# The Big Bang Theory: Evidence, Implications, and Unresolved Questions in Cosmology

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Publication Date: 2025/08/22

**Abstract: The leading scientific explanation for the origin of the universe is the Big Bang theory, according to which our universe began 13.8 billion years ago from an infinitely dense and hot point, expanding rapidly into the expanse we see today [1]. The theory emerged from a historical shift from the previously known static universe models [2]. Resultantly, it transformed cosmology in the 20th century. We will also go through the basics of Big Bang Theory and its key evidence, like Cosmic Microwave Background Radiation, Redshift of Galaxies, and Abundance of light elements present in the Universe, to make us understand how our universe evolved. Observational support remains based on these pillars: redshift, CMB and primordial element abundances. The paper also examines perplexing issues related to dark matter, dark energy, and the universe's first moments that remain unresolved. Inflation theory, the singularity problem and what (if anything) might have existed before the Big Bang is also covered. This paper shows a concise and engaging way of explaining the great Big Bang debate by interweaving it with the scientific discoveries of today as well as historical context, making this subject more accessible to all who are interested in humankind's efforts to uncover how the cosmos began. It also takes into account the involvement of modern-day technology and future research in either supporting or possibly redefining the way we look at the universe's origin and fate.**

***Keywords:*** *Big Bang Theory, Cosmic Microwave Background (CMB), Redshift, Dark Matter and Dark Energy, Cosmology and Universe Evolution.*

**How to Cite:** Devansh Pande (2025) The Big Bang Theory: Evidence, Implications, and Unresolved Questions in Cosmology. *International Journal of Innovative Science and Research Technology*, 10(8), 894-899.
https://doi.org/10.38124/ijisrt/25aug660

## I. INTRODUCTION

Picture a time when everything in the universe — space, time, matter and energy — was contained within an infinitely small point of infinite temperature and density. Until, in an instance of infinite deceleration, it exploded and the universe came into being. It's the punch line to the Big Bang theory: [3] the best description cosmologists have of how everything we see came into being in a timely manner.

Nearly a century after it was proposed, the Big Bang model has revolutionised our conception of the cosmos with support from many different types of observations [4], such as those made using telescopes and particle accelerators, or based on mathematical models. But it continues to be a topic of fascination and debate, one that also raises such mysteries as dark energy and the universe's long-term fate.

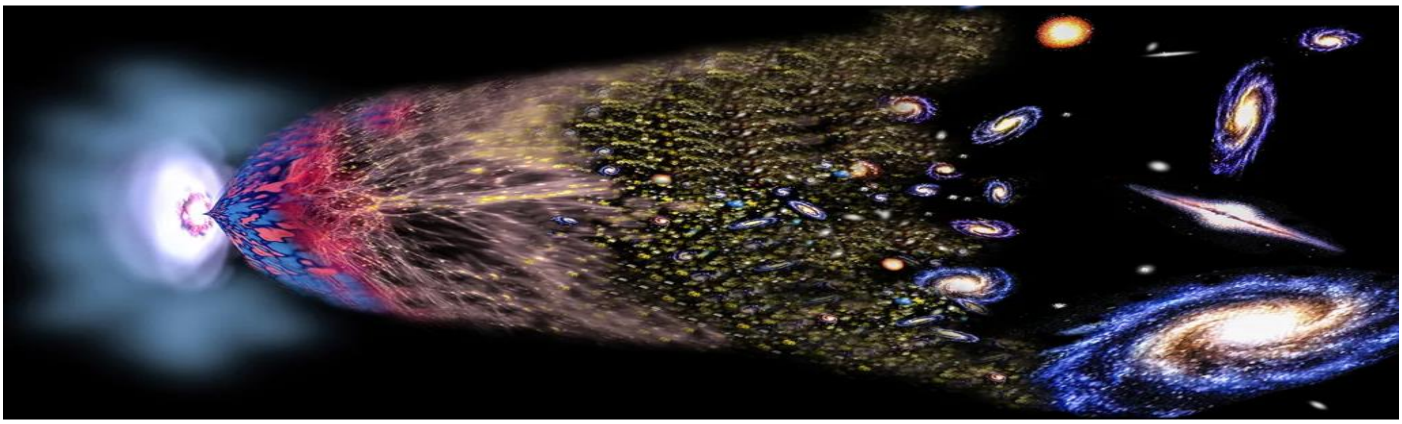

Fig 1 A Graphical Representation of the Big Bang as Illustrated by an Artist. (Photo by David A. Aguilar) as taken from Smithsonian Magazine. [4]

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug660

This paper goes over the basics of Big Bang Theory, the observations that underpin it, and some outstanding issues that confound our understanding. It also considers the Big Bang in context with other cosmological theories, of which only the steady state and cyclic universe have ever been proposed historically [5], signalling its place on the trajectory of scientific ideas. It combines historical perspective with peer-reviewed literature and modern cosmology research to draw a big picture from both observational data and theoretical models.

