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PROGRESS TOWARD A YOUNG-EARTH RELATIVISTIC COSMOLOGY

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ABSTRACT

Another paper of mine at this conference shows evidence that the biblical cosmos has finite boundaries, and that our earth is near the center. If we put those boundary conditions into the equations of Einstein's general theory of relativity, we get an expanding cosmos in which clocks (and all physical processes) tick at different rates in different parts of the universe. The physics is that of a universe-sized "white hole" (a black hole running in reverse), with a shrinking event horizon and matter expanding out of it. At the event horizon, clocks would be momentarily stopped relative to clocks further out. At one critical moment of the expansion, the event horizon would reach the earth, and clocks there would also momentarily stop.

I propose that the critical moment arrived on earth during the fourth day of creation. During that day, billions of years would elapse in the distant sky, allowing light from galaxies to reach the earth within one ordinary day of earth's time. This theory also explains the red shifts of galaxies and the cosmic microwave background. As measured by clocks on earth, the age of the universe today could be as small as the face-value biblical age of about 6000 years.

KEYWORDS

Cosmology, general relativity, age of universe, galactic red shifts, cosmic microwave background, black holes.

1. INTRODUCTION

O God! I could be bounded in a nutshell, and count myself a king of infinite space, were it not that I have bad dreams — Hamlet, Act II.

God used relativity to make a young universe! That idea, the main thesis of this paper, may seem startling to many people, some of whom may regard relativity as an invention of the devil. But I am proposing here that God invented relativity as an essential part of His universe, and that one feature of relativity in particular, called *gravitational time dilation* by some authors, enabled light from distant galaxies to get to earth in a very short time — within one ordinary day, as measured by clocks here on earth.

People having philosophical problems with relativity may be interested to know that it is possible to separate the mathematics of the theory itself from the philosophical "baggage" so often attached to it, and that a simple conceptual model can do away with the paradoxes people often object to. For example, few people know that Einstein himself came back to the idea of a luminiferous ether in 1920 [15, pp. 13, 23]. The speed of light would be constant with respect to such an ether, and then the equations of relativity would require that clocks and measuring rods moving with respect to the ether change in such a way as to always give the same number for the speed of light. I.e., objects moving through the ether would be changed by that motion. Clocks would actually slow down, measuring rods would actually shorten, and the speed of light would seem to be independent of motion [39, p.7]. By re-affirming an absolute reference frame, this view of relativity dumps the philosophical baggage and resolves the paradoxes. Section 15 briefly discusses why we might expect relativity to be in operation very early during creation week.

I hope this paper will help convince some of the doubters that relativity is not an enemy of creationism, but is instead a friend. Young-earth creationism needs friends in the area of cosmology, because up to this time, in my opinion, we have had no scientifically satisfactory explanation of the large-scale phenomena we observe in the heavens. The most important of those phenomena are:

1. **Light from distant galaxies** — We see light from galaxies which are billions of light-years away, as measured by a variety of techniques. Light travelling such great distances at today's speed would take billions of years to reach us.

2. **Galactic red shifts** — The wavelengths of light from each galaxy are shifted toward the red side of the spectrum by a factor roughly proportional to the distance of the galaxy from us. There are some exceptions, but the overall trend is very clear and must be explained.
3. **Cosmic microwave background** — The earth is immersed in a bath of low-power microwave (centimeter to millimeter wavelength) electromagnetic radiation whose spectrum is exactly like that of the thermal radiation (heat waves, black-body radiation) found within a cavity whose walls are very cold, at 2.74 Kelvin. After correction for the earth's motion through space, this radiation is very uniform, having variations with direction no greater than one part in 100,000.

All of these phenomena fit reasonably well into the "big-bang" cosmologies, and as such seem to point to a long time scale, billions of years, for the cosmos. Yet creationist scientists have found a great deal of evidence pointing to a very short time scale, much less than millions of years, for the earth and solar system. Good science requires that we try to reconcile both the young-earth data and the cosmological data, thus motivating a creationist cosmology to explain the above phenomena.

In the past, creationists have proposed several such explanations. The most prominent of these are: (i) the mature creation theory (light created in transit) [51, p. 369] [49, pp. 222-223] [11, pp. 88-89], (ii) the Moon-Spencer theory (shortcut for light) [33] [2] [7], (iii) the Setterfield *c*-decay theory (decrease in speed of light) [35] [16] [8], and (iv) the Ackridge-Barnes-Slusher theory (heating of galactic gas and dust) [2]. All of these theories seem inadequate to me. First, their proponents cite no decisive biblical support. By "decisive" I mean direct statements in the Bible which would clearly favor one theory over another; for example, statements that God created the light in transit, or made it take a shortcut, or speeded it up.

Second, none of these theories explain all three of the large-scale astronomical phenomena listed above. Theories (i) through (iii) seek mainly to explain light transit time. Theory (iv) seeks only to explain the cosmic microwave background. Third, each has severe scientific deficiencies. Theory (i) makes no scientific predictions and therefore cannot be checked. Theories (ii) through (iv) appear to many creationist scientists to have been falsified by the data, although a few remaining advocates of each theory might still disagree. Thus it appears that creationists have not yet produced a satisfactory cosmology.

To meet that need, this paper delves deeply into Einstein's general theory of relativity, going well beyond the special theory of relativity which marks the limit of most physicists' training. It will involve the strange physics of black holes, and it will be rather mathematical. The subject itself requires these things, but I will try to simplify matters as much as possible. For non-physicists I will explain the essential equations in words. For physicists without training in general relativity, I will include concepts that I found helpful as I learned the topic, but such comments may not be very helpful to the non-physicist. I ask you to please bear with me in all these esoterica, because the reward will be great — a non *ad hoc* cosmology which explains the large-scale astronomical phenomena and yet is fully consistent with a young earth.

2. BIG-BANG THEORIES ASSUME AN UNBOUNDED COSMOS

In their book *The Large Scale Structure of Space-Time*, Stephen Hawking and George Ellis [24; p.134] spell out the most fundamental assumption of the modern big-bang cosmologies:

However we are not able to make cosmological models without some admixture of ideology. In the earliest cosmologies, man placed himself in a commanding position at the centre of the universe. Since the time of Copernicus we have been steadily demoted to a medium sized planet going round a medium sized star on the outer edge of a fairly average galaxy, which is itself simply one of a local group of galaxies. Indeed we are now so democratic that we would not claim our position in space is specially distinguished in any way. We shall, following Bondi [4], call this assumption the *Copernican principle*.

A reasonable interpretation of this somewhat vague principle is to understand it as implying that, when viewed on a suitable scale, the universe is approximately spatially homogeneous.

By "homogeneous," Hawking and Ellis mean that all parts of the universe at any given time are essentially the same. In particular, they mean that all sections of the 3-dimensional space we live in have about the same average matter density ρ , provided that the sections are big enough to allow a good average. This same assumption is fundamental to a larger class of theories called Friedmann, or Robertson-Walker, cosmologies. These include not only the big-bang theories, but also older theories such as Einstein's static cosmos and DeSitter's empty expanding cosmos. Even Fred Hoyle's steady-state cosmology makes the same assumption — homogeneity throughout space. An older name for this "Copernican principle" is the "Cosmological principle."

Notice that Hawking and Ellis call the Copernican principle an "admixture of ideology." By this they mean that it does not come from direct observation but instead from a body of ideas that some people feel to be true. In a recent article in *Nature* [20], astrophysicist Richard Gott spells out the essential reasoning behind the principle:

In astronomy, the Copernican principle works because, of all the places for intelligent observers to be, there are by definition only a few special places and many nonspecial places, so you are likely to be in a nonspecial place.

To clarify this reasoning further, the idea behind the Copernican principle is that we are on this planet as the result of random processes only — not because of the choice of a purposeful God — and thus it would be unlikely we are in a special place. Of course, this idea of randomness is the essence of Darwinism. Richard Gott noted this connection with evolutionary ideas to build his case that we are not in a privileged location:

Darwin showed that, in terms of origin, we are not privileged above other species.

So the essential idea behind the Copernican principle is that of a universe ruled by randomness. Since many scientists see a great deal of purpose in nature, there is good reason to question the validity of that principle.

Supporters of the Copernican principle do not rest completely on ideology. They do point out that on a large scale, the universe appears *isotropic* from our point of view. That is, it looks pretty much the same in every direction, especially when we look at the cosmic microwave background. This observed isotropy could indeed result from homogeneity, and thus it is consistent with the Copernican principle. However, logic does not require the reverse line of reasoning — homogeneity as a result of isotropy. In this paper I will show by example that one can conceive of a universe which is isotropic from our viewpoint but not homogeneous.

I have spent some time on the Copernican principle because it has a profound effect on cosmological theory. Richard Gott underlines its importance:

The idea that we are not located in a special spatial location has been crucial in cosmology, leading directly to the homogeneous and isotropic Friedmann cosmological models ...

You may be wondering at this point what it is about the Copernican principle, or spatial homogeneity, that makes it "crucial." To help you understand, let me spell out clearly an implication of homogeneity which often goes unstated: Homogeneity would mean that our 3-dimensional universe would have *no edges and no center!* If there were an edge or center, observers near those places would be special; they would see and measure different things than other observers, thus violating the Copernican principle.

Suppose you were able to travel instantly to any place in our 3-dimensional space. The Copernican principle says that no matter how far you might travel, you could never find a point where the average mass density ρ is much different than here. You would never encounter an end to the conventional universe of stars and galaxies. There would be no edges or boundaries. In more technical terms, matter in that sort of cosmos is required to be *unbounded*. Mathematicians call this kind of requirement a "boundary condition." Section 4 shows how this boundary condition, when applied to the equations of general relativity, results in the big-bang cosmologies. Section 3 below is an introduction for physicists to the essentials of general relativity. People less mathematically inclined can skip sections 3 and 4 without great loss of understanding.

