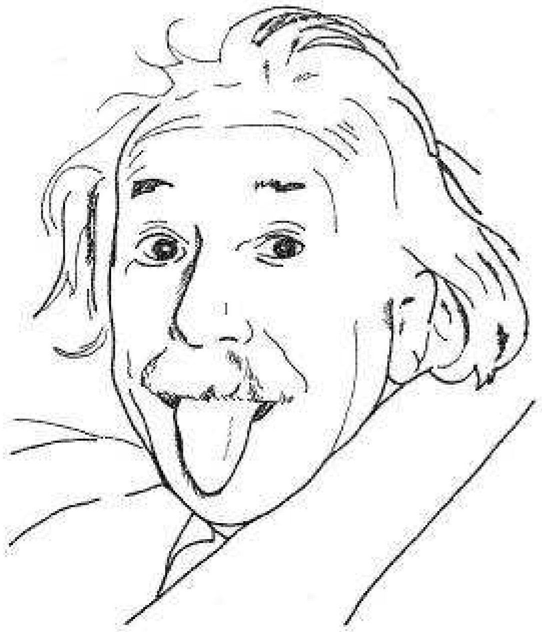
2- SCIENCE



3- CHARACTERISTIC

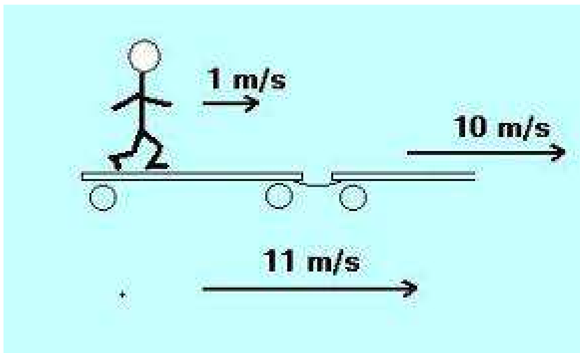
Associated words and expressions: Gravitational Force - Galaxy - Light - Mass - Sun - Earth - Universe (expansion) - Speed of light.

The **theory of relativity** is essentially attributed to Albert Einstein (1879-1955). It is the domain of physics that describes the structure of the universe by associating four coordinates, three connected to the geometry of space and one connected with time (see the entry *Universe-expansion*). This very complex theory is based on experiments of great simplicity which prove that the speed of light in space is a constant: c = 300 000 km/s. No particle can travel beyond this value, no physical effect can be propagated and no signal can be transmitted at a velocity superior to *c*. Another aspect of relativity consists in the choice of an **absolute reference**: the Earth revolves around the Sun, which itself is moving in the Galaxy which is simultaneously undergoing a movement of not only of rotation but also a linking to the expansion of the universe. **The results of a measurement change from one system to another.**



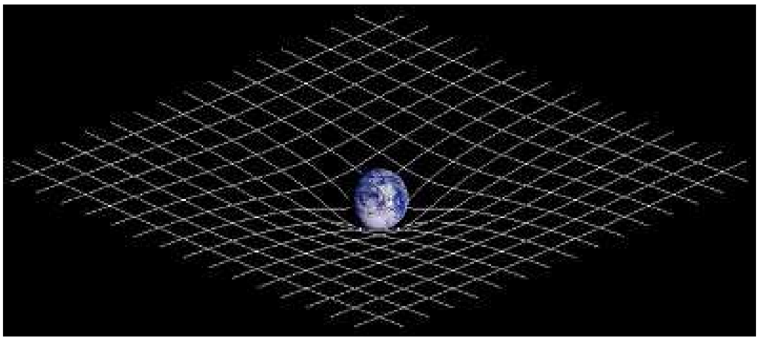
Albert Einstein (by Carole Marion)

A traveller walking in the carriage of a train can measure his own movement relative to the carriage as well as to the ground. The results are very different. A traveller walks at a speed of one metre per second in a carriage but if this is moving at 10 metres per second, then the speed of the traveller is 11 metres per second as seen by a static observer next to the rails. The notion of movement of a body makes sense only when compared to another body. In this example, we understand that time passes in the same way for all observers: it is supposed to be **absolute**.



Movement of a traveller in a moving carriage. For an observer on the ground, he is moving at a speed of 11 m/s.

In the domain of light, things are different. **The speed of light is independent of the movement of the observer**. If our traveller is in a rocket moving at a speed of 100,000 km/s along a beam of light, he will nonetheless see this beam moving at the speed of light, and not at 300,000 – 100,000 = 200,000 km/s. For very high speeds, **time** is no longer an absolute, it is relative. A traveller travelling in a rocket at a speed close to that of light, and coming back to Earth after six months would find it has aged by two million years! Thus there is a **relativity of the laws** of physics when speed is very high. These properties enter within the context of **restricted relativity**.



The curvature of space in the vicinity of a massive body.

Einstein developed his work to show with **general relativity** that the geometry of the universe has surprising properties. He demonstrated that one of the four interactions, gravity, is capable of **locally modifying space by bending it**. This surprising property acts on light beams which, whilst in space they move in a straight line, in the neighbourhood of a body having a very large mass, they bend space in that locality. Relativity applies to the whole universe to describe its geometry. However, on Earth, where velocities are very low compared with that of light (man walking, car, train, plane), the laws of nature used in everyday life are a simplification of the laws of relativity. If we go back to the example of the traveller moving in a train, relativity shows us that his speed, measured by an observer placed close to the rails, is actually very slightly less than 11 metres per second. This difference is imperceptible to us..

Revolution (orbit)

The sign REVOLUTION shows two spherical bodies of which one turns around the other. Just like the word “revolution”, the sign REVOLUTION is usually used in the sense of "social troubles, radical changes". Contrary to what we might believe, to use the same sign with the sense of "trajectory of a celestial body around the other one" is not an easy task: it is in fact the first sense of this sign as used in the 19th century. The period when LSF was came into being is the period of the triumph of celestial mechanics, the founder of which was *Pierre-Simon de Laplace* (1749-1827) in his *Explanation of the system of the world* (L’*Exposition du système du monde,* 1796), and popularized by the discovery of the planet Neptune by *Urbain Le Verrier* (1811-1877) by sole means of mathematical calculation (1846). The word and the sign *revolution*, with their astronomical sense, were taught in schools for deaf children.

Associated words and expressions: Celestial mechanics - Exoplanet - Planet - Rotation - Satellite - Star - Sun.

The **revolution** of a planet around the Sun, of a satellite around a planet, of an exoplanet around a star, or even a star around another star, is a measure of the time required to make a complete journey: it describes the **orbit** of one body around another. So the revolution of the Earth around the Sun, which we know as a terrestrial year, is 365 days, 6 hours, 9 minutes and 9.5 seconds, or 365.25 days. One year of the planet Jupiter lasts 11 years and 315 days, one year of Saturn is 29 years and 165 days, etc. One should not confuse **revolution** with **rotation** which measures the time which a planet or a star takes to turn on its own axis.

Root

In Sign Language, the sign for ROOT reproduces the mathematical symbol for root, which is √. We note that this reproduction is made from the point of view of the "speaker"; from the point of view of the "observer", the shape of the symbol is inverted.

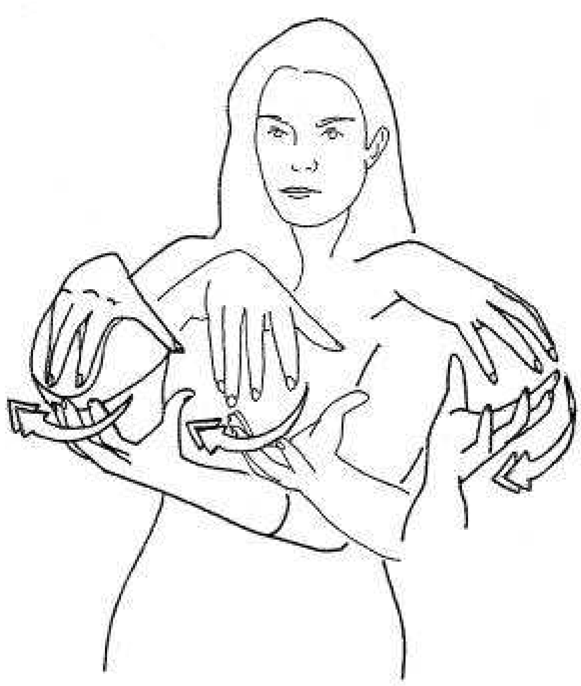
Associated words and expressions:
Spectroscopy - Wavelength.

The square root of x *is* a number a such as the multiplication of a by itself is x. In other words, $a \times a = x$ or $a^2 = x$. Conversely, $\sqrt{x} = a$, or: $x^{½} = a$. Note that the root of a number can be positive or negative so that: $\sqrt{9} = +3$, but also $\sqrt{9} = -3$.

The cube root of x is the number b such as $b \times b \times b = x$. So the cube root of 27 is 3. In mathematics, we also use the fourth, fifth roots, etc.

Rotation

To represent the **rotation** of a celestial object, both hands have the shape of a spherical object which revolves. The same movement is repeated in three different places to indicate that at the same time as it turns on itself, the celestial body is moving in space.



Associated words and expressions: Earth - Galaxy - Jupiter - Planet - Satellite - Star - Sun - Venus.

All the objects of the sky, the planets, satellites, stars and galaxies, are in **rotation;** they turn on themselves around their axis. The day on Earth is defined by the rotation of our planet around its axis in 23hrs 56min and 4sec. The speed of rotation of the various planets varies; the fastest is Jupiter which turns on itself in 9hrs 53min and the slowest is Venus at 224 days and 17hrs. Other objects of the universe are also in rotation: the Sun is a star of which the rotation takes 28 days, whereas our own galaxy, the *Milky Way*, rotates every 240 million years.

Saturn

The planet **Saturn** is represented by a round hand which represents the planet, while the other hand draws the outlines of a ring.

Associated words and expressions: Equator - Planet - Satellite - Solar System.

The **planet Saturn** with its ring is doubtless the most famous planet of the Solar system. It is a real marvel, easily accessible to the observer by means of simple binoculars. Its immense ring was discovered by the Dutch astronomer *Christiaan Huygens* (1629-1695).

Distance : Saturn is 1,421,179,772 km from the Sun.
Diameter : 60,270 km ; it is the second biggest planet of the Solar system.
Mass : 95 times larger than the mass of the Earth.
Inclination : its axis is slightly more inclined that of the Earth: 26,7°.
Rotation : the duration of a day on Saturn is only 10hrs 47min 6sec ; this is why the planet is flattened by 10 % at the two poles.
Revolution : Saturn achieves a revolution around the Sun in 29 years and 165 days.
Temperature : -130°C average.

Saturn as seen in a telescope. © ESO.

Atmosphere : it is very thick and identical to the atmosphere of Jupiter, with wide cloudy bands which are stretched out in parallel to the equator. It is essentially comprises hydrogen (H_2) at more than 93 %, helium (He) at more than 5 %, methane (CH_4) at 0.2 %, ammonia (NH_3), ethane (C_2H_6) and water vapour.

Rings : The nine rings of Saturn extend over 120,000 km, but they are only one kilometre thick on average. They are made up of pebbles and rocks of all sizes as well as with blocks of ice. They are separated by empty zones such as the **Cassini division** which is easy to observe with a small telescope.

Satellites : Saturn is accompanied by about sixty satellites, the principal ones being *Mimas*, *Encelade*, *Tethys*, *Dione*, *Rhea*, *Titan*, *Hyperion*, *Japet* et *Phoebe*. The satellite *Titan*, bigger than the Moon, is also the biggest in the Solar System. It is easily visible with a small telescope. Its characteristics are the following:

Name	Diameter (km)	Distance from the planet (km)	Duration of revolution	Discovery
Titan	5,150	1,223,000	15days 22hr 42 mi	Huygens (1655)

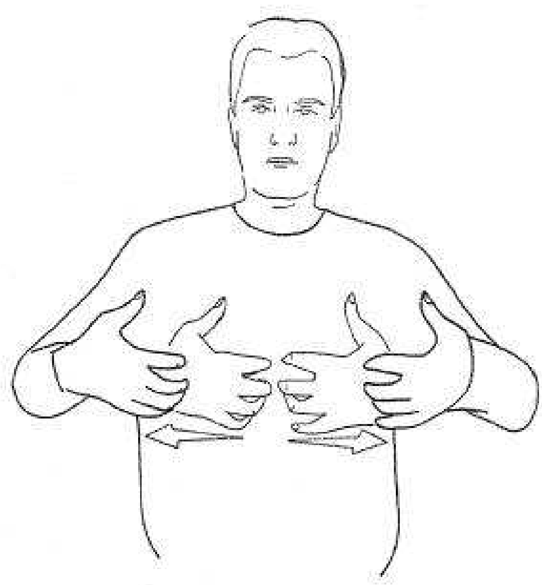
Astronomers have observed a thick atmosphere around **Titan**, composed mostly of nitrogen (N_2 - 95 %), and also methane (CH_4) and more complex organic compounds such as ethane (C_2H_6), acetylene (C_2H_2) or ethylene (C_2H_4).

These components indicate that a form of life could exist on Titan, the atmosphere being thick enough to maintain sufficient temperature by a greenhouse effect. It is with the aim of learning more about it that the *Cassini-Huygens* spacecraft was launched from the Earth on October 15th, 1997. After a journey of seven years, the *Huygens* module landed smoothly on Titan on January 14th, 2005. The images taken during the descent and after the landing show solid regions formed by dunes, identical to sandy ones, and large lakes of liquid methane. No form of life has been detected up to now.

Image of Titan as seen from the spacecraft Huygens. © NASA/JPL

Science

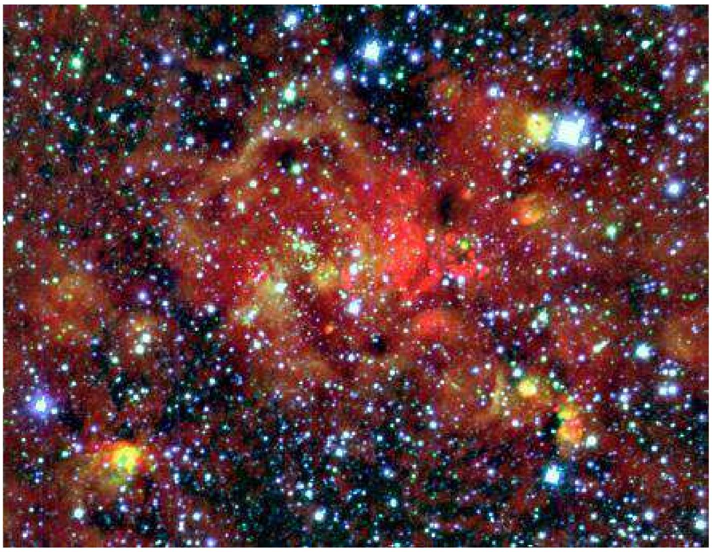
The sign SCIENCE represents the rib cage just as deaf children would see it drawn in their natural sciences books.



Associated words and expressions:
Astronomy - Earth - Universe - Wavelength.

The word **science** derives from the Latin *scientia* which means "knowledge". Science groups together all the activities which allow us to know, from experience, the world and the universe which surround us, their past, their present and their future.

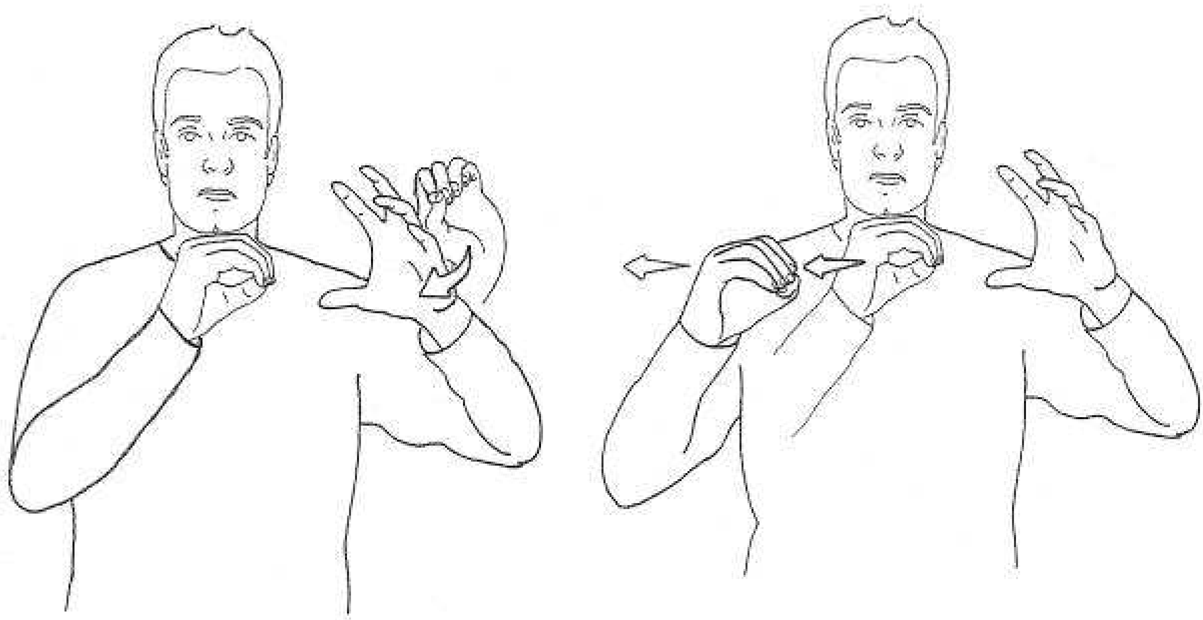
In the Middle Ages, the first universities taught mainly disciplines connected to the "human sciences": grammar, dialectic, rhetoric, etc. These were gradually replaced by a teaching inherited from the Greeks and the Arabs, emphasizing mathematics, geometry and astronomy. For scholars, these disciplines allowed them to describe reality, whether on the Earth or in space, by making all sorts of measurements and analyses. Today, the understanding of the universe which surrounds us calls on numerous domains of science. Astronomy allows us to observe, in the various wavelengths, celestial bodies, their physics, the understanding of their movements, and their chemistry, allowing us to know their composition and their evolution. Disciplines such as biology teach us about the evolution of life and the possibility of life beyond the Earth.



