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Cosmology without the Cosmological Principle and without Violating the Copernican Principle: Taub-NUT Universe

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Abstract

We develop a theory of cosmology, which is not based on the cosmological principle. We achieve this without violating the Copernican principle. It is well known that the gravitational redshift associated with the Schwarzschild solution applied to the distant supernova does not lead to the observed redsift-distance relationship. We show, however, that generalizations of the Schwarzschild metric, the Taub-NUT metrics, do indeed lead to the observed redshift-distance relationship and to the observed time dilation. These universes are not expanding rather the observed cosmological redshift is due to the gravitational redshift associated with these solutions. Time dilation in these stationary universes has the same dependency on redshift that generally has been seen as proof that space is expanding. Our theory resolves the Hubble tension.

Keywords

Cosmology, General Relativity

1. Introduction

The standard theory of cosmology is based on both the cosmological principle, which maintains that the universe is homogeneous and isotropic and the Copernican principle, which maintains that the earth relative to cosmological observations is not in anyway in a special location in the universe. However, resent work indicates that the cosmological principle may not be valid. Thus, we may require a theory of cosmology, which is not based on the cosmological principle. Below we develop such a theory, whereby our theory does not violate the Copernican principle. We follow Einstein's approach in his formulation of special relativity

[1]. He based special relativity on two experimental facts—the principle of relative motion and the constancy of the speed of light. Similarly, we base our theory on two observational cosmological facts: the redshift-distance relationship and time dilation. We assume the applicability of general relativity and therefore demand that a cosmological fundamental tensor must be a solution to Einstein's field equations.

The idea of developing cosmological theory based on observations without extraneous assumptions is not original. This approach has been explored by: [2]-[5]. Our approach and our results differ completely from these efforts.

First, we discuss a number of reasons which motivate the formulation of a theory of cosmology without the cosmological principle.

1.1. Occam's Razor

"The more assumptions you have to make, the more unlikely an explanation" (Wikipedia). The cosmological principle is an assumption and we show that it is not required to formulate a theory of cosmology. Specifically, we achieve agreement between theory (General Relativity) and observations (redshift-distance and time dilation) without the cosmological principle and without violating the Copernican principle.

1.2. Impossibility of Validating the Cosmological Principle

The cosmological principle states that the universe is both homogeneous and isotropic. Isotropy can be confirmed through observations. However, homogeneity cannot be directly observed [6]-[9] because we observe on the past lightcone and not on spatial surfaces. Consequently, it is not possible to confirm the validity of the cosmological principle through astronomical observations.

The impossibility of validating the cosmological principle means that the standard theory of cosmology is based on an assumption, which may or may not be valid. This circumstance behooves us to develop a theory of cosmology, which is not based on the cosmological principle.

1.3. Observations

Even though homogeneity can not be validated through observations, it is possible via astronomical observations to falsify homogeneity [7]. In fact, discoveries of large scale structures seem to question the validity of the cosmological principle [10]-[19].

In addition, there are reports that isotrophy may not be valid [17] [20] [21].

1.4. Fundamental Problems with the Standard Theory of Cosmology

1.4.1. Dark Energy

In the standard theory of cosmology the cosmological redshifts are due to the expansion of space, then the observed redshift-distance relation for Type Ia Supernova leads to the conclusion that the expansion rate of the universe is increasing rather than decreasing as attractive gravity demands [22] [23]. This means there must be something else in the universe (an unknown form of energy), which is overwhelming attractive gravity. We call this unknown energy dark energy, which corresponds in Big Bang cosmology to negative pressure. Dark energy can be explained by a non-zero cosmological constant. The cosmological constant, however, corresponds to the energy of the vacuum. But theoretical calculations of the vacuum energy density according to quantum field theory differ from the astronomically measured value by up to about 123 orders of magnitude [24]. To say the least this vacuum catastrophe is an incredibly embarrassing circumstance.

It is understood that the introduction of dark energy into the standard theory of cosmology is necessary because it is based on the cosmological principle [7]. Thus, if we negate this principle and assume we reside in a part of the universe, which is in a large void, then dark energy is not required to achieve agreement between theory and observations. Instead agreement is obtained by nonlinear inhomogeneity and curvature [6] [25]-[59].

