

Glossary

A

absorption the process in which light or other electromagnetic radiation gives up its energy to an atom or molecule. For example, ozone in our atmosphere absorbs ultraviolet radiation.

absorption-line spectrum a spectrum showing dark lines at some narrow color regions (wavelengths). The lines are formed by atoms absorbing light, which lifts their electrons to higher orbits.

acceleration a change in an object's velocity (either its speed or its direction).

accretion the addition of matter to a body. Examples are gas falling onto a star and asteroids colliding and sticking together.

accretion disk a nearly flat disk of gas or other material held in orbit around a body by its gravity.

achondrite a meteorite lacking chondrules, associated with larger bodies whose gravity and internal heating has caused them to differentiate.

active galaxy a galaxy whose central region emits abnormally large amounts of electromagnetic radiation from a small volume. Examples are radio galaxies, Seyfert galaxies, and quasars.

adaptive optics a technique for adjusting a telescope's mirror or other optical parts to compensate for atmospheric distortions, such as seeing, thereby giving a sharper image.

aether a substance at one time proposed to be the substance that made it possible for light waves to travel through otherwise empty space.

AGN active galactic nucleus. The core of an active galaxy.

alpha particle a helium nucleus: two protons plus (usually) two neutrons.

altitude an object's angular distance above the horizon.

amino acid a carbon-based molecule used by living organisms to build protein molecules.

angstrom unit a unit of length used in describing wavelengths of radiation and the sizes of atoms and molecules. One angstrom = 10^{-10} meters.

angular momentum a measure of an object's tendency to keep rotating and to maintain its orientation. Mathematically, it depends on the object's mass, M , radius, R , and rotational velocity, V , and is proportional to MVR .

angular size a measure of how large an object looks to you. It is defined as the angle between lines drawn from the observer to opposite sides of

an object. For example, the angular diameter of the Moon is about 0.5° .

annular eclipse an eclipse in which the body in front does not completely cover the other. In an annular eclipse of the Sun, a bright ring of the Sun's disk remains visible around the black disk of the Moon. We therefore see a ring (annulus) of light around the Moon.

anthropic principle the principle that the properties we observe the Universe to possess are limited to those that make our existence possible.

antimatter a type of matter that, if brought into contact with ordinary matter, annihilates it, leaving nothing but energy. The positron is the antimatter analog of the electron. The antiproton is the antimatter analog of the proton. Antimatter is observed in cosmic rays and can be created from energy in the laboratory.

aphelion the point in an orbit where a body is farthest from the Sun.

association a loose grouping of young stars and interstellar matter.

asterism an easily identified grouping of stars, often part of a larger constellation. For example, the Big Dipper.

asteroid a small, generally rocky, solid body orbiting the Sun and ranging in diameter from a few meters to hundreds of kilometers.

asteroid belt a region between the orbits of Mars and Jupiter in which most of the Solar System's asteroids are located.

astronomical unit (AU) a distance unit based on the average distance of the Earth from the Sun.

atmospheric window a wavelength band in which our atmosphere absorbs little radiation. For example, on Earth the visible window ranges from about 300 to 700 nanometers, allowing the light we can see with our eyes to pass through the atmosphere.

atom a submicroscopic particle consisting of a nucleus and orbiting electrons. The smallest unit of a chemical element.

aurora the light emitted by atoms and molecules in the upper atmosphere. This light is a result of magnetic disturbances caused by the solar wind. Often called the northern or southern lights.

autumnal equinox the autumn equinox in the Northern Hemisphere. Fall begins on the autumnal equinox, which is on or near September 22.

averted vision looking slightly to one side of a dim object so that you see it slightly away from the center of your field of view. This allows you to

see a faint object better, although at a sacrifice of sharpness.

azimuth a coordinate for locating objects on the sky. Azimuth is the angle measured eastward from due north to the point on the horizon below the object.

B

barred spiral galaxy a galaxy in which the spiral arms wind out from the ends of a central bar rather than from the nucleus.

belt a dark band in a Jovian planet's atmosphere, encircling the planet. Gas in the belts appears to be descending and warming.

Big Bang the event that, according to many astronomical theories, created the Universe. It occurred about 13.7 billion years ago and generated the expanding motion that we observe today.

binary stars two or more stars in orbit around each other, held together by their mutual gravity.

bipolar flow narrow columns of high-speed gas ejected by a protostar in two opposite directions.

blackbody an object that is an ideal radiator when hot and a perfect absorber when cool. It absorbs all radiation that falls upon it, reflecting no light; hence, it appears black. Stars are approximately blackbodies. The radiation emitted by blackbodies obeys Wien's law and the Stefan-Boltzmann law.

black hole an object whose gravitational attraction is so strong that its escape velocity equals the speed of light, preventing light or any radiation or material body from leaving its "surface."

BL Lac object a type of active galaxy named for the peculiar galaxy BL Lac. These objects generally are strong radio sources, and their visible light varies rapidly and erratically.

blueshift a shift in the wavelength of electromagnetic radiation to a shorter wavelength. For visible light, this implies a shift toward the blue end of the spectrum. The shift can be caused by the motion of a source of radiation toward the observer or by the motion of an observer toward the source. For example, the spectrum lines of a star moving toward the Earth exhibit a blueshift. *See also Doppler shift.*

Bode's rule a numerical expression for the approximate distances of most of the planets from the Sun.

Bok globule small, dark, interstellar cloud, often approximately spherical. Many globules are the early stages of protostars.

brown dwarf a star that has a mass too low for it to begin nuclear fusion.

bulge the dense, central region of a spiral galaxy.

C

carbonaceous chondrite a type of meteorite containing many tiny spheres (chondrules) of rocky or metallic material stuck together by carbon-rich material.

CCD charge-coupled device. An electronic device that records the intensity of light falling on it. CCDs have replaced film in most astronomical applications.

celestial equator an imaginary line on the celestial sphere lying exactly above the Earth's equator. It divides the celestial sphere into northern and southern hemispheres.

celestial pole an imaginary point on the celestial sphere directly above the Earth's North or South Pole.

celestial sphere an imaginary sphere surrounding the Earth representing the sky. Ancient astronomers pictured celestial objects as attached to it.

Cepheid a class of yellow-giant pulsating stars. Their pulsation periods range from about 1 day to about 70 days. Cepheids can be used to determine distances. *See also* **standard candle**.

Chandrasekhar limit the maximum mass of a white dwarf above which it collapses. Approximately 1.4 solar masses. Named for the astronomer who first calculated that such a limit exists.

chondrite a meteorite containing small spherical grains called chondrules.

chondrule a small spherical grain embedded in a meteorite.

chromosphere the lower part of the Sun's outer atmosphere that lies directly above the Sun's visible surface (photosphere).

cluster a group of objects (stars, galaxies, and so forth) held together by their mutual gravitational attraction.