A region of the Milky way composed of stars, gas and dust, the study of which calls for different domains of science. © ESO

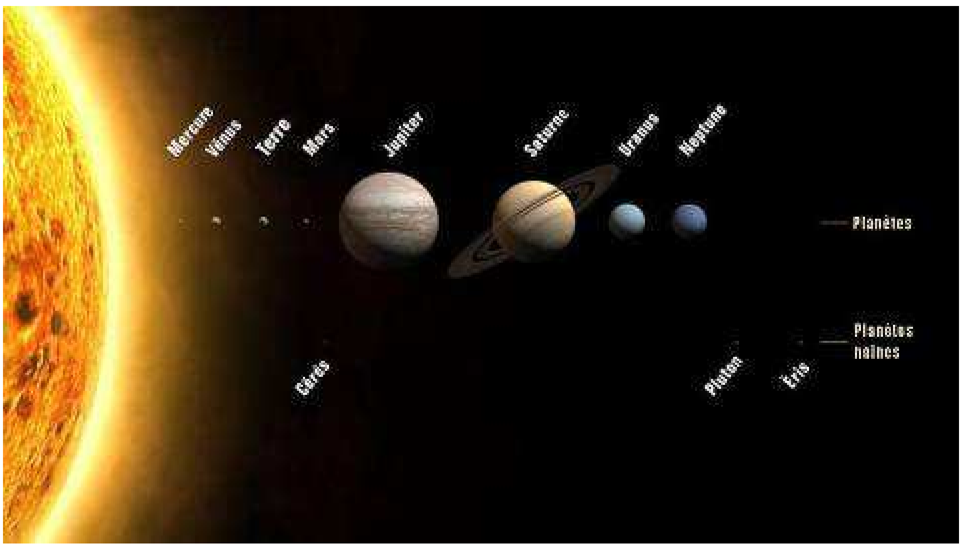
Solar System

A fist opening up represents the Sun, the source of light for the planets. The other hand, in the shape of the letter "O", moves away from it with slight oscillating motion to represent the succession of the planets. Note that, in this context, the sign for "SUN" is not the same as when it is represented alone (see the entry Sun).



Associated words and expressions: Asteroid - Astronomical Unit - Comet - Earth - Exoplanet - Galaxies - Io - Jupiter - Light Year - Mars - Mercury - Meteorite - Moon - Neptun - Planet - Planetesimal - Pluton - Satellite - Saturn - Sun - Titan - Uranus - Venus.

The **Solar system** basically consists of the Sun and eight planets. The order of the planets, by increasing distance from the Sun, is **Mercury**, **Venus**, **Earth**, **Mars**, **Jupiter**, **Saturn**, **Uranus** and **Neptune**.

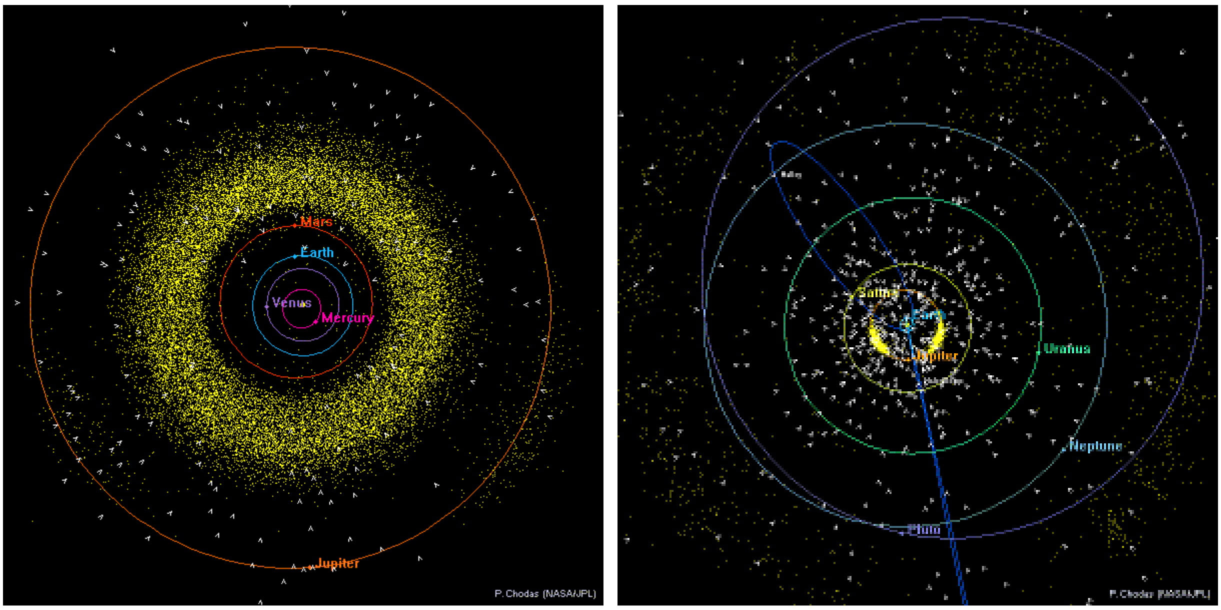


The Sun and the planets. © NASA/JPL

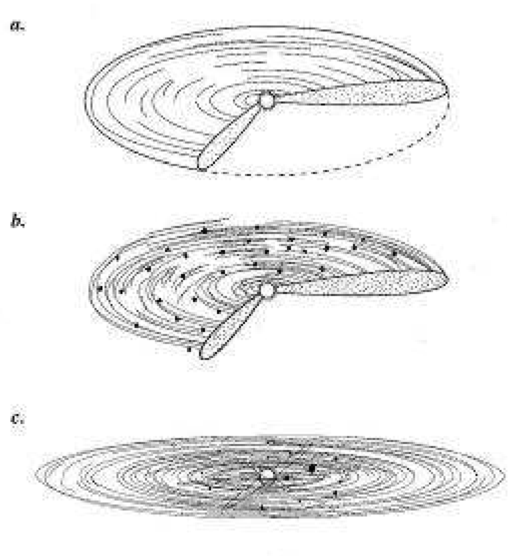
The **Solar system** is a part of our Galaxy, where it was formed approximately 4.5 billion years ago. Although it is immense with a radius of dozens of billions of km, it is nevertheless only a tiny point in our Galaxy. This consists of 200 billion stars forming a gigantic disc with a radius of 50,000 light years. The Solar system is more or less 32,000 light years from its centre and makes a revolution around the centre of the Galaxy every 240 million years at a velocity of 200 km/s.

The planets of the Solar system are quite different. Leaving the Sun, we first find **four small-sized planets**: Mercury, Venus, Earth (with the Moon), and Mars (with two small satellites). These planets are **rocky** ones and they have a **low gravity** as well as **a very thin atmosphere**: 100 km of thickness for the Earth, 150 km for Venus and only 50 km for Mars. You then have to go more than 5 astronomical units to find **four big planets**: Jupiter, Saturn, Uranus and Neptune. They are enormous and **very dense balls of gas** and are all accompanied by **numerous satellites** as well as by complex **rings**. The chemical composition of their liquid atmosphere is identical with hydrogen ($H2$) and helium (He) in the same proportions as the Sun. We suppose that there is a rocky core in the centre of each planet. Their satellites are very different being either covered with an ice layer or with active volcanoes as on Io, one of the satellites of Jupiter, or with an atmosphere as on Titan, the biggest satellite of Saturn.

The Solar system also comprises **small planets** such as Pluto and its satellite Charon, as well as Quaoar, Sedna etc., along with thousands of **comets** and tens of thousands of **asteroids** and **meteorites**. The orbits of the planets around the Sun are more or less on the same plane which is tilted at 7° to that of the solar equator. All the planets revolve in the same direction as the rotation of the Sun in almost circular orbits.



The Solar system on 2008 January 1st; note the asteroid belt between Mars and Jupiter. The small arrows correspond to the position of the comets. © NASA/JPL



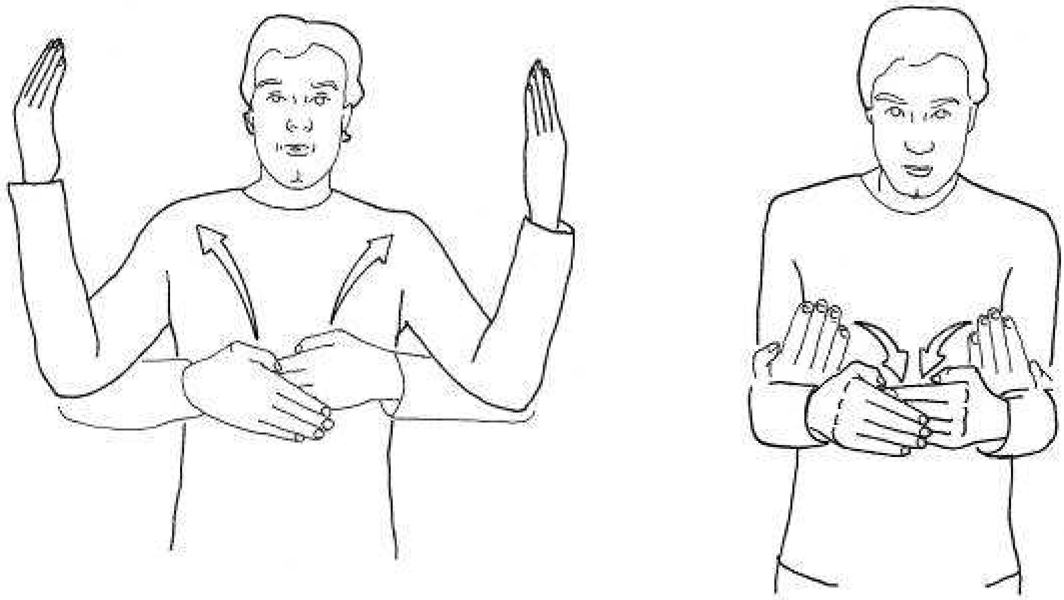
Formation of the planets, (a) disk with gas and dust, (b) planetesimals and dust, (c) planets. © DP/Encyc.Universalis

Formation of the Solar system

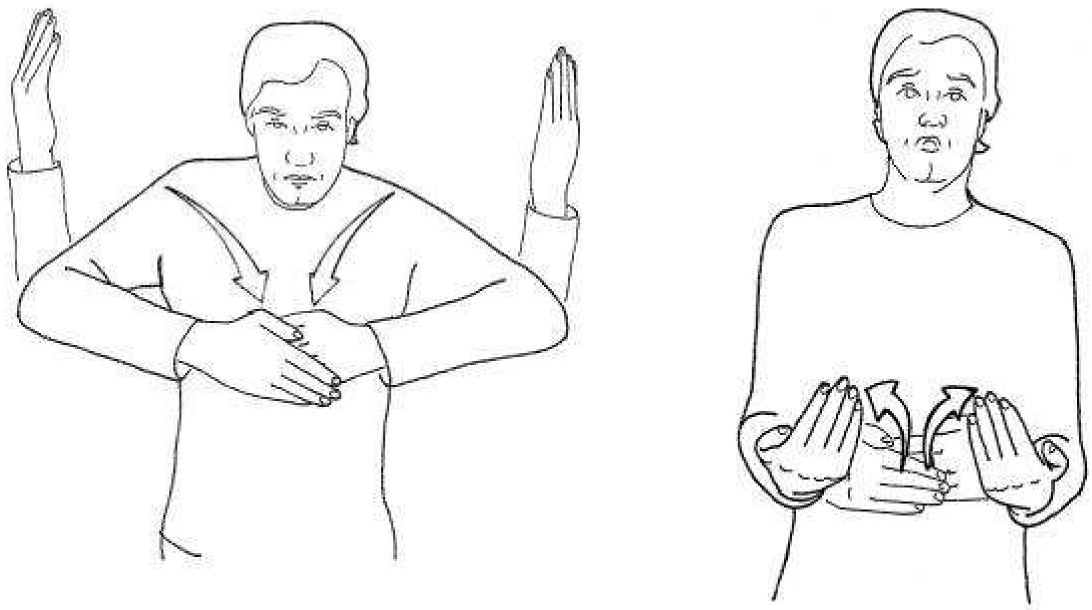
The Sun and the planets were born at the same time, from a disk of gas (**a**) self-rotating in which bubbles of gas condense, each bubble mixing with some dust to form a **planetesimal** approximately 100 km in diameter (**b**). By colliding, these planetesimals gather together in time to constitute more and more massive objects ending finally with the formation of the planets Mercury, Venus, Earth and Mars as well as in the cores of the "gaseous" planets, Jupiter, Saturn, Uranus and Neptune (**c**). This model of formation would be the same everywhere in space and so many stars would be surrounded by planets. As the majority of the exoplanets discovered since 1995 are situated at some tens of light years from the Sun, the study of their formation will be a very valuable test of this model.

Solstice

The signs DAY and NIGHT are based on the same concepts as the expressions "sunrise" and "nightfall" with the hands moving upwards and away (DAY) and falling and coming together (NIGHT). By changing the size of the movement, we can produce the signs LONG DAY, SHORT DAY, LONG NIGHT, SHORT NIGHT. The combination of these four components allows us on the one hand to represent the **summer solstice**, characterized by a long day followed by a short night and, on the other, the **winter solstice** which is represented by a long night followed by a short day.



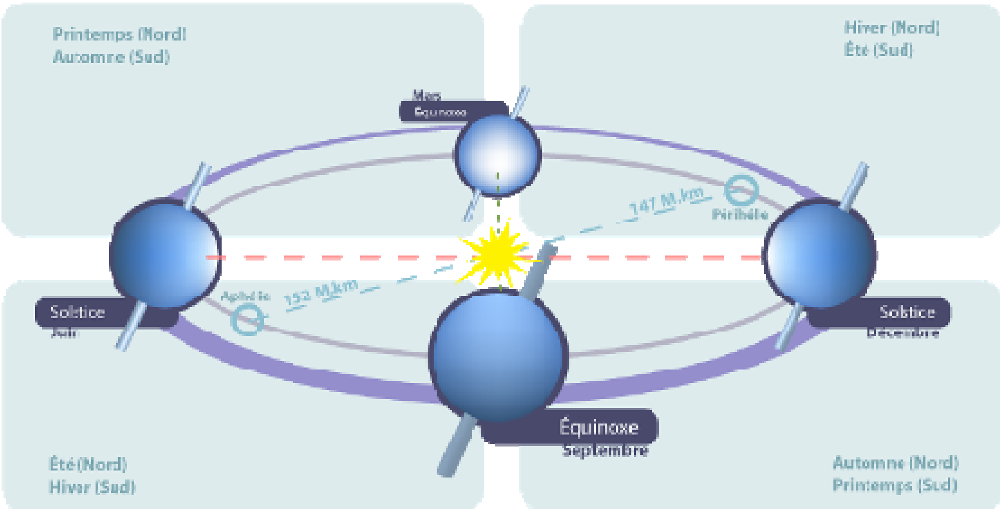
SUMMER SOLSTICE : LONG DAY AND SHORT NIGHT.



WINTER SOLSTICE : LONG NIGHT AND SHORT DAY.

Associated words and expressions: Equinox - Rotation - Revolution - Season - Revolution - Tropic of Cancer - Tropic of Capricorn.

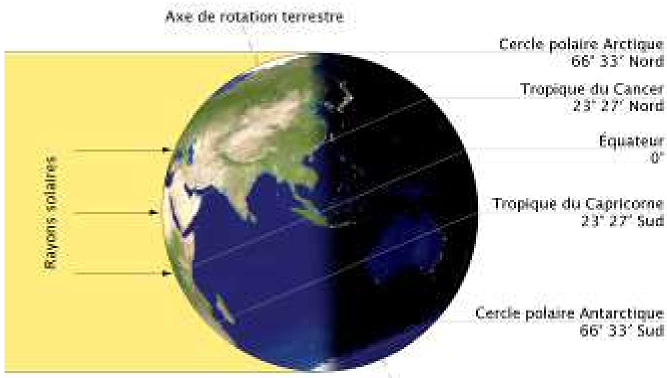
As the axis of rotation of the Earth is tilted at an angle of 23° 27', the duration of day and night changes over the year everywhere on Earth. This slope is also the cause of the four **seasons** which would not exist if the Earth's axis was perpendicular to its revolution around the Sun. In Europe, the day lengthens in winter and in spring from the end of December to the end of June but becomes shorter in summer and in autumn from the end of June to the end of December. This effect is the opposite in the southern hemisphere. There are thus times when the day is the longest and the night shortest (or the opposite): they are the **solstices**. There are also times when the duration of the day and the night are equal: they are the **equinoxes** (see this entry).



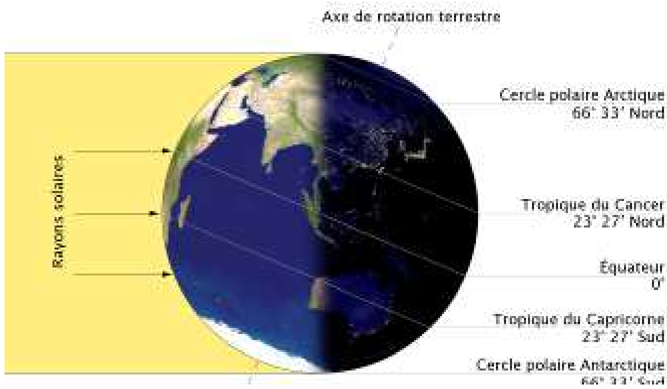
The revolution of the Earth around the Sun. © Nicolas Dufresne

Every year, according to the position of the axis of inclination of the Earth with respect to the Sun, the latter is vertically above the **Tropic of Cancer** on June 21st or 22nd. Six months later, it passes directly above the **Tropic of Capricorn** on December 21st or 22nd.

In June, the Sun seems to rise very high in the sky as its brilliance warms our atmosphere more directly and for longer than in winter, when the shortness of the day does not give it much time to transmit its heat. Conversely, it is the southern regions which benefit from this over the same period, the balance between both hemispheres occurring only during the **equinoxes**.



