GRADES 3–6

SPACE DICTIONARY FOR KIDS

The Everything Guide for Kids Who Love Space

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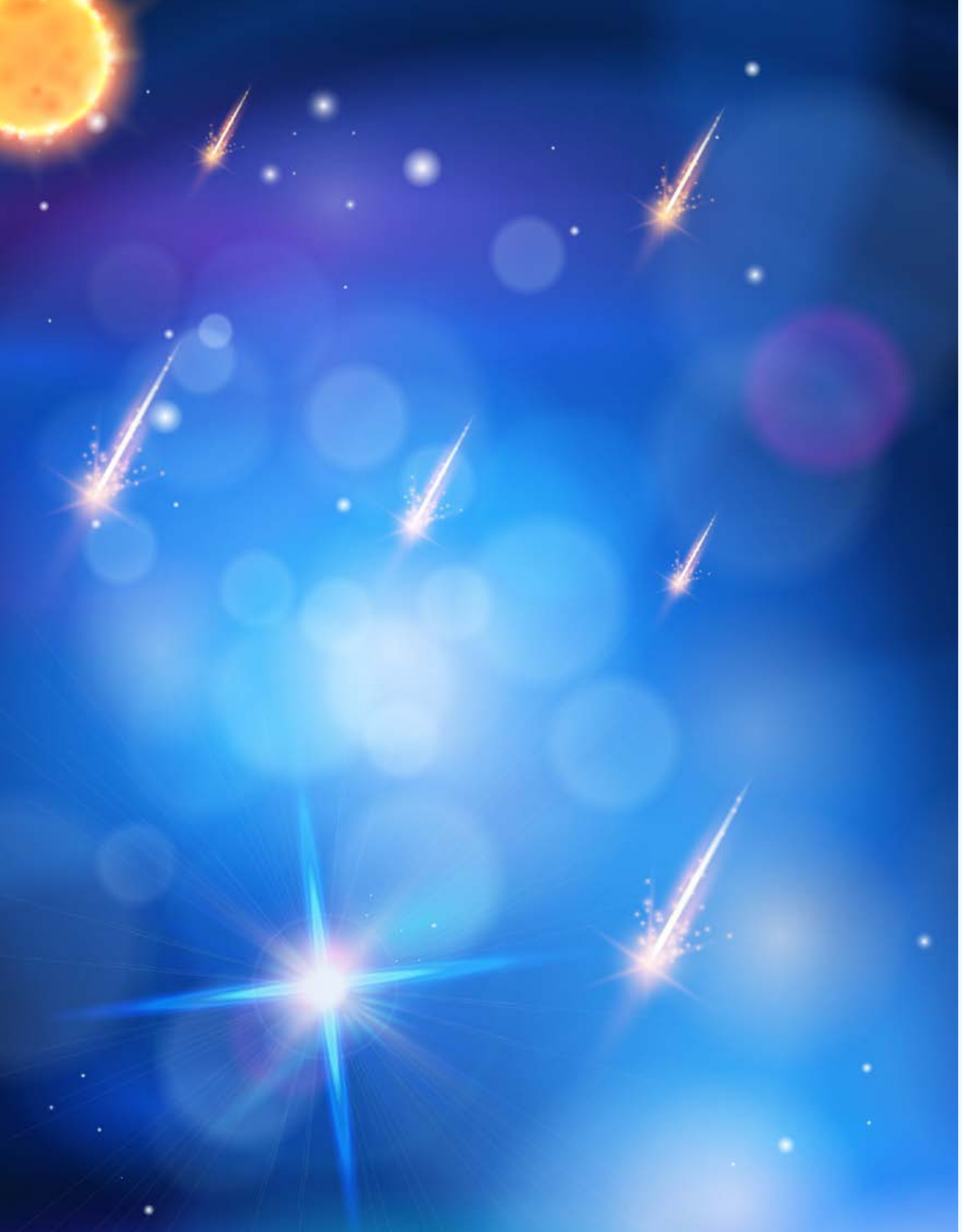


Stars and Galaxies

The Universe Today

The universe today is a far different place than it was 13.7 billion years ago. Shortly after the Big Bang, the universe was a hot swirl of hydrogen and helium atoms. Today the universe consists of a dazzling variety of objects—stars and planets, galaxies, nebulas, and mysterious black holes to name a few.

Although early astronomers believed stars were eternal and unchanging, we know now that all stars are constantly changing. As stars change, so does the universe itself. Stars take the smallest atoms in the universe—the hydrogen and helium atoms that were created in the Big Bang—and press them together to form larger atoms. Everything around us, from the ground you walk on to the air you breathe to your own body and the book in your hands, is made up of atoms that were created deep inside of stars.

Creating new atoms comes at a terrible cost to stars. Once they've used up the hydrogen in their cores to make larger atoms, stars begin to die. The most massive stars exit the celestial stage as a spectacular supernova, spraying their new atoms into space and then collapsing down to become a tiny neutron star or a black hole. Smaller stars like our sun expand to hundreds of times their original size and shine brighter than they ever have before, and then quietly shrink back down into a white dwarf the size of a planet.

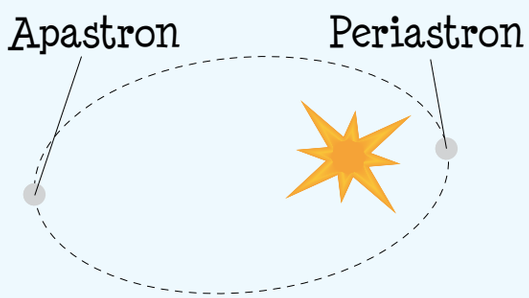
But the end of a large star doesn't mean the end of change, because the atoms that were blown into space in the supernova can swirl together to form a whole new solar system. A smaller star just like our sun can form, orbited by an active family of planets, asteroids, comets, and meteoroids. Stars are forming and dying every day in the universe, bringing about continuous changes in their galaxies.

This chapter contains some of the strangest terms in all of astronomy—words like pulsar, quasar, black hole, magnetar, blazar, along with red giant, blue supergiant, and black dwarf. This is the vocabulary of deep space astronomy—the study of the universe outside of our own solar system.

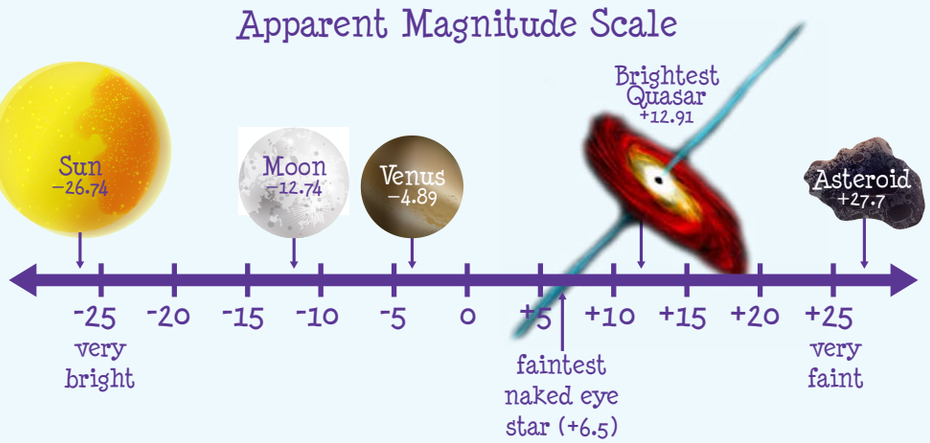
Andromeda Galaxy: The closest galaxy to the Milky Way. It is a spiral galaxy 2.3 million light-years away, and is the most distant thing that can be seen with the naked eye. It appears to us as a dim star in the constellation Andromeda and is best seen on moonless nights. The Andromeda galaxy has about three times as many stars as the Milky Way.

Hey, watch where you're going! The Andromeda Galaxy is on a collision course with the Milky Way. In about 4 billion years, the two galaxies will collide and become one massive elliptical galaxy.

Apastron: The point in a binary star system where the two stars are farthest apart, or the point where a body orbiting a star is farthest from the star.



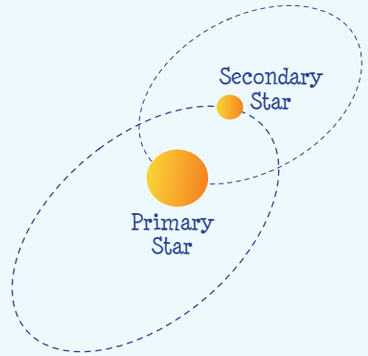
Apparent Magnitude: A measurement of how bright a star (or other object) looks from Earth. Closer objects can appear brighter even if they're not giving off as much light as a more distant object. Apparent magnitude is also sometimes called *apparent brightness* or *relative magnitude*. (See *Absolute Magnitude*, p. 20.)



Asterism: A group or "picture" of stars that is not a constellation. An asterism might only have stars from one constellation, or be a combination of parts of several constellations. Common examples of asterisms are the Big Dipper (contained entirely within the constellation Ursa Major) and the summer triangle (composed of stars in the constellations Aquila, Lyra, and Cygnus).

Barnard's Star: A red dwarf star about 6 light-years from Earth. It is the closest star in the Northern Hemisphere and is located at a point in the sky that makes it convenient to study, so Barnard's Star is one of the most-studied stars. Like all red dwarfs, it is too small and dim to be seen with the naked eye.

Binary Star: A system of two stars that orbit a common center. Usually one star is brighter than the other, and is called the *primary star*. The dimmer star is called the *secondary* or *companion star*. A system with more than two stars is called a *multiple star system*. More than half of the stars visible in the night sky are believed to be binary stars, but to the naked eye they each appear as single stars.



Collapsar: Short for "collapsed star," a collapsar is the core of a star after it has exhausted all its fuel and died. A collapsar can be a white dwarf, a neutron star, or a black hole.

Color Index: A system for classifying stars based on their color and temperature. A star with a lower color index is bluer and hotter than a star with a higher color index, which is redder and cooler.

Star Temperature (K)	Star Color
2,000–3,000	
3,000–4,000	
4,000–6,000	

Star Temperature (K)	Star Color
6,000–10,000	
10,000–20,000	
20,000–30,000	

Cygnus X-1: The first black hole ever discovered. Cygnus X-1 was first discovered in 1964 as an unknown object giving off X-rays. In 1971 it was determined that it has a mass almost 15 times as much as the sun, but is far too small to be a star, meaning it can only be a stellar mass black hole. Its event horizon has a diameter of about 54 miles (88 km).

Dark Nebula: A cloud of gas and dust that does not give off any light. We can only see it because it blocks the light coming from stars that are behind it, creating a patch of sky without stars. Dark nebulae are normally visible only through telescopes.

Black beauty! The Horsehead Nebula is a dark nebula composed of dust and non-luminous gas whose shape is outlined by red light from emission nebula IC 434. It is located in the constellation Orion.

Deep-Sky Object: An object outside the solar system, usually a galaxy, nebula, or star cluster.

Deep Space: Outer space beyond our solar system. Deep space astronomy is the study of distant objects such as other stars and galaxies. Deep space astronomy is one of the main branches of astronomy along with planetary astronomy, which is the study of objects within our solar system.

Deuterium: Most hydrogen atoms are made up of one proton and one electron, but deuterium is a version of hydrogen that has a neutron along with a proton in its nucleus. Deuterium is sometimes called heavy hydrogen.

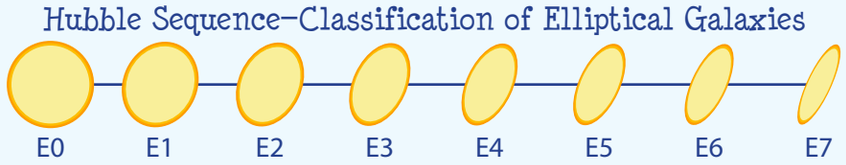
Double Star: Sometimes the term *double star* is used to mean a *binary star*, but it can also mean two stars that appear to be very close together in the sky, even if one is actually much farther away from Earth than the other.

Dwarf Galaxy: A small, dim galaxy that is usually found orbiting a larger galaxy. The Milky Way contains 200–400 billion stars, but a typical dwarf galaxy may contain only a few billion stars. Dwarf galaxies may be the leftover pieces resulting from collisions between full-size galaxies, and are often found orbiting large galaxies.

Milky White and the 20 Dwarves? The Milky Way galaxy is orbited by at least 20 dwarf galaxies. The best known of these are the Large Magellanic Cloud and the Small Magellanic Cloud (p. 41).

Dwarf Star: Stars are classified as dwarf, giant, or supergiant. The vast majority are dwarf stars, also known as *main sequence stars*. At least three-fourths of the stars in the Milky Way are red dwarfs, and there are many orange dwarfs as well. Our sun is a yellow dwarf. Not all dwarfs in space are stars: Brown dwarfs are balls of gas that are too small to become stars, and white dwarfs and black dwarfs are the remains of dead stars.

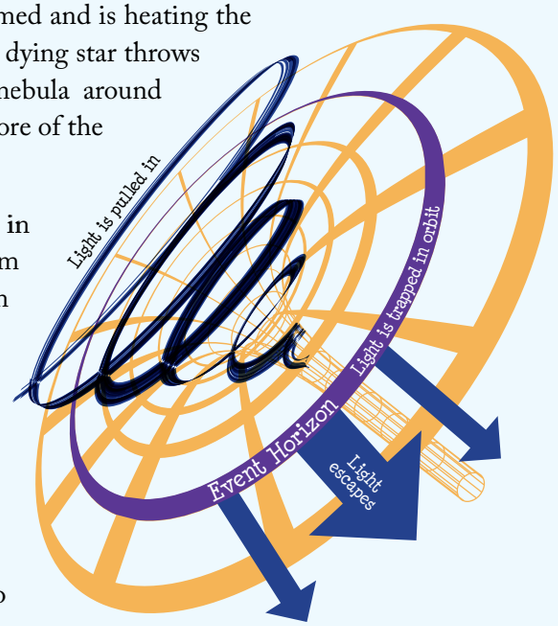
Elliptical Galaxy: A galaxy that is shaped like a squashed or stretched sphere. Elliptical galaxies are usually made of old, dim stars, and don't have much dust and gas in them for forming new stars.