3. BASICS OF GENERAL RELATIVITY

In 1916, eleven years after his first paper on special relativity, Albert Einstein presented his completed general theory of relativity [13]. In it he pictured space and time as being like a material which is stretched and bent by the presence of mass. Some authors resist this "geometrical" and material interpretation of space [48, p. 147] [50, p. 34], but I prefer it for two reasons: (1) it provides a heuristic picture for an otherwise very difficult subject, and (2) there are some biblical hints favoring it (see my exegetical paper at this conference). Einstein described the stretching and bending by specifying the *interval* between two events occurring at slightly different points in space and time. The interval ds is defined such that if it is a real number, it is proportional to the "natural time" or *proper time* interval $d\tau$ registered by a physical clock as it travels on a trajectory between the two events:

$$ds = c d\tau \quad (1)$$

In the system of units I am using, the proportionality factor is the speed of light, c . (If ds is an imaginary number, i.e., if $ds^2 < 0$, then the interval is equal to i times the distance between the two events in a reference frame where they are simultaneous. Some authors define the interval with an opposite sign convention.) Einstein specified the square of the interval by means of an equation called the *metric*:

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu, \quad \mu, \nu = 0, 1, 2, 3 \quad (2)$$

The indices μ and ν run from 0 through 3, representing time and the three space dimensions respectively. The four quantities dx^μ represent the distances in time and space between the two events. For example, calling time τ and using polar coordinates (r, θ, ϕ) we might have $(dx^0, dx^1, dx^2, dx^3) = (d\tau, dr, d\theta, d\phi)$. The quantity $g_{\mu\nu}$ represents the $\mu\nu$ th component of the *metric tensor*. In four dimensions, a ("second-rank") tensor is a set of 16 numbers which transform in certain ways when you change coordinate systems. Subscripted indices represent "covariant" tensors, which transform like the derivatives of a scalar function. Superscripted indices represent "contravariant" tensors, which transform like vectors. This equation has both types of tensor, with the metric tensor being in its covariant form and the distances being in their contravariant form. In his paper Einstein introduced his *summation convention*: if you see the same index repeated as both a superscript and subscript, then sum over that index. For example, this means that the right side of eq. (2) represents the sum of 16 different terms. The metric tensor $g_{\mu\nu}$ is fundamentally important in general relativity.

The major contribution in Einstein's 1916 and 1917 [12] papers was his set of 16 gravitational field equations

$$R^{\mu\nu} = \Lambda g^{\mu\nu} - \frac{8\pi G}{c^4} \left(T^{\mu\nu} - \frac{1}{2} g^{\mu\nu} T \right) \quad (3)$$

which govern the curvature (see section 5) of spacetime [39, p. 180]. Put very simply, these equations say that the amount of matter at a given point in spacetime determines the curvature of spacetime at that point. There is a deep similarity to the equations governing a stretched membrane with weights on it, except that here the membrane has four dimensions instead of two. The quantity $R^{\mu\nu}$ on the left side of (3) represents the $\mu\nu$ th component of the *Ricci* tensor, which contains various second-order time and space derivatives of the metric tensor. The Ricci tensor is related to the curvature of spacetime [19, p. 39]. In some simple situations it reduces to the D'Alembertian operator

$$\square \equiv \nabla^2 - \frac{1}{c^2} \frac{\partial^2}{\partial \tau^2} \equiv \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{c^2} \frac{\partial^2}{\partial \tau^2}$$

applied to the components of the metric tensor [39, pp. 181,190]. In simple static situations, it reduces further to the Laplacian operator ∇^2 applied to the metric components.

On the right side of eq. (3), Λ is the famous "cosmological constant," which can be interpreted as being proportional to an external pressure or tension applied to the membrane of spacetime. (It does not really have to be a constant, but can depend on position or time; nevertheless, most studies keep it a constant, usually zero.) G is the Newtonian gravitational constant.

The second tensor $T^{\mu\nu}$ on the right side of eq. (3) is the *energy-momentum* tensor. It is a "source term" specifying how much mass-energy and momentum (due to non-gravitational fields) are present, causing distortions in spacetime. The third term of eq. (3) contains a scalar function T , which is simply the sum $g_{\mu\nu} T^{\mu\nu}$. The third term represents an additional mass-energy present because of the interaction of the gravitational field with the non-gravitational mass, and it, too, distorts spacetime.

4. FROM GENERAL RELATIVITY TO BIG-BANG COSMOLOGY

The usual approach in cosmology is to figure out first what form the energy-momentum tensor $T^{\mu\nu}$ should have throughout space, and then to find out what form the metric tensor $g_{\mu\nu}$ in eq. (2) must have in order to satisfy the resulting Einstein equations (3). Often cosmologists make two (reasonable) simplifying approximations: (i) treat the galaxies as non-interacting "dust," i.e., as if they are too far apart to interact significantly, and (ii) assume the galaxies are at rest with respect to space locally; i.e., their only motions are due to the expansion of space. With those approximations the only non-zero component of the energy-momentum tensor is the mass density ρ [39, p. 226]:

$$T^{00} = \rho \quad (4)$$

Here's where the Copernican principle enters the equations. The principle requires that the mass density ρ in eq. (4) be independent of the space coordinates, *throughout all available space*. Using that boundary condition, many textbooks show that the following metric [48, p. 412], usually called the *Robertson-Walker* metric, is a solution of eq. (3):

$$ds^2 = c^2 d\tau^2 - a^2 \left(\frac{d\eta^2}{1 - k\eta^2} + \eta^2 d\Omega^2 \right) \quad (5)$$

Here η is a dimensionless radial coordinate. It is a *co-moving* coordinate, meaning the coordinate system moves with the expansion of space, as if it were a grid somehow painted onto space itself. That means for any given galaxy, η will remain the same throughout the expansion. Please note: in the Robertson-Walker metric, the origin of coordinates is completely arbitrary. It can be anywhere in our 3-dimensional space. Thus this metric is fully consistent with the Copernican principle.

The "cosmic" time τ in the Robertson-Walker metric is same as the proper time or "natural" time in eq. (1). It is the time measured by a set of clocks throughout the universe, each one riding with a galaxy as it moves with the expansion of space. These clocks can all be synchronized with one another. Later on I will introduce a distinctly different time, t , often called *Schwarzschild time*, or "coordinate" time. The difference between these two types of time measurements constitutes the essence of this paper, so stay alert for the distinctions.

The symbol a in eq. (5) is the *radius of curvature* of space and has units of distance; it depends on the cosmic time τ . (Some authors define a to be dimensionless and call it the "scale factor"; η would then have units of distance.) The radius of curvature relates the co-moving coordinate η with a radial coordinate r which is not co-moving:

$$r = a(\tau) \eta \quad (6)$$

The coordinate r has units of distance and is defined such that the circumference of a circle of radius r is $2\pi r$. For a particular galaxy, r increases as the radius of curvature increases, whereas η remains the same.

The symbol c in eq. (5) represents the speed of light, which is constant in the (τ, r) system for $k = 0$ or near the origin. In other coordinate systems — such as the Schwarzschild system I will introduce later — the speed of light can be c times a function of space and time and therefore not constant. In such systems c by itself does not represent the speed of light but is merely a convenient multiplying constant. (Very often general relativists use physical units such that $c = 1$.) The symbol $d\Omega$ in eq. (5) is the angle subtended, in spherical coordinates, by the two spacetime events defining the interval, so that we have:

$$d\Omega^2 \equiv d\theta^2 + \sin^2\theta\, d\phi^2$$

The constant k in the Robertson-Walker metric is very important. It can have the values 1, 0, or -1 , depending on whether the space being described has, respectively, a positive, zero, or negative curvature. When $k = 1$, η has values between 0 and 1. I will try to clarify this concept of curvature in the next section.

5. CURVED SPACE AND FIVE DIMENSIONS

The above equations and ideas use four dimensions, one of time and three of space. They are rather mystifying to the newcomer, especially the idea that space might be curved. He asks a very natural question: "What direction could space be curved *toward*?" One of the trade secrets of general relativity is that we can answer this question if we grant admission to the idea of at least one more dimension. In particular, eq. (5) for the case of positive curvature ($k = 1$) has a rather neat geometrical interpretation: our 3-dimensional space would be merely the surface of a "hypersphere" existing in a "hyperspace" having ordinary geometric laws — except that it would have four space dimensions instead of three! Light and all physically observable matter would be confined to moving in the surface. Time would be an extra dimension, a fifth dimension, dealt with separately. To be explicit, the surface of this hypersphere would have Cartesian coordinates (w, x, y, z) such that:

$$w^2 + x^2 + y^2 + z^2 = a^2 \tag{7}$$

where a is the radius of curvature in eq. (5). Except for the extra dimension w , this is identical to the equation for a 3-dimensional sphere of radius a . Modern relativists say that the hypersphere is a "3-sphere [since its surface is 3-dimensional] embedded [existing] in a Euclidian [ordinary geometry] space of 4 [space] dimensions" [31, p. 704]. Since the radius a increases with time, we can think of the hypersphere as a four-dimensional rubber balloon being inflated. Galaxies would be like pennies pasted on the surface of the balloon; they would all be spreading apart as we inflate the balloon. Many textbooks use this example, but most of them neglect to tell the reader that the balloon has four space dimensions.

Figure 1 shows how equations (5) and (6) with $k = 1$ relate to this concept. As I mentioned before, the location of the origin (through which we put the w axis) on the surface of the hypersphere is completely arbitrary. The angle θ represents the amount of rotation around the w axis; the angle ϕ is suppressed. The figure shows three ways to specify the radial distance of a galaxy from the origin: the angle χ or the radial coordinate η (both of which are co-moving), or the radial coordinate r (which is not co-moving).

This hyperspherical cosmos may seem like science fiction, but it was Einstein who introduced the concept into cosmology in 1917 [12, p. 185, eq. (10)], using eq. (7) with different notation. However, he quickly performed some mathematical sleight-of-hand and swept the extra space dimension w under the rug, so that it was no longer explicit in the equations. Since then, most relativists try to regard it as a convenient mathematical fiction [29, p. 360]. Some, like John A. Wheeler [31, p. 704], even seem rather antagonistic to the possibility of the extra dimension being real:

Excursion off the sphere is physically meaningless and is forbidden. The superfluous dimension is added to help the reason in reasoning, not to help the traveler in traveling.

