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Contribution of Hubble Space Telescope Towards Unraveling the secrets of the Big Bang

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ABSTRACT

The Hubble Space Telescope (HST) is a space-based observatory that has provided groundbreaking insights into the universe since its launch. It is one of the most significant astronomical observatories ever launched into space. It was deployed in low Earth orbit by the Space Shuttle 'Discovery' on April 24, 1990. Named after the astronomer Edwin Hubble, the telescope was developed as a joint project between NASA (National Aeronautics and Space Administration) and the ESA (European Space Agency). The space observatory has made significant contributions to our understanding of the universe and has played a crucial role in unraveling the secrets of the Big Bang. Its significance stems from its remarkable contributions to the field of astronomy, astrophysics, and space exploration.

Keywords: *Space observatory; The Big Bang; Low Earth Orbit; Space Shuttle; Astronomy; Astrophysics; Space Exploration*

INTRODUCTION TO THE HUBBLE SPACE TELESCOPE

The Hubble Space Telescope, named after renowned astronomer Edwin Hubble, stands as one of the most extraordinary achievements in space exploration. Launched into orbit by NASA in 1990, this cutting-edge observatory has revolutionized our understanding of the cosmos and provided humanity with breathtaking images and groundbreaking discoveries. Equipped with advanced optics, the Hubble Space Telescope's primary advantage lies in its ability to peer into the universe from above Earth's atmosphere. By avoiding the distortion caused by the atmosphere, Hubble delivers incredibly clear and sharp images of celestial objects, capturing distant galaxies, nebulae, and planets with unprecedented detail. Throughout its lifetime, Hubble has unveiled numerous cosmic phenomena, such as the expansion rate of the universe, distant exoplanets, and black holes at the hearts of galaxies. Its contributions to astrophysics and cosmology have been invaluable, enabling scientists to test theories and refine our understanding of the universe's origins and evolution.

But this pinnacle of human intelligence was once referred to as-"A billion dollar mistake" due to the initial problems encountered with the telescope. The mistake in question was related to the telescope's primary mirror, which was ground to the wrong shape. The mirror had a flaw known as a "spherical aberration," which caused the telescope's images to be blurry and significantly reduced its capabilities. This issue was not discovered during pre-launch testing, leading to the telescope being sent into space with a faulty mirror. The cost of the Hubble Space Telescope project was approximately $1.5 billion at the time, and this flaw jeopardized the entire mission's success. Once the telescope was in orbit, astronomers and scientists realized the problem with the mirror and were concerned that the mission might be a failure. However, despite the initial setback, NASA and the scientific community were determined to find a solution. A servicing mission, STS-61, was launched in December 1993 to fix the Hubble Space Telescope. During this mission, astronauts installed corrective optics to compensate for the mirror's flaw. The mission was a resounding success, and the Hubble Space Telescope has since become one of the most valuable and productive astronomical instruments ever built (Hub).