Embryonic Star Cloud: See *Nebula*, p. 44.

Emission Nebula: A cloud of interstellar gas that has been heated up by a nearby star so much that it emits colorful light. This usually happens either when a new star has just formed and is heating the nebula it was born from, or when a dying star throws off its outer layer and creates a nebula around itself, which is then heated by the core of the star that created it.

Event Horizon: The region in space surrounding a black hole from which nothing, not even light, can escape the black hole's gravity. The event horizon is considered the point of no return because anything that reaches the event horizon gets sucked into the black hole. The greater the mass of the black hole, the larger the event horizon is. The event horizon is also called the *Schwarzchild radius*.

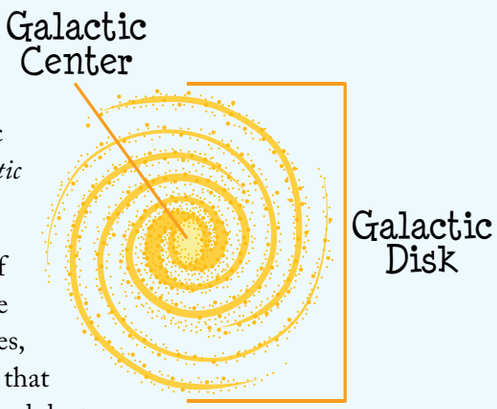


Evolved Star: A star that is almost at the end of its life. Most stars evolve to become red giants before either collapsing into white dwarfs or exploding as supernovas.

Extragalactic: Outside of the Milky Way.

Fusion: A process in which two or more atoms are pressed together to form one larger atom. This process gives off large amounts of energy. The heat and light from the sun come from the fusion of hydrogen atoms into helium in the core of the sun.

Galactic Center: The bright central part of a galaxy. The galactic center is small compared to the rest of the galaxy, and usually contains a supermassive black hole. The galactic center is sometimes called the *galactic nucleus*.

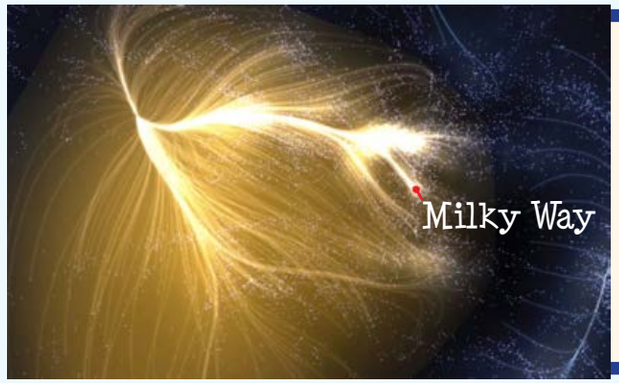


Galactic Disk: Some types of galaxies, such as the Milky Way, are shaped like a flat circle. In these galaxies, the galactic disk is the visible region that contains all of the stars, planets, gases, and dust that make up the galaxy.

Galaxy: A collection of billions of stars that are held together in a group by gravity. Our galaxy is called the Milky Way and contains anywhere from 200–400 billion stars. Galaxies that contain a few billion stars or less are called *dwarf galaxies*.

Giant Space Frisbee™!
The Milky Way is spinning around its center and moving through space at about 1.3 million miles per hour.

Laniakea: The galaxy supercluster that contains the Milky Way. The Laniakea Supercluster stretches more than 520 million light-years and contains more than 100,000 galaxies grouped into 300–500 galaxy clusters. Laniakea is Hawaiian for "immeasurable heaven."

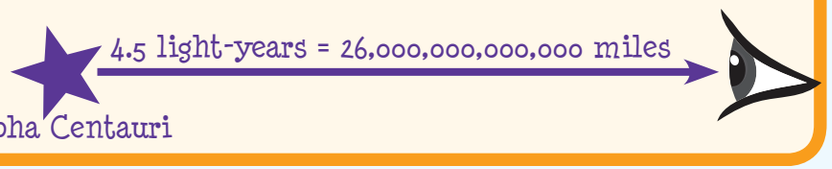


Home sweet home. The Laniakea Supercluster is home to our galaxy, the Milky Way, and 100,000 other nearby galaxies.

Lenticular Galaxy: A flat, circular galaxy that doesn't have a spiral structure like the Milky Way does. A lenticular galaxy looks like an elliptical galaxy that has been squashed flat. Just like elliptical galaxies, lenticular galaxies are made up almost completely of older stars, and very few new stars are forming there.

Light-year: The distance light can travel in a vacuum in one year. One light-year is almost 6 trillion miles: 5,878,499,810,000 miles to be exact, or 9,460,528,400,000 kilometers.

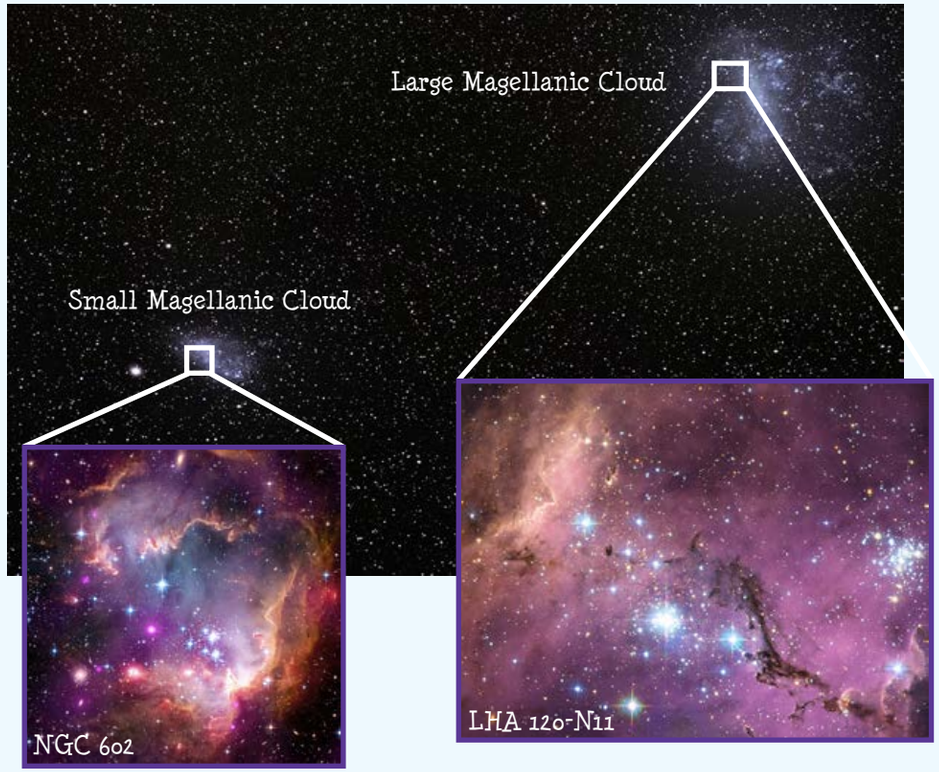
Speedy delivery! Alpha Centauri, the closest star system to our sun, is a triple star that is about 4.5 light-years away from Earth. When you look up and see light from Alpha Centauri, that light has been traveling through outer space for almost 4.5 years before it reaches your eye.



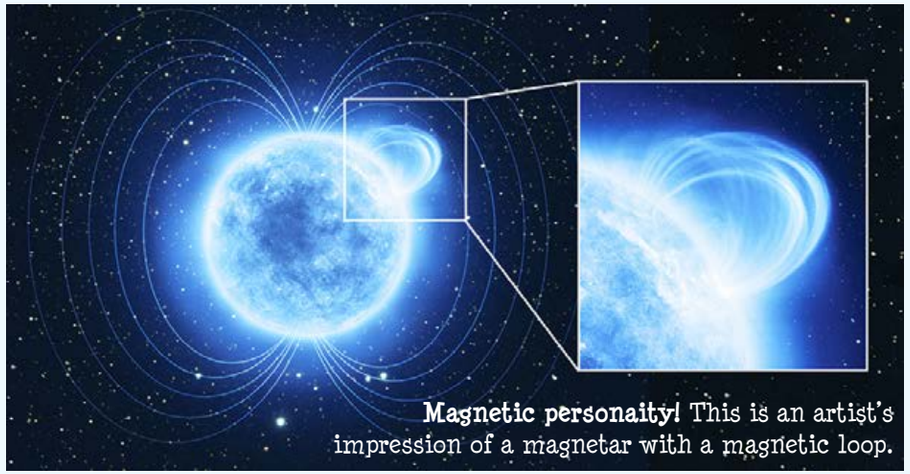
Local Group: Galaxies are not evenly distributed in the universe, and instead tend to be found in clusters. The cluster that contains the Milky Way is known as the local group. The Milky Way and Andromeda are by far the two largest galaxies in the local group. There are a total of about 54 galaxies in the local group. Almost all of them are dwarf galaxies.

Luminosity: The total amount of energy given off by a star in one second. Luminosity depends on the size of the star and the color or temperature of the star. Luminosity increases as size increases, and also increases as the surface temperature of the star increases (or as the color shifts from red toward blue).

Magellanic Clouds: The Large and Small Magellanic Clouds are two dwarf galaxies that orbit the Milky Way. They both look like they were once spiral galaxies, but gravity from the Milky Way has deformed them and turned them into irregular galaxies. The Magellanic Clouds are visible to the naked eye in the Southern Hemisphere.



MAGNETAR: A special type of neutron star that has a powerful magnetic field. The magnetic field causes the magnetar to give off high energy X-rays and gamma rays. The magnetic field of a magnetar decays after about 10,000 years, and then the energy emissions stop. At that point the magnetar is like a regular neutron star.



Magnetic personality! This is an artist's impression of a magnetar with a magnetic loop.

MAIN SEQUENCE: The diagonal line of stars on a Hertzsprung-Russel diagram that shows stars getting bigger and brighter as they get hotter. Main sequence stars are normal, healthy stars that are fusing hydrogen to helium in their cores. All main sequence stars are dwarf stars. Stars that are not in the main sequence in the H-R diagram have either run out of hydrogen in their core and entered the last part of their life, or are already dead.

MEGAPARSEC: A distance equal to a million parsecs, or about 3.26 million light-years. Megaparsecs are usually used to measure distances too big to even use light-years, such as the distance between galaxies or galaxy clusters.

MESSIER CATALOG: A list of deep sky objects that was first compiled by Charles Messier in 1771 and was expanded upon until 1960, resulting in a total of 110 objects. The Messier catalog includes many nebulas, star clusters, and galaxies that are visible from the Northern Hemisphere, each identified with an M-number. For example, M1 is the Crab Nebula, and the Andromeda galaxy is M31.

Charles Messier, c. 1770

MESSIER OBJECT: An object in deep space that is included in the Messier catalog.

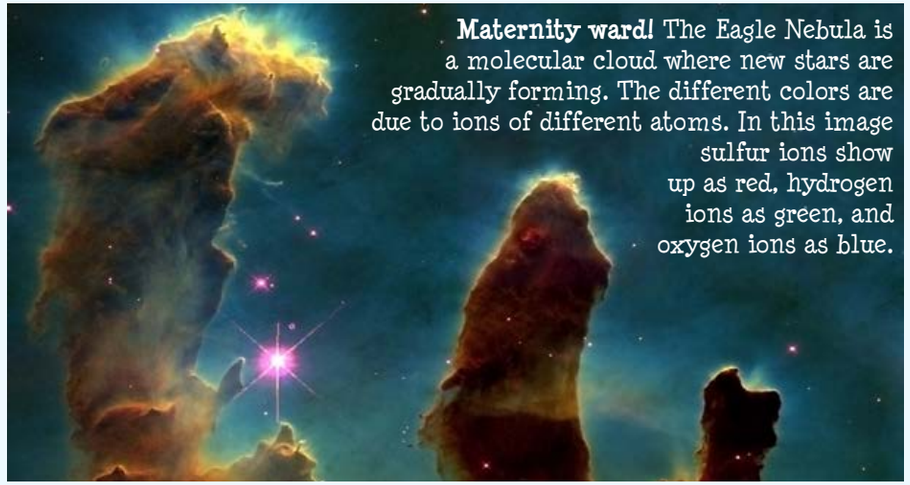
MILKY WAY: The spiral galaxy that contains our solar system. The Milky Way is estimated to contain about 200–400 billion stars, although it may contain as many as one trillion stars. Our sun is located on one of the spiral arms about halfway out from the center of the Milky Way. In the center of the Milky Way is a supermassive black hole that weighs more than four million times as much as our sun.

Why don't we know? The reason it's so hard to know exactly how many stars are in the Milky Way is that most stars are red dwarfs (p. 49), which give off very little light and also have very little mass, and therefore very little gravity. This makes them hard to detect when they're far away. The Milky Way could contain hundreds of millions of red dwarfs that we don't know about.

MILLISECOND PULSAR: An ordinary pulsar will rotate on its axis once every 1–10 seconds, but a millisecond pulsar spins around on its axis hundreds of times each second. Most millisecond pulsars are very old neutron stars that have accreted new matter over long periods of time. Adding mass caused them to spin faster.

Let me off! The fastest-spinning pulsar (p. 48) discovered so far rotates on its axis 716 times in one second!