A major drawback of the above publications is that they violate the Copernican principle, which states that we are not in an exceptional location in the universe. In contrast to the above mentioned authors we do not assume that we are in a local void or for that matter in any other inhomogeneity meaning that our theory does not violate the Copernican principle.

1.4.2. Hubble Tension

For almost a century since its first measurement by Hubble in 1929 the value of the Hubble constant, H, has been the subject of intense debate. In the last few years a new dimension has been added to this debate because there appears to be a significant discrepancy between the values of H derived from present-day universe (cepheids, supernova, lensed quasars, tip of the red giant branch), which are minimally dependent on cosmological theory and those derived from early universe observations (cosmic microwave background and baryon acoustic oscillations), which are based on the standard cosmological theory, ΛCDM, whereby ΛCDM in turn is based on the assumption that the universe is expanding. This discrepancy is known as Hubble tension.

Specifically, there appears to be a significant discrepancy, $\geq 5\sigma$ *[60]* [61] between the value of the Hubble constant as determined by early universe measurements [62]-[64] and late universe measurements [65]-[83]. For reviews see [84]-[88] and [89] for a non-technical comprehensive review. There have been many attempts to explain this discrepancy by modifying ΛCDM such as [90]-[98], just to mention a few.

There is no consensus on how to modify ΛCDM. We suggest that the solution to the Hubble tension lies completely outside ΛCDM.

In 1922 the concept of expansion of space was first introduced by Friedmann [99]. Independently in 1927 Lemaitre [100] discovered the same concept, but he also went on to derive Hubble's law, a value for Hubble's constant, and to introduce the concept of a "primordial atom", which today we call the Big Bang. Big Bang cosmology rests on the assumption that cosmological redshifts are caused by the expansion of space.

The most fundamental observational relationship in cosmology is the redshift-distance relationship, which Hubble [101] is often given credit, although historically inaccurate [102]-[106]. At the end of his publication Hubble specifically mentioned that the observed redshifts of extragalactic nebula could be caused by gravitational redshift, which following [107] he called "an apparent slowing down of atomic vibrations". De Sitter's work differs from our results because he did not employ the metrics below, which had not yet been discovered.

Hubble also mentioned that they could be caused by scattering on intervening material particles. In his publication Hubble however did not investigate these later possibilities instead he simply assumed that cosmological redshifts are Doppler shifts caused by radial velocity. Before Hubble this assumption was also made by Wirtz [108].

Humason [109], who worked with Hubble, made it clear that it was in no way certain that cosmological redshifts correspond to velocities. Consequently, he referred to them as "apparent velocities". Later Hubble and Tolman [110] explicitly stated that the cosmological redshift-recessional velocity relationship is an "assumption". Hubble eventually turned away from the expanding universe interpretation and embraced the infinite static universe [111] [112]. Critical discussions of this assumption can be found in [113]-[116]. We suggest that the most fundamental question of cosmology is: Are the observed cosmological redshifts due to the expansion of space?

1.4.3. Horizon, Magnetic Monopole, Flatness, Lithium, Antimatter

The Big Bang theory, however, still possesses other fundamental problems. There are the horizon, magnetic monopole and flatness problems. Some scientists feel the theory of inflation resolves these issues [117]-[119], but others are of a different opinion [120] [121], while still others suggest that a varying speed of light (VSL) is a viable alternative to cosmic inflation [122]-[127]. There is also the lithium problem [128] whereby 3 times as much lithium is produced during Big Bang nucleosynthesis as is observed. Finally, but certainly not least, the standard theory of cosmology predicts that the universe should contain equal amounts of matter and anti-matter, which we do not observe.

1.4.4. The Young Universe

According to the standard theory of cosmology our universe came into existence 13.78 billion years ago with none of the structures we see in the universe today that is galaxies, etc. Simulations of the formation of galaxies lead to the expectation that fully developed galaxies should not exist before about 1 billion years after the Big Bang. However observations from both the Hubble and the James Webb Space Telescopes show that many such galaxies do exist [129]-[135]. However the work of [136]-[141] appears to ameliorate this circumstance.

The Taub-NUT universes do not possess this discrepancy between theory (simulations) and observations because they have no age limitations. There is an indication that the oldest stars could be older than the 13.78 Gyr predicted by the standard theory. For instance HD140283, the Methuselah star, has an age of 14.46 Gyr [142], although the estimated error of ±0.8 Gyr means it possibly could be younger than the age of the universe. In addition more refined models of stellar evolution lead to the conclusion that the age of Methuselah star may be 13.7 [143] or even 12 Gyr [144].

