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A Brief Overview of the Big Bang Theory with Frontier Attachments

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Abstract. The work briefly summarizes the Standard Big Bang Model, with some new frontier works demonstrating a more realistic Big Bang scenario. The main contributions are from the development of String Theory and Cosmology. The deduction and establishment of the Big Bang Theory undergo continuous contributions, from the microwave background radiation and the observation of Hubble's constant, the first impression resulting in the basic structure of the theory, to the later works, such as Friedman's equation, which introduced the theory to be rational. While there are still many details waiting to be fully understood, in this summary, we review the extensive bang process from the perspective of frontier research in string theory, both singular and non-singular models, and the related scenarios derived from the standard model of the big bang theory. We also examine the evidence supporting the model and the pre-big bang cosmology and provide a brief overview of the universe's fate based on the trend of Hubble's constant about string theory. The scenarios under different evolutive trends of Hubble's constant, related briefly to the string theory, were roughly calculated and proved to demonstrate the final state, or the universe's fate, where there is evidence for an always-existing universe. We also demonstrate the possible scenario of a cyclic model, which may be an alternative model for the real sense of the universe's evolution.

Keywords: cosmology, string theory, Big Bang Model, pre-big-bang cosmology, inflation, duality symmetry.

1. Introduction

The formation of the big bang theory involves hundreds of years of evolution where the sense of the nature of the universe grows to be more axiomatic and unambiguous. The actual scenario of the big bang theory as well requires the newly discovered, proved, established, and summarized theories to create an even more precise and actual recognition of the wide-range-covering theory. In this paper, we introduce the frontier of string cosmology to the evolving Big Bang theory to contribute to a firmer overview of the notion of the big bang. Without a doubt, there are still emphases left to be tested, along with which this work is simply a step towards an even more vivid scenario.

The brief standard content of the big bang theory is that the universe started at a singularity, where "time and space are meaningless." At the same time, both the temperature and density got infinite, then came a wild continuous expansion that was both homogeneous and isotropic in an extraordinarily hot and dense [1]. The expansion happened in multiple dimensions, thus resulting in a curvature over the universe's space [2]. At the birth of the universe, the curvature was drastic. In contrast, as time evolves, the curvature has been so mild that we can approximately take the universe to be flat in the way of Riemannian geometry [3]. The universe's curvature can be assumed as a hypersphere in this scene. An important feature is that the expanding is that space itself expands instead of matters expanding in a particular space [4].

The evolving frontiers of cosmology and physics, especially in string theory and quantum mechanics, do expand and deepen the recognition of the axiom of the functionality of the universe. However, with the limitation of securable observations, pre-big-bang cosmology still demonstrates a clearer perspective on the universe. The part of the universe's evolution striking the most will be precisely the first second when both natural laws and matter, fundamental forces, were formed from something like the string, which we will introduce afterward. The basic idea of string theory provides a reasonable explanation of the formation of fundamental forces and matter. While slimmer string natures and matter structures have yet to be observed, the theory still explains the inside phenomena and axioms of the universe's birth. The big bang theory received dozens of criticisms in the first few decades after its invention. However, the theory has been even more firmly accepted and proven from simple phenomena and its structure that is accessible to most cosmological observations. In the paper, we work out the regulation and process of deduction of Hubble's constant, and at the same time, we give our simple work on the equation that predicts the fate and final evolution of the universe. Friedman's equation, under the equipped simple model, fixes up the list of shortages that offer limitations towards the accuracy of the model's prediction. In addition, we refine the model to be more accurate to the real-world scene.

The involvement of inflationary cosmological models implies the claim that the universe is still undergoing inflation in specific areas of the universe, causing the universe to be composed of areas of separately thermalized regions, inflating regions, and post-inflationary regions [2]. The three parts are currently unified to form the current universe. In the reference frame of the co-moving, thermalized regions will expand, with a growing proportion of matters lying in the thermalized zones. As a result, the proportion of inflating zones will decrease and tend to disappear as time evolves [2]. While in comparison with the expansion of the inflating zones, the effect will strongly outweigh the increase of thermalized zones. Thus, a universe with a spacetime that undergoes eternal inflation is introduced [4]. This is different from the Standard Model’s hypothesis that inflation is finite. The mechanism of inflationary cosmology confines the Standard Model’s reliability. The continuing inflation zones and the increased thermalized zones conflict with the simplified zone’s assumption of a future universe reaching a thermalized state or heat death. The existence of continuous inflation implies an assumption of the existence of inflation in the pre-big-bang sense. Thus, an inflation-owned singularity will never be rational since inflation requires spacetime, which did not exist at the moment of inflation.