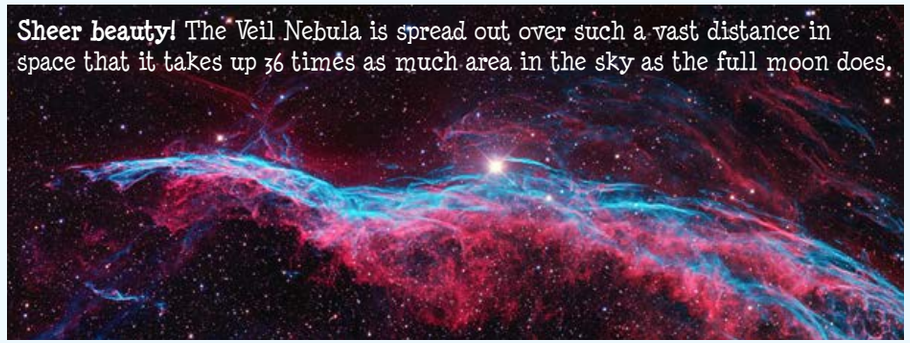
MOLECULAR CLOUD: A molecular cloud is a special kind of nebula. It is more dense and not as hot as a typical nebula, and this allows hydrogen atoms in the cloud to come together to form hydrogen molecules. Molecular clouds do not give off light the way nebulas do, but because the material in them is closer together, molecular clouds are likely places for new stars to form.



Maternity ward! The Eagle Nebula is a molecular cloud where new stars are gradually forming. The different colors are due to ions of different atoms. In this image sulfur ions show up as red, hydrogen ions as green, and oxygen ions as blue.

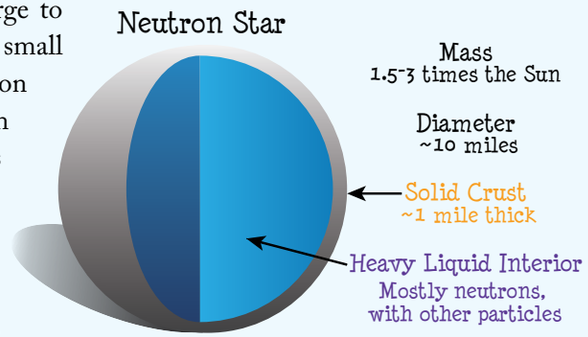
MULTIPLE STAR: Often times what looks like one star in the sky is really two or more stars that orbit each other in space. They're so close together that to us they look like one bright star. Alpha Centauri, the third brightest star in the sky, is really a three-star system.

NEBULA: A massive cloud of gas and dust in space, so large that it can create thousands of stars and solar systems. Some nebulas are regions in a galaxy where new stars are currently being formed, and other nebulas are the scattered leftovers of exploded stars, which can eventually be used to form new stars.

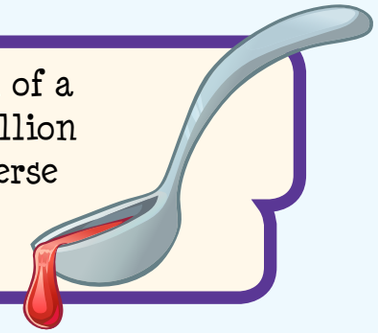


Sheer beauty! The Veil Nebula is spread out over such a vast distance in space that it takes up 36 times as much area in the sky as the full moon does.

NEUTRON STAR: The collapsed core of a star that was too large to become a white dwarf but too small to become a black hole. Neutron stars are only about 10 miles in diameter but can have a mass up to three times as much as the sun. Neutron stars are made up almost entirely of neutrons. Pulsars and magnetars are special types of neutron stars.



Small but heavy. One teaspoon of a neutron star would weigh 100 million tons. The only thing in the universe that is more dense than a neutron star is a black hole.



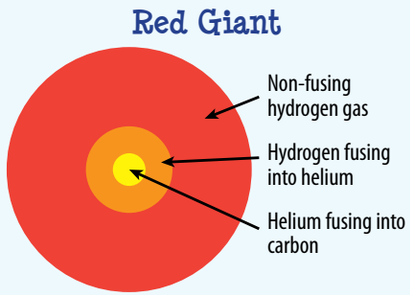
NGC: NGC stands for the New General Catalogue, which is the most comprehensive list of objects in deep space. The NGC contains 7,840 objects, which are known as NGC objects. Each object has its own identification number. For example, the Crab Nebula is NGC 1952, and the Andromeda galaxy is NGC 224. The NGC identification number is based on the position of the object in the sky.

NOVA: A star that goes through cycles of being very bright and very dim. Often the dim phase is not visible to the naked eye, so the bright phase looks like a new star in the sky. The word *nova* is Latin for "new."

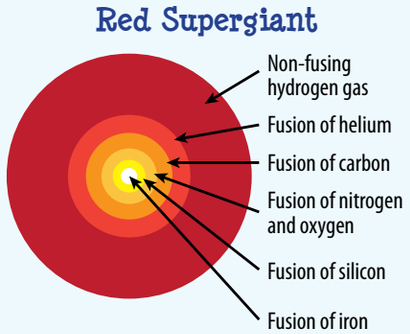
GK Persei
(Nova Persei 1901)

NUCLEAR FUSION: See *Fusion*, p. 31.

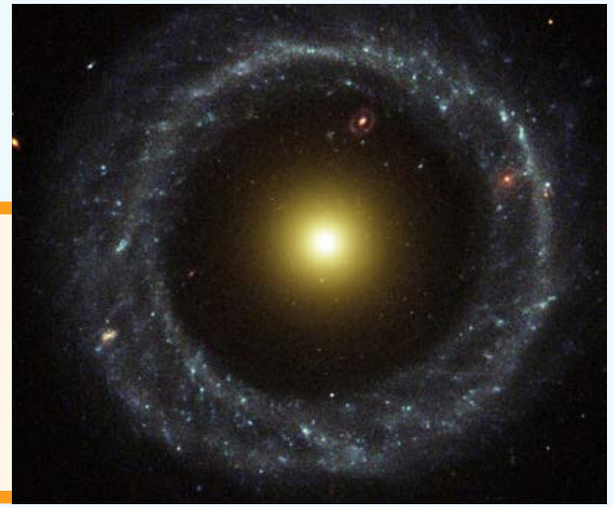
Red Giant: A star that has fused all of the hydrogen in its core, and now only has a thin shell of hydrogen surrounding a helium core. Most red giants have less mass than the sun, but are 20–100 times larger. Because red giants have so much surface area giving off light they can be several hundred times brighter than the sun. When our sun has consumed all of the hydrogen in its core it will become a red giant.



Red Supergiant: Red supergiants, like red giants, are stars that have fused all of the helium in their cores. Supergiants develop from bigger stars than giants do, usually stars between 10 and 40 times the mass of the sun. Supergiants are defined by their brightness rather than their size, so supergiant stars are not always bigger than giant stars, but they are always brighter—up to hundreds of thousands times brighter than the sun.



Ring Galaxy: A galaxy that consists of a bright center surrounded by a large ring of stars. The ring in a ring galaxy is usually made up of many bright, young, blue stars. Ring galaxies don't form naturally, and are the result of a galaxy interacting with another galaxy or cloud of matter.



One ring to rule them all. Hoag's Object is a ring galaxy containing about 8 billion stars. Nobody knows for sure how it ended up shaped like this.

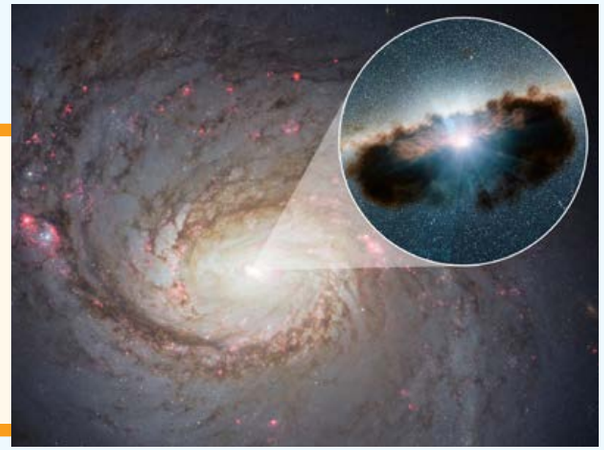
Schwarzschild Radius: The largest volume that a given mass could have and still be considered a black hole. For example, for the sun to become a black hole, all of the mass of the sun would have to be squished inside a sphere that has a diameter of less than two miles (3 km). The Schwarzschild radius for Earth is about a third of an inch (8.7 mm). The radius of an actual black hole can never be known, but the Schwarzschild radius for a black hole is equal to the black hole's event horizon.

Seyfert Galaxy: A spiral galaxy with an unusually bright center. A Seyfert galaxy is like a dim quasar: In a quasar, the core is so bright it outshines the entire rest of the galaxy, but in a Seyfert galaxy the core isn't as bright, so the spiral galaxy is still visible. About one out of 10 galaxies in the universe is a Seyfert galaxy.

Galaxy light, galaxy bright! The supermassive black hole in the center of Seyfert galaxy NGC 6300 is about 300,000 times the mass of the sun.

Singularity: A point in space where mass has been crushed into an infinitely small volume with infinite density. The center of a black hole is the most common example of a singularity. The Big Bang was a singularity that exploded.

Supermassive Black Hole: A black hole that has a mass equal to that of millions or billions of stars. Supermassive black holes are usually found in the centers of galaxies, including the Milky Way. Scientists aren't sure how supermassive black holes are formed, but they think it might be by the collapse of gigantic clouds of dust and gas.



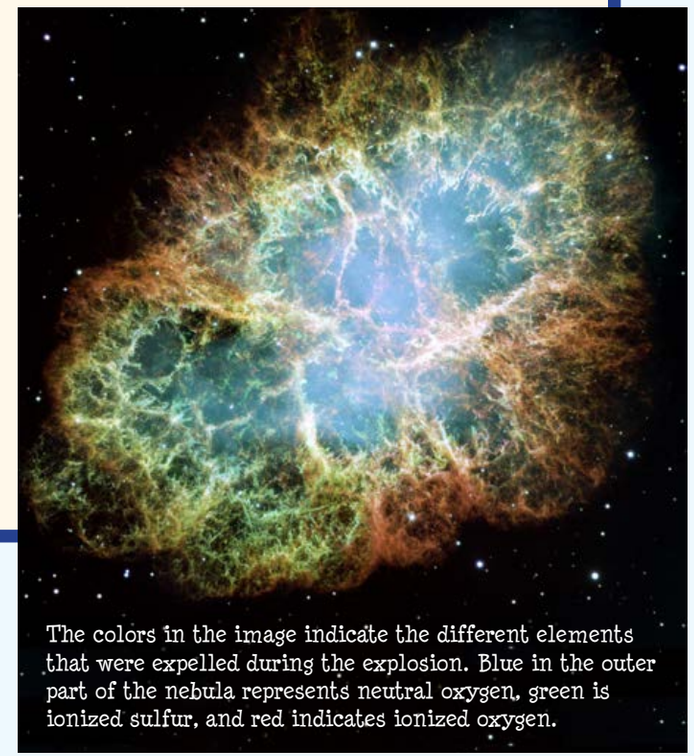
Hide and seek! The supermassive black hole in the center of galaxy NGC 1068 is partially hidden by thick clouds of gas and dust.

Supernova: When a large dying star explodes at the end of its lifetime, that event is called a supernova. The outer layers of the star are blown out into space, and the core of the star collapses down into either a neutron star or a black hole. The gases that are blown out from the exploding star form a nebula or glowing cloud in space known as a supernova remnant. A supernova is the biggest explosion ever seen in space.

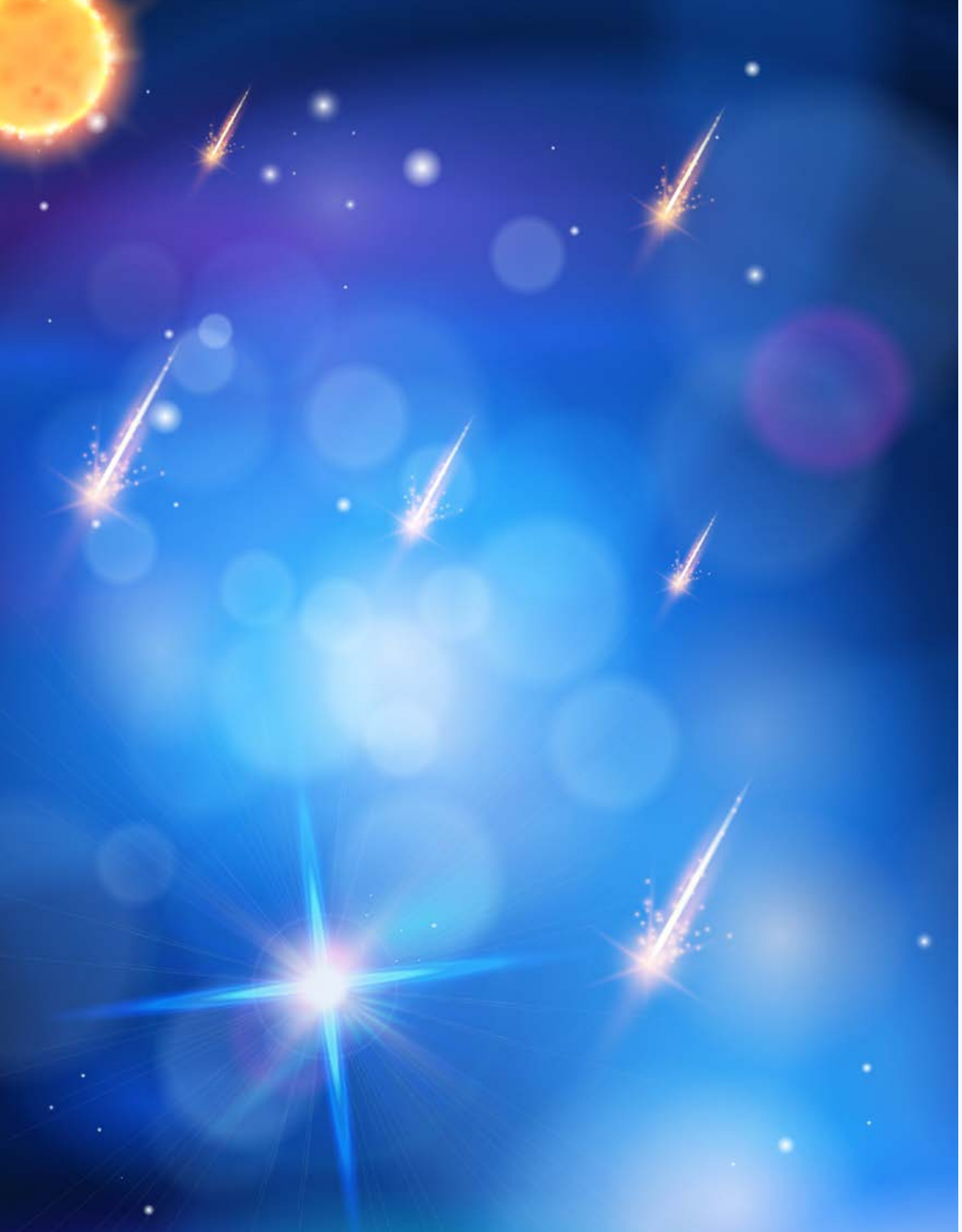
I wanna see one! Well, you might get to. A galaxy like ours has about one supernova every 50 years, but we haven't seen one in the Milky Way for more than 300 years, so we're way overdue. If a star in our galaxy does go supernova, it might be bright enough to see during the day. The daytime star would last about a month, and the supernova would remain visible at night for 6 months to a year. After that you would need a telescope to see it.