1.4.5. Synopsis

The Big Bang theory, which following Lemaitre assumes that the observed cosmological redshifts are due to the expansion of space, has been extremely successful. It predicts the redshift-distance relationship, the existence of the Cosmic Microwave Background (CMB) and its properties, primordial nucleosynthesis, and supports observational evidence that the universe is evolving.

Despite the fundamental difficulties of the standard theory of cosmology outlined above, the achievements of the standard theory are so impressive that the overwhelming majority of theoretical work in cosmology today involves just extensions and refinements of this theory. In contrast we develop below a theory of cosmology, which is not based on the assumption that cosmological redshifts are due to the expansion of space instead our theory maintains they are caused by the gravitational redshift.

2. The Gravitational Field Equations

After Einstein [145] developed a framework for the theory of general relativity, Einstein sought field equations, which would correspond to the field version of Newton's universal law of gravitation. Einstein [146] and independently Hilbert [147] achieved this in November 1915 [148]. However, when Einstein [149] tried to apply his theory of gravitation to the universe as a whole (cosmology), he found that his equations from 1915 appeared to be incompatible with a static mass distribution of constant density. He discovered that a consistent model of the universe could be developed, if he added an additional term to his field equations that contained a constant, λ.

Einstein's and Hilbert's field equations from 1915 are:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -8\pi G T_{\mu\nu} \tag{1}$$

and Einstein's field equations from 1917 are:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \lambda g_{\mu\nu} = -8\pi G T_{\mu\nu} \tag{2}$$

$R_{\mu\nu}$ is the Ricci tensor, $g_{\mu\nu}$ the fundamental tensor, R the curvature scalar, $T_{\mu\nu}$ the energy-momentum tensor, G the gravitational constant, the speed of light is 1 and λ is a number, which is called the cosmological constant[1]. In order to differentiate between the two sets of equations we call Equation (1) the Einstein-Hilbert field equations and Equation (2) the Einstein field equations. The spherically symmetric solution of the Einstein-Hilbert field equations for the empty space surrounding a non-rotating point mass is called the Schwarzschild solution [150]. The corresponding solution of Einstein's field equations is called the Kottler solution [151]. If $\lambda > 0$, the Kottler metric is also known as the Schwarzschild-de Sitter metric and if $\lambda < 0$, as the Schwarzschild-anti-de Sitter metric.

3. Theory

The solutions to the field equations are expressed in terms of the equation:

$$\mathrm{d}s^2 = g_{\mu\nu}\mathrm{d}x^{\mu}\mathrm{d}x^{\nu} \tag{3}$$

$\mathrm{d}s$ is the line element, $g_{\mu\nu}$ is the metric tensor or fundamental tensor and both $\mathrm{d}x^{\mu}$ and $\mathrm{d}x^{\nu}$ are coordinates. The metric tensor contains constants, whose values are obtained from observations. In the specific case of cosmology the basic observational relationships are the redshift-distance diagram and time dilation, which we will employ to derive the constants contained in the metric tensor.

A valid cosmological metric tensor must satisfy three conditions. It must be a solution to the field equations of general relativity, it must lead to the observed redshift-distance relationship and to the observed time dilation. Below we show that among the well known solutions to the field equations of general relativity there are at least four, which lead to the observed redshift distance relationship and to the observed time dilation.

3.1. Gravitational Redshift

It has long been believed that the gravitational redshift can not explain the observed cosmological redshift. This is true for the Schwarzschild metric [150], which is widely employed to study the general relativistic phenomenon associated with most stars and planets specifically the earth and sun. If, however, the Schwarzschild metric is applied to type Ia Supernova it does not yield the observed redshift-distance relationship fosterning the belief that the gravitaional redshift can not explain the observed cosmological redshift.

To the contrary we will show that generalizations of the Schwarzschild solution—the Taub-NUT solutions do however lead to the observed redshift-distance relationship and to the observed time dilation. In the following we develop a theory of cosmology based on the gravitational redshift associated with the Taub-NUT solutions to the Einstein field equations of general relativity.

