The Universe

The universe is all of space, time, matter, and energy that exist. Universe is not just space, but space is just the framework or the scaffolding in which the universe exists. As Space and time are intimately connected in a four-dimensional fabric called space-time.

Age of Universe

The universe is not infinitely old. According to modern astronomical measurements, the universe began to exist about 13.7 billion years ago.

Size of Universe

It has not yet been scientifically determined exactly how large the universe is. It may indeed be infinitely large, but we have no way yet to confirm this possibility scientifically.

Cosmic Horizon

The farthest limit to our viewing is called the cosmic horizon, which is about 13.7 billion light-years away in every direction. Everything within that cosmic horizon is called the observable universe.

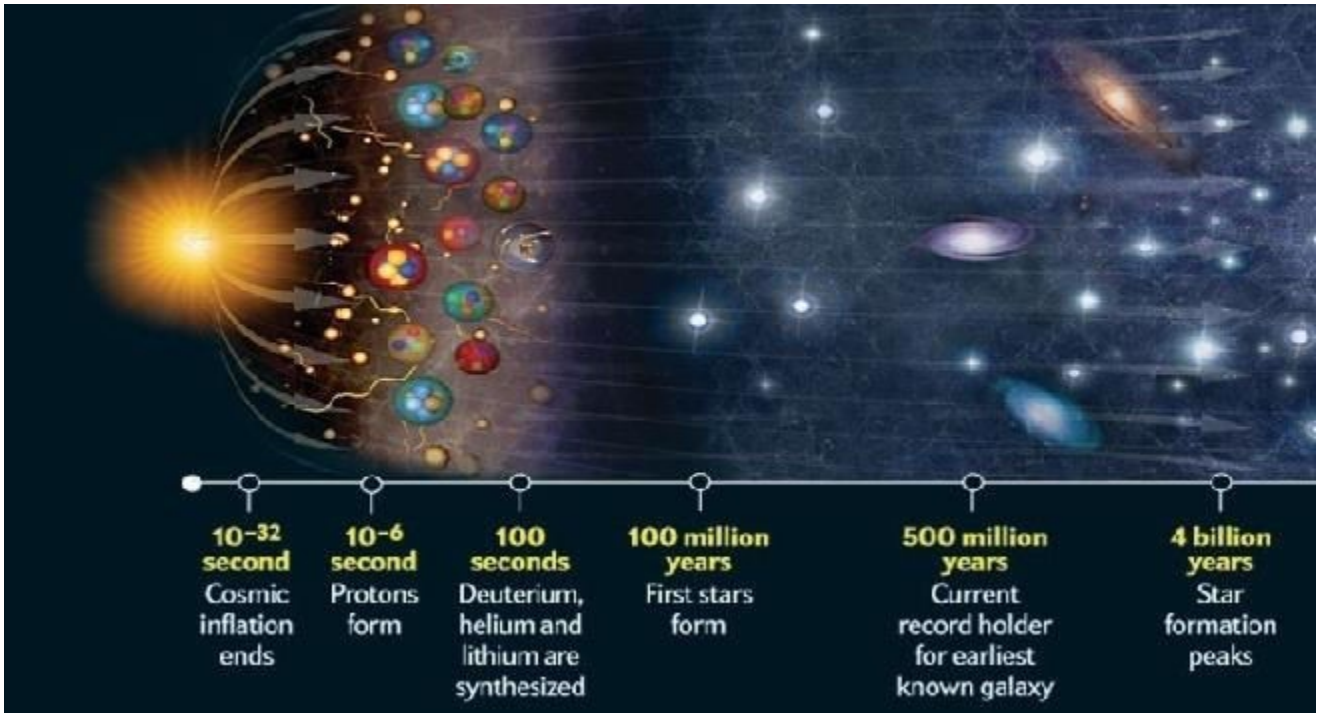
Structure of Universe

The structure of the universe—as opposed to the structure of matter in the universe— is determined by the shape of space. The shape of space is, surprisingly, curved. On a very large scale—millions or even billions of light-years across—space has a three- dimensional "saddle shape" that mathematicians refer to as "negative curvature".

BIG BANG THEORY

In 1929, Edwin Hubble analyzed and concluded that the galaxies are drifting apart. This became one of the cornerstone of the Big Bang theory.

Big Bang theory remains a theory as of now. The key evidences to Big Bang theory include expansion of universe and the cosmic microwave background radiation.