Possibly some of this antagonism stems from a distaste for certain 19th-century ideas, either those of the spiritualists, who seized upon hyperspace as a place for ghosts to inhabit, or those of some Christians, who imagined hyperspace as the dwelling place of God. Most likely, it stems from a desire to have the 3-dimensional universe of matter and energy be all of what exists, not merely a part of a much larger reality. Carl Sagan [42, p. 4] expressed this desire as though it were either a definition or a fact:

The cosmos is all that is or ever was or ever will be.

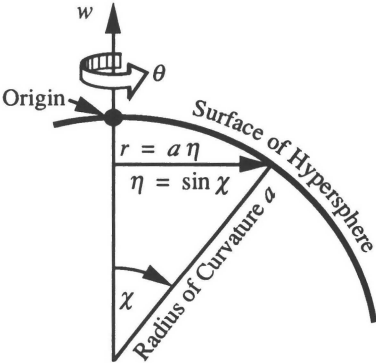


Figure 1. Positive-curvature cosmos

Creationists, on the other hand, need not be adverse to the possibility of a reality larger than the visible universe, particularly since there are Biblical hints of an extra dimension (see my Biblical paper). One of the difficulties, of course, is being able to visualize or imagine an extra dimension. One help in that regard is Rudy Rucker's mind-stretching little book, *The Fourth Dimension* [41]. Rucker's amusing illustrations and unabashed romps in the fields of speculation make his book an enjoyable introduction to these ideas for both lay person and scientist.

Thus far I have discussed only the case of positive curvature, $k = 1$. We can also visualize the case of zero curvature, $k = 0$, with an extra dimension. In this case, our 3-dimensional space would be the surface of a flat sheet (thin in the w direction) of rubber in a four-dimensional space. Again we glue pennies to the sheet to represent the galaxies, and we represent the expansion by stretching the sheet in the x , y , and z directions. Figures 2 and 3 illustrate the $k = 1$ and $k = 0$ cases by including the w -axis and suppressing the z -axis:

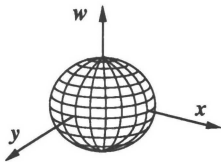


Figure 2. Positive-curvature cosmos

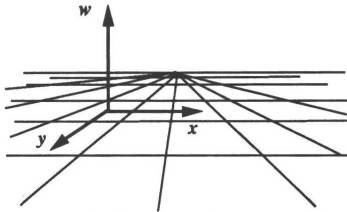


Figure 3. Zero-curvature cosmos

For the case of negative curvature, $k = -1$, we would have a saddle-shaped rubber sheet instead of a flat one. None of these universes has an edge or boundary for the matter in them. The positive-curvature universe has a finite size. If you could travel far enough in one direction (being confined to the surface of the hypersphere), you would eventually come back to your starting point. This feature makes it a *closed* cosmos. But in your travels you would never reach an edge to the stars and galaxies in it (since the matter is spread uniformly over the surface of the hypersphere), making it an *unbounded* cosmos. Thus the positive-curvature Robertson-Walker cosmos would be closed and finite, but unbounded.

The zero- and negative-curvature (flat and saddle-shaped) universes are not finite. In them, if you traveled in one direction, you could never come back to your starting point. Yet you would never encounter an edge to matter, since the matter in them extends out to infinity. These two kinds of universe would be *open* and unbounded. Thus *all Robertson-Walker (including big-bang) cosmologies have unbounded matter*.

6. MAJOR MISCONCEPTIONS ABOUT BIG-BANG THEORY

At this point we have enough background to grapple with some very common misconceptions. Most people, including most scientists, think that big-bang theorists picture a small sphere of matter exploding outward in a large, pre-existing, empty 3-dimensional space. The outer edge of the exploding matter would then be a boundary between the matter and the empty space surrounding it. But the public's picture of the big bang is wrong! In the case of the closed universe, big-bang mathematics actually says that our 3-dimensional space itself was as small as the matter. Then our 3-dimensional space expanded along with the matter. In other words, big-bang theorists imagine that in the beginning the radius a of their four-dimensional balloon was very small, but that *even then, matter was uniformly distributed along its surface*, and so matter would have no boundary in 3-dimensional space. Journalist Timothy Ferris [17] thinks that the public misconception on this point stems from the name "big bang" itself, which was originally a derogatory label the theory's opponents stuck on it:

The term "big bang" is misleading in several respects. It implies that the expansion of the universe involved matter and energy exploding like a bomb into preexisting space. Actually the theory depicts all matter, energy, and space-time as having been bound up in the infant, high-density universe. Then, as now, all space was contained in the cosmos, even when the cosmos was smaller than an atom.

However, some of the blame for the public confusion should rest on popularizers like Ferris himself, who neglects to tell his readers that his word "space" really means the 3-dimensional space we inhabit, and who withholds from them the clarifying concept of another space dimension. Also he doesn't say that his words apply only to the positive-curvature versions of big-bang theories. For the zero- and negative-curvature (open) cases, big-bang mathematics actually says that in the beginning space and matter were infinitely large, and matter everywhere had a very high density and temperature. I.e., even at the beginning, the size and mass of the universe would be *infinite*. If in the beginning you had drawn a circle on the flat or saddle-shaped sheets, the circle would get larger as the expansion proceeded, while the density and temperature would get smaller. In other words, the open versions of the big-bang universes start infinitely large and get larger! I can understand why the popularizers are reluctant to explain these concepts to the public.

Two other misconceptions stem from the primary misconception I have mentioned above. The first is that there would be gravitational forces pointing toward the assumed center of the big bang. The second is that those

assumed forces would be so strong that the initial phases of the big bang would be in a black hole (I will say much more about black holes later). But in the actual big-bang theory there is no center in 3-dimensional space for gravitational forces to point to. Every point in 3-dimensional space would have, on the average, an equal amount of matter at large distances in all directions from the point. So the overall gravitational force on each point due to the surrounding universe would be zero. (Of course the gravitational forces from nearby objects, such as our own planet, would not be zero but quite substantial.) Because of this cancellation, no large-scale pattern of gravitational forces would exist, and so a big-bang cosmos could never be in a black hole.

A fourth misconception is that no galaxy could move away from us faster than the speed of light. But many books on standard cosmology [46, pp. 148-149] point out that for every point in our 3-D space there is a "horizon" beyond which the recession velocity would exceed the speed of light, and that galaxies should exist beyond that horizon. However, at the horizon, the red shift would be infinitely large, and it would be impossible for us to see beyond it. In cosmology, matter cannot move through our 3-D space faster than the locally-measured speed of light, but *space itself* is not limited that way. (Some authors [see section 4] dislike, for philosophical reasons, this picture of space itself expanding, but they offer no alternative picture to help explain the distinctions.) For example, going back to Fig. 1, matter and light waves can only move along (or in) the surface of the hypersphere, and they cannot move faster than c with respect to the surface in their vicinity. But the surface itself can move radially outward faster than the speed of light, and according to the $k = 1$ version of big-bang theory, it is doing so right now. In fact, Alan Guth's "inflationary" version of big-bang cosmology [21] has the hypersphere, during an early phase of its expansion, increasing its radius a at 10^{20} times the speed of light!

A fifth misconception is that the red shifts of the galaxies are Doppler shifts, i.e. caused by the velocity of the galaxies away from us at the time the light starts its journey toward us. But one undergraduate textbook [23, pp. 236, 245-246] and many graduate textbooks [39, p. 213] make it clear that the red shifts are an *expansion* effect. As space is stretched out, the lengths of all electromagnetic waves passing through the space are similarly stretched out. Consequently, the *speed* of recession doesn't matter, only the *amount* of expansion that takes place as the light travels to us, whether the expansion is fast or slow. Somehow this distinction has escaped even most physicists, unless they are specialists in general relativity. I will say more about this in Section 14.

In summary, the widely accepted big-bang cosmologies have five little-known features which are very important to understand here:

1. *Matter in the universe never had any boundaries, has none now, and never will.*
2. *There is no large-scale pattern of centrally-directed gravitational forces.*
3. *The universe never was in a black hole.*
4. *Space can expand faster than the speed of light.*
5. *The red shifts are not Doppler shifts.*

It is ironic that so many enthusiastic supporters of the big bang are completely ignorant of these basic features of the theory they promote.

7. REASONS TO CONSIDER A BOUNDED COSMOS

Section 2 shows that the Copernican principle is an entirely arbitrary assumption, an "admixture of ideology" as Hawking and Ellis put it. Therefore it makes scientific sense to explore the consequences of the opposite assumption, a bounded universe. The matter in such a universe would not occupy all the available 3-dimensional space, but instead there would be empty space beyond the matter.

Another paper of mine at this conference, "A Biblical Basis for Creationist Cosmology," concludes that:

1. **The cosmos is bounded** — Interstellar space, the ordinary heavens of stars and galaxies, has a finite (though very large) size and a definite boundary. Beyond it are "the waters above the heavens," of undetermined thickness. For some unspecified distance beyond those waters there exists more space of the same sort as interstellar space, but empty of matter.
2. **The earth is near the center** — Interstellar space has a center of mass, and the earth is "near" it by cosmic standards, meaning the present distance between the earth and the center is small compared to billions of light-years.
3. **The cosmos has been expanded** — God "stretched out" interstellar space at some time in the past, probably during creation week. Space may or may not be expanding now.
4. **The cosmos is young** — God created the universe in six earth days, i.e., in six ordinary rotation periods of our particular planet.

The biblical paper offers evidence that, of all the known ways to understand the relevant scriptures, these are the most straightforward. If that is true, then it should be clear that these are not *ad hoc* assumptions, invented only recently to solve cosmological problems — because the Bible greatly predates our awareness of those problems. Thus these conclusions provide a very reasonable "admixture of ideology" to build our cosmological models upon. Conclusions 1 and 2 are the most important ones to our discussion right now. They are essentially the opposite of the Copernican principle, and so fit our scientific motivation to see what a non-Copernican cosmology would be like.