Key features of the Hubble Space Telescope

- **Optical Telescope:** Hubble is primarily an optical telescope, designed to observe visible and near-infrared light. Its position above the Earth's atmosphere allows it to capture clearer and sharper images compared to ground-based observatories, which are affected by atmospheric distortion.
- **Mirrors and Instruments:** Hubble has a 2.4-meter (7.9-foot) diameter primary mirror that collects and focuses light. Several scientific instruments on board the telescope can analyze this light to study various aspects of the universe, such as the Cosmic Origins Spectrograph, the Advanced Camera for Surveys (ACS), and the Wide Field Camera 3 (WFC3).
- **High-Resolution Imaging:** The Hubble Space Telescope is known for its exceptional image clarity and resolution. It has allowed astronomers to observe celestial objects in unprecedented detail, capturing stunning images of galaxies, nebulae, stars, and planets.
- **Wide Field Camera:** Hubble is equipped with several scientific instruments, including the Wide Field Camera (WFC). This camera provides a broad field of view, allowing it to capture large regions of the sky in a single exposure.
- **Spectroscopy:** Hubble's spectrographs break down the light from distant objects into its component wavelengths, enabling scientists to study the chemical composition, temperature, and motion of celestial objects.
- **Ultraviolet Imaging:** One of Hubble's unique capabilities is its ability to observe ultraviolet light, which is not possible from the Earth's surface due to the filtering effect of the atmosphere. This feature has been crucial for studying the early universe, quasars, and the interstellar medium.
- **Space-based Observations:** By orbiting above the Earth's atmosphere at an altitude of approximately 547 kilometers (340 miles), Hubble avoids atmospheric distortion and light pollution, allowing for clearer observations.
- **Observations:** Hubble has contributed to a wide range of astronomical research, including the study of distant galaxies, stars, planets, and other celestial objects. It has made numerous groundbreaking discoveries, including measuring the rate of expansion of the universe (Hubble's Law), providing evidence for the existence of supermassive black holes at the centers of galaxies, and identifying and characterizing distant exoplanets.
- **Repair and Upgrades:** Throughout its operational lifetime, Hubble has undergone several servicing missions by astronauts aboard the Space Shuttle to repair and upgrade its instruments and systems. These servicing missions have extended Hubble's life and improved its capabilities.
- **Public Outreach:** Hubble's captivating images have not only contributed to scientific knowledge but also sparked public interest and enthusiasm for astronomy. Its visually striking photographs have been widely shared and become iconic representations of the cosmos.

A series of theories speculating the origin of the universe before the Big Bang

- **Inflationary Theory:** It posits that in the early moments following the Big Bang, the universe underwent a rapid exponential expansion. Proposed to address certain cosmological mysteries, it explains the observed isotropy of the cosmic microwave background radiation and the large-scale structure of the universe. This theory suggests that a hypothetical inflation field drove this expansion, causing space-time to rapidly stretch, smoothing out irregularities and laying the groundwork for the universe's subsequent evolution. Inflationary Theory provides a resolution to the horizon problem and the flatness problem, which refer to inconsistencies in the standard Big Bang model (Guth, 2004).

- **Steady State Theory:** It is a cosmological model that proposes that the universe has always existed in an unchanging state, with no beginning or end. According to this theory, the universe maintains a constant average density as new matter is continuously created to fill the space left by the expansion of the universe. The galaxies move away from each other due to the expansion, but new matter arises to create new galaxies, thus preserving the overall appearance of the universe. The Steady State Theory was popular in the mid-20th century but gradually lost support due to observational evidence, such as the discovery of the cosmic microwave background radiation, which strongly supported the Big Bang Theory as the more plausible explanation for the origin and evolution of the universe (Bondi, 1948).

- **Oscillating Universe Theory:** It posits that the universe undergoes an eternal cycle of expansion and contraction. According to this hypothesis, after the Big Bang, the universe expands, driven by the force of the initial explosion. However, the expansion eventually slows down due to gravity, leading to a reversal of the process. The universe contracts, culminating in a Big Crunch, where all matter and energy collapse into a singularity. Subsequently, a new Big Bang occurs, initiating another cycle. This theory suggests that the universe's history repeats infinitely with no beginning or end. However, since the late 20th century, observational evidence, including the accelerated expansion discovered through dark energy, has shifted scientific consensus away from the Oscillating Universe Theory, favoring the idea of an expanding universe with no ultimate contraction (Tolman, 1934).

- **Multiverse Theory:** It is a speculative concept in cosmology and theoretical physics that proposes the existence of multiple universes, beyond our observable universe. It suggests that our universe might be just one of many universes, each with its own set of physical laws, constants, and conditions. Some of its interpretations include- Parallel universes, Bubble universes, Many worlds interpretation (Quantum Mechanics), etc. (Everett, 1950s).