Another indication of a non-singular big bang model is that, from the duality symmetries, a component of string theory, a pre-big bang scenario is that the universe started with a condition of cold and empty [5]. The duality symmetry is in the form:

$$\dot{\beta}^{(n)} = \prod_{k=1}^{n} \left(\frac{1}{N}\frac{d}{dt}\right)^{k} \beta_i(t) \#(1)$$

Where $n^{3}1$. The exact content of the duality symmetry will be introduced in the main body.

Noticeably, the derivation of the scale factor plays a vital role in the cosmological model without an initial singularity. The organized frontier discoveries demonstrate that a cosmological model contains no initial singularity, unlike that involved in the standard model. The recognition that the universe was created, rather than having existed before the significant bang incident, is also abandoned. The correction regulates the universe's curvature to be tiny without the quantum-loop effects. At the

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same time, a hypothesis of the existence of a string phase after the big bang, if it is still called so, at the situation firm, proves the absence of the initial singular [6].

2. The content of the theory

The brief standard content of the big bang theory is that the universe started at a singularity, where "time and space are meaningless." At the same time, the temperature and density got infinite; wild continuous expansion was both homogeneous and isotropic under extraordinarily hot and dense [1]. The expansion happened in multiple dimensions, thus resulting in a curvature over the space of the universe [1,4]

At the birth of the universe, the curvature was drastic. In contrast, as time evolves, the curvature has been so mild that we can approximately take the universe to be flat in the way of Riemannian geometry [5]. In this scene, the universe's curvature can be assumed as a hypersphere [5]. An important feature is that the expanding is that space itself expands instead of matters expanding in a particular space [2].

2.1. The Formation Of Fundamental Forces And Matters

As time passes, the universe continues to expand, and due to sufficient cooling, a phase transition causes cosmic inflation [7]. The four fundamental forces and matter formed at the very beginning, after approximately 10−43 seconds. Though in today's view, we take the four fundamental forces as something usual and eternal, "during 0~10−43 seconds, the four forces were united as one" [8]. The period is now identified as the Plank Epoch [8]. The process of the correct formation of the fundamental forces is still under exploration, while the general impression is that the process carried on along with the cooling of the universe, at 10−43 seconds, the gravitation first separated from the other unified forces during the Grand Unification Epoch [3]. Then came the phase transition that resulted in an even exponential decrease in the temperature. This led to the electroweak epoch, where the strong nuclear force separated from the unity, leaving only electromagnetic and weak nuclear forces. The behavior prior to the Plank Epoch cannot be explained by the quantum mechanics of the time. The inner theories of the period are still in the mist.

As evolution carried on, the universe's temperature and density decreased. Then a process, reheating, happened to heat the universe enough to support the formation of quark-gluon plasma and all other elementary particles [9,10]. The mechanism of symmetry-breaking phase transitions then transformed the fundamental forces and elementary particle parameters into their current forms, with the electromagnetic force and the weak nuclear force becoming the last pair to be separated from the unified status [11].

The process of baryogenesis, which leads to an excess of quarks and leptons over their antimatters, is still under exploration. Moreover, the additional explanations for the process have blanks that must be filled in to make sense. There are still dozens of mists from the first few seconds of the Big Bang event waiting to be unraveled.

"A brand new non-standard cosmological scenario of the Big Bang has been developed, where a "Big Bounce replaces singularity," [5] at a high but finite curvature. This study is obtained from the duality symmetries of string theory. This may lead to a different model of the theory, but the final breakthrough has not been made. Research also shows that the natural laws were formed randomly, though deducing from the inflection models is not precisely probable [12].

2.2. Expansion Afterwards

Hubble's law states that all galaxies travel away from us except those closest to the Milky Way (Hubble's law does not apply). Since our position in the Universe has no special status, Hubble's law applies to observers anywhere in the Universe, i.e., the galaxies they observe are also moving away from them. All points, regardless of where they are on the sphere's surface, are moving apart, similar to how an expanding balloon looks with galaxies on its surface. Of course, this is not a literal representation of the universe but rather a metaphor for how it is expanding.