In standard relativistic cosmology there are three distinct possible causes of redshift: Doppler, gravitational and cosmological [24]. We will show that the observed cosmological redshift, z, is due to the gravitational redshift. Conse-

[1]We do not employ the usual symbol, Λ, for the cosmological constant. Instead we use Einstein1917 Einstein's original symbol, λ. Our theory differs from ΛCDM. Consequently, there is no reason to assume that $\lambda = \Lambda$.

quently, we will conclude there are only two causes of redshift in relativistic cosmology: Doppler and gravitational.

In general the gravitational spectral shift between any two points A and B in space is given by [24] [152]-[154]:

$$z = \sqrt{\frac{g_{00}(r_B)}{g_{00}(r_A)}} - 1 \tag{4}$$

We assume that r_A in the above equation is a constant meaning that we can let $\gamma = g_{00}(r_A)$. Consequently, we can drop the subscripts to obtain:

$$(z+1)^2 = \frac{g_{00}(r)}{\gamma} \tag{5}$$

This equation tells us that the gravitational redshift depends on the $g_{00}(r_A)$. We will explicitely show that the Schwarzschild $g_{00}(r_A)$ does not lead to the redshift-distance relationship. However, we will also show that the $g_{00}(r_A)$ of specific generalizations of the Schwarzschild solution, Taub-NUT solutions, do lead to the observed redshift-distance relationship and to the observed time dilation.

In order to emphasize and make clear that we are referring to the gravitational redshift associated with cosmological solutions to the Einstein field equations and not to the well known gravitational redshift associated with the Schwarzschild solution, in this work we refer to the left side of the above equation as the cosmological gravitational redshift.

3.2. Time Dilation

Time dilation in relativity is defined via the proper time, $\mathrm{d}\tau = \sqrt{\mathrm{d}s^2}$. In our cosmological theory the proper time is:

$$\mathrm{d}\tau = \sqrt{g_{00}}\,\mathrm{d}t \tag{6}$$

We employ Equation (5) to obtain the relationship between time dilation and redshift in our theory of cosmology. We find:

$$\mathrm{d}\tau = \sqrt{\gamma}(z+1)\mathrm{d}t \tag{7}$$

Suggestions by Wilson [155] and Rust [156] that light curve broadening should occur in Type Ia Supernova, if the universe is actually expanding, have been observationally confirmed by [104] [157]-[159]. These authors found a time dilation or slowing down of the supernova by the factor of $(z+1)$. They interpreted this result as evidence that cosmological redshifts are caused by an expanding universe.

The above equation for time dilation in the stationary universe has the same $(z+1)$ dependency, but it is not associated with cosmic expansion rather it is due to the gravitational redshift. We conclude: the observed light curve broadening can not be used to prove that the universe is expanding. Segal, Andrews and Holushko [160]-[162] came to the same conclusion although their theoretical standpoints are completely different than ours.

Comparing the above equation with observations of time dilation we conclude: $\gamma = 1$ and Equation (5) reduces to:

$$(z+1)^2 = g_{00}(r) \tag{8}$$

We remind the reader that we call the left side of Equation (8) the cosmological gravitational redshift.

3.3. Cosmological Solutions to the Field Equations

In our work cosmological solutions to the field equations of general relativity refer to those that lead to the observed redshift-distance relationship and to the observed time dilation.

The solutions to the field equations contain constants. Our objective in this work is to demonstrate that the cosmological gravitational redshift explains the observed redshift-distance relationship and the observed time dilation. So we are not concerned with the physical meaning of the constants. Rather we merely ask: What numerical values must the constants assume so that they lead to the observed redshift-distance relationship and to the observed time dilation. Consequently, this initial formulation of our theory is purely parametric.

To obtain the numerical values of the constants in $g_{00}(r)$ we will employ Equation (8). The left side of this equation is known from observations, whereas the right side is theoretical and comes from the solutions to the field equations of general relativity. The numerical values of the constants in $g_{00}(r)$ are obtained by curve fitting the $g_{00}(r)$ to the observations.

The first two solutions of the field equations that we consider are the most well known and also the simplest, the Schwarzschild and Kottler metrics. For the Kottler metric we have:

$$g_{00} = 1 - \frac{\alpha}{r} - \frac{\lambda}{3} r^2 \tag{9}$$

Inserting this into Equation (8) yields:

$$(z+1)^2 = 1 - \frac{\alpha}{r} - \frac{\lambda}{3} r^2 \tag{10}$$

The above equation is valid for the Schwarzschild metric too if we let $\lambda = 0$.

