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TOWARDS A YOUNG UNIVERSE COSMOLOGY

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ABSTRACT

Distant starlight is one of the most challenging natural phenomena to reconcile with a recent creation. Most creationist cosmologies attempt to address this apparent contradiction between God's two books by appealing to the flexibility associated with our definition of time (Hartnett 2007; Humphreys 2008; Lisle 2010). In their current formulation, these cosmologies allow for long cosmological times periods while preserving short time periods on earth (they can thus be viewed as young earth but old universe cosmologies). Assuming that astronomical distance measurements are accurate, a consistent young universe cosmology would appear to require either some form of mature creation (i.e., local generation of starlight that is only apparently distant) or a variation in the speed of light. There is a vast literature on a variable speed of light (both creationist and non-creationist), often accompanied by a fair bit of controversy and misunderstanding. Creationist explorations have relied on suspect extrapolations of uncertain historical measurements to argue for a speed of light that has decreased since the time of Creation (Setterfield 1987). However, a speed of light that varies with gravity stands on much firmer theoretical footing. In particular, there is a direct mathematical analogy between weak-field gravity and a varying speed of light (Barceló et al. 2011). This paper will explore some of the implications associated with assuming that this analogy represents an underlying physical reality. One implication of this picture is that cosmological redshifts are due to a spatial variation in the speed of light (Dicke 1957) rather than to the expansion of space, although in principle both physical effects could be operating in concert. If light propagates faster in regions of space where gravity is weak, the extremely low gravitational potential of cosmological voids may be sufficient to put the entire universe in causal contact with the Earth on the time scale of Biblical history. Attributing cosmological redshifts to a spatial variation in the speed of light alone would obviate the need for dark energy, and a model in which the speed of light increases in the outskirts of galaxies has the potential to explain galactic rotation curves without invoking dark matter or modifying Newtonian dynamics. Finally, the model predicts a redshift evolution for the Tolman surface brightness signal (Hubble and Tolman 1935) that differs from that predicted by an expanding universe model, with the current model being more in line with observations. Not only does this hypothesis provide a straightforward solution to the problem of distant starlight, its connection with gravity also points the way towards the development of a robust and predictive young universe cosmological model.

KEY WORDS

cosmology, gravity dependent speed of light, distant star light

INTRODUCTION

The light from distant stars poses a significant challenge to any attempt to reconcile natural revelation with a recent creation. How can we see light from stars and other astronomical objects that are tens of thousands to billions of light years away from us if the earth has been in existence for fewer than 10,000 years? Resolving this tension scientifically requires modifying 1) distance measurements, 2) our notions of time, or 3) the constancy of the speed of light. The first is quite difficult to justify, as astronomical distance measurements are very well established (Faulkner 2004). Most creationist cosmologies take the second approach by invoking some form of relativistic time dilation (Hartnett 2007; Humphreys 2008). The model of Lisle (2010) is something of a combination of the second and third approaches, as it departs from the conventional definition for the speed of light and also allows for long time scale processes to occur at large distances. The goal of this paper is to direct attention to the third approach as a promising avenue for creationist cosmological research.

For various reasons, creationists are reluctant to entertain the third approach as a viable option. Previous explorations in this area have generated a significant amount of controversy in the creation science community (Setterfield 1987), and the present paper is not an attempt to revive that particular controversy. Another reason for our reluctance is the strong association in both scientific and popular culture between Einstein's theories of relativity and the notion that the speed of light is a universal constant. As I shall argue below, however, there are solid physical reasons for considering a varying speed of light, and one can do so without violating any of Einstein's theories. A compelling motivation for doing so is that most existing creationist cosmologies can be viewed as young earth but old universe, in the sense that they allow for astrophysical processes to take place on long time scales, even while those time scales are short in the reference frame of the earth. A consistent young universe cosmology (which seems to be a more natural fit with the Biblical record) requires either some form of mature creation or a variable speed of light.

