A

absolute brightness: The apparent brightness a star would have if it were placed at a standard distance of 10 parsecs from Earth.

absolute zero: The lowest point on any temperature scale, the temperature at which all (non-quantum mechanical) motion ceases; hence absolute zero occurs at zero degrees in the Kelvin scale, -273 degrees on the centigrade (Celsius) scale and -459.7 degrees on the Fahrenheit scale.

absorption line: Dark line in an otherwise continuous bright spectrum, where light within one narrow frequency range has been moved. A region of the electromagnetic spectrum, limited in frequency and wavelength, from which electromagnetic radiation has been removed, so that the intensity of the radiation falls below that of the neighboring spectral regions.

absorption, X-ray: X-ray photons - tiny high-energy packets of electromagnetic radiation - are absorbed by encounters with individual atoms in the Earth's atmosphere, and to a lesser extent, in interstellar space, or around the source of X-rays.

abundances of the elements: The amounts of each chemical element relative to hydrogen in the universe, or a star or in some particular object.

acceleration: The rate of change of velocity of a moving object.

accretion disk: A disk of gas and dust that can accumulate around a center of gravitational attraction, such as a normal star, a white dwarf, neutron star, or black hole. As the gas spirals in due to friction, it becomes hot and emits radiation.

Active Galactic Nucleus (AGN): The central region of a galaxy that shows unusual energetic activity.

active galaxy: A galaxy which shows explosive activity and can emit large amounts of energy, especially from its central regions.

Advanced X-ray Astrophysics Facility (AXAF): Renamed the Chandra X-ray Observatory and launched on July 23, 1999, the largest and most sophisticated X-ray observatory to date.

angular momentum: The momentum of rotation about a fixed axis.

angular resolution: The ability of a telescope to distinguish two adjacent objects on the sky, or to study the fine details on the surface of some object; often synonymous with "clarity" or "sharpness."

angular size: The apparent size of an object, measured by the angle the object subtends, in degrees of arc, minutes of arc, or seconds of arc.

antimatter: Matter made of antiparticles, i.e., particles with identical mass and spin as those of ordinary particles, but with opposite charge and magnetic properties. When a particle and its antiparticle meet they can mutually annihilate and produce energy.

apparent brightness: The brightness of an object as it naturally appears in the sky.

arc degree: A unit of angular measure of which there are 360 in a full circle.

arc minute: A unit of angular measure of which there are 60 in 1 arc degree.

arc second: A unit of angular measure of which there are 60 in 1 arc minute (or therefore 3600 in 1 arc degree).
astronomy: Branch of science dedicated to the study of everything in the universe that lies above Earth's atmosphere.
atmosphere: A layer of gas confined close to a planet's surface by the force of gravity.
atom: Building block of matter, composed of positively charged protons and neutral neutrons in the nucleus, surrounded by negatively charged electrons.

B

baryons: Heavy subatomic particles, such as protons and neutrons, that make up the nuclei of atoms.
Big Bang: The event that most cosmologists consider to have been the beginning of the universe, in which space-time originated in a state of enormously high temperature and density and subsequently expanded and cooled.
binary star system: A system in which two stars orbit about their common center of gravity.
black-body radiation: The characteristic way in which the intensity of radiation emitted by a hot object in thermal equilibrium depends on frequency. The frequency at which the emitted intensity is highest is an indication of the temperature of the radiating object. Also referred to as the Planck curve.
black holes: A dense, compact object whose gravitational pull is so strong that - within a certain distance of it - nothing can escape, not even light. Black holes are thought to result from the collapse of certain very massive stars at the ends of their evolution.
blazars: a class of active galaxies that exhibit rapidly variable emission from the radio through gamma-ray band. The radiation is predominantly from jets moving near the speed of light. Blazars are thought to be radio galaxies with their jets oriented toward Earth.
blue giant: Large, hot, bright star at the upper left end of the main sequence on the H-R diagram. Its name comes from its color and size.
blue shift: Motion-induced change in the observed wavelength from a source that is moving toward us. Relative approaching motion between the object and the observer causes the wavelength to appear shorter (and hence bluer) than if there were no motion at all.
blue supergiant: The very largest of the large, hot, bright, stars.
Bohr model: First theory of the hydrogen atom to explain the observed spectral lines. This model rests on three ideas: that there is a state of lowest energy, that there is a maximum energy, beyond which the electron is no longer bound to the nucleus, and that within these two energies the electron can only exist in certain energy levels.
brown dwarf: Clouds of collapsing gas and dust that did not contain enough mass to initiate core nuclear fusion. Such objects are then frozen somewhere along their pre-main sequence contraction phase, continually cooling into compact dark objects. Because of their small size and low temperature, they are extremely difficult to detect observationally.

C

celestial coordinates: Pair of quantities-right ascension and declination-similar to longitude and latitude on Earth, used to pinpoint locations of objects on the celestial sphere.
celestial equator: The projection of the Earth's equator onto the celestial sphere.
celestial sphere: Imaginary sphere surrounding the Earth, to which all objects in the sky were once considered to be attached.
center of mass: The "average" position in space of a collection of massive bodies, weighted by their masses. In an isolated system this point moves with constant velocity, according to Newtonian mechanics.
Cepheid variable: Star whose luminosity varies in a characteristic way, with a rapid rise in brightness followed by a slower decline. The period of a Cepheid variable star is related to its luminosity, so a determination of this period can be used to obtain an estimate of the star's distance.
Chandrasekhar limit: The upper limit to the mass of a white dwarf (equals 1.4 times the mass of the Sun).
Chandra X-ray Observatory (CXO): Formerly called AXAF, Chandra was launched July 23, 1999, and is the largest and most sophisticated X-ray observatory to date.
charge-coupled device (CCD): An electronic device used to detect photons, composed of many tiny pixels, each of which records a buildup of charge to measure the number of photons striking it.
closed universe: Geometry that the universe as a whole would have if the density of matter is above the critical value. A closed universe is finite in extent, and has no edge, like the surface of a sphere. It has enough mass to stop the present expansion, and will eventually collapse.
clusters of galaxies: Galaxies can swarm together to form groups and clusters of galaxies held together by their mutual galaxy. X-ray observations show that these enormous systems of galaxies are filled with colossal clouds of hot gas. These clouds have temperatures as high as a hundred million degrees and contain as much mass as all the stars in the galaxies in the cluster.
cold dark matter: Hypothetical class of dark-matter candidates made up of slow-moving subatomic particles, such as supersymmetric relics of a very early stage of the Big Bang.
collecting area: The total area of a telescope that is capable of capturing incoming radiation. The larger the telescope, the greater its collecting area, and the fainter the objects it can detect.
Compact Galaxy Group: A galaxy group typically contains less than about 50 galaxies bound together by gravity. Although they contain fewer galaxies than the better-known galaxy clusters, they are an important class of objects because most galaxies reside in them, and the typical galaxy group is similar to the Local Group that contains our galaxy.
Compton scattering: The scattering, or collision, of a photon with an electron.
conservation of energy: A fundamental law of modern physics which states that the sum of the various forms of energy must always remain constant in any physical process.