The zero point of the redshift-distance relationship is: $z = 0$ at $r = 0$, whereby Equation (8) becomes: $g_{00}(0) = 1$. But, this point does not exist according Equation (10) because $\frac{\alpha}{r} \to \infty$, as $r \to 0$. Thus, neither the Kottler nor the Schwarzschild metric leads to the observed redshift-distance relationship and they are therefore not cosmological solutions meaning that the gravitational redshifts associated with them are not cosmological. In addition two more well known solutions that are not cosmological are the Kerr solution, which corresponds to a rotating massive body and the Kerr solution with the cosmological constant.

The Schwarzschild metric is not a cosmological solution, however, generalizations to the Schwarzschild metric are cosmological solutions. Taub [163] discovered a solution to the Einstein field equations, which Newman, Unti and Tamburino [164] extended to a larger manifold, whose initials form the "NUT" of "Taub-NUT". They also proved that the Taub-NUT solutions are a generalization of the Schwarzschild solution. We found four solutions of the Taub-NUT family that are cosmological. Specifically, we applied these Taub-NUT metrics to the supernova from which the cosmological redsifts are derived. Below we give the $g_{00}(r)$ components of the fundamental tensor for each of the four solutions and by comparing these theoretical $g_{00}(r)$ with observations of redshift-distance we derive the numerical values of the constants they contain.

3.4. Comparison of Theory with Observations of Type Ia Supernova

In this section we compare the theoretical cosmological gravitational redshift on the right side of Equation (8), with the observed redshift-distance diagram from Vincenzi *et al.* [165], which consists of 1829 Type Ia supernova. The data contains the observed relationship between spectral shift, z, and distance modulus, μ. We employ:

$$r = 10^{\left(\frac{\mu}{5}+1\right)-9} \tag{11}$$

to convert μ to r, the distance of a supernova in Gpc.

The Vincenzi *et al.* data [165] contains the errors in the redshift, z, but in our analysis we employ $(z+1)^2$, which is the cosmological gravitational redshift, so we need to compute the error in this quantity. Expansion of $(z+1)^2$ is:

$$(z+1)^2 = z^2 + 2z + 1 \tag{12}$$

If the uncertainity in z is δz, then the uncertainity in z^2 is $\sqrt{2}\delta z$ and the uncertainity in $2z$ is also $\sqrt{2}\delta z$ [166]. Thus the uncertainity in $(z+1)^2$ is $2\sqrt{2}\delta z$, which is significantly larger than δz.

3.4.1. Taub-NUT

The part of the Taub-NUT solution that interests us is: [167]

$$g_{00}(r) = -\frac{r^2 - 2\alpha r - n^2}{r^2 + n^2} \tag{13}$$

n is called the NUT parameter. As mentioned above we do not attempt to give α and n in our cosmological theory a physical meaning. In this work we are concerned only with their numerical values. Assuming the validity of the Big Bang theory [163] Taub applied his metric to cosmology. In contrast we employ this metric to compute the cosmological gravitational redshift and show that it leads to the observed redshift-distance relationship.

Curve fitting the above equation to the left side of Equation (8) leads to numerical values of the constants: $\alpha = 219.822$ and $n = 31.204$. **Figure 1** shows that Equation (8) along with the above equation leads to the observed redshift-distance relationship.

