



## The Milky Way

### What Is The Milky Way Galaxy?

The Milky Way is the galaxy we live in. It contains the Sun and at least one hundred billion other stars. Some modern measurements suggest there may be up to 500 billion stars in the galaxy. The Milky Way also contains more than a billion solar masses' worth of free-floating clouds of interstellar gas sprinkled with dust, and several hundred star clusters that contain anywhere from a few hundred to a few million stars each.

### What Kind Of Galaxy Is The Milky Way?

Figuring out the shape of the Milky Way is, for us, somewhat like a fish trying to figure out the shape of the ocean. Based on careful observations and calculations, though, it appears that the Milky Way is a barred spiral galaxy, probably classified as a SBb or SBc on the Hubble tuning fork diagram.

### Where Is The Milky Way In Our Universe?

The Milky Way sits on the outskirts of the Virgo supercluster. (The centre of the Virgo cluster, the largest concentrated collection of matter in the supercluster, is about 50 million light-years away.) In a larger sense, the Milky Way is at the centre of the observable universe. This is of course nothing special, since, on the largest size scales, every point in space is expanding away from every other point; every object in the cosmos is at the centre of its own observable universe.

### Within The Milky Way Galaxy, Where Is Earth Located?

Earth orbits the Sun, which is situated in the Orion Arm, one of the Milky Way's 66 spiral arms. (Even though the spiral arms of the Milky Way or any other galaxy are not solid structures, the size scale of the galaxy is so large that the density wave will last for millions of years; it is therefore appropriate to say we are "in" the arm at this period in cosmic history.) Earth and the Sun are about 25,000 light-years away from the galactic centre.

### Why Is Our Galaxy Called The Milky Way?

Barred spiral galaxies are comprised of a disk that has the vast majority of stars in the galaxy, and a bar-shaped bulge at the centre that also contains a large concentration of stars. In Earth's night sky, the disk of the galaxy stretches all the way around the sky and is about as wide as an outstretched hand. If one looks up at it with the unaided eye, it appears as a starry stream of light stretching from one side of the sky to the other. Ancient Chinese astronomers called this band of light the "Silver River," while ancient Greek and Roman astronomers called it a "Road of Milk" (Via Lactea). This was translated into English as the "Milky Way." When astronomers realized that we live in a galaxy, the name Milky Way was used to refer not just to this band of stars, but also to the entire galaxy.

### How Large Is The Milky Way?

Current measurements indicate that the stellar disk of the Milky Way is about 100,000 light-years across and 1,000 light-years thick. If the Milky Way disk were the size of a large pizza, then the solar system might be a microscopic speck of oregano halfway out from the centre to the edge of the crust. The bar-bulge structure of the Milky Way is about 3,000 light-years high and maybe 10,000 lightyears long. If you take into account the dark matter in the Milky Way, its size increases dramatically. Based on current measurements, at least 90 percent of the mass in the Milky Way's gravitational field is made up of dark matter, so the luminous stars, gas, and dust of the galaxy are embedded at the centre of a huge, roughly spherical dark matter halo more than a million light-years across.

### How Fast Is Earth Moving Within The Milky Way Galaxy?

Earth (and the solar system) is moving through the Milky Way's disk in a stable, roughly circular orbit around the galactic centre. The latest astronomical measurements indicate that our orbital velocity around the centre of the Milky Way is about 450,000 miles per hour (200 kilometres per second). That is almost a thousand times the cruising speed of most commercial jetliners. Even so, the Milky Way is so huge that one complete orbit takes about 250 million years.

## The Milky Way's Neighbourhood

### What Other Galaxies Are Near The Milky Way Galaxy?

"Near" is a relative term when it comes to galaxies. Within a few million light-years of the Milky Way are several dozen galaxies that make up the Local Group. Some of those galaxies, such as the Sagittarius dwarf galaxy, are almost in physical contact with the Milky Way's outskirts.