8. GRAVITY IN A BOUNDED COSMOS

Let us now see what differences boundaries make. First of all, the existence of boundaries requires the existence of a center of mass. This means that a large-scale pattern of *gravitational force* must exist throughout the cosmos, everywhere pointing toward the center of mass. If we are near the center, then the fact that the universe looks isotropic (the same in every direction) to us means that the universe must be approximately spherically symmetric. To keep things simple (they are going to get complex enough anyway) for this paper, let's assume (i) no overall rotation of the cosmos and (ii) that the mass density ρ is constant out to a radius r_0 from the center, and zero beyond that. Also, for this section only, let's ignore the effects of expansion. In that case, the large-scale gravitational force is approximately related to a Newtonian *gravitational potential* Φ [29, p. 298, 1st footnote] which depends on the radius r as follows:

$$\Phi(r) = -2 \pi G \rho \left(r_0^2 - \frac{1}{3} r^2 \right) \text{ for } r \leq r_0, \text{ and } \Phi(r) = -\frac{Gm}{r} \text{ for } r > r_0, \tag{7}$$

where m is the total mass of the universe,

$$m = \frac{4}{3} \pi \rho r_0^3 \tag{8}$$

(For those not familiar with this concept, gravitational potential is the energy you would need to lift one kilogram of mass from some point at radius r up to a point very far beyond radius r_0 , where the gravitational force is essentially zero. It is also one-half the square of the *escape velocity* at that point, which is how fast you would have to throw the mass in order for it to escape the bounds of the universe.) Figure 4 shows how the depth of this gravitational potential "well" decreases with increasing distance r from the center. The slope of the walls of the well gives the gravitational force; the steeper the wall, the greater the force. You can think of this well as being caused by the weight of a mass upon a stretched rubber membrane. The more concentrated the mass, the deeper the well, as Figure 5 shows.

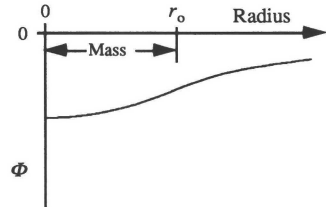


Figure 4. Gravitational potential "well."

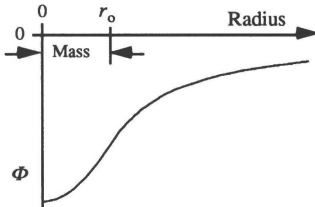


Figure 5. Well with more concentrated mass.

The earth, being near the center, would be near the bottom of this well, with most of the universe being at a higher (less negative) gravitational potential.

9. GRAVITY SLOWS TIME DOWN

The above differences in gravitational potential from place to place would produce differences in the rates of clocks — and all physical processes. To see this, let's consider an approximate general relativistic metric for this situation [45, p. 185]:

$$ds^2 \approx \left(1 + 2 \frac{\Phi}{c^2} \right) c^2 dt^2 - \left(1 - 2 \frac{\Phi}{c^2} \right) (dx^2 + dy^2 + dz^2), \tag{9}$$

where the Cartesian coordinates (x, y, z) are related to the spherical coordinates (r, θ, ϕ) in the usual way. This approximation is good when $|\Phi| \ll c^2$. Imagine the two events marking off the interval ds as being the successive ticks of a clock which is motionless in this system of coordinates. Since the two ticks take place at the same location in space, the distance differences dx, dy , and dz are all zero. Using that information plus eq. (1) in eq. (9), and taking the positive square root, gives us the following relation between the proper (or "natural") time interval $d\tau$ measured by physical clocks and the time interval dt , which is the *Schwarzschild time* (or "coordinate" time) I warned you to watch out for:

$$d\tau \approx \left(1 + \frac{\Phi}{c^2} \right) dt$$

(10)

Other authors have also derived this equation [29, pp. 248-249]. Notice that when the gravitational potential is zero, the two types of time intervals are equal, so that $d\tau = dt$. This means that Schwarzschild time t is the time measured by a clock which is not in a gravitational field. Far beyond the boundary radius r_0 of the cosmos, the gravitational potential is practically zero, so t is the time registered by very distant clocks. If we could make a set of ideal clocks throughout the universe which were not affected by gravity, we could theoretically synchronize all those clocks with one of the very distant clocks [31, pp. 597]. (One way to make such a set of gravitationally-
unaffected clocks would be to let all the clocks in the set fall freely, since by Einstein's equivalence principle and

also by experimental observation, free fall is equivalent to zero gravity. Another way, in theory, would be to determine the gravitational potential at every point in space and compensate the clock rates accordingly.) The synchronized set would then measure Schwarzschild time. We could think of the whole set as being "God's clock," an ideal clock completely unaffected by such mundane things as gravity. As such, Schwarzschild time makes a good standard against which we can compare the rates of less ethereal and more variable clocks.

In this light, eq. (10) says that natural, physical, clocks are indeed affected by gravity. Since the gravitational potential Φ has negative values, the equation says that wherever Φ is not zero, $d\tau$ is less than dt . I.e., clocks in a gravitational field tick slower than clocks which are not in a gravitational field. Moreover, the deeper you go into a gravitational well, the slower physical clocks tick. Although this effect is nearly unknown to the public, many authors in general relativity describe it. Here is a sampling:

... it follows that clocks fixed at a lower potential go slower than clocks fixed at a higher potential. This is called "gravitational time dilation" [39, p. 21].

The rate of a clock is accordingly slower the greater is the mass of the ponderable matter in its neighbourhood [14, p. 92].

Thus at finite distances from the masses there is a "slowing down" of the time compared with the time at infinity [29, p. 302].

Clocks go slower in the vicinity of large masses [46, p. 27].

The second quote is by Einstein. This general-relativistic *gravitational time dilation* is not the same as the well-known "velocity" time dilation (slowdown of clocks due to motion) of special relativity. General relativity says that gravity slows down not only clocks, but also *all physical processes*: atoms, nuclei, chemical and biochemical reactions, electromagnetic waves, nerve impulses in your brain, sand in an hourglass, the watch on your arm, rotations and orbits of planets — everything! Thus we would have no direct means of observing this slowdown in our vicinity, because all of the ways we could notice or measure it are also slowed down. The slowdown is *locally* transparent to us; we cannot detect it by measurements just at one place. For example, if we were to measure the speed of light with physical clocks located near the Sun, we would get the same number as we do on earth. However, if we could do the measurements with ideal Schwarzschild clocks, we would find that the speed of light is lower near the Sun. So in general relativity, even the speed of light is affected by gravity [18, p. 23] — if we use the right clocks!

The only previous author I know of who seems to have included something like gravitational time dilation in a cosmology is Gerald L. Schroeder. His article in the *Jerusalem Post* [44] contains few scientific details, but it appears to have clocks ticking fast at the center and slow at the edge of the cosmos — just the reverse of what the equations in this section show. After submitting the first draft (8/30/93) of this article, I finally succeeded in contacting him; as far as I can tell from his reply (10/29/93), his concepts are quite different from the cosmology I am presenting here.

10. THE SLOWDOWN OF TIME — PRESENT AND PAST

Gravitational time dilation is not mere theory, however. There are ways to measure it, and it has been measured many times. Below are some samples:

1. **Deflection of electromagnetic waves** — Half of the famous deflection of light as it passes the Sun is due to gravitational slowing of the speed of light, the other half coming from the effect of gravity on space. For many years, critics of general relativity correctly pointed out that the solar eclipse measurements of the deflection of starlight were very inaccurate. But in 1975, measurements of radio waves from three quasars as the Sun passed close to them in the sky confirmed Einstein's prediction of the deflection to an accuracy of better than 1% [39, p. 22].
2. **Radar in the solar system** — In 1965, I. I. Shapiro measured the travel times of radar waves passing by the Sun and bouncing back from the planet Venus. The results confirmed the predictions of general relativity, particularly gravitational time dilation, to within 3% [46, pp. 41-45]. A few years later, the travel times of radio signals from the Mariner 6 and 7 spacecraft also confirmed the theory to about the same accuracy.
3. **Atomic clocks in airplanes** — In 1971 Joseph Hafele and Richard Keating flew atomic clocks in eastbound and westbound airline flights, trying to measure the effect of gravitational time dilation due to the change of altitude. After correcting for velocity time dilation, they confirmed gravitational time dilation to within 10%. Four years later a team from the University of Maryland did a similar experiment, but more accurately, confirming the predicted time dilation to an accuracy of nearly 1% [46, pp. 29-35].
4. **Atomic clocks on the ground** — Wolfgang Rindler [39, p. 21] reports: "Indeed, owing to this effect [gravitational time dilation], the U.S. atomic standard clock kept since 1969 at the National Bureau of Standards at Boulder, Colorado, at an altitude of 5400 ft, gains about five microseconds per year relative to a similar clock kept at the Royal Greenwich Observatory,

England, at an altitude of only 80 ft, both clocks being intrinsically accurate to one microsecond per year."

These and other experiments make it clear that gravitational time dilation is real. However, 5 microseconds/year per mile of altitude difference does not seem like a large effect. How big would the effect be for the whole universe at present? To answer that question we need to determine the gravitational potential $\Phi(0)$ at the center of the universe. Solving eq. (8) for ρ and substituting it into eq. (7) with $r = 0$ gives us the potential at the center in terms of the total mass m and radius r_0 of the universe:

$$\Phi(0) = -\frac{3}{2} G \frac{m}{r_0} \quad (11)$$

Now we need to estimate the radius r_0 and mass density ρ of the universe. The most distant radio galaxies observed are supposed to be about 12 billion light-years away [8], according to the standard cosmological interpretation of their red shifts, so let us try $r_0 = 20$ billion light-years. The observed density of luminous matter in our cosmic neighborhood is on the order of 10^{-28} kg/m³ [34, pp. 323-329]. Using those numbers in eq. (8) gives us an estimate for the mass of the universe:

$$m \approx 3 \times 10^{51} \text{ kg} \quad (12)$$

Using the mass and radius above in eq. (11) gives us a potential of $-1.7 \times 10^{15} \text{ m}^2/\text{s}^2$ at the center of the universe. Plugging that potential into eq. (10) shows that clocks at the center should presently be ticking only about 2% slower than clocks very far away. So, given the above density and size, clock rates should be about the same throughout today's universe. (Of course, if "dark matter" proves to be substantial or the size of the cosmos is much greater than 20 billion light-years, clock rates would be very different in different parts of the universe even today.)