CNO cycle/process a reaction involving carbon, nitrogen, and oxygen (C, N, and O) that fuses hydrogen into helium and releases energy. The process begins with a hydrogen nucleus fusing with a carbon nucleus. Subsequent steps involve nitrogen and oxygen. The carbon, nitrogen, and oxygen act as catalysts and are released at the end of the process to start the cycle again. The CNO cycle is the dominant process for generating energy in main-sequence stars that are hotter and more massive than the Sun.

coma the gaseous atmosphere surrounding the head of a comet.

comet a small body in orbit around the Sun, consisting of a tiny, icy core and a tail of gas and dust. The tail forms only when the comet is near the Sun.

compact stars very dense stellar remnants or "dead" stars whose radii are much smaller than the Sun's. These stars include white dwarfs, neutron stars, and black holes.

condensation conversion of free gas atoms or molecules into a liquid or solid. A snowflake forms in our atmosphere when water vapor condenses into ice.

conjunction the appearance of two astronomical objects in approximately the same direction on the sky. For example, if Mars and Jupiter happen to appear near each other on the sky, they are said to be in conjunction. *Superior conjunction* refers to a planet that is approximately in line with the Sun but on the far side of the Sun from the Earth. *Inferior conjunction* refers to a planet that lies approximately between the Sun and the Earth.

conservation of angular momentum a principle of physics stating that the angular momentum of a rotating body remains constant unless forces act to speed it up or slow it down. Mathematically, conservation of angular momentum states that MVR is a constant, where M is the mass of a body moving with a velocity, V , in a circle of radius, R . One extremely important consequence of this principle is that if a rotating body shrinks, its rotational velocity must increase.

conservation of energy a principle of physics stating that energy is never created or destroyed, although it may change its form. For example, energy of motion may change into energy of heat.

constellation a grouping of stars in the night sky. Astronomers divide the sky into 88 constellations.

continuous spectrum a spectrum with neither dark absorption nor bright emission lines. The intensity of the radiation in such a spectrum changes smoothly from one wavelength to the next.

convection the rising and sinking motions in a liquid or gas that carry heat upward through the material. Convection is easily seen in a pan of heated soup on a stove.

convection zone the region immediately below the Sun's visible surface in which its heat is carried by convection.

Coriolis effect a deflection of a moving object caused by its motion across the surface of a rotating body. The Coriolis effect makes storms on Earth spin, generates large-scale wind systems, and creates cloud belts on many of the planets.

corona the outer, hottest part of the Sun's atmosphere.

coronal hole a low-density region in the Sun's corona. The solar wind may originate in these regions.

cosmic horizon the maximum distance one can see out into the Universe at a given time. The horizon lies at a distance in light-years approximately equal to the age of the Universe in years.

cosmic microwave background (CMB) radiation from the young Universe that began traveling through space after hot gas from the Big Bang expanded and cooled enough to become transparent. The radiation is visible in all directions and appears to have a temperature of only 2.73 K because of the redshift caused by the expansion of the Universe.

cosmic rays extremely energetic particles (protons, electrons, and so forth) traveling at nearly the speed of light. Some rays are emitted by the Sun, but most come from more-distant sources, perhaps exploding supernovas.

cosmological constant a term in the equations that Einstein developed to describe the expansion of the Universe. The cosmological constant has the effect of a repulsive "force" opposing gravity. *See also* **dark energy**.

cosmological principle the hypothesis that, on average, the Universe looks the same to every observer, no matter where he or she is located in it.

cosmology the study of the structure and evolution of the Universe.

crater a circular pit, generally with a raised rim and sometimes with a central peak. Crater diameters on the Moon range from centimeters to several hundred kilometers. Most craters on bodies such as the Moon are formed by the impact of solid bodies, such as asteroids.

critical density the minimum overall density of the Universe needed to provide enough gravity to make it eventually stop expanding and collapse. If the density is less than or equal to the critical density, the Universe will expand forever.

crust the rigid surface of a planet, moon, or other solid body.

curvature of space the bending of space by a mass, as described according to Einstein's general theory of relativity. Black holes bend the space around them, curving it so that the region within the black hole is cut off from the rest of the Universe. The Universe too may be curved in such a way as to make its volume finite.

curvature of the Universe the overall curvature of space in the Universe produced by a combination of all its matter and energy. The Universe appears to be very close to the critical density, at which there is no overall curvature, a condition astronomers describe as a "flat" Universe.

D

dark adaption the process by which the eye changes to become more sensitive to dim light.

dark energy a form of energy (or a cosmological constant) detected by its effect on the expansion of the Universe. It causes the expansion to speed up. The nature and properties of dark energy are unknown.

dark matter matter that emits no detectable radiation but whose presence can be deduced by its gravitational attraction on other bodies.

dark nebula a dense cloud of dust and gas in interstellar space that blocks the light from background stars.

daughter atoms the atoms produced by the decay of a radioactive element. For example, uranium decays into lead. These lead atoms are daughter atoms.

daylight saving time the time kept during summer months by setting the clock ahead one hour. This gives more hours of daylight after the workday.

declination one part of a coordinate system for locating objects in the sky north or south of the celestial equator. Declination is analogous to latitude on the Earth's surface.

degeneracy pressure the pressure created in a dense gas by the interaction of its electrons. Degeneracy pressure does not depend on temperature.

degenerate gas an extremely dense gas in which the electrons and nuclei are tightly packed. The pressure of a degenerate gas does not depend on its temperature.

density the mass of a body or region divided by its volume.

density-wave model a theory to account for the spiral arms of galaxies. According to the theory, waves of higher density traveling through the disk of a galaxy pull stars and interstellar gas into a spiral pattern.

deuterium a form of hydrogen in which the nucleus contains a neutron in addition to a proton. Sometimes called "heavy hydrogen."

differential gravitational force the difference between the gravitational forces exerted on an object at two different points. The effect of this force is to stretch the object. Such forces create tides and, if strong enough, may break up an astronomical object. *See also* **Roche limit**.

differentiation the separation of previously mixed materials inside a planet or other object. This is the same separation that occurs when a dense material, such as iron, settles to the planet's

core while low-density material floats to the surface.

diffraction a bending of the path of light (or other electromagnetic waves) as it passes through an opening or around an obstacle. Diffraction limits the ability to distinguish fine details in images.

disk the flat, round portion of a galaxy. The Sun lies in the disk of the Milky Way.

dispersion the spreading of light or other electromagnetic radiation into a spectrum. A rainbow is an example of dispersion of light caused by raindrops.

DNA deoxyribonucleic acid. The complex molecule that encodes genetic information in all organisms here on Earth.

Doppler shift the change in the observed wavelength of radiation caused by the motion of the emitting body or the observer. The shift is an increase in the wavelength if the source and observer move apart and a decrease in the wavelength if the source and observer approach. *See also* **redshift** and **blueshift**.

Drake equation a formula, named after the astronomer who proposed it, used to estimate the number of civilizations that might be present in the Milky Way that are capable of communicating with us.

dust tail a comet tail containing dust that reflects sunlight. The dust in a comet tail is expelled from the nucleus of the comet.

dwarf a small, dim star.

dwarf planet an object that orbits the Sun and is massive enough that its gravity compresses it into an approximately spherical shape. However, it has not swept its orbital region clear of other objects of comparable mass.

dynamo model a proposed physical process for generating magnetic fields in astronomical bodies. The process involves the generation of electric currents from an interaction between rotation and convection in an electrically conductive liquid.