- **String Theory and M-theory:** String theory and M-theory are theoretical frameworks in physics that aim to describe the fundamental nature of the universe. String theory proposes that the basic building blocks of the universe are not point-like particles but tiny, vibrating strings. These strings can produce different particles depending on their vibrations, encompassing all known particles in physics, including gravity. However, string theory requires extra spatial dimensions beyond the familiar three dimensions of space and one of time. To reconcile this, M-theory emerged as an extension of string theory. M-theory suggests that these strings are not the only fundamental objects; it also incorporates higher-dimensional entities called membranes or branes. These branes exist in multiple dimensions, and interactions between them govern the behaviour of particles and forces. M-theory unifies various string theories that emerged earlier and includes an 11-dimensional framework. It is considered an ambitious attempt to unify all fundamental forces and particles into a single, coherent theory of everything. Despite its promising potential, both string theory and M-theory remain speculative, as they lack experimental confirmation. Researchers continue to explore their mathematical implications and connections to other areas of physics, hoping to gain insights into the nature of the universe at its most fundamental level (Veneziano, 1968).

- **Cyclic Universe Theory:** It is a cosmological model that suggests the universe undergoes an infinite series of cycles of creation, evolution, and destruction. This theory is an alternative to the widely accepted Big Bang theory, which proposes that the universe began with a singular event approximately 13.8 billion years ago.

  In the cyclic universe theory, the sequence of events follows this general pattern:

  1. **Big Bang**: Each cycle starts with a Big Bang-like event, where the universe is born from a high-density and high-temperature state.
  2. **Expansion and Evolution**: After the initial explosion, the universe expands, cools down, and evolves over an extremely long period.
  3. **Dark Energy Dominance**: As the universe expands, it is suggested that dark energy, a mysterious form of energy that counteracts gravity and causes the universe's expansion to accelerate, plays a significant role.
  4. **Expansion Slows Down**: Despite dark energy's influence, the expansion eventually slows down due to the cumulative gravitational pull of matter and other forces.

5. **Big Crunch**: In the cyclic model, the universe's expansion will eventually reverse, leading to a contraction phase.
6. **Big Crunch Singularity**: The contraction phase culminates in a "Big Crunch," where the universe's density and temperature become infinitely high, resulting in a singularity similar to the initial state before the previous Big Bang.
7. **New Big Bang**: The cycle then begins anew, with a new Big Bang initiating a new universe and starting the whole process over again.

The cyclic universe theory was proposed as a possible solution to the problem of explaining the eventual fate of the universe and whether it will continue expanding forever or eventually collapse. By suggesting that the universe undergoes an infinite series of cycles, the theory avoids the question of a definitive beginning or end to the cosmos (Steinhardt).

LITERATURE REVIEW

- **Alan Guth (1980):** (Guth, 2004) His proposal of cosmic inflation is a crucial part of modern cosmology and helps explain some of the observed features of the universe, such as its overall homogeneity, isotropy, and large-scale structure. The inflationary theory suggests that the universe underwent a rapid exponential expansion during the early moments of its existence, shortly after the Big Bang, which could account for various cosmological observations and issues, such as the horizon problem and the flatness problem.
- **Hermann Bondi, Thomas Gold and Fred Hoyle (1940s):** (Bondi, 1948) The steady-state theory posits that the universe has always existed in a continuous state of expansion, with new matter being continuously created to maintain a constant average density as the universe expands. This concept was in contrast to the Big Bang theory, which suggests that the universe originated from a hot and dense initial state and has been expanding since then. Though the steady-state theory was an interesting alternative, it faced several observational challenges and was eventually largely discredited due to mounting evidence in favour of the Big Bang theory. The discovery of the cosmic microwave background radiation in 1965 provided strong support for the Big Bang model, leading to its widespread acceptance among the scientific community.
- **Richard Tolman and Albert Einstein (1930):** (Tolman, 1934) According to the oscillating universe concept, after a Big Bang, the universe expands, but gravity eventually slows down this expansion, leading to a contraction phase. During this contraction, the universe collapses back into a singularity, initiating another Big Bang and restarting the cycle. The idea assumes that the process repeats indefinitely. However, it faces challenges related to the observed acceleration of the universe's expansion and lacks strong empirical evidence. As a result, alternative theories like the Big Freeze or Big Rip have gained more support in contemporary cosmology.
- **Hugh Everett III (1950s-60s):** (Everett, 1950s)His interpretation of the universe’s origin suggests that all possible outcomes of a quantum event actually happen in separate branches of the universe, leading to a multitude of parallel universes.
- **Gabriele Veneziano (1968):** (Veneziano, 1968) He published a paper that laid the foundation for string theory. He formulated the first model (Veneziano amplitude) to describe strong nuclear interactions using strings.
- **Subrahmanyan Chandrasekhar (1930s):** (Chandrashekhar)He investigated the idea of a closed, oscillating universe that would undergo cycles of expansion and contraction.
- **Paul Steinhardt, Neil Turok, and Justin Khoury (1990s):** (Steinhardt) Their model was a part of the broader theory of brane cosmology, which involves extra spatial dimensions and the idea that our universe is a three-dimensional "brane" embedded in a higher-dimensional space.