As an aside, a brief comment on mature creation is in order. While mature creation is the best answer to a great many of the objections to a recent creation, and indeed an essential part of any creationist

account of origins, it seems appropriate to limit its application to miraculous events such as Creation and the Noahic Flood. The regular and predictable operation of the natural world, which is so often used today as an argument against God's existence or involvement with His creation, is in fact a great testimony to His faithfulness and immutability. While it is true that God upholds the universe by the word of His power at all times (Hebrews 1:3), the essence of miracles lies in their rarity: "The sun stopped in the midst of heaven and did not hurry to set for about a whole day. There has been no day like it before or since, when the LORD heeded the voice of a man" (Joshua 10:13b-14). The mature creation of light signals from distant stars that mankind observes in the course of history essentially collapses all of observational astronomy outside of a ~6000 light-year horizon into the miraculous. This is not an argument against the use of mature creation in principle, but rather an argument that it should be applied to distant starlight only as a last resort.

The basic assumptions of a young universe cosmology as I am defining it here are these: 1) the time frame of the earth can be applied to the entire universe (i.e., there are no relativistic effects on cosmological scales), 2) the universe (not just the Earth) has been in existence for only thousands of Earth years, and 3) light signals that we receive on Earth from distant sources were generated *at* their apparent sources *within that time frame*. The only resolution to the distant starlight problem under these assumptions is an increase in the speed of light signals as they propagate through space between their sources and earth. I will begin by showing that a variable speed of light is consistent with Einstein's theories of relativity. I will then review some of the existing (non-creationist) literature on a varying speed of light as an analog of weak field gravity, along with some of the basic physics of wave propagation in an inhomogeneous medium. I will go on to give some observations of my own that suggest this analogy may point to an underlying physical reality, and discuss some of the implications this idea has for a young universe cosmology.

MAIN

Skepticism towards a variation in the speed of light is well founded, since physical laws, along with their associated fundamental constants, can and should be relied upon in the natural realm (although the level of certainty we attribute to them is often unjustified by actual experience). Well established physical laws can of course be modified based upon new understanding or new experiments, the modification of Newton's laws by Einstein's theories of relativity being a prime example. Such modifications are not arbitrary, of course: Einstein's theories reduce to Newton's for velocities that are small compared to the speed of light. But they remain genuine modifications, and as long as new theories do not contradict established theories where their validities overlap, attempted modifications are a perfectly reasonable (albeit difficult) undertaking. All such new theories, of course, require confirmation by experiment in order to be established.

Similar considerations apply to the fundamental constants. The well established value for the speed of light ($c_0 = 3 \times 10^{10}$ cm/s) has only been measured within the Solar System, and while Einstein's theories are consistent with this value being a universal constant, they do not require it (to insist that they do is to affirm the consequent). The only requirement for the validity of Einstein's theory of special relativity is that the speed of light be independent of the velocity of an observer, not that it be a universal constant. As with all physical theories consisting of a set of differential equations, the theory is local, connecting only adjacent points in spacetime, and it has nothing to say about either the value of c or its variation with space and time. The fact that numerical calculations in relativity can be (and typically are) done with $c = 1$ is one indication that their results are independent of the value of the speed of light.

The best way to think about the role of c in the theory of relativity is that it sets a limiting value for velocity. The theory does not say what that limiting value is, nor does it require it to be constant with space or time. To see that this is true, one has only to consider a meta-material in which the speed of light varies (Genov et al. 2009) to see that the theory of special relativity would apply to such a material, with the only difference being that the speed of light would be modeled as $c(x, y, z, t)$ rather than as a constant. We are accustomed to regarding the speed of light in vacuum as a universal constant, but one can derive the theory of relativity without that assumption (Frank and Rothe 1911; Berzi and Gorini 1969), and the only experimental result that can be stated with certainty is that $c_0 = 3 \times 10^{10}$ cm/s in the Solar neighborhood.

Not only that, but the theory of general relativity (in the weak field regime) can be formulated precisely in terms of a varying speed of light. One of the earliest explorations of this idea was by Dicke (1957), who showed that gradients in the vacuum permittivity μ and permeability ε (recall that $c = 1/\sqrt{\mu\varepsilon}$) could mimic a gravitational force field. These ideas eventually developed into scalar-tensor theories of gravity. In addition, there is a vast literature on analog theories of gravity, one of which is a varying vacuum permittivity and permeability, or equivalently, a varying speed of light (Barceló et al. 2011). I will not review these theories in detail here, but the important point is that the theory of gravity in the weak field regime (i.e., where a test mass does not distort the space time continuum in its vicinity) is entirely equivalent to the theory for a varying speed of light.