In so doing, it seeks to shed light on this deep idea for the first-time readers of cosmology, while providing a glimpse at why it remains scientifically relevant. In order to appreciate how this concept has progressed, from being a speculative suggestion to the leading cosmological model in existence, it is necessary to start with its history.

## II. HISTORICAL CONTEXT

The concept of a finite, beginning-end universe was not always accepted. For the first half of the 20th century, many scientists believed that the universe had no beginning and no end. It had always been around, more or less as it is today. At last, in the year 1915, the tide began to turn when Albert Einstein introduced his theory of general relativity. This describes gravity as the curvature of spacetime. The equations of Einstein imply the universe was dynamic, like a balloon that could inflate or deflate, but he rejected this option at first by invoking a cosmological constant to keep the universe static [6].

In the 1910s, American astronomer Vesto Slipher started measuring galaxies' spectra and showed that nearly all of them had redshifts—evidence they were receding from us [7]. Although the significance of these early observations was not fully appreciated at the time, they paved the way for events in the 1920s to clarify that perception forever, as a Russian mathematician named Alexander Friedmann and a Belgian priest named Georges Lemaître both used Einstein's equations to predict an expanding universe.

In 1927, Lemaître proposed that the universe originated from a "primaeval atom", which conceived the foundation for the Big Bang theory [8]. Even the term 'Big Bang' was originally coined in 1949 by British astronomer Fred Hoyle [9], who, being a vocal critic, actually favoured a steady-state model over an expanding universe where new matter is created to keep up the density as space expands. Competing with this model was Richard Tolman's oscillating universe model and other alternatives.

Advances in radio astronomy and microwave detection technologies during the decades immediately after World War II started to give us a new set of tools by which we could investigate our galaxy. There were also philosophical and cultural discussions: the question of whether the Big Bang concept was compatible with a cosmic genesis or not was raised, as well as whether it coincided with theological creation; scientists like Lemaître themselves emphasised that these models did not have to be mixed up with religious beliefs.

Yet by the 1950s, a growing body of observational evidence — most notably the cosmic microwave background in 1965 — would firmly tip cosmology towards Lemaître's standpoint, reshaping our understanding of the cosmos [10].

## III. THE BIG BANG MODEL

According to the Big Bang theory, the universe began some 13.8 billion years ago as an infinitely small, hot and dense point [1]. Importantly, this singularity is a mathematical extrapolation from the general relativity equations of Einstein [6]. Most physicists believe that as one goes back toward the beginning of time, quantum gravitational effects in those earliest instances would take over from the singularity, and a more physically correct description can be found, though a theory of quantum gravity has likely not been established [11].

This singularity quickly began to grow in an event we call the Big Bang [3], although it was not an explosion into an existing space but rather the creation of space and time. At one millionth of a second after the Big Bang, known as the Planck epoch ($10^{-43}$ seconds) [12], it was so hot and dense that standard laws of physics did not work. Soon after that, during the inflationary epoch, the universe may have expanded exponentially and erased any irregularities to create a comfortable context for galaxy formation [13].

Even as the universe expanded, it cooled enough for basic particles such as quarks and electrons to condense out of an energy state within the first microsecond. Within three minutes protons and neutrons combined to form the nuclei of light elements like hydrogen and helium in a process called nucleosynthesis [14].

