Was the Universe Born Inside a Black Hole?

Charles Peterson
BS Mechanical Engineering
Faculty Mentors: Dr. Nikodem Poplawski and Dr. Chris Haynes

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 dis-

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 $n_s = 0{:}965 \quad 0{:}006$ 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]:

$$\frac{\dot{a}^2}{c^2} + k = \frac{1}{3}k\tilde{e}a^2 = \frac{1}{3}k(h_{?}T^4 \quad a h_{nf}^2 T^6)a^2; \tag{1}$$

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

$$K = b(k\tilde{e})^2; \tag{3}$$

where $k = 1$, $\tilde{e}$ is the effective energy density in the universe, b 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 (T^6) than the positive term (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:

$$b < b_{cr} = \frac{\sqrt{6}}{32}\frac{h_{n1}h_{nf}^3(\hbar c)^3}{h_{?}^3}: \tag{4}$$

For standard-model particles, $b_{cr} \quad 1{=}929$.

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**.

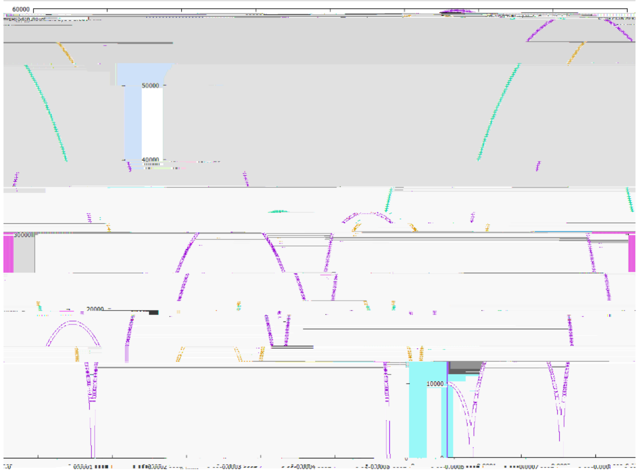


Figure 1: A sample scale factor of a universe in a black hole as a function of time.

Figure 2 shows the logarithm of the scale factor as a function of the logarithm of time for $b=b_{\mathrm{cr}} = 0{:}988$. 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**.

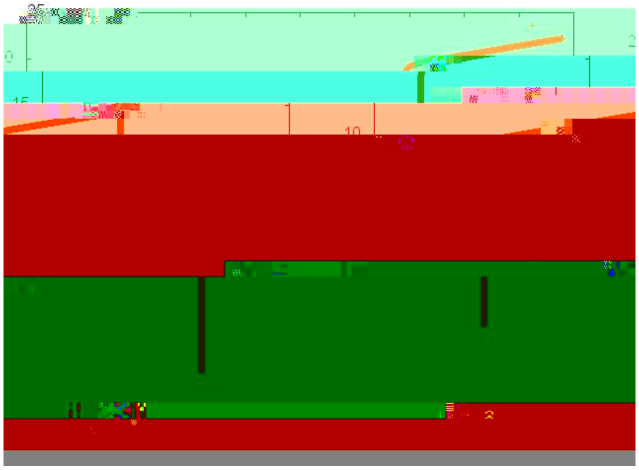


Figure 2: The common logarithm of the scale factor (in m) as a function of the common logarithm of time (in s) for $b=b_{\mathrm{cr}} = 0{:}988$. The initial scale factor is 10 km. The universe has two nonsingular bounces. The second bounce is the Big Bounce.

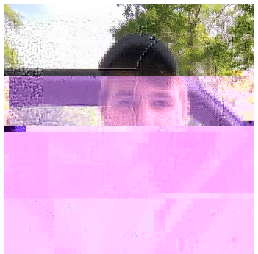
Figure 3 shows the logarithm of the scale factor as a function of the logarithm of time for $b=b_{\mathrm{cr}} = 0{:}997$. The universe has always a finite size, validating **Hypothesis I** similarly to cosmic inflation, and then decelerates its expansion. A straight line between 0 s and 10^{42} s indicates that the expansion is exponential. Since the value of *b*

[10] G. F. R. Ellis and M. S. Madsen, Class. Quantum Grav. **8**, 667 (1991).

[11] S. Desai, private communication.

Acknowledgments

I want to thank Dr. Nikodem Poplawski for putting his students above all else. I have never met someone with such a genuine love of science and such a willingness to foster in others the love of science. Furthermore, I would like to thank Dr. Chris Haynes who was integral in determining how to meaningfully design, construct, and convey the research. Moreover, I truly appreciate the contributions of Dr. Shantanu Desai who helped with the data analysis, Carol Withers and Janice Sanderson who organized the Summer Undergraduate Research Fellowship, and the donors of this fellowship who made this opportunity possible.



Charles Peterson is a sophomore in the Mechanical Engineering program in the Tagliatela College of Engineering at the University of New Haven with a minor in Physics.

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