It is instructive to consider the propagation of sound through earth's atmosphere as an analogy for a spatially varying speed of light. The dispersion relation is the same for sound waves as for light waves: $\omega = ck$, where ω and c are the frequency and speed of the wave, and $k = 2\pi / \lambda$ is the wave number, with λ the wave length. The speed of sound varies with altitude, since $c \sim \sqrt{T}$ and the temperature varies with height. The temperature gradient in the atmosphere changes sign several times between the troposphere and the thermosphere, so the speed of a sound wave will either increase or decrease depending on the layer of the atmosphere in which it is propagating. If the atmosphere is in a steady state, the frequency of the sound wave will remain constant and the wavelength will vary as $\lambda \sim c^{-1} \sim T^{1/2}$, i.e., it will increase (decrease) when the temperature decreases (increases). By analogy with visible light, an increase (decrease) in the wavelength of a sound wave corresponds to a red (blue) shift. The ratio of wavelengths is given by

$$\lambda_o / \lambda_e \equiv 1 + z = c_e / c_o, \quad (1)$$

where the subscripts e and o denote a quantity in the emitted and observed region, respectively.

In a moving medium the frequency is replaced with the doppler-shifted frequency $\omega \pm \mathrm{v}k$, where v is the velocity of the medium, so that in general $\omega = (c \pm \mathrm{v})k$. A shift in the wavelength of a wave can thus occur due to either a variation in the wave speed or motion of the background medium. For a shift due to motion of the background medium, the ratio of wavelengths is given by

$$\lambda_o / \lambda_e = \omega_e / \omega_o = 1 \pm \mathrm{v} / c \qquad (2)$$

if it is assumed that the wave speed remains constant between emitter and observer. These considerations apply to light waves as well as to sound waves, as long as the motion of the background is non-relativistic. Equation (1) applies to light propagating through a medium whose index of refraction varies from unity, and equation (2) is the expression for a non-relativistic Doppler shift. In Big Bang cosmology, the ratio of wavelengths is given by

$$\lambda_o / \lambda_e = a_o / a_e, \qquad (3)$$

where a is the scale factor of the universe. A comparison of expressions (1) and (3) indicates that the cosmological redshift of light could be attributed to a spatial variation in the speed of light rather than (or in addition to) the expansion of the universe. While I believe the above considerations alone provide sufficient motivation to explore the implications of a varying speed of light for creationist cosmology, I would like to point out two additional considerations that strengthen the case for pursuing this line of research.

First, Dicke (1957) goes through the constraints required to ensure that a varying speed of light is consistent with known physics. If the fine-structure constant remains fixed, for example, atomic energy levels remain unchanged. This requires $\mu \propto \varepsilon$, so that $c \propto \varepsilon^{-1}$, a constraint that Barceló et al. (2011) refer to as a “somewhat unphysical restriction.” On the contrary, what this in fact implies is a constraint on the impedance of the medium. The impedance $Z = \sqrt{\mu/\varepsilon}$ of a medium, which reduces in vacuum to the impedance of free space $Z_0 = \sqrt{\mu_0/\varepsilon_0} \approx 377\Omega$, is a measure of the resistance of the medium to the propagation of electromagnetic waves through it. In addition, the impedance of an optical or acoustic medium is the quantity that governs the amount of reflection and transmission that occurs as a wave propagates through regions in which the properties of the medium change significantly on length scales that are short compared to the wave length of the propagating wave. Just as discrete transmission components must be impedance matched to provide optimal transmission with minimal reflection, a constant impedance in a continuous medium allows a wave to propagate freely without reflection. Rather than being unphysical, then, $\mu \propto \varepsilon$ implies a *constant impedance*, a profound physical constraint that suggests that a varying speed of light may have a basis in physical reality. If what we refer to as the space-time continuum behaves like a dielectric medium, this constraint would be necessary to allow the propagation of light through the cosmos without reflection.