  In the ekpyrotic universe model, the cyclic nature of the universe arises from collisions between branes in higher-dimensional space, causing a repeating cycle of cosmic events. The collisions would produce a Big Bang and a subsequent expansion, followed by a period of contraction, and then another collision to initiate a new Big Bang, thus repeating the cycle indefinitely.

THE ORIGIN AND EXPLANATION OF THE BIG BANG

Origin of The Big Bang Theory

The Big Bang theory is a scientific explanation for the origin of the universe. It proposes that the universe began as a hot, dense, and infinitely small point known as a singularity around 13.8 billion years ago, and then it rapidly expanded and continues to expand to this day.

The idea of the Big Bang theory originated from the work of several scientists over a period of time:

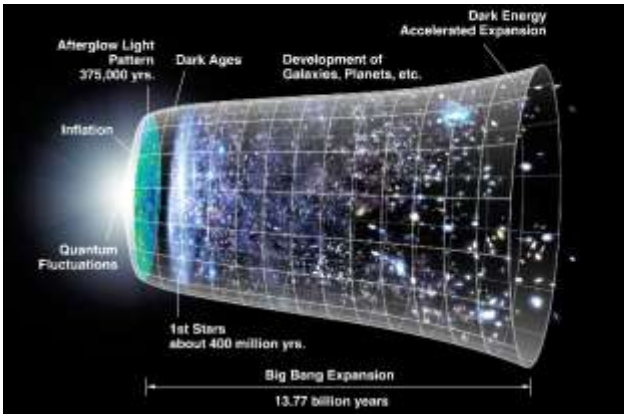
1. **Georges Lemaître (1894-1966)**, a Belgian physicist and Catholic priest, is often credited with first proposing the concept of an expanding universe based on Albert Einstein's general theory of relativity. In 1927, he published a paper in which he described a universe that was initially concentrated in a "primeval atom" and then expanded.
2. In the 1940s, the term "Big Bang" was coined by the British astronomer **Fred Hoyle (1915-2001)**. Ironically, Hoyle did not support the Big Bang theory but used the term somewhat mockingly during a BBC radio broadcast to describe the theory proposed by his opponents. However, the name stuck, and it is now commonly used to refer to the theory.
3. Subsequently, observational evidence, such as the discovery of cosmic microwave background radiation in **1964 by Arno Penzias and Robert Wilson**, strongly supported the Big Bang theory. The cosmic microwave background radiation is considered one of the most compelling pieces of evidence for the early hot and dense state of the universe.

What is The Big Bang?

The Big Bang theory is a scientific explanation for the origin and evolution of the universe. It proposes that the universe began as a singularity, an infinitely dense and hot point, approximately 13.8 billion years ago. In an explosive event known as the Big Bang, this singularity rapidly expanded, creating space, time, and all matter and energy in the cosmos. In the initial moments, the universe was extremely hot and dense, with temperatures beyond comprehension. As it expanded, it also cooled down, allowing fundamental particles like protons, neutrons, and electrons to form. These particles then combined to form the first atoms—primarily hydrogen and helium. Over millions of years, gravity acted as a shaping force, causing these early gas clouds to collapse and form the first stars and galaxies. Stars, in turn, initiated nuclear fusion reactions, synthesizing heavier elements like carbon, oxygen, and iron. These newly formed elements were then scattered through space when stars exploded in massive supernovae.