EXPANSION OF THE UNIVERSE

Universe is expanding but the scientists say that this expansion has not been at same rate all the times. Scientists say that for a very small fraction of second (Planck Time or

10 Scientists say that for a very small fraction of second (Planck Time or 10-43 seconds), universe underwent hyperinflationary expansion, which suddenly expanded the diameter of universe by at least a factor of ten billion billion. This is the so called Hyperinflationary model of expansion of universe.

Long after the hyperinflation ended, the expansion returned to an almost-constant rate, slowed down very slightly, and then billions of years ago started speeding up. Right now, the expansion rate of the universe is slowly but surely increasing. We live in an accelerating universe.

Cosmic Microwave Background

In the 1960s, astronomers at Bell Telephone Laboratories in USA were testing some of their instruments when the detected an ubiquitous microwave static that came from all directions in the sky. This discovery was later used as a proof to big bang theory.

Cosmic Microwave Background refers to the leftover energy from the hot, early universe that still fills space and permeates the cosmos in every direction.

Hubble Constant

The expansion rate of the universe is called the Hubble Constant in honor of Edwin Hubble (1889–1953). Currently the best measured value of the Hubble Constant is about73 kilometers per second per mega parsec.

This implies that if a location in space is one million parsecs from another location, then in the absence of any other forces or effects the two locations will be moving apart from one another at the speed of 263,000 kilometers per hour!

Hubble measured the galaxies' Doppler effect—the shift in the observed color of objects moving toward or away from an observer—by mounting a machine called a spectrograph on a telescope. He split the light from distant galaxies into its component parts and measured how far the wavelengths of emitted light shifted toward longer wavelengths.

Doppler Effect Definition

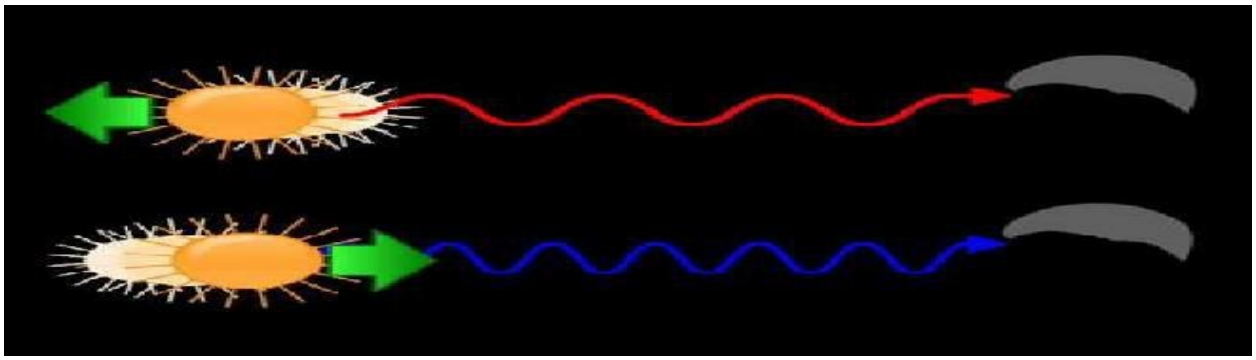
Doppler Effect is named after Christian Johann Doppler (1803–1853). It occurs when a source of sound (or any other wave) is moving toward or away from a listener. If the source is moving toward the listener, the sound wave's wavelength decreases, and the frequency increases, making the sound higher-pitched.

Conversely, if the source is moving away from the listener, the sound wave's wavelength increases, and the frequency decreases, making the sound lower-pitched. The next time a car or train passes by you on the street, listen to the sound it is making as it approaches and then moves away.

Doppler Effect For Light: Blue Shift and Red Shift

When an object emitting light—or any kind of electromagnetic radiation, for that matter—moves toward someone, the wavelength of its emitted light is decreased.

Conversely, when the object moves away, the wavelength of its emitted light is increased. For visible light, the bluer part of the spectrum has shorter wavelengths, and the redder part of the spectrum has longer wavelengths. Thus, the Doppler effect for light is called a "blue shift" if the light source is coming toward an observer, and a "red shift" if it is moving away. The faster the object moves, the greater the blue shift or red shift.



Black Holes

Each object has its own gravity which depends on its size and mass. The objects which have highest mass in smallest size would exert most gravity. The ultimate combination of large mass and small size is called a black hole. A black hole exerts such massive gravitational force that its escape velocity is equal or more than speed of light. The idea came in 18th century that such objects were so small and massive that particles of light could not escape from them and this would be black. When the general theory of relativity was confirmed, scientists started to explore the implications of gravity as the curvature of space by matter. Scientists realized that there could be locations in the universe where space was so severely curved that it would actually be "ripped" or "pinched off." Anything that fell into that location would not be able to leave. This idea of an inescapable spot in space—a hole where not even light could leave—led physicists to coin the term "black hole."