The summer solstice in Europe. © NASA



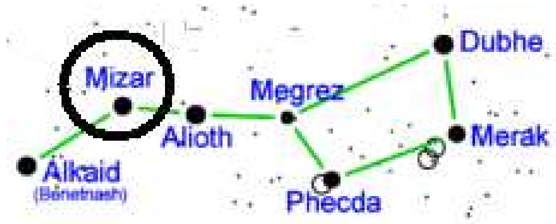
The winter solstice in Europe. © NASA

Star (binary)

To translate the idea of a binary star, we make the sign STAR then put the hands in the shape of pincers, representing two small objects of round shape coming next to each other. For the etymology of the sign STAR, see the entry *Star-general*.

Words and associated expressions:
Astronomer - Black hole - Diameter - Dimension - Distance - Earth - Light year - Mass - Neutron star - Planet - Star (diameter) - Star (name) - Star (variable) - Sun.

When we look with the naked eye at the Big Dipper (Plough or Great Bear) constellation, far from the city lights, we can easily see that the last but one star of the “pan” shape ζ UMa called also *Mizar*, is accompanied by a small star close by, the name of which is *Alcor*. This couple moreover makes for an excellent visual test. Dozens of thousand stars live like this in couples, some of which are **visual,** i.e. when the two stars are of very different distances but appear to be almost aligned with the Earth, and many others which are **physical couples**, in other words two stars of which one is in revolution around the other, in the same way as a planet turns around the Sun.

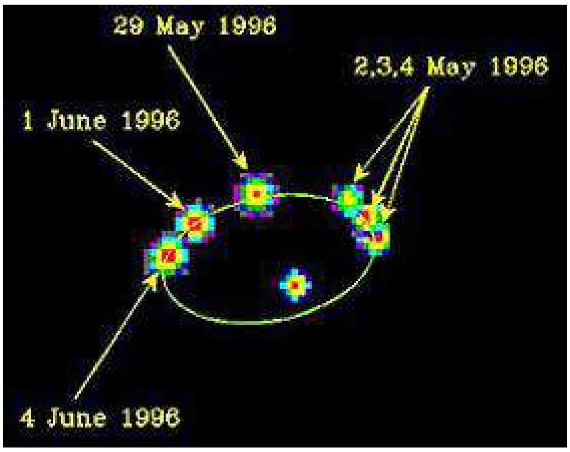


The position of Mizar in the « pan » shape of the Big Dipper.

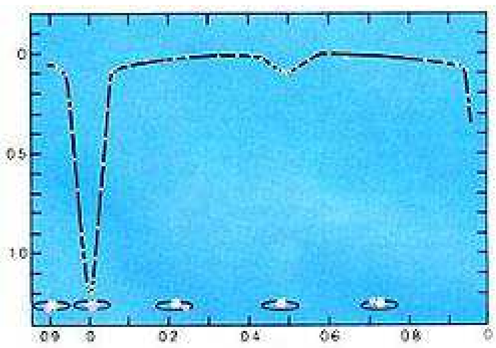
The observation of binary stars allows us to know their mass from the laws of mechanics. Astronomers regularly observe the movement of a star with regard to the other by measuring the changes of position and the **angular distance**, in other words the small angle which, as seen from the Earth, separates them both. So, the couple *Mizar-Alcor*, which is 90 light years from the Earth, is seen at an angle of 0.2°, which corresponds to 0.25 light years. This distance is much too great so that although both stars are not physically connected:, they appear to form a visual couple, which appears to be the case because of their alignment with the Earth.
However, Mizar does have a real physical

companion, visible with a small telescope at an angular distance of 14″. Moreover, each of the two is itself a very close binary star. Numerous brilliant stars are in fact magnificent couples with contrasting visible colours visible with a small refractor or a telescope, such as *Albireo* (ß Swan), formed by two yellow and blue stars at an angular distance of 35″, or *Alamak* (γ Andromede), formed by two orange and blue stars separated at 10″.

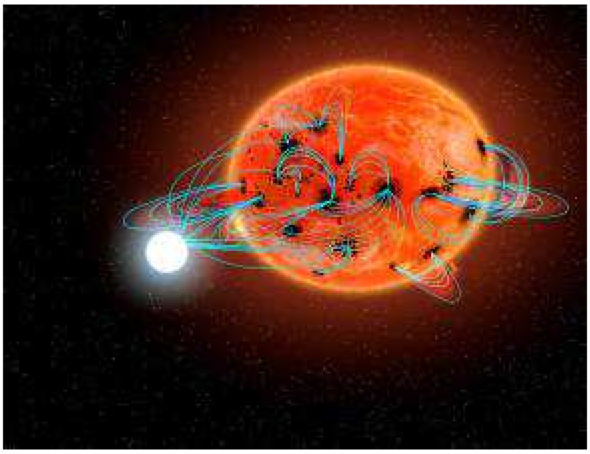
We can find in the *Stellar Atlas* at the end of this dictionary several classical binary stars that easy to observe.



The binary star Mizar. © NASA



The brightness variation of Algol.



A binary star in interaction with an exchange of matter between the components. © NOAO

The eclipsing binary stars

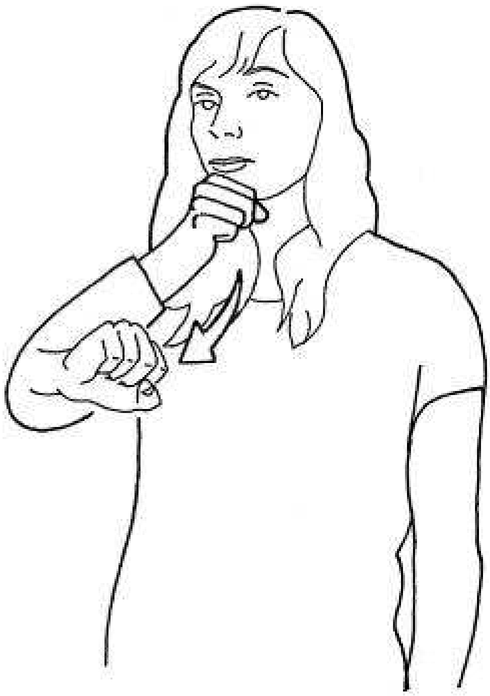
For numerous binary stars, the Earth is in the plane of their orbit. It thus happens that one of them passes in front of the other, causing an eclipse which modifies the total brightness of both stars. This is the case of *Algol* (ß Perseus) the variability of which was discovered by the deaf English astronomer *John Goodricke* (see the entry *Star-variable*).

Very different couples

As technology progresses, astronomers are discovering closer and closer binary stars. Some of them are so close to each other that they can exchange their matter, especially if they are of very different types. It even happens that the couple is comprises an ordinary star and a companion which can be a neutron star or a black hole. Their detection is only possible thanks to the X-rays they emit. By studying these very particular couples, astronomers try to understand if they have to deal with a joint evolution of both of them or if one of them was "captured" by the other. They also try to work out the eventual fate of these couples.

Star (Christmas)

The Christmas star is indicate by the sign STAR (q.v.) followed by the sign CHRISTMAS. This second sign is indicative of Santa Claus's beard.



CHRISTMAS

Associated words and expressions:
Astronomer - Comet - Earth - Nova - Solstice - Star - Supernova.

The Bible mentions the appearance of a celestial body in the sky during the birth of Jesus. According to tradition, a star or a comet would have encouraged the kings to follow the road to Bethlehem in Judea. What phenomenon would they have observed at that time and what could have been the date of the nativity?

The date of Christmas on December 25th was decreed in the year 334 AD to replace the Roman orgies celebrating the winter solstice. On the other hand, precise research shows that an error of several years occurred in the Christian calendar since the nativity: of Jesus would most likely have taken place in either 7 or 5 BC. Neither archaeological research nor ancient documents, in particular those of the Chinese dynasties, mention a new star (nova or supernova) or a spectacular comet during this period (Halley's comet passed near the Earth fourteen years earlier).

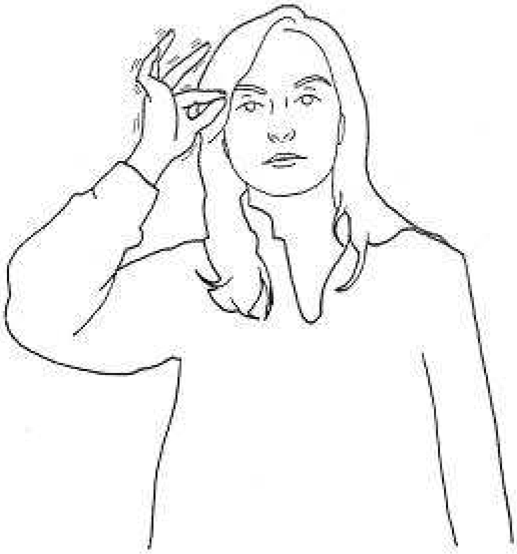
The worship of the kings and Halley's comet painted by Giotto di Bondone (1267-1337).

However, it does happen that planets seem to get closer to each other even if they are in reality at very different distances from each other thus giving the impression, as seen from the Earth, of a particularly spectacular double or triple celestial body. This relatively frequent phenomenon is called a **conjunction**. For the astronomers, such a conjunction, observed in the autumn of the year 7 BC or in the spring of the year 5 BC could correspond to the nativity.

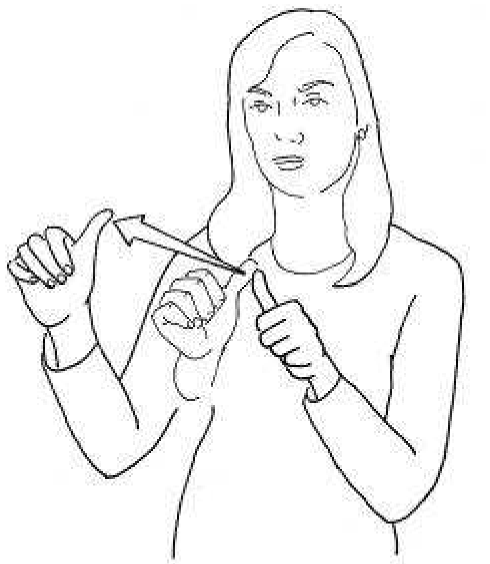
A **conjunction** is easily represented in Sign language by placing the hands in apart and then moving them closer to each other until they are almost aligned at eye-level.

Star (Distance)

The concept of the distance of a star is translated by the sign STAR followed by the sign DISTANCE. For the etymology of these two signs, see the entries *Star (general)* and *Distance*.



STAR



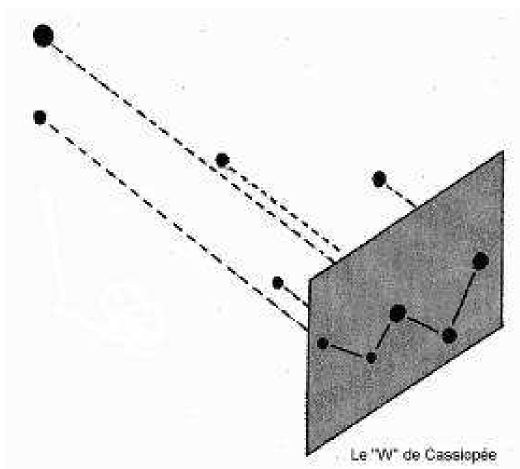
DISTANCE

Words and associated expressions: Astronomer - Light year - Light (velocity) - Magnitude - Parsec - Spectral type - Sun.

The **distance** of the stars is very important. A star is in fact a distant sun the light of which needs years, often decades, to reach us at a speed of 300,000 km per second. That is why astronomers measure the distance of stars in light years and parsecs which are units much better adapted than the kilometre for such large numbers. Apart from the Sun, the closest star visible with the naked eye is called *Rigil Kent.* It is the α (alpha) star of the constellation of Centaurus which is 4.2 light years distant from the Earth.

The observation of the night sky on a fine night gives the impression that all stars are situated at the same distance. In olden days, it was believed that stars were fixed to a big black sphere called **The Firmament.**

However, stars have very different distances. For example, the constellation Cassiopeia includes five brilliant stars arranged in the shape of the letter "W". As shown in the illustration, these five stars are situated at very different distances from us (in light years):

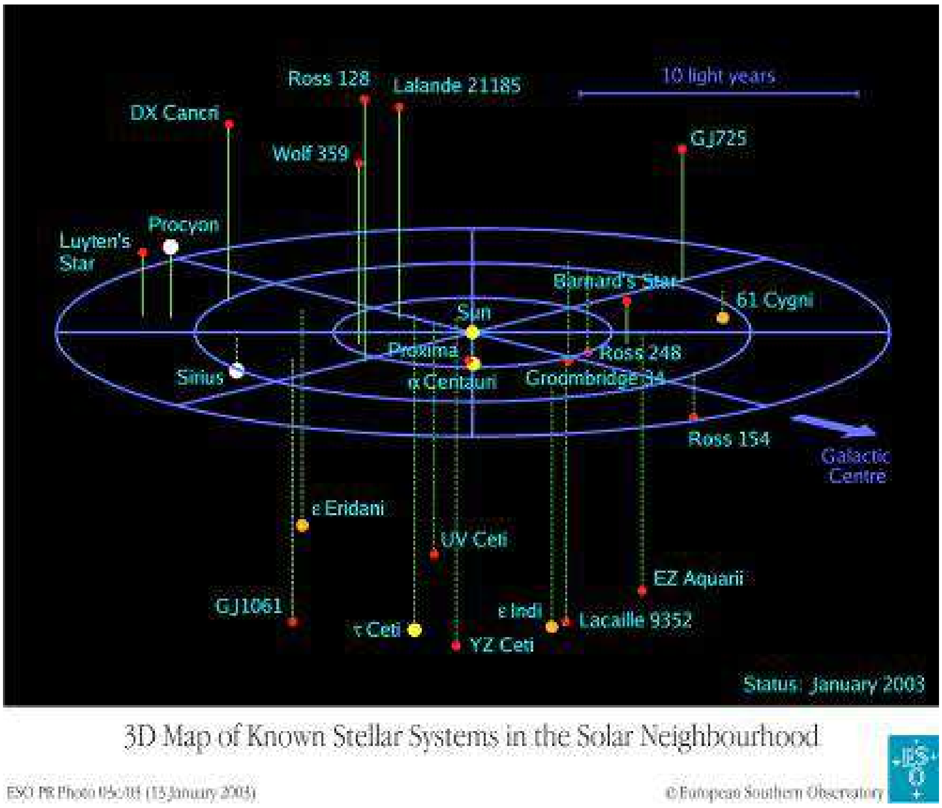


The five stars forming the letter « W » in the constellation of Cassiopeia.

ε 500 LY | **γ** 100 LY | **β** 46 LY

δ 76 LY | **α** 160 LY

Among the most brilliant stars, *Sirius* (α Canis Majoris) is 8.64 light years distant, *Vega* (α Lyrae) 26.42 light years, *Arcturus* (α Bootes) 35.88 light years, *Canopus* (α Carinae) 195.7 light years, *Rigel* (ß Orion) 815.5 light years, etc. In other words, the light which comes to us from *Canopus* left this star during the end of the reign of Napoleon I 195.7 years ago and that of *Rigel* at the time of the construction of the Gothic cathedrals. **Every star's light is further in the past than the star's distance!** You will find in the Sky Atlas at the end of this dictionary the description of the main stars visible to the naked eye, grouped in constellations, with their brightness (magnitude), their spectral type, their class and their distance.



The closest stars around the Sun situated at a distance of less than 10 light years. © ESO.

Star (evolution)

The evolution of stars is represented with the sign STAR followed by the sign EVOLUTION. This second sign is a metaphorical gesture with the hands inverting their direction in one slow and continuous movement as if opening up on the axis of time. For the etymology of STAR, see the entry *Star (general)*.

EVOLUTION

Words and associated expressions:
Constellation - Distance - Dimension - Earth - Energy - Galaxy - Nebula (planetary) **-** Nova - Nuclear (reactions) - Planet - Sun - Star - Supernova - Solar System - Temperature.

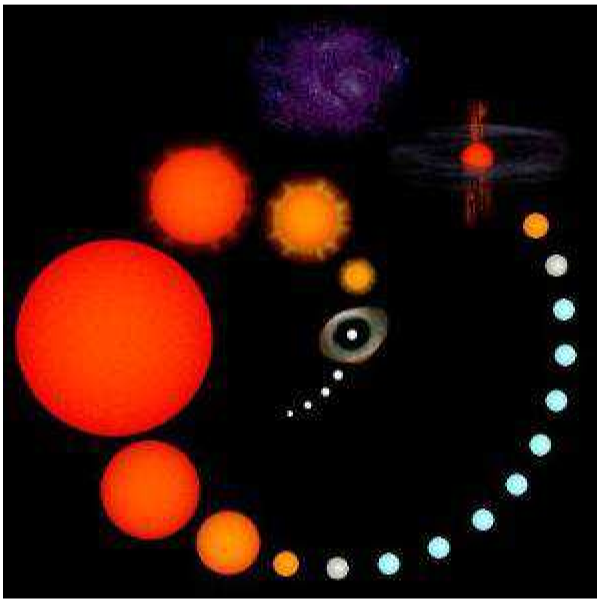
Stars are born, live and die. During their existence, they create most of the natural elements, from the "lightest" such as carbon, nitrogen or oxygen, to the "heaviest" such as lead, mercury or uranium. The Solar system and the Earth were formed 4.55 billion years ago in a cloud of gas and dust, rich with all these elements (see the entrance *Solar system*), resulting from the material of millions of stars which was scattered after their death. Thus we can say that human beings are made of stardust.
We describe below the **evolution of a solar-type star**. For the **massive** stars, see the entries *Nova* and *Supernova.*

Stars are born in the arms of the galaxies rich in gas. Inside these clouds, the gas is hot and dense enough for big bubbles, **protostars** ("baby stars"), to form. When the central temperature is enough high (approximately fifteen million degrees), nuclear reactions start transforming hydrogen into helium. The star begins its existence and escapes from its cloud. As shown in **the diagram of the stars** in the section **Star (type)**, it becomes a point of the **Main Sequence** on which the star will remain during the largest part of its life.

A nursery of stars in a molecular cloud.
© NASA/Hubble Telescope.