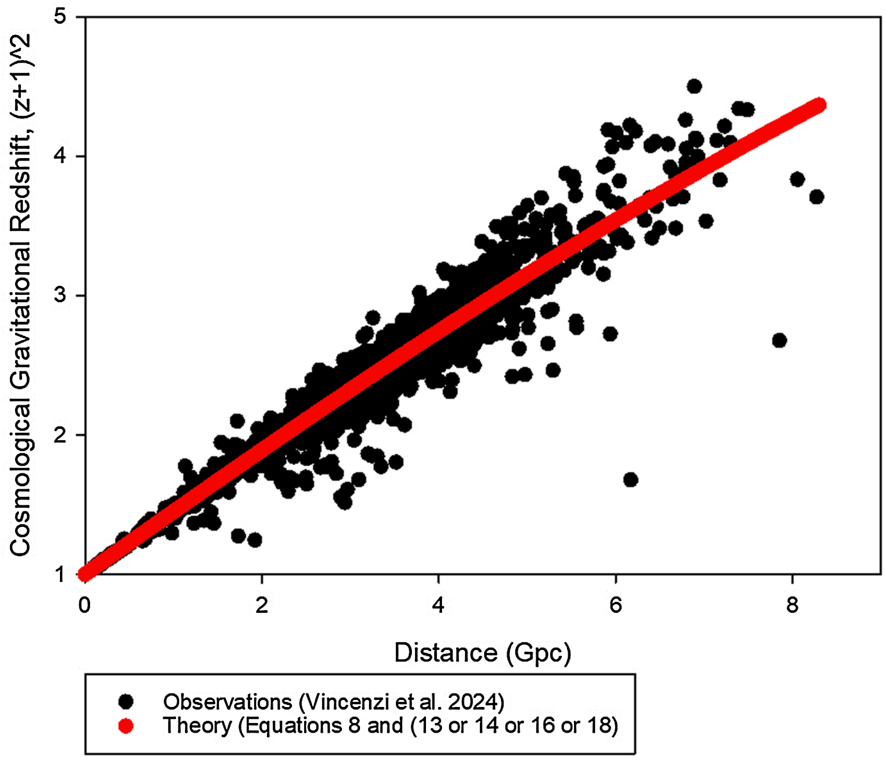

Figure 1. Cosmological gravitational redshift, $(z + 1)^2$ vs. distance.

3.4.2. Lorentzian Taub-NUT

This metric is actually referred to as the Charged Lorentzian Taub-NUT metric. As mentioned above we do not attempt to give the constants in the above equation a physical meaning in our cosmological theory. In this work we are concerned only with their numerical values of the constants. So the word "charged" in the name of the metric certainly in no way implies that the universe is charged. So in order to avoid confusion in this work we drop the word "charged".

Following Abbasvandi [168]:

$$g_{00}(r) = -\left(\frac{r^2 - 2\alpha r - n^2 + 4n^2 g^2 + e^2}{r^2 + n^2} - \frac{3n^4 - 6n^2 r^2 - r^4}{l^2\left(r^2 + n^2\right)}\right) \quad (14)$$

Curve fitting the above equation with Equation (8) leads to agreement between theory and observation except for a small constant difference at $r < 0.5$ Gpc. However, if we demand $g_{00}(0) = 1$ as mentioned above, we obtain the constraint:

$$e = \frac{\sqrt{3n^4 - 4n^2 g^2 l^2}}{l} \quad (15)$$

Curve fitting these last two equations to the left side of Equation (8) leads to the numerical values: $\alpha = 219.822$, $n = -31.204$, $l = 2.56554 \times 10^8$ and $g = 1$. Figure 1 shows the agreement between theory and observation. This agreement also holds for $r < 0.5$ Gpc.

3.4.3. Taub-Nut AdS

Following Mann [169]:

$$g_{00}(r)=\frac{l^{-2}\left(r^2+s^2\right)^2+\left(\kappa+4l^{-2}s^2\right)\left(r^2-s^2\right)-2\alpha r}{r^2+s^2} \tag{16}$$

s is the NUT charge and the cosmological constant is: $\lambda=-\frac{3}{l^2}$. We were not able to curve fit this equation due to lack of convergence. However, when we added the condition: $g_{00}(0)=1$, which led to the equation:

$$\kappa=\frac{l^2-3s^2}{l^2} \tag{17}$$

We were able to obtain a fit with the constants: $\alpha=219.822$, $s=31.204$ and $l=7.251\times10^{7}$. The values of l lead to: $\lambda=-5.706\times10^{-16}$. **Figure 1** depicts this fit.

3.4.4. Kerr-Taub-NUT

The Kerr-Taub-NUT metric is a solution to the vacuum Einstein-Maxwell equations, which is locally analytic. We obtain the g_{00} from Miller [170]

$$g_{00}(r)=a^2\frac{\sin(\theta)^2}{\Sigma(r)}-\frac{\Delta(r)}{\Sigma(r)} \tag{18}$$

with:

$$\Sigma(r)=r^2+\left(l+a\cos(\theta)\right)^2 \tag{19}$$

and

$$\Delta(r)=r^2-2\alpha r-l^2+a^2+e^2 \tag{20}$$

Curve fitting leads to an agreement between theory and observation for $r>0.2$ Gpc. At radial distances less than this value, a small constant deviation occurs. So we demand that the condition $g_{00}(0)=1$ be fulfilled. This leads to the equation:

$$l=\frac{\left(-a^2-e^2-a^2\cos(2\theta)\right)\sec(\theta)}{2a} \tag{21}$$

Curve fitting now leads to complete agreement between theory and observation over the entire range of the observational data with the constants: $a=171.068$, $\theta=-412.148$, $\alpha=219.822$ and $e=93.8984$. **Figure 1** shows this agreement.