constellation: A grouping of stars in the night sky into a recognizable pattern. Most of the constellations get their name from the Latin translation of one of the ancient Greek star patterns that lies within it. In more recent times, a number of additional groups were introduced by more modern astronomers, and there are now 88 standard configurations recognized.

contact binary: A binary star system in which both stars have expanded to fill their Roche lobes and the surfaces of the two stars merge. The binary system now consists of two nuclear burning stellar cores surrounded by a continuous common envelope.

continuous spectrum: Spectrum in which the radiation is distributed over all frequencies, not just a few specific frequency ranges. A prime example is the black-body radiation emitted by a hot, dense body.

convection: Churning motion resulting from the constant upwelling of warm fluid and the concurrent downward flow of cooler material to take its place.

convection zone: Region of a star's interior, lying just below the surface, where the material of the star is in constant convective motion. This region extends into the solar interior to a depth of about 20,000km.

Copernican revolution: The realization toward the end of the sixteenth century that Earth is not at the center of the universe.

core: The central region of a planet, star, or galaxy.

corona: The outermost atmosphere of a star (including the Sun), millions of kilometers in extent, and consisting of highly rarefied gas heated to temperatures of millions of degrees.

cosmic abundances: A standard listing of the relative numbers of the various elements, determined by studies of the spectral lines in astronomical objects and averaged for many stars in our cosmic neighborhood.

cosmic microwave: background radiation The microwave radiation coming from all directions that is believed to be the redshifted glow of the Big Bang.

cosmic rays: Atomic nuclei (mostly protons) that are observed to strike the Earth's atmosphere with exceedingly high energies.

cosmic string: Cosmic strings are thin strands of ultrahigh density matter that are predicted by some theories to have been left over from an extremely early era of the universe. Cosmic strings would have a width that is far less than an atomic nucleus, and a mass of about 10 million billion tons per centimeter. A kilometer of cosmic string material would weight as much as the Earth! They would make closed loops or stretch across the universe and perhaps have an infinite length. Cosmic strings are not to be confused with superstrings, the tiny subatomic loops of matter that according to superstring theory are the fundamental building blocks of all particles.

cosmological constant: A modification of the equations of general relativity that represents a possible repulsive force in the universe. The cosmological constant could be due to the energy density of the vacuum.

cosmology: The study of the origin and evolution of the universe as a whole.

critical mass density of universe: The cosmic density corresponding to the dividing line between a universe that recollapses and one that expands forever. The universe is infinite in extent, and has zero curvature. The expansion will continue forever, but approach an expansion speed of zero.

D

dark dust cloud (dark nebula): A region of interstellar space containing a rich concentration of gas and dust in an irregular but well-defined cloud that obscures the light from stars beyond it.
dark energy: A mysterious source of energy introduced to explain the acceleration of the expansion of the Universe. One possible explanation is that it is the energy present in empty space - "vacuum energy" - which has the properties of a repulsive force.
dark halo: A large envelope of dark matter around a galaxy that is postulated to explain the rapid rotation of galaxies and other observations.
dark matter : A term used to describe the mass in galaxies and clusters of galaxies that can be inferred to exist from its gravitational effects, but has not been directly detected by electromagnetic radiation.
declination: Celestial coordinate system used to measure latitude above or below the celestial equator on the celestial sphere.
decoupling: Event in the early universe when atoms first formed, and after which photons could propagate freely through space.
Deep Space Network: NASA's three ground stations (in Spain, Australia, and California) that are used to relay commands to an orbiting spacecraft, such as the Chandra X-ray Observatory.
degree: A unit of angular measure. There are 360 degrees in a complete circle.
density: A measure of the compactness of the matter within an object, computed by dividing the mass by the volume of the object.
deuterium: An isotope of hydrogen in which there is a neutron bound to the proton in the nucleus. Often called "heavy hydrogen" because of the extra mass of the neutron.
differential rotation: The tendency for a gaseous sphere, such as a jovian planet or the Sun, to rotate at a different rate at the equator than at the poles. For a galaxy or other object, a condition where the angular speed varies with location within the object.
diffraction: The ability that waves have to bend around corners. The diffraction of light establishes its nature as a wave.
Doppler Effect: Apparent change in wavelength of the radiation from a source due to its relative motion away from or towards the observer.
dust grain: A term for dust particles in the space between the stars. Sizes vary over a wide range but are typically about one micrometer, comparable to the wavelength of visible light.
dust lane: A lane of dark, obscuring interstellar dust in an emission nebula or galaxy.
dwarf: Any star with a radius comparable to, or smaller than that of the Sun (including the sun itself).

E

eccentricity: A measure of the flatness of an ellipse, equal to the distance between the two foci divided by the length of the major axis.

eclipse: Event during which one body passes in front of another, so that the light from the occulted body is blocked.

eclipsing binary: Rare binary-star system that is aligned in such a way from Earth we observe one star pass in front of the other, eclipsing the other star.

Eddington limit: The limit beyond which the radiation force on matter is greater than the gravitational force.

electric field: A field extending outward in all directions from a charged particle, such as a proton or an electron. The electric field determines the electric force exerted by the particle on all other charged particles in the universe; the strength of the electric field decreases with increasing distance from the charge according to an inverse-square law.

electromagnetic radiation: Consists of massless packets of pure energy called photons produced by changes in the energy of charged particles, usually electrons. Photons travel through space at the speed of light. When the changes of energy are small, streams of photons can be described as waves of changing electric and magnetic fields, called electromagnetic waves. The most familiar type of electromagnetic radiation is visible light, but the full spectrum of electromagnetic radiation includes radio, microwave, infrared, ultraviolet, X rays and gamma rays.

electromagnetic spectrum: The entire range of electromagnetic waves, named in order of increasing frequency or energy, ranges from radio waves, to microwave, to infrared, to visible or optical, to ultraviolet, to X rays, to gamma rays.

electromagnetism: The union of electricity and magnetism, which do not exist as independent quantities, but are in reality two aspects of a single physical phenomenon.