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug660

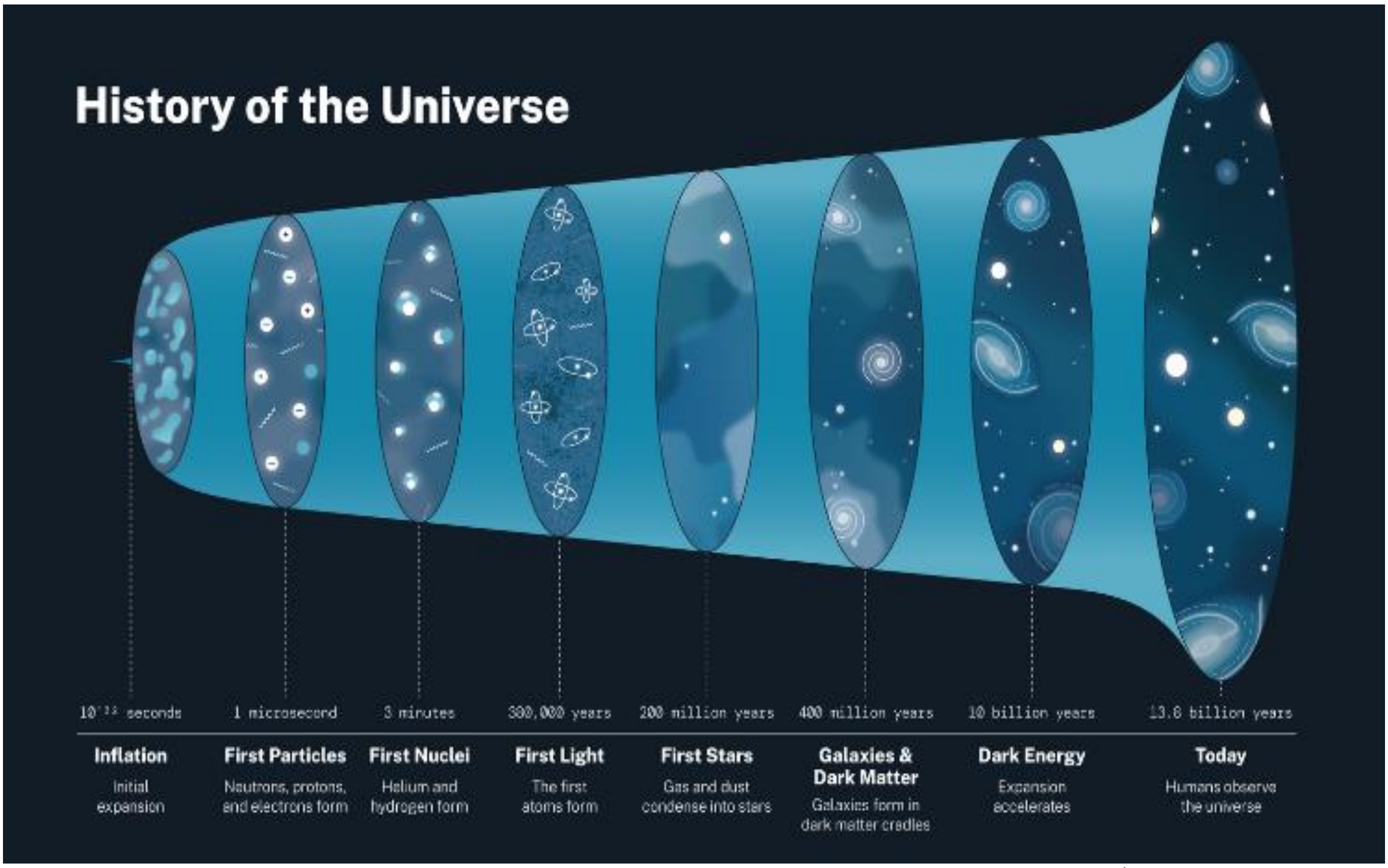


Fig 2 A Figure Representing the History of the Universe. As taken from Science.nasa.gov on 04th August 2025 [15]

In the next 380,000 years, the universe cooled so that electrons and protons or nuclei were finally able to combine to form neutral atoms: this recombination meant that the universe turned transparent and light could propagate freely. Today, we detect this light as the cosmic microwave background (CMB), which has been stretched to microwaves [16]. This was succeeded by the cosmic dark ages, a time when nebulous hydrogen gas populated space, but no stars [17]. Billions of years ago, tiny density fluctuations due to the force of gravity began to form under bolder CMB ripples — which we can now detect — attracted mass into the first stars and galaxies in a process called reionisation that ended this dark age [17].

The universe continued to expand, forming stars, galaxies, and planets over billions of years, leading to the cosmos we observe today. Initially, this expansion decelerated due to gravitational attraction, but in more recent cosmic history, dark energy began to dominate, causing the expansion to accelerate [15].