4. Comparison with Other Cosmological Theories

4.1. Big Bang Theory

Physical theories are based on assumptions. Different theories are based on different assumptions. Big Bang Theory is based on the Cosmological Principle, that is on the assumptions of homogeneity and isotropy. They lead to the Friedman-Lemaitre-Robertson-Walker (FLRW) metric.

Our theory is not based on the cosmological principle rather is based on the

Taub-Nut solutions to the field equations of general relativity. They are spatially homogeneous. The fundamental tensors employed in our cosmological theory are not the metric of our entire universe for all spacetime, in the sense that the FLRW metric claims to be, rather they are the metrics associated with the celestial sources from which we obtain the observed redshift-distance relationship. These metrics are a generalization of the Schwarzchild metric [164].

In our theory non-relativistic matter and the CMB are not included (more on this circumstance below). This differs from Big Bang cosmology, where the deceleration parameter and consequently the redshift-distance relationship which depends upon it, is determined by the average density of matter and energy in the universe. In our cosmology to the contrary the redshift-distance relationship is determined by well known solutions to the field equations of general relativity, whereby the average density of matter and energy in our universe play absolutely no role.

In Big Bang cosmology dark energy is an unknown form of energy required to explain the acceleration of the expansion of space. In our theory of cosmology there is no expansion and therefore no accelerated expansion and therefore no need to introduce the concept of dark energy as it is understood in ΛCDM cosmology. Consequently, the vacuum catastrophe mentioned in the introduction does not exist in our theory. This circumstance is to be expected because [171] noted that the proposed existence of dark energy comes about because of the assumption of the homogeneity of the distribution of matter in space, which is not an assumption of our cosmological theory.

In addition the other fundamental problems of the Big Bang theory: horizon, magnetic monopole, flatness and the prediction that the universe should contain equal amounts of matter and anti-matter also do not exist in our theory.

In the Big Bang theory to a good approximation the redshift is [24]:

$$z = \frac{H_0}{c} r + \frac{1}{2}\left(\frac{H_0}{c}\right)^2 (1+q_0) r^2 \tag{22}$$

where H_0 is Hubble's constant and q_0 is the deceleration parameter. It follows that the gravitational redshift would be:

$$(z+1)^2 = \left(\frac{H_0}{c} r + \frac{1}{2}\left(\frac{H_0}{c}\right)^2 (1+q_0) r^2 + 1\right)^2 \tag{23}$$

The values obtained by curve fitting this equation with Equation (8) do not lead to agreement between observation and theory. We conclude: the Big Bang theory and our theory are incompatible with each other.

We believe this conclusion is important and we strengthen it with the following: Using the Taub-NUT solution specifically Equation (8) and Equation (13) along with the above equation we are led to the equation:

$$-\frac{r^2 - 2\alpha r - n^2}{r^2 + n^2} = \left(\frac{H_0}{c} r + \frac{1}{2}\left(\frac{H_0}{c}\right)^2 (1+q_0) r^2 + 1\right)^2 \tag{24}$$

Solving the above equation for α we obtain:

$$\alpha(r)=\frac{1}{2r}\left(n^2+r^2\right)\left(-\frac{n^2}{n^2+r^2}+\frac{r^2}{n^2+r^2}+\left(1+\frac{H_0}{c}r+\frac{1}{2c^2}H_0\left(1+q_0\right)r^2\right)^2\right) \quad (25)$$

But the Taub-NUT solution tells us that α is a constant and is not a function of r. Again we conclude: the Big Bang theory and our theory are incompatible with each other. We suspect this incompatibility means that both theories can not be correct, that is at least one of the two theories is false. Finally, we note if we assume $q_0=0$ in the above equations, we obtain the same results and come to the same conclusions.

We note that it has been questioned whether the standard theory of cosmology actually incorporates the cosmological principle "faithfully" [172]. In addition we also note that there are models of cosmology, which are related to the cosmological principle or the Copernican principle [173]-[176].