electron: An elementary particle with a negative electric charge. Electrons orbit the nucleus of an atom. They can be torn away from an atom by collisions with other particles or photons.

electron degeneracy pressure: The pressure produced by the resistance of electrons to compression once they are squeezed to the point where quantum effects become important.

electron volt (eV): The energy gained by an electron accelerated by a potential of 1 volt.

element: Matter made up of one particular atom. The number of protons in the nucleus of the atom determines which element it represents.

elementary particle: One of the basic particles of matter. The most familiar of the elementary particles are the proton, neutron, and electron.

ellipse: Geometric figure resembling an elongated circle. An ellipse is characterized by its degree of flatness, or eccentricity, and the length of its long axis. In general, bound orbits of objects moving under gravity are elliptical.

elliptical galaxy: Category of galaxy in which the stars are distributed in an elliptical shape on the sky, ranging from highly elongated to nearly circular in appearance.

emission line: Bright line in a specific location of the spectrum of radiating material, corresponding to emission of light at a certain frequency.
emission nebula: A glowing cloud of hot interstellar gas. The gas glows as a result of a nearby young star which is ionizing the gas. Since this gas is mostly hydrogen, the emitted radiation falls predominantly in the red region of a spectrum, because of a dominant hydrogen emission.
emission spectrum: The pattern of spectral emission lines, produced by an element. Each element has its own unique emission spectrum.
equilibrium: A condition of balance between forces, or competing processes, such as emission and absorption of radiation.
escape velocity: The speed necessary for an object to escape the gravitational pull of an object. Anything that moves away from the object with more than the escape velocity will never return.
event horizon: Imaginary spherical surface surrounding a black hole, with radius equal to the Schwarzschild radius, within which no event can be seen heard, or known about by an outside observer.
evolutionary theory: A theory which explains observations in a series of gradual steps, explainable in terms of well-established physical principles.
excited state: The state of an atom when one of its electrons is in a higher energy orbital than the ground state. Atoms can become excited by absorbing a photon of a specific energy, or by colliding with a nearby atom.
extinction: The dimming of starlight as it passes through the interstellar medium.

F

flare, solar: Explosive event occurring in or near an active region on the Sun.
flatness problem: One of two conceptual problems with the Standard Big Bang model, which is that there is no natural way to explain why the density of the universe is so close to the critical density.
fluorescence: The absorption of a photon of one energy, or wavelength, and re-emission of one or more photons at lower energies, or longer wavelengths.
force: Action of an object that causes momentum to change. The rate at which the momentum changes is numerically equal to the force.
frequency: The number of wave crests passing any given point in a given period of time.
fusion: Mechanism of energy generation in the core of the Sun in which light nuclei are combined, or fused, into heavier ones, releasing energy in the process.

G

galactic bulge: Thick distribution of warm gas and stars around the galactic center.
galactic cannibalism: A galaxy merger in which a larger galaxy consumes a smaller one.
galactic center: The center of the Milky Way, or any other, galaxy. The point about which the disk of a spiral galaxy rotates.

galactic disk: Flattened region of gas and dust that bisects the galactic halo in a spiral galaxy. This is the region of active star formation.

galactic halo: Region of a galaxy extending far above and below the galactic disk, where globular clusters and other old stars reside.

galactic nucleus: Small central high-density region of a galaxy. Most galactic nuclei are thought to harbor a supermassive black hole.

galaxy: A gravitationally-bound system of stars, gas, dust and

galaxy cluster: Galaxies can swarm together to form groups and clusters of galaxies held together by their mutual gravity. X-ray observations show that these enormous systems of galaxies are filled with colossal clouds of hot gas. These clouds have temperatures as high as a hundred million degrees and contain as much mass as all the stars in the galaxies in the cluster.

gamma ray: Region of the electromagnetic spectrum, beyond x-rays, corresponding to radiation of very high frequency and very short wavelength.

gamma-ray burst: An outburst that radiates tremendous amounts of energy, equal to or greater than a supernova, in the form of gamma rays and X-rays. At least two classes of gamma-ray bursts have been identified: short-duration bursts lasting less than a few seconds, and more powerful, long-duration gamma-ray bursts that last a few minutes. Long-duration bursts may be produced by black holes formed in the explosion of extremely massive stars, or hypernovas. Short duration bursts may be related to the merger of two neutron stars, or of a neutron star and a black hole.

Giant Molecular Cloud (GMC): Huge, cool clouds of dust grains, and gas, much of which is in the form of molecules. GMC's appear to be where most of the stars are formed in galaxies.

giant star: A star with a radius between 10 and 100 times that of the Sun.

globular cluster: Tightly bound, roughly spherical collection of hundreds of thousands, and sometimes millions, of stars spanning about 100 light years. Globular clusters are distributed in the halos around the Milky Way and other galaxies.

Grand Unified Theories: Theories which describe the behavior of the single force that results from unification of the strong, weak, and electromagnetic forces in the early universe.

gravitational field: Field created by an object with mass, extending out in all directions, which determines the influence of that object on all others. The strength of the gravitational field decreases as the square of the distance.

gravitational instability: A condition whereby an object's (inward-pulling) gravitational potential energy exceeds its (outward-pushing) thermal energy, thus causing the object to collapse.

gravitational lensing: Banding of light from a distant object by a massive foreground object.

gravitational red shift: A prediction of Einstein's general theory of relativity. Photons lose energy as they escape the gravitational field of a massive object. Because a photon's energy is proportional to its frequency, a photon that loses energy suffers a decrease in frequency, or redshift, in wavelength.

gravity, (gravitational force): The attractive effect that any massive object has on all other massive objects. The greater the mass of the object, the stronger is its gravitational pull.
gravitational wave: The gravitational analog of an electromagnetic wave whereby gravitational radiation is emitted at the speed of light from any mass that undergoes rapid acceleration.
ground state: The lowest energy state that an electron can have within an atom.

