Lexicon

absolute luminosity the amount of light from an astrophysical object collected by a telescope.

address distance the distance between two objects when the scale factor is unity.

adiabatic a change in the thermodynamic state of a material without the loss of heat.

alpha decay A radioactive emission of a helium nucleus from a larger nucleus.

alpha particle a helium nucleus consisting of two protons and two neutrons, emitted in radioactive decays. Sometimes called an alpha ray.

alpha ray a helium nucleus consisting of two protons and two neutrons, emitted in radioactive decays.

anti-matter Distinct from matter: anti-neutrons, anti-protons, positrons, and anti-neutrinos are anti-matter particles.

astronomer a scientist who studies the universe by making observations using telescopes.

astronomical unit (AU) a unit of measure equal to the distance from the earth to the sun: 149,597,871 kilometers (or 92,955,807.3 miles, or 8.3 light minutes). The AU provides a convenient unit of measure for distances in the solar system: From the earth to the sun is one (1) AU, Mars lies at 1.52 AU, to Saturn is 9.5 AU, and Pluto (on average) is 39.5 AU. .

astrophysicist a scientist who uses physics to understand objects in the cosmos. Astrophysicists may also make astronomical observations.

atmospheric neutrino a low-mass, chargled particle created in the interaction of a cosmic ray with a nucleus in the atmosphere.

axion a very light particle hypothesized in an extension to the nuclear interaction. The axion could account for dark matter.

baryon a class of particles containing three quarks that include protons and neutrons. About 575 types of baryons have been observed at accelerators and in cosmic rays, but only protons and neutrons form stable nuclei. While protons never decay, an unbound neutron will decay after about 15 minutes.

Baryon acoustic oscillation the motion of baryonic matter inside dark matter fluctuations in the very early universe.

Baryonic matter particles composed of three quarks. Protons and neutrons are baryons.

beta decay the decay of a neutron in a nucleus or by itself to a proton, electron, and anti-neutrino.

beta ray electron or positron emitted in radioactive decay.

Big Bang nucleosynthesis the production of the lightest nucleons in the first few minutes of the Big Bang.

black body a body that emits radiation with a power proportional to the fourth power of the body's temperature..

black hole a region of space-time from which light cannot escape, usually thought to be formed when a star explodes and a large fraction of the matter collapses inward.

block size another name for scale factor.

boson a class of matter particles that are not fermions. Identical bosons can occupy the same point in space while having the same momentum.

broadband a device or communication channel that works with signals across a wide range of frequencies.

Bullet Cluster two colliding clusters of galaxies about 3 Gly from Earth. Observations of the Bullet Cluster indicate the presence of dark matter.

causal contact two events whose space-time coordinates allow light to traverse between them without exceeding the speed of light. The term refers to the earlier event having the possibility of causing the later event.

caustic a region, usually linear, in a wave of particles or fluid of much higher density than the surroundings. A wave moving into a changing environment can develop a caustic.

Cephied variable star a class of stars whose brightness varies with a frequency that depends on the star's mass.

charge frequently used to refer to electrical charge, a property of a particle or substance to experience a repulsive force in the presence of a like charge, and an attraction in the presence of an opposite charge. Other forces also have charges that determine their strength, and the term can more generally refer to the strength of an interaction between two particles.

Coma Cluster a cluster of 1,000 galaxies 323 Mly from Earth, spanning about 4 degrees on the sky.

cosmic microwave background (CMB) radio waves that pervade the universe. The CMB was visible light that began freely propagating when hydrogen formed 370,000 years after the Big Bang, rendering the universe transparent to radiation. As the universe expanded, the CMB photons stretched from visible to microwave wavelengths.

cosmic ray an energetic particle, such as a proton, photon, or neutrino, traversing the Milky Way.

cosmological constant a numerical factor Einstein added to his original field equations to described a universe in steady state.

cosmological principle the assumption that the universe is the same everywhere, homogeniety, and the same in every direction, isotropy.

cosmologist a scientist who studies the universe as whole. Cosmologists usually also are astrophysicists.

coulomb interaction the force between two electrically charged particles.

current charges in motion, usually referring to charge motion inside a wire.

dark energy a negative pressure form of energy uniformly spread through all of space, causing the universe to expand.

dark matter matter not associated with the production of light in stars. Dark matter concentrates around galactic clusters and galaxies, along with normal matter.

decoupling a point in time when the average energy of particles in the universe becomes low enough such that one species of particles falls out of thermal equilibrium with the rest of the universe.

deuteron a proton and neutron bound together to form an isotope of hydrogen.