How Black Holes Are Detected?

One way of finding black holes is to observe the matter moving around in a orbit at much higher speed than expected. By carefully mapping this motion, the third law of Kepler and Newton's law of gravitation can be applied without seeing the actual object at the centre of the orbit. Another way of finding black holes is to look at them as sources of X-ray radiation. The tremendous gravitational field of the black hole can produce huge amount of light nearby and around itself even if it itself is black. Just as a meteorite or spacecraft gets hot as it enters Earth's atmosphere, the in falling matter gets hot from the frictional drag too, sometimes reaching temperatures of millions of degrees. That hot material glows brightly and emits far more X-ray radiation and radio waves than would normally be expected from such a small volume of space. The scientists search for such small spaces with abnormally high X-Ray radiation to look for black holes.

Types of Black Holes

There are two categories of black holes viz. low mass and super massive are known to exist, and a third kind (primordial blank hole) has been hypothesized but not yet detected.

Low mass / Stellar Black Hole

Stellar black hole or low-mass black hole is found wherever the core of a very massive star (usually 20 or more times the mass of the Sun) has collapsed.

Super Massive Black Hole

Super massive black hole is found at the centres of galaxies and is millions or even billions of times more massive than the Sun. Our Galaxy also has a black hole at its centre.

Primordial Black Hole

The third kind of black hole called a primordial black hole is found at random locations in space. It is hypothesized that these black holes were created at the beginning of cosmic expansion as little "imperfections" in the fabric of space-time. However, no such black hole has yet been confirmed to exist.

How Many Black Holes Are Known Today?

Today, thousands of black holes are known to exist, and the total population of black holes may number in the many billions.

Structure of a Black Hole?

The centre of the black hole is called the singularity. It is a single point that has no volume but infinite density. The laws of physics as we understand them simply do not work at the singularity of a black hole the way they do in the rest of the universe. Surrounding the singularity is a boundary called the event horizon.

This is the place of no return, where the escape velocity for the black hole is the speed of light. The more massive the black hole is, the farther the event horizon is from the singularity, and the larger the black hole is in size.

The singularity at the centre of any black hole has no volume. The size of the event horizon however, varies depending on the black hole's mass.

The mathematical relationship between the mass of a black hole and the size of its event horizon was derived by the German astrophysicist Karl Schwarzschild (1873–1916), and in his honor, the radius of a black hole's event horizon is called Schwarzschild radius.

STRUCTURE OF A BLACK HOLE

- The point at the center of a black hole is called a *singularity*.
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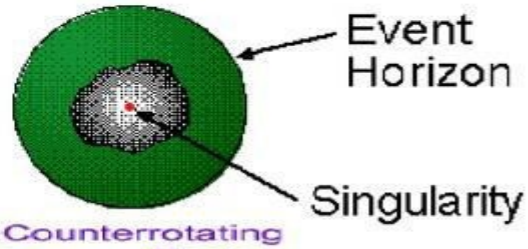

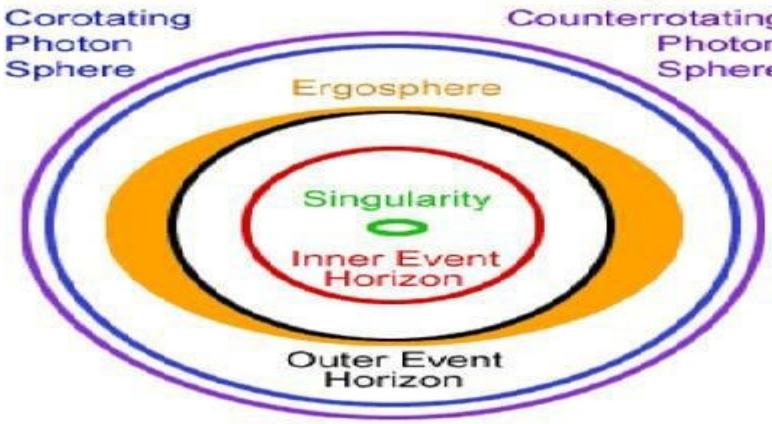

The Radius of stellar black holes is few hundred miles while that of super massive black holes is few million to billion miles. Further, if Sun is squeezed small enough to become a black hole; its radius would be around three miles only. If earth is squeezed into a black hole, its radius would be about three-quarters of an inch.

Properties of Black Holes

Black holes have huge densities and the key properties they have include mass (weight), rotation (spin) and electric charge.