As the universe continued to expand, galaxies moved further apart from one another. Scientists observed that the universe is not only expanding but also accelerating in its expansion due to the mysterious dark energy, which constitutes about 68% of the universe's total energy-matter content. The Big Bang theory provides a consistent framework for understanding the cosmic microwave background radiation, a faint glow of leftover radiation from the early universe, discovered in 1965. This discovery played a crucial role in validating the theory. While the Big Bang theory successfully explains the universe's evolution from its early moments to its current state, it doesn't provide insights into what happened at the moment of the singularity. Understanding the extreme conditions during the initial singularity requires a theory of quantum gravity—a bridge between the theories of general relativity and quantum mechanics—which remains an ongoing challenge in modern physics.

In summary, the Big Bang theory is a widely accepted scientific model describing the birth and evolution of the universe, beginning with an immensely hot and dense singularity that expanded and eventually led to the formation of galaxies, stars, and the vast cosmos we observe today (Thep. Big Bang).



HOW HUBBLE SPACE TELESCOPE HELP VALIDATE THE BIG BANG THEORY

The Hubble Space Telescope (HST) has made significant contributions to our understanding of the universe and has played a crucial role in unraveling the secrets of the Big Bang. Launched in 1990, Hubble has been one of the most successful and iconic scientific instruments in history, providing astronomers with a unique and clear view of the cosmos from above Earth's atmosphere. Here are some of its key contributions to our knowledge of the Big Bang:

1. **Determining the Age of the Universe:** One of Hubble's most groundbreaking achievements was accurately determining the age of the universe. By measuring the rate of the universe's expansion, known as the Hubble constant, scientists were able to estimate the age of the universe and conclude that it originated from a hot and dense state about 13.8 billion years ago. This knowledge solidified the Big Bang theory as the leading explanation for the universe's origin.
2. **Observations of Distant Galaxies:** Hubble has been instrumental in observing and studying distant galaxies that are billions of light-years away. By analyzing light from these distant galaxies, astronomers can see the universe as it was in its early stages, providing valuable insights into the conditions shortly after the Big Bang.
3. **Cosmic Microwave Background (CMB) Studies:** The Big Bang theory predicts the existence of a faint afterglow of radiation from the early universe called the Cosmic Microwave Background (CMB). Hubble has contributed to CMB studies by making precise measurements of its fluctuations, which has helped confirm the Big Bang theory's predictions and provided essential details about the universe's early history.
4. **Probing Dark Matter:** Hubble's observations of galaxy clusters have allowed scientists to study the effects of dark matter on the large-scale structure of the universe. Dark matter played a significant role in the early universe's evolution and its gravitational effects are visible in the distribution of galaxies and galaxy clusters. By understanding dark matter's influence, scientists gain deeper insights into the processes that occurred during the Big Bang.
5. **Studying the First Stars and Galaxies:** Hubble has also been crucial in studying the earliest stars and galaxies that formed after the Big Bang. These observations offer valuable information about the universe's infancy, helping to refine our understanding of the early stages of cosmic evolution.
6. **Probing the Expansion of the Universe:** Hubble has been used to study the expansion rate of the universe over time, which provides important constraints on various cosmological models and theories related to the Big Bang.
7. **Dark Energy:** Hubble's observations of distant supernovae led to the discovery of the accelerated expansion of the universe, which is driven by a mysterious force called dark energy. Understanding dark energy is vital to grasping the universe's ultimate fate and its implications for the Big Bang theory.

CONCLUSION

The Hubble Space Telescope has been instrumental in advancing our understanding of the Big Bang. By capturing awe-inspiring deep space images and precise measurements of distant galaxies' redshifts, it confirmed the universe's expansion and the concept of the Big Bang. Hubble's observations of the Cosmic Microwave Background radiation provided crucial evidence, supporting the theory. It allowed scientists to measure the age of the universe and the distribution of matter, shedding light on its early history and leading to significant breakthroughs in cosmology. Hubble's pioneering work has revolutionized our perception of the universe's origins and continues to inspire further exploration.

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