Double beta decay a very rare process in which an atomic nucleus emits two electrons. There are two kinds of double beta decay: one in which two neutrinos are emitted along with the two electrons, and another type without neutrino emission.

dynamical law a law that describes how forces are produced.

electrodynamics the theory of charged particles such as electrons and protons.

electromagnetic radiation any for of radiation generated by the motion of charged particles. See electromagnetic spectrum.

electromagnetic spectrum the range of electromagnetic radiation from radio waves to gamma rays. Fig. 1 shows the electromagnetic spectrum. .

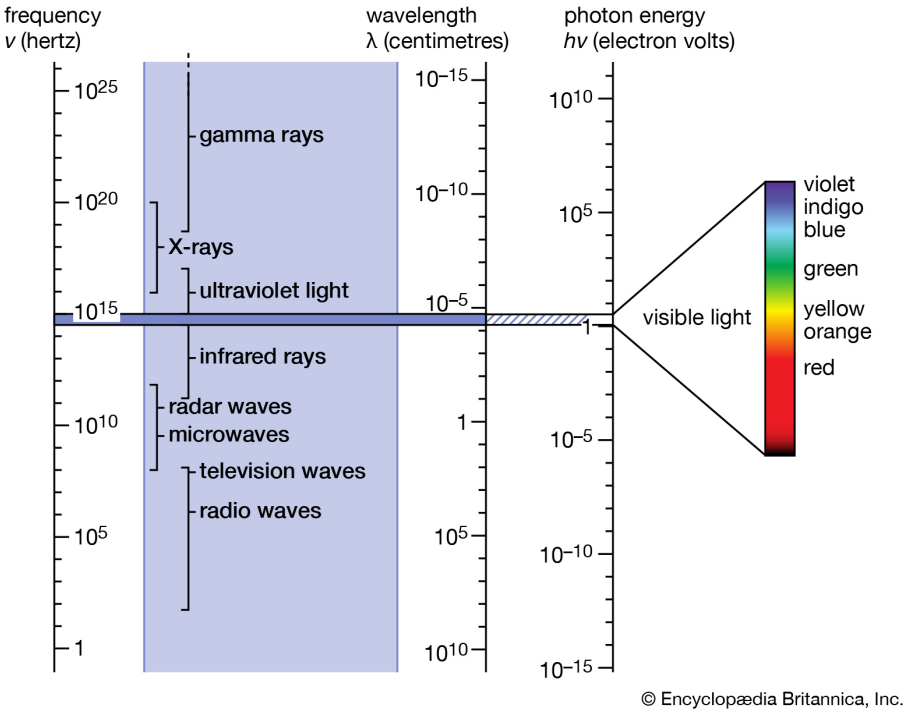

Figure 1: The electromagnetic spectrum.

electron a point-like negatively charged particle weighing 1/2,000th of a proton. Electrons are stable and form atoms when they orbit atomic nuclei composed of protons and neutrons.

electron volt the energy of a particle with unit charge accelerated across one volt of potential. 1 eV=$1.6 \times 10^{-19} J$.

element a class of atoms with Z protons. Elements have isotopes that have varying number of neutrons. An element has characteristic chemical properties.

energy density amount of energy per unit volume at a certain location.

energy threshold when measuring a particle with a detector, the minimum energy the particle must have to be detected. For a particle collision, the minimum total energy in the center of mass the colliding particles must have to produce a given final state.

equilibrium the condition between two bodies at the same temperature or an extended body whose temperature is the same everywhere.