But what about clock rates in the past? If the universe has indeed expanded, as both the biblical and scientific data indicate, then the radius r_0 of the universe was smaller in the past. That means the potential well would have been deeper than now, as eq. (11) shows and Figure 5 illustrates. In fact, eq. (11) suggests that if r_0 was about fifty times smaller, the depth of the gravitational potential well would have been about c^2 . That means the escape velocity [see footnote below eq. (7)] from a point near the center would have been about the speed of light — so light from the center could not have escaped the universe! Also, using $-c^2$ for the potential in eq. (10) suggests that clocks at the center would have been stopped!

Values of potential as large as c^2 are well beyond the limits ($|\Phi| \ll c^2$) whereby equations (9) and (10) are good approximations. However, it is clear that strange things would have happened to light and time when the universe was smaller. The next section delves into those peculiarities with a more accurate metric.

11. BLACK HOLES AND WHITE HOLES

A month after Einstein published his field equations (3) with $\Lambda = 0$, Karl Schwarzschild, a German physicist serving in the Prussian army, found the first exact solution of them [30, p. 119] [29, p. 301, eq. (100.14)], a metric which describes spacetime in the vacuum surrounding a sphere of mass m :

$$ds^2 = \left(1 - \frac{r_s}{r}\right) c^2 dt^2 - \frac{dr^2}{1 - \frac{r_s}{r}} - r^2 d\Omega^2, \text{ where } r_s \equiv \frac{2Gm}{c^2} \quad (13)$$

The radial distance r is the same as in eq. (6). The time t is same as the Schwarzschild time defined in the previous section. In 1923, G. D. Birkoff [4] found that the Schwarzschild metric is valid even for contracting or expanding masses, as long as they remain spherically symmetric. The parameter r_s , called the *Schwarzschild radius*, is a critical size of great importance. Using the mass given by eq. (12), the Schwarzschild radius of the universe would be:

$$r_s = 450 \times 10^6 \text{ light-years}, \quad (14)$$

i.e., about a half-billion light-years. Remember that in the previous section we assumed the universe presently has a matter radius r_0 of 20 billion light-years. If in the past the universe were 50 times smaller, all of its matter would be inside its Schwarzschild radius. To understand what this means, we must now discuss *black holes* and *white holes*.

In the mid-1960's John Wheeler applied the term "black hole" to the idea of a collapsing star whose matter has all fallen within its Schwarzschild radius. It turns out that light or matter from such a star can never escape beyond the Schwarzschild radius. The sphere defined by the Schwarzschild radius is called the *event horizon*, because from outside it, you could never see events happening inside it. Light and matter from outside could fall into the event horizon, but nothing could ever return from it — hence the name "black hole." As more and more matter falls into a black hole, its mass increases, and so its event horizon always is moving outward. Jean-Pierre Luminet's book, *Black Holes*, recently translated into English [30], is an excellent introduction to the topic for both laymen and scientists.

There are a few misconceptions about black or white holes we should dispose of here. The first is that in them densities and tidal forces (which try to pull things apart) are always huge. But if you take the mass of eq. (12) and spread it uniformly throughout a sphere whose radius is that of eq. (14), you get a density of only 8×10^{-24} kg/m³. Tidal forces would also be tiny. If you were to concentrate all the mass into an infinitesimal "singularity" at the very center, then the density would be infinite at that point, but zero everywhere else. Tidal forces near the singularity would be very great, but forces further out would remain small. A black hole has an event horizon long before a singularity forms, and a white hole need not have a singularity except possibly (not necessarily) at the instant of its creation. Thus forces and densities aren't necessarily large. The second misconception is that black holes are black inside. But light can and probably does exist within them. We just can't see it from outside the event horizon.

There is good astronomical evidence that black holes actually exist [30, pp. 250-252]. Astronomers have identified three objects in the sky which emit x-rays of the sort which matter falling into a black hole would emit: Cygnus X-1, LMC X-3, and A 0620-00. Each of these is a double star system, with a visible star orbiting an invisible companion. The mass of each of the companions appears to be well above 3 solar masses, the theoretical limit to the mass a compact star can have without collapsing into a black hole.

The same equations which describe a black hole also allow for the existence of an "anti-black hole" or *white hole*, the term some astrophysicists use for the idea of a black hole running in reverse. A white hole would expel matter out of its event horizon instead of pulling matter into it. Light (and matter) would leave the white hole, but no light (or matter) could go back in. As matter leaves the white hole, its mass decreases, so its event horizon would move inward. Eventually the event horizon would reach radius zero and disappear, leaving behind a widely-distributed collection of ordinary matter. The term "white hole" never really became popular, perhaps because such an object would be a source, not a "hole." Luminet suggests the poetic name "white fountain" [30, p. 165]. I like that term, but as yet it has not become familiar enough to be useful.

Matter cannot sit still inside an event horizon [29, p. 311]. In a black hole, matter *must* move inward; in a white hole, matter *must* move outward.

There is no evidence as yet that small white holes exist. However, eq. (14) suggests that the *universe* started as a white hole! This conclusion follows directly from boundedness and expansion. Such an origin is quite different from big-bang theories.

12. TIME AND THE EVENT HORIZON

Let's consider what happens to clocks near the event horizon. Again setting dr and $d\Omega$ equal to zero in eq. (13), using eq. (1), and taking the positive square root as we did in section 9, we get a relation between proper time $d\tau$ and Schwarzschild time dt :

$$d\tau = \sqrt{1 - \frac{r_s}{r}} dt, \quad \text{for } r > r_s \quad (15)$$

At great distances outside the event horizon, we again see that the two types of time are the same. As r decreases and gets close to the value r_s , the proper time intervals become much smaller than the Schwarzschild time intervals. Stephen Hawking [25, p. 87] tells the story of a man, say an astronaut, falling toward the event horizon of a large black hole. Here I paraphrase the story as follows:

The astronaut is scheduled to reach the event horizon at 12:00 noon, as measured by his watch (proper time). An astronomer watching from very far away (thus being on Schwarzschild time) sees the watch tick slower and slower as the astronaut approaches the event horizon, a dark sphere blocking off a starry background. The astronomer sees the watch reach 11:57 a.m. After an hour (of Schwarzschild time) the watch reaches 11:58. After a day (of Schwarzschild time), he sees the watch reach 11:59. The astronomer never does see the watch reach 12:00. Instead he sees the motionless images of the astronaut and his watch getting redder and dimmer at the event horizon, finally fading from view completely.

Hawking didn't describe very much of what the astronaut sees, so I will take up his story:

As the astronaut approaches the event horizon, he looks back through a telescope at the astronomer's observatory clock (Schwarzschild time) and sees it running faster and faster. He sees the astronomer moving rapidly around the observatory like a movie in fast-forward. He sees planets and stars moving very rapidly in their orbits. The whole universe far away from him is moving at a frenzied pace, aging rapidly. Yet the astronaut sees his own watch is ticking normally. Finally when the astronaut's watch (proper time) reaches 12:00 noon, he sees that the hands of the astronomer's clock are moving so fast they have become a blur. As he passes the event horizon, he feels no unusual sensations, but now he sees bright light inside the horizon. His watch reaches 12:01 and continues ticking. He looks back toward the astronomer and sees ...

To find out what the astronaut sees next, we must figure out what happens to clocks inside the event horizon. Eq. (15) does not apply when r is less than r_s . But if we consider that inside the event horizon the escape velocity must be greater than the speed of light, then we could say that the gravitational potential Φ must be

more negative than $-c^2$. Eq. (10) then suggests (but does not require because of its limits of approximation) that $d\tau$ and dr might have opposite signs — the two types of clocks might run in opposite directions!

It appears to be another "trade secret" of general relativity, unpublicized by the adepts, that black hole theory supports this astonishing possibility. Figure 6 is adapted from a well-respected graduate textbook by John Wheeler and two colleagues, Kip Thorne and Charles Misner [31, p. 825]. It shows how the Schwarzschild time t varies as the astronaut's inward fall decreases the radius r . The arrows show the direction of increasing proper time; that is, the astronaut's watch increases its reading from point A to point B to point C. Although the Schwarzschild time goes to infinity at point B, the proper time τ does not. As the astronaut continues falling past the event horizon, the Schwarzschild time *decreases* (even while the proper time is increasing), all the way to point C. Thus, although the Schwarzschild time goes to infinity at the event horizon, the *net* amount of Schwarzschild time elapsed in going from A to C is finite. The proper time elapsed is also finite, and it is smaller than the net Schwarzschild time elapsed [31, p. 848]. Also notice that the slope of the astronaut's trajectory as it approaches C is nearly zero. This means that as measured in Schwarzschild time, the astronaut's speed is much greater than c and approaches infinity! Wheeler feels that Schwarzschild time is a bad "choice" of coordinates in this case, its "unhappy" features being shown in two ways:

... (1) in the fact that t goes to ∞ partway through the motion; and (2) in the fact that t thereafter decreases as τ (not shown) continues to increase.

Wheeler's word "choice" implies that Schwarzschild time is merely a matter of arbitrary theoretical taste, having no particular connection with physical measurements. However, as I pointed out in section 9 in my comments on eq. (10), Schwarzschild time has a clear physical meaning. It tells us the relation between local clocks and clocks at a distance, or between rates of physical processes and clocks unaffected by gravity. For example, it can tell us what the astronaut sees outside the event horizon when he himself is inside it:

... and he sees (since light can go inward through the horizon) the astronomer's clock still running so fast that the hands are a blur. As he watches, the hands of the clock slow down enough to let him see that they are moving very rapidly *counterclockwise*. The huge amount of time he saw the clock record before he crossed the event horizon is now being taken away. As the astronaut continues inward away from the event horizon, the astronomer's clock slows down toward normal speed, but it is still going backwards. The astronaut's own watch now reads 12:05. He sees the astronomer back away from the telescope and walk backwards toward the door. As far as the astronaut can see, time in the whole universe outside the event horizon is running *backwards*.

