The Wilkinson Microwave Anisotropy Probe

GLOSSARY

Acceleration (of the expansion of space): The expansion, or stretching, of the universe at an increasing rate. (also see *cosmic expansion, cosmological constant*)

Age of the universe: Refers to the age of the observable universe. Cosmologists use the rate of the expansion of space (the Hubble constant) to determine the age of the universe. Knowing the rate at which galaxies are separating, and the distances among them, one can work backwards to determine how much time has passed when, in theory, there was no separation at all.

Most cosmologists expect the expansion rate to change with time. They had thought that the rate was faster in the past and that it slowed down to its current rate as gravity from all the mass in the universe gradually overcame the momentum from the Big Bang. Recently, however, astronomers observed very bright exploding stars called supernova to measure the universal expansion, and the results of these observations indicate that the universal expansion is speeding up, or accelerating.

This implies that the expansion rate was less in the past, so it took more time for galaxies to reach their present separations than if they had always been receding at the more rapid current rate. This indicates that the universe is actually older than it appears from a simple calculation using the current Hubble constant.

Anisotropy: Different when measured in different directions. In 1992, NASA's Cosmic Background Explorer (COBE) satellite detected tiny fluctuations, or "anisotropy," in the cosmic microwave background. It found, for example, that parts of the sky have a temperature of 2.7251 Kelvin, while other parts have a temperature of 2.7250 Kelvin. These temperature fluctuations are related to fluctuations in the density of matter in the early universe and thus carry information about the initial conditions for the formation of cosmic structures, such as galaxies, clusters, and voids.

Big Bang theory: The widely accepted theory for the evolution of our universe. Big Bang theory postulates that 12 to 14 billion years ago, the portion of the universe we can see today was only a few millimeters across. It has since expanded from this hot, dense state into the vast and much cooler cosmos we currently inhabit. We can see remnants of this hot, dense matter today in the form of the now very cold cosmic microwave background radiation, which pervades the universe and is visible to microwave detectors.

Clusters and superclusters of galaxies: The largest gravitationally bound structures in the Universe. A cluster of galaxies contains up to a few thousand galaxies, and the entire structure is roughly spherical and spans approximately 100 megaparsecs. Clusters of galaxies are thought to be held together gravitationally by hidden dark matter and are therefore the subject of much study. The Milky Way galaxy belongs to a small, irregular cluster called The Local Group. The Virgo Cluster is the closest large cluster.

Closed universe: A universe that is finite but without an edge or boundary, like the surface of a ball.

Cold Dark Matter: An exotic type of matter that does not interact with light. It is transparent, or "dark," and astronomers only know of its existence by its gravitational influence on ordinary matter.

Cosmic consistency: A term referring to a unified model that simultaneously explains all relevant cosmic observations. WMAP data, combined with other precision cosmological observations, point to a model that can predict key parameters, such as: the age and shape of the Universe, the era for first star light, the Hubble constant, and the matter and energy content in the Universe.

Contents (of the universe): The types of matter and energy that comprise the universe. Ordinary matter (atoms that make up stars, planets, and ourselves) is about 5% of the content of the universe. An unknown type of exotic matter, called "cold dark matter," is about 25%. About 70 percent of the "stuff" in the universe is mysterious dark energy. WMAP has refined these measurements further.

Cosmic expansion: The expansion, or stretching, of space as time passes. This is the fundamental part of Big Bang theory. In 1929, Edwin Hubble announced that observations of galaxies showed that they were systematically moving away from us with a speed that was proportional to their distance from us. The more distant the galaxy, the faster it was receding from us. The Hubble law is just what one would expect for a homogeneous expanding universe, as in the Big Bang theory. No galaxy occupies a special place in this universe.

Cosmic horizon: The limit of the observable universe. We can only see to a distance of the speed of light times the age of the universe. This is our observable cosmic horizon.

Cosmic Microwave Background (CMB): Radiation that is the remnant heat left over from the Big Bang; it's afterglow. The CMB radiation was emitted long before stars or galaxies ever existed. This radiation blankets the universe today at a rather chilly and uniform 2.73 Kelvin, or about -270 Celsius. Temperature fluctuations in the CMB today reflect density fluctuations moments after the Big Bang. These density fluctuations gave rise to the vast web-like structure of galaxies and voids we see today. By studying the detailed physical properties of the radiation, we can learn about conditions in the universe at very early times and also on very large scales.