H

H-R (Hertzsprung-Russell) diagram: A plot of luminosity versus temperature for a group of stars that can be used to classify the evolutionary state of stars.
helium capture: The formation of heavy elements by the capture of a helium nucleus. For example, carbon can form heavier elements by fusion with other carbon nuclei, but it is much more likely to occur by helium capture, which requires less energy.
helium flash: An explosive event in the post-main-sequence evolution of a low-mass star. When helium fusion begins in a dense stellar core, the burning is explosive in nature. It continues until the energy released is enough to expand the core, at which point the star achieves stable equilibrium again.
Herbig-Haro objects: Clouds of dust and gas that are either part of high-speed jets of gas streaming away from very young stars, or clouds of gas that have been hit by such jets.
high-mass star:: A star that is about 8 or more times the mass of the Sun.
homogeneity: Assumed property of the universe such that the number of galaxies in an imaginary large cube of the universe is the same no matter where in the universe the cube is placed.
horizon problem: One of two conceptual problems with the standard Big Bang model, which is that some regions of the universe which have very similar properties are too far apart to have exchanged information in the age of the universe.
horizontal branch: Region of the H-R diagram where post-main sequence stars again reach hydrostatic equilibrium. At this point, the star is burning helium in its core, and hydrogen in a shell surrounding the core.
hot dark matter: A class of candidates for the dark matter in the universe, composed of lightweight, rapidly moving particles, such as neutrinos, much less massive than the electron.
Hubble Classification scheme: Method of classifying galaxies according to their appearance, developed by Edwin Hubble.
Hubble's Constant: The constant of proportionality which gives the relation between recessional velocity and distance in Hubble's Law.
Hubble's Law: Law that relates the observed velocity of recession of a galaxy to its distance from us. The velocity of recession of a galaxy is proportional to its distance.
Hubble Space Telescope: The first large optical telescope launched above the Earth's atmosphere and carrying instruments sensitive to visible and ultraviolet light. The telescope was

built by NASA with major contributions from the European Space Agency, and was launched in April, 1990.

hydrogen shell burning: Fusion of hydrogen in a shell that is driven by contraction and heating of the helium core. Once hydrogen is depleted in the core of a star, hydrogen burning stops and the core contracts due to gravity, causing the temperature to rise, heating the surrounding layers of hydrogen in the star, and increasing the burning rate there.

I

image: The representation of an object produced when light from the object is reflected or refracted by a mirror or a lens.

inertia: The tendency of an object to continue in motion at the same speed and in the same direction, unless acted upon by a force.

inflation: Short period of extremely rapid cosmic expansion early in the history of the universe. During inflation, the universe swelled in size by a factor of 10 to the 50th power.

infrared: Region of the electromagnetic spectrum just outside the visible range, corresponding to light of a slightly longer wavelength than red light.

infrared telescope: Telescopes designed to detect infrared radiation.

intensity: A basic property of electromagnetic radiation that specifies the amount or strength of the radiation flowing in a specific direction.

interference: The ability of two or more waves to interact in such a way that they either reinforce or cancel each other.

interferometer: Collection of two or more telescopes working together as a team, observing the same object at the same time and at the same wavelength. The effective diameter of an interferometer is equal to the distance between its outermost dishes.

interferometry: Technique in widespread use to dramatically improve the resolution of telescopes, especially radio telescopes. Several radio telescopes observe the object simultaneously, and a computer analyzes how the signals interfere with each other.

intergalactic matter: Matter in the space between galaxies.

intergalactic space: The space between galaxies.

interplanetary matter: Matter in the space between planets.

interplanetary space: The space between planets.

interstellar dust: Dust particles in the space between the stars. Sizes vary over a wide range but are typically about one micrometer, comparable to the wavelength of visible light

interstellar matter (or medium:) Interstellar gas and dust.

interstellar space: The space between stars.

inverse-square law: The law that a field follows if its strength decreases with the square of the distance. Fields that follow the inverse square law rapidly decrease in strength as the distance increases, but never quite reach zero.

ion: An atom with one or more electrons removed (or added), giving it a positive (or negative) charge.
ionization: The process by which ions are produced, typically by collisions of electrons, ions, or photons.
ionosphere: The part of the Earth's atmosphere above about 50 km where the atoms are significantly ionized and affect the propagation of radio waves.
irregular galaxy: A strangely shaped galaxy, often rich in interstellar matter, but apparently not a member of any of the major classes of spiral or elliptical galaxies.
isotopes: Nuclei containing the same number of protons but different numbers of neutrons. Most elements can exist in several isotopic forms. A common example of an isotope is deuterium, which differs from normal hydrogen by the presence of an extra neutron in the nucleus.
isotropy: Assumed property of the universe such that the universe looks the same way in every direction.

J

jet: A highly directed flow of matter, or radiation that comes from such a flow.
Julian Day (JD): Astronomers simplify their timekeeping by merely counting the days, and not months and years. Each date has a Julian Day number (JD), beginning at noon, which is the number of elapsed days since January 1st, 4713 B.C. For instance, January 1st, 1993, was JD 2448989; January 2nd, 1993, was JD 2448990; and January 1st, 2000, was JD 2451545.

K

Kelvin temperature scale: An internationally agreed upon temperature scale, equal to the Celsius (or centigrade) scale plus 273 degrees; hence water freezes at 273 kelvins and boils at 373 kelvins.
Kepler's Laws of Planetary Motion: Three laws which summarize the motions of the planets about the Sun, or more generally, the motion of one body around another under the influence of gravity.
Kerr black hole: A rotating black hole.
kiloelectron volt (keV):
kilometer: A unit of distance equal to 0.6214 mile.
kinetic energy: The energy of an object due to its motion.

L

Lagrange point: One of five special points in the plane of two massive bodies orbiting one another, where a third body of negligible mass can remain in equilibrium.
Lenticular Galaxies: So-called because they appear to be shaped like lenses. A lenticular galaxy has a spherically shaped component like an elliptical galaxy, and a disk. It is generally gas poor and contains few if any young stars.

light curve: The variation in brightness of a star with time.
lighthouse model: The leading explanation for pulsars. A small region of the neutron star, near one of the magnetic poles, emits a steady stream of radiation which sweeps past Earth each time the star rotates. Thus the period of the pulses is just the star's rotation period.
light year: The distance that light, moving at a constant speed of 300,000km/s, travels in one year. One light year is about 10 trillion kilometers.
Local Group: The small galaxy group that includes the Milky Way Galaxy, the Andromeda Nebula, and about 20 smaller galaxies.
look-back time: The time in the past at which the light we now receive from a distant object was emitted.
luminosity: One of the basic properties used to characterize stars, luminosity is defined as the total energy radiated by a star each second, at all wavelengths.
luminosity class: A classification scheme which groups stars according to the width of their spectral lines. For a group of stars with the same temperature, luminosity class differentiates between supergiants, giants, main-sequence stars and subdwarfs.