Fast Fourier Transform (FFT) an algorithm for converting a time varying electrical signal into its frequency components.

fermion a class of matter particles with the characteristic feature that two identical such particles, electrons for example, cannot be in the same place with the same momentum.

fine-tuning problem the requirement that Standard Model parameters must have precise values in order for the mass of the Higgs boson to have its measured value.

fluctuation a quantum mechanical variation in mass density.

force a property whose application to a body changes the body's momentum.

force carrier particles such as photons that communicate a force from one matter particle to another.

frame a coordinate system for specifying the position of objects.

frequency the number of oscillations at a fixed point in space of an electromegntic wave.

galaxy a gravitationally bound collection of stars, gas, dust, and dark matter. A typical galaxy contains one to 10 billion stars in a flat disk.

galaxy cluster a gravitationally bound group of galaxies. Galaxy clusters may contain several thousand galaxies.

gamma ray a very energetic photon, typically emitted in nuclear transitions.

gauge boson bosons that carry forces between two particles. The term "gauge" refers to a specific class of particles, incorporated in the Standard Model, that result from a quantum mechanical degree of freedom. The photon, gluon, and weak force carriers are all gauge bosons.

general theory of relativity Einstein's theory of gravity published in 1915, which uses the distortion of space and time to explain motion near massive objects.

generation in the Standard Model, similar particles occur in pairs, and each pair is a generation. For example, the lowest mass generation of quarks is the (up, down) generation.

gluon a force carrier for the strong interaction that causes quarks to interact. The gluon plays the same role for the strong interaction as the photon does for the electromagnetic interaction.

gravitational lensing the distortion of an image caused by the light from the image passing through a gravitational field between the light and an observer.

gravitational wave propagating waves of space-time caused by the motion of large masses.

gravitational well a region of large gravitational attraction caused by the presence of matter.

hadron a sub-atomic particle composed of quarks. For example, baryons have three quarks, and mesons have a quark and an anti-quark.

HI region an interstellar region of neutral hydrogen gas.

Higgs boson a particle in the Standard Model with about 125 proton masses that pervades all of space, interacting with every particle constantly, giving the particles their mass.

hole a missing electron in matter, e.g. a superconductor. Holes are positively charged and mobile. Think of a hole as an empty seat in an otherwise full theater–the hole can "move" by the person next it switching seats.

homogeniety the property of an extended system that all meaningful variables are the same at teach point.

Hubble flow the local motion of galaxies expanding with the universe.

inertia the tendency of an object in motion to remain in motion and an object at rest to remain at rest.

inertial frame a frame moving at constant veolcoty with respect to the observer.

inflation the rapid expansion of the universe from $10^{-36} to 10^{-32}$s after the Big Bang. Inflation is caused by a hypothesized particle transitioning to its lowest energy state.

ionization energy loss the loss of energy of a high-speed, charged particle by pulling an electron off of a nearby atom.

isotope a chemical element with a specific number of neutrons in its nucleus. For example, there are two isotopes of helium, ^{3}He, whose nucleus consists of two protons and one neutron and ^{4}He that has two protons and two neutrons in its nucleus.

isotropy the p[roperty of an exgtended system that all directions are the same.

kinematic law the study of the fundamental properties of motion. A kinematic law relates motion to applied forces.

Large and Smarge Magellanic Clouds (LMC and SMC) small galaxies 163 ly outside the Milky Way galaxy. Gravity holds them to the Milky Way, making the LMC and the smaller Small Magellanic Cloud satellites of the Milky Way.

lepton matter particles that do not strongly interact. Electrons and neutrinos are leptons.

light year (ly) the distance traveled by light in one year, 9.3×10^{15}m.

luminous matter normal matter bound in stars or dust clouds that emits or reflects light.

luminous matter matter bound in stars or dust clouds that emits or reflects light. Also referred to as visible matter, luminous matter.

MacGuffin an insignificant object that serves to advance a story line. Originally used by Alfred Hitchcock, who said in a 1935 interview, "It might be a Scottish name, taken from a story about two men on a train. One man says, 'What's that package up there in the baggage rack?' And the other answers, 'Oh, that's a MacGuffin.' The first one asks, 'What's a MacGuffin?' 'Well,' the other man says, 'it's an apparatus for trapping lions in the Scottish Highlands.' The first man says, 'But there are no lions in the Scottish Highlands,' and the other one answers, 'Well then, that's no MacGuffin!' So you see that a MacGuffin is actually nothing at all.".

mass the proportionality constant between force and acceleration; how much force is needed to produce one unit of acceleration. Also the strength of an interaction between a body and the local gravitational field.

mass density the amount of mass per unit volume at a certain location.

mass-energy used to signify the stuff of the universe. Mass-energy included the rest mass and kinetic energy of the stuff.