A white hole would reverse this fantastic voyage. Figure 7 shows the spacetime path of an astronaut as a white hole expels him out of its event horizon. Light and material from outside cannot move inward through the event horizon, so the astronaut cannot see the outside universe. However, an astronomer outside the event horizon would be able to see the astronaut clearly, since light and material can and do flow out of the event horizon. The arrows again show the direction of increase of proper time, from A to B to C. Again, it only takes a finite amount of proper time for the astronaut to go beyond the event horizon.

Let's say the astronaut is scheduled to cross the event horizon at 12:00 midnight by his watch. Here is his view of events:

As the astronaut begins his journey out of the white hole, there is bright light behind him, but the event horizon looks like a black wall in front of him. As he approaches the wall he glances at his watch; it reads 11:59 p.m. A minute later, as his watch reaches 12:00 midnight, he passes through the event horizon. He feels no particular sensation, but suddenly he sees the whole starry universe outside the event horizon. He can still see the bright light coming from behind. Looking through a telescope at the astronomer's observatory clock, he sees its hands moving very rapidly

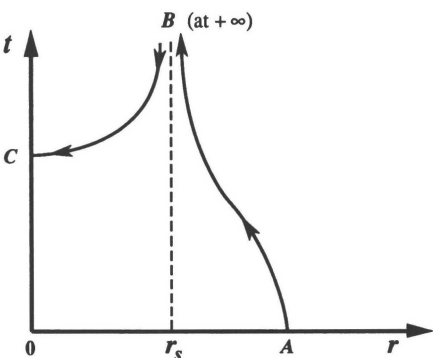


Figure 6. Astronaut falling into a black hole.

Also notice that the slope of the astronaut's trajectory as it approaches C is nearly zero. This means that as measured in Schwarzschild time, the astronaut's speed is much greater than c and approaches infinity! Wheeler feels that Schwarzschild time is a bad "choice" of coordinates in this case, its "unhappy" features being shown in two ways:

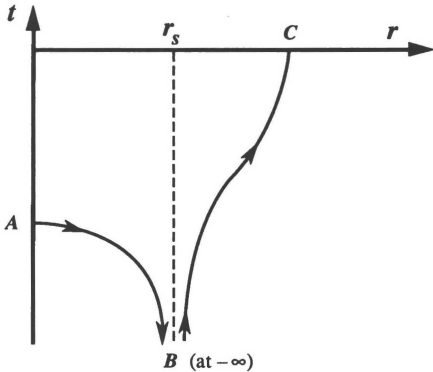


Figure 7. Astronaut expelled out of a white hole.

clockwise, and the astronomer is moving very rapidly around the observatory. Looking elsewhere, the astronaut sees the whole universe moving in fast-forward, aging very rapidly. As the astronaut gets further away from the event horizon, he sees the astronomer's clock slowing down to more normal speeds. As he arrives at the observatory, the astronomer's clock has finally slowed down to the speed of the astronaut's watch.

The astronaut tells the astronomer how fast the astronomer was aging. The astronomer has seen some strange things too, and he tells the astronaut how slowly the astronaut was aging. They argue for a while, and then finally decide that black holes and white holes do strange things to time, especially near the event horizon. But strange as such effects may seem, they are a real possibility, according to our best experimental and theoretical knowledge of physics. If the universe is bounded and has expanded, then these odd "time warps" in the past history of the cosmos are an unavoidable scientific consequence. However, creationists need not try to avoid them, because they work in our favor to allow a young universe.

13. WHAT HAPPENS INSIDE THE MATTER SPHERE

Thus, if the universe is bounded and has expanded, there was a time in its early history when all its matter was well within the event horizon, not yet having expanded to the 450 million light-years of eq. (14). During that time, the Schwarzschild metric for vacuum, eq. (13), would be valid through all the empty space between the matter and the event horizon, as well as outside it. But at some point in the expansion, the outermost matter would reach the event horizon. After that, matter would be flowing out of the event horizon, and we would expect the event horizon to start shrinking. But to properly understand what happens inside the matter's boundary, we need a different metric than eq. (13). This section will provide such a metric and explore some of its consequences.

By the time the matter reaches the event horizon, we can consider most of it as "dust," that is, the various clusters of matter are far apart enough not to be interacting significantly. Many authors on general relativity deal with the collapse of a uniform sphere of dust to become a black hole [29, pp. 316-321] [48, pp. 342-349]. The same equations apply to our situation of a uniform dustlike sphere expanding out of a white hole, except that all motions run in reverse [29, p. 320]. Therefore we can use the same metric as they derive.

The result of their work is that inside the sphere, the metric is *almost* identical to the Robertson-Walker metric, eq. (5), for $k=1$. In the co-moving coordinate system (η, τ) of eq. (5), let's define η_0 as the co-moving radial coordinate of the sphere's edge. Then for values $\eta \leq \eta_0$, eq.(5) is a valid metric. However there is one very important difference. Whereas for an unbounded Robertson-Walker cosmos, the origin can be anywhere, here the origin of coordinates *must be at the center* of the sphere and nowhere else. But seen from the center of the sphere, many phenomena will be the same as in a Robertson-Walker cosmos.

Outside the sphere, the metric has to be the same as the Schwarzschild metric, eq. (13). Therefore at the edge of the matter, at $r = r_0$ for the Schwarzschild metric and at $\eta = \eta_0$ for the Robertson-Walker metric, the two solutions must coincide. But since the two metrics use different types of coordinates, we must convert one of the metrics to the other set of coordinates. For our purposes we need the metric inside the sphere in terms of the Schwarzschild coordinates (r, t) . Only two authors I know of follow that procedure, Steven Weinberg [48, pp. 345-346] and Oskar Klein [28, pp. 67-72]. Klein's interpretation of some of his mathematics is now somewhat outdated; see [29, p. 309-320] for a more recent view. But his mathematics are correct, and his exposition and notation are more suited to our needs. Unfortunately for many people, Klein's article is in German, with no published English translation that I know of. I have translated the relevant sections into English for my own convenience, and I will be happy to make the translation available to anyone who can use it [28].

As Schwarzschild did, Klein sets the cosmological constant Λ equal to zero in Einstein's equations (3). He then obtains a solution in the form of the following metric:

$$ds^2 = \beta c^2 dt^2 - \alpha dr^2 - r^2 d\Omega^2 \quad (16)$$

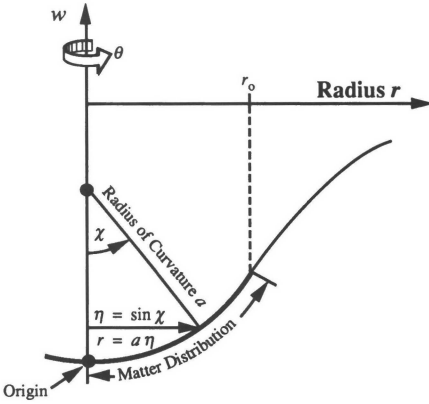
where α and β are functions to be specified below. Inside the sphere, for $r \leq r_0$, we have:

$$\alpha = \frac{1}{1 - \frac{a_0^2 r^2}{a^3}}, \quad \text{where } a_0 \equiv \sqrt{\frac{3c^2}{8\pi G \rho_0}} \quad (17)$$

As before, a is the radius of curvature of space, which varies with proper time τ . Under these conditions a will reach a maximum value a_0 , which eq (17b) relates to the minimum matter density ρ_0 occurring at the time of maximum a . Equations (6) and (8) are also valid here, so you can use them to get ρ_0 in terms of the total mass m and η_0 .

Figure 8 (on the next page) illustrates the geometry of the bounded cosmos described by equations (16) and (17), again using the extra space dimension w and suppressing the angle ϕ . As in Figure 1, the angle θ represents the amount of rotation around the w axis. The radius r_0 shows the edge of the matter distribution, also denoted by the co-moving coordinate η_0 . The location of the origin cannot be moved, but must remain at the center of the matter distribution as shown. In all other ways, space inside r_0 is simply a section of the hypersphere shown in Figure 1, corresponding to the Robertson-Walker metric. Inside the sphere, the *proper distance* [48, p. 415, eq. (14.2.21)] along the surface of the hypersphere at any given proper time would be a χ .

Figure 8. Geometry of bounded cosmos.



Outside of r_0 , space corresponds to the Schwarzschild metric. The similarity of Figure 8 to Figure 5 is significant, but only approximate. The other coefficient of eq. (16) is related to time and therefore of more interest to us. It is:

$$\beta = \frac{\left[1 - \frac{a_0}{a} \left(1 - \frac{(1 - \eta_0^2)^{3/2}}{(1 - \eta^2)^{1/2}}\right)\right]^2}{\left(1 - \frac{a_0}{a} \eta^2\right) \left[1 - \frac{a_0}{a} \left(1 - \frac{(1 - \eta_0^2)^{1/2}}{(1 - \eta^2)^{1/2}}\right)\right]^3} \quad (18)$$

To decipher this rather formidable expression, it may help to remember that η and η_0 are the co-moving radial coordinates of, say, a galaxy and the edge of the sphere, respectively. So for a galaxy, the only variable in this equation that changes with proper time is the radius of curvature a , which is always equal to or less than a_0 . Certain combinations of η and a will cause the

numerator to be zero, so natural clocks would be stopped at the corresponding radii and times.

Now we need to find out how the radius of curvature a of the sphere of matter depends on proper time τ . For the case of the cosmological constant $\Lambda = 0$, many authors [27, pp. 320,321] derive $a(\tau)$ from the Einstein field equations (3). For my purposes it is easier to use $\tau(a)$:

$$\tau = \pm \frac{\tau_0}{\pi} \left[\text{Arccos} \left(2 \frac{a}{a_0} - 1 \right) + 2 \sqrt{\frac{a}{a_0} - \left(\frac{a}{a_0} \right)^2} \right], \text{ where } \tau_0 \equiv \frac{a_0}{c} \quad (19)$$

where I use the plus sign for a collapsing sphere and a minus sign for an expanding one.

Figure 9 shows the curve traced out by eq. (19), a cycloid. The left side of the curve shows the radius of curvature a increasing from zero at proper time $-\tau_0$ on up to its maximum value of a_0 at $\tau = 0$. If nothing intervened, the sphere would continue on to the right side of the curve, collapsing to a singularity at proper time $+\tau_0$. Thus the sphere would start as a white hole and end as a black hole.

