FROM NOTHING TO EVERYTHING – THE STORY OF THE BIG BANG

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INTRODUCTION

The Big Bang theory is one of the most popular notions of the formation of the universe. According to this theory, over 13.8 billion years ago, the universe was astounding hot and dense, and all the energy was concentrated in an infinitely small singularity. The singularity expanded and formed the totality we know today. The universe started to grow rapidly from the burst of expansion and cool down. The universe is still expanding today providing us with galaxies, planets, stars, and other celestial objects. The Big Bang theory is defended by the identification of cosmic microwave background radiation and the finding of continuous increase of distance among the galaxies. The impact of the Big Bang theory in astronomy and cosmology is very significant. The theory itself explains the origin of everything and forms the basis of our knowledge about the universe. We have been able to discover the concept of cosmic inflation and understand the extensive structure of the universe we know today. The abundant presence of elements like hydrogen and helium can be explained by the theory as the early universe was capable of their formation.

HISTORY

Olbers' paradox refers to the problem of why the sky is dark at night. If we believe that the universe is uniformly populated with stars then if you are looking into space, your line of sight will eventually intersect with the surface of a star. This suggests that the sky must be bright throughout without any dark space between them which is opposite to what we observe [1]. Olbers' paradox comes from the name of the German astronomer Heinrich Wilhelm Olbers, who in 1826 discussed this paradox in his paper. In the 1920s, Edwin Hubble who was an observational cosmologist from America observed galaxies outside the range of the Milky Way galaxy is moving away from us. The galaxies further from us were moving further away at a faster rate than the ones closer to us. The discovery of the expanding universe transformed cosmological thinking [2]. Hubble discovered the redshift in 1929 and eventually became the evidence of the Big Bang theory. Redshift is the displacement of astronomical objects toward longer wavelengths, i.e., red. The Doppler effect is held responsible for the change in wavelength that is due to the motion between the source of waves and the observer [3].

Another proof of the Big Bang theory is the cosmic microwave background radiation which was accidentally discovered by two American scientists Arno Penzias and Robert Wilson. They discovered radio noise that was the same in all directions and the noise seemed to come from the sky. The vague background radiation is the remains of the hot and dense early universe that proved the theoretical predictions [4,6]. The concepts of expanding the universe were described further using Albert Einstein's theory of general relativity. His equations played an essential role in understanding the evolution of the universe. The mathematical groundwork to describe the expanding universe through the Big Bang theory was done by

Alexander Friedmann, George Lemaître, Howard Robertson, and Arthur Walker in 1948. There was another theory, proposed by Fred Hoyle, Hermann Bondi, and Thomas Gold called the Steady State Theory that suggested that the universe was infinite and unchanging.

KEY CONCEPTS AND OBSERVATIONAL EVIDENCE

The fundamental components of the Big Bang Theory are cosmic expansion, cosmic microwave background radiation, and redshift.

The cosmic expansion:

According to Hubble's law, "galaxies appear to be racing away from one another with the apparent velocity of recession being linearly proportional to the distance of the object." [5] The expansion of the universe is the idea of the galaxies drifting further away from one another continuously. Just after the Big Bang, there was a stage of rapid expansion known as cosmic inflation. The universe expanded exponentially during this period stretching it far beyond what it was initially. After this phase, the universe continued to expand at a slower rate, and due to gravity galaxies and galaxy clusters started to form. The concept of cosmic expansion signifies the finite age of the universe and that it has been expanding since its formation. This allows scientists to look back in time and trace the occurrence of the Big Bang.[7]

The cosmic microwave background radiation:

It is the faint glow of microwave radiation that fills the entire universe and is nearly uniform in all directions. Moments after the Big Bang the was filled with high energy photons, electrons, protons, and other particles. The universe was extremely hot. With the expansion of the universe, it also cooled down. For the next few hundred thousand years the universe cooled down enough for the electrons and protons to combine and form hydrogen atoms. This process is known as recombination. The formation of the hydrogen atoms made the universe transparent to radiation. Since the universe was filled with low-energy photons during recombination, the stretched-out photons shifted to longer wavelengths as the universe expanded. The energy of these photons decreases due to which they fall into the microwave portion of the electromagnetic spectrum. The tiny temperature fluctuations in the CMB are detected by satellites like the Cosmic Microwave Background Explorer (COBE) and Planck. [8]

The redshift:

It is a phenomenon where light or other electromagnetic waves from distant objects appear to be shifted toward longer wavelengths as they travel through space. The relative motion between the source of light and the observer causes this shift and is very important evidence of cosmic expansion. [9]

CHALLENGES

Although the Big Bang theory is the most successful theory of the origin of the universe, like any other theory it faces some challenges. One of the significant challenges related to the Big Bang Theory is the “horizon problem”. The horizon problem is a cosmological challenge that arises from the observed large-scale uniformity of the universe’s temperature and structure. As we know the finite age of the universe (about 13.8 billion years), there has not been enough time for light or other signals to travel and establish equilibrium between distant regions. The widely spread regions of the universe shouldn’t have had enough time to exchange temperature information and reach such uniformity. To tackle the horizon problem scientists proposed the hypothetical theory of cosmic inflation offering a mechanism for the rapid expansion of the early universe that could account for the observed uniformity. According to cosmic inflation, the universe expanded exponentially, smoothing out temperature variations and ensuring that distant regions reached thermal equilibrium.

The Big Bang theory should be able to describe the large-scale structure and dynamics of the universe including the formation and behaviour of galaxies and galaxy clusters. However, it was observed that the visible matter in the galaxies (stars, dust, gas) and their observed mass are insufficient to account for the gravitational forces needed to explain the observed motions of the stars within the galaxies within clusters. The rotation curves of galaxies and the motion inside the clusters suggest that there is more mass present than what we see. The additional mass, which does not emit or interact with electromagnetic radiation was named as dark matter to tackle this challenge [10].

It was assumed that the expansion initiated by the Big Bang would come to rest with time due to the gravitational force between matter. However, through observations, it was found the universe's expansion is not slowing down but accelerating instead. The galaxies are drifting further away from each other at an ever-increasing rate. To justify the accelerated expansion scientists introduced dark energy. It is a mysterious, repulsive force that opposes gravity and drives the expansion of the universe. [11]

FUTURE RESEARCH

The Big Bang theory is an evolving and vibrant topic for research, especially with the countless possibilities that lie in the universe. The researchers are trying to understand the early stages of the Big Bang and replicate the model of cosmic inflation. They are finding evidence of cosmic inflation through cosmic microwave background. One of the biggest mysteries is the dark matter and dark energy. The researchers are working to develop a way to detect dark matter and to understand the dark energy better. For researchers, investigating the formation of the first galaxies in the universe is a priority, and telescopes like the James Webb Space Telescope help astronomers peer back in time and observe the earliest galaxies.

CONCLUSION

the Big Bang theory is one of the most successful and influential theories related to the origin of the universe and it has paved the way for many theories in cosmology and astronomy. It compiles the story of the origin of the universe through a burst of energy and the expansion of the universe that started with cosmic inflation. The evidence of cosmic inflation and the Big Bang can be traced through the redshift and cosmic microwave background radiations. Through the Big Bang, we could understand the formation of the galaxies and galaxy clusters along with an increase in the distances between them. The terms like dark energy and dark matter were introduced based on the Big Bang theory. In conclusion, the story of the Big Bang that explains our origin is an important area of research if we want to thrive further.

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