Thus, an expansion trend of the universe is shown to depend on time passed. This phenomenon can be described using a scale factor $a(t)$, where:

$$r(t) = a(t)\#(2)$$

By the simultaneous of the two equations above, H is deduced as a parameter in terms of time, defined as:

$$H(t) = \frac{\dot{a}(t)}{a(t)}\#(3)$$

Therefore, the positive value of a's second derivative is deduced by taking the time derivative of both the Friedman and the fluid equations. Hence, the universe is accelerating its expansion.

$$\frac{\ddot{a(t)}}{a(t)} =-\frac{4\pi}{3c^2}(\varepsilon + 3p)\#(4)$$

The universe is expanding, but we do not consider how far it will expand. Instead, we think backward. The earlier the time, the smaller the universe and the denser it will be. In a homogeneous universe, the temperature of all parts should be the same, so when it expands, it should be adiabatic and, therefore, more relaxed. Therefore, the early universe should also have had a high temperature. We can also conclude that the universe began at a minor point known as the Big Bang.

2.3. The Proof of the Big Bang Theory

There are clear facts supporting the Big Bang model, even though it was widely assumed that the universe was static for a long time, which even Einstein believed. The first is Hubble's law, which asserts that a star accelerates as it moves away from the Earth. The Hubble diagram's slope represents the constant rate of cosmic expansion induced by the stretching of space-time itself [13]. The cosmic background radiation is the additional factor. This is condensed proof.

The expansion of the universe, deduced from Hubble's law, demonstrates that the universe follows a homogeneous and isotropic expansion. Thus, it is clear that the universe started at a single point, the singularity. According to Hubble's law, this makes sense a lot. For the CBR, firstly, from the redshift, they are observed from the furthest radius of our horizon. Because the horizon's radius is finite and the universe is expanding according to the Big Bang Theory and Hubble's Law, the area observed from Earth is limited by the two features. As they pass through the whole life of the universe, that is a long time. The progressive redshift has summed up quite a long wavelength, while they were visible light at the beginning. Thus, we conclude that there were a large number of lights, accurately visible lights, produced instantly at the Big Bang. This is how we deduce that the universe was hot and dense in the first few instants after the Big Bang.

2.4. Along with the Model

The model also argues that the phenomena of a limited horizon result from the universe's finite age and light's finite speed. The universe's expansion at the Big Bang Event exceeded the speed of light for a period. According to Hubble's law, the speed of the universe's expansion relative to the earth to an extinct point may well exceed the speed of light in the future. Note that this does not go against special relativity since the speed at the moment is fake, which is just a phenomenon of expanding space. This leads to the problem that, at some moment, the exerted light can not reach the observer anymore.

2.5. The Pre-big-bang Period

Several models have been made to explain, in hypothesis, the formation of the big bang. The simplest is that the big bang was caused by quantum fluctuations [14,15]. The second is that spacetime is finite, with Hartle-Hawking no boundary condition. In this scene, the universe is self-sufficient [16].

3. The fate of the universe

Due to limited research and observations, the universe's fate is still unclear. An important feature is critical density. As the universe evolves, two scenarios will form, greater or smaller. In the more significant situation, the universe tends to form a Big Crunch [11]. Moreover, the opposite, the smaller (and equal), there will form a Big Freeze [17]. In the situation of the first one, "the universe will grow denser and hotter, and the result might be several new big bangs. In this scene, the universe lasts, in our view, forever, but there will be countless stages that start with Big Bang and ends with Big Crunch," which feels empty and lonely from a human's s perspective. Moreover, for the Big Freeze, there might be almost 0 CBR, and the universe keeps expanding, then everything goes beyond our sight. There can also be heat death, where all thermodynamic energy exhausts [4]. Moreover, since the decaying nature of protons is yet to be discovered, the baryonic matter may decay, and even black holes may evaporate [6]. In this situation, finally, only energy exists, with nothing more. Another model is Big Rip [5] that the matter of the universe, and even the spacetime itself, will be progressively torn apart from the expansion [5].

While the Big Crunch is less to be concerned about happening according to present research, the fate of the universe is more likely to be the Big Freeze, or Big Rip, depending on the proton's lifetime.