E

eclipse the blockage of light from one astronomical body caused by the passage of another between it and the observer. The shadow of one astronomical body falling on another. For example, the passage of the Moon between the Earth and Sun can block the Sun's light and cause a solar eclipse.

eclipse seasons the times of year, separated by about 6 months, when eclipses are possible. At any given eclipse season, both a solar eclipse and a lunar eclipse generally occur.

eclipsing binary a binary star pair in which one star periodically passes in front of the other, totally

or partially blocking the background star from view as seen from Earth.

ecliptic the path that the Sun appears to make around the celestial sphere as the Earth moves along its orbit. The path gets its name because eclipses can occur only when the Moon crosses the ecliptic.

electric charge the electrical property of objects that causes them to attract or repel one another. A charge may be either positive or negative.

electric force the force generated by electric charges. It is attractive between unlike charges (+−) but repulsive between like charges (++ or --).

electromagnetic force the force arising between electrically charged particles or between charges and magnetic fields. Forces between magnets are a special case of this force. This force holds electrons to the nucleus of atoms, makes moving charges spiral around magnetic field lines, and deflects a compass needle.

electromagnetic radiation a general term for any kind of electromagnetic wave.

electromagnetic spectrum the assemblage of all wavelengths of electromagnetic radiation. The spectrum includes the following wavelengths, from long to short: radio, microwave, infrared, visible light, ultraviolet, X rays, and gamma rays.

electromagnetic wave a wave consisting of alternating electric and magnetic energy. Ordinary visible light is an electromagnetic wave, and the wavelength determines the light's color.

electron a low-mass, negatively charged subatomic particle. Electrons orbit the atomic nucleus but may at times be torn free. *See also* **ionization**.

element a fundamental substance, such as hydrogen, carbon, or oxygen, that cannot be broken down into a simpler chemical substance. Approximately 100 elements occur in nature.

ellipse a geometric figure related to a circle but flattened into an oval shape.

elliptical galaxy a galaxy in which the stars smoothly fill an ellipsoidal volume. Abbreviated E galaxy. The stars in such systems are generally old (Pop II).

emission the production of light, or more generally, electromagnetic radiation by an atom or other object.

emission-line spectrum a spectrum consisting of bright lines at certain wavelengths separated by dark regions in which there is no light.

emission nebula a hot gas cloud in interstellar space that emits light.

energy a measure of the ability of a system to do work or cause motion.

energy level any of the numerous orbitals that an electron can occupy in an atom or molecule, roughly corresponding to an electron orbit.

epicycle a fictitious, small, and circular orbit superimposed on another circular orbit and proposed by early astronomers to explain the retrograde motion of the planets.

equator the imaginary line that divides the Earth (or other body) symmetrically into its northern and southern hemispheres. The equator is perpendicular to a body's rotation axis.

equinox the time of year when the Sun appears to cross the celestial equator. At this time, the number of hours of daylight and night are approximately equal. The vernal and autumnal equinoxes mark the beginning of the spring and fall seasons.

escape velocity the speed needed for an object to travel away from another body to overcome its gravitational attraction and not be pulled back. Mathematically, the escape velocity, V_{esc} , is defined as $\sqrt{2GM/R}$ where M is the body's mass, R is its radius, and G is the gravitational constant.

eukaryotes cells with nuclei. Most cells in current terrestrial organisms have nuclei and are thus eukaryotes.

Evening Star the planet Venus seen low in the western sky after sunset. (Sometimes used for other bright planets.)

event horizon the location of the "boundary" of a black hole. An outside observer cannot see in past the event horizon.

excited the condition in which the electrons of an atom are not in their lowest energy level (orbit).

exclusion principle the condition that no more than two electrons may occupy the same energy state in an atom. This limitation leads to degeneracy pressure.

exoplanet a planet not orbiting our Sun.

F

false-color picture/photograph a depiction of an astronomical object in which the colors are not the object's real colors. Instead, they are colors arbitrarily chosen to represent other properties of the body, such as the intensity of radiation, that we cannot see.

Fermi paradox an argument that we are probably the only technological civilization that has ever arisen in the Milky Way. Fermi suggested that if any such civilization had existed, it would have covered the whole Galaxy in a time much shorter than the evolution of humans.

fission the splitting of an atomic nucleus into two or more smaller nuclei.

flare an outburst of energy on the Sun. *See also solar flare.*

flat universe a universe that extends forever with no curvature. Its total energy is zero.

fluorescence the conversion of ultraviolet light (or other short-wavelength radiation) into visible light.

focus (1) one of two points within an ellipse used to generate the elliptical shape. Planets orbit along ellipses with the Sun at one focus of the ellipse. (2) a point in an optical system in which light rays are brought together. The location where an image forms in such systems.

frequency the number of times per second that a wave vibrates.

fundamental forces the four basic forces of nature: gravitation, electromagnetism, the weak force, and the strong force. Electromagnetism and the weak force are now recognized to both be part of an "electroweak" force. According to some modern theories, all of the forces are different forms of a single, more fundamental, unified force.

G

Gaia hypothesis the hypothesis that life does not merely respond to its environment but actually alters its planet's atmosphere and temperature to make the planet more hospitable. For example, by photosynthesis, plants have created an oxygen-rich atmosphere on Earth, which shields the plants from dangerous ultraviolet radiation.

galactic cannibalism the capture and merging of one galaxy into another.

galaxy a massive system of stars held together by their mutual gravity. Typical galaxies have a mass between about 10^7 and 10^{13} solar masses. Our Galaxy is the Milky Way.

galaxy cluster a group of galaxies held together by their mutual gravitational attraction. The Milky Way belongs to the Local Group galaxy cluster.

Galilean relativity a method for determining the relative speeds of motion seen by observers moving with respect to each other. This method works satisfactorily for motions at low speed, but it fails when the speed becomes an appreciable fraction of the speed of light.

Galilean satellites the four moons of Jupiter discovered by Galileo: Io, Europa, Ganymede, and Callisto.

gas giant a planet that grew largely by gravitationally attracting gas from the disk of gas out of which a planetary system forms. Jupiter and Saturn are thought to be gas giants.

general relativity Einstein's theory of gravity. The theory describes how mass and energy "curve" space and time so that objects move along the paths described by the gravitational "force."

geocentric models models of the Solar System centered on the Earth. Many of the earliest attempts to describe the Solar System were geocentric in that they supposed that the planets moved around the Earth rather than around the Sun.

giant a star of large radius and large luminosity.

glitches abrupt changes in the pulsation period of a pulsar, perhaps as the result of adjustments of its crust.

global warming a phenomenon in which the Earth's surface temperature has been observed to increase significantly over the last century. Most scientists attribute the change to increasing levels of gases that cause the greenhouse effect, released by human activities such as burning fossil fuels and deforestation.

globular cluster a dense grouping of old stars, containing generally about 10^5 to 10^6 members. They are often found in the halos of galaxies.

globule *See Bok globule.*

granulation texture seen in the Sun's photosphere. Granulation is created by clumps of hot gas that rise to the Sun's surface.

grating a piece of material that creates a spectrum by reflecting light from, or passing it through, many very fine and closely spaced parallel lines.

gravitational lens an object that bends space (and thereby the light passing through the space) by its gravitational attraction and focuses the light to create an image of a more distant object. *See also curvature of space.*

gravitational lensing the bending of light from a distant object to form an image, usually strongly distorted by the gravitation of a mass between the distant object and the observer. *See gravitational lens.*

gravitational redshift the shift in wavelength of electromagnetic radiation (light) created by a body's gravitational field as the radiation moves away from the body. Only extremely dense objects, such as white dwarfs, produce a significant redshift of their radiation.

gravitational waves a wavelike bending of space generated by the acceleration of massive bodies.

gravity the force of attraction that is between two bodies and is generated by their masses.

greatest elongation the position of an inner planet (Mercury or Venus) when it lies farthest from the Sun on the sky. Mercury and Venus are

particularly easy to see when they are at greatest elongation. Objects may be at greatest eastern or western elongation according to whether they lie east or west of the Sun.

greenhouse effect the trapping of heat by a planet's atmosphere, making the planet warmer than would otherwise be expected. Generally the greenhouse effect operates if visible sunlight passes freely through a planet's atmosphere but the infrared radiation produced by the warm surface cannot escape readily into space, because of gases such as carbon dioxide or water vapor.