## IV. EVIDENCE SUPPORTING THE BIG BANG

The evidence for the Big Bang theory is hence built upon numerous independent lines of research, all pointing towards a hot, dense origin, followed by an expansion of the universe [1]. The first clear hint of this came in 1929; when the American astronomer Edwin Hubble discovered that not only are galaxies moving away from us, but the light from those receding galaxies is stretched into longer, redder wavelengths, a property called redshift [18]. This implied that the universe is expanding, similar to dots on an inflated balloon becoming more distant from one another. According to Hubble's Law, the further away a galaxy is from us, the speed at which it moves away from us becomes faster as well [19] and so if we go back in the flow of time when these galaxies were much closer, they should converge into just one point. The most recent determinations give a measurement of the Hubble constant as 70 km/s/Mpc, and an age for the universe of approximately 13.8 billion years [20].

Another cornerstone is the cosmic microwave background (CMB), discovered accidentally in 1965 by Arno Penzias and Robert Wilson. This faint glow, uniform across the sky, is the remnant heat from the Big Bang, cooled to just about 2.7 Kelvin above absolute zero. Detailed maps from satellites like the Cosmic Background Explorer (COBE), the Wilkinson Microwave Anisotropy Probe (WMAP) [21], and the Planck spacecraft reveals tiny anisotropies—minute temperature fluctuations in the CMB—that represent the seeds from which galaxies and large-scale cosmic structures formed. These precise measurements provide strong support for the Big Bang model and have helped rule out competing theories such as the steady-state model [22] [23].

In addition, the light element abundances, in particular about 74% hydrogen and about 24% helium (by mass), are very close to what theory predicts from Big Bang nucleosynthesis for how much should have been produced in the first few minutes of the universe's evolution. A more accurate determination of the primordial deuterium and lithium abundances also tightens cosmological models as

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug660

well as the early universe physics, providing crucial tests of theoretical predictions [24] [25].

The distribution of galaxies and the universe's large-scale structure are two more pieces of observable data that fit with what we would expect from early density fluctuations that were amplified by gravity. Baryon Acoustic Oscillations (BAO) are regular, periodic changes in the density of visible baryonic matter. They have been seen in the large-scale clustering of galaxies more recently [26], which supports the Big Bang theory's prediction of the universe's expansion history.

## V. IMPLICATIONS OF THE BIG BANG

The Big Bang theory alters the way the history of our universe and its components are perceived. It says space and time are not fixed, but dilating over billions of years [3]. This expansion leads to an estimate that the universe is around 13.8 billion years of age calculated by using the Hubble constant and CMB data. The theory also describes how cosmic structures formed: slight density fluctuations in the earlier universe, magnified by gravity, gave rise to galaxies, clusters and superclusters [18] [1] [20] [17].

In addition, the Big Bang offers context with respect to what the universe is made of: it suggests that only about 5% of the universe is ordinary matter (stuff like stars, planets, and gas) while a further 27% consists of dark matter — an invisible form that influences gravity but does not produce light — and 68% is made up of dark energy, a force driving an accelerated expansion across the universe [27].

