Distance ladder in cosmology :

The cosmic distance ~~tall~~ ladder (also known as the extragalactic distance scale) is the succession of methods by which the astronomers determine the distances to celestial objects. A real direct distance measurement of an astronomical object is possible only for those objects that are close enough (within about a thousand parsecs) to Earth. The techniques for determining distances to ~~Earth~~ more distant objects are all based on various measured correlations between methods that work at close distances and methods that work at large distances. Several methods rely on a standard candle, which is an astronomical object that has a known luminosity. The ladder analogy arises because no single technique can measure distances at all ranges encountered in astronomy. Instead one method can be used to measure nearby distances, and so on. Each rung of the ladder provides information that can be used to determine the distances at the next higher rung.

Almost all astronomical objects used as physical distance indicators belong to a class that has a known brightness. By comparing this known luminosity to an objects observed brightness, the distance to the object can be computed within using the inverse-square law. These objects of known brightness are termed standard candles.

If we want to measure the distance in parsecs the equation becomes even more simple. With the angle of arc seconds, the equation $p = \frac{1}{a}$ will give the distance p in parsecs.

Cosmic distance ladder is used to approximate distances to objects which we could never actually measure. Each step of this ladder is based on extensive research and allows us to determine distances to very distant celestial objects. The further we go up the ladder, the less precise the distance calculation becomes.

The first three rungs of the cosmological distance ladder are the i) radius of the earth ii) the distance to the moon and iii) the distance to the sun the 1st two distances can be obtained without a telescope.

The ladder has rungs of objects with certain properties that let astronomers confidently measure their distance. Jumping to each subsequent rung relies on methods of for measuring objects that are ever further away, the next step on piggybacking (on some one's back or shoulders) on the previous one.

Cepheid Variables:

A Cepheid variable is a type of star that pulsates radially, varying in both diameter and temperature. It produces changes in brightness with a well-defined stable period and amplitude. A strong direct relationship between a Cepheid variable's luminosity and pulsating period established Cepheids as important indicators of cosmic bench mark for scaling galacting and extragalactic distances. This robust (strong) characteristics of classical Cepheids was discovered in

1908 by H.S. Leavitt after studying thousands of variable stars in the magnetic clouds. This discovery allows one to know the true luminosity of a Cepheid by simply observing its pulsating period. This in turn allows one to determine the distance to the star, by comparing its known luminosity to its observed brightness.

The term Cepheid originates from Delta Cephei in the constellation Cepheus, identified by John Goodricke in 1784, the 1st of its type to be so identified.

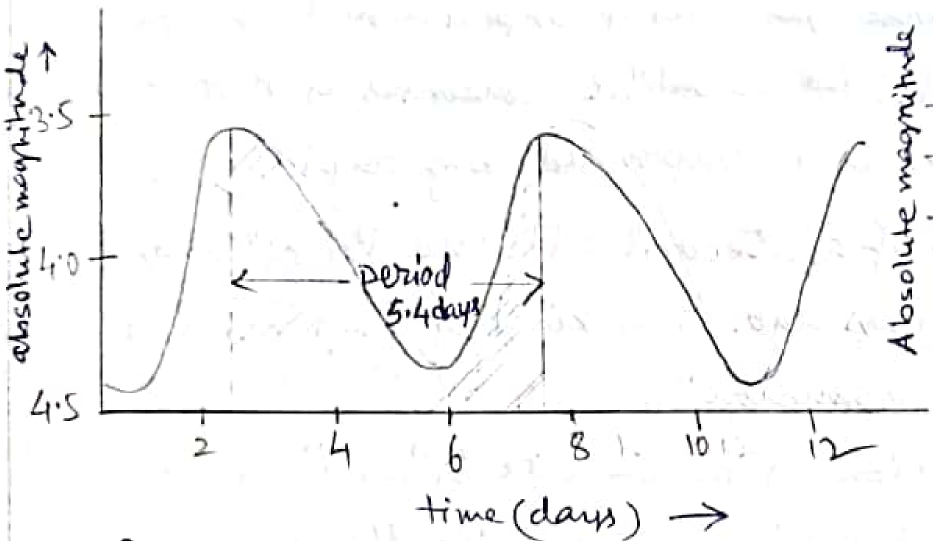

fig.1: Brightness variation of δ-Cephei (3.6 – 4.3 magnitude)