Great Red Spot a reddish colored region in Jupiter's atmosphere, larger than the Earth. It appears to be a stable atmospheric vortex, having been seen since some of the earliest telescopic observations in the 1600s.

Gregorian calendar the calendar devised at the request of Pope Gregory XIII and essentially the civil calendar used throughout the world today. It omits the leap year for century years not divisible evenly by 400.

H

H II region a region of ionized hydrogen. H II regions generally have a pink/red glow and often surround luminous, hot, young stars.

halo the approximately spherical region surrounding spiral galaxies that contains mainly old stars, such as the globular clusters. The halo also contains large amounts of dark matter.

Hawking radiation radiation that black holes are hypothesized to emit as a result of quantum effects. This radiation leads to the extremely slow evaporation of black holes.

heliocentric models models of the Solar System centered on the Sun. Compare to **geocentric models**.

helium flash the beginning of helium fusion in a low-mass star. The fusion begins explosively and causes a major readjustment of the star's structure.

highlands the old, heavily cratered regions on the Moon.

horizon the line separating the sky from the ground. *See also* **cosmic horizon**.

H-R diagram a graph on which stars are located according to their temperature and luminosity. Most stars on such a plot lie along a diagonal line, called the main sequence, which runs from cool, dim stars in the lower right, to hot, luminous stars in the upper left.

Hubble constant the multiplying constant H in Hubble's law, $V = Hd$. The reciprocal of the Hubble constant (in appropriate units) is approximately the age of the Universe.

Hubble's law a relation between a galaxy's distance, d , and its recession velocity, V , which states that more distant galaxies recede faster than nearby ones. Mathematically, $V = Hd$, where H is the Hubble constant.

hydrogen burning nuclear fusion of hydrogen into helium. It is not "burning" like ordinary fire but is instead the transformation of one kind of atom into another accompanied by the release of energy.

hydrostatic equilibrium the condition in which pressure and gravitational forces in a star or planet are in balance. Without such balance, bodies will either collapse or expand.

hypothesis an explanation proposed to account for some set of observations or facts.

I

ice giant a large, gas-rich planet that grew primarily through the accretion of ice-rich planetesimals. Uranus and Neptune are thought to be ice giants.

ideal gas law *See* **perfect gas law**.

inclination the tilt angle of an astronomical object's spin or its orbit.

inertia the tendency of an object at rest to remain at rest and of a body in motion to continue in motion in a straight line at a constant speed. *See also* **mass**.

inferior conjunction *See* **conjunction**.

inferior planet a planet whose orbit lies between the Earth's orbit and the Sun. Mercury and Venus are inferior planets.

inflation the rapid expansion of the early Universe by an enormous factor.

infrared a wavelength of electromagnetic radiation longer than visible light but shorter than radio waves. We cannot see these wavelengths with our eyes, but we can feel many of them as heat. The infrared wavelength region runs from about 700 nm to 1 mm.

inner core the innermost part of a planet, also called the *solid core*. The Earth's inner core is a mixture of solid iron and nickel.

inner planet a planet orbiting in the inner part of the Solar System. Sometimes taken to mean Mercury, Venus, Earth, and Mars.

instability strip a region in the H-R diagram indicating stars that pulsate.

interferometer a device consisting of two or more telescopes connected together to work as a single instrument. Used to obtain a high resolving power, the ability to see small-scale features. Interferometer telescopes have been constructed operating at radio, infrared, and visible wavelengths.

international date line an imaginary line from the Earth's North to South Pole, running approximately down the middle of the Pacific Ocean. It marks the location on Earth at which the date changes.

interstellar cloud a cloud of gas and dust in between the stars. Such clouds may be many light-years in diameter.

interstellar grains microscopic solid dust particles in interstellar space. These grains absorb starlight, making distant stars appear dimmer and redder than they truly are.

interstellar matter matter in the form of gas or dust in the space between stars.

inverse-square law (1) any law in which some property varies inversely as the square of the distance, d . Mathematically, as $1/d^2$. (2) the law stating that the apparent brightness of a body decreases inversely as the square of its distance.

ion tail a stream of ionized particles evaporated from a comet and then swept away from the Sun by the solar wind.

ionization the removal of one or more electrons from an atom, leaving the atom with a positive electric charge. Under some circumstances an extra electron may be attached to an atom, in which case the atom is described as negatively ionized.

ionized a condition in which the number of an atom's electrons does not equal the number of its protons. Typically, this means the atom is missing one or more electrons.

irregular galaxy a galaxy lacking a symmetric structure.

J

jets narrow streams of gas ejected from any of several types of astronomical objects. Jets are seen near protostars and in many active galaxies.

jet stream a narrow stream of high-speed wind that blows in the atmosphere of a planet. Such winds occur on Earth and many other planets.

joule a unit of energy. Expending one joule per second equals one watt of power.

Jovian planet one of the giant, gaseous planets: Jupiter, Saturn, Uranus, and Neptune, or most exoplanets. The name *Jovian* was chosen because the structure of Jupiter (or Jove) is representative of the others.

Julian calendar a 12-month calendar devised under the direction of Julius Caesar. It includes a leap year every four years.

K

Kepler's three laws laws that describe the motion of planets around the Sun. The first law states that planets move in elliptical orbits with the Sun off-center at a focus of the ellipse. The second law states that a line joining the planet and the Sun sweeps out equal areas in equal times. The third law relates a planet's orbital period, P , to the semi-major axis of its elliptical orbit, a . Mathematically, the law states that $P^2 = a^3$, if P is measured in years and a in astronomical units.

Kirkwood gaps regions in the asteroid belt with fewer than the average number of asteroids. The gaps result from the gravitational force of Jupiter removing asteroids whose orbits have periods that are a simple fraction of Jupiter's period.

Kuiper belt a region from which some comets come. The region appears to extend from the orbit of Neptune, past Pluto, out to approximately 55 AU.

L

late heavy bombardment a period about 600 million years after the Solar System formed when there appears to have been a high level of impact cratering events.

law of gravity a description of the gravitational force exerted by one body on another. The gravitational force is proportional to the product of the bodies' masses and the inverse square of their separation. If the masses are M and m and their separation is d , the force between them, F , is $F = G M m / d^2$, where G is a physical constant.

light electromagnetic energy.

light-gathering power a measure of the ability of a telescope (or other device) to collect light. It is generally proportional to the *area* of the telescope's mirror or lens. For example, a telescope with a 6-inch diameter lens has a four times larger light-gathering power than a telescope with a 3-inch diameter lens.

light-year a unit of distance equal to the distance light travels in one year. A light-year is roughly 10^{13} km, or about 6 trillion miles.

liquid core the molten interior of a planet, also called the *outer core*.

Local Group the small cluster or group of several dozen galaxies to which the Milky Way belongs.