Wormholes and Cosmic Strings

Wormholes and cosmic strings are theoretical imperfections in space-time. While a Black hole has one point of singularity, the wormhole may have two points – one where matter can only enter and another where matter can only exit. No worm hole has been detected so far, so they are only in theory and science fiction.

A cosmic string is a theoretical, vibrating stand that is like a black hole but instead of being a point or sphere, it is a long but very think crease left in otherwise smooth universe. Cosmic string is also theoretical and no such string has been detected so far.

Dark Matter and Dark Energy

In 1930s, astronomers noticed that in some galaxy clusters, some of the galaxies were moving extra fast than possible with available matter (and its gravitational force). The question was – Is there any matter which is not visible to us but exerts its gravitation responsible for keeping the galaxies put together? Again in 1970s researchers proposed that stars of Andromeda galaxy were moving so fast that there needs to be present some tremendous amount of matter which does not emit any electromagnetic radiation but exerts gravity. Since it does not emit any EM radiation, it's not visible to telescopes and thus is called dark matter. Later, the scientists confirmed that dark matter does exist and is important constituents of the galaxies and clusters of galaxies and puts them together. Further, it is now estimated that 80% of the matter in universe is dark matter.

The direct observational evidence of the dark matter comes from careful observations of the rotation rate of the galaxies. To scientists, the galaxies appear to be surrounded by giant or galactic halo containing matter capable of exerting gravitational influence but not emitting any

observable radiation. Further, it was also indicated that majority of agalaxy's mass lays in this very large halo, which is around 10 times the diameter of the visible galaxy. For example, our own Milky Way galaxy contains about 100 billion stars and it is thought to have been surrounded by a dark matter halo that probably extends out to about 750,000 light-years. The mass of this dark matter halo appears to be about 10 times greater than the estimated mass of all the visible stars in our galaxy.

DARK ENERGY

Albert Einstein had introduced a mathematical term into his equations tokeep a balance between cosmic expansion and gravitational attraction. This term became known as the "cosmological constant," and seemed to represent an unseen energy that emanated from space itself.

After Edwin Hubble and other astronomers showed that the universe was indeed expanding, the cosmological constant no longer appeared to be necessary, and so it was not seriously considered again for decades.

Then, starting in the 1990s, a series of discoveries suggested that the "dark energy" represented by the cosmological constant does indeed exist.

Current measurements indicate that the density of this dark energy throughout the universe is much greater than the density of matter—both luminous matter and dark matter combined.

Though astronomers have measured the presence of this dark energy, scientists still have no idea what causes this energy, nor they have a clue what this energy is made of.

The quest to understand the cosmological constant in general, and dark energy in particular, is one of the great unsolved questions in astronomy.

COMPOSITION OF DARK MATTER

But nobody has a real idea of what dark matter is and what these galactic halos are made of. However, there are some educated guess works divided into two schools of thoughts. One schools supports MACHOS or Massive Compact Halo Objects and another school advocates WIMPs or Weekly Interacting Massive Particles. However, no dark matter particle has ever been detected.

Implication of Dark Matter On Shape of Universe

Dark matter in the universe exerts a gravitational pull in the expanding universe. The more dark matter there is in the universe, the more likely it would be that the universe would have a closed geometry, and that the universe would end in a Big Crunch.Continued expansion of the universe means that the total amount of dark energy keeps increasing.Since the total amount of mass in the universe is not increasing, that means that the expansive effect of dark energy will ultimately overcome the contractive effect of dark matter. The more dark energy there is, the more open the geometry of the universe will tend to be, and the faster the expansion rate of the universe will increase over time.

Galaxies

A galaxy is a vast collection of stars, gas, dust, and dark matter that forms a cohesive gravitational unit in the universe. In a way, galaxies are to the universe what cells are to the human body: each galaxy has its own identity, and it ages and evolves on its own, but it also interacts with other galaxies in the cosmos.

Within the observable universe alone, there exist an estimated 50 to 100 billion galaxies.

Types of Galaxies

Galaxies are of various kinds mainly divided into four types viz. elliptical, normal spirals, barred spirals and irregular.

Hubble Sequence and Tuning Fork Diagram

Hubble had proposed a way to classify galaxies based on their shapes. He proposed a "sequence" of galaxy types: from E0 (sphere-shaped elliptical galaxies) to E7 (cigar- shaped elliptical), S0 (lenticular galaxies) to Sa and SBa (spiral galaxies with large bulges and bars), Sb and SBb (spirals with medium-sized bulges and bars), and Sc and SBc (spirals with small bulges and bars). The sequence is known as the Hubble sequence, and it is often shown visually as a Hubble "tuning fork diagram."