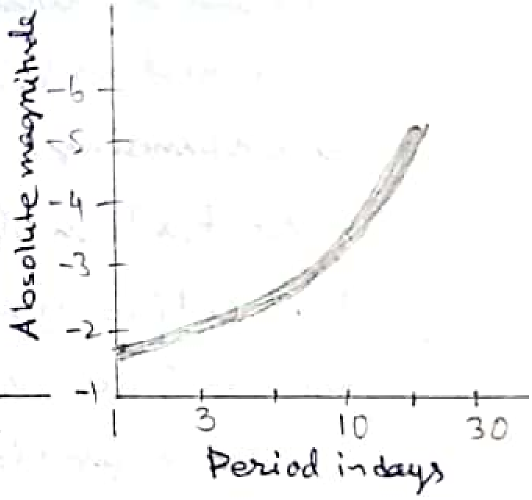

Fig.2: The period luminosity relation for the cepheid variables

Cepheid variables are the most important type of variable because it has been discovered that their periods of variability are related to their absolute luminosity. This makes them invaluable as a contributor to astronomical distance measurement. The periods are very regular and range from 1 to 100 days. The shape of the cepheid luminosity curve is often referred to as a "shark fin" shape when plotted as magnitude vs period. It should be noted that the smooth curve is an average behaviour.

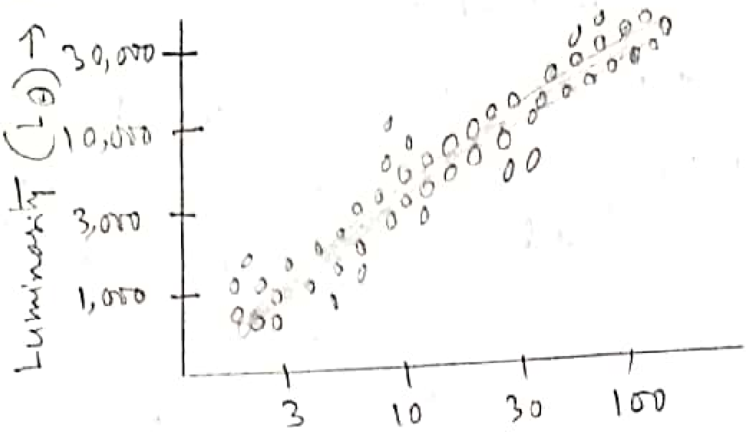

Fig. 3: Type I cepheid variables

Cosmic expansion of the universe and the Hubble law:

Based on large quantities of experimental observation and theoretical work, the scientific consensus is that space itself is expanding. It is expanded very rapidly within the first fraction of a second after the Big Bang, approximately 13.8 billion years ago. This kind of expansion is known as "metric expansion"

The expansion of the universe is the increase in distance between any two given gravitationally unbound parts of the observable universe with time. It is an intrinsic expansion whereby the scale of space itself changes. The universe does not expand "into" anything and does not require space to exist " outside it.

The energy from the big bang drove's the universe's early expansion. Since then, gravity and dark energy have engaged in a cosmic tug of war. Gravity pulls galaxies closer together, dark energy pushes them apart. Whether the universe is expanding or contracting depends on which force dominates gravity or dark energy.

Vesto Slipher (1875–1969) observed the spectra of those galaxies which were investigated by Edwin Hubble and his co-workers from Lowell Observatory. He observed that the emission and absorption lines in the spectra were not found at the same wavelengths at which these features appeared in the laboratory generated spectra. The pattern shows that the lines were almost always shifted to longer wavelengths.

The redshift is defined as

$$Z = \frac{\lambda_0 - \lambda_e}{\lambda_e} \longrightarrow (1)$$

where $\lambda_e \rightarrow$ wavelength at emission

$\lambda_0 \rightarrow$ wavelength at absorption

This expression is same as the one written ~~by~~ for Doppler's shift with z equal to the speed of an object moving away from us (V) divided by the speed of light. Hubble interpreted Slipher's redshift as Doppler shifts and concluded that almost all the galaxies in the universe are moving away from the Milky Way.

Hubble thus made the greatest discovery in the history of astronomy — A galaxy's recession velocity is proportional to its distance. The velocity at which ~~the~~ a galaxy is moving away from us is proportional to the distance of the galaxy. This is known as the Hubble's law. It is written as

$$\boxed{V = H_0 \times d} \longrightarrow (2)$$

where, $V \rightarrow$ the recession velocity

$d \rightarrow$ distance to the galaxy

$H_0 \rightarrow$ Hubble's constant or Hubble parameter

Hubble's law says that the universe is expanding at uniformly. It also describes a homogeneous universe. The present value of Hubble parameter is set at 71 Km/sec/Mpc (Mpc → megaparsec).