Second, Dicke (1957) covers some of the cosmological implications of a variable speed of light, and shows that the speed of light varies with the square of the redshift:

$$c = c_0(1 + z)^2, \qquad (4)$$

a scaling that arises from a combination of a change in atomic length scales (the Bohr radius scales as $c^{1/2}$) and the wave length change during propagation given by expression (1). Since the redshift of the Cosmic Microwave Background (CMB) is $z \sim 1000$, this in turn implies that the speed of light is 10^6 times faster at the CMB than it is on Earth. This is close to the discrepancy between the age of the universe in Big Bang cosmology and the Biblical age ($10^{10} / 10^4$), an encouraging result. If light were to propagate at $10^6 c_0$ throughout its entire route, this would imply that the edge of the observable universe is in causal contact with the earth on the time scale of Biblical history. Such a claim cannot be made, however, based upon cosmological redshifts alone. The reason for this is that $z > 1$ only for $r > r_H \equiv c_0/H_0 \sim 4$Gpc (for $H_0 \sim 70$ km/s/Mpc), i.e., cosmological redshifts are negligible over a volume that is billions of light years across. The fact that $c \sim 10^6 c_0$ near the CMB does not resolve the light time travel problem and further considerations are required to reconcile the two disparate time scales.

Before getting into those additional considerations, an important implication follows from what has been discussed thus far. It is natural to assume that if cosmological redshifts are in fact due to a spatial variation in c, the cosmological parameters that are currently associated with the expansion of the universe would instead reflect gradients in the speed of light. The Hubble constant H would be a measure of dc/dr and the deceleration parameter q would be a measure of d^2c/dr^2. Using the definitions $H_0 \equiv dc/dr|_{r=0}$ and $q_0 \equiv -(c_0/H_0^2)d^2c/dr^2|_{r=0}$, one can construct an expression for the speed of light that is valid for small redshifts:

$$c = c_0(1 + r/r_H + 0.25r^2/r_H^2), \qquad (5)$$

where I have used $q_0 = -0.5$. This expression is only valid for $r \ll r_H$. In general $c(r)$, would be determined by the redshift distance relation, which does not admit a simple analytic form. What is readily apparent from expression (5) is that what is interpreted as an accelerated expansion in Big Bang cosmology is simply a reflection of the fact that the speed of light varies non-linearly with radius. This obviates the need for dark energy.

However, while removing the need for dark energy is a fortuitous side benefit of a varying speed of light, we are still left with the problem of distant starlight, because as discussed above, the observed cosmological redshifts are simply not large enough to bring the universe into causal contact with Earth on the scale of 10^4 years. If the redshift distribution traces the variation in the speed of light emitted from distant galaxies, we are still left with the possibility that light travels even faster in regions of low gravity. This would be consistent with the theory outlined by Dicke (1957), with the additional assumption that c_0 is set by the dominant gravitational potential in the Solar neighborhood. The gravitational Poisson equation, derived by taking the steady-state limit of Dicke’s theory and given by his equation (53), takes the form

$$c^{-1/2}\nabla^2 c^{-1/2} = -(K/4)\rho, \qquad (6)$$

where the constant K is determined to be $16\pi G$ by solving (6) for a spherically symmetric source and assuming that $c = c_0$ at infinity (away from the gravitational source). It is not the case, however, that gravity is negligible at large distances from the Sun. The

gravitational potential of the Galaxy in the Solar neighborhood is approximately ten times larger than the gravitational potential of the Sun, i.e., the Solar System rotates about ten times faster around the center of the Galaxy than the Earth rotates around the Sun. The gravitational potential of the Galaxy does not affect the dynamics within the Solar System for the same reason that astronauts in orbit about the Earth are weightless: in both cases, the orbiting objects are in centrifugal balance, with their rotational energy being equivalent to the gravitational potential energy of the mass they orbit. The fact that gravity cannot be dynamically felt in these situations does not imply that it is not there.

Assuming that the Galactic potential is the dominant source of gravity in the Solar neighborhood (although it may in fact be dominated by larger structures such as the Local Group or the Virgo cluster), the speed of light in the Galaxy would be determined by the solution of equation (6) using the Galactic distribution of baryonic (visible) matter