Lorentz factor a term that designates how much an object's time, space, and mass are altered as a result of its motion. The factor is very close to 1 except at speeds approaching the speed of light.

luminosity the amount of energy radiated per second by a body. For example, the wattage of a lightbulb defines its luminosity. Stellar luminosity

is usually measured in units of the Sun's luminosity (approximately 4×10^{26} watts).

lunar eclipse the passage of the Earth between the Sun and the Moon so that the Earth's shadow falls on the Moon.

M

MACHO (massive compact halo object) any body of planetary or stellar mass orbiting in the Milky Way's halo that produces very little detectable light. These objects have been hypothesized to be a significant part of the Milky Way's dark matter.

Magellanic Clouds two small companion galaxies of the Milky Way.

magnetic field a representation of the means by which magnetic forces are transmitted from one body to another. A compass needle points along the direction of the Earth's magnetic field.

magnetic lines of force fictitious lines used to visualize the orientation and strength of a magnetic field.

magnitude a unit for measuring stellar brightness. The smaller the magnitude, the brighter the star.

main sequence the region in the H-R diagram in which most stars, including the Sun, are located. The main sequence runs diagonally across the H-R diagram from cool, dim stars to hot, luminous ones. Stars on the main sequence fuse hydrogen into helium in their cores. *See also* **H-R diagram**.

main-sequence lifetime the time a star remains a main-sequence star, fusing hydrogen into helium in its core.

mantle the solid, outer part of a planet. This part is immediately below the crust and may flow very slowly due to heat rising from the core.

mare a vast, smooth, dark, and congealed lava flow filling a basin on the Moon and on some planets. Many maria have roughly circular shapes.

maria plural of *mare*.

maser an intense radio source created when excited gas amplifies some background radiation. *Maser* stands for *microwave amplification by stimulated emission of radiation*.

mass a measure of the amount of material an object contains. A quantity measuring a body's inertia.

mass-luminosity relation a relation between the mass and luminosity of main-sequence stars. Higher-mass stars have higher luminosity.

Maunder minimum the time period, from about A.D. 1600 to 1740, during which the Sun was relatively inactive. Few sunspots were observed during this period.

mean solar day the standard 24-hour day. The mean solar day is based on the average day length over a year. (The time interval from solar noon to solar noon varies slightly throughout the year.)

megaparsec a distance unit equal to 1 million parsecs and abbreviated Mpc.

metal astronomically, any chemical element more massive than helium. Thus, carbon, oxygen, iron, and so forth are called metals.

meteor the bright trail of light created by small solid particles entering the Earth's atmosphere and burning up. A "shooting star."

meteor shower an event in which many meteors occur in a short space of time, all from the same general direction in the sky. The most famous shower is the Perseids in mid-August.

meteorite the solid remains of a meteor that falls to the Earth.

meteoroid the technical name for the small, solid bodies moving within the Solar System. When a meteoroid enters our atmosphere and heats up, the trail of luminous gas it leaves is called a meteor. When the body lands on the ground, it is called a meteorite. ("A meteoroid is in the void. A meteor above you soars. A meteorite is in your sight.")

method of standard candles *See* **standard candle**.

Milky Way Galaxy the Galaxy to which the Sun belongs. Seen from Earth, the Galaxy is a pale, milky-white band in the night sky.

Miller-Urey experiment an experimental attempt to simulate the conditions under which life might have developed on Earth. Miller and Urey discovered that amino acids and other complex organic compounds could form from the gases that are thought to have been present in the Earth's early atmosphere, if the gases are subjected to an electric spark or ultraviolet radiation.

millisecond pulsar a pulsar whose rotation period is about a millisecond.

minute of arc a measure of angle equal to one-sixtieth of a degree.

model a theoretical representation of some object or system.

molecule two or more atoms bonded into a single particle, such as water, H_2O (two hydrogen atoms bonded to one oxygen) or carbon dioxide, CO_2 (one carbon atom bonded to two oxygen atoms).

Moon illusion the illusion in which the Moon appears larger when near the horizon than when seen high in the sky.

Morning Star the planet Venus seen in the eastern sky before dawn. (Sometimes applied to other bright planets.)

N

nanometer a unit of length equal to 1 billionth of a meter (10^{-9} meters) and abbreviated nm. Wavelengths of visible light are several hundred nanometers. The diameter of a hydrogen atom is roughly 0.1 nm.

neap tide the abnormally small tide occurring when the Sun's and Moon's gravitational effects on the ocean partially offset each other.

near-Earth object an asteroid with an orbit that crosses Earth's orbit or comes close to it.

nebula a cloud in interstellar space.

negative curvature a form of curved space sometimes described as being "open" in that it has no boundary. Negative curvature is analogous to a saddle shape.

neutrinos tiny neutral particles with little or no mass and immense penetrating power. These particles are produced in great numbers by the Sun and other stars as they fuse hydrogen into helium, and also by supernova explosions.

neutron a subatomic particle of nearly the same mass as the proton but with no electric charge. Neutrons and protons compose the nuclei of atoms.

neutron star a very dense, compact star composed primarily of neutrons.

Newton's first law of motion the law that a body continues in a state of rest or uniform motion in a straight line unless made to change that state by forces acting on it. *See also inertia.*

Newton's second law of motion $F = ma$. In words, the amount of acceleration, a , that a force, F , produces depends on the mass, m , of the object being accelerated.

Newton's third law of motion the law that when two bodies interact, they exert equal and opposite forces on each other.

nonthermal radiation radiation emitted by charged particles moving at high speed in a magnetic field. The radio emission from pulsars and radio galaxies is nonthermal emission. More generally, nonthermal means "not due to high temperature."

north celestial pole the point on the celestial sphere directly above the Earth's North Pole. Objects on the sky appear to circle around this point.

North Star any star that happens to lie very close to the north celestial pole. Polaris has been the North Star for about 1000 years, and it will continue as such for about another 1000 years, at which time a star in Cepheus will be nearer the north celestial pole.

nova a process in which a surface layer of hydrogen builds up on a white dwarf and then fuses explosively into helium, making the white dwarf visible for a few weeks. Nova explosions do not destroy the white dwarf and may be recurrent.

nuclear fusion the binding of two light nuclei to form a heavier nucleus, with some nuclear mass converted to energy. For example, the fusion of hydrogen into helium. This process supplies the energy of most stars and is commonly called "burning" by astronomers.

nucleosynthesis the formation of elements, generally by the fusion of lighter elements into heavier ones. For example, the formation of carbon by the fusion of three helium nuclei.

nucleus the core of an atom around which the electrons orbit. The nucleus has a positive electric charge and constitutes most of an atom's mass.

nucleus of a comet the core, typically a few kilometers across, of frozen gases and dust that make up the solid part of a comet.

nucleus of a galaxy the central region of a galaxy, often containing a supermassive black hole.

O

Olbers' paradox an argument that in an infinite Universe, the sky should be bright at night, filled with the light from many distant stars and galaxies.