Massive Compact Halo Object (MACHO) astrophysical objects whose size is small enough and whose density is high enough to cause microlensing of light from a star. PBHs are MACHOs.

matter two uses. First, the matter particles in the Standard Model: quarks and leptons. Quarks and leptons bind in various ways to form matter. Second, distinct from anti-matter: Neutrons, protons, electrons, and neutrinos are matter particles. The first use includes anti-matter. .

matter density amount of matter per unit volume at a specific location.

microlensing the apparent brightening of a star or other luminous object by an intervening object of planetary to stellar mass.

microwaves high-frequency radio waves. Cell phones use microwaves to send and receive signals to cell phone towers.

modified Newtonian dynamics a theory proposing a gravitational force law different from Newton's force law in an attempt to explain the effects of dark matter.

muon a heavy, unstable lepton that decays to an electron and neutrinos in two millionths of a second.

nebula from the German word for "foggy," nebula referred to extended astrophysical objects later referred to as galaxies.

neutrino a chargeless, very light particle that interacts only weakly and gravitationally. There are three different kinds of neutrinos, each associated with a charged lepton.

neutron a chargeless particle with a mass slightly heavier than the proton. Unbound neutrons have a lifetime of about 15 minutes, while neutrons bound in a nucleus or a neutron star are stable. Neutrons and protons bind together to form an atomic nucleus.

neutron star a collapsed star dense enough to have converted all its protons into neutrons.

number density a number of particles in a unit of volume at a specific location.

parsec an abbreviation for parallax arc-second, the distance from which the earth's orbit subtends 1 second of arc, equal to 3.1×10^{16}m or 3.3 ly.

parsec the distance at which the Earth's orbit radius around the Sun, 1 AU, subtends on sec of arc. Equal to 3.26 ly.

particle annihilation the collision and conversion of a particle and its anti-particle to another form of matter. Electrons and positrons may collide and annihilate to form photons, neutrinos, or other particles, depending on the energy of the collision.

particle physicist a scientist who either develops theories or performs experiments to understand the interactions between fundamental particles.

particle theory the branch of particle physics tasked with developing formal theories that comprehensively explain experimental observations.

phase transition a change in state of matter from one form to another. Water freezing into ice is an example of a phase transition.

phonon a propagating vibration in a lattice of atoms. Phonons can be described quantum mechanically as particles.

photo electric effect the emission of electrons from a metal surface that occurs when the electromagnetic radiation illuminating the metal surface is above a threshold value. Early evidence for the quantization of light into photons.

photon the force carrier for the electromagnetic force. Photons carry light, radio waves, and gamma rays. Photons are bosons.

pion the lightest nuclear particle consisting of a quark and an anti-quark from the lightest quark generation.

planckConstant the ratio between the energy and frequency of a photon, denotesd as h. $h = 4.1 \times 10^{-15}$ eV-s.

positron the anti-particle of the electron.

potential well a region of large attraction from a force.

primordial black hole a black hole formed in the early universe by quantum mechanical density fluctuations.

proton a heavy, positively charged particle that binds with other protons and neutrons to form the atomic nucleus.

pulsar a neutron star with a strong magnetic field spinning tens to hundreds of times per second.

quantum chromodynamics (QCD) Quantum Choromodynamics, also known as the strong interaction, which binds the nucleus.

quark a point-like particle found in protons and neutrons. Quarks are fermions.

quasar short for quasi-stellar radio source; the most distant observable objects, probably super-massive black holes in the centers of large galaxies.

radiation a general term for particles emitted when other particles decay. Without a modifier, radiation usually refers to light (photons).

radio wave the part of the electromagnetic spectrum up to terahertz frequencies. .

radiometer a device for measuring the power of electromagnetic radiation.