4.2. Cosmic Microwave Background

In the theory of the expanding universe, the CMB is the radiation left over from the Big Bang. Clearly, our theory of cosmology demands that the CMB must have a different origin. This task however has already been accomplished by the many scientists, who have discussed its origin without Big Bang cosmology. First Guillaume [177] [178] calculated that the temperature of interstellar space from the presence of starlight to be 5.6 ˚K and Eddington [179] 3.1 ˚K while Regener [180] using the energy density of cosmic rays found it to be: 2.8 ˚K, which is very close to the measured value of: 2.72548 ˚K [181]. Nernst [182] calculated the temperature of intergalactic space to be: 0.75 ˚K and Finlay-Freundlich [183] [184] calculated $1.9\text{ K}\leq T\leq 6.0\text{ K}$ for its temperature.

All of the above calculations were made without employing the notion of a Big Bang. Born [185] was the first to realize that these temperatures mean that the electromagnetic waves emitted would fall in the radio region. No one looked for these electromagnetic waves and they (the CMB) were serendipitously discovered by Penzias and Wilson [186]. Following Kellermann's [187] suggestion one can spreculate how the history of cosmology might have been very different, if radio astronomers had looked for and found the CMB based on the above calculations and Born's insight. In fact, because these values were more accurate than those initially predicted by proponents of the Big Bang (Alpher, Herman and Gamow [188]-[191]), Assis and Neves [112] concluded that the CMB provides evidence for a non-expanding universe rather than for an expanding one. Other non-Big Bang explanations for the origin of the CMB are: [128] [192]-[196].

4.3. Stationary Universes

The concept of a non-expanding universe is not at all new. In fact, historically, it was the first theory of physical cosmology. Starting with Olbers [197] and continuing with Einstein, DeSitter, Lense, Lanczos and Nernst [149] [198]-[201] it dominated up until the 1920's. The discovery of cosmological redshifts by Slipher 1915 eventually caused a change of thought.

The cosmological redshift-recessional velocity relationship being an assumption has opened the door to a variety of possible explanations for the origin of cosmological redshifts (see [202] for a review). One of these explanations was that the observed cosmological redshift is due to the gravitational redshift [203].

Many of these explanations come under the broad term tired-light hypothesis. Starting with Zwicky [204] [205] and continuing with Hubble and Tolman [110] [206]. A non-expanding universe explanation for the cosmological redshift is also found in many other publications: [115] [162] [183]-[185] [196] [207]-[221].

Our approach is not related to any of these other explanations. It differs from them in that in our theory of cosmology the origin of the observed cosmological redshift is the gravitational redshift. This interpretation of redshift agrees with the work of [222]-[225] although his approach to cosmology is completely different than ours.

5. Conclusion

The standard theory of cosmology is based on both the cosmological and Copernican principles. In contrast we have developed a theory of cosmology, which is not based on the cosmological principle but maintains the validy of the Copernican principle. The goodness of the fit in **Figure 1** makes clear that a stationary (non-expanding) universe explains the observed redshift-distance relationship. It also explains the observed time dilation, which has generally been seen as proof that space is expanding. Thus, the cosmological principle and the concept of the expansion of space are not needed to explain these fundamental observational relationships in cosmology.

In our theory of cosmology there is no Big Bang and therefore no early universe as it is understood in ΛCDM cosmology. Consequently, there is no Hubble tension and no need for the concept of dark energy in our theory of cosmology.

Both ΛCDM and our cosmology are based on the field equations of general relativity. However, Big Bang cosmology assumes that cosmological redshifts are caused by the expansion of space, whereas our theory suggests that they are a manifestation of the gravitational redshift associated with the Taub-NUT solutions to Einstein's field equations, whereby these solutions are generalizations of the Schwarzschild solution.

From the standpoint of our cosmology, the concepts of the cosmological principle and more generally the concepts of Big Bang cosmology are superfluous. Because of the myriad of problems associated with the modern theory of cosmology—Occam's razor, the impossibility of validating the cosmological principle and astronomical observations that appear to violate it, as well as dark energy, the Hubble tension and others we conclude that we may live in a Taub-NUT universe and not in the Friedman-Lemaitre-Robertson-Walker universe of the standard theory of cosmology.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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