## What is the largest galaxy in the Local Group?

The Andromeda galaxy, which is slightly larger than the Milky Way, is the largest galaxy in the Local Group. Andromeda is also known as Messier 31, or M31, because it is the thirty-first object listed in the famous catalogue of night-sky objects compiled by Charles Messier in 1774.

Local Group Galaxies			
Galaxy Name	Galaxy Type	Distance (kiloparsecs)	Absolute Visual Magnitude
Milky Way	barred spiral	0	-20.6
Sagittarius dwarf	elliptical	24	-14.0
Large Magellanic	Cloud irregular	49	-18.1
Small Magellanic	Cloud irregular	58	-16.2
Ursa Minor dwarf	elliptical	69	-8.9
Draco dwarf	elliptical	76	-8.6
Sculptor dwarf	elliptical	78	-10.7
Carina dwarf	elliptical	87	-9.2
Sextans dwarf	elliptical	90	-10.0
Fornax dwarf	elliptical	131	-13.0
Leo II dwarf	elliptical	230	-10.2
Leo I dwarf	elliptical	251	-12.0
Phoenix	irregular	390	-9.9
NGC 6822	irregular	540	-16.4
NGC 185	elliptical	620	-15.3
IC 10	irregular	660	-17.6
Andromeda II dwarf	elliptical	680	-11.7
Leo A	irregular	692	-11.7
IC 1613	irregular	715	-14.9

## How Do Astronomers Measure Distances To Galaxies?

The original measurement of the distance from Earth to the Andromeda galaxy, which was done by Edwin Hubble in the 1920s, has been refined over the past century. Today, except for specific distance measurements to test particular astronomical methods, most astronomers use the Hubble Law—the relationship between redshift and distance—to measure the distance to distant galaxies.

## Nebulae, Quasars, And Blazars

### What Is A Nebula!

A nebula, derived from the Latin meaning “mist,” is any cloud or collection of interstellar medium in one location in space. Nebulae are produced in many different ways. For example, they can be gathered together by gravity, dispersed by stars, or lit up by a powerful radiation source nearby. As beautiful as nebulae are, however, most of them nonetheless

contain only a few thousand atoms or molecules per cubic centimetre. This is many times sparser than even the best laboratory vacuum chambers on Earth can achieve.

### How Many Kinds Of Nebulae Are There?

There are numerous kinds of nebulae, which bear informal as well as formal names. Generally, types of nebulae are described either by their appearance (for example, dark nebulae, reflection nebulae, and planetary nebulae) or the physical processes that create them (such as protostellar nebulae, protoplanetary nebulae, or supernova remnants).

### What Are Some Of The Best-known Gaseous Nebulae?

The table below lists some famous nebulae.

Some Well-Known Gaseous Nebulae		
Common Name	Catalogue Name	Nebula Type
Crab Nebula	Messier 1	supernova remnant
Dumbbell Nebula	Messier 27	planetary nebula
Eagle Nebula	Messier 16	star forming region
Eskimo Nebula	NGC 2392	planetary nebula
Eta Carina Nebula	NGC 3372	star forming region
Helix Nebula	NGC 7293	planetary nebula
Horsehead Nebula	Barnard 33	dark nebula
Hourglass Nebula	MyCn 18	planetary nebula
Lagoon Nebula	Messier 8	star forming region
Orion Nebula	Messier 42	star forming region
Owl Nebula	Messier 97	planetary nebula
Ring Nebula	Messier 57	planetary nebula
The Coal Sack	N/A	dark nebula
Trifid Nebula	Messier 20	star forming region
Veil Nebula	NGC 6992	supernova remnant
Witch Head Nebula	IC 2118	reflection nebula

### What Is A Quasar?

The term "quasar" is short for "quasi-stellar radio source." The term came into general usage in the 1960s, when astronomers studying cosmic radio sources noticed that many of them looked like stars on photographs. Subsequent studies showed that they were not stars at all, but rather active galactic nuclei. Nowadays, the word "quasar" is often used to mean any quasi-stellar object (QSO), whether or not it emits radio waves.