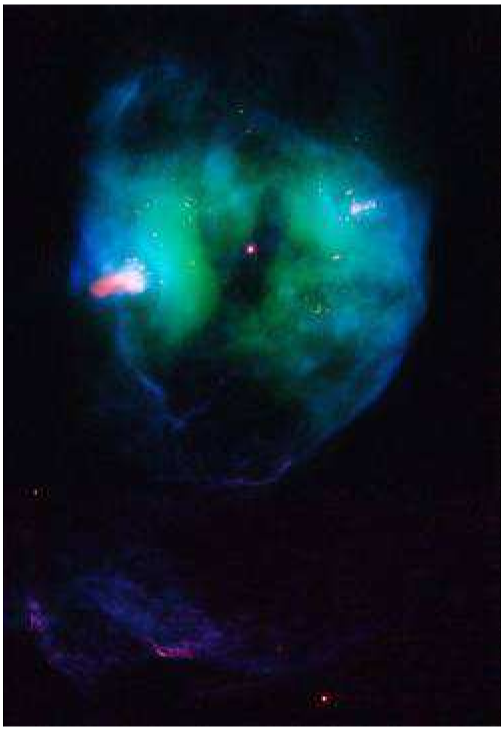
The star uses its hydrogen as fuel. The nuclear reactions which occur in its central regions transform the hydrogen into helium; one gram of hydrogen releases an energy of 600 billion joules! (See the entry *Energy*). The star can so continue its existence over several billion years, just as the Sun does. If we could accelerate time so that the life time of a star becomes equal to that of a man, then the life of man would be reduced to only forty seconds!

When the star has no more hydrogen, it burns its helium which it transforms into carbon, then into oxygen, into silicon, into magnesium, etc. Following these reactions, the central temperature increases gradually and the star dilates, becoming a **red giant** which, if put in place of the Sun, would reach the planet Mars! At the end of tens of million years, the star's central matter ends up by collapsing in on itself just like a soufflé taken out of the oven, while the outside regions, which are rich in chemical elements, created inside the star are ejected to form a magnificent *planetary nebula* (see this entry).



The life cycle of a star. After its birth in a cloud of gas, the star shines during several billion years while remaining identical to itself (here in blue). Then it dilates to become a red giant, before collapsing by ejecting of the material (planetary nebula) and to end as a white dwarf. © A. Nadeau

The star collapses in on itself to become a **white dwarf**, whose diameter is only a few hundred or thousand kilometres. Compressed into a so small space, the material is so dense that a thimble could contain several hundred kilos! Thereafter, the dying star diminishes very slowly, while its material begins to be dispersed into the surrounding space. Both phases, **red giant** and **white dwarf**, are represented on the **diagram of the stars** in the section *Stars-types*.

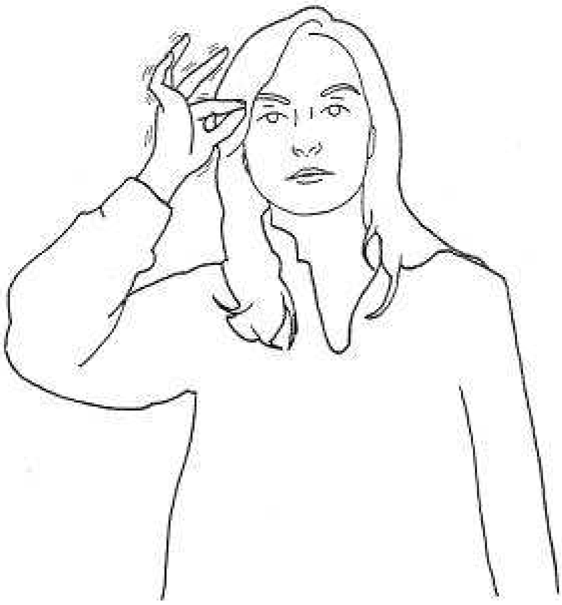


The planetary nebula NGC2371. Note the central star which has ejected its material. © NASA/HST

However the material ejected by the star before dying is not lost. It is rich in all the elements that the star synthesised during its life. This enriched material is used to make new stars and planets on which life can maybe appear and develop. Thus the evolution of stars is an ecological cycle.

Star (general)

In the sign STAR, the hand in the shape of a pincer symbolises an object of round shape and apparently small dimensions. The movement of oscillation of the wrist imitates the sparkling of stars. The location on the temple refers to an object situated way up high.



Words and associated expressions:
Astronomer - Binary (star) - Constellation - Dimension - Distance - Evolution - Nuclear (physics) - Solar System - Sun - Telescope - Temperature - Variable (star).

The sky we observe is little different from that of the ancients. The stars seem immovably fixed to the celestial vault. A hundred years ago, it would have been difficult to know the distance or the dimension of the stars. It was even more problematic to explain the cause of their brilliance. Why do stars shine? How do they evolve? We had to wait for the 20th century with modern telescopes and the progress in nuclear physics to understand that stars are born, live and die, just like human beings, and that they are in permanent evolution.

The expression "Celestial Vault" means the complete visible night sky (see this entry).

Since ancient times, astronomers drew up more and more detailed catalogues of stars. They grouped them at first in constellations. The astronomer *Hipparchus*, in the 2nd century BC, established a catalogue of 1,024 stars. Arabic astronomers then gave names to the most brilliant stars (the reader will find some of these names in the Sky Atlas). Over the centuries, catalogues grew quickly and nowadays, we have listed about 200 billion stars just in our Galaxy.

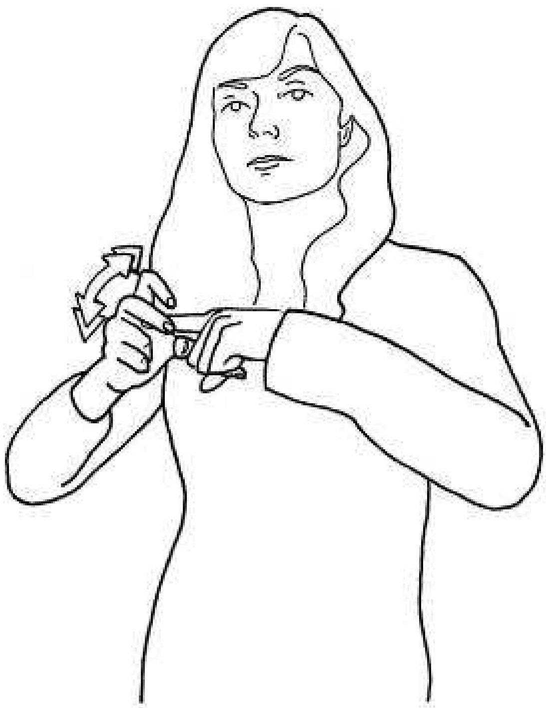
Stars are very distant suns. They are defined by their distance, their dimension, their temperature and other characteristics such as their binarity and variability. Thanks to their observations, astronomers have succeeded in understanding their physics and evolution.

A small portion of the sky with thousands of stars. © ESO

The study of the evolution of the stars requires much patience because the life of a human being in comparison with a star approximates to two seconds of our own existence! An astronomer has to collect the maximum of information to reconstitute the history of a star, the life of which can reach several billion years. Our Sun was created with the Solar system approximately 4.6 billion years ago and is nowadays in the middle of its existence. Thanks to astrophysics, we can now associate man with the stars because we consist of atoms which were synthesised in stars from the beginning of the universe. **To know the life of stars is to know man also.**

Stars (types)

The stars are divided into various spectral types, according to their temperature. The spectral type of a star is named with one of the letters O, B, A, F, G, K, M, and we indicate it in Sign language by means of the corresponding manual letter. Three classes, dwarfs, giants, and supergiants (even bigger than the giants), linked to their diameter, are also designated by corresponding signs.



TEMPERATURE

DIAMETER

Associated words and expressions: Alphabet - Astronomer - Constellation - Distance - Magnitude - Mars - Nuclear (reactions) - Planet - Sun - Spectroscopy - Star (general) - Star (evolution).

Stars shine thanks to the nuclear reactions which occur in their central regions, where the temperature reaches fifteen million degrees. However, if this central temperature is in practice identical from one star to another, their surface temperatures vary a lot.

The Sun has a surface temperature of 5,800° which corresponds to its yellow colour, but there are thousands of hotter stars (blue colour) or colder (red colour). The colour of a star is thus an indicator of its surface temperature. The analysis of the light of the stars is made by the spectroscopy. It is from the spectra of the stars that astronomers can classify them according to their physical characteristics.

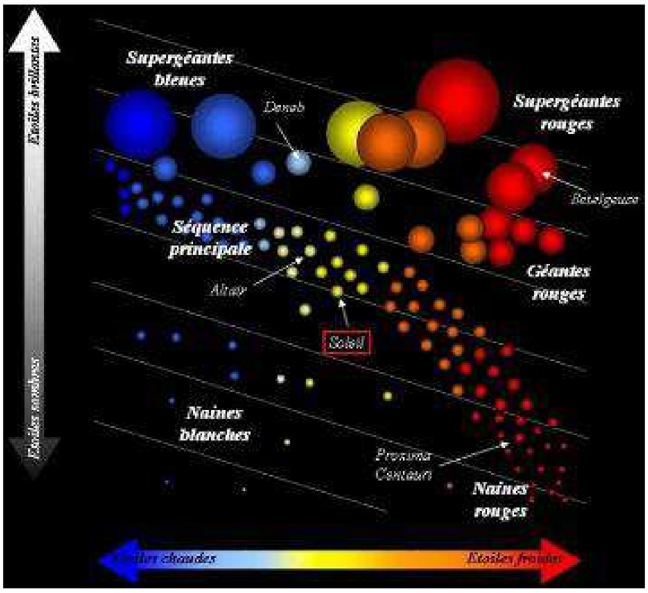
We have only to observe the sky with the naked eye to notice that stars have different colours: Vega (Lyrae) is white, whereas Arcturus (Bootes) is yellow; and in the constellation of Orion, Rigel is white whereas Betelgeuse is red. Astronomers have classified stars into seven main categories, subdivided into nine subgroups called the **spectral type**. It allows us to know the physical and chemical characteristics of the stars and to deduce all of their properties. The table below shows the seven main categories with the corresponding temperature and colour.

A small portion of the sky full of stars with different colours, mixed with gas. © ESO

Spectral type	Temperature	Colour	Examples
O	25,000° - 45,000°	blue	*Mintake* (δ Orion), *Naos* (ζ Puppis)
B	9,500° - 25,000°	blue – white	*Rigel* (β Orion), *Achernar* (α Eridan)
A	7,100° - 9,500°	white	*Sirius* (α Canis Majoris), *Vega* (α Lyrae)
F	5,800° - 7,100°	white – yellow	*Procyon* (α Canis Minoris)
G	4,600° - 5,800°	yellow	*Capella* (α Aurogae), *the Sun*
K	3,200° - 4,600°	yellow – orange	*Arcturus* (α Bootes)
M	1,800° - 3,200°	red	*Antarès* (α Scorpiud)

For the extremely cold stars, classes **R**, **N**, and **S** have been created. Every star is defined by its magnitude, in other words the quantity of light it emits, and the nature of this light corresponds to the class of the star.

The diagram of the stars

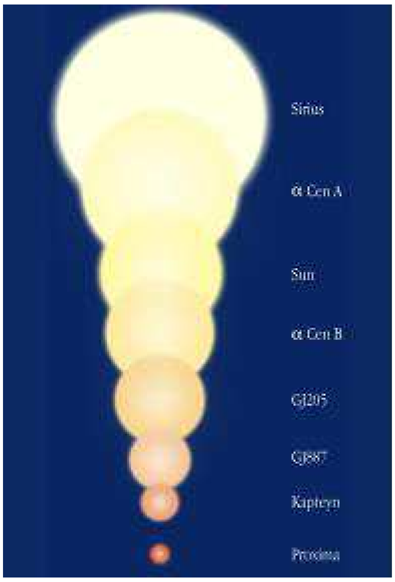


The diagram of the stars (also called the Hertzsprung-Russell diagram). © Florent Renaud

In the 1910s, two astronomers, *Hertzsprung* and *Russell*, created a diagram the horizontal axis of which represents the temperature of the stars, whereas the vertical axis represents their luminosity or magnitude. This diagram shows that the majority of stars (including the Sun) are situated on a sinuous band called the **Main Sequence** which falls from the upper left towards the right. Above this is the family of the **giants** and the **supergiants,** hot stars to the left and cold to the right; and, below, the family of the **dwarfs**, white and red stars. Thus there are three main classes of stars:

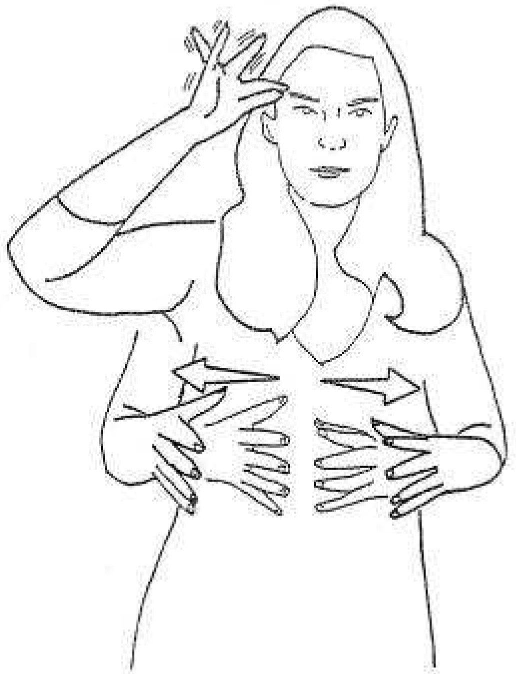
- dwarf stars
- giant star
- supergiant stars

Stars are of very different sizes and temperatures but, as seen from the Earth, a cold dwarf star close to us can appear as brilliant as a very distant hot giant star. The above diagram represents in reality the various stages of the life of a star, from its youth until its old age (see the entry *Star-evolution*). The dimension of stars is remarkable. The Sun, with its 700,000 km diameter, is a dwarf star, whereas certain supergiant stars, put in place of the Sun in the Solar system, would extend up to the orbit of the planet Mars! You can find in the *celestial Atlas* at the end of this dictionary the description of the main stars visible with the naked eye, grouped in constellations, with their brightness (magnitude), their spectral type, their class and their distance.



Comparison of the size of several nearby stars compared with the Sun. © ESO

Star (variable)

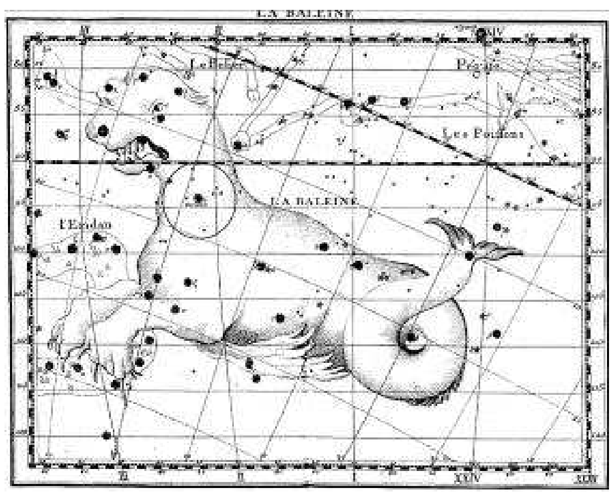


The concept of a variable star is translated with the sign STAR, followed by a sign which evokes the increase and the decrease of the visible brightness of all the variable stars as well as the actual movement of dilation and contraction of the most important of them, the Cepheid variables. For the etymology of STAR, see the entry STAR (general).
To indicate more precisely a variable star of the family "eclipsing binary", we use the sign ECLIPSE (see the corresponding entry).

Associated words and expressions:
Constellation - Dimension - Distance - Earth - Eclipse - Galaxy - Nova - Refractor - Sun - Supernova - Star (binary) - Star (name) - Telescope - Temperature.

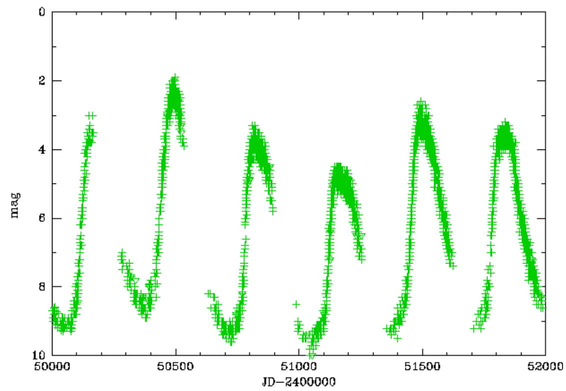
In days gone by, we thought that stars always remained identical to each other. However, throughout history new stars appeared from time to time whereas others disappeared before becoming visible again a few weeks or a few months later. There are two families of very different stars here. Those which appear suddenly in the sky before declining constitute the family of the "**novae**" (plural of the Latin “nova”) and the "**supernovae**" (plural of Latin “supernova”). Those of which the brightness changes more or less regularly constitute the family of the **variable stars**. We know of tens of thousands of these variable stars which are classified into several categories. They are real lighthouses in the sky that are conspicuous by their youth or their maturity. Whether we talk about a young **cepheid**, or an old **Mira** or an **eclipsing binary**, variable stars show the vitality of the celestial bodies which surround us. We can find the description of the most characterful of them in the *Sky Atlas* at the end of this dictionary.

The most famous of the variable stars is *Mira Ceti*, "the Wonderful" in the constellation of the Whale (Ceti), known since the earliest days to disappear before reappearing. The French astronomer Ismaël Bouillaud (1605-1694) noticed the periodic return of its brightness every 333 days. Nowadays, thousands of such stars of this type are listed: among the variable stars; they constitute the group of **mira stars**. They are extremely cold supergiants of M-type (see the entry *Star types*), whose magnitude oscillates on average between 3 and 10 every 300 to 500 days.

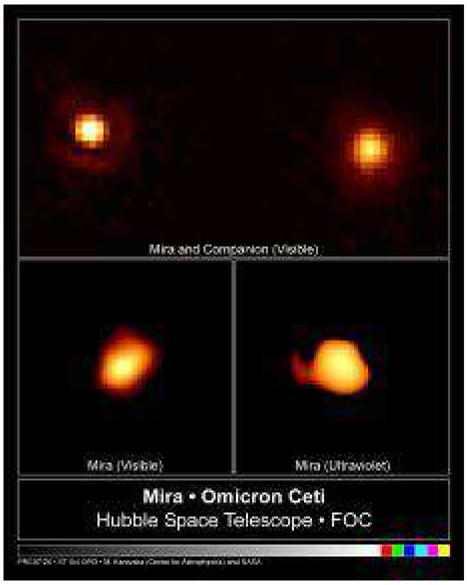


The star « Mira Ceti » in the neck of the constellation of the Whale (in the small circle).