M

Magellanic Clouds: Two nearby small irregular galaxies about 160,000 light years (Large Magellanic Cloud), and 200,000 light years (Small Magellanic Cloud) distant, visible to the naked eye from the southern hemisphere
magnetic field: Field which accompanies any electric current or changing electric field, and governs the influence of magnetized objects on one another.
magnetosphere: The region of space surrounding a rotating, magnetized object in which the motions of charged particles are controlled by the object's magnetic field..
magnitude: The method we use today to compare the apparent brightness (magnitude) of stars began with Hipparchus, a Greek astronomer who lived in the second century BC. Hipparchus called the brightest star in each constellation "first magnitude." Ptolemy, in 140 A.D., refined Hipparchus' system and used a 1 to 6 scale to compare star brightness, with 1 being the brightest and 6 the faintest.
main sequence: A well-defined band on an H-R diagram on which most stars tend to be found, running from the top left of the diagram to the bottom right.
main-sequence turnoff: Special point on an H-R diagram for a cluster. If all the stars in a particular cluster are plotted, the lower mass stars will trace out the main sequence up to the point where stars begin to evolve off the main sequence toward the red giant branch. The point where stars are just beginning to evolve off is the main-sequence turnoff.
mass: A measure of the total amount of matter contained within an object.
mass-luminosity relation: The dependence of the luminosity of a main-sequence star on its mass. The luminosity increases roughly as the mass raised to the third power.

mass-radius relation: The dependence of the radius of a main-sequence star on its mass. The radius rises roughly in proportion to the mass.
matter-dominated universe: A universe in which the density of matter exceeds the density of radiation. The present-day universe is matter-dominated.
matter-antimatter annihilation: A highly efficient process in which equal amounts of matter and anti-matter collide and destroy each other, producing a burst of energy, primarily in the form of gamma rays.
micro-quasar:: A stellar-mass black hole that launches powerful jets of particles and radiation.
microwave radiation: Radiation between radio and infrared wavelengths, having a wavelength between about 0.1 and 10 cm.
microwave background radiation: See cosmic microwave background radiation.
Milky Way Galaxy: The specific galaxy to which the Sun belongs, so named because most of its visible stars appear overhead on a clear, dark night as a milky band of light extending across the sky.
millisecond pulsar: A pulsar whose period indicates that the neutron star is rotating nearly 1000 times each second.
minute of arc: See "
molecular cloud: A cold, dense interstellar cloud which contains a high fraction of molecules. It is widely believed that the relatively high density of dust particles in these clouds plays an important role in the formation and protection of the molecules.
molecular cloud complex: Collection of molecular clouds that spans as much as 150 light years and may contain enough material to make millions of Sun-sized stars.
molecule: A tightly bound collection of atoms held together by the electromagnetic fields of the atoms. Molecules, like atoms, emit and absorb photons at specific wavelengths.
momentum: A measure of the state of motion of a body; the momentum of a body is the product of its mass and velocity. In the absence of a force, momentum is conserved.

N

nebula: General term used for any "fuzzy" patch on the sky, either light or dark; a cloud of interstellar gas and dust.
neutrino: An electrically neutral elementary particle that is one of the products of nuclear fusion reactions. Neutrinos have little or no mass, move at close to the speed of light, and interact very weakly with matter.
neutrino oscillations: Possible solution to the solar neutrino problem, in which the neutrino has a very tiny mass. In this case, the correct number of neutrinos can be produced in the solar core, but on their way to Earth, some can "oscillate," or become transformed into other particles, and thus go undetected.
neutron: An elementary particle with roughly the same mass as a proton, but which is electrically neutral. Along with protons, neutrons form the nuclei of atoms.

neutron capture: The primary mechanism by which very massive nuclei are formed in the violent aftermath of a supernova. Instead of fusion of like nuclei, heavy elements are created by the addition of more and more neutrons to existing nuclei.

neutron star: A dense stellar remnant produced by the collapse of the core of a massive star as part of a supernova that destroys the rest of the star. Typically neutron stars are composed almost entirely of neutrons, are about 20km in diameter, are about 1.5 times as massive as the Sun.

Newtonian mechanics: The basic laws of motion, postulated by Newton, which are sufficient to explain and quantify virtually all of the complex dynamical system behavior found on Earth and elsewhere in the universe.

non-thermal radiation: Radiation released by virtue of a fast-moving charged particle (such as an electron) interacting with a magnetic force field or other particles; this process has nothing to do with heat.

north celestial pole: Point on the celestial sphere directly above the Earth's north pole.

nova: A star that suddenly increases in brightness, often by a factor of as much as 10,000, then slowly fades back to its original luminosity. A nova is the result of an explosion on the surface of a white dwarf star, caused by matter falling onto its surface from the atmosphere of a binary companion.

nuclear force: The force that binds protons and neutrons within atomic nuclei, and which is effective only at distances less than about 10-13 centimeter.

nuclear fusion: A nuclear process that releases energy when lightweight nuclei combine to form heavy-weight nuclei.

nucleosynthesis: The building up of heavy elements from lighter ones by nuclear fusion.

nucleus: Dense, central region of an atom, containing both protons and neutrons, and orbited by one or more electrons.

O

omega: Symbol used to denote the ratio of the mass density of the universe to the critical mass density.

opacity: A quantity that measures a material's ability to block electromagnetic radiation. Opacity is the opposite to transparency.

open cluster: Loosely bound collection of tens to hundreds of stars, a few parsecs across, generally found in the plane of the Milky Way.

open universe: Geometry that the universe would have if the density of matter were less than the critical value. In an open universe there is not enough matter to halt the expansion of the universe. An open universe is infinite in extent.

P

pair production: Process in which a very high-energy photon interacts with another photon or a strong magnetic field to give rise to a particle-anti-particle pair.
parallax: The apparent motion of a relatively close object with respect to a more distant background as the location of the observer changes.
parsec: The distance at which a star must lie in order that its measured parallax due to the Earth's orbit around the Sun is exactly 1 arc second, equal to 3.3 light years.
partial eclipse: Celestial event during which only a part of the occulted body is blocked from view.
period: The time needed for a complete cycle of repetitive motion; for example the time for an orbiting body to complete one revolution about another body, or the time needed for a pendulum to make a complete swing.
period-luminosity relation: A relation between the pulsation period of a Cepheid variable and its absolute brightness. Measurement of the pulsation period allows the distance of the star to be determined.
photoelectric effect: A basic physical phenomenon that demonstrates radiation to be composed of particles.
photon: Individual packet of electromagnetic energy that makes up electromagnetic radiation.
photosphere: The visible surface of the Sun, lying just above the uppermost layer of the Sun's interior, and just below the chromosphere.
pixel: One of many tiny picture elements, organized into an array, making up a digital image.
planet: One of nine major bodies that orbit the Sun, visible to us by reflected sunlight.
planetary nebula: The ejected envelope of a red giant star, spread over a volume roughly the size of our solar system, with a hot central star that is in the process of becoming a white dwarf star.
plasma: A state of matter wherein all atoms are ionized; a mixture of free electrons and free atomic nuclei.
polarization: The alignment of the electric fields of emitted photons, which are generally emitted with random orientations.
positron: Atomic particle with properties identical to those of a negatively charged electron, except for its positive charge. This positron is the antiparticle of the electron. Positrons and electrons annihilate each other when they meet, producing pure energy in the form of gamma rays.
potential energy: Stored energy that can be converted into other forms; especially gravitational energy.
precession: The slow change in the direction of the axis of a spinning object, caused by some external influence.
primordial nucleosynthesis: The production of elements heavier than hydrogen by nuclear fusion in the high temperatures and densities which existed in the early universe.