Supernova Remnant: The cloud of gas that was expelled from a star that has gone supernova. Most supernova remnants look a bit like giant soap bubbles in space, as they are hollow spheres of colorful glowing hot gas that expand outward from the core of the star. If a supernova remnant is large enough, it can become a nebula and new stars can form from the remains of the old one.

I'm not crabby! The Crab Nebula in the constellation Taurus is a supernova remnant from a star that exploded in 1054 A.D. It doesn't look anything like a crab, but William Parsons, the 3rd Earl of Rosse, who discovered it in 1840, drew a picture of it that looked a little like a crab, and the name stuck. You can't see the Crab Nebula with the naked eye, but on a clear night you can see it with good binoculars or a telescope. The star that exploded to form the Crab Nebula was too small to become a black hole, and its core collapsed into a pulsar (p. 48) in the center of the nebula.



The colors in the image indicate the different elements that were expelled during the explosion. Blue in the outer part of the nebula represents neutral oxygen, green is ionized sulfur, and red indicates ionized oxygen.



The Solar System

You Are Here

Our solar system is a lot like a family, with eight or nine children orbiting a parent in the center. But if the solar system were a family, it would have to be a family of wacky misfits from some bizarre cartoon comedy.

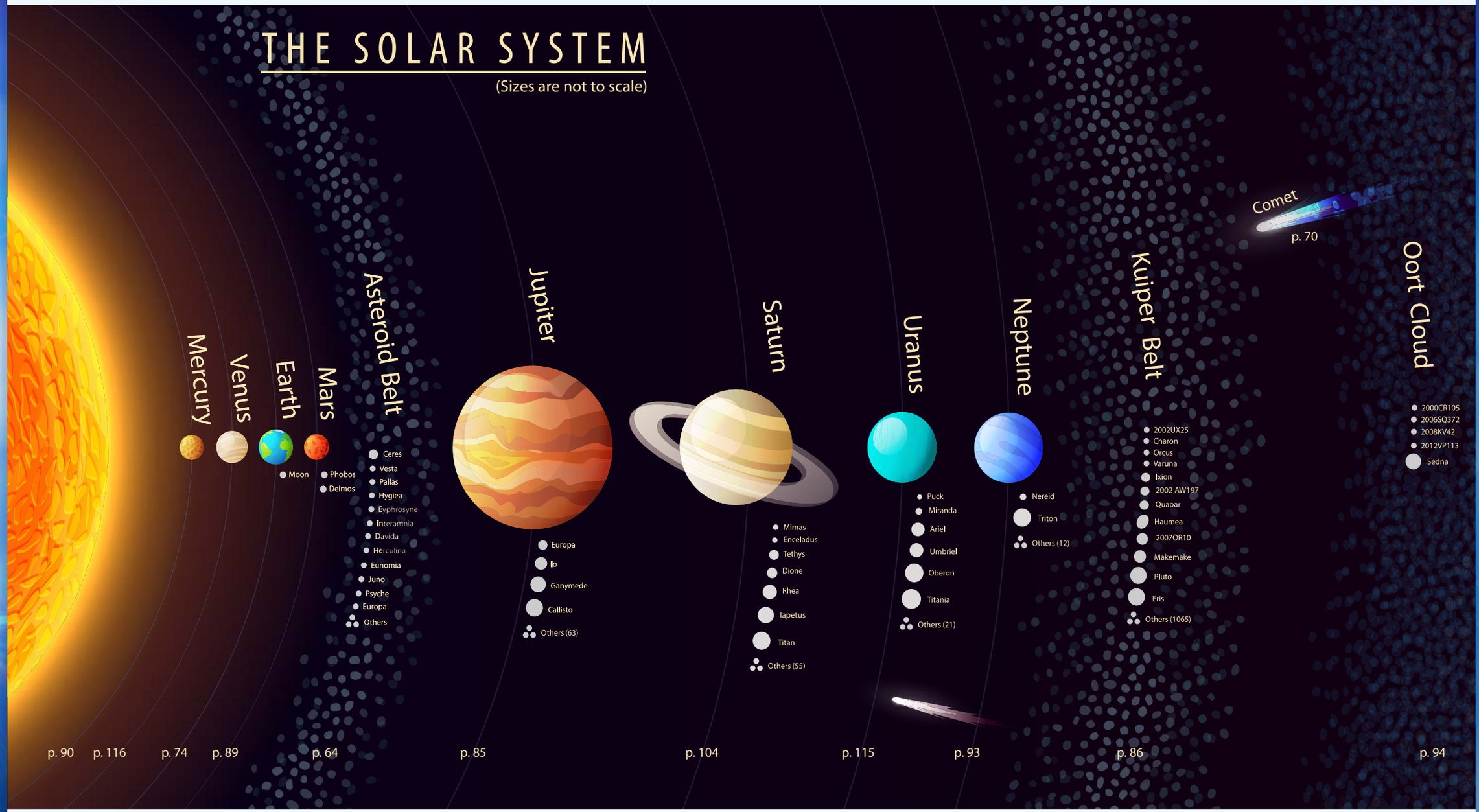
In the center of it all is a big, fat, screaming parent, the sun. The sun is constantly erupting in violent outbursts, and its deadly solar wind continually washes over everything in the solar system. There's no getting away from this hot, angry parent because the sun's gravity keeps all of the kids grounded for life, trapped in their orbits and unable to escape.

Although all of the planet-children were formed at the same time as the sun and from the same cloud of gas and dust, no two planets are alike. Tiny Mercury, the baby of the family, is simultaneously roasting hot on one side and freezing cold on the other. Venus is a brutal pressure cooker that has destroyed every probe that ever landed there, like a stormy teenager screaming "Stay out of my room!" Easygoing Earth, meanwhile, is home to tropical beaches and winter ski resorts and rain forests and deserts—but cold, hard Mars, right next door, is a barren rock covered with rust. Things only get stranger from there, with the hulking big brother Jupiter, made of the same material as the sun, and glamorous Saturn, the beauty queen of the family, whose sparkling rings of ice and dust glitter against the darkness of space like a jeweled necklace. The ice giants Neptune and Uranus are the closest things to twins in our solar system family, except that unlike any of its brothers and sisters, Uranus orbits the sun while lying on its side. There may also be a long-lost ninth child in the family, a planet almost the size of Neptune but still undiscovered, keeping its distance from the rest of its kooky family in an orbit so far away we have never even seen it.

In addition to this crazy cast of oddball planets, the solar system is home to asteroids, meteoroids, and comets whose eccentric paths have them running through the house like of out of control cats and dogs, sometimes on a collision

course with a planet or moon. Other small objects, composed mostly of ice and rock, quietly circle in the distant Kuiper belt like spectators pretending not to be part of the same family, but whether they like it or not, they're part of our solar system as well.

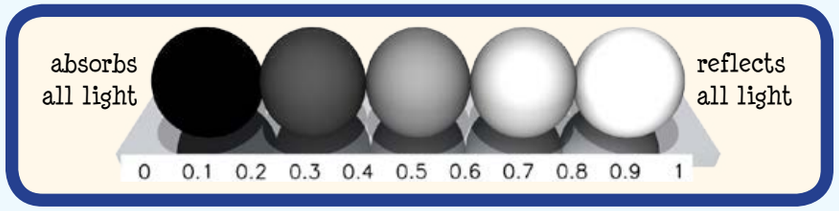
This is our solar system. It's a crazy place with so much going on that the more we learn about the solar system, the more questions we have. These are some of the words planetary astronomers use when studying our solar system and the processes and interactions that occur within it.



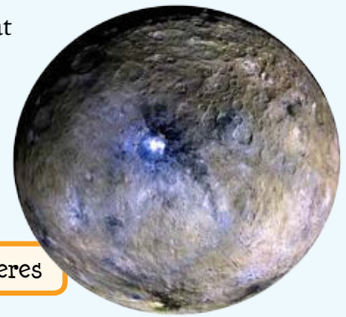
Ablation: When a meteor enters Earth's atmosphere, it heats up from friction with the air, and the outer surface of the meteor begins to burn up and tear away. This loss of material from the surface is called ablation. Ablation causes some meteors to erode away completely before they ever reach the Earth's surface.

Aerolite: Aerolite is another word for a stony meteorite, which is a meteorite that is made up mostly of silicate rock. Silicate rock is the same kind of rock that makes up most of the Earth's crust, so it's hard to tell an aerolite from an ordinary Earth rock.

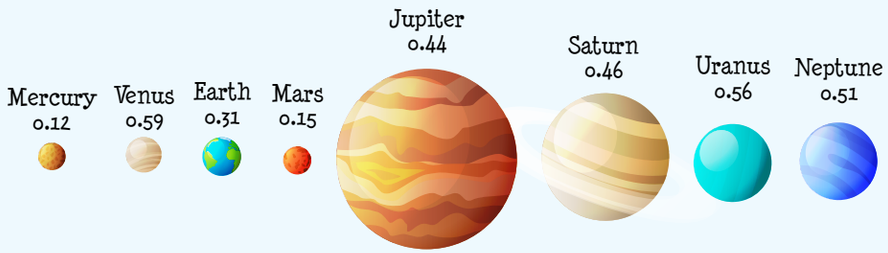
Albedo: Albedo is a measure of how well an object in space reflects light. Something that absorbs all light has an albedo of 0, and a perfect mirror that reflects all light would have an albedo of 1. The albedo of an object in the solar system can provide clues about its composition or texture.



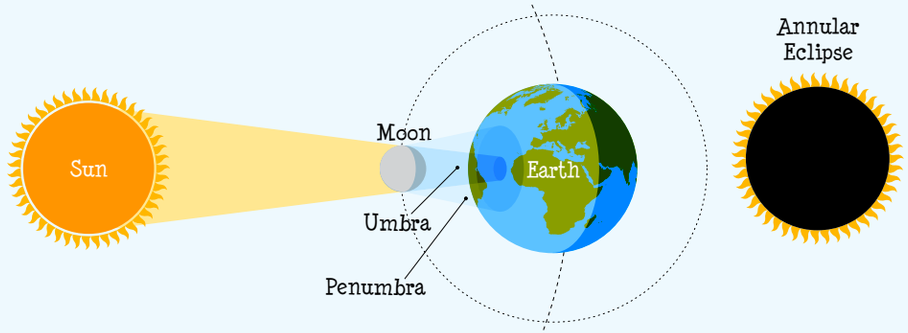
Albedo Feature: A bright spot or dark spot that reflects light much better or worse than the surrounding area. The dwarf planet Ceres has many bright albedo features. Albedo features are often due to variations in the surface of a body, such as a flat plain that reflects light well or a rough surface that does not.


The dwarf planet Ceres

Albedo of the Planets

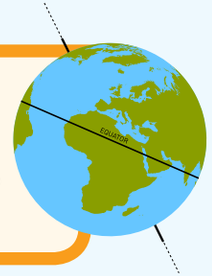


Annular Eclipse: When the moon eclipses the sun at a point when the moon is farthest in its orbit from the Earth, the moon is not large enough in the sky to completely cover the sun. When this happens, a bright ring of sun remains visible around the circumference of the moon during the eclipse and the sun looks like a ring of fire in the sky. This kind of eclipse is known as an annular eclipse. *Annular* means "ring-shaped."



Antipodal Point: The antipodal point of a planet is the point on the exact opposite side of the planet from whatever you're talking about. The antipodal point of the North Pole is the South Pole.

That's a long, wet bus ride! If you live in the continental United States, the antipodal point of your school is a spot in the Indian Ocean west of Australia.



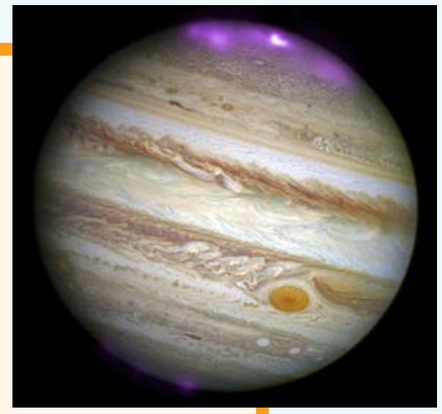
Aphelion: The point in a planet, asteroid, or comet's orbit around the sun where it is farthest from the sun. (See illustration on p. 97.)

Apogee: The point in the orbit of the moon or other satellite around the Earth where it is farthest from the Earth. (See illustration on p. 97.)

Apparition: This word has two meanings in astronomy, and neither of them is "ghost." Apparition can mean the moment when an object such as a comet first becomes visible after a period of time when it was not visible. Apparition can also refer to the range days that the object remains visible before it goes away again.

AU: See *Astronomical Unit*, p. 65.