## Star Basics

### What Is A Star?

A star is a mass of incandescent gas that produces energy at its core by nuclear fusion. Most of the visible light in the universe is produced by stars. The Sun is a star.

### How Many Stars Are There In The Sky?

Without the interference of light from ground sources, a person with good eyesight can see about 2,000 stars on

any given night. If both hemispheres are included, then about 4,000 stars are visible. With the help of binoculars or telescopes, however, the number of visible stars increases dramatically. In our Milky Way galaxy alone, there are more than 100,000,000,000 stars, and in our observable universe there are at least a billion times that number.

### What Is The Closest Star To Earth?

The Sun is the closest star to Earth. It is 150 million kilometres away from Earth on average.

### Other Than The Sun, What Is The Next Closest Star To Earth?

The closest star system to Earth is the multiple star system Alpha Centauri. The faintest star in that system, known as Proxima Centauri, has been measured to be 4.3 light-years away from Earth. The main star in Alpha Centauri is about 4.4 lightyears away. The table below lists other nearby stars.

Stars Closest to the Sun		
Name	Spectral Type	Distance in Light-Years
Proxima Centauri*	M5V (red dwarf)	4.24
Alpha Centauri A*	G2V (sun-like)	4.37
Alpha Centauri B*	K0V (orange dwarf)	4.37
Barnard's Star	M4V (red dwarf)	5.96
Wolf 359	M6V (red dwarf)	7.78
Lalande 21185	M2V (red dwarf)	8.29
Sirius	A1V (blue dwarf)	8.58
Sirius B	DA2 (white dwarf)	8.58
Luyten 726-8A	M5V (red dwarf)	8.73
Luyten 726-8B	M6V (red dwarf)	8.73
Ross 154	M3V (red dwarf)	9.68
Ross 248	M5V (red dwarf)	10.32
Epsilon Eridani	K2V (orange dwarf)	10.52
Lacaille 9352	M1V (red dwarf)	10.74
Ross 128	M4V (red dwarf)	10.92
EZ Aquarii	M5V (red dwarf)	11.27
Procyon A	F5V (blue-green dwarf)	11.40
Procyon B	DA (white dwarf)	11.40
61 Cygni A	K5V (orange dwarf)	11.40
61 Cygni B	K7V (orange dwarf)	11.40
Struve 2398 A	M3V (red dwarf)	11.53
Struve 2398 B	M4V (red dwarf)	11.53
Groombridge 34 A	M1V (red dwarf)	11.62
Groombridge 34 B	M3V (red dwarf)	11.62

## What Is A Constellation?

A constellation is akin to an asterism (An asterism is a star-pattern that is not a constellation <http://homepage.mac.com/kvmagruder/bcp/aster/general/asterism.htm>), but it is usually much more complicated, containing more stars or larger areas of the sky. A few asterisms are constellations: the asterism called the Southern Cross, for example, is the constellation Crux (the Cross). Modern constellations are mostly named after mythological themes, such as gods, legendary heroes, creatures, or structures. Although most constellations resemble the figures after which they are named, others are not as recognizable. The constellations encompass the entire celestial sphere and provide a visual reference frame. Astronomers can plot the stars and other objects in the universe using constellations, charting the apparent movement that is caused by Earth's own rotation and orbit.

## How Many Constellations Are There?

The current, internationally agreed-upon map of the sky contains 88 constellations. Some well-known constellations include Aquila (the Eagle), Cygnus (the Swan), Lyra (the Harp), Hercules and Perseus (two mythological heroes), Orion the Hunter and Ophiucus the Knowledge-seeker (two other mythological characters), Ursa Major and Ursa Minor (the Big Bear and Little Bear), and the constellations of the zodiac. The table below lists well-known constellations.