Clusters of Galaxies and dark matter:

Galaxy clusters, which consists of thousands of galaxies, are important for exploring dark matter because they reside in a region where such matter is much denser than average. Scientists believe that the heavier a cluster is, the more dark matter it has in its environment. Gravitational lensing and X-ray radiation from massive galaxy clusters ~~f~~ confirms the presence of dark matter. Galaxies and clusters of galaxies contain about 10 times more dark matter than luminous matter.

In the standard Lambda-CDM model of cosmology, the total mass energy content of the universe contains 5% ordinary matter and energy, 27% dark matter and 68% of a form of energy known as dark energy. Most studies have focused upon the inner regions of clusters, where the density of stars is the greatest, but no conclusive detection of dark matter has been made.

The evidence of dark matter lies with gravity. Gravity is the force or "glue" that holds the universe together. Everything in the universe is mutually attracted to everything else.

But more massive pieces of dark matter known as macroscopic dark matter or macros could lurk (remain unobserved) in cosmos. In this theory, macros could directly interact with physical objects such as human bodies causing significant damage.

While globular clusters are normally considered to be almost devoid of dark matter, the study of the dynamical properties of sample clusters suggested the presence of exotically concentrated dark matter.

Most of the mass in clusters cannot be seen in visible light or in X-rays. Around 1-2% mass comes from stars, 10% from the gas in between the galaxies in the cluster - the intra-cluster medium, and the remaining 85-87% is Dark Matter.

[Dark Matter: Dark matter is composed of particles that don't absorb, reflect, or emit light. So ~~they~~ they cannot be detected by observing electromagnetic radiation. Dark matter is the material that cannot be seen directly. Based on current data, at most some 24 ~~million~~ trillion metric tons of dark matter lies between earth and moon. Such a dark matter halo (a circular band of coloured light) might explain the anomalies seen in the orbits ~~the~~ of the Pioneer, Galileo, Cassini, Rosetta and Near Mission space craft etc.

Dark matter can refer to any substance which interacts predominantly via gravity with visible matter (eg. stars & planets). Hence in principle it need not be composed of a new type of fundamental particle, but could, at least in part, be made up of standard baryonic matter, such as protons or neutrons.

Dark matter could be white dwarfs, the remnants of cores of dead small to medium size stars. Dark matter could also be neutrons stars or black holes the remnants of large stars after they explode.]

Concept of The Hot Big Bang :

The Hot Big Bang is the period at which whose end-stages we are living, during which the observable patch of the universe was initially dense and hot. During this period it has been expanding and cooling. The expansion has been slowing until recently.

Although this type of universe was proposed by Russian mathematician Friedmann and Belgian astronomer Georges Lemaitre in the 1920s, the modern vision was developed by Russian-born American physicist George Gamow and collegues in the 1940s.

In contrast, cosmologists believe the Big Bang flung (act of throwing violently) energy in all directions at the speed of light and estimate that the temperature of the universe was 1000 ~~times~~ trillion degrees Celsius at just a ~~ty~~ tiny fraction of a second after the explosion.

Early universe was so hot because electrons began to combine with hydrogen and helium nuclei. High energy photons from this period rushed outward

The early universe was so hot that as it has expanded and cooled, the highly energetic photons from that time have had their wavelength stretched tremendously.

A CERN (European Council for Nuclear Research) experiment at the Large Hadron Collider created the highest recorded temperature ever when it reached 9.9 trillion degrees Fahrenheit. The experiment was meant to make a primordial goop (a thick, slimy substance) called a quark-gluon plasma behave like a frictionless fluid.

Key observations supporting the big bang theory include — 1) expansion of the universe 2) cosmic microwave background radiation 3) abundances of the lightest chemical elements and 4) age of the oldest known stars.

In short the big bang theory is how the astronomers explain the way the universe began. It is the idea that the universe began as just a single point, then expanded and stretched to grow as large as it is right now — and it is still stretching.

Oscillating Universe :

The Oscillating Universe Theory is a cosmological model that combines both the Big Bang and Big ~~Crunch~~ Crunch as part of a cyclical event. For example, the oscillating universe theory briefly considered by Albert Einstein in 1930. He theorized a universe following an eternal series of oscillations, each beginning with a Big Bang and Ending with a Big Crunch. In between the universe would expand for a period of time before the gravitational attraction of matter causes it to collapse back in and undergo a bounce.