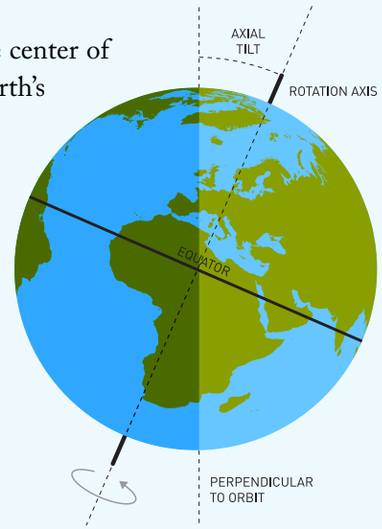
Aurora: A colorful glow in the night sky that occurs high in the atmosphere above the polar regions of Earth. When the solar wind reaches Earth's upper atmosphere, it interacts with the Earth's magnetic field and releases energy in the form of light. The aurora at the North Pole is called the aurora borealis, or northern lights. The aurora at the South Pole is the aurora australis, or southern lights.



More auroras than our auroras. Say that three times fast! Other planets also have auroras at their magnetic poles. Jupiter and Saturn both have large auroras, and auroras have also been seen on Neptune and Uranus.

Axis: An imaginary line that runs through the center of a rotating object like the axle of a wheel. The Earth's axis goes from the North Pole to the South Pole.

Binary Asteroid: Two asteroids that are orbiting one another. When the asteroids are close to the same size, they are sometimes called *binary companions* or *double asteroids*.



Blue Moon: Because the moon goes through a full cycle every 29 days, but most months have 30 or 31 days, sometimes there will be a full moon at the beginning of a month and a second full moon at the end of the same month. This second full moon in one month is called a *blue moon*. A blue moon can also be an extra moon that occurs in a particular season (four full moons in 3 months) or in a year (13 full moons in 12 months). A blue moon isn't really blue, and is just a regular full moon.

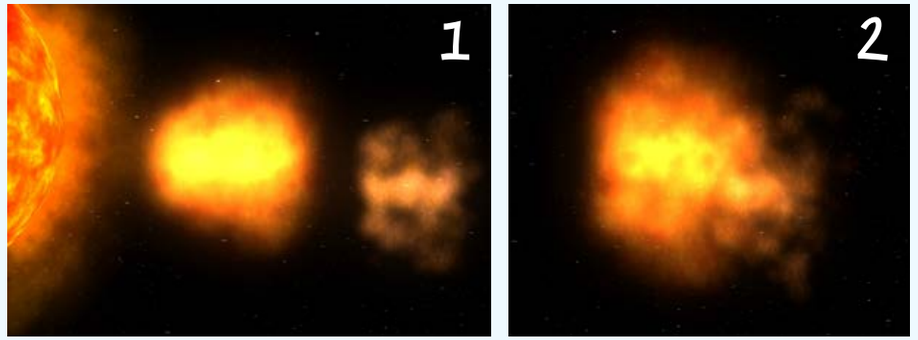
This name makes more sense. The second new moon in a single month is called a black moon.

Body: See *Celestial Body*, p. 68.

Bolide: An exceptionally bright meteor, which usually breaks up or even explodes from excessive heat as it travels through the atmosphere.

Callisto: Jupiter's second-largest moon, Callisto is essentially a planet-sized asteroid in orbit around Jupiter. Callisto is entirely composed of rock and ice just like an asteroid, but is almost the same size as Mercury. Unlike smaller asteroids, Callisto is massive enough that its gravity has pulled it into a sphere.

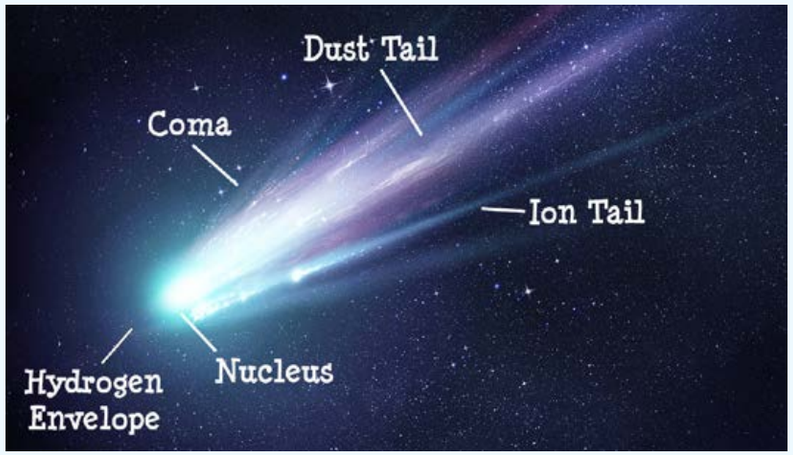
Cannibal Coronal Mass Ejection: An especially powerful coronal mass ejection (CME) that races outward from the sun and swallows up slower-moving CME's ahead of it. When a cannibal CME is directed toward Earth, it can disrupt satellites, navigation systems, and radio communications.



(1) A bright solar flare launches a coronal mass ejection followed by another. They meet in space and (2) merge into one.

COMET: A mass of icy rock that has a highly elliptical orbit around a star. When the comet is far away from the star, it looks a lot like a small asteroid—this is the comet's nucleus. As the comet gets closer to the star, it heats up and its surface begins to vaporize. This cloud of gas and dust coming off the nucleus shows up as the comet's coma and a tail, with the tail always pointed away from the star. As the comet moves away from the star again, the coma and tail die down and the nucleus continues its orbit until its next apparition.

COMET NUCLEUS: The central part of a comet made mostly of dust and ice, usually a few miles across.



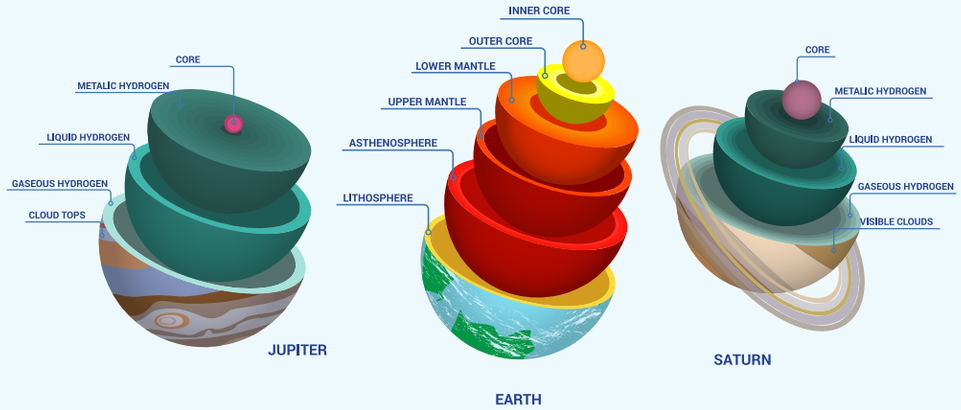
Asteroid or comet? A comet's nucleus and an asteroid are made up of almost the exact same material. They are both composed mostly of rock with some ice, and are sometimes described as dirty snowballs or icy dirtballs.

Orbit in peace. Each trip past the sun burns away a little more of the comet's nucleus, until eventually everything that can be vaporized away is gone and only a large rock remains. This is called a *dead comet*.

CONJUNCTION: This word has two different meanings in astronomy. (1) A conjunction occurs when two objects in the night sky appear to come close together. For example, when the planets Venus and Jupiter move close together in the sky it is called a conjunction. (2) Any time another planet (or the moon) lies on a straight line with Earth and the sun.

CONSTELLATION: A pattern of stars as seen from Earth in the night sky that represents a picture of some kind. There are 88 constellations. The word "constellation" is sometimes used to describe not just the stars themselves but also the region of the night sky where those stars are located.

CORE: The central part of a planet, star, or galaxy. The composition of the core is different from other parts of the planet, star, or galaxy.



CORONA: The outermost layer of the sun's atmosphere. It is made up of billowing waves of hot plasma with a temperature of more than a million degrees, and extends millions of miles into space. Because the sun's surface is so bright, the corona is only visible during a solar eclipse. *Corona* comes from the Latin word meaning "crown."

DWARF PLANET: A celestial body orbiting the sun that is massive enough to be rounded into a ball by its own gravity, but which has not cleared the area around its orbit of planetesimals. Dwarf planets are larger than asteroids but smaller than planets. The largest dwarf planets in our solar system are Pluto and Eris near the outer edge of our solar system, and Ceres in the asteroid belt between Mars and Jupiter. The classification of dwarf planet was created in 2006 following the discovery of Eris.

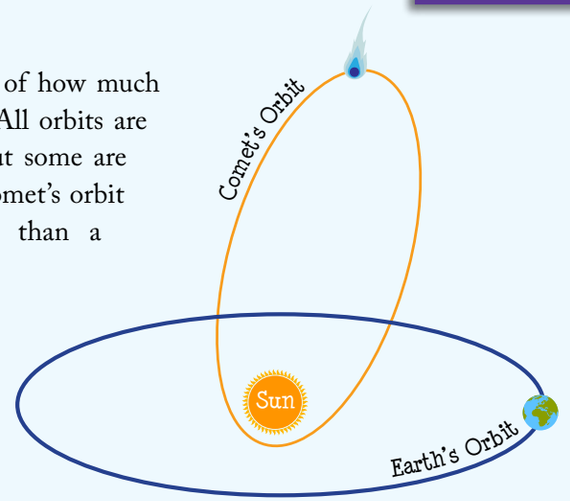
Twinning? The dwarf planet Eris is known as Pluto's twin because of its similar size. Its discovery was a big reason why Pluto was demoted from planet status–a controversial decision.

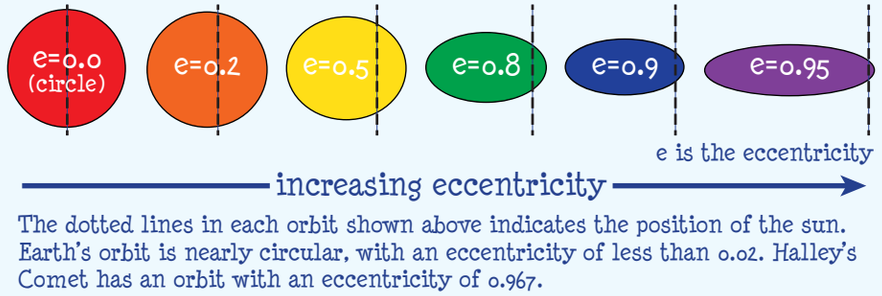
An "EPIC" View. This image of Earth was captured in 2015 by NASA's Earth Polychromatic Imaging Camera (EPIC). It was taken from a million miles away!

EARTH: The third planet from the sun and the only planet in our solar system that is known to support life. Earth lies in the narrow celestial habitable zone around the sun where water exists on the surface of the planet in liquid form instead of only as ice or gaseous vapor. Earth is 93 million miles, or one astronomical unit (AU), away from the sun.

EARTHSHINE: When the moon is only partly lit by the sun, such as a crescent or gibbous moon, the dark portion isn't entirely dark: You can still sometimes make out details in the dark area because there is a faint light shining on it. This faint light is sunlight that is reflected off the Earth, and is called earthshine.

ECCENTRICITY: A measure of how much an orbit deviates from circular. All orbits are elliptical rather than circular, but some are more elliptical than others. A comet's orbit has much greater eccentricity than a planet's orbit.

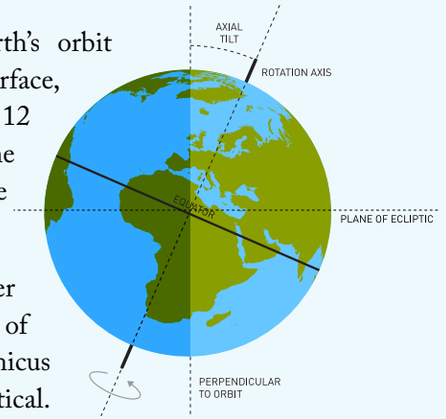




The dotted lines in each orbit shown above indicates the position of the sun. Earth's orbit is nearly circular, with an eccentricity of less than 0.02. Halley's Comet has an orbit with an eccentricity of 0.967.

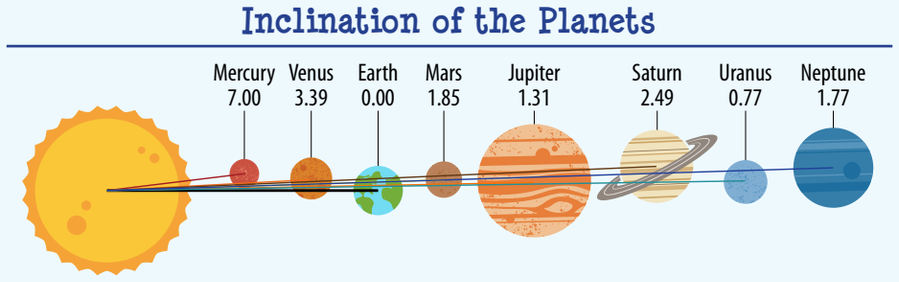
ECLIPSE: When our view of one celestial body is blocked partially or totally by another celestial body that is moving in front of it. (See *Lunar Eclipse*, p. 87, and *Solar Eclipse*, p. 107.)

ECLIPTIC: If you could take the Earth's orbit around the sun and turn it into a flat surface, that flat surface would be the ecliptic. The 12 constellations of the Zodiac all lie on the ecliptic; the other 76 constellations are above or below the ecliptic.



ELLIPSE: An oval shape. Johannes Kepler discovered in the early 1600s that the orbits of the planets are not perfect circles as Copernicus said they were, but are actually slightly elliptical.