recoil particle a stationary particle struck by an energetic particle, receiving momentum, and moving or recoiling.

redshift the stretching of light waves to longer wavelengths, toward the red end of the visible spectrum.

scalarBoson bosons that do not carry angular momentum. The Higgs boson is a scalar boson.

scale factor the time varying size of an increment in address distance, also called conformal distance. Also refereed to as block size..

scientific notation a means of expressing large numbers by indicating the number of zeros (the exponent) following a mantissa that gives value. Examples: 10^0=1, 10^1=10, 3$\times$ 10^3=3,000, 6.5$\times$ 10^6=6,500,000.

scintillation light light produced by charged particle moving inside of certainly materials, called scintillators, whose chemical composition make them produce optical photons from the ionization caused by a charged particle moving through the material.

single-sided bound an experimental or theoretical results that bounds a quantity from above of below, for example, accelerator experiments that unsuccessfuly searched for the Higgs boson in the 1990's were able to place lower limits on the Higg's boson's mass.

special theory of relativity Einstein's 1905 theory of kinematics based on the velocity of light remaining the same for all observers.

spectrograph an instrument on a telescope for measuring the spectrum of the incoming light.

spiral galaxy a galaxy with characteristic spiral arms. There are also elliptical and spherical galaxies.

standard candle an astrophysical object whose absolute luminosity can be calibrated, allowing a distance measurement using the apparent luminosity.

Standard Model the reigning theory of fundamental interactions between particles.

sterile neutrino a speculative additional neutrino that does not interact with normal matter.

string theory an approach to unifying the Standard Model and gravity by treating particles as vibrations on closed one-dimensional energy fields called strings.

strong interaction one of the four known forces in nature, this short-range force confines quarks inside a proton. The strong forces also bind the neutrons and protons that make up a nucleus.

strong lensing gravitational lensing of a distant source by an intervening mass that is strong enough to create multiple images of the distant source.

substructure concentrations of dark matter within galaxies.

super nova a star that burns out its hydrogen fuel, collapses, and then explodes, creating a bright flash of light lasting days, ejecting particles into the universe and leaving a black hole or neutron star as a remnant.

supersymmetry (SUSY) a speculative theory that aims to solve the fine-tuning problem by postulating an as-yet-undiscovered partner particle for every particle in the Standard Model.

tau a cousin of the electron with a mass 3,400 times larger. The tau lepton is unstable and can decay to a muon, electron, or hadrons, and a tau neutrino.

tau lepton a heavy lepton that decays into electrons, muons, or quarks and neutrinos.

temperature the average energy of particles when they are in thermal equilibrium.

tidal force the stretching force felt by a body in a spatially changing gravitational field. The ocean tides on Earth partially result from the water on the side of the earth closer to the sun feeling a greater gravitational pull than the water on the side of the earth farthest away from the sun.

tracker a particle detector that determines the trajectory of a charged particle passing through it. When used in a magnetic field, it can determine the momentum of the particle.

vacuum expectation value (vev) the quantum mechanics probability of finding a particle in the vacuum, the state where no other particles are present. In the Standard Model, the vacuum expectation value for an electron is zero; while for the Higgs boson, the vacuum expectation value is not zero. The zero zero vacuum expectation value for the Higgs boson is part of the mechanism that causes all particles to have mass.

vector boson bosons that carry one unit of angular momentum. All the force carriers in the Standard Model are vector bosons. Also called gauge bosons.

virial theorem a general theorem from mechanics relating the kinetic energy with the potential energy of a bound system of particles.

visible matter matter associated with the production of light in stars.

wavelength the distance between crests in an electromangetic wave.

weak lensing gravitational lensing of a distant source by an intervening mass that produces a distortion of the image of the distant source but no multiple images.

Weakly Interacting Massive Particle (WIMP) a particle not found in the Standard Model that could be dark matter, as yet unobserved.

weight the force on a mass caused by a gravitational field.

white dwarf a collapsed star that has burned out all its fuel but does not have enough mass to be a neutron star or black hole.

z teh redshift./. Numverically, z is the fractional change in wavelength from the motion of the emitter along the line of site between the observer and the emitter.