Astronomers have studied what causes the variability of **mira stars** and have concluded that it is a complex result of shock waves propagating in their atmosphere. Observations made with the largest telescopes show the large diameter of these stars which, put in place of the Sun, would reach the Earth!



The variation of the brightness of the star Mira Ceti between magnitudes 2 and 10 over 5 years. © AFOEV



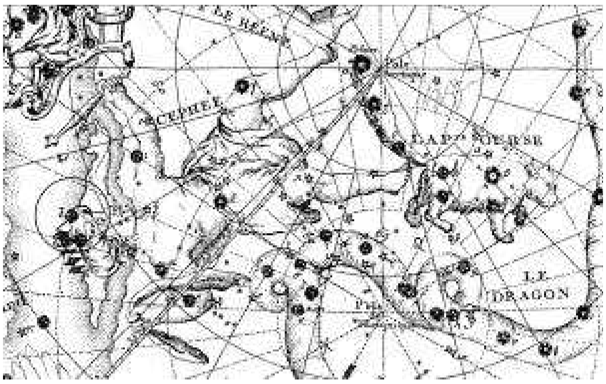
The star Mira Ceti and its extended atmosphere observed with the Hubble Space Telescope. © NASA/HST

There are other families of variable stars. In 1669, the astronomer *Montanari* discovered the regular variations of the star *Algol* (ß Perseus, whose Arabic name means "the carrier of the head of the devil"). *John Goodricke* notes that this star has a cycle of 2 days, 20 hours and 48 minutes. *Algol* is a member of the **eclipsing binary stars**, whose variation of brightness is due to the regular passage of a less brilliant star in revolution around it (see the entry Star-binary).

John Goodricke, deaf astronomer

John Goodricke.

Born on September 17th, 1764 at Groningen (Holland), of an English diplomat father and a Dutch mother, John Goodricke became deaf at the age of five following scarlet fever. Having been a pupil at the Braidwood Academy, the first school for deaf children in Great Britain, he became passionate about the astronomy and determined the duration of the variation of brightness of the star *Algol* in 1783. In the same way, he discovered that *Sheliak* (ß Lyrae), which changed its brightness every 12 days and 20 hours, is also an **eclipsing binary** star composed of two giant stars in mutual revolution. Another star which drew his attention: was δ Cepheus where he noted its variations of brightness between magnitudes 3.7 and 4.6 every 5 days and 9 hours.

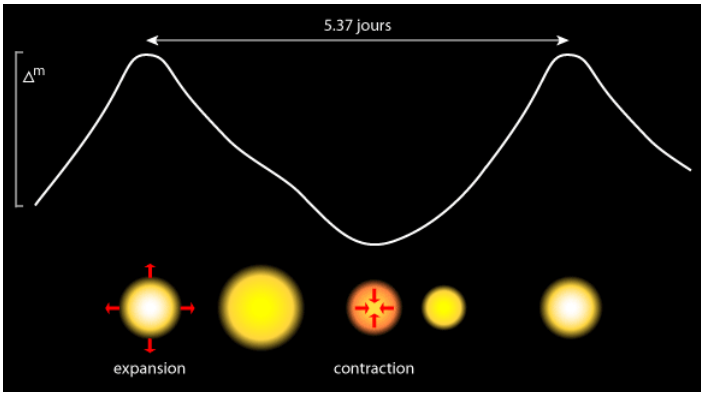


The position of δ Céphée (on the left in a circle).

However, the variation of brightness is not caused in the same way as for *Algol* and *Sheliak*: δ Cepheus belongs to a new family of variable stars *the Cepheids*. Becoming a member of the Royal Society, John Goodricke died from pneumonia on 20 th April 1786 at York in England. He was just 21 years old.

Nicaragua stamp with John Goodricke. In miniature , the portrait of Nicolas Copernicus.

Cepheids are young giant stars which dilate and contract, as a breathing lung would. This movement causes a very regular variation in their brightness as the star's matter tries to stabilize while in motion. Thus δ Cépheus increases its radius (18 million km, i.e. 30 times that of the Sun!) by 2 million km with every pulsation. We find cepheids as well in our own Galaxy as well as in nearby ones. The polar star is also a cepheid, but its variations of brightness are imperceptible to the naked eye.

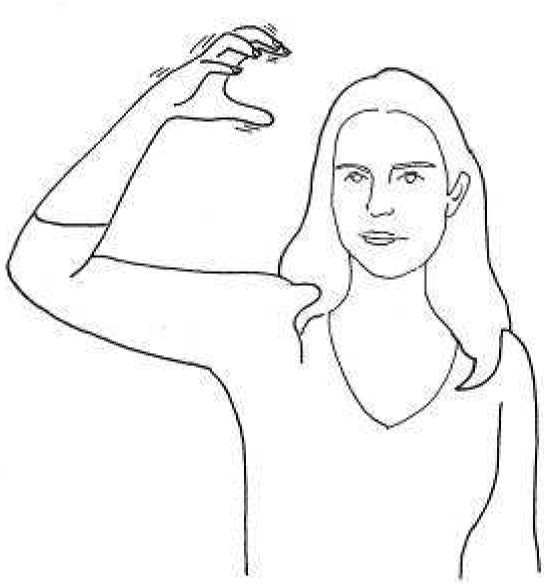


The luminous variations of δ Cepheus. © SAR

At the beginning of the 20th century, the American astronomer *Henrietta Leavitt* (1868-1921) discovered that the longer the duration of variation of a cepheid, the greater its absolute magnitude (see the entry *Magnitude*). Thanks to this relationship, astronomers can **calculate the distance of the nearby galaxies** very precisely. Note that *Henrietta Leavitt* was hearing-impaired.

Sun

The sign **Sun** is represented by a hand making the shape of a sphere, positioned at height and making small oscillations symbolizing the light and the heat which it emits.

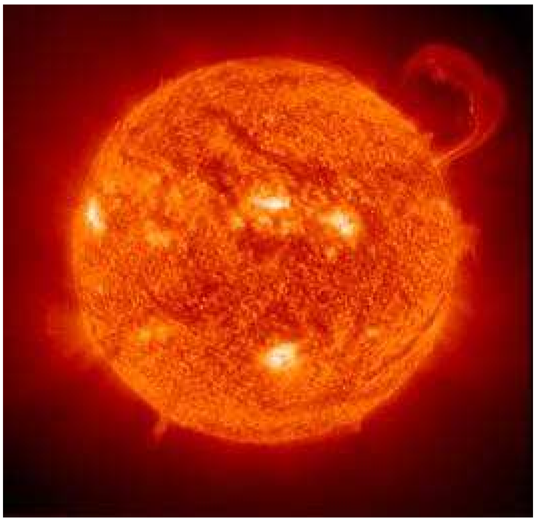


Associated words and expressions: Absolute magnitude - Astronomical unit - Galaxy - Light year - Mercury - Nuclear reaction - Red giant - Star - Solar System - Spectral Type - Visual magnitude - White dwarf.

The Sun has always held a very special place in different civilizations. In Antiquity, it was considered a god: *Râ* for the Egyptians, *Belenos* for the Gauls, *Apollo* for the Greeks, *Pachacamac* for the Native Americans of the South, *Rha* for the Polynesians. King Louis XIV is known as the *Sun King* whereas the Japanese tradition makes the imperial family of *Amaterasu* descendants of the goddess of the Sun. Work on the evolution of the Earth has shown that, without the Sun, life would not have been able to appear on its surface.

The Sun is the star the closest to the Earth.

Distance : the Sun is situated at an average distance of 149,597,870 km from the Earth, which represents *one astronomical unit (AU)*.
Average Diameter : 1,392,000 km.
Inclination : its axis is slightly inclined with an angle of 7° 15'.
Rotation : being constituted by gas, the Sun’s equator moves faster than its poles. The average rotation is 27 days and 7 hours.
Magnitude : as seen from the Earth, the Sun is very bright : its *visual magnitude* is -26.73, while its *absolute magnitude* is 5.3.
Temperature : the average temperature on the surface of the Sun is 5,800°C ; in its centre, it reaches 15,000,000°C. The Sun is a yellow dwarf star with spectral type G2.
Mass : 2×10^{30} kg.



The Sun and its eruptions. © NASA/JPL

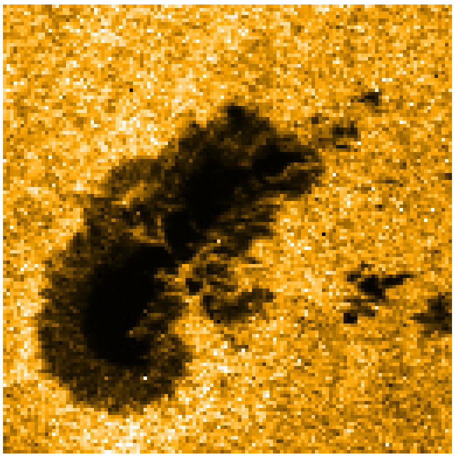
The Sun is one of the 200 billion stars which populate our Galaxy. It is situated at an average distance of 30,000 light years from its centre and at 50 light years from its Galactic plane. It makes a revolution around the centre of the Galaxy every 240 million years at a speed of 220 km/s.

Atmosphere : the Sun is composed of roughly 75% hydrogen and 25% helium. We can also find traces of all kinds of elements: iron, magnesium, sulphur, carbon, etc. The Sun has been shining since its creation 4.6 billion years ago, its source of energy being maintained by the cycle of nuclear reactions which occur in its central regions. Every second, several million tons of hydrogen are transformed into helium by providing large quantities of energy which transfer to the surface of the Sun to be ejected in the form of light and particles in every direction. The Earth benefits from this source of energy which brings us heat and light without which life would be impossible.

The structure of the Sun includes three zones. The **core** is the region where the nuclear reactions occur. It has a radius of about 140,000 km and the temperature in the centre reaches fifteen million degrees. The **convective zone** is 490,000km thick: the material transfers heat towards its exterior. Finally, the **photosphere** is the surface of the Sun with a thickness of about 400km. This is what we see from the Earth. It is formed of cells which look like immense grains of rice and it is there that sunspots are formed.

Jets of material on the surface of the Sun; a part falls again whereas the rest is ejected into space bringing heat and light. © NASA/JPL

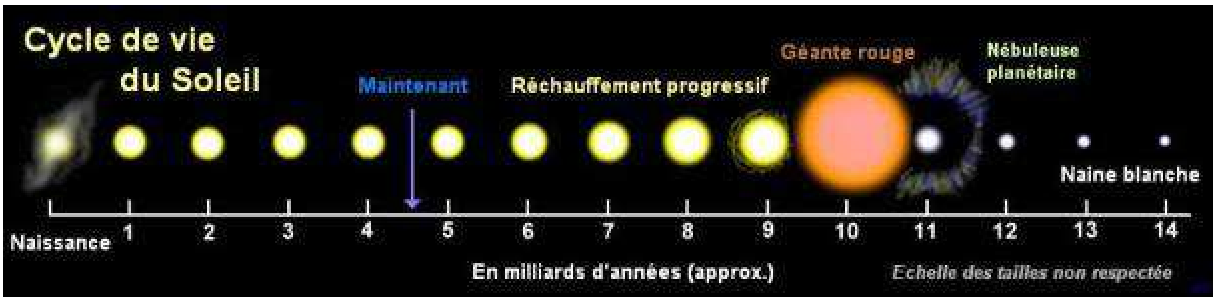
The surface of the Sun or " photosphere". This is the small layer, visible from the Earth, where sunspots are formed. © NASA/JPL



Group of sunspots.© Observatoire de Paris

Sunspots have been observed since the 17th century. Variable in shape, they can be anything from 1,500 to 80,000 km in size and are generally visible over several days. They are formed in the same way as cyclones on the Earth and are maintained by the powerful solar magnetic field. Their temperature is between 1,500 to 2,000° lower than elsewhere on the Sun's surface. Astronomers have noticed that these spots are more numerous approximately every eleven years: this is the **cycle of the solar activity**, the origin of which remains uncertain; the last peak of activity took place in 2012.

There are numerous eruptions linked to the Sun's activity. These are jets of high energy particles which are diffused at high speed in every direction. When they come close to the Earth, they are captured by our planet's magnetic field and follow this towards the North Pole, thus protecting us from their harmful effects. From time to time, they succeed in exciting the hydrogen in the atmospheric water vapour thus causing the magnificent Aurora Borealis which appears in the sky of Canada and the Scandinavian countries.



History of the Sun.

History of the Sun

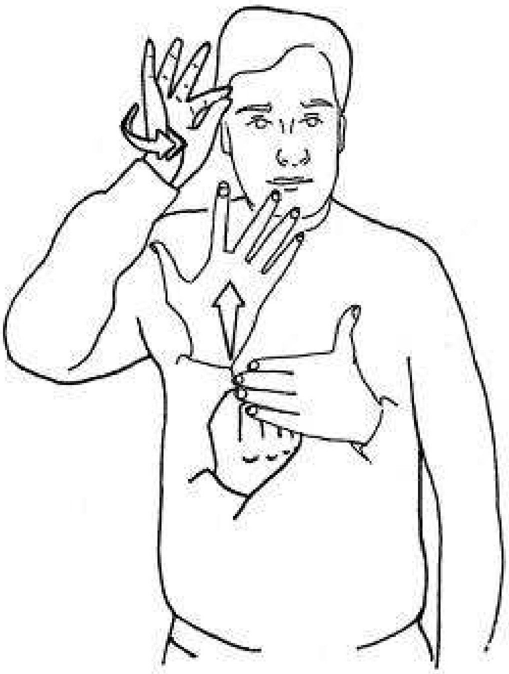
The birth of the Sun, along with the Solar system, took place 4.6 billion years ago from a cloud of gas which condensed by gradually increasing its temperature until it reached fifteen million degrees in its central regions, allowing nuclear reactions to start. For the past four billion years, right up to the present day, the Sun has not stopped transforming its hydrogen into helium: every second, spending the equivalent in energy of 9×10^{16} tons of dynamite. However, the reserves of hydrogen will eventually run out which will cause the helium to burn and be transformed into other elements such as carbon, nitrogen and oxygen. These reactions will raise the temperature of the core and the Sun will begin to dilate. It will become a red giant star which will reach the orbits of Mercury, Venus then Earth. These planets will then be destroyed. Approximately 250 million years later, the Sun will collapse slowly on itself, by ejecting its top layers, to become a white dwarf some hundreds of kilometers in diameter. In the meantime, future generations will have to find a new planet on which to settle.

Without the Sun, life would not have been able to develop on the Earth. **However its brilliance can be very dangerous**:
- You should never observe it directly, neither with the naked eye nor with an instrument. Its brilliance causes irreversible damage to the retina, leading to blindness.
- During an eclipse of Sun, it is essential to take a lot of precautions by using effective filters to protect the eyes.

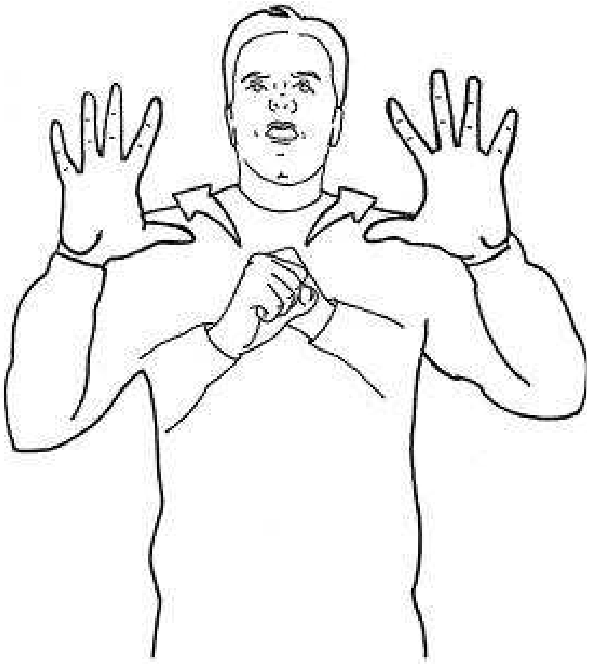
It is also essential to protect the body from the Sun's rays because these can be harmful under certain conditions, in particular in summer when, with the fashion for tanning, a part of its ultraviolet rays can cause "sunburn" and increase the risk of developing cancer, particularly of the skin and the breasts.

Supernova

The notion of SUPERNOVA is expressed with the sign NOVA followed with the sign EXPLOSION. A supernova is thus represented in Sign Language as “a new star which explodes”. The fists which open while moving apart largely represent an explosion followed by the ejection of matter into space. For the etymology of NOVA, see the corresponding entry.



NOVA

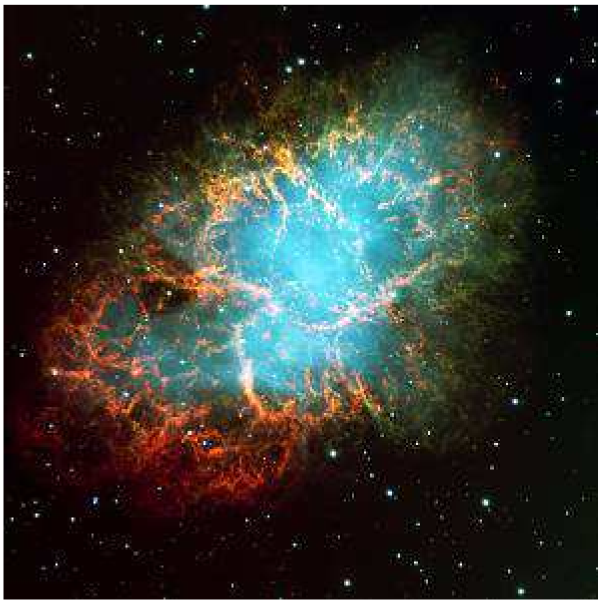


EXPLOSION

Associated words and expressions: Constellation - Distance - Dimension - Light Year - Magellanic clouds - Nova - Nuclear (reactions) - Star (evolution) - Star (type) - Sun - Temperature.