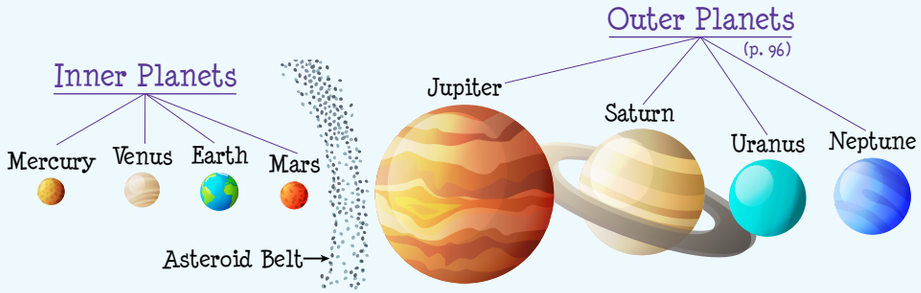
INCLINATION: The orbits of the planets in our solar system do not all lie in the same flat plane. Most of them are pretty close, but each one is a little different. Inclination is the angle of how tilted each planet's orbit is compared to Earth's orbit. Uranus has the lowest orbital inclination, at less than one degree of tilt compared to Earth's orbit. Mercury has the highest orbital inclination at 7 degrees of tilt compared to Earth's orbit.



INFERIOR CONJUNCTION: When Mercury or Venus lies on a straight line in between the Earth and the sun.

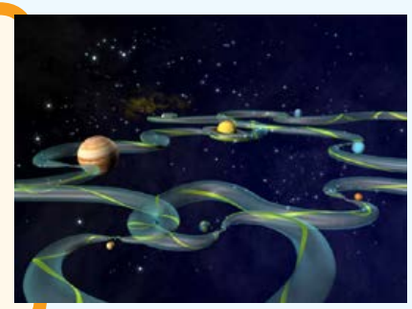
INFERIOR PLANET: A planet whose orbit lies between Earth's orbit and the sun. Mercury and Venus are the only two inferior planets in our solar system. Sometimes the term inferior planet is used to mean any planet whose orbit is smaller than the orbit of the planet you're talking about: For example, Earth is an inferior planet to Mars, and all of the other planets are inferior to Neptune. (See *Superior Planet*, p. 111.)

INNER PLANET: Any of the planets in our solar system that are closer to the sun than the asteroid belt. These are the small rocky planets Mercury, Venus, Earth, and Mars.



INTERPLANETARY: The space in between the planets, or something that involves more than one planet such as an interplanetary space mission.

Highway to the cosmos. This space "freeway," envisioned by a NASA engineer, was designed for NASA's Genesis mission and finds paths through gravity fields for spacecraft to travel. It can be used to calculate the amount of fuel needed for interplanetary space missions.

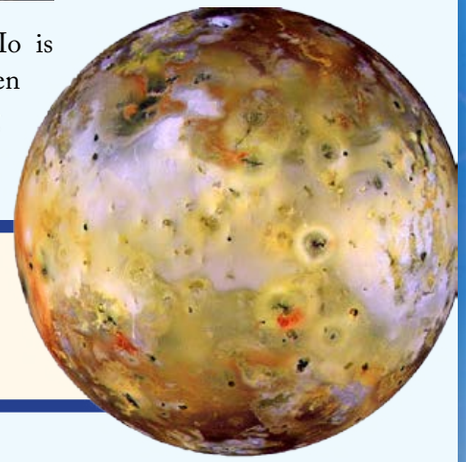


INTERPLANETARY MAGNETIC FIELD: A magnetic field that stretches out from the sun throughout our solar system. The interplanetary magnetic field is created by the solar wind.

INTERPLANETARY MATTER: Traces of dust, gas, and other debris that are found between the planets in the solar system.

Meteoroids (p. 91) are small interplanetary bodies. Meteor showers like the one pictured here occur when Earth gets close to a comet's debris.

IO: One of Jupiter's four large moons. Io is caught in a gravitational tug of war between Jupiter and its other large moons, resulting in a surface on Io that is peppered with active volcanoes.

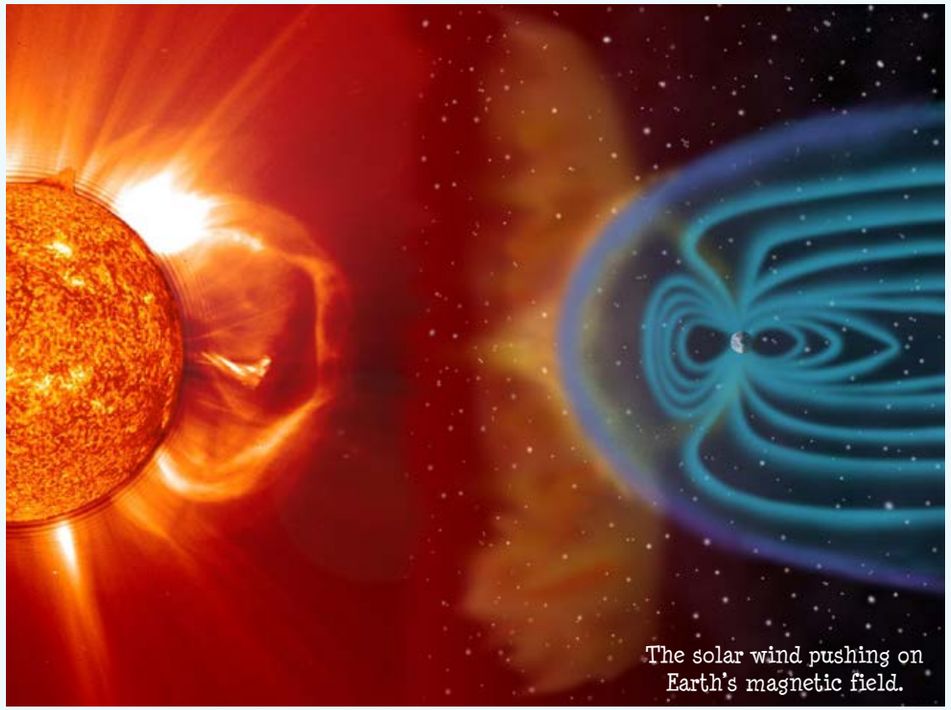


Hot and cold! Io's average surface temperature is -200°F, but it is pockmarked with volcanoes that are as hot as 3000°F.

LUNAR MONTH: The amount of time that passes between successive full moons or successive new moons. A lunar month is 29 days 12 hours and 44 minutes. This is how long it takes the moon to make one complete orbit around the Earth. A lunar month is also called a *synodic month* or a *lunation*.

Must be a full moon tonight! Centuries ago people thought odd behavior was caused by the moon, and insane people were said to be *moonstruck*. The modern word *lunatic* also implies that the moon is to blame.

MAGNETIC FIELD: Many planets including Earth have iron cores that act as giant magnets. These magnets create a region of space around the planet called a magnetic field. The Earth's magnetic field helps protect the Earth from cosmic rays by steering them around the planet.



The solar wind pushing on Earth's magnetic field.

MAGNETIC POLE: The opposite ends of a magnet where the magnetic forces are strongest are known as the magnetic poles. Earth's magnetic poles are a few hundred miles from its geographic North and South Poles.

Upsy-daisy! The Earth's magnetic North and South Poles switch places about once every 450,000 years on average. It has been 780,000 years since the last geomagnetic reversal, and some scientists believe the next one could begin during our lifetimes.

MAIN BELT: Another name for the asteroid belt that lies between the orbits of Mars and Jupiter. Asteroids that orbit here are referred to as *main belt asteroids*.

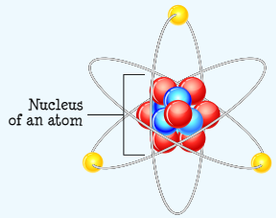
MAJOR PLANET: A regular planet, as opposed to a dwarf planet or a minor planet. Our solar system has eight major planets.

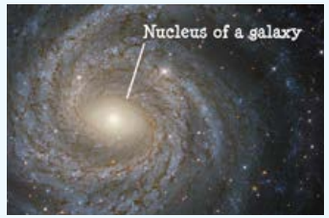
MARE: A dark, flat region on the surface of the moon. The word *mare* is Latin for "sea," because early astronomers thought these dark regions on the moon were actual seas. The Sea of Tranquility where Apollo 11 landed is a mare.

MARS: Also known as the red planet, Mars is the first planet after Earth as you move away from the sun. The reddish color of Mars is due to high levels of iron oxide (rust) in its soil. Mars has mountains, valleys, volcanoes, and polar ice caps, and a thin atmosphere made up almost entirely of carbon dioxide. There is evidence that Mars once had surface water and may even have supported microscopic forms of life, but this has not yet been proven.

Night fright! Mars was the Roman god of war, known to the Greeks as Ares. Mars's two moons, Phobos and Deimos, are named after the twin sons of Ares in Greek mythology. Their names mean "fear" and "terror."

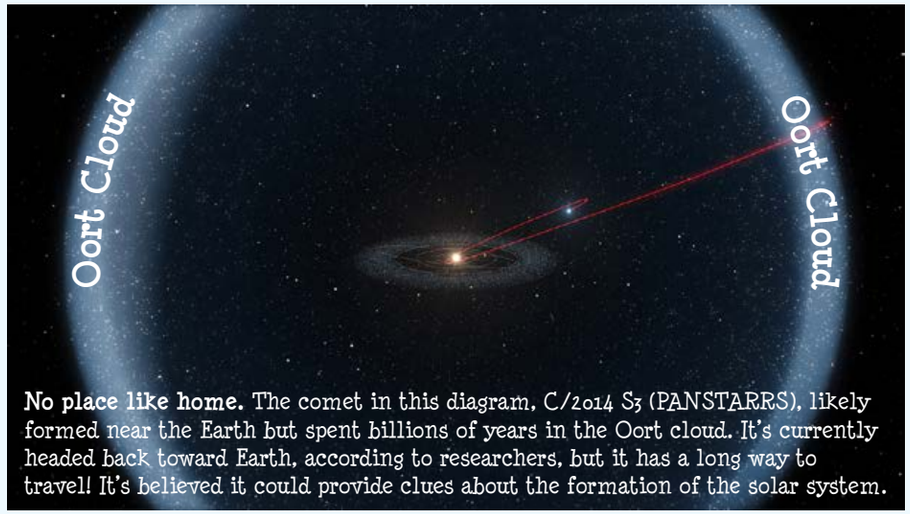
NUCLEUS: The central core of an atom, comet, or galaxy. The nucleus of an atom is made up of protons and neutrons and contains nearly all of the mass of the atom. The nucleus of a comet is an icy rock that becomes the center of the comet's head (or coma) when it approaches a star. The nucleus of a galaxy is a dense region of stars and may also contain a black hole.





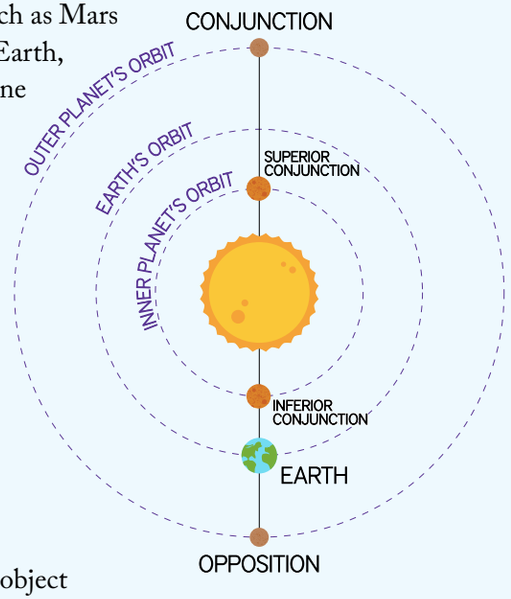
OBLATE SPHEROID: Most planets are not perfectly round, they are more like slightly squashed spheres that are a little shorter from top to bottom and a little wider around the middle. This kind of squashed spherical shape is called an oblate spheroid.

OORT CLOUD: A gigantic spherical cloud of icy planetesimals that surrounds our solar system. The Oort cloud lies a thousand times farther from the sun than the Kuiper belt, and stretches halfway to Proxima Centauri, the next nearest star to our sun. The Oort cloud is home to billions of comets. Even though objects in the Oort cloud are bound to the sun by gravity, the Oort cloud is considered to be outside of our solar system because it is well beyond the heliopause, or the point where the solar wind dies down to nothing.



No place like home. The comet in this diagram, C/2014 S3 (PANSTARRS), likely formed near the Earth but spent billions of years in the Oort cloud. It's currently headed back toward Earth, according to researchers, but it has a long way to travel! It's believed it could provide clues about the formation of the solar system.

OPPOSITION: When a planet such as Mars is at a place in its orbit that the sun, Earth, and the planet all lie on a straight line with the Earth in the center, the planet is said to be in opposition. Only planets whose orbits are farther from the sun than Earth's can be in opposition. Planets appear brightest in the night sky when they are in opposition. If we could see phases of Mars the way we can see phases of the moon, opposition would be a "full Mars."



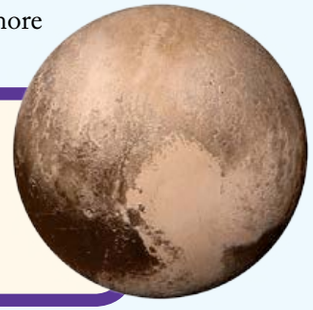
ORBIT: The elliptical path that an object follows as it goes around a bigger object, such as a moon around a planet or a planet around a star.

ORBITAL PERIOD: The length of time it takes for one body to orbit another. Earth's orbital period around the sun is one year. The moon's orbital period around Earth is about 29 days, or one lunar month. The precise amount of time in Earth days it takes for each planet to complete its orbit can be seen below.

Planet	# of Days
Mercury	88 days (0.2 years)
Venus	225 days (0.6 years)
Earth	365 days (1 year)
Mars	687 days (2 years)

Planet	# of Days
Jupiter	4,333 days (12 years)
Saturn	10,756 days (30 years)
Uranus	30,687 days (84 years)
Neptune	60,190 days (165 years)

Pluto: A dwarf planet beyond Neptune's orbit. Pluto was considered to be a planet from 1930 to 2006, when new discoveries revealed similar-sized objects in the same area of space. Pluto's internal composition is ice and rock, similar to an asteroid or comet, making Pluto more like a very large asteroid than a planet.