proper motion: The angular movement of a star across the sky, as seen from the Earth, measured in seconds of arc per year. This movement is a result of the star's actual motion through space.
proton: An elementary particle, carrying a positive electric charge, a component of all atomic nuclei. The number of protons in the nucleus of an atom dictates what type of atom it is.
proton-proton chain: The chain of fusion reactions, leading from hydrogen to helium, that powers main-sequence stars.
protoplanet: Clump of material, formed in the early stages of solar system formation, that was the forerunner of the planets we see today.
protostar: Stage in star formation when the interior of a collapsing cloud of gas is sufficiently hot and dense that it becomes opaque to its own radiation, but not hot enough for the onset of nuclear reactions.
pulsar: Object that emits radiation in the form of rapid pulses with a characteristic pulse period and duration. Generally used to describe the pulsed radiation from a rotating neutron star.
pulsating variable star: A star whose luminosity varies in a predictable, periodic way.

Q

quantization: The fact that light and matter on small scales behave in a discontinuous manner, and manifest themselves in the form of tiny "packets" of energy, called quanta.
quantum: A discrete physical unit into which something can be divided, for example a photon, or the difference in energy states in an atom.
quantum mechanics: The framework of laws governing the behavior of particles on atomic and subatomic levels. It starts with the assumption that energy is not infinitely divisible, but comes in quanta.
quark: A fractionally charged, basic building block of protons, neutrons, and other elementary particles.
quasars: Originally, a distant, highly luminous object that looks like a star. Strong evidence now exists that a quasar is produced by gas falling into a supermassive black hole in the center of a galaxy.
Quasi-periodic Oscillations (QPO's): Variations in the intensity of X-radiation from sources that show periodic behavior for short time intervals, and a variety of periods.

R

radar: Acronym for Radio Detection And Ranging. Radio waves are bounced off an object, and the time at which the echo is received indicates its distance.
radial motion: Motion along a particular line of sight, which induces apparent changes in the wavelength (or frequency) of radiation received.
radiation: A way in which energy is transferred from place to place in the form of a wave. Light is a form of electromagnetic radiation.

radiation belts: Zones or belts of charged particles that are trapped in magnetic fields around the Earth.

radiation-dominated universe: Early epoch in the universe, when the density of radiation in the cosmos exceeded the density of matter.

radiation pressure: The transfer of momentum carried by electromagnetic radiation to a body that the radiation impinges upon.

radio: Region of the electromagnetic spectrum corresponding to radiation of the longest wavelengths.

radio galaxy: Type of active galaxy that emits most of its energy in the form of long-wavelength radiation.

radio lobe: Roundish region of radio-emitting gas, lying well beyond the center of a radio galaxy.

radio telescope: Large instrument designed to detect radiation from space in radio wavelengths.

radioactivity: The release of energy by rare, heavy elements when their nuclei decay into lighter nuclei.

radius-luminosity-temperature relation: A mathematical proportionality, arising from Stefan's Law, which allows astronomers to indirectly determine the radius of a star once its luminosity and temperature are known.

reaction wheel: Wheels on the spacecraft which change the spacecraft attitude.

red dwarfs: Small, cool faint stars at the lower-right end of the main sequence on the H-R diagram, whose color and size give them their name.

red giant star: An evolved star that has exhausted the hydrogen fuel in its core and is powered by nuclear reactions in a hot shell around the stellar core. The diameter of a red giant is much larger than that of the Sun, and its surface temperature is relatively low, so that it glows with a red color.

red-giant branch: The section of the evolutionary track of a star that corresponds to continued heating from rapid hydrogen shell burning, which drives a steady expansion and cooling of the outer envelope of the star. As the star gets larger in radius and its surface temperature cools, it becomes a red giant.

red shift: Change in the wavelength of light emitted from a source moving away from us. The relative recessional motion causes the wave to have an observed wavelength longer (and hence redder) than it would if it were not moving. The cosmological red shift is caused by the stretching of space as the universe expands.

red supergiant: An extremely luminous and large red star.

reddening: Dimming of starlight by interstellar matter, which tends to scatter high-frequency (blue) components of the radiation more efficiently than the lower-frequency (red) components.

reflecting telescope: A telescope which uses a carefully designed mirror to gather and focus light from a distant object.

refracting telescope: A telescope which uses a lens to gather and focus light from a distant object.

refraction: The tendency of a wave to bend as it passes from one transparent medium to another.

relativistic particle: A particle moving at nearly the speed of light.

relativity, general theory: A theory formulated by Einstein that describes how a gravitational field can by replaced by a curvature of space-time.

relativity, special theory: A theory formulated by Einstein that describes the relations between measurements of physical phenomena by two different observers who are in relative motion at constant velocity.

resolution: In astronomy, "resolution" or "resolving power" refers to the ability of a telescope to distinguish details. "Angular resolution" refers to the ability to distinguish details in an image. For example, Chandra can distinguish details that are only half an arc second apart. If your eyes had similar resolving power, you could read the letters on a stop sign at a distance of 12 miles! "energy resolution" refers to the ability to distinguish the energies or wavelengths of photons. In visible light, this amounts to the ability to distinguish different colors. When Chandra makes an observation with the transmission gratings in place, it can distinguish thousands of different X-ray energies or colors.

revolution: Orbital motion of one body about another, such as the Earth about the Sun.

right ascension: Celestial coordinate used to measure longitude on the celestial sphere. The zero point is the position of the Sun on the vernal equinox.

Roche limit: Often called the tidal stability limit, the Roche limit gives the distance from a planet at which the tidal force, due to the planet, between adjacent objects exceeds their mutual attraction. Objects within this limit are unlikely to accumulate into larger objects. The rings of Saturn occupy the region within Saturn's Roche limit.