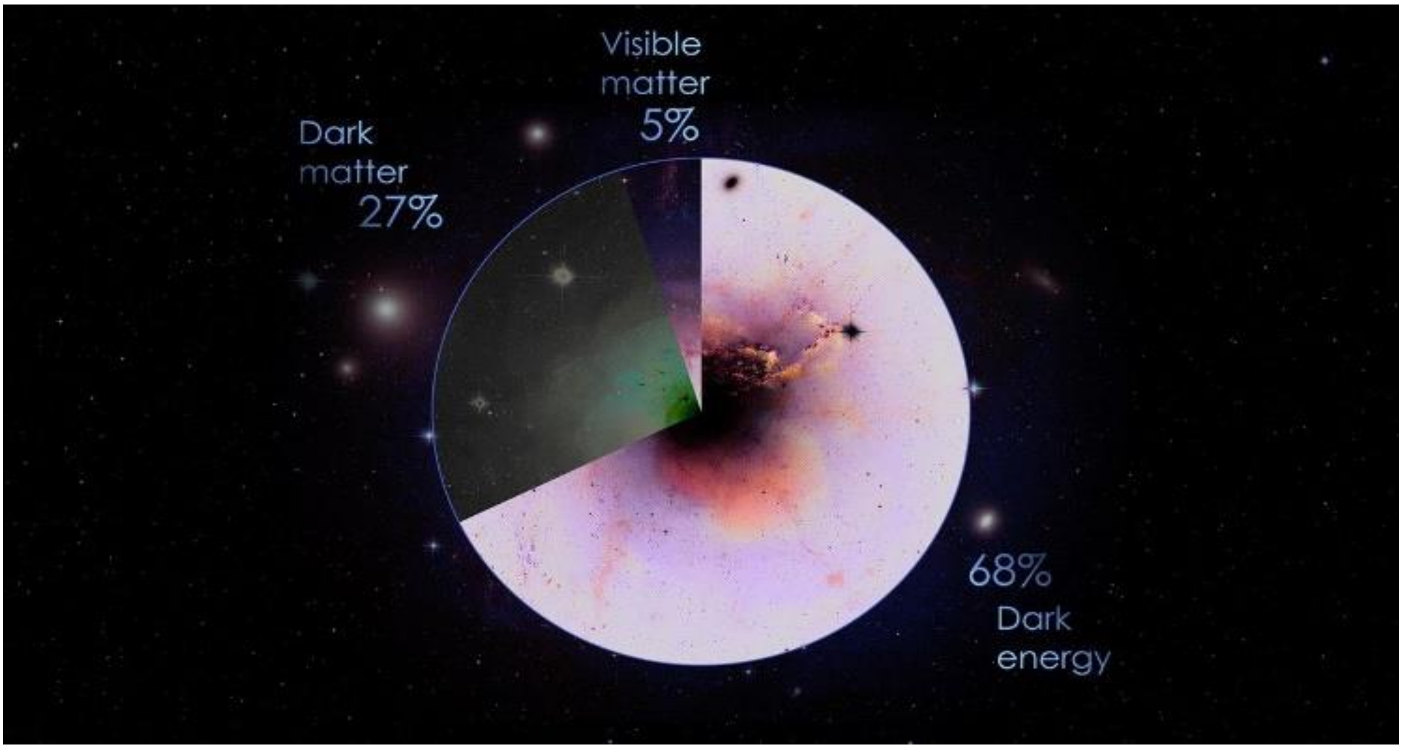


Fig 3 A Figure Representing the Three Components of the Universe as taken from Science.nasa.gov [Credits – NASA's Goddard Space Flight Center] [27]

➢ *These Discoveries Raise Profound Questions:*

- What triggered the Big Bang?
- What is the universe's ultimate fate?
- Will it expand forever, collapse, or reach a stable state?

The theory also challenges philosophical and cultural perspectives. It suggests a universe with a beginning. This prompts debates about causality and the nature of existence.

## VI. CHALLENGES AND OPEN QUESTIONS

Despite being a remarkably successful theory, the Big Bang faces several challenges and unanswered questions. The first is the singularity itself - a point of infinite density where the laws of physics cease to apply [1]. This is circumvented by models such as inflation that say the universe expanded extremely quickly in its first $10^{-36}$ seconds or so, smoothing everything down and providing us a way to rationalise why the universe is homogeneous [13].

Inflation, though, has not been proven and exists by speculation only. Dark matter and dark energy make up an overwhelming portion of the universe. However, we know practically nothing about what they are [27] [15]. To find answers, experiments such as those at the Large Hadron Collider keep probing for clues. Even if inflation potentially provides a partial resolution, the "horizon problem"—the question regarding how distant parts of the universe come to have almost uniform temperatures because they could never have interacted—remains [28].

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug660

Furthermore, the theory cannot account for whatever came before the Big Bang. This has led to speculation about phenomena such as quantum fluctuations or the cyclic universe. These gaps that remain in our knowledge expose deficiencies and what existing observations and theories are incapable of explaining, thus necessitating future discoveries and new ideas to better understand the Big Bang picture.