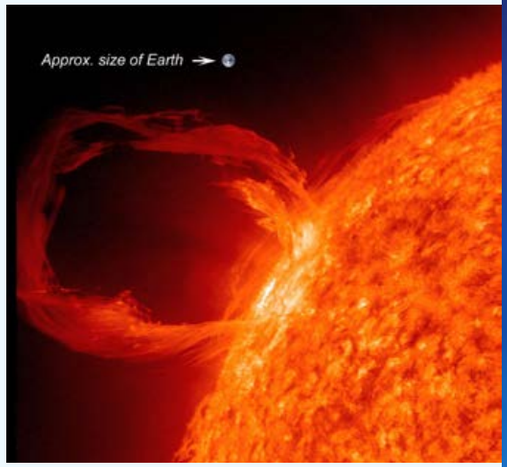
The girl who named a planet. The name Pluto was suggested by 11-year-old Venetia Burney from England.

Precession: In addition to orbiting the sun and rotating on its axis, the Earth has a third circular motion, called precession. In the same way that a spinning top begins to wobble before it falls down, the Earth wobbles very slowly as it rotates on its axis. This wobbling is called precession. It takes the Earth about 26,000 years to complete one full wobble (one period of precession). Because of precession, Earth's North and South Poles are always slowly changing the directions they point to in space.

Pick a star, any star! The North Star changes due to Earth's precession. Polaris is currently the North Star, but in 3000 B.C. the North Pole pointed toward a star named Thuban in the constellation Draco. In 13,000 years, the North Pole will point toward a star named Vega. Another 13,000 years after that, it will be back to pointing at Polaris.

Primary Atmosphere: A primary atmosphere is an atmosphere around a planet that was formed directly from the protoplanetary disk at the same time the planet itself formed. Because the protoplanetary disk was a dense mass of mostly hydrogen and helium, that's what a primary atmosphere is made of. The atmospheres of Jupiter and Saturn are primary atmospheres. (See *Secondary Atmosphere*, p. 105.)

Prominence: An explosion of ionized gas that erupts from the sun's lower atmosphere (the chromosphere), and can extend more than 100,000 miles into space. That's about 12 times the diameter of Earth.



Protoplanet: A stage in the formation of a planet where the planet is nearly complete. Protoplanets are generally round and have a core, mantle, and crust, but are still growing by attracting nearby planetesimals.

Protoplanetary Disk: A rotating disk of dense gas that surrounds a newly formed star. As the components of a protoplanetary disk condense into larger bodies, the protoplanetary disk evolves into a debris disk and eventually into planets and moons.

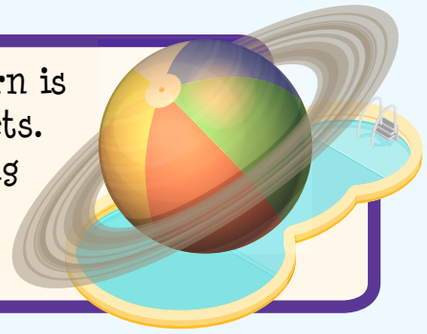
Regolith: The layer of loose rock, soil, and dust on the surface of a terrestrial planet, moon, or asteroid. The fine dust covering the surface of the moon is regolith that was produced mainly by impacts with meteoroids.

Saros Cycle: Lunar eclipses and solar eclipses occur at regular intervals that are 18 years, 11 days, and 8 hours apart. This period of time is called a Saros cycle.

Satellite: Any object that orbits a larger body. A moon is a natural satellite, and Earth is also orbited by many man-made satellites that relay information to and from Earth, such as telephone transmissions, television, weather information, and GPS navigation. There are currently about 1,100 active satellites in orbit around Earth, plus another 2,600 that no longer work.

Saturn: The second largest planet in our solar system, yellowish in color and known for its ring system. Saturn is a gas giant like Jupiter, composed primarily of hydrogen and helium, and is a ball of gases without a solid surface. Saturn's rings are made almost entirely of water ice, along with some small rocky debris and dust. Saturn's rings begin about 4,100 miles (about half of the diameter of Earth) above the planet's surface, and extend 75,000 miles (or nearly eight Earth diameters) into space.

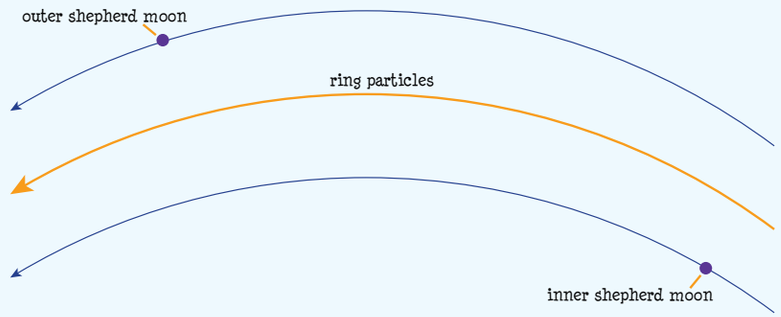
That's a big beach ball! Saturn is the least dense of all the planets. If you could find a swimming pool big enough to throw it into, Saturn would float.



Secondary Atmosphere: A secondary atmosphere is a planetary atmosphere that did not form directly from the protoplanetary disk at the same time the planet itself was being formed. A secondary atmosphere forms from gases leaking out of the planet through volcanic activity and by the accumulation of material from comet and asteroid impacts. Secondary atmospheres are much less dense than primary atmospheres. Venus, Earth, and Mars all have secondary atmospheres.

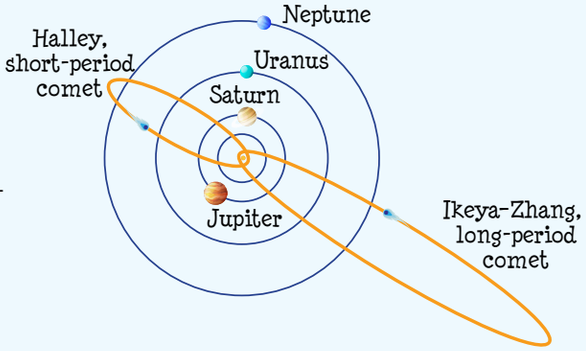

Secondary atmosphere escapes from the interior.

Shepherd Moon: Ringed planets sometimes have moons that orbit near or even within the rings, and the gravitational pull of these shepherd moons helps hold the material of the rings in place. All of the outer planets in our solar system have shepherd moons.

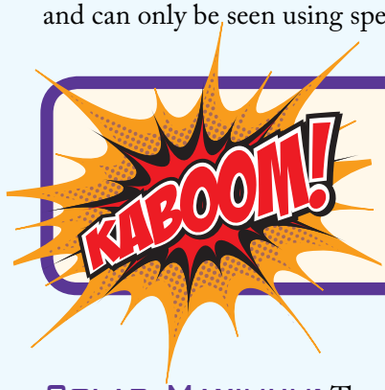


Shooting Star: Another name for *meteor*.

Short-Period Comet: A comet that orbits the sun at least once every 200 years. Halley's Comet with a 76-year orbital period is the best-known short-period comet.



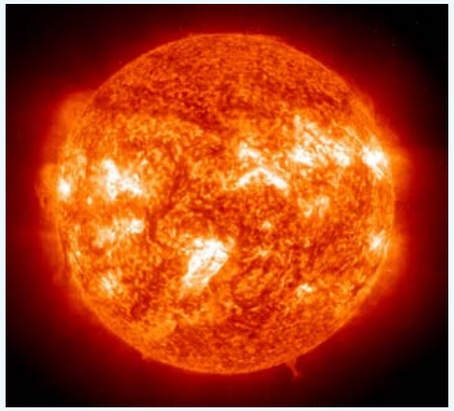
Solar Flare: A sudden outward eruption on the sun's surface that shows up as a flash of brightness usually lasting less than one hour. Solar flares are the largest explosions in the solar system, but they are not visible to the naked eye and can only be seen using specialized equipment.



The energy released by an average solar flare is equal to more than a billion nuclear bombs exploding all at once.

Solar Maximum: The point in the solar cycle where sunspot activity is at its peak and the output of radiation and particles from solar flares is highest. During Solar Cycle 23, which lasted from 1995 to 2008, there was a peak of 120 sunspots per month during the solar maximum.

Solar Minimum: The point in the solar cycle where sunspot activity is quietest and the output of radiation and particles from solar flares is lowest. During the solar minimum, days at a time can pass with no solar flares. During the solar minimum of the Solar Cycle 23 (1995 to 2008), there was an average of less than two sunspots per day or 60 per month, with more than 800 days that had no sunspots at all.



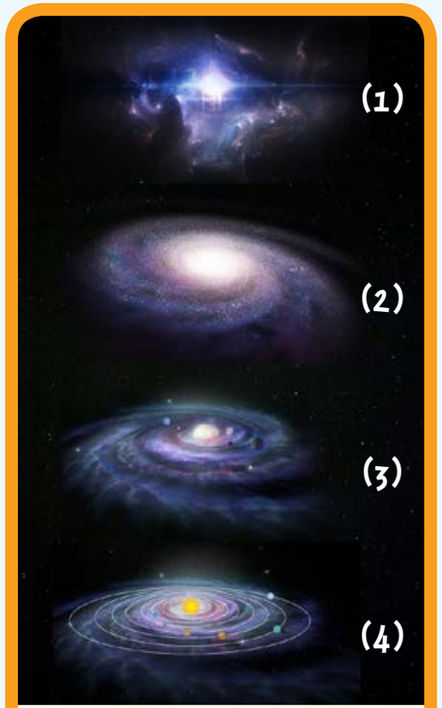
Solar maximum
from July 19, 2000

Solar minimum
from March 18, 2009

Solar Nebula: A nebula is a large cloud of dust and gas in space. The solar nebula is the nebula from which our solar system formed about 4.6 billion years ago.

Solar System: The sun and all of the celestial bodies that are caught within the sun's gravitational pull. In addition to the sun, the eight planets, and their moons, our solar system includes asteroids, comets, and meteoroids. The solar system is usually considered to end at the heliopause (the point where the solar wind from the sun ends), which occurs past the Kuiper belt but before the Oort cloud. The Oort cloud is still bound by the sun's gravity but is also affected by the gravity of objects passing by outside of our solar system.

Solar Wind: A stream of high-energy, electrically charged particles (mostly protons and electrons) that flows outward from the sun in all directions at speeds of more than a million miles per hour. The solar wind is what causes comet tails to point away from the sun. When the solar wind reaches Earth it causes the northern and southern lights.

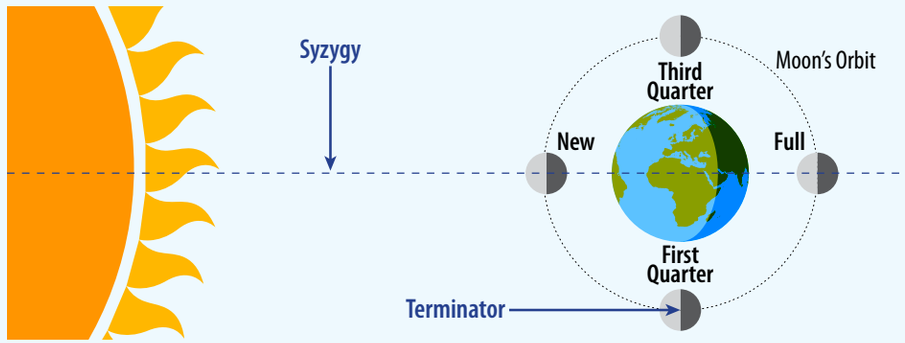


Solar system formation. (1) Solar nebula (2) Gravity draws the solar nebula into a flat, rotating disk, bringing dust particles closer together. (3) Dust grains collide and stick together, forming larger clumps of matter. Through repeated collisions, moon-sized planetesimals are formed—the solar system is a chaotic swirl of countless small bodies in a cloud of gas. (4) Solar wind from the newly-forming sun in the center blows the gases away into space. Some planetesimals are thrown out of the system by collisions and gravity, some find a stable orbit around the sun, and others continue to grow, forming planets and moons.

Synchronous Rotation: The moon takes about 29 days to complete one orbit around the Earth, and it also takes the same amount of time to make one complete revolution on its axis. When the time it takes to complete one orbit is the same as the time required to complete one rotation, that's called synchronous rotation. The result of synchronous rotation is that the same side of the moon is always facing Earth.

Synodic Month: See *Lunar Month*, p. 88.

Syzygy: Any straight-line configuration of three bodies in the solar system. When the sun, Earth, and moon are in syzygy, we will have either a full moon or a new moon, depending on whether the moon is at the end of the line or in the middle.



Terminator: The boundary line between day and night on any celestial object. When you see a half moon in the sky, the straight side is the terminator.

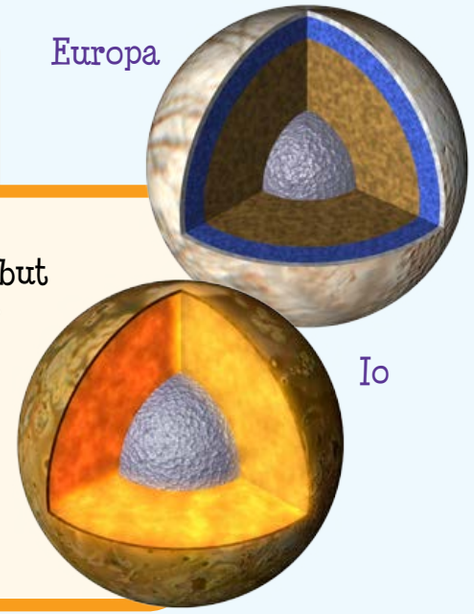
Terrestrial: An adjective used to describe anything originating on Earth or related to Earth. Small rocky planets are known as terrestrial planets because of their similarity to Earth.

Terrestrial Planet: Any small planet that is composed mainly of rock and iron, such as Mercury, Venus, Earth, and Mars.