According to current research, the Big Crunch is less likely to occur, but the universe's fate is more likely to be the Big Freeze or Big Rip, depending on the proton's lifetime.

3.1. The Proof of the Scenario

The newly developed string theory does an excellent job of predicting the universe's fate, though most of the obtained theories have not been firmly convinced. There are several structures in string theory that are not under consideration, which are, separately, type II and heterotic strings and Bosonic strings. The two very strongly in affecting Hubble's constant. Hubble's constant is generally accepted as a constant value but only functions for a short time. The type II tendency is to decrease the constant to eventually negative as time evolves, while the heterotic and the Bosonic do the opposite. A noticeable trend is that type II tends to perform a finite life span of the universe, but the conjugate two other kinds tend to demonstrate an infinite life span of the universe. Namely, the fate of such a universe is a Big Crunch for the type II superstring structure, whereas it is a Big Rip for bosonic and heterotic strings. The different scenarios lead the universe into different categories of fates, being a cycle of formation and destruction or the long-lasting infinite time [18].

Several pre-Big-Bang theories as well concentrate on the formation of the Big Bang. One of the works states that the collapse of another universe caused the formation of the Big Bang event into a singularity, which requires the reconstruction of the universe's evolution [19]. The theory, also known as the Big Bounce Theory, said that the universe is infinite, coming through an endless cycle of collapse and expansion, which is coherent with the Big Crunch Theory, that all things undergo the same cycle of formation, destruction, and new birth. Along with the theory, other hypotheses require new physics to be proved or disproved, such as that the universe was hibernating until something set it in motion. This idea says that the pre-Big Bang universe was a small, flat, high-pressure space that was "metastable" or stable until it found an even more stable state. Moreover, another quite outstanding one is the multiverse, which sounds like science fiction. Yet they are all not proven or disproved and are waiting for further discovery [5].

3.2. Brief Sheet of Epochs After the Big Bang Event

(1) 0s: The moment of the beginning of the cosmic explosion. Its density and temperature are at a very high state.

(2) $10^{-35}s$: The end of the grand unified theory, separating the strong nuclear force from the weak electric force, was, therefore, the initial surge. Before this, the number of quarks (antiquarks) was equal to that of photons.

(3) $10^{-32}s$: At the end of the surge, the universe expands rapidly from 10-25m to 0.1m, and the main components are photons, quarks and antiquarks, and colored gluons. Protons are unstable, so there are no elements at this stage.

(4) $10^{-12}s$: The separation of the weak nuclear and electromagnetic forces, during which time there is little activity in the universe, is often referred to as a "barren" period.

(5) $10^{-2\sim-3}s$: This is the period of synthesis of the primordial elements of the universe.

(6) $10^{11}s$: At this time, photons and baryons decouple. Before this time, the energy density of radiation was higher than that of matter, after which the universe was dominated by matter because the binding of free electrons accompanies decoupling to nuclei to form atoms, the most familiar form of matter.

(7) $10^{16}s$: Galaxies, planets, and stars began to form.

(8) $10^{18}s$: From this stage onwards, as time passes, galaxies continue to recede, and the temperature of the universe continues to fall.

4. Cyclic model, a closer hypothesis

The former Standard Big Bang Model is currently less capable of organizing inflating and post-inflating zones in the cosmos, which contains the visible universe, the post-inflation zone. The cons of the former standard model may not be the exact perfect demonstration of the cosmos' formation and evolution. While in the Cyclic Model, the non-singular region, where the Big Bang, in the concept of the former standard model, can be better explained as inflation itself that is usual.

The discovered cosmological constant and cosmic acceleration led to the shortage of the standard model, whose blank was left for the initial condition that started the big bang. Along with the contents mentioned before in the introduction and other chapters, it is seen that the standard model awaits evolution cycles to explain the true nature better. This does not mean that the standard picture is irrational or meaningless, but the one-time contributions led the whole species to the common fact of the universe. Without the contributions, more accurate scenarios can hardly be formed without the background of the standard model.