Well-Known Constellations		
Name	Common Name	Well-Known Stars in the Constellation
Aquila	The Eagle	Altair
Auriga	The Charioteer	Capella
Bootes	The Hunter	Arcturus
Canis Major	The Big Dog	Sirius
Canis Minor	The Little Dog	Procyon
Carina	The Keel	Canopus
Crux	The Southern Cross	Acrux
Cygnus	The Swan	Deneb
Gemini	The Twins	Castor, Pollux
Leo	The Lion	Regulus
Lyra	The Harp	Vega
Orion	The Hunter	Rigel, Betelgeuse, Bellatrix
Ursa Major	The Big Bear	Dubhe, Alcor, Mizar
Ursa Minor	The Little Bear	Polaris (The North Star)

## Who Made The First Astronomical Star Catalogues And Charts?

Hipparchus, an ancient Greek astronomer of the second century B.C.E., is best remembered for his astronomical measurements and the instruments he created to make them. Hipparchus constructed an atlas of the stars visible without a telescope and categorized them by brightness. The first major astrometric satellite, which used parallax to measure the positions of and distances to more than 100,000 stars, was named Hipparcos in his honour. Star catalogues increased dramatically in size after telescopes were invented. James Bradley (1693–1762) was England's Astronomer Royal from 1742 until his death 20 years later. He prepared an accurate chart of the positions of over 60,000 stars. German astronomer Johann Elert Bode (1747–1826), who became director of the Berlin Observatory in 1786, published an enormous catalogue of stars and their positions in 1801.

## What Is The North Star?

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## Is There A South Star?


Right now, there is no easily visible star near the south celestial pole. There are many asterisms and celestial objects relatively near the pole, so it is possible to triangulate between them and roughly find the location of the south celestial pole.

## What Are The Brightest Stars In The Night Sky?

The brightest stars in the night sky as viewed from Earth are Sirius, the "Dog Star," in the constellation Canis Major (the Big Dog); Canopus, in the constellation Carina (the Keel); and Rigel Kentaurus, more commonly known as Alpha Centari, in the constellation Centaurus (the Centaur). These three stars are not, however, the three stars in the night sky that emit the most light; they are the three stars that emit the most light that reaches Earth.

The Brightest Stars as Seen from Earth

Name	Constellation	Spectral Type	Apparent V Magnitude	Distance (in light-years)
Sun	N/A	G2V (yellow dwarf)	-26.72	0.0000158
Sirius	Canis Major	A1V (blue dwarf)	-1.46	8.6
Canopus	Carina	A9II (blue giant)	-0.72	310
Arcturus	Bootes	K1III (red giant)	-0.04(variable)	37
Alpha Centauri A	Centaurus	G2V (yellow dwarf)	-0.01	4.3
Vega	Lyra	A0V (blue dwarf)	0.03	25
Rigel	Orion	B8I (blue supergiant)	0.12	800
Procyon	Canis Minor	F5V (blue-green dwarf)	0.34	11.4
Achernar	Eridanus	B3V (blue dwarf)	0.50	140
Betelgeuse	Orion	M2I (red supergiant)	0.58(variable)	430
Agena	Centaurus	B1III (blue giant)	0.60(variable)	530
Capella A	Auriga	G6III (yellow giant)	0.71	42
Altair	Aquila	A7V (blue dwarf)	0.77	17
Aldebaran	Taurus	K5III (red giant)	0.85(variable)	65
Capella B	Auriga	G2III (yellow giant)	0.96	42
Spica	Virgo	B1V (blue giant)	1.04(variable)	260
Antares	Scorpio	M1I (red supergiant)	1.09(variable)	600



## How Far Are The Farthest Stars?

Among the 4,000 or so stars in the night sky that are visible to the unaided eye, the most distant among them are several thousand light-years away. The light from more distant stars is visible, however, when many of them are associated together in a star cluster or nearby galaxy. It is possible to see, for example, the combined starlight of the Large Magellanic Cloud (about 170,000 light-years away), the Small Magellanic Cloud (about 240,000 light-years away), or even the Andromeda galaxy (about 2.2 million light-years away) with unaided eyes. Using telescopes, we can see starlight from galaxies that are more than 12 billion light-years away.