Third Quarter: A phase of the moon that is half lit by the sun and half in shadow as it shrinks from a full moon toward a new moon. In the Northern Hemisphere, the illuminated part of a third quarter moon is shaped like a backward capital D. A third quarter moon rises in the east around midnight, is high overhead around 6 a.m., and sets in the west around noon.

Tidal Force: The entire moon does not feel the same gravitational pull from the Earth because gravity is weaker at farther distances. So the points on the moon that are closest to Earth feel a stronger gravitational pull than the points that are farther away. This difference in pulling force felt by an object is called tidal force. When tidal forces are large they can deform objects, cause them to heat up inside, or even tear them apart.

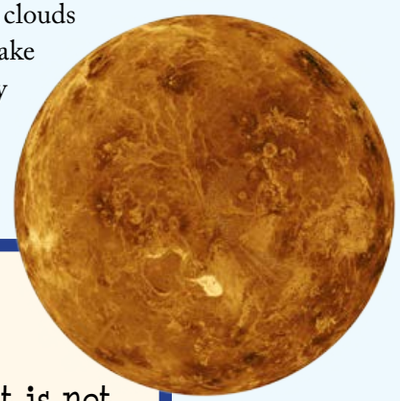
Warmer on the inside!
Jupiter's moons show evidence of being heated inside from tidal forces due to Jupiter's gravity. Europa has an icy exterior, but contains liquid water under the surface where it is warmer. Tidal forces have heated Io even more, giving it a mantle made of molten rock and a surface covered with active volcanoes.



Titan: Saturn's largest moon. Titan is larger than the planet Mercury, is made up mostly of rock and ice, and has seas of liquid methane on its surface. Titan's atmosphere is made up almost entirely of nitrogen gas, but contains thick yellow smog that hides the surface of the moon from view.

Transit: The passage of a smaller body in front of a much larger one, such as Venus passing in front of the sun, where the smaller object does not eclipse the larger one, but covers only a small area of it.

Venus: A terrestrial planet that is slightly smaller than Earth. Venus is sometimes called Earth's sister planet because it is so close in size, but the two planets are very different. Venus has a thick atmosphere of carbon dioxide that traps heat and helps make Venus the hottest planet in our solar system, at nearly 900°F (480°C). Venus has thick clouds of sulfuric acid that reflect sunlight light and make Venus the second brightest object in the night sky after the moon. The sulfur in Venus's atmosphere is also what gives the planet its yellow color.



The forecast for tomorrow . . . cloudy! Venus appears to be the brightest star in the sky due to reflected sunlight—but the sunlight is not reflecting off the planet, it's bouncing off the thick atmosphere that surrounds Venus. The atmosphere on Venus is so thick that you can't actually see the planet with an optical telescope.

Waning: We say the moon is waning when the lit portion that we can see is shrinking from a gibbous moon down to a crescent moon as it goes from a full moon to a new moon.

Waxing: We say the moon is waxing when the lit portion that we can see is growing from a crescent moon to a gibbous moon on its way to being a full moon.

Zodiacal Light: A faint white glow that can sometimes be seen above the horizon in the direction of the sun before sunrise or after sunset. It is caused by sunlight that is scattered by space dust in the plane of the solar system, but it is so faint that it is washed out by moonlight or outdoor lighting. Zodiacal light is most easily seen before sunrise in the spring and after sunset in the fall.

A busy night sky! This 2014 image shows Venus and a band of zodiacal light on the left. The central band of the Milky Way appears as well, with a streak of a meteor on the right. The bright spot to the left of the meteor is the plume of an Ariane 5 rocket launching from Kourou, French Guiana.

And Beyond!

The Future of Private Space Travel

Throughout the 20th century, only governments of large nations could afford to develop space programs, but now many private companies are also beginning to provide services in space. These are just a few examples.

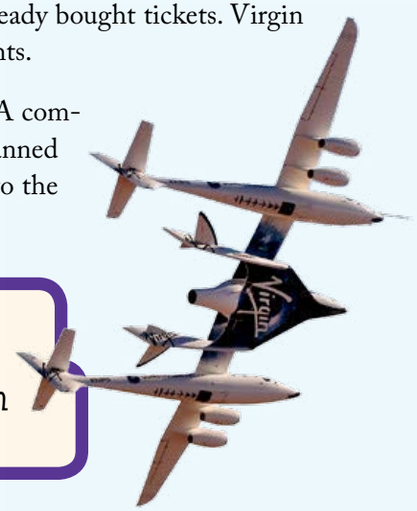
Bigelow Aerospace (1999–Present): A company based in Nevada that is developing inflatable rooms that can be attached to space stations to increase the living space available to astronauts.

Blue Origin (2000–Present): A space travel company based in Washington state that is working to develop reusable spacecraft to make orbital space travel less expensive.

SpaceX (2002–Present): A space travel company based in California that uses its unmanned Dragon spacecraft to send supplies to the International Space Station. SpaceX is currently developing Dragon V2, a reusable spacecraft that will be able to carry up to seven astronauts into orbit.

Virgin Galactic (2004–Present): A company based in California that is working to provide space flights to tourists. These flights would go into space but not into orbit. Although the first flight is not yet scheduled, by the end of 2015 more than 700 people had already bought tickets. Virgin Galactic's long-range plans include orbital flights.

Orbital ATK (2015–Present): A company based in Virginia that makes an unmanned cargo ship that is used for delivering supplies to the International Space Station.



Ticket to ride! In 2016, the ticket price for a quick trip into space with Virgin Galactic was $250,000.

Astronomy Timeline

When you think of a fortuneteller, you don't normally picture a scientist, but in a way that's exactly what scientists are. One of the main goals of science is to be able to predict the future. Scientists make observations and conduct experiments and then use the information they gain to develop theories. If a theory is able to predict the outcome of new experiments before they are carried out, then the theory is regarded as valid, but if the theory's predictions are wrong, then the theory is modified or discarded.

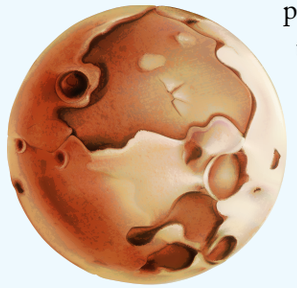
It should come as no surprise, then, that astronomy is the oldest science. Stone-age civilizations around the world studied the stars in the night skies thousands of years ago and found repeating patterns in what they saw. These patterns allowed hunters to predict when the moon would be full again and when the night sky would be moonless. Farming civilizations learned how to predict the changing of the seasons, and created calendars to help determine the best time to plant crops. Early astronomers saw repeating patterns in the positions of the stars, the phases of the moon, and even in the movements of the five "wandering stars" called planets. Many ancient civilizations, including the Greeks, Middle Easterners, and Mayans, developed their knowledge of astronomical patterns to the point where they were able to predict eclipses.

But not everything in the night sky was predictable. Sometimes without warning a bright new light would appear for weeks or months, something that looked like a large star but with a long, flowing tail of light. It made sense to early astronomers that if the stars could be used to predict the future, then these unexpected new stars must be predicting something as well. Because the early astronomers had no explanation for where these strange new stars came from, people's imaginations took over and the appearance of a comet was almost always regarded as an evil omen. The first sight of a comet could fill people with fear—they were convinced that something bad was about to happen, but they didn't know what. The early Chinese astronomers referred to comets as "vile stars."

A comet appeared shortly before Julius Caesar was assassinated in 59 B.C. Halley's Comet appeared in 1066 before the English king Harold Godwinson lost the Battle of Hastings to William the Conqueror. Two comets were seen over England in 1664 and 1665, and within months came the Great Plague of London, which killed almost 100,000 people over the next 2 years. Comets were routinely blamed for harmful natural events such as earthquakes, volcanic eruptions, and droughts. It wasn't until Edmond Halley, studying the paths of earlier comets as past astronomers recorded them, realized that some of the previous comets were actually the same comet returning again and again. Halley used his observations to predict that a comet that appeared in 1682 would return again in 1758. Halley's correct prediction helped demystify comets and show that they are not divine omens at all, but simply celestial objects that are subject to the same laws of physics as the Earth, moon, and planets.

The oldest science of them all has evolved over thousands of years to become the most technologically advanced science, but one thing has remained the same: astronomers continue to use observations of the sky to make predictions about the future. Astronomers have determined that our sun will eventually expand into a red giant before casting off its outer layers and ending its life as a white dwarf. They have predicted that our galaxy will one day collide with our larger neighbor Andromeda. Einstein's theories predicted the existence of black holes, gravitational waves, and wormholes. Black holes were confirmed in 1971 and gravitational waves were measured in 2015, but wormholes remain just a prediction—at least for now. The pace of discovery in astronomy is faster than ever before, and today hardly a week goes by without the announcement of some new discovery in astronomy.

There have been far too many advances in astronomy over the centuries to list them all here. In fact, the advances in astronomy that have been made in the past 5 years alone are more than enough to fill a book this size. This timeline includes the most important and sometimes most surprising discoveries in astronomy from its earliest days to the present. All of the B.C. dates in this timeline cannot be known for certain and are approximate.



8000 B.C. The Warren Field calendar in Scotland is built. This is a series of 12 pits dug into the ground that once probably held wooden posts. The pits correlate with phases of the moon, making this the oldest known astronomical calendar. It is believed that prehistoric hunter/gatherers used this calendar to predict the changing of the seasons and the migration times of different animal prey.

4900 B.C. The Goseck circle is built in Germany. The Goseck circle is a set of large concentric circles made of ditches and mounds in the ground, with two circular wooden fences. The outer fence that enclosed all the other circles had a diameter of 246 feet. The two gates in that fence aligned perfectly with sunrise and sunset on the winter solstice.

3000–1500 B.C. Stonehenge is a large circle of monoliths in southern England that was built and rebuilt over a period of about 15 centuries. Stonehenge as we know it today was finished around 1500 B.C. It is about 100 feet in diameter and is made up of massive rectangular blocks of stone—the largest is 30 feet tall and weighs 40 tons. The stones are aligned so that small gaps in the stones line up with the direction of sunrise on the summer solstice and sunset on the winter solstice.

2300 B.C. The Sumerians record the movements of the five planets visible to the naked eye and also name the 12 constellations of the zodiac.

2296 B.C. The first recorded observation of a comet by astronomers in China.

2137 B.C. First recorded solar eclipse, also by astronomers in China.

1500 B.C. The earliest known sundial is developed in Egypt. A sundial is a clock for telling the time of day based on the position of a shadow cast by the sun.

The ancient emperors of China based their calendars on the movements of the sun and moon, and also believed that the stars predicted the future, so they employed a large number of astronomers to keep detailed records of the night skies. As a result, many of the earliest astronomical observations available to us today were made thousands of years ago by Chinese astronomers.

2005 The Huygens lander from the Cassini–Huygens space probe lands on Saturn's moon Titan, becoming the first successful landing on an alien moon.

2006 Pluto is reclassified as a dwarf planet following the discovery of Eris in 2005.

Space probe Stardust, launched in 1999, successfully returns to Earth a capsule of dust and particles collected from the coma of Comet Wild 2.

Brian May, the guitar player for the rock band Queen, was a graduate student in astrophysics studying the motion of dust clouds in the solar system when his band suddenly became popular. He quit graduate school in 1974 and became an international rock star. In 2006, he returned to graduate school to finish his research, and completed his Ph.D. at Imperial College London in 2007. He was able to pick up where he left off because between 1974 and 2006 almost no other research was done in the subject he was studying.

2009 The Kepler space observatory is launched, designed specifically to search for exoplanets.

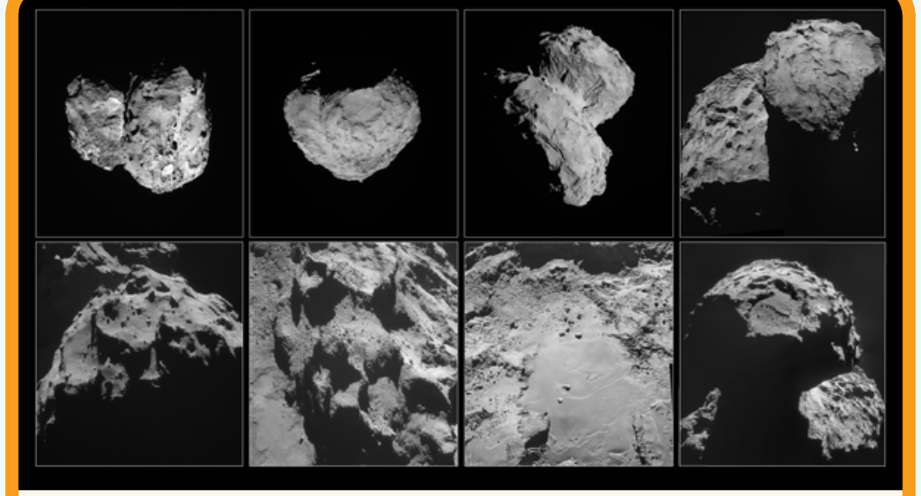
2011 *MESSENGER* becomes the first space probe to orbit the planet Mercury.

Dawn becomes the first space probe to orbit an asteroid, Vesta.

2012 Curiosity, the largest and most technologically advanced Mars rover, lands on Mars. Its mission includes looking for signs of life.

The Voyager 1 space probe, launched in 1977, leaves the solar system and transmits data from interstellar space.

2014 The European Space Agency's Rosetta space probe orbits a comet named 67P/Churyumov–Gerasimenko and sends back photos of the surface that show cliffs almost 500 feet high and boulders the size of houses. Rosetta sends down a lander called Philae, which successfully lands on the comet.



These images of comet 67P/Churyumov–Gerasimenko were taken by Rosetta between August and November 2014.

2015 The space probe New Horizons flies past Pluto, providing the first close-up images of Pluto.

The Mars Reconnaissance Orbiter provides evidence that liquid water flows intermittently on the surface of Mars.

Gravitational waves are first detected, resulting from a collision between two black holes 1.3 billion light-years away.

View of Pluto on July 14, 2015.

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