## VII. FUTURE DIRECTIONS IN COSMOLOGY

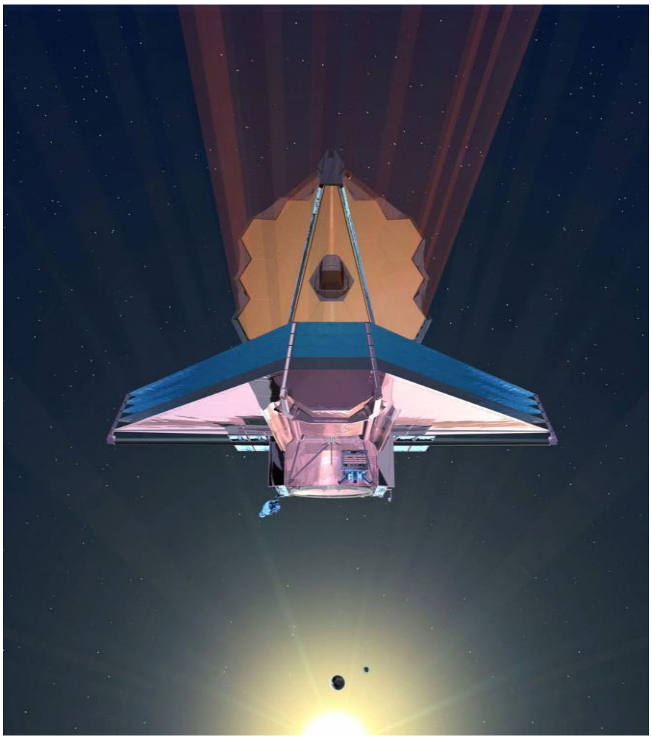

Fig 4 An Image Representing the James Webb Space Telescope in action (Image Credit: NASA) as taken from space.com’s Article 'Cosmic Miracle!' James Webb Space Telescope Discovers the Earliest Galaxy Ever Seen [29]

Technology and observation are helping us understand the Big Bang better. But the next cyclopean detectors made operational in space, such as the James Webb Space Telescope, allows astronomers to see even further back into the universe's past at galaxies that date from a few hundred years after the Big Bang [29]. Experiments such as the Simons Observatory and the Square Kilometer Array are set to be able to map this CMB more precisely than ever before, allowing for study of inflation and early universe dynamics [30].

Particle accelerators explore conditions similar to the ones from the early stages of the Big Bang, which could detect new physics. At the same time, various theoretical models such as string theory and loop quantum gravity are being explored in order to marry general relativity with quantum mechanics, which may eventually shed some light on the singularity. These projects vow to hone in on the Big Bang model, solving it mystery and maybe even reveal our universe as but one among many unto itself. The quest to understand the Big Bang is far from over. Each discovery today, brings us closer to unravelling the cosmos’s origins.

## VIII. CONCLUSION

The Big Bang theory itself, combining mathematical intuition with observational verification, told a gripping story of the universe's beginning that revised our understanding of a timeless void into an active and non-static cosmos. It is consistent with redshift observations, the cosmic microwave background and the abundance of light elements it predicts, and is central to explaining how stars and Galaxies form.

Yet, mysteries like dark energy, the singularity, and the universe’s ultimate fate remind us that the story is incomplete. By making these concepts accessible, this paper hopes to ignite curiosity about the cosmos.

Moreover, it invites readers to ponder humanity’s place in a universe that began with a bang, and continues to surprise us with its secrets.

## REFERENCES

[1]. A. May, "What is the Big Bang Theory?," Space.com, 30 January 2025. [Online]. Available: https://www.space.com/25126-big-bang-theory.html. [Accessed 29 July 2025].

[2]. P. A. LaViolette, "Expanding or static Universe: Emergence of a new paradigm.," International Journal of Astronomy and Astrophysics, vol. 11, no. 2, p. 190–231, 2021.

[3]. M. R. Manglik, Philosophy of Science and Cosmology, E. P. Experts, Ed., EduGorilla Publication, 2023, p. 187.

[4]. C. Dreifus, "What Astronomers Are Still Discovering About the Big Bang Theory," Smithsonian Magazine, March 2014. [Online]. Available: https://www.smithsonianmag.com/smithsonian-institution/what-astronomers-are-still-discovering-about-big-bang-theory-180949794/. [Accessed 06 August 2025].

[5]. H. Kragh, "Quasi-steady-state and related cosmological models: a historical review," arXiv preprint, 2012.

[6]. H. Nussbaumer, "Einstein’s conversion from his static to an expanding universe," EPJ H, vol. 39, p. 37–62, 2014.

[7]. V. M. Slipher, "Radial velocity observations of spiral nebulae," The Observatory, 13 April 1917.

[8]. H. Kragh, "Georges Lemaître, Pioneer of Modern Theoretical Cosmology," Foundations of Physics, vol. 48, p. 1333–1348, 2018.

[9]. H. Kragh, "Naming the big bang," Historical Studies in the Natural Sciences, vol. 44, no. 1, pp. 3- 36, 2012.