Cosmological constant: A type of energy or matter that has a repulsive force, increasing the rate of expansion of the universe. Einstein first proposed the cosmological constant as a mathematical fix to the theory of general relativity. In its simplest form, general relativity predicted that the universe must either expand or contract. Einstein thought the universe was static, so he added this new term to stop the expansion. Friedmann, a Russian mathematician, realized that this was an unstable fix, like balancing a pencil on its point, and proposed an expanding universe model, now called the Big Bang theory. When Hubble's study of nearby galaxies showed that the universe was expanding, Einstein regretted this introduction of the cosmological constant. Recently, however, observations of very bright and distant exploding stars called supernova indicate that the universal expansion is speeding up, or accelerating. The cosmological constant is an example of the type of energy that could accelerate the expansion rate.

Cosmological principle: The idea that the universe, on the large scale, appears the same wherever you look. That is, the matter in the universe is homogeneous and isotropic when averaged over very large scales.

Cosmology: The scientific study of the large-scale properties of the universe as a whole. This scientific method is used to understand the origin, evolution, and ultimate fate of the universe. Like any field of science, cosmology involves the formation of theories or hypotheses about the universe, which make specific predictions for phenomena that can be tested with observations. Depending on the outcome of the observations, the theories need to be abandoned, revised, or extended to accommodate the data.

Critical density: An average density of matter and energy in the universe that would keep it balanced between two fates: eternal expansion and collapse. The universe would continue to expand, but at an ever-decreasing rate.

Dark energy: A type of energy that has repulsive properties, providing an anti-gravity effect that increases the rate of the expansion of the universe. (also see *cosmological constant*)

Decoupling: a period 380,000 years after the Big Bang when photons, or light particles, separated from matter and could propagate freely. Prior to this time, the scattering of photons on electrons in the dense, expanding Universe coupled matter with energy. When the Universe cooled to about 3,000 degrees, electrons could combine with protons, freeing photons. (also see *surface of last scatter, reionization*)

Flat universe: A universe in which the overall shape of space has no positive or negative curvature. Parallel lines never meet in a flat universe, as opposed to a universe that is curved. (also see *geometry*)

Galaxies: Immense aggregations of stars, gas, and dust held together by their mutual gravity. Our home, the Milky Way galaxy, is a typical large, spiral-shaped galaxy. It is about 100,000 light years across, and our Sun is one of about 100 billion stars that populate the Milky Way galaxy. One light year is almost six trillion miles or nearly 9.5 trillion kilometers.

Geometry (of the universe): The overall shape of the universe. The density and pressure of the matter and energy in the universe determine its shape, and its shape determines if it is finite or infinite. Space can be "positively" curved like the surface of a ball; it can be "negatively" curved like a saddle; or it can be "flat" and infinite in extent — our "ordinary" conception of space. It is possible that the universe has a more complicated global topology than that which is portrayed here.

Hubble constant: The rate of the expansion of the universe. It is usually expressed in kilometers per second per megaparsec. One megaparsec equals 3.26 million light years; one light year is almost 9.5 trillion kilometers or about 6 trillion miles. WMAP has refined this measurement.

Inflation: A theory that proposes a period of extremely rapid (exponential) expansion of the universe shortly after the first instant of its existence. Inflation theory complements Big Bang theory. The Big Bang theory successfully explains the expansion of the universe, the cosmic microwave background spectrum, and the origin of the light elements. However, it leaves open a number of important questions, namely: Why is the universe so uniform on the largest length scales? What physical process produced the initial fluctuations in the density of matter? Why are there so many photons (particles of light) in the universe? And why is the physical scale of the universe so much larger than the fundamental scale of gravity, the Planck length, which is one billionth of one trillionth of the size of an atomic nucleus?

The Inflation theory, developed by Alan Guth, Andrei Linde, Paul Steinhardt, and Andy Albrecht, offers answers to these and several other open questions in cosmology. It proposes a period of extremely rapid expansion a fraction of a second after the Big Bang, when the visible universe expanded from a tiny to cosmic scale in a thousandth of a second, faster than light. In its simplest form, the Inflation theory makes a number of important predictions: the geometry of the universe is flat; fluctuations in the primordial density in the early universe had about the same amplitude on all physical scales; and there should be, on average, equal numbers of hot and cold spots in the fluctuations of the cosmic microwave background temperature.