[Big crunch - The Big crunch is a hypothetical scenario for the ultimate fate of the universe, in which the expansion of the universe eventually reverses and the universe recollapses, ultimately causing the cosmic scale factor to reach zero. This is an event potentially followed by a reformation of the universe starting with another Big Bang.] The vast majority of evidence indicates that this hypothesis is not correct. Instead, astronomical observations show that expansion of the universe is accelerating rather than being slowed by gravity. It suggests that the universe is far more likely to end in heat death.]

In the 1920s, theoretical physicists, most notably Albert Einstein, considered the possibility of a model for the universe as an alternative to the model of an expanding universe. Howerever, work by Richard C. Tolman in 1934 showed that these early attempts failed because of the cyclic problem. According to the 2nd law of thermodynamics, entropy can only increase. This implies that successive cycles grow longer and larger. Extrapolating back in time, cycles before the present one become shorter and smaller culminating again in a Big Bang and does not replacing it. This puzzling situation remained for many decades until the early the 21st century when the recently discovered dark energy component provided new hope for a consistent cyclic cosmology. In 2011, a five year survey of 2,00,000 galaxies and spanning seven billion years of cosmic time confirmed that dark energy is driving our universe apart at accelerating speeds.

One new cyclic model is the brane cosmology model of the creation of the universe. It was proposed in 2001 by Paul Steinhardt of Princeton University and Neil Turok of Cambridge University. The theory describes a universe exploding into ~~not existing~~ existence not just once, but ~~reaped~~ repeatedly over time. The theory could potentially explain why a repulsive form of energy known as the cosmological constant, which is accelerating the expansion of the universe, is several orders of magnitude smaller than predicted by the Standard Big Bang Model.

Cosmic Microwave Background (CMB):

The cosmic microwave background, in Big Bang cosmology, is a kind of electromagnetic radiation which is a remnant from an early stage of the universe. It is also known as 'relic radiation'. The CMB is a faint cosmic background radiation filling all space. It is an important source of data on the early universe because it is the oldest electromagnetic radiation in the universe, dating to the epoch of

recombination. With a traditional optical telescope, the space between stars and galaxies (the background) is found to be completely dark. However, a sufficiently sensitive radio telescope shows a faint background noise, or glow, that is not associated with any star, galaxy, or other object. This glow is strongest in the microwave region of the radio spectrum. The accidental discovery of the CMB in 1965 by American radio astronomers Arno Penzias and Robert Wilson was the culmination of work initiated in the 1940s [culmination – the attainment of the highest point of altitude reached by a heavenly body, passage across the meridian, transit]
and earned Nobel Prize in Physics by the discoverers in 1978.

CMB is the landmark evidence of the Big Bang, origin of the universe. When the universe was young, before the formation of stars and planets, it was denser, much hotter and filled with an opaque fog of hydrogen plasma. As the universe expanded the plasma grew cooler and the radiation filling it expanded to longer wavelengths. When the temperature has dropped enough, protons and electrons combined to form neutral hydrogen atoms. Unlike the plasma this nearly, these newly conceived atoms could not scatter the thermal radiation by Thomson's scattering and so the universe became transparent. cosmologists refer to the time period when neutral atoms first formed as the recombination epoch. The event shortly afterwards when photons started to travel freely through space is referred to as photon decoupling. The photons that existed at the time of photon decoupling have been propagating ever since, though growing less energetic, since the expansion of space causes their wavelength to increase overtime (and wavelength is inversely proportional to energy according to the Planck's relation). This is the source of the alternative term relic radiation. The surface of last scattering refers to the set of point in space at the right distance from us so that we are now receiving photons originally emitted from those points at the Time of photon decoupling.

According to the theory of quantum fields in curved space-times, the origin of these microwave photons is related to the redshifted particles created in the early universe, when the production of particles by the expanding background played a significant role.

The CMB represents the heat left over from the Big Bang. we cannot see CMB by naked eye, but it is everywhere in the universe. It is invisible to humans, because it so cold, just 2.3 K.

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When we see Jupiter shining in the night sky, for example, we are looking about an our back in time. But the light from distant galaxies captured by telescopes today was emitted millions of years ago. The CMB is the oldest light we can see - the farthest back both in time and space that we can look.

What the most striking characteristic of the CBB is the uniformity.

Why is CBB so cold? As the universe expanded the light was stretched into longer and less energetic wavelengths. By the time the light reaches us, 14 billion years later, we observe it as low energy microwaves at a temperature of 2.7K. This is why CMB is so cold now. The expansion of space cools down the CMB.

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