Roche lobe: An imaginary surface around a star. Each star in a binary system can be pictured as being surrounded by a tear-shaped zone of gravitational influence, the Roche lobe. Any material within the Roche lobe of a star can be considered to be part of that star. During evolution, one member of the binary star can expand so that it overflows its own Roche lobe, and begins to transfer matter onto the other star.

rotation: Spinning motion of a body about an axis.

rotation curve: Plot of the orbital speed of disk material in a galaxy against its distance from the galactic center. Analysis of rotation curves of spiral galaxies indicates the existence of dark matter.

RR Lyae star: Variable star whose luminosity changes in a characteristic way. All RR Lyae stars have more or less the same period.

S

satellite: A body that orbits around a planet, such as the Moon (a natural satellite) or the Chandra X-ray Observatory (an artificial telescope), both of which orbit around the Earth.

SO Galaxy: Galaxy which shows evidence of a thin disk and a bulge, but which has no spiral arms and contains little or no gas.
SBO Galaxy: An SO-type galaxy whose disk shows evidence of a bar.
Schwarzschild radius: The distance from the center of a non-rotating black hole such that, if all the mass were compressed within that region, the escape velocity would equal the speed of light. Once a stellar remnant collapses within this radius, light cannot escape and the object is no longer visible. See event horizon.
scientific method: The set of rules used to guide science, based on the idea that scientific "laws" be continuously tested, and replaced if found inadequate.
second of arc: See "
Seyfert galaxy: Type of active galaxy that exhibits intense energetic activity from a small region within the nucleus of an otherwise normal-looking spiral galaxy.
shock waves: A wave front marked by an abrupt change in pressure caused by an object or material moving faster than the speed of sound. For example, a sonic boom produced by an aircraft going faster than the speed of sound.
singularity: A point in the universe where the density of matter and the gravitational field are infinite, such as the center of a black hole.

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(SIRTF) Space Infrared Telescope Facility: NASA's Great Observatory for infrared astronomy, later renamed

S

solar flare: An outburst caused by the sudden release of energy that heats and accelerates matter in the solar atmosphere, and produces a sudden brightening over a wide range of wavelengths.
solar wind: A flow of hot charged particles leaving the Sun.
south celestial pole: Point on the celestial sphere directly above the Earth's south pole.
spacetime: A synthesis of the three dimensions of space and of a fourth dimension, time; a hallmark of relativity theory.
spectral class: Classification scheme, based on the strength of stellar spectral lines, which is an indication of the temperature of a star.
spectral line: A radiative feature observed in emission (bright) or absorption (dark) at a specific frequency or wavelength.
spectrometer: Instrument used to produce detailed spectra of cosmic objects. Usually, a spectrometer records a spectrum in electronic form on a computer.
spectroscope: Instrument used to view a light source so that it is split into its component colors.

spectroscopic binary: A binary-star system which from Earth appears as a single star, but is known to contain more than one star because of the back-and-forth Doppler shifts that are observed as the two stars orbit one another. another.

spectroscopic parallax: Method of determining the distance to a star by measuring its temperature and then determining its absolute brightness by comparing with a standard H-R diagram. The absolute and apparent brightness of the star gives the star's distance from Earth.

spectroscopy: The study of the way in which atoms absorb and emit light electromagnetic radiation. Spectroscopy allows astronomers to determine the chemical composition of stars.

spectrum: See

speed of light: The fastest possible speed, according to the currently known laws of physics. Electromagnetic radiation exists in the form of waves or photons moving at the speed of light.

spiral arm: Distribution of material in a galaxy in a pinwheel-shaped design apparently emanating from near the galactic center.

spiral density wave:

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(i): a wave of matter formed in the plane of planetary rings, similar to ripples on the surface of a pond, which wrap around the rings forming spiral patterns similar to grooves in a record disk. Spiral density waves can lead to the appearance of rings.

(ii): A proposed explanation for the existence of galactic spiral arms, in which coiled waves of gas compression move through the galactic disk, triggering star formation.

S

spiral galaxy: Galaxy composed of a flattened, star-forming disk component which may have spiral arms and a large central galactic bulge.

Spitzer Space Telescope: NASA's Great Observatory for infrared astronomy was launched in August 2003. Formerly named

S process: "Slow" nuclear fusion that occurs in highly evolved stars when a neutron is slowly captured by a nucleus.

standard candle: Any object with an easily recognizable appearance and known luminosity, which can be used in estimating distances. Supernovae, which all have the same peak luminosity (depending on type) are good examples of standard candles and are used to determine distances to other galaxies, see also Cepheid variable.

star: A glowing ball of gas held together by its own gravity and powered by nuclear fusion in its core.

star cluster: A grouping of anywhere from a dozen to a million of stars which formed at the same time from the same cloud of interstellar gas. Stars in clusters are useful to aid our understanding of stellar evolution because they are all roughly the same age and chemical composition, and lie at roughly the same distance from the Earth.

starburst galaxy: Galaxy in which a violent event, such as near-collision, has caused a sudden, intense burst of star formation in the recent past.
stellar evolution: The changes experienced by stars as they originate, mature, and grow old.
stellar nucelosynthesis: The process by which heavier elements are formed from lighter ones by nuclear fusion in the cores of stars.
stellar occulation: The dimming of starlight produced when a solar system object such as a planet, moon or ring, passes directly in front of a star.
stellar wind: The outflow of gas, sometimes at speeds as high as hundreds of kilometers per second, from a star.
strong force: See "nuclear force."
subgiant branch: The section of an evolutionary track of a star that corresponds to changes that occur just after hydrogen is depleted in its core, and core hydrogen burning ceases. Shell hydrogen burning heats the outer layers of the star, which causes a general expansion of the stellar envelope.
supercluster: Grouping of several clusters of galaxies into a larger, but not necessarily gravitationally bound, unit.
supergiant star: An extremely luminous, massive star with a radius between 100 and 1000 times that of the Sun.
supermassive black hole: A black hole with a mass much greater than the most massive stars (100 solar masses). The central regions of virtually every galaxy are thought to contain a supermassive black hole of a million solar masses or more.
supernova: Explosive death of a star, caused by the sudden onset of nuclear burning in a white dwarf star (Type Ia), or gravitational collapse of the core of massive star followed by a shock wave that disrupts the star(Type II, Type Ib, Ic). A supernova is one of the most energetic events of the universe and may temporarily outshine the rest of the galaxy in which it resides.
supernova remnant: The expanding glowing remains from a supernova.
synchrotron radiation: Type of nonthermal radiation caused by high-speed charged particles, such as electrons, emitting radiation as they are accelerated in a magnetic field.
synchronous orbit: State of an object when its period of rotation is exactly equal to its average orbital period. The Moon is in synchronous orbit, and so presents the same face toward Earth at all times.