The end of life of a massive star (see the entry *Star-type*) is spectacular. Such a star, the mass of which is at least thirty times greater than that of the Sun, becomes a very brilliant **supernova** (plural *supernovae*) which ejects the main part of its matter into space, whereas the destabilized core of the star collapses on itself and its matter reaches an enormous density of several tens of tons per cubic centimetre!

The nuclear reactions which transform hydrogen into helium in the central regions of a massive star allow it to survive about ten million years by fighting against its own "obesity", preventing it from collapsing on itself under the effect of its own weight. Exhausted by this repeated effort, the star eventually becomes "out of breath" whilst the helium starts new nuclear reactions from which new elements will be synthesised: beryllium, carbon, oxygen, magnesium, etc., up to iron which will accumulate in the centre of the star while raising its temperature by between five and ten billion degrees.
This strong increase of temperature provokes a gigantic explosion of the star, whereas the central matter collapses on itself to give rise to a **neutron star** and then a pulsar (see this entry).



The "Crab" supernova M1, remains of a massive star which exploded on July 4th 1054. © ESO

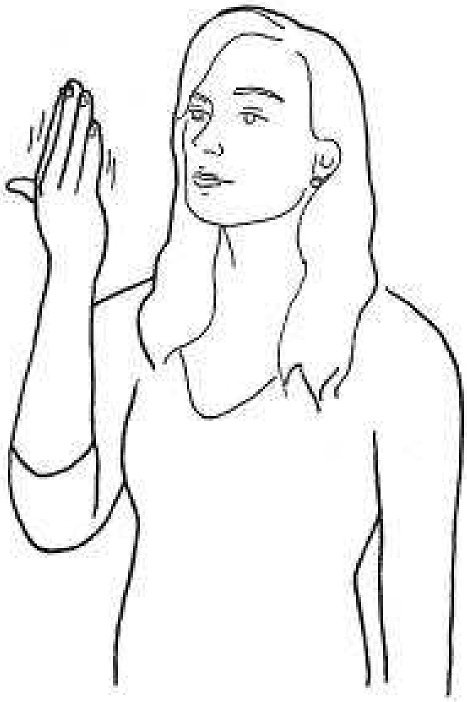
The **Crab supernova** appeared in the constellation of Taurus on July 4th 1054 before disappearing in May 1056. It was visible in daylight although it was 6,520 light years (L.Y) distant; today it has a diameter of 7.5 L.Y. Other supernovae have been observed, in particular in 1572 in the constellation of Cassiopeia and in 1604 in the constellation of Ophiuchus. More recently, in 1987, a supernova appeared in the Large Magellanic Cloud at a distance of 168,000 light years from the Earth which was visible with the naked eye.

The energy and the radiation released by a supernova are such that any form of life less than some hundred light years distant would disappear. Fortunately, no massive star is situated near the Earth. As the brightness of supernovae increases considerably during its explosion, astronomers can observe them in extremely distant galaxies.

Telescope

The telescope is represented by the sign ASTRONOMICAL REFRACTOR which figures an optical instrument directed towards the sky followed by the sign MIRROR which specifies the nature of the instrument. The addition of the sign SATELLITE allows us to define telescopes in orbit around the Earth such as the Space telescope.

REFRACTOR

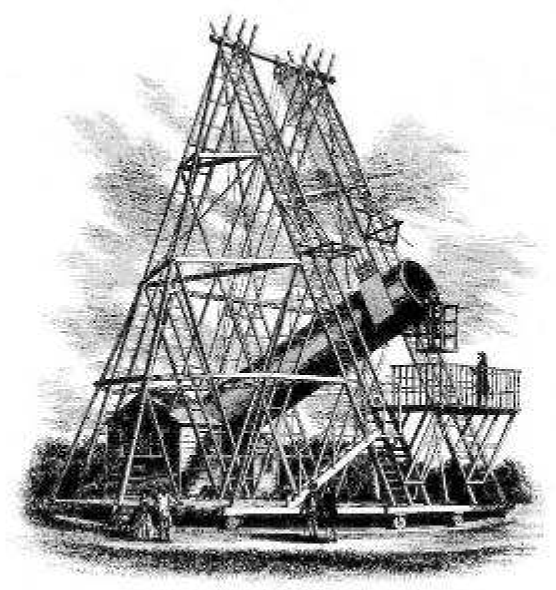


MIRROR

Associated words and expressions: Azimuthal mount - Astronomical refractor - Diameter - Equatorial mount - Satellite.

The word **telescope** comes from Greek *to see far*. It indicates an instrument designed for astronomy observations. It was invented after the astronomical refractor by replacing the lens of the objective by a concave mirror. This is identical to the small magnifying mirrors used in bathrooms to see details of the body better.

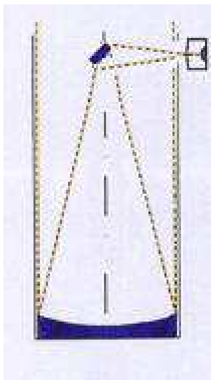
Isaac Newton (1642-1727) is often considered as the inventor of the telescope but, in fact, it is much older and resulted from research by different opticians over time. The concave mirror concentrates the light of a celestial source in a point called the **focus**, just like a magnifying glass, so that it can then be analyzed by all sorts of instruments, cameras, spectrographs, etc. Over time, the mirrors of telescopes have not stop growing in size, going in three centuries from some centimeters in diameter to more than eight meters. There are also assemblies of mirrors placed side by side to build bigger and more powerful instruments. Telescopes are generally known by the diameter of their main mirror.



One of the telescopes constructed by William Herschel (1738-1822). © DP

Telescopes contain various optical systems, the most common of which is the **newton** system, often used for amateurs' instruments, and the **cassegrain** system which is used in many of the large telescopes. The latter also use other optical combinations.

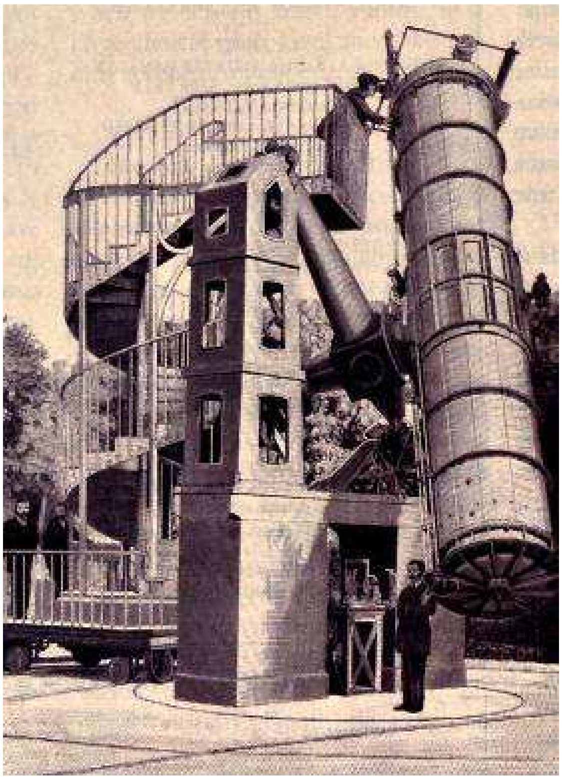
© Observatoire de Paris



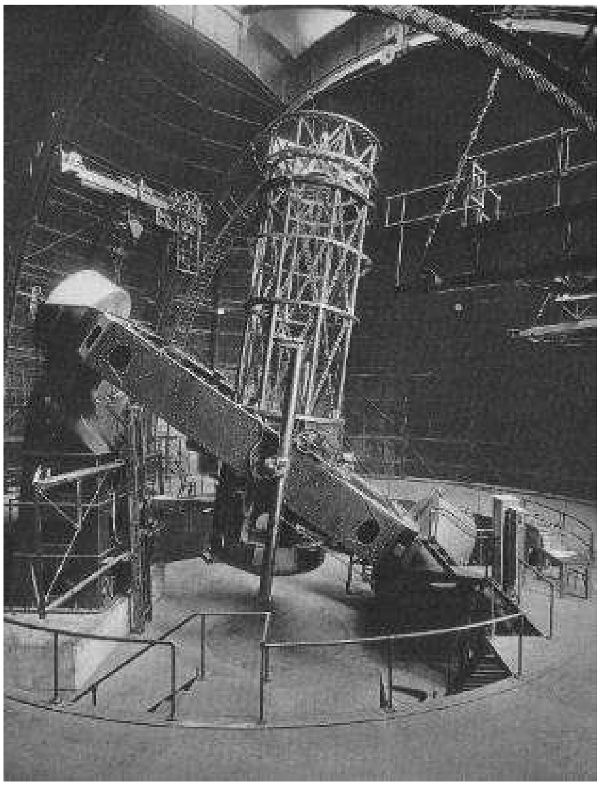
*Optical **newton** combination. We observe on the side of the instrument.*

*Optical **cassegrain** combination. We observe behind the main mirror.*

Telescopes are mounted on two main axes allowing them to point at the same time in every direction of the sky, and to compensate for the movement of rotation of the Earth through the help of motors (note that it is not stars and galaxies which move in the sky, but the Earth which is turning). The oblique axes are called the **equatorial mount** (see the entry *Astronomical refractor*). With their two axes, vertical and horizontal, which are called the **altazimutal mount**, large modern telescopes can thus compensate for the movement of the Earth.



The old 1.20m telescope of Paris observatory. © Obs. Paris



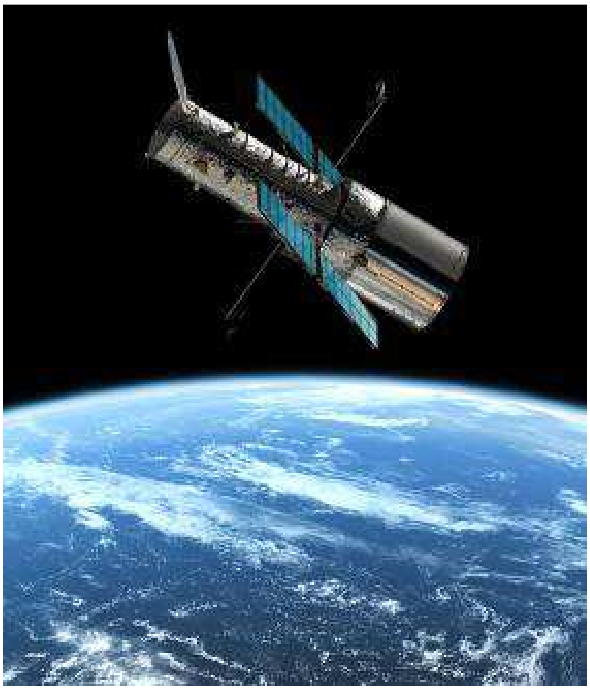
The 2.54m (100 inches) telescope of Mount Wilson observatory (California).

The 3.60m telescope at ESO-La Silla (Chile). Note the tilted axe of the equatorial mount. © ESO

The 3.50m New Technology Telescope (NTT) at ESO-La Silla (Chile) and its azimuthal mount. © ESO.

Besides ground telescopes, there are also telescopes in orbit around the Earth, such as the *Hubble Space telescope* with its 2.40m mirror. As it doesn't suffer from meteorological disturbance, it can be used to observe all the time.

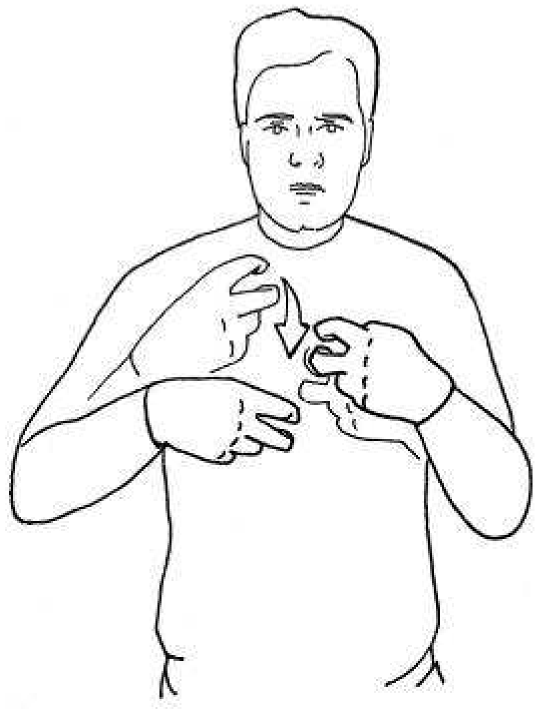
One of the four instruments of the " Very Large Telescope" at ESO-Paranal (Chile) with its 8.20m diameter mirror whose weight is 42 tons. © ESO



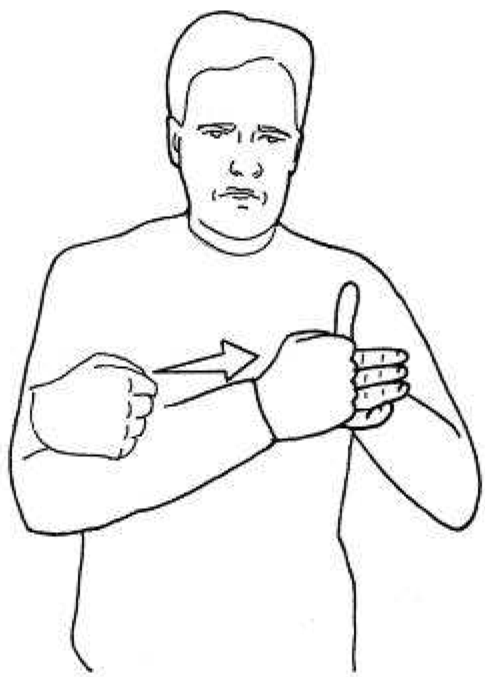
The "Hubble Space telescope" in orbit around the Earth. © NASA/HST

Transneptunian (objects)

The TRANSNEPTUNIAN OBJECTS are located beyond the orbit of **Neptun**, the most distant planet of the Solar system. They are represented by the sign STONE, followed with the sign AT THE END. The sign STONE derives from HARD, a hand in double hook striking the back of the other hand as to feel hardness; it then evolved by a symmetry, both hands taking the same shape.



HARD



AT THE END

Associated words and expressions: Astronomer - Astronomical unit - Neptun - Planet - Pluto - Revolution - Solar system - Sun.

After the discovery of Pluto in 1930, the astronomers wondered if other even more distant planets could exist. It is necessary to wait until 1992 to observe, thanks to the large telescopes, a first object which received the name of 1992QB1 (baptized then Radha). Afterward, several others were detected: Orcus, Ixion, Varuna, Quaoar, Sedna, etc. To distinguish the « major planets » (from Mercury to Neptun), we agree to call them here « small planets », although they are not considered by the astronomers as real planets. The table below gives the characteristics of ten of these **small transneptunian planets**, so distant from the Sun that this one, as seen from one of them, would appear only as a star among the others. These small rocky planets are plunged in a permanent night; because of an extremely low temperature inferior to -230°C they can have ice on their surface there.

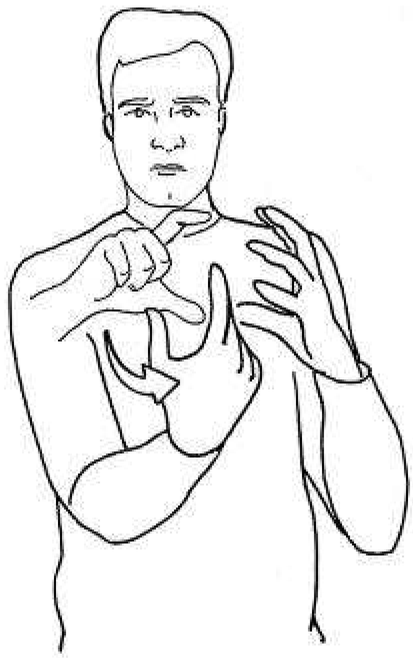
Distance to the Sun (millions of km)	Name	Diameter (km)	Duration of the revolution (years)	Date of the discovery
5 901	47171-TC36	550	248	1999
5 910	Ixion	759	248	2001
5 920	Orcus	1 600	248	2004
6 231	24835-SM55	702	269	1995
6 451	Varuna	1 060	283	2000
6 472	19308-TO66	600	284	1996
6 489	Quaoar	1 250	286	2002
6 893	Chaos	347	313	1998
10 123	Eris	2 600	557	2005
75 000	Sedna	1 450	11 374	2003

Sedna has a very excentric orbit, its distance to the Sun varying from 11 to 140 billion km. It is the most distant small planet known up to now, in revolution around the Sun in more than 11 000 years! The small planet 47171-TC36 has a satellite, as well as *Eris* whose satellite was baptized *Dysnomia*; the latter has a diameter of 350 km and turns at a distance of 30 000 km from Eris in approximately 14 days. The majority of these small planets belong to the **Kuiper belt** situated beyond Neptun, in a region distant from 30 to 50 astronomical units from the Sun. It received the name of the American astronomer *Gerard Kuiper* (1905-1973), whose works had allowed to predict the existence of small objects beyond Neptun.

Comparison of several transneptunian small planets with the Earth. © NASA

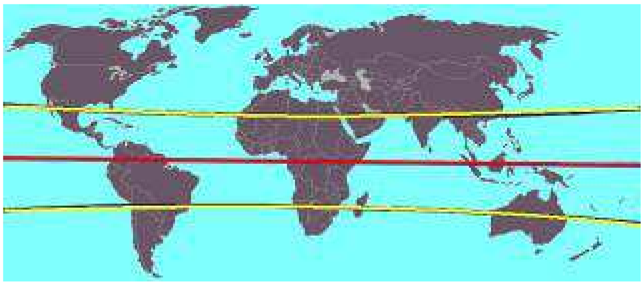
Tropic

The sign TROPIC is made with a hand in a small crescent shape which simultaneously draws two imaginary lines around the Earth, represented by the other hand. The index finger draws the Tropic of Cancer while the thumb draws the Tropic of Capricorn.



Associated words: Earth - Equator - Equinox - Solstice - Sun - Zenith.

The **Tropic of Cancer** and the **Tropic of Capricorn** are two circles, parallel to the equator. The first is situated at 23.5° North of the equator, and the second at 23.5° South. In the zone delimited by these two circles, we can see, during the course of a year, the Sun passing at its zenith, which is not possible if we are situated to the North of the Tropic of Cancer (for example in Paris), or to the South of the Tropic of Capricorn.