## Why Do Stars Shine?

Stars shine because nuclear fusion occurs in their core. Nuclear fusion changes lighter elements into heavier ones and can release tremendous amounts of energy in the process. The most powerful nuclear weapons on Earth are powered by nuclear fusion, but they are puny compared to the nuclear explosiveness of the Sun.

## What Is A Sunspot?

Sunspots, when viewed by visible light, appear as dark blemishes on the Sun. Most sunspots have two physical components: the umbra, which is a smaller, dark, featureless core, and the penumbra, which is a large, lighter surrounding region. Within the penumbra are delicate-looking filaments that extend outward like spokes on a bicycle wheel. Sunspots vary in size and tend to be clustered in groups; many of them far exceed the size of our planet and could easily swallow Earth whole. Sunspots are the sites of incredibly powerful, magnetically driven phenomena. Even though they look calm and quiet in visible light, pictures of sunspots taken in ultraviolet light and in X rays clearly show the tremendous energy they produce and release, as well as the powerful magnetic fields that permeate and surround them.

## What Is A Solar Flare?

Solar flares are sudden, powerful explosions on the surface of the Sun. They usually occur when large, powerful sunspots have their magnetic fields too tightly twisted and torqued by the hot, swirling plasma in the Sun. The magnetic field lines unwind and break suddenly, and the matter and energy that had been contained rushes outward from the Sun. Solar flares can be many thousands of miles long, and they can contain far more energy than all of the energy consumption of all of human history on Earth.

## What Is A Supernova?

A supernova is a tremendous explosion that occurs when the core of a star exceeds the Chandrasekhar limit, and its collapse is not halted by electron degeneracy. When that happens, it takes only a fraction of a second for the stellar core to collapse into a dense ball about ten miles across. The temperature and pressure becomes almost immeasurably hot and high; and the recoil of that collapse causes an enormous detonation. More energy is released in ten seconds than the Sun will emit in its entire ten billion year lifetime, as the guts of the star are blown outward into interstellar space. There are two general types of supernovae. A Type I supernova is the result of an existing, older white dwarf that gains enough mass to exceed the Chandrasekhar limit, causing a runaway collapse. A Type II supernova is produced by a single high mass star whose gravity is so strong that its own weight causes the stellar core to reach a mass beyond the Chandrasekhar limit.

# The Sun

## How Bright Is The Sun Compared To Other Stars?

The apparent magnitude of the Sun is a large negative number. As viewed in visible light, the Sun has  $m_v = -26.7$  brightness because it is so close and, thus, has the lowest apparent magnitude of any celestial object. The Sun's absolute magnitude is 4.8 as viewed in visible light. This number, unlike the Sun's apparent magnitude, is roughly in the middle of the range of most stars.

## What Is The Size And Structure Of The Sun?

The Sun has a core at its center; a radiative zone surrounding the core; a convective zone surrounding the radiative zone; a thin photosphere at its surface; and a chromosphere and corona that extends beyond the photospheric surface. In all, the Sun is about 1,372,500 kilometres across, which is about 109 times the diameter of Earth. The different zones and layers in and around the Sun exist because the physical conditions—mostly temperature and pressure—of the Sun change depending on the distance from the Sun's centre. At the core, for example, temperatures exceed 15 million degrees Kelvin, whereas the inner part of the convective zone is just under 1 million degrees Kelvin, and the photosphere is about 5,800 degrees Kelvin.