T

T Tauri star: A class of very young, often flaring stars on the verge of reaching the main sequence.
telemetry: The automatic measurement and transmission of data by wire, radio, or other means from remote sources, as from space vehicles, to receiving stations for recording and analysis. Telemetry is used on satellites to monitor environmental conditions, equipment parameters, the position of the satellite, etc.

telescope: Instrument used to capture as many photons as possible from a given region of the sky and concentrate them into a focused beam for analysis.
temperature: A measure of the amount of heat in an object, and an indication of the speed of the particles that comprise it.
thermal radiation: Radiation released by virtue of an object's heat; namely, by charged particles interacting with other charged particles.
thick disk: Region of a spiral galaxy where an intermediate population of stars resides, younger than the halo stars, but older than stars in the disk.
tidal bulge: Elongation of the Earth caused by the difference between gravitational force on the side nearest the Moon and the force on the side farthest from the Moon. The long axis of the tidal bulge points toward the Moon. More generally, the deformation of any body produced by the tidal effect of a nearby gravitational object.
tidal force: The variation in one body's gravitational force from place to place across another body - for example, the variation of the Moon's gravity across the Earth.
tides: Rising and falling motion that bodies of water follow, exhibiting daily, monthly and yearly cycles. Ocean tides on Earth are caused by competing gravitational pull of the Moon and Sun on different regions of the Earth.
time dilation: A prediction of the theory of relativity, closely related to the gravitational redshift. To an outside observer, a clock lowered into a strong gravitational field will appear to run slow.
total eclipse: Celestial event during which one body is completely blocked from one view by another.
transmission grating: A device that disperses light into a spectrum of wavelengths when it passes through a finely constructed grating.
transverse motion: Motion perpendicular to a particular line of sight, which does not result in Doppler shift in radiation received.
triangulation: Method of determining distance based on the principles of geometry. A distant object is sighted from two well- separated locations. The distance between the two locations and the angle between the line joining them and the line to the distant object are all that are necessary to ascertain the object's distance.
triple-alpha process: The generation of Carbon-12 from the fusion of three helium-4 nuclei (alpha particles). Helium-burning stars occupy a region of the H-R diagram known as the horizontal branch.
Tully-Fisher relation: A relation used to determine the absolute luminosity of a spiral galaxy. The rotational velocity, measured from the broadening of spectral lines, is related to the total mass, and hence the total luminosity.
turbulence: The disordered, irregular motion of matter, so complex as to defy description except in a statistical manner.

21-centimeter radiation: Radio radiation emitted when an electron in the ground state of a hydrogen atom flips its spin to become parallel to the spin of the proton in the nucleus.

T

type-I supernova: One possible explosive death of a star. When accretion of gas from a companion star in a binary system or merger with another white dwarf push a white dwarf star's mass over the Chandrasekhar limit of 1.4 solar masses, the temperature in the core of the white dwarf star increases, triggering explosive nuclear fusion reactions that release an enormous amount of energy. The star explodes in about ten seconds, leaving no remnant. The expanding cloud of ejecta glows brightly for many weeks as radioactive nickel produced in the explosion decays into cobalt and then iron.
type-II supernova: One possible explosive death of a star, in which the massive highly evolved stellar core rapidly implodes and then explodes, destroying the surrounding star.

U

ultraviolet: Region of the electromagnetic spectrum, just outside the visible range, corresponding to wavelengths slightly shorter than blue light.
universe: The totality of all matter, radiation and space; everything accessible to our observations.

V

Van Allen belts: Doughnut-shaped regions of magnetically trapped charged particles high above the Earth's atmosphere.
variable star: A star whose luminosity changes with time.
visible spectrum: The small range of the electromagnetic spectrum that human eyes perceive as light. The visible spectrum ranges from about 4000 to 7000 angstroms, corresponding to blue through red light.
visible light: The small range of the electromagnetic spectrum that human eyes perceive as light. The visible spectrum ranges from about 400 to 700 nm, corresponding to blue through red light.
visual binary: A binary star system in which both members are resolvable from Earth.
void: Large, relatively empty region of the universe around which superclusters of galaxies are organized.

W

wave: A pattern that repeats itself cyclically in time and space. Waves are characterized by the velocity with which they move, their frequency, and their wavelength.
wave period: The amount of time required for a wave to repeat itself at a specific point in space.
wavelength: The distance between successive crests of a wave.

weak force: The nuclear force involved in radioactive decay. The weak force is characterized by the slow rate of certain nuclear reactions such as the decay of the neutron, which occur with a half-life of 11 min.
white dwarf: A star that has exhausted most or all of its nuclear fuel and has collapsed to a very small size; such a star is near its final stage of life.
white light: Visible light that contains approximately equal proportions of all colors.
Wolf-Rayet stars: Wolf-Rayet stars are hot luminous stars that are rapidly losing mass in a wind. They represent a late stage of evolution for massive stars (initial mass greater than about 40 suns). The outer, hydrogen-rich, envelope of the star has been driven off by radiation pressure, exposing the hot helium core. In a few million years or less they will explode as a supernova. A Wolf-Rayet phase is also present in some central stars of planetary nebulae. In these stars, which have lower masses and will evolve into white dwarfs, the outer envelope has been expelled in the red giant phase, exposing the hot core. Such stars show many of the characteristics of standard Wolf-Rayet stars and are referred to as "Wolf-Rayet type" stars.

X

XMM/Newton: The European Space Agency's large X-ray observatory, launched on Dec 10, 1999, which is capable of sensitive x-ray spectroscopic observations.
X-ray: Region of the electromagnetic spectrum corresponding to radiation of high frequency and short wavelengths, far outside the visible spectrum.
X-ray burster: X-ray source that radiates thousands of times more energy than our Sun, in short bursts that last only a few seconds. A neutron star in a binary system accretes matter onto its surface until temperatures reach the level needed for hydrogen fusion to occur. The result is a sudden period of rapid nuclear burning and release of energy.

Z

zero-age main sequence: The region on the H-R diagram, as predicted by theoretical models, where stars are located at the onset of nuclear burning in their cores.
zeroth-order image: A zeroth-order image obtained by HETG consists of photons that go "straight through" the gratings, i.e., are not redirected (dispersed) according to their energies. This is analogous to the case of an optical diffraction grating: if you look at a light bulb through such a grating, you see the bulb, and you also see spectra of the bulb off to each side of the bulb. The fact that you see the light bulb "straight through" the grating is due to the fact that the grating forms a "zeroth-order" image of the bulb at your eye.
zodiac: The twelve constellations through which the Sun moves as it follows its path on the ecliptic.