Oort cloud a vast region in which comet nuclei orbit. This cloud lies far beyond the orbit of Neptune.

opacity the blockage of light or other electromagnetic radiation by matter.

open cluster a loose cluster of stars, generally containing a few hundred members.

opposition the configuration of a planet when it is opposite the Sun in the sky. If a planet is in opposition, it rises when the Sun sets and sets when the Sun rises.

orbit the path in space followed by a celestial body.

orbital a description of an electron's possible location in an atom as it "orbits" the nucleus. At these tiny scales, the electron's position can be described only in terms of probabilities, due to the wave nature of matter.

outer core the molten interior of a planet; also called the *liquid core*.

outer planet a planet whose orbit lies in the outer part of the Solar System. Jupiter, Saturn, Uranus, and Neptune are outer planets.

ozone a form of oxygen consisting of three oxygen atoms bonded together. Its chemical symbol is O_3 . The ozone in our atmosphere absorbs, and

thus shields us from, the Sun's harmful ultraviolet radiation.

P

panspermia a theory that life originated elsewhere than on Earth and came here across interstellar space either accidentally or deliberately.

parallax the shift in an object's position caused by the observer's motion. A method for finding distances based on that shift.

parsec a unit of distance equal to about 3.26 light-years (3.09×10^{13} km), defined as the distance at which an observer sees the maximum angle between the Sun and the Earth to be one arc second.

perfect gas law a law relating the pressure, density, and temperature of a gas. It states that the pressure is proportional to the density times the temperature. This is also called the *ideal gas law*.

perihelion the point in an orbit closest to the Sun.

period the time required for a repetitive process to repeat. For example, orbital period is the time it takes a planet or star to complete an orbit. Pulsation period is the time it takes a star to expand and then contract back to its original radius.

period-luminosity relation a law stating that the longer the period of a pulsating variable star, the more luminous it is.

phases the changing illumination of the Moon or other body that causes the body's apparent shape to change. The following is the cycle of lunar phases: new, crescent, first quarter, gibbous, full, gibbous, third quarter, crescent, new.

photo dissociation the breaking apart of a molecule by intense radiation.

photon a particle of visible light or other electromagnetic radiation.

photosphere the visible surface of the Sun. When we look at the Sun in the sky, we are seeing its photosphere.

Planck time the brief interval of time, about 10^{-43} second immediately after the Big Bang, when quantum fluctuations are so large that current theories of gravity can no longer describe space and time.

planet a body in orbit around a star that is large enough to have taken on a round shape, and that has cleared the path of its orbit of all bodies of comparable size.

planetary nebula a shell of gas ejected by a low-mass star late in its evolutionary lifetime. A planetary nebula typically appears as a glowing gas ring around a central white dwarf.

planetesimal one of the numerous small, solid bodies that, when accreted together, form a planet.

plate tectonics the idea that the crust of the Earth (or some other planet) is divided into large regions (plates) that move very slowly over the planet's surface. Interaction between plates at their boundaries creates mountains and activity such as earthquakes.

polarity the property of a magnet that causes it to have a north and south pole.

population (Pop) I the younger stars, some of which are blue, that populate a galaxy's disk, especially its spiral arms.

population (Pop) II the older, redder stars that populate a galaxy's halo and bulge.

population (Pop) III a hypothetical stellar population consisting of the first stars that formed in a galaxy, composed of only hydrogen and helium.

positive curvature bending of space leading to a finite volume. A space that is "closed." A universe with positive curvature is analogous to a spherical shape.

positron a subatomic antimatter particle with the same mass as the electron but a positive electric charge. An electron's antiparticle.

precession the slow change in direction of the pole (rotation axis) of a spinning body or of the orientation of an orbit.

pressure the force exerted by a substance such as a gas on an area divided by that area. That is, pressure \times area = force.

principle of equivalence an idea developed by Einstein to understand that gravity is equivalent to an accelerating frame of reference.

prokaryotes cells without nuclei. The first lifeforms on Earth were prokaryotes.

prominence a cloud of hot gas in the Sun's outer atmosphere. This cloud is often shaped like an arch, supported by the Sun's magnetic field.

proper motion shift of a star's position on the celestial sphere, in other words, motion perpendicular to our line of sight. This motion is normally so gradual that thousands of years must pass before changes become noticeable to the unaided eye.

protein any of many complex organic molecules composed of a chain of amino acids. Proteins serve many functions in cells, including structure and metabolism.

proton a positively charged subatomic particle. One of the constituents of the nucleus of an atom along with neutrons.

proton-proton chain the nuclear fusion process that converts hydrogen into helium in stars like the

Sun and thereby generates their energy. This is the dominant energy-generation mechanism in cool, low-mass stars.

protoplanetary disk a disk of gas and dust surrounding a young star out of which planetary systems form.

protostar a star still in its formation stage, heated by gravitational contraction.

pulsar a spinning neutron star that emits beams of radiation that happen to sweep across the Earth each time the star spins. We observe the radiation as regularly spaced pulses.

pulsate to expand and contract regularly. For example, pulsating variable stars swell and shrink in a predictable, regular fashion.

Q

quantized the property of a system that allows it to have only discrete values.

quark a fundamental particle of matter that interacts via the strong force; basic constituent of protons and neutrons.

quasar a peculiar galaxy characterized by a large redshift, high luminosity, and an extremely small, active core. Quasars are among the most luminous and most distant objects known to astronomers.

R

radial velocity the velocity of a body along the line of sight. That is, the part of its motion directly toward or away from the observer.

radiant the point in the sky from which meteors in showers appear to come. *See also meteor showers.*

radiation pressure the force exerted by radiation on matter.

radiative zone the region inside a star where its energy is carried outward by radiation (that is, by photons).

radioactive decay the breakdown of an atomic nucleus by the emission of subatomic particles.

radioactive element an element that undergoes radioactive decay and breaks down into a lighter element.

radio galaxy a galaxy, usually an elliptical, that emits abnormally large amounts of radio energy from huge lobes of hot gas ejected from the galaxy.

rays long, narrow, light-colored markings on the Moon or other bodies that radiate from young craters. Rays are debris "splashed" out of the crater by the impact that formed it.

recession velocity the velocity of an external galaxy (or other object) away from our Galaxy due to the expansion of the Universe.

recombination era a period of time about 400,000 years after the Big Bang when matter cooled enough for electrons to combine with nuclei to form neutral atoms.

reddening the alteration in a star's color as seen from Earth as the star's light passes through an intervening interstellar dust cloud. The dust preferentially scatters the blue light from the beam, leaving the remaining light redder.

red giant a cool, luminous star whose radius is much larger than the Sun's.

redshift a shift in the wavelength of electromagnetic radiation to a longer wavelength. For visible light, this implies a shift toward the red end of the spectrum. The shift can be caused by a source of radiation moving away from the observer or by the observer moving away from the source. For example, if a star is moving away from Earth, its spectrum lines exhibit a redshift. *See also Doppler shift.*

reflection nebula an interstellar cloud in which the dust particles reflect starlight, making the cloud visible.

reflector a telescope that uses a mirror to collect and focus light.

refraction the bending of light when it passes through one substance and enters another.

refractor a telescope that uses a lens to collect and focus light.

regolith the surface rubble of broken rock on the Moon or other solid body.

resolving power the ability of a telescope or instrument to discern fine details. Larger-diameter telescopes have greater (that is, better) resolving power.

resonance a condition in which the repetitive motion of one body interacts with the repetitive motion of another so as to reinforce the motion. Sliding back and forth in a bathtub to make a big splash is an example.

rest frame a system of coordinates that appear to be at rest with respect to the observer.

retrograde motion the drift of a planet westward against the background stars. Normally planets shift eastward because of their orbital motion. The planet does not actually reverse its motion. The change in its direction is caused by the change in the position from which we view the planet as the Earth overtakes and passes it.

rifting the breaking apart of a continental plate.

right ascension a coordinate for locating objects on the sky, analogous to longitude on the Earth's surface. Measured in hours and minutes of time.

rilles narrow canyons on the Moon or other body.