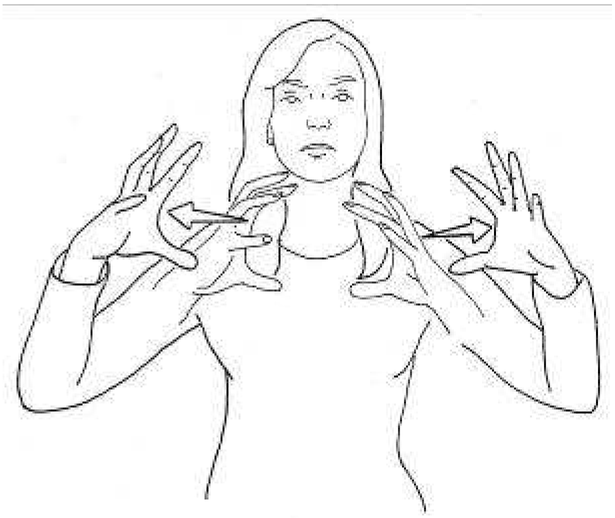


Both tropical circles (in yellow) on both sides of the equator (in red). At the top, the Tropic of Cancer, below, the Tropic of Capricorn.

When the Sun is at the zenith of the Tropic of Cancer, we have the **summer solstice** in the northern hemisphere and the **winter solstice** in the southern hemisphere. Between these two extremes, the Sun passes twice a year at the vertical of the equator and this corresponds to the spring equinox and to the autumn equinox. This phenomenon is linked to the inclination of the axis of the Earth.

Universe (expansion)

The **expansion of the universe** is represented by the sign UNIVERSE (see the entry *Universe-history*) followed by the sign EXPANSION which shows a spherical object increasing in volume.

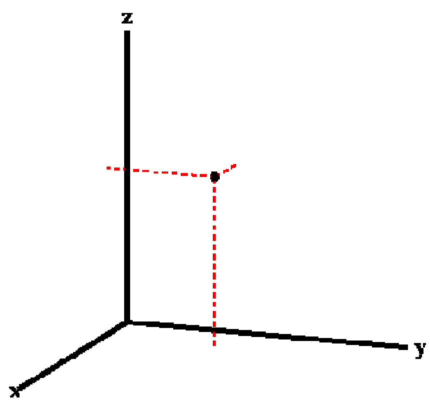


EXPANSION

Associated words and expressions: Chemical element - Doppler-Fizeau effect - Galaxy - Interaction (gravitation) - Light year - Planet - Spectrum - Spectral line - Spectroscopy - Star - Telescope.

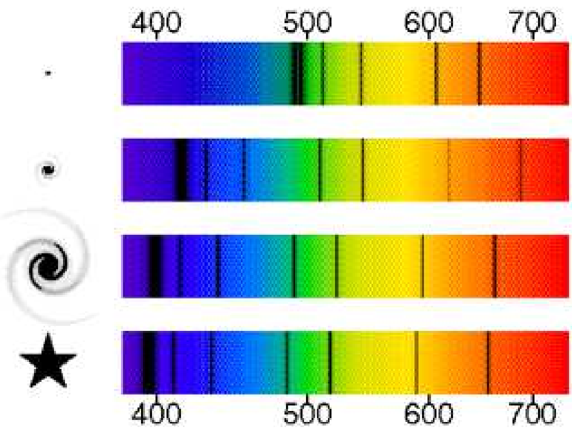
The structure of the universe is one of **space-time**. Planets, stars and galaxies evolve in a space with **four dimensions**. A straight line is defined by a dimension *x*, a plane with two dimensions *x*,*y*, a space by three dimensions *x*,*y*,*z*. To these three dimensions we add time *t* which defines the space-time of the universe: (*x*,*y*,*z*,*t*).

Every day, we are immersed in space-time: an appointment in a building is possible only if we know the address and coordinates of the building (*x*= longitude, *y*= latitude), the level of the meeting place (*z*= height) and the time of the appointment (*t*= time). This structure with three space dimensions and a time dimension lets us describe the evolution of the universe since its origin 13.7 billion years ago.



Location of a point in a three-dimension space.

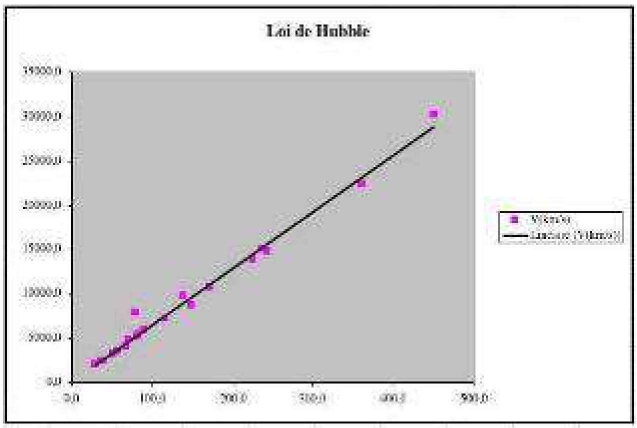
In 1929, the astronomer *Edwin Hubble* (1889-1953) obtained the first spectra of galaxies with a telescope and noticed that the spectral lines of the various chemical elements emitted by the stars and by the gas of the galaxies wee shifted towards the large wavelengths because of the Doppler-Fizeau effect (see the entry *Spectroscopy*).



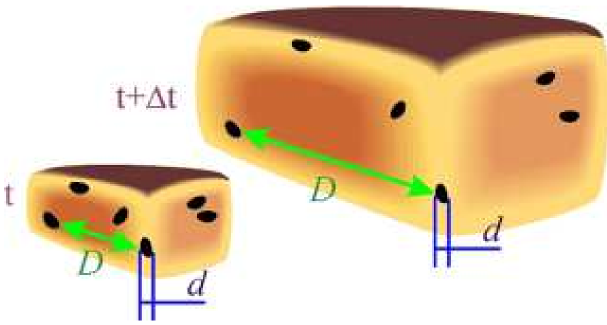
© Wikipedia

The spectroscopic analysis of stars, galaxies, quasars, etc., shows that the spectral lines are shifted. A star, below, shows a set of lines between the wavelengths of 400 and 700 nanometers. A galaxy moving away (above the star) has its lines moving towards the large wavelengths (towards the red domain of the spectrum or **redshift**). This shift increases when the galaxies are more and more distant.

Hubble concluded that galaxies were moving away from each other just as, for example, a soufflé with raisins which the chef puts in the oven; the more the gateau inflates, the more the grapes move away from each other. Hubble thus showed that the further the galaxies are from us, the greater their recession velocity: this is **Hubble's law**. This relationship shows that space increases in volume; so, by the interplay of space and time, **the universe is expanding**.



Hubble's law *establishes that the distance of the galaxies (horizontal axis in millions of light-years) is linked to their recession velocity (vertical axis in km/s). © Observatoire de Paris*



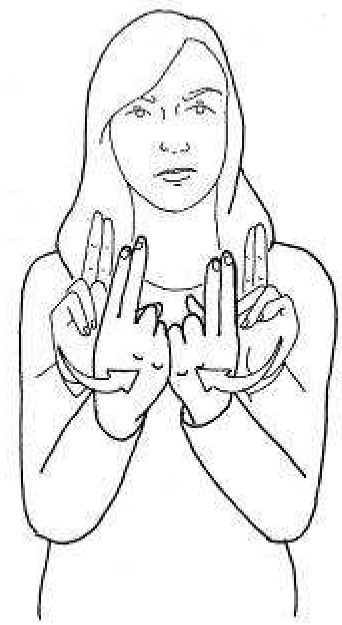
As a soufflé which expands in an oven and increases the distance between the raisins, the expansion of the universe increases the distance between galaxies during an interval of time Δt (delta t).

This expansion of the universe, which was considered for a long time as a "theory", is now generally admitted, especially since other discoveries, such as the 3K cosmological background (see the entry universe-background), and the initial abundance of the light elements (helium) came to support the cosmological model emanating from Big Bang (see the entry universe-history). In this expansion however, there are peculiar effects linked to local gravitational interaction; this is the way our Galaxy and the Local Group (see this entry) depart from the general movement of expansion because of the gravitational action of enormous superclusters of galaxies situated in the direction of the constellation of the Centaur.

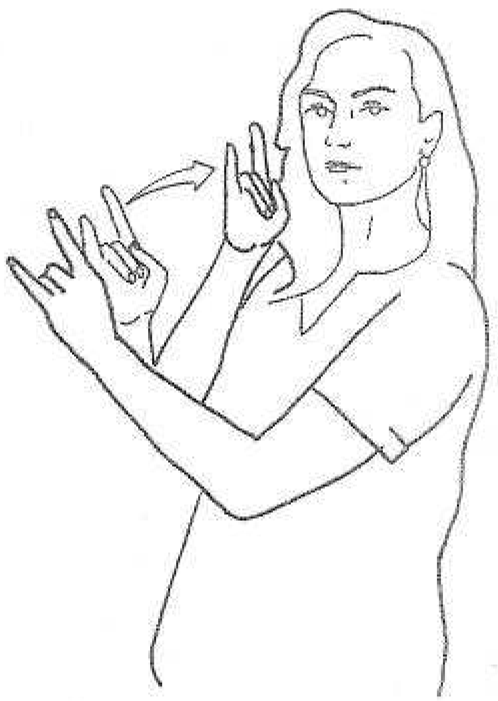
This is moreover why astronomers pose questions about the future of the universe. Is this expansion going to continue indefinitely or, under the influence of gravitational interaction which attracts bodies, is it going to stop its expansion and to start a phase of recession? At present the question still has no answer. Research undertaken since the beginning of the 21st century with the large telescopes seems moreover to indicate that the expansion of the universe would be in a phase of acceleration.

Universe (history)

The universe is represented with both hands showing the letter “ U”, initial of the word *universe*, which then draw the outlines of a sphere. For the etymology of the sign HISTORY, see the entry *Astronomy-history*.



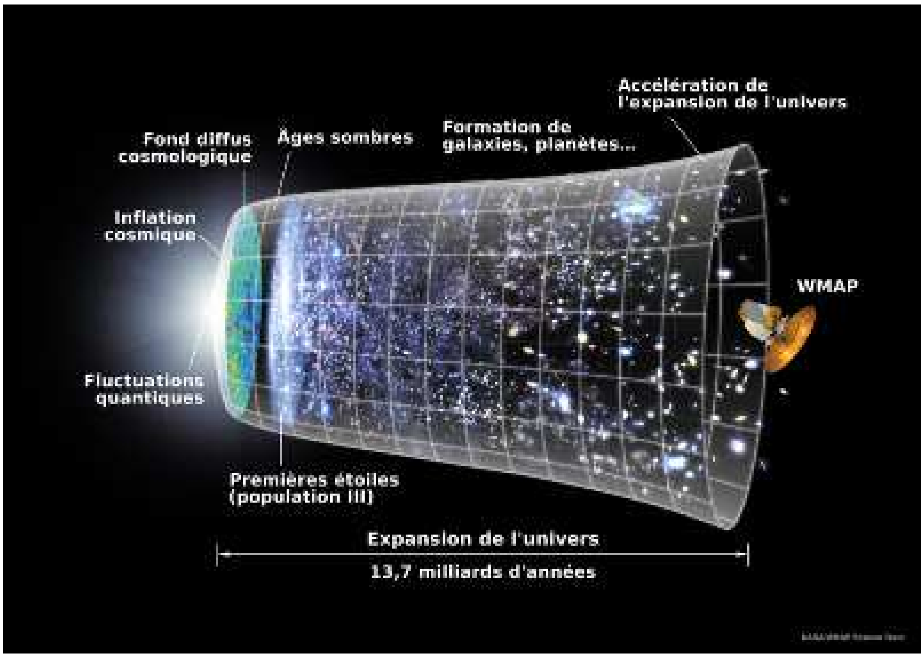
UNIVERSE



HISTORY

Associated words and expressions: Atom - Astronomer - Big Bang - Cluster (galaxies) - Electron - Galaxy - Interaction - Kelvin - Electron - Neutron - Photon - Proton - Relativity - Star (evolution) - Supercluster (galaxies) - Universe (emission) - Universe (expansion).

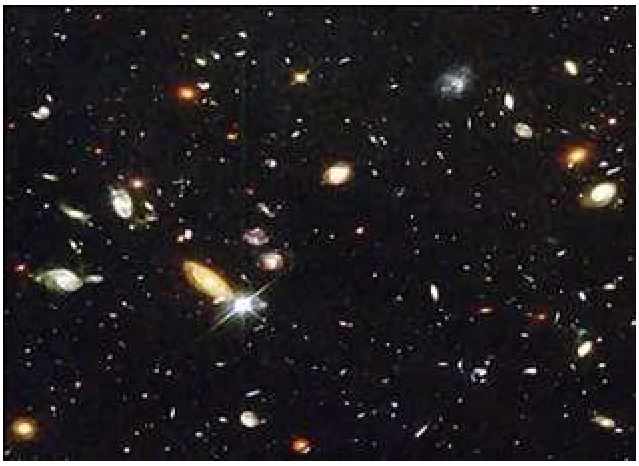
From Antiquity up to the 18th century, man thought that the universe which surrounds us was infinite and eternal, and often associated with the divine for theological reasons emanating from the great revealed religions. Later on, if astronomers and philosophers envisaged a "beginning" of the universe, they had to wait for the works of *Albert Einstein* (1879-1955) on relativity and the discovery of the expansion of the universe, the emission of the cosmological 3K-background and the initial abundance of elements to understand that the universe was created from a kind of explosion called the **Big Bang** (see this entry), 13.7 billion years ago. Gradually, astronomers have succeeded in collecting the pieces of this puzzle, allowing them to reconstruct little by little the history of the universe.



History of the universe since the Big Bang. © NASA/WMAP

In the extreme conditions of the Big Bang, the physics of the universe can only be described through the so-called **Great Unified Theory**, where the four forces of nature are gathered into one. The primordial universe was a microscopic space filled with photons and with **quarks**, the latter being the elementary constituents of neutrons and protons. Very quickly, gravitational force differentiated from the other three this precipitating the universe into a phase of rapid expansion called **the inflation**. The universe was then a boiling soup of electrons, **positrons** (electrons with a positive charge), protons, neutrons, photons, etc. Immediately after the Big Bang, the temperature was 10^{27} degrees (1 followed with 27 zeros). One second later, it was no more than ten billion degrees (1 followed with 10 zeros). The electromagnetic and weak nuclear interactions also broke up. Particles evolved under the influence of nuclear reactions. At the end of the first three minutes, the universe cooled down to a temperature of a billion degrees.

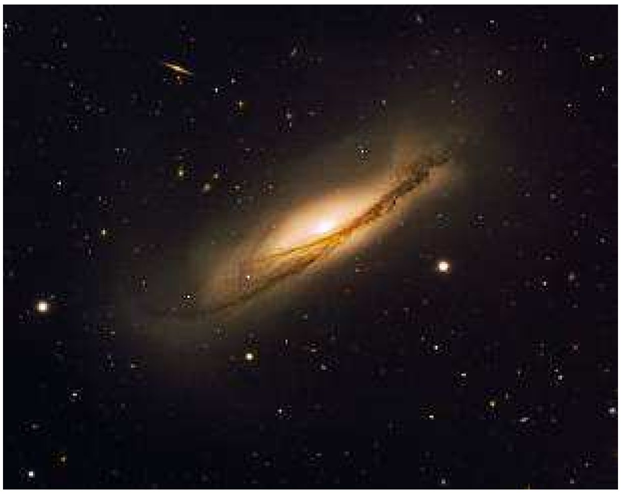
During the following hundred thousand years, the whole universe was immersed in the background emission following the Big Bang. The fusion of protons and electrons resulted in neutrons, allowing the formation of the first atomic nuclei: deuterium, helium and lithium. The universe still continues to dilate and cool. If the primordial universe was "opaque" with the particles which filled it, the situation changed gradually when the temperature decreased at the end of several hundred thousand of years. The photons which constitute light began to be scattered freely: the universe then became transparent with a dissociation of light and matter. We then had to wait for several million years so that matter could get organized into the form of galaxies and galaxy clusters.



A galaxy field, several billion light-years away. © NASA/HST.

Chemistry itself came into existence only when the temperature became lower than ten thousand degrees, allowing the formation of the atoms of hydrogen, helium and lithium.

Atoms group together gradually to form concentrations of matter, which is at the origin of clusters and superclusters of galaxies. These very large-scale structures fill approximately 10% of the universe, and are isolated by large regions which are empty of baryonic (light) matter. Inside the individual galaxies, stars are born, evolve and die, enriching the interstellar environment with chemical elements (see the entry *Star-evolution*). What we observe today is the result of the expansion and the cooling of the universe, during which its limits have not stopped expanding, whereas the temperature has lowered gradually to three degrees Kelvin (see the entry *Universe-emission*).

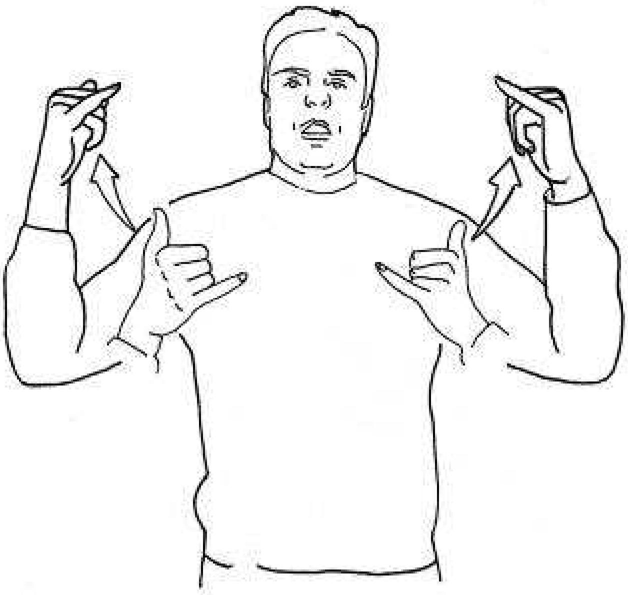


A galaxy member of a cluster: NGC 3190. ©ESO.