Klein calculated the Schwarzschild time t it would take for a sphere of dust to collapse from its maximum radius of curvature a_0 (at a Schwarzschild time defined as $t = 0$) to some smaller radius of curvature a . I have recalculated his expression for the reverse situation to get the time t it would take the dust sphere to expand from a radius of curvature a out to the maximum radius of curvature a_0 . I have kept Klein's definition of $t = 0$ as being the time that the radius of curvature reaches its maximum, so all times before that instant are negative. Modifying Klein's nomenclature a bit, I get the following expression for the Schwarzschild time:

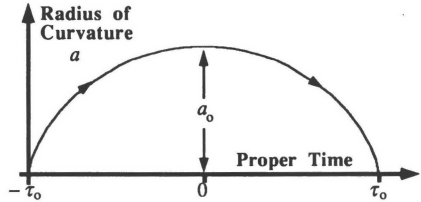
$$t = -t_0 \left[\frac{b^3}{1 + b^2} \log \left(\frac{\zeta + b}{\zeta - b} \right) + \frac{\zeta}{1 - \zeta^2} + \frac{(1 + 3b^2)}{1 + b^2} \left(\frac{\pi}{2} - \text{Arctan} \zeta \right) \right] \quad (20)$$

The parameters t_0 , ζ , and b in the above equation are defined as follows:

$$t_0 \equiv \frac{a_0}{c \sqrt{1 - \eta_0^2}}, \quad \zeta \equiv \sqrt{\frac{a_0}{a_0 - a}} \sqrt{\frac{1 - \eta_0^2}{1 - \eta^2}} - 1, \quad b \equiv \frac{\eta_0}{\sqrt{1 - \eta_0^2}}, \quad (21)$$

The normalizing parameter t_0 is a constant, has units of time, and is greater than the time it would take light to travel a distance a_0 . The parameter ζ is a dimensionless variable which gets larger as the radius of curvature a increases with proper time. The parameter b is a constant. Just to refresh your memory, η is the co-moving radial coordinate and is r/a ; η_0 is the value of η for the edge of the matter, namely r_0/a . Figure 10 (on the next page) plots eq. (20) with the matter radius set at $\eta_0 = 0.5$. The solid curve shows the real part of the normalized Schwarzschild time t/t_0 at the center of the universe, that is, for $\eta = 0$. The dashed curve shows t/t_0 at the edge of the matter sphere, that is, for $\eta = \eta_0 = 0.5$. Notice that as the expansion factor a/a_0 increases to roughly the value 0.25, the dashed curve goes to minus infinity and then returns, just as the curve in Figure 7. This marks the point in the expansion when the event horizon reaches the edge. A little later in the expansion, at

Figure 9. Expansion and contraction of sphere



$a/a_0 = 0.35$, when the event horizon reaches the center, the solid curve also goes to minus infinity and returns. Inside the event horizon the Schwarzschild time also has a relatively small but non-zero imaginary component. The interpretation of an imaginary interval in section 3 (as spacelike rather than timelike) suggests that this imaginary part contributes to the stretching of space inside the event horizon.

Although the dashed and solid curves coincide at the beginning and end of the expansion, they are considerably different in between. The dashed line goes to minus infinity at a smaller value of a/a_0 than the solid line does because the event horizon reaches the edge of the matter sooner than it reaches the center.

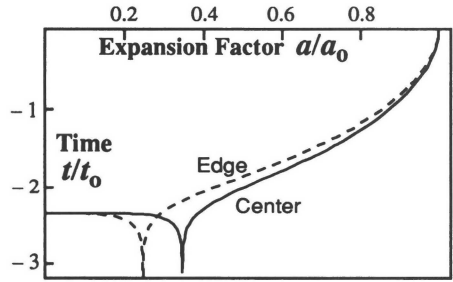


Figure 10. Schwarzschild time at two places.

After the event horizon reaches the center, the dashed curve is significantly above the solid curve until the end of the expansion. The difference between these two lines represents a large difference in Schwarzschild age. During much of the expansion, the outer parts of the universe would be older than the inner parts. At a given stage in the expansion, the age difference would be proportional to the distance from the center. Figure 11 shows how the difference in age, $t(\eta) - t(0)$, depends on the proper distance (see Figure 8). The values used in this figure are all consistent with $r_0 = 20$ billion light-years, $\eta_0 = 0.5$, and $a/a_0 = 0.4 : a_0 = 40$ billion light-years, $t_0 = 46.2$ billion years, and $a = 16$ billion light-years. The curve has different shapes at other expansion factors, but the overall age increase to billions of years at large distances exists during most of the expansion after the event horizon reaches earth.

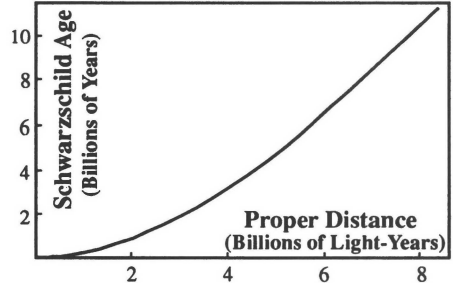


Figure 11. Age versus distance from the earth.

Except very near the event horizon, the speed of light as measured in Schwarzschild coordinates is close to c , so these large Schwarzschild ages allow time for light to cover most, if not all, the great distances to get to us during the expansion. If the expansion can take place within six days of proper time as measured on earth, then we have at least an approximate solution to the problem of seeing galaxies while standing on a young earth. Eq. (19b) shows that when the cosmological constant Λ is zero, the expansion is very slow. However, cosmologists have long known that large values of Λ , corresponding to a large tension applied to space, will enormously accelerate the expansion [32]. As I pointed out in Section 5, there is no physical law preventing an expansion much faster than the speed of light. What we really need to be specific at this point is the generalized form of equations (17) through (21) for non-zero Λ . I have made good progress on this purely mathematical problem, but as of May 30, 1994, I have not had time to complete it. The equations of this section are not a specific solution, but they imply that a solution exists, and they offer a rough outline of its basic features. Thus I think we have the main features of an answer to the light transit time problem.

14. RED SHIFTS AND THE COSMIC MICROWAVE BACKGROUND

Many authors show how the Robertson-Walker metric, eq. (5), leads to a red shift in the wavelength of electromagnetic radiation as the universe expands [48, pp. 415-418]. Since the same metric applies to our bounded cosmos with center-oriented coordinates (see beginning paragraphs of previous section), we can use the same result to specify the red shift as seen from the center:

$$\frac{\lambda_2}{\lambda_1} = \frac{a_2}{a_1} \quad (22)$$

Here λ_1 and λ_2 are, respectively, the wavelengths of the light at emission and reception; a_1 and a_2 are, respectively, the radii of curvature of the cosmos at emission and reception. Often astronomers specify red shifts in terms of a dimensionless parameter z , which is defined as $(\lambda_2 - \lambda_1)/\lambda_1$, changing eq. (22) to the form:

$$z = \frac{a_2}{a_1} - 1 \quad (23)$$

I have also derived these results from Klein's metric, eq. (16). In an expanding cosmos, a_2 is greater than a_1 , so λ_2 is greater than λ_1 and the red shift parameter z is positive. Notice that these equations do not depend on velocity at all, so the effect cannot be a Doppler shift, as I explained in Section 5. Instead the effect is entirely due to the change of the radius of curvature of space while the photons are *in transit*. If you think of light as waves traveling on a sheet of rubber, these equations say that, as the sheet is stretched out, the wavelengths stretch out along with it. The equations say that the rate of expansion has nothing to do with the amount of red

shift, which depends only on the initial and final values of a . As far as the red shifts are concerned, it does not matter whether the expansion took place in 20 billion years or six days.

In 1929, Edwin Hubble found that the red shifts of light from galaxies are approximately proportional to their distance r [26]:

$$z \approx \frac{H}{c} r \quad (24)$$

As I mentioned in section 1, there are exceptions to this, but the trend is very clear. The parameter H is called the *Hubble constant*. At present, astronomers cannot measure great distances to better than a factor of two, so they do not know the Hubble constant to better than that accuracy. But whatever the exact distances are, the cosmology I am outlining here asserts that the galaxies were indeed at those great distances when the light they emitted began its journey to us. It also asserts that the amount of expansion occurring between emission and reception was roughly the same as the standard theory claims. Thus, without doing any detailed calculations, we can say that the value of the Hubble constant given by this theory should be about the same as observed.

We now come to the third item on my list of large-scale phenomena to be explained, the cosmic microwave background radiation. Various authors have shown [49, p. 533, eq. (15.6.17)] that if when space has a radius of curvature a_1 , it is filled with thermal radiation corresponding to a temperature T_1 , then when space expands to a radius of curvature a_2 , the same stretching effect which caused the red shift of light waves will also red-shift the heat waves, dropping the thermal radiation temperature to a value T_2 given by:

$$\frac{T_2}{T_1} = \frac{a_1}{a_2} \quad (25)$$

Thus, if the early cosmos was filled with thermal radiation of high temperature and uniformity, then the expansion of a bounded cosmos would have the same kind of low-temperature microwave background we observe today. The next section shows that such radiation in the early cosmos would be a very reasonable result of the Genesis account.

15. RECONSTRUCTION OF SOME CREATION EVENTS

Now let's use our imaginations and try to reconstruct some of the events of the creation week from both the biblical and scientific information. At some points I will have to speculate in order to provide specific details, so please regard this reconstruction as a tentative outline of events, subject to radical revision as we learn more.

In the biblical paper I show evidence that in the first instant of creation the "deep" consisted of ordinary liquid water at normal density and temperature. This requires the existence of functioning water molecules with their constituent atoms, electrons and nuclei; in turn that requires electromagnetic and nuclear forces to be in operation. These forces (especially electromagnetism) are deeply enmeshed with relativity, and so their existence implies that relativity was operating at this time. There is also biblical evidence that gravity was operating at that instant, and if it were very strong, there would be a clearly-defined interface between the water and the presumed vacuum above it. Gravity would also shape the water into a sphere. There is biblical evidence that the sphere was slowly rotating with respect to the space within which it existed. There was no visible light at the surface of the sphere.