## What Is The Sun Made Of?

The Sun's mass is composed of 71 percent hydrogen, 27 percent helium, and 2 percent other elements. In terms of the number of atoms in the Sun, 91 percent are hydrogen atoms, 9 percent are helium atoms, and less than 0.1 percent are atoms of other elements. Most of the stars in the universe have a similar chemical composition

## How Hot Is The Sun?

The temperature at the centre of the Sun is about 27 million degrees 15 million degrees Kelvin. This is typical for stars that convert hydrogen into helium using the proton-proton chain, but it is hotter than some stars and much cooler than others. This is especially true if these other stars harbour fusion processes other than the proton-proton chain, such as the carbon-nitrogen-oxygen cycle or the triple-alpha reaction. The temperature at the surface of the Sun is about 5,800 degrees Kelvin. The surface temperatures of stars range typically from about 3,000 to 30,000 degrees Kelvin, though in some special kinds of stars the surface temperatures can be higher or lower than this range.

## What Is A Planetary System?

A planetary system is a system of astronomical objects that populate the vicinity of a star. This includes objects like planets, asteroids, comets, and interplanetary dust. In a more general sense, this also includes the star itself, its magnetic field, its stellar wind, and the physical effects of those things, including ionization boundaries, and shock fronts.

## What Is Our Own Planetary System Called?

The Sun is the gravitational anchor of the planetary system where we live. The term "solar" refers to anything having to do with the Sun; so we call our own planetary system the solar system. Often, astronomers will refer to other planetary systems as "solar systems" too, though that is not technically correct.

## How Large Is Our Solar System?

Our solar system reaches out to the orbit of the most distant planet, Neptune, or about three billion miles (five billion kilometres) away from the Sun. Beyond Neptune is the Kuiper Belt, a thick, doughnut-shaped cloud of small icy bodies that extends to about 12 billion kilometres. Beyond that still is the Oort Cloud, which is a huge, thick, spherical shell thought to contain trillions of comets and comet-like bodies. The Oort Cloud may extend as far as a light-year, nearly ten trillion kilometres, out from the Sun.

# Planet Basics

## What is a planet?

There have been many attempts to define the term "planet" over the centuries, but to date there is still no universally agreed-upon scientific definition of the term. Generally speaking, however, a planet usually refers to an object that is not a star (that is, has no nuclear fusion going on in its core); that moves in orbit around a star; and is mostly round because its own gravitational pull has shaped it into, more or less, a sphere.

## What Are The General Characteristics Of The Planets In Our Solar System?

All the planets in our solar system, by the current scientific classification system, must satisfy three basic criteria:

- 1 A planet must be in hydrostatic equilibrium— a balance between the inward pull of gravity and the outward push of the supporting structure. Objects in this kind of equilibrium are almost always spherical or very close to it.
- 2 A planet's primary orbit must be around the Sun. That means objects like the Moon, Titan, or Ganymede, are not planets, even though they are round due to hydrostatic equilibrium, because their primary orbit is around a planet.
- 3 A planet must have cleared out other, smaller objects in its orbital path, and thus must be by far the largest object in its orbital neighbourhood. This means that Pluto is not a planet, even though it meets the other two criteria; there are thousands of Plutinos in the orbital path of Pluto, and it crosses the orbit of Neptune, which

is a much larger and more massive object. The eight objects in our solar system that meet all three criteria are Neptune, Uranus, Saturn, Jupiter, Mars, Earth, Venus, and Mercury.

The Planets of Our Solar System				
Name	Mass (in Earth masses*)	Diameter (in Earth diameters**)	Distance to Sun (in AU***)	Orbital Period (in Earth years)
Mercury	0.0553	0.383	0.387	0.241
Venus	0.815	0.949	0.723	0.615
Earth	1	1	1	1
Mars	0.107	0.532	1.52	1.88
Jupiter	317.8	11.21	5.20	11.9
Saturn	95.2	9.45	9.58	29.4
Uranus	14.5	4.01	19.20	83.7
Neptune	17.1	3.88	30.05	163.7

\*One Earth Mass equals  $5.98 \times 10^{24}$  kilograms.

\*\*One Earth Diameter equals 12,756 kilometres.

\*\*\*An astronomical unit (AU) is the distance from Earth to the Sun and is roughly  $1.5 \times 10^8$  kilometres.