Was the Universe Born Inside a Black Hole?

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Abstract

Black-Hole Cosmology (BHC) proposes that every black hole forms a new universe on the other side of its event horizon. This hypothesis can be validated by solving numerically the equations governing the dynamics of a universe in a black hole and calculating quantities that can be compared with the temperature fluctuations of the observed Cosmic Microwave Background (CMB) radiation. These fluctuations provide the most useful data currently being used by cosmologists studying the early universe. The numerical results in this research substantiate the hypothesized BHC predictions and indicate that further research is required. Substantiated predictions would suggest that the universe did, in fact, originate from a black hole existing within a parent universe.

1. Background

In 1927, Georges Lemaitre proposed that the universe was initially extremely dense and hot. He further proposed that the universe then experienced a period of rapid expansion. The essence of this hypothesis is what constitutes the Big-Bang Theory. Two years later, Edwin Hubble discovered that the universe is expanding. In 1948, Ralph Alpher discovered that this theory matches observational data from the lightest elements in the universe. In 1964, Arno Penzias and Robert Wilson discovered the Cosmic Microwave Background (CMB) radiation coming from all directions in the sky. The radiation is comprised of remnants left over from the early universe and gives scientists clues as to the origin of the universe. The CMB, however, did not explain why the universe looked very uniform at the largest scales. It was from this dilemma that physicists developed the Inflation Theory. This theory hypothesizes that the universes uniform appearance can be attributed to its rapid expansion shortly following the Big Bang. This theory accurately predicted the CMB temperature slightly changing with the direction of the sky [1].

Although Big-Bang cosmology with inflation answers many questions, it does not fully explain how the universe was created. Big-Bang cosmology theorizes that the universe began as a point of infinite density (singularity). This supposition does not make physical sense and consequently indicates that the understanding of physics in the early universe is incomplete. Moreover, inflation theorists have had to introduce hypothetical types of matter which have never been observed. These theorists also rely on models that have been frequently adjusted in order to match their predictions. As a result, Big-Bang cosmology does not indicate what existed before the Big Bang.

The answer to this fundamental problem might come from BHC [2, 3, 4]. BHC proposes that the universe was created by a black hole which exists within a parent universe. If a star is sufficiently massive, it will collapse at the end of its evolution into a black hole due to its own gravity. Matter cannot escape from a black hole because the escape velocity at the boundary of a black hole, called an event horizon, is faster than the speed of light and any object with mass cannot travel as fast as the speed of light. Consequently, not even light can escape the black hole hence the name. Matter inside a black hole collapses until it reaches a small region of extremely high density. It would be at this instant that the matter stops collapsing and bounces outwards, but cannot leave the black hole. After this bounce, the matter in a black hole would then have to expand into a new region of space which becomes a new universe. Such a universe is expanding, like the three-dimensional analogue of the two-dimensional surface of a growing balloon.

In this scenario, the matter in a black hole does not collapse to a singularity. To make this scenario possible, a repulsive interaction that opposes gravitational attraction and prevents singularities must appear at extremely high densities existing in black holes. In fact, adding quantum-mechanical angular momentum (spin) of elementary particles to Einstein's theory of gravitation (general theory of relativity) generates at such densities a repulsive force called torsion which opposes gravitational attraction and prevents singularities. A theoretical framework for this mechanism is called the Einstein-Cartan theory [5, 6, 7].

Although BHC may explain the origin of the universe it has yet to generate specific predictions about the observed CMB temperature fluctuations. These fluctuations would provide the most important data being used by cosmologists studying the early universe.

2. Hypothesis

We argue that the matter in a black hole collapses to an extremely high but finite density, bounces, and expands into a new space (it cannot go back). Every black hole, because of torsion, becomes a wormhole (Einstein-Rosen bridge) to a new universe on the other side of its boundary called the event horizon [4].

If this scenario is correct then we would expect that:
Such a universe never contracts to a point (**Hypothesis I**).
A universe should never collapse into a point because torsion will become a significant repulsive force around the density of 10^{50} kg/m^3 and will prevent the further collapse of matter beyond approximately 10^{96} kg/m^3. Such a universe would collapse into a region of finite size and subsequently expand [4, 8] .

We would also expect that:
This universe may undergo multiple bounces between which it expands and contracts (**Hypothesis II**).
This behavior is determined by quantum particle production which affects the dynamics of the universe. After a bounce, the universe expands and its temperature decreases. If the universe does not have enough mass to reach a size at which the vacuum energy can expand it to infinity, it eventually stops expanding and reaches a crunch. The universe then contracts until it reaches another bounce, after which it expands again. Because of particle production near a bounce, the size of the universe factor at a given bounce is larger than that at the preceding bounce. The size of the universe at a given crunch is larger than that at the preceding crunch. When the universe produces sufficient amounts of mass, it reaches the size at which the repulsive vacuum energy becomes a dominant form of energy in the universe. The universe then begins to accelerate and expands indefinitely [8].