If the past of the universe has been accessible thanks to observation and analysis, astronomers still cannot look at its future with any certainty. In particular, they don't know whether the expansion will continue or if, under the influence of the gravitational interaction, it will stop. In this second hypothesis, the universe would then enter recession and begin to collapse. The most recent observations actually seem to support the first hypothesis, that of a universe with an ever-increasing speed of expansion.

Universe (microwave background radiation)

The notion of **microwave background radiation** of the universe at three degrees kelvin is expressed by the signs RADIATION and the number THREE, followed by the manual letter K. If the context requires, we can precede them with the sign UNIVERSE (see the entry *Universe-history*).
The sign RADIATION is the sign usually translated by *powerful*, but realized here with a particular breadth. For its etymology, see the entry *Quasar*.



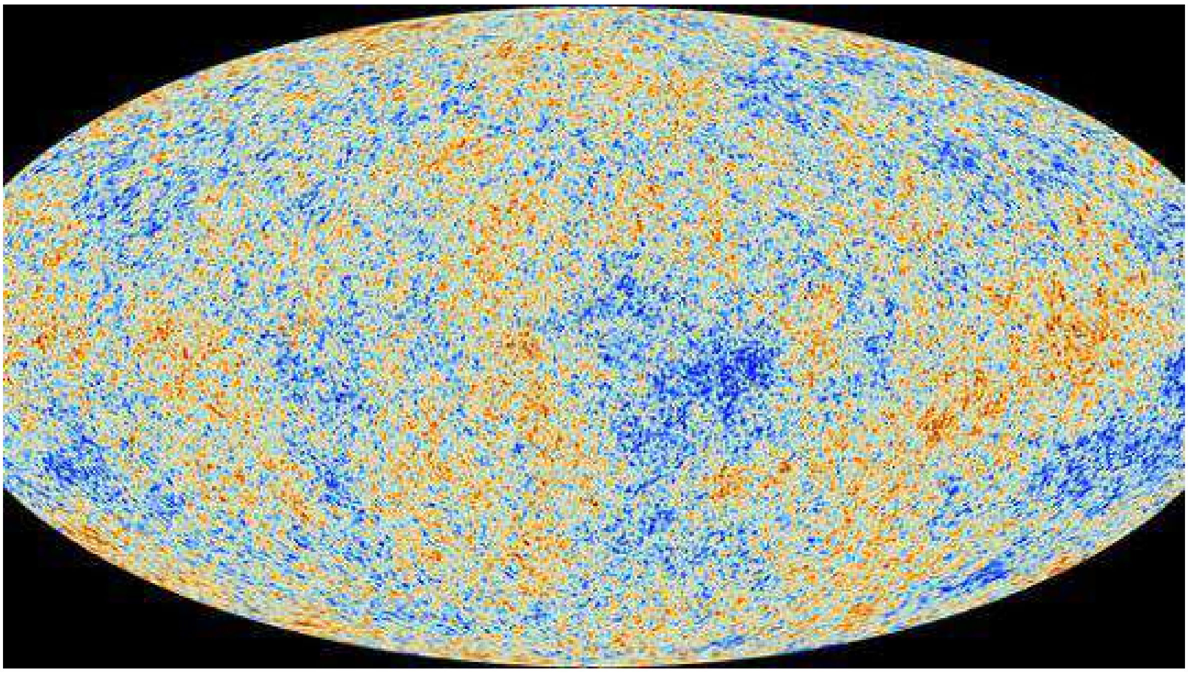
RADIATION

Associated words and expressions:
Astronomer - Big Bang - Degree Kelvin - Galaxy - Radiotelescope - Temperature - Universe - Universe (expansion).

The movement of recession of the galaxies is not the only phenomenon which confirms the reality of Big Bang and the expansion of the universe. If astronomers have now all the reasons for arguing that the observable universe began 13.7 billion years ago, it is because they also detected the traces of this initial "explosion". After the extreme heat produced by the Big Bang, estimated at a temperature of 10^{37} degree K (kelvin), the universe slowly cooled during the billions of years which followed, but there is still to-day a remaining 3K **microwave background radiation**.

This fossil emission was discovered in 1965 by *Arno Penzias* and *Robert Wilson*, by means of a radio telescope installed in New Jersey, at a 4,080 megahertz frequency. This emission, which arrives from the depths of space and time, is absolutely constant, whatever the direction of the observation. It tells us about the state of the universe at its early stages, indicating that the original matter was of a perfectly homogeneous constitution and temperature. This emission underwent only a slow cooling in time, all the while keeping its initial characteristics.

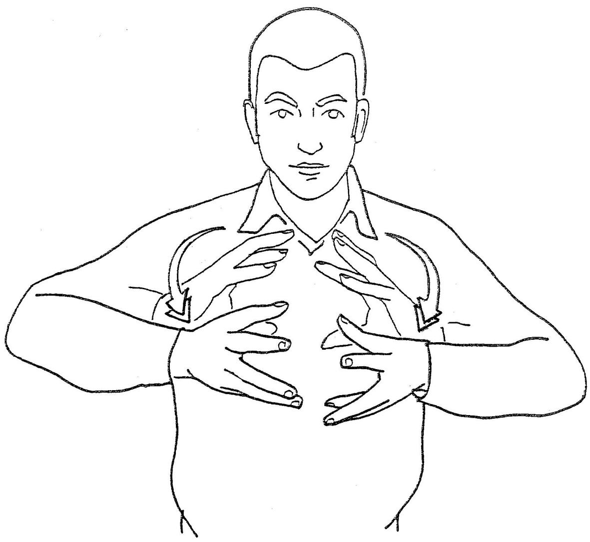
Astronomers confirmed the existence of this cosmic microwave background radiation by the launch of the **satellite COBE** in 1990 and later with the **PLANCK satellite**. Measured on about fifty frequencies, the temperature of the fossil radiation is 2.726 kelvins, with an accuracy of 0.01%.



Map of the microwave cosmic microwave background radiation obtained with the PLANCK satellite in 2010.
© NASA

Uranus

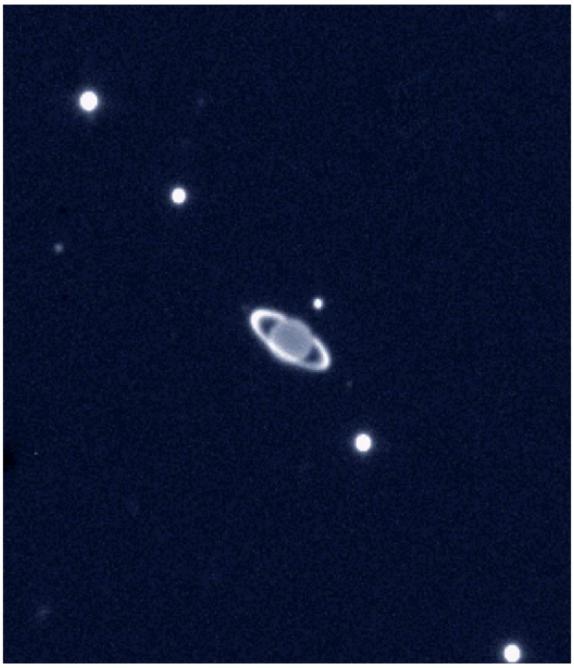
The sign URANUS comes from the sign PLANET (see the entry *Earth*): hands have the shape of a spherical object which turns on itself while moving in the space. In the case of Uranus, the movement of rotation of the wrists is made in the same direction as the forward movement, according to one of the characteristics of the planet.



Associated words and expressions:
Astronomer - Earth - Planet - Satellite - Saturn - Solar system - Sun - Velocity.

The planet **Uranus** was discovered by the English astronomer of German origin, William Herschel (1738-1822) on March 13th, 1781 with a small telescope which he had built himself. Uranus can be easily observed with binoculars.

Distance : Uranus is 2,880,000,000 km from the Sun.
Diameter : 51,000 km ; Uranus is much bigger than the Earth.
Mass : its mass is only 14.58 times greater than the Earth's.
Inclination : **the planet "rolls" on itself almost in the direction of its trajectory around the Sun (just as a petanque ball running on the ground).**
Rotation : the duration of a day on Uranus is only 10 h 42 min.
Revolution : 84 years and 7 days.
Temperature : -205°C.
Atmosphere : it is 7,500 km thick and mainly composed of hydrogen (H_2) 83%, helium (He) 15%, methane (CH_4) and ammonia (NH_3). Clouds at high altitude have been detected along with winds which can reach speeds of 100km/s.



Uranus and its rings observed with the Very Large Telescope. © ESO

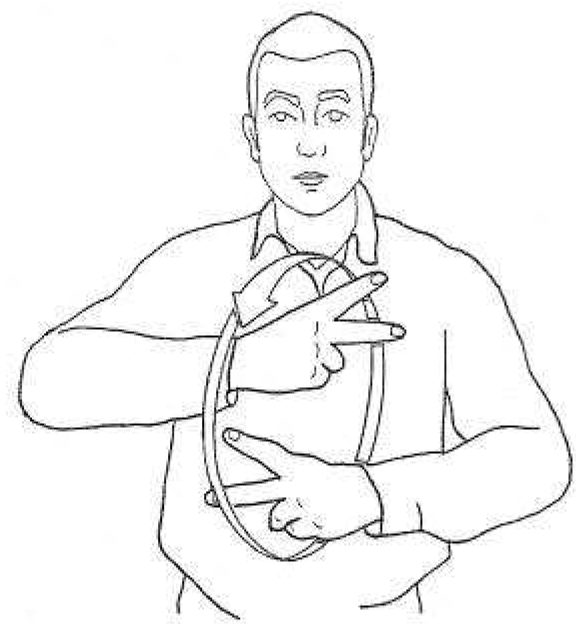
Rings : Just like Saturn, Uranus is surrounded with a system of rings which are some kilometers thick ; thirteen rings were discovered in 1977.

Satellites: Uranus is accompanied by at least 27 satellites, the biggest of which were discovered in the 18th and 19th centuries. They have the following characteristics:

Name	Diameter (km)	Distance from the planet (km)	Duration of revolution	Discovery
Miranda	200	135,000	1 d 9 hr 56 min	Kuiper (1948)
Ariel	900	190,000	2 d 12 hr 29 min	Lassel (1851)
Umbriel	700	267,000	4 d 3 hr 27 min	Lassel (1851)
Titania	1,700	438,000	8 d 16 hr 56 min	Herschel (1787)
Obéron	1,600	586,000	13 d 11 hr 7 min	Herschel (1787)

Venus

The sign VENUS represents the movement of the violent winds which travel round the planet in four days. The hands in the shape of a fork have 2 meanings - the letter " V", which is the first letter of the word "wind" but also the first letter of the word *Venus*.



Associated words and expressions: Crater - Crescent - Distance - Earth - Meteorite - Moon - Phase - Quartier - Satellite - Solar system - Sun - Volcano.

The planet **Venus** is, after the Sun and the Moon, the most glittering celestial body in the sky. As it is closer to the Sun than the Earth, we always see it near the Sun, either at sunrise, or at sunset. This is why the ancients had nicknamed Venus "*the shepherd star"* because a shepherd kept his herd and adjusted his day according to the rhythm of the Sun. Because of its brightness in the sky, the Greeks gave it the name of *Venus*, the goddess of beauty.

Distance : Venus is 108,208,900 km from the Sun.
Diameter : 12,300 km, almost equal to the Earth diameter.
Mass : 0.82 times that of the Earth.
Inclination : its rotation axis is tilted at only 3° 23'.
Rotation : the duration of a day on Venus is very long. It rotates very slowly in 243 days in the opposite direction to that of the Earth.
Revolution : Venus has a revolution around the Sun in 224 days and 17 hours ; its revolution is slightly shorter than its rotation.

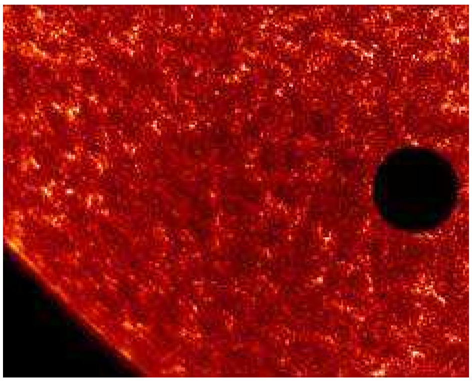
Venus covered with its thick clouds.© NASA/JPL

Temperature and atmosphere: the atmosphere is extremely thick with an average temperature of +460°C. It consists of carbon dioxide (carbon dioxide CO_2) 95 % and nitrogen (N_2) 4 %. The high density of CO_2 provokes a **greenhouse effect** by trapping the heat of the sun's rays, which explains why the temperature is so high. **We can thus understand the risks of warming of the Earth by the increase of carbon dioxide in our atmosphere; we must protect our planet from this danger**.

The Venus very hot surface at a temperature of 460°C. © NASA/JPL

Relief: the relief of Venus was studied by spacecraft. There are numerous plains with hills and some high plateaus from 3,000 to 4,000 meters in height, as well as volcanoes, of which the *Mount Maxwell* who has a height of 11,800 m. We have observed old lava flows and craters of meteorites. In such a hot world, there is probably no life.

Phases : Seen from the Earth, Venus presents phases like Mercury and the Moon, with **quarters** and **crescents** (see the entry: *Moon*) depending on whether it's lit from the front or the side. A binocular or a small telescope are sufficient for observing it as a crescent, a quarter or a disk. It has no known satellite.

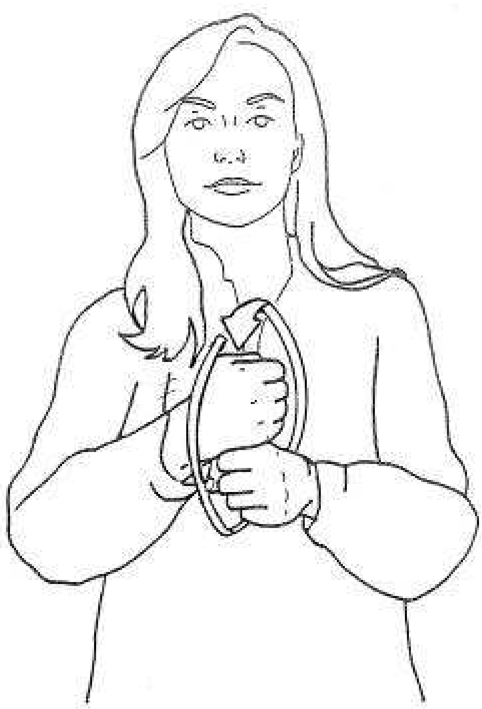


Passage of Venus in front of the Sun, on june 9th 2006. © NASA

As Venus is closer to the Sun than the Earth, we sometimes see it passing in front of the Sun's disk, like a small black spot. This spectacular phenomenon can easily be observed by seriously protecting the eyes from the sunlight. These transits allowed our forebears to measure the distance of the Earth to the Sun by geometrical methods of triangulation by measuring simultaneously the accurate position of Venus on the Sun from two of the most distant possible locations on Earth. The last passage occured on June 6th, 2012; we will have to wait until the year 2117.

Year

The sign YEAR, with the two closed hands in mutual vertical revolution represents the annual trajectory of the Earth around the Sun. This sign has been used in France since the beginning of the 19th century.

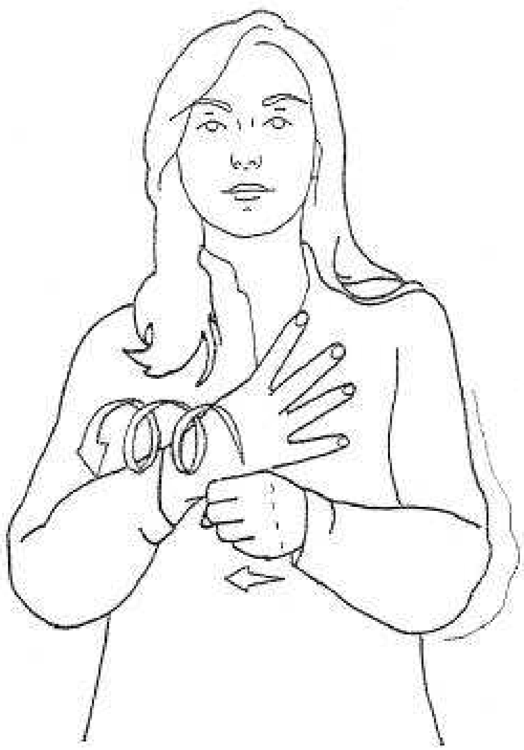


Associated words and expressions: Earth - Exoplanet - Light - Planet - Revolution - Sun - Star - Solar System - Year.

The **year** is the time necessary for a planet to make a complete revolution around the Sun or a star. The Earth revolves around the Sun in 365 days, 6 hours, 9 minutes and 9.5 seconds. For the other planets of the solar system, the value of the year is given with reference to that of the Earth.

A leap year is represented in Sign Language as “every four years” with the same description as above except that one hand must show the number FOUR and repeat a winding movement.

For the terrestrial year, the extra six hours added to the 365 days are added every four years so that we have $6 \times 4 = 24$ hours i.e. the duration of a day. This is why one day is added every four years, on 29th February. This is called a **leap year**. The year 2012 was a leap year as are 2016, 2020, 2024, etc.



ANNEE BISSEXTILE

In astronomy, we distinguish other kinds of the year: the **sideral year** corresponds to the time for the Sun to be in exactly the same place among the stars as observed from a fixed point on Earth. In our lives, the duration of the **civil year** is 365 days, and 366 days every four years (leap year). Each planet of the Solar System has its own year corresponding to the duration of its revolution around the Sun: 686.96 days for Mars, 4,335.355 days (11.87 years) for Jupiter, 10,757.737 days (29.45 years) for Saturn etc.

The **light-year** (q.v.) is a specific unit used in astronomy to measure very large distances.

Zenith and Nadir

In accordance with the definition of the word, the sign ZENITH is expressed by pointing the index finger upward, the other opened hand representing the night sky. The sign NADIR is expressed in the opposite direction.

ZENITH

NADIR

In astronomy, the **zenith** is the point of the sky situated vertically above the place where we are on Earth. As the Earth is round, the zenith changes from place to place. The **nadir** is the point of the sky diametrically opposed to the zenith.

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