[10]. A. A. a. W. R. W. Penzias, "A Measurement of Excess Antenna Temperature at 4080 Mc/s," The Astrophysical Journal, vol. 142, p. 419–421, July.

[11]. Institute of Physics, "The big bang," Institute of Physics , [Online]. Available:

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug660

https://www.iop.org/explore-physics/big-ideas-physics/big-bang. [Accessed 26 July 2025 ].
[12]. G. A. M. Marugán, "Loop Quantum Cosmology: A cosmological theory with a view," Journal of Physics: Conference Series, vol. 314, no. 1, September 2011.
[13]. Fiveable, "Planck Epoch – Honors Physics," 2024. [Online]. Available: https://library.fiveable.me/key-terms/honors-physics/planck-epoch. [Accessed 03 August 2025].
[14]. Fiveable, "inflationary epoch – Astrophysics I," 2024. [Online]. Available: https://library.fiveable.me/key-terms/astrophysics-i/inflationary-epoch. [Accessed 03 August 2025].
[15]. U.S. Department of Energy, "DOE Explains...Nucleosynthesis," U.S. Department of Energy, [Online]. Available: https://www.energy.gov/science/doe-explainsnucleosynthesis. [Accessed 03 August 2025].
[16]. NASA, "Dark Energy," science.nasa.gov, [Online]. Available: https://science.nasa.gov/dark-energy/. [Accessed 04 August 2025].
[17]. Astronomy.com, "How did the first element form after the Big Bang?," 12 December 2018. [Online]. Available: https://www.astronomy.com/science/how-did-the-first-element-form-after-the-big-bang/. [Accessed 03 August 2025].
[18]. nasa.gov, "Early Universe," [Online]. Available: https://science.nasa.gov/mission/webb/early-universe/. [Accessed 04 August 2025].
[19]. CERN, "The early universe," CERN, [Online]. Available: https://www.home.cern/science/physics/early-universe. [Accessed 04 August 2025].
[20]. A. Kaya, "Hubble's law and faster than light expansion speeds," American Journal of Physics, vol. 79, no. 11, pp. 1151-1154, November 2011.
[21]. R. Lokhande, Estimating the Age of the Universe: A Hubble Constant Approach, 2023.
[22]. M. H. G. H. N. J. A. K. M. L. S. S. M. L. P. D. N. S. G. S. T. C. L. Bennett, "First-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Preliminary Maps and Basic Results," The Astrophysical Journal Supplement Series, vol. 148, no. 1, pp. 1-27, 2003.
[23]. A. A. Penzias and R. W. Wilson, "A Measurement of Excess Antenna Temperature at 4080 Mc/s," The Astrophysical Journal, vol. 142, pp. 419-421, 1965.
[24]. G. F. Smoot and D. Scott, "Cosmic Microwave Background Radiation," Encyclopedia of Cosmology, pp. 1-18, 2018.
[25]. B. D. Fields, "The Primordial Lithium Problem," Annual Review of Nuclear and Particle Science, vol. 61, pp. 47-68, 2011.
[26]. G. Steigman, "Primordial Nucleosynthesis in the Precision Cosmology Era," Annual Review of Nuclear and Particle Science, vol. 57, pp. 463-491, 2007.
[27]. B. Bassett and R. Hlozek, "Baryon acoustic oscillation," in Dark energy: observational and theoretical approaches, vol. 246, 2010, p. 53.
[28]. NASA, "The Universe's Building Blocks," NASA, [Online]. Available: https://science.nasa.gov/universe/overview/building-blocks/. [Accessed 05 August 2025].
[29]. E. P. Tryon and R. A. Meyers, "Cosmic Inflation," in Encyclopedia of Physical Science and Technology (Third Edition), New York, Academic Press, 2003, pp. 779 - 822.
[30]. R. Lea, "'Cosmic miracle!' James Webb Space Telescope discovers the earliest galaxy ever seen," 31 May 2025. [Online]. Available: https://www.space.com/astronomy/cosmic-miracle-james-webb-space-telescope-discovers-the-earliest-galaxy-ever-seen. [Accessed 05 August 2025].
[31]. L. B. Glaser, "Simons Observatory begins measurements to probe Big Bang inflation," 20 June 2024. [Online]. Available: https://research.astro.cornell.edu/news/simons-observatory-begins-measurements-probe-big-bang-inflation. [Accessed 06 August 2025].