A cyclic model that today's observations and hypotheses tend to be is that the cosmos undergoes endless expansion, inflation, reaching the critical for a contraction, then contraction, and finally coming back to the original state of the foregone cycle, starting a newer one. During each cycle, the entropy produced will be added together since the expansion and contraction happen to the space-time itself rather than matters, which follows the principle of entropy in the second law of thermodynamics. The cyclic model does not go against the entropy principle in which way. Like the content in the standard model, the universe under the cyclic model, under our suggestion, is still infinite and positively curved, rather than in some perspective's flat universe.

The basic mathematics of the universe is the scalar field and the potential of a four-dimensional in quantum field theory. Moreover, the ingredients of the model mainly come from the string theory and M- theory. Unlike the scenario in the inflating model, the universe's expansion in the event boundary is typical for physical volumes outside the boundary, which may be in a different state in the inflating model that the spaces outside the boundary may be in the process of inflation. Thus the inflating zones will be the major of the physical volume of the universe.

4.1. Fundamentals of Cyclic Model

Several scenarios about the universe's fate, as those mentioned in the chapter, the fate of the universe, do support the formation of a cycling universe or a universe that satisfies the requirements of forming a cyclic model. For the scenario of Big Crunch, the universe tends to grow hotter and, at the same time, denser, which even satisfies the requirements for a new Big Bang, which may not require a singularity.

The cyclic model was based on the notion that the Big Bang event was not the start of the time; instead, it was a transition from an earlier state to another, inflation. Secondly, the universe would be cyclic, with hardly an initial or end time. In this notion, the universe formed on the past cycles will also influence the current one, which explains the entropy problem of the current universe. Thirdly, the

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current universe's large-scale structure got a frame from events earlier than the big bang event, which tends to be a bunch of slow contractions instead of a rapid expansion after the event.

The formation of the cyclic model is mainly based on M-theory, that the universe involves two branes separated by bulks. On the first brane, the observable particles, like baryons and leptons, are constrained in the brane to move along. While dark matters lie on the other brane that cannot form weak interact force. Though the theory is a logical deduction, explaining the facts and phenomena still makes sense. Many physical and cosmological deductions were of irrational sense at the time but later proved correct. This does not sentence the correctness of any predictions, but the observations and experiments finally sentence which is correct. While in a supersymmetric vacuum state, the branes do not interact with each other. While in a state of supersymmetry breaking, a force proportional to the 'distance' between branes tends to form that attracts each other. From the suggestion, there would also be potential energy, where the moduli field decides the separation of the branes.

In the scenario, the existence of potential results in collisions, the big bang, of the branes in regular intervals of time. Moreover, the energy lost produced during the Big Bang caused the formation of newly produced matter and radiation. In a practical four-dimensional theory, a brief period after the big bang is dominated by the kinetic energy in between the branes, which decreases dramatically afterward as the universe expands. The high temperature produced from this will finally get diluted by the universe's expansion, though it once lasted for billions of years in each cycle. Moreover, from the interbrain force and potential, the inflation will only last for a finite time. This may result in a partially different scenario from the previous one attempted to construct. From the base assumption that matter and radiation are restricted inside the branes, the background densities tend not to diverge at each cycle. New entropy gets created, while older ones remain diluted. Unlike the previous one, entropy density moves to near zero at each end of the cycle or the end of the contraction.

4.2. Limitations of the cyclic model

The cyclic model is short of factual observations, which is only logically developed from simplified models and newly established String theory and M theory, which are also short of experimental proof. The theory still waits for the observation or research on if the bounce of each cycle occurs literally to prove it. Moreover, if inflation happens, then current observations are restricted from directly observing the moments of the big bang since the speed of inflation strongly overweighs that of light, resulting in the moment of the big bang permanently lying outside our light cone.

5. Conclusion

The standard model of the big bang itself has several shortages in explaining the phenomena and contents of itself; At the same time, this does not claim that the model is meaningless or out of fashion. Instead, the model was the first to correctly demonstrate the outline of the universe's evolution and established the cyclic model, which includes the content of the big bang model as a typical cycle of the cycling universe. From the contents above, we do suggest that the cyclic model may be a better alternative as a model for the evolution of the universe as it is built on the frontier research of M theory and String theory, which is a more innovative model in explaining the universe and the fundamental nature of the cosmos and everything inside which. Moreover, on the other hand, the standard model does not fit a non-singular big bang, which is capable of a cyclic model. Thus a better certainty on the cyclic model could be constructed.

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