In addition, we would expect that:
Increasing the production rate decreases the number of bounces in the dynamics of a universe in a black hole (**Hypothesis III**).
A smaller production rate would require more bounces (each of which produces matter from particle production) for such a universe to reach the size at which it can expand to infinity. A larger production rate would require fewer bounces. A sufficiently high production rate would result in one bounce.

Our Universe may thus have been formed in a black hole existing in another universe. The last bounce, called the Big Bounce, would correspond to the Big Bang. We would then expect that:
The scalar spectral index n_s obtained from mathematical analysis of our hypothesis is consistent with the observed value $n_s = 0.965 \pm 0.006$ obtained from the CMB data [9] (**Hypothesis IV**).
This quantity describes the quantum fluctuations in the early universe and how these fluctuations were amplified through the rapid inflation of the universe into the density perturbations which seed the large-scale (extragalactic) structure of the universe. Its values consistent with observations would substantiate BHC.

3. Methodology

In order to operationalize and test BHC, the research was divided into two parts. The first part involved writing a computer program in the Fortran programming language to numerically solve a system of two coupled, ordinary, first-order differential equations that describe the dynamics of a closed universe in a black hole. They were solved using forward Euler integration. These equations are the Friedmann equations (Einstein-Cartan equations for a homogeneous and isotropic universe) modified by quantum particle production from the vacuum in the presence of strong gravitational fields near a bounce [8]:

$$\frac{\dot{a}^2}{c^2} + k = \frac{1}{3}\kappa\tilde{\varepsilon}a^2 = \frac{1}{3}\kappa(h_\star T^4 - \alpha h_{\mathrm{nf}}^2 T^6)a^2, \tag{1}$$

$$\frac{\dot{a}}{a} + \frac{\dot{T}}{T} = \frac{cK}{3h_{n1}T^3}, \tag{2}$$

$$K = \beta(\kappa\tilde{\varepsilon})^2, \tag{3}$$

where $k = 1$, $\tilde{\varepsilon}$ is the effective energy density in the universe, β is a dimensionless particle production coefficient, and dot denotes the derivative with respect to the cosmic time t. These equations give the scale factor (size) a and temperature T of the universe as functions of t. The other quantities in these equations are constants related to the gravitational constant, speed of light, and the numbers of particle species.

Since the negative term on the right-hand side of Equation (1) scales with T faster ($\sim T^6$) than the positive term ($\sim T^4$), $\dot{a}$ reaches zero and a reaches a local minimum at a positive value. Near this instant, repulsion from torsion is stronger than gravitational attraction. Such a minimum scale factor defines a bounce.

To avoid an infinitely long exponential expansion of the universe, the value of the particle production coefficient must be smaller than a critical value cr:

$$\beta < \beta_{\mathrm{cr}} = \frac{\sqrt{6}}{32}\frac{h_{n1}h_{nf}^3(\hbar c)^3}{h_\star^3}. \tag{4}$$

For standard-model particles, $\beta_{\mathrm{cr}} \approx 1/929$.

The second part of this research involved evaluating whether or not the results generated by the computer program match the CMB data. Since the rapid recoil after the bounce could be the cause of an exponential expansion of the early universe, its characteristics should match the observed universes size and mass as functions of time, its geometry, and several variables which describe the fluctuations in the CMB temperature. The calculations derived from a graphical representation of the data should match the observed value of the scalar spectral index n_s.

4. Results

First, one of the goals of the numerical analysis was to calculate the size of a universe in a black hole with respect to time. Figure 1 shows a sample scale factor $a(t)$ of such a universe from the time at which a black hole forms. Several bounces occur, validating **Hypothesis II**.

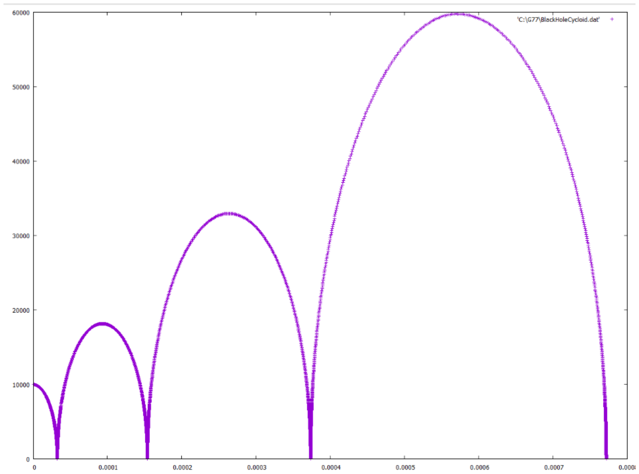

Figure 1: A sample scale factor of a universe in a black hole as a function of time.