To contain all the mass of the visible universe, equations (8) and (12) say that the sphere would have an initial radius of at least *one light-year*. (Actually the size would have to be greater than that to account for the mass of the "waters above the heavens," but that mass is unknown.) One light-year is surprisingly small compared to the present cosmos, but it is still large enough to justify the biblical name of the sphere, "the deep." The sphere would be well within its event horizon, which according to eq. (14) would be 450 million light-years further out. Thus the universe started as either a black hole or white hole. I suggest here that it was a black hole, and that God let gravity take its course. The physics of black holes (section 11) do not permit matter in a black hole to remain motionless; it must fall inward. So unless God intervened, the sphere would collapse inward. The fall would be faster than the speed of light, as measured in Schwarzschild coordinates (remember the great speed of the astronaut as he approached point C in Fig. 6).

As the radius of the sphere shrank, the temperature, pressure, and density would rise to enormous values. Descending into the interior, we would find a depth at which molecules would be dissociated and atoms would be ionized. Further down, nuclei would be torn apart into neutrons and protons. Yet further down, even elementary particles would be ripped apart, making a dense plasma of gluons and quarks.

At a certain range of depths, thermonuclear fusion reactions would begin, forming heavier nuclei from lighter ones (nucleosynthesis) and liberating huge amounts of energy. An intense light would illuminate the interior. As the compression continued, the fusion reactions would reach a shallow enough depth to allow light to reach the surface, thus ending the darkness at that level. The strong gravity would cause light leaving the surface to return to it, so light at the surface would be coming from all sides. The sphere would have no dark side.

As the compression continued, the gravity would become so strong that light could no longer reach the surface, thus re-darkening it. The exegetical paper offers biblical evidence that the Spirit of God became a localized light source, giving the sphere a bright side and a dark side.

Meanwhile, conservation of angular momentum would have caused the sphere to speed up its rotation as the collapse proceeded. To be consistent with the Genesis account, the surface would execute a full rotation between the beginning and the end of day one. When the rotation of the sphere reached relativistically significant speeds, the Schwarzschild metric would no longer be an accurate description of the vacuum outside the sphere. Instead the more complex Kerr metric [24, pp. 161-168] would have to be used, and I haven't taken on that problem yet. As yet there is no known exact metric for the conditions inside the sphere at this point. However, because (as measured in Schwarzschild coordinates) the distance is about a light-year and the velocity of collapse is greater than c , we can say that the collapse would take less than a year of Schwarzschild time. Proper time as measured at the surface of the sphere would be less than the Schwarzschild time, and I suspect that it amounted to an ordinary day.

At some point the black hole had to become a white hole. I propose that God did this on day two by increasing the cosmological "constant" Λ to a large positive value, beginning a rapid, inflationary expansion of space. He marked off a large volume within the ball wherein material would be allowed to pull apart into fragments and clusters as it expanded, but He required the "waters below" and the "waters above" to stay coherently together, as Figure 12(a) illustrates:

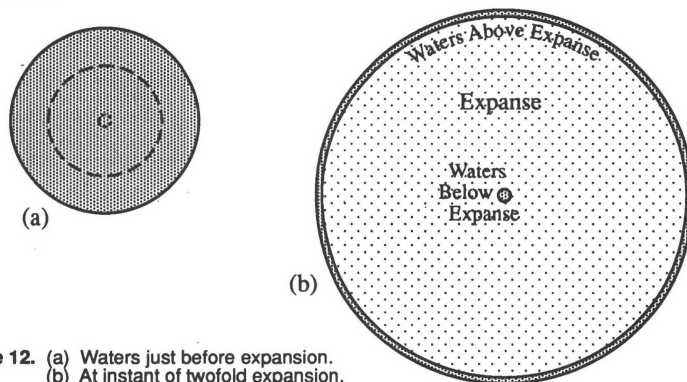


Figure 12. (a) Waters just before expansion.
(b) At instant of twofold expansion.

Cooling would proceed as rapidly as the expansion. Visible matter would cool directly by expansion, and also by losing heat to the material of space itself, according to general relativity [40, pp. 344, 355-356] [36]. Matter above and below the expanse would expand but stay dense. Matter in the expanse would be drawn apart into clusters of hydrogen and helium plasma. Figure 12(b) illustrates this phase of the expansion. At some point in the expansion, when the radius of curvature a was about a thousand times smaller than today's value, the plasma in the expanse would cool to about 3000 Kelvin, at which point the plasma would begin forming atoms and the expanse would become transparent.

At this point, thermal radiation in the expanse would be very uniform and have a blackbody spectrum, having been surrounded by optically thick walls above and below during the previous stage of expansion. According to eq. (25), the radiation temperature would now begin dropping from 3000 Kelvin to much lower values, in direct proportion to the increase in the radius of curvature a . At the end of the expansion, the radiation temperature would have dropped to the 2.76 Kelvin we see today. This explanation of the cosmic microwave background is not too different from that provided by the big bang theories, except for the boundedness and the optically thick "walls" around the expanse.

16. DAYS THREE TO SIX

The inflationary expansion of space could possibly have had second-order effects on nuclear forces and on the transport of heat from hot matter to the material of space itself [40, pp. 344, 355-356] [36]. If so, such mechanisms could explain the evidence for both rapid radioactive decay and rapid volume cooling which creationists have lately begun to notice. God could have used radioactive decay on the third day to heat the continental cratons (which today contain most of the earth's radioactive nuclei) and provide power for other geologic work, followed by volume cooling to solidify batholiths and the asthenosphere. The thermal expansion of the supercontinent would make it more buoyant with respect to the mantle rock, lifting the continent above the waters and causing them to gather in the ocean basins.

At some time during the expansion, probably on the third day, the waters above the heavens would reach the event horizon and pass beyond it. After that the event horizon would begin rapidly shrinking toward the earth. At the same time, gravity would be drawing together the atoms of hydrogen, helium, and other elements in each cluster left behind by the expansion. There would be plenty of Schwarzschild time for that process.

I suggest that the event horizon reached earth early in the morning of the fourth day. During that day of proper time on earth, according to my theory, billions of years worth of physical processes took place in the distant cosmos. I also suggest that early in the fourth morning, God finished coalescing the clusters of material left

behind in the expansion and allowed thermonuclear fusion to ignite in the newly-formed stars. At this point, the stars would find themselves clustered into galaxies. As with other things in the Genesis account, the formation of stars, solar system(s?), and galaxies would be caused by a combination of natural events and direct action by God. At this point I am not trying to be specific as to which was which. During the fourth day the distant stars aged billions of years, while their light also had that much time to travel here. While the light from the most distant galaxy we have seen was traveling to us, the universe expanded by about a factor of five, stretching the light's wavelength by the same factor and giving it a red-shift parameter of about four [see eq. (23)].

My biblical paper gives reasons to think that God stopped the expansion, reducing Λ to a small positive value or zero, before the evening of the sixth day. (The biblical paper points out some evidence for another episode of expansion during the Genesis flood.) Thus Adam and Eve, gazing up for the first time into the new night sky, would be able to see the Milky Way, the Andromeda galaxy, and all the other splendors in the heavens that declare the glory of God.

17. CONCLUSION

Jean-Pierre Luminet [30, p. 161] quotes Dennis Sutton as writing that "the frontiers of science are always a bizarre mixture of new truth, reasonable hypothesis, and wild conjecture." By those criteria, then, you will probably agree that this paper is on the "frontiers of science" — or perhaps beyond! But I want to remind you that the essential hypothesis of this paper, that matter in the universe is bounded, is quite reasonable. After all, every other created thing we know of has limits, so why should we expect even the biggest thing God created to be any different?

Furthermore, the hypothesis is not something I concocted myself to generate an *ad hoc* explanation for the cosmological difficulties of young-earth creationism. Instead the idea of a bounded universe flows very naturally from the central idea of young-earth creationism: that the Bible is to be taken straightforwardly.

If the universe is bounded, the main points of this cosmology follow quite scientifically from the amount of visible matter in the universe, the evidence for its expansion, and the experimentally well-established general theory of relativity. The logical conclusion is that the universe began its existence in a black hole or a white hole. The phenomena surrounding black holes seem strange to us mainly because we are unfamiliar with them, not because they are impossible. At any rate, I did not invent the idea of such phenomena. The only thing I have done is apply the same ideas to the universe as a whole and explore some of the consequences.

At this point, I consider this paper only the outlines of a theory. As such it furnishes us with qualitative answers to the major cosmological phenomena I listed in the introduction, but it is not yet well enough developed to make detailed quantitative predictions which would observationally distinguish it from conventional theories. A large amount of work needs to be done to bring it to that point, far more than I can do alone, so I invite other creationist scientists and students to join me in this work.

There is a good possibility that developments of this theory can explain many of the anomalies encountered by the conventional theories, such as superluminal quasar jets [10], proportions of nuclei found in the cosmos [18], vestiges of rotation in the cosmos [37], numbers of galaxies at large red shifts [6], the extraordinary uniformity of the cosmic microwave background [38], the extreme brightness of the universe (10^9 photons per nucleon) [27], the cosmological constant problem [49], the flatness problem [43], and so forth.

In particular, the "quantized" distribution of galactic red shifts [3] [22], observed by various astronomers with increasing certainty over the last few decades, seems to contradict the Copernican principle and all cosmologies founded on it — including the Big Bang. But the effect seems to have a ready explanation in terms of my new non-Copernican "white hole" cosmology.

This paper covers a great deal of scientific territory unfamiliar to many readers. But the bottom line is simple: God used relativity to make a young universe.

ACKNOWLEDGEMENTS

A number of people have helped me greatly in this work. Roy Holt asked a question that made me realize the importance of the Copernican principle. John Baumgardner has encouraged me and helped untangle my thinking. James Driit has given sensible advice and been a good editor. Gerald Schroeder's ideas [44], referred to in Section 8, though not quite correct, may have helped me solidify mine. Barry Setterfield's theory, while not correct in my eventual opinion, was a great stimulus to me. A creationist astrophysics graduate student at a major university has helped me on several mathematical problems. Many other creationist friends have prayed for this project. My heartfelt thanks go to all these people.

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