Roche limit the distance from an astronomical body at which its gravitational force can pull apart another astronomical body.

rotation axis an imaginary line through the center of a body about which the body spins.

rotation curve a plot of the rotation velocity of the stars or gas in a galaxy at different distances from its center.

RR Lyrae stars a type of white, giant, pulsating variable stars with a period of about one day or less. They are named for their prototype star, RR Lyrae.

runaway greenhouse effect greenhouse effect in which heat trapping grows as temperature rises, so the planet's atmosphere becomes extremely hot, as has occurred on Venus.

S

satellite a body orbiting a planet.

scattering the random redirection of a light wave or photon as it interacts with atoms or dust particles.

Schwarzschild radius the radius of a black hole. The distance from the center of a black hole to its event horizon.

scientific method the process of observing a phenomenon, proposing a hypothesis on the basis of the observations, and then testing the hypothesis.

scientific notation a shorthand way to write numbers using ten to a power. For example, $1,000,000 = 10^6$ and $2000 = 2 \times 10^3$. Also called "powers-of-ten notation."

scintillation the twinkling of stars caused by the atmosphere. *See seeing.*

seeing a measure of the steadiness of the atmosphere during astronomical observations. Under conditions of bad seeing, fine details are difficult to see. Bad seeing results from atmospheric irregularities moving between the telescope and the object being observed.

seismic waves waves generated in the Earth's interior by earthquakes. Similar waves occur in other bodies. Two of the more important varieties are S and P waves. The former can travel only through solid material; the latter can travel through either solid or liquid material.

selection effect an unintentional selection process that omits some set of the objects being

studied and leads to invalid conclusions about the objects.

self-propagating star formation a model that explains spiral arms as arising from stars triggering the birth of other stars around them. The resulting pattern is then drawn out into a spiral by the galaxy's rotation.

semimajor axis half the long dimension of an ellipse.

SETI Search for Extraterrestrial Intelligence. Some such searches involve automatic "listening" to millions of radio frequencies for signals that might be from other civilizations.

Seyfert galaxy a variety of active galaxy with a small, abnormally bright nucleus containing hot gas. Named for the astronomer who first drew attention to these objects.

shell source a region in a star where the nuclear energy generation occurs around the core rather than in it.

shepherding satellites satellites that by their gravitational attractions prevent particles in a planet's rings from spreading out and dispersing. Saturn's F-ring is held together by shepherding satellites.

short-period comet a comet whose orbital period is shorter than 200 years. For example, Halley's comet has a period of 76 years.

sidereal day the length of time from the rising of a star until it next rises. The length of the Earth's sidereal day is 23 hours 56 minutes.

sidereal period the time it takes a body to turn once on its rotation axis or to revolve once around a central body, as measured with respect to the stars.

sidereal time a system of time measurement based on the motion of stars across the sky rather than the Sun.

silicates materials composed of silicon and oxygen, and generally containing other substances as well. Most ordinary rocks are silicates. For example, quartz is silicon dioxide.

solar cycle the cyclic change in solar activity, such as sunspots and solar flares, rising and declining about every 11 years.

solar day the time interval from one sunrise to the next sunrise or from one noon to the next noon. That time interval is not always exactly 24 hours but varies throughout the year. For that reason, we use the mean solar day (which, by definition, is 24 hours) to keep time.

solar eclipse the passage of the Moon between the Earth and the Sun so that our view of the Sun is partially or totally blocked. *See also total eclipse.*

solar flare a sudden increase in brightness of a small region on the Sun. This flare is caused by a magnetic disturbance.

solar nebula the rotating disk of gas and dust from which the Sun and planets formed.

solar nebula theory the theory that the Solar System formed from a rotating cloud of gas and dust, the solar nebula.

Solar System the Sun, planets, their moons, and other bodies that orbit the Sun.

solar wind the outflow of low-density, hot gas from the Sun's upper atmosphere. It is partially this wind that creates the tail of a comet, by blowing gas away from the comet's immediate surroundings.

solid core the inner iron-nickel core of the Earth or another planet. Despite its high temperature, the core is solid because it is under great pressure. Also called the *inner core*.

solstice (winter and summer) the beginning of winter and summer. Astronomically the solstice occurs when the Sun is at its greatest distance north (June) or south (December) of the celestial equator.

south celestial pole the imaginary point on the celestial sphere directly over the Earth's South Pole.

special relativity a theory developed by Einstein to explain why the speed of light is always the same, regardless of the motion of the source of the light or the observer. The theory shows (and experiment has confirmed) that an object's mass, length, rate of time passage, and other quantities change depending on the speed of the observer relative to the object.

spectral type an indicator of a star's temperature. A star's spectral type is based on the appearance of its spectrum lines. The fundamental types are, from hot to cool: *O, B, A, F, G, K, and M.*

spectrograph a device for making a spectrum.

spectroscopic binary a type of binary star for which the spectrum lines exhibit a changing Doppler shift as a result of the orbital motion of one star around the other.

spectroscopy the study and analysis of spectra.

spectrum electromagnetic radiation (for example, visible light) spread into its component wavelengths or colors. The rainbow is a spectrum produced naturally by water droplets in our atmosphere.

spicule a hot, thin column of gas in the Sun's chromosphere.

spiral arm a long, narrow region containing young stars and interstellar matter that winds outward in the disk of spiral galaxies.

spiral galaxy a galaxy with a disk in which its bright stars form a spiral pattern.

spring tide the abnormally large tides that occur at new and full moon.

standard candle a type of star or other astronomical body in which the luminosity has a known value, allowing its distance to be determined by measuring its apparent brightness and applying the inverse-square law: Cepheid variable stars, supernovas, and so forth.

standard time a uniform time kept within a given region so that all clocks there agree.

star a massive, gaseous body held together by gravity and generally emitting light. Normal stars generate energy by nuclear reactions in their interiors.

star cluster a group of stars, numbering from hundreds to millions, held together by their mutual gravity.

Stefan-Boltzmann law the law that the amount of energy radiated from 1 square meter in 1 second by a blackbody of temperature T is proportional to T^4 .

stratosphere a layer of Earth's atmosphere extending from about 12 to 50 km above the surface. A layer of ozone is found there.

strong force the force that holds protons and neutrons together in the atomic nucleus. Sometimes called the *nuclear force*.

subatomic particles particles making up an atom, such as electrons, neutrons, and protons, or other particles of similar submicroscopic size.

subduction the sinking of one crustal plate where it encounters another.

sunspot a dark, cooler region on the Sun's visible surface created by intense magnetic fields.

supercluster a cluster of galaxy clusters. One of the largest structures in the Universe.

super-earth a category of exoplanet with a radius about 1.25 to 2 times the Earth's radius.

supergiant a very large-diameter and luminous star, typically at least 10,000 times the Sun's luminosity.

superior conjunction *See conjunction.*

superior planet a planet orbiting farther from the Sun than the Earth. Mars, Jupiter, Saturn, Uranus, and Neptune are superior planets.

supermassive black hole a huge black hole, containing millions to billions of solar masses, at the center of most large galaxies.