Figure 2 shows the logarithm of the scale factor as a function of the logarithm of time for $\beta/\beta_{\rm cr} = 0.988$. The graphical representation of this dynamics indicates that the matter in a black hole does not collapses to a point and the universe has always a finite size, validating **Hypothesis I**. This universe has two nonsingular (finite-size) bounces, which also validates **Hypothesis I**.

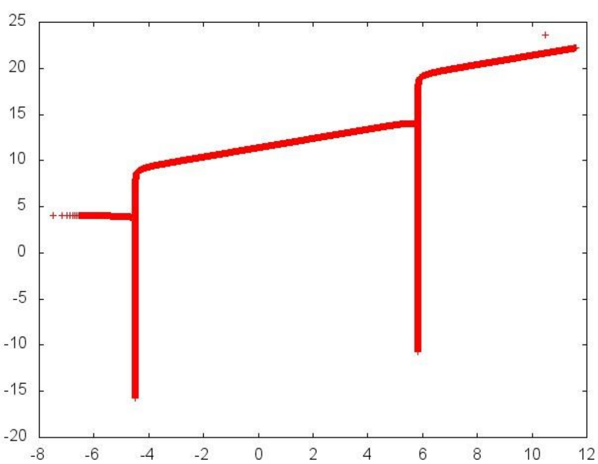

Figure 2: The common logarithm of the scale factor (in m) as a function of the common logarithm of time (in s) for $\beta/\beta_{\rm cr} = 0.988$. The initial scale factor is 10 km. The universe has two nonsingular bounces. The second bounce is the Big Bounce.

Figure 3 shows the logarithm of the scale factor as a function of the logarithm of time for $\beta/\beta_{\rm cr} = 0.997$. The universe has always a finite size, validating **Hypothesis I**, and one nonsingular bounce. The smallest possible size of a black hole derived solely from the amount of matter it contains. Since torsion prevents matter from collapsing beyond a certain density, this critical density together with the amount of matter a black hole contains determines the smallest possible size of that black hole. Since each bounce produces new matter, the smallest possible size of a black hole is transient and will increase with each bounce due to the particle production at each bounce. This behavior is shown in Figure 2, where the second bounce occurs at a greater value of the scale factor than the first bounce.

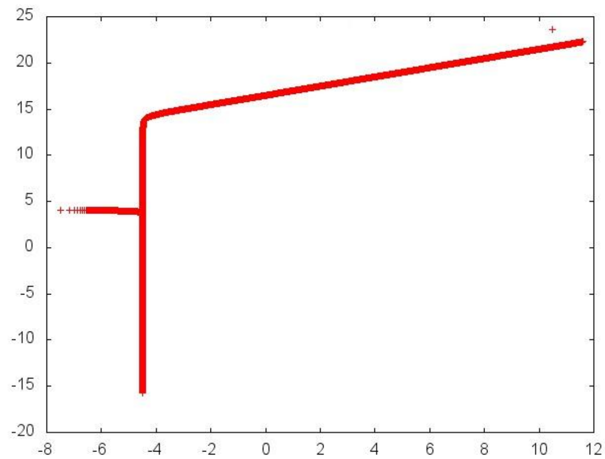

Figure 3: The common logarithm of the scale factor (in m) as a function of the logarithm of time (in s) for $\beta/\beta_{\rm cr} = 0.997$. The initial scale factor is 10 km. The universe has one nonsingular bounce which is the Big Bounce.

Second, more numerical computations were done in which only the particle production coefficient β was changed. Table 1 shows the number of bounces before the universe reaches the matter-radiation equality temperature (which is about 8820 K) as a function of the ratio of the particle production coefficient to its critical value, $\beta/\beta_{\rm cr}$. This analysis shows that a smaller value of this coefficient results in a larger number of bounces necessary for the universe to cool to a fixed temperature. This result validates **Hypothesis III**. It also indicates that a smaller particle production coefficient results in each bounce producing less matter than in the universe undergoing bounces with a larger coefficient. It was also discovered that for a zero value of this coefficient, the universe would have a infinite number of bounces.

$\beta/\beta_{\rm cr}$	Number of bounces
0.996	1
0.984	2
0.965	3
0.914	5
0.757	10

Table 1: The number of bounces before the universe cools to the matter-radiation equality temperature as a function of the ratio of the particle production coefficient to its critical value, $\beta/\beta_{\rm cr}$.