Kelvin: a unit of temperature, abbreviated as "K". Zero K is the complete absence of heat, called "absolute zero" and equal to minus 273.15 degrees Celsius. Similarly, 273.15 Kelvin is the same as 0 degrees Celsius.

L2 Orbit: An orbit about the second Lagrange point of the Sun-Earth system. Lagrange points are positions in space where the gravitational pull of two large masses precisely equals the centripetal force required to rotate with them. L2 is four times farther from the Earth than the Moon in the direction opposite the Sun, or about one million miles (1.5 million kilometers) from Earth. From L2, MAP has an unobstructed view of the sky, and is free from near-Earth disturbances such as magnetic fields and microwave emission.

Lyman-alpha forest: A series of absorption lines (in a spectral readout, resembling tree trunks) associated with very distant quasars. These numerous, single, narrow absorption lines are a result of primordial matter lying within the line of sight of a quasar, blocking some of the quasar's light from reaching us. Scientists use the Lyman-alpha forest to trace how mass (matter) congregates on the size scale of a few megaparsecs, which is smaller than galaxy redshift surveys.

Megaparsec: A distance of one million parsecs. One parsec equals 3.2616 light years or 30.86 million million kilometers. Parsec is short for parallax second, the distance at which the semi-major axis of the Earth's orbit subtends an angle of one arc second.

Multifrequency: Five frequency bands from 22 GHz to 100 GHz allow emission from our Galaxy and environmental disturbances to be modeled and removed based on their frequency dependence.

Observable universe: (See *cosmic horizon*)

Open universe: A universe that will continue to expand forever; where the pull of gravity is not sufficient to overcome the momentum of cosmic expansion.

Planck time: A time equal to 5.4×10^{-43} second, a tiny fraction of a second. The uncertainty principle of quantum mechanics prevents any speculation in times shorter than the Planck time after the Big Bang. Planck time is based on the Planck constant, a fundamental constant relating the wavelike and particle-like duality of electromagnetic radiation. The four fundamental forces — gravity, electromagnetic, weak, and strong — are thought to be unified at Planck time.

Redshift: The shifting of light to less energy. The energy level of light corresponds to its color; blue light has more energy than red. Thus, the shifting of light to less energetic forms came to be called "redshift." Light has wavelike properties related to its energy level; the faster it is vibrating, the more energy it carries. More rapid vibration corresponds to a higher frequency and a shorter wavelength (distance between the crests of a wave). Conversely, slow vibration corresponds to a lower frequency and a longer wavelength. The stretching of space lengthens the wavelength of light by putting more space between the crests of its waves. (Imagine drawing a wavy line on a rubber band and then stretching the rubber band.) It is the stretching of space that causes the redshift of light from distant galaxies and the cooling of the cosmic microwave background light. As such, redshift is used to measure distances, with more distant objects having a higher redshift.

Reionization: Commonly refers to the era of first star light when, after a prolonged "dark age," stars formed and ionized atoms. Ionization is a state in which an atom is missing one or more of its electrons, usually due to heat. After the Big Bang, the Universe was too hot to allow electrons to bind with protons. Then the Universe expanded and cooled, allowing this binding (called recombination), roughly 380,000 years after the Big Bang. Reionization took place hundreds of millions of years after this.

Structure (of the universe): The pattern of galaxies, galaxy clusters, and other features in the universe.

Supernova: An exploding star (plural: supernovae). Supernovae can outshine a hundred billion suns; this extreme brilliance lets astronomers use them as cosmic beacons to study the remote universe. Observations of distant supernovae indicate that the expansion of the universe is accelerating.

Surface of last scatter: The limit of the observable universe probed by the cosmic microwave background, 380,000 years after the Big Bang. Refers to the time when the universe cooled enough to allow electrons to bind with protons, which made the universe more transparent to light.

Universe: The totality of all that physically exists.

WMAP: The NASA Wilkinson Microwave Anisotropy Probe, launched on June 30, 2001, and named in honor of the late David Wilkinson of Princeton University. This NASA satellite surveys the entire cosmic microwave background, the first and oldest light in the universe.