supernova an explosion that occurs at the end of some stars' evolution. Astronomers identify two main kinds of supernovas: Type Ia and II. Type Ia occurs in a binary system in which one star is a white dwarf. The explosion is triggered when mass from a companion star falls onto the white dwarf, raising its mass above the Chandrasekhar limit and causing the star to collapse. Collapse heats the white dwarf so that its carbon and oxygen fuse explosively, destroying the star and leaving no remnant. Type II probably occurs when a massive star's iron core collapses. A type II supernova leaves either a neutron star or a black hole, depending on the mass of the collapsing core.

supernova remnant the debris ejected from a star when it explodes as a supernova. Typically, this material is hot gas, expanding away from the explosion at thousands of kilometers or more per second.

surface gravity the acceleration caused by gravity at the surface of a planet or other body.

synchronous rotation the condition where a body's rotation period is the same as its orbital period. The Moon rotates synchronously as it orbits the Earth.

synchrotron radiation a form of nonthermal radiation emitted by charged particles spiraling at nearly the speed of light in a magnetic field. Pulsars and radio galaxies emit synchrotron radiation. The radiation gets its name because it was first seen in synchrotrons, a type of atomic accelerator.

synodic period the time between repeated configurations of a planet or moon. For example, the time between oppositions of a planet or between full moons.

T

21-centimeter radiation a spectrum line at radio wavelengths produced by non-ionized (neutral) hydrogen.

tail the plume of gas and dust from a comet. The plume is produced by the solar wind and radiation pressure acting on the comet. The tail points away from the Sun and gets longer as the comet approaches perihelion.

terrestrial planet a rocky planet similar to Earth in size and structure. The terrestrial planets are Mercury, Venus, Earth, and Mars.

tidal braking the slowing of one body's rotation as a result of gravitational forces exerted on it by another body.

tidal bulge a bulge on one body created by another body's gravitational attraction on it. Two tidal bulges form, one on the side near the attracting body and one on the opposite side.

tides the rise and fall of the Earth's oceans created by the gravitational attraction of the Moon. Tides also occur in the solid crust of a body and its atmosphere.

time dilation the slowing of time due to the effects of special and general relativity.

time zone one of 24 divisions of the globe, centered at every 15 degrees of longitude. In each zone, a single standard time is kept. Most zones have irregular boundaries.

total eclipse an eclipse in which the eclipsing body totally covers the other body. Only at a total solar eclipse can we see the Sun's corona.

transit the passage of a planet directly between the observer and the Sun. At a transit, we see the planet as a dark spot against the Sun's bright disk. From Earth, only Mercury and Venus can transit the Sun.

trans-Neptunian objects (TNOs) numerous small, icy objects orbiting in the outer part of the Solar System beyond the orbit of Neptune.

triangulation a method for measuring distances. This method is based on constructing a triangle, one side of which is the distance to be determined. That side is then calculated by measuring another side (the base line) and the two angles at either end of the base line.

triple alpha process the fusion of three helium nuclei (alpha particles) into a carbon nucleus. This process is sometimes called helium burning, and it occurs in many old stars.

troposphere the lowest layer of the Earth's atmosphere, extending up to about 12 km, where convection leads to clouds and precipitation.

T Tauri star a type of extremely young star that varies erratically in its light output.

tuning-fork diagram a diagram devised by Hubble to classify the various forms of spiral, elliptical, and irregular galaxies. The diagram is named for its shape.

turnoff point the location on the main sequence where a star's evolution causes it to move away from the main sequence toward the red giant region. The location of the turnoff point can be used to deduce the age of a star cluster.

twin paradox a supposed paradox in special relativity arising from the difference in time measurement of two observers moving relative to each other. It is usually expressed in terms of a twin who travels to a distant star and returns to Earth to find that the other twin has aged much more than the first twin. The paradox is explained because the motion of the twins is not symmetric. The twin traveling away from Earth experiences accelerations that the twin remaining on Earth does not experience.

Type Ia supernova *See supernova.*

U

ultraviolet a portion of the electromagnetic spectrum with wavelengths shorter than those of visible light but longer than those of X rays. By convention, the ultraviolet region extends from about 10 nm to 400 nm.

Universal time the time kept at Greenwich, England. Universal time is the same as Greenwich mean time. Most local times (in the continental United States, these are Eastern, Central, Mountain, and Pacific) differ from it by a whole number of hours.

Universe the largest astronomical structure we know of. The Universe contains all matter and radiation and encompasses all space.

V

Van Allen radiation belts doughnut-shaped regions surrounding the Earth containing charged particles trapped by the Earth's magnetic field.

variable star a star whose luminosity changes over time.

vernal equinox the spring equinox in the Northern Hemisphere. Spring begins on the vernal equinox, which is on about March 20.

Virgo Supercluster the cluster of galaxy clusters in which the Milky Way is located. The Local Group is one of its members.

visible spectrum the part of the electromagnetic spectrum that we can see with our eyes. It consists of the familiar colors violet, blue, green, yellow, orange, and red, extending from about 400 nm to 700 nm.

visual binary star a pair of stars held together by their mutual gravity and in orbit about each other,

and that can be seen with a telescope as separate objects.

visual double star two stars that appear to lie very close together on the sky but in reality are at greatly different distances.

W

wavelength the distance between wave crests. It determines the color of visible light and is usually denoted by the Greek letter λ .

wave-particle duality the theory that electromagnetic radiation may be treated as either a particle (photon) or an electromagnetic wave.

weak force the force responsible for radioactive decay of atoms. Now known to be linked to the electromagnetic force at high energies and therefore called the electroweak force.

white dwarf a dense star whose radius is approximately the same as the Earth's but whose mass is comparable with the Sun's. White dwarfs burn no nuclear fuel and shine by residual heat. They are the end stage of stellar evolution for stars like the Sun.

white light visible light exhibiting no color of its own but composed of a mix of all colors. Sunlight and many artificial light sources are "white."

Wien's law a relation between a body's temperature and the wavelength at which it emits radiation most intensely. Hotter bodies radiate more intensely at shorter wavelengths. Mathematically, the law states that $\lambda_{\text{max}} = 2.9 \times 10^6 / T$, where λ_{max} is the wavelength of maximum emission in nanometers and T is the body's temperature on the Kelvin scale.

WIMP (weakly interacting massive particle) A hypothetical subatomic particle that interacts only

through the weak force and gravity. This could be a form of dark matter since it does not interact with electromagnetic radiation.

X

X rays a portion of the electromagnetic spectrum with wavelengths of about 0.01 nm to 10 nm.

X-ray binary a binary star system in which one of the stars, or the gas associated with a star, emits X rays intensely. Such systems generally contain a collapsed object such as a neutron star or a black hole.

Y

year the time it takes the Earth to complete its orbit around the Sun; that is, the period of the Earth's orbit.

Z

Zeeman effect the splitting of a single spectrum line into two or three lines by a magnetic field. A method for detecting magnetic fields in objects from their spectra.

zenith the point on the celestial sphere that lies directly overhead at your location.

zodiac a band running around the celestial sphere in which the planets move.

zone a white band in a Jovian planet's atmosphere, encircling the planet. It appears that in these zones gas is rising and cooling, forming cloud particles.

zone of avoidance a band running around the sky in which few galaxies are visible. It coincides with the Milky Way and is caused by dust that is within our Galaxy. This dust blocks the light from distant galaxies.