Furthermore, it was discovered that if the particle production coefficient β is slightly less than its critical value $\beta_{\rm cr}$, the universe undergoes only one bounce which generates enough mass to grow very rapidly (exponentially) for a short period of time and resemble our universe. Figure 4 shows such a dynamics in which the universe accelerates and expands in linear size by a factor of e^{60} (60 e-folds) in about 10^{-42} s, similarly to cosmic inflation, and then decelerates its expansion. A straight line between 0 s and 10^{-42} s indicates that the expansion is exponential. Since the value of β is not yet known, our analysis shows also that this value must be close to the critical value.

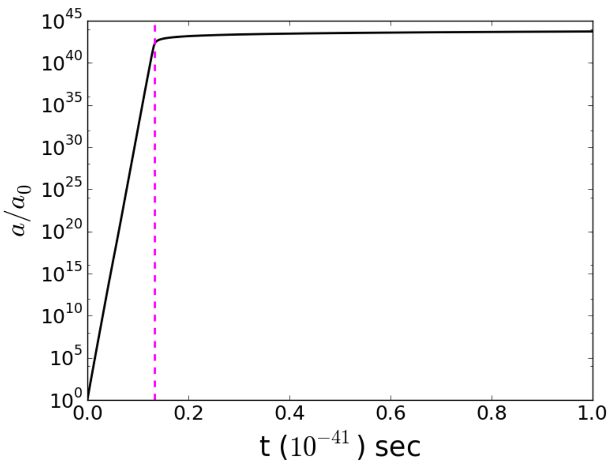

Figure 4: The ratio of the scale factor $a(t)$ to its initial value a_0 as a function of time for $\beta/\beta_{cr} = 0.9998$. The time $t = 0$ is set at the Big Bounce. The dashed magenta line indicates the transition from acceleration to deceleration. We obtain about 60 e-folds.

Finally, the values of the scalar spectral index n_s were calculated [10, 11], for different values of the initial scale factor a_0 and for a range of the particle production coefficient β near $\beta_{\rm cr}$, as shown in Figure 5. It was discovered that n_s depends on β, but is not too sensitive to a_0. Moreover, the calculated values of n_s in BHC are consistent with the observed CMB value n_s [9] for a small range of β and a wide range of a_0, validating **Hypothesis IV**.

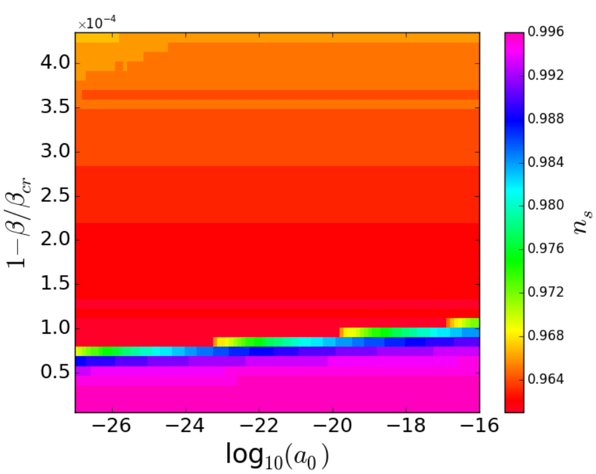

Figure 5: Predicted values of the scalar spectral index n_s as a function of the common logarithm of the initial scale factor (in m) and $\beta/\beta_{\rm cr}$. Red indicates values consistent with $n_s = 0.965 \pm 0.006$ from the 2015 Planck observations of the CMB.

5. Discussion and Conclusion

If BHC is consistent with the CMB observations, then our current understanding of gravity and high-energy physics may need to be modified to include torsion. There may also be new forms of energy which could revolutionize energy production and even space travel. If these forms of energy exist, they could open up new possibilities for propulsion systems which currently are beyond the present technology and energy requirement.

The results of the numerical analysis in this research validated all four proposed hypotheses. From these results we can make several conclusions.

The first conclusion is that the dynamics of the very early universe formed in a black hole depends on the quantum-gravitational particle production rate β, but is not too sensitive to the initial scale factor a_0.

Second, inflation (exponential expansion) can be caused by particle production with torsion if β is near some critical value $\beta_{\rm cr}$. Numerical analysis using this value results in a universe whose early expansion mirrors the inflationary expansion of our universe.

Third, since the calculated values for n_s are consistent with the 2015 Planck data from the CMB [9], it further supports the assertion that the Universe may have been formed in a black hole.

The mathematical framework in [8] only contains one free parameter (particle production coefficient) whose range is constrained through graphical data in Figure 5. Only having one free parameter makes this theory more solid than the Inflation Theory which has at least two. BHC expands rather than refutes Inflation Theory by providing a natural mechanism for rapid acceleration.

If and when quantum gravity is solved, we will know what the particle production rate is. If this rate matches the rate predicted in this research, it would provide a strong support for BHC. Otherwise, it would indicate that major changes are needed within the physical or mathematical framework of BHC.

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He began his research in the freshman year and is determined to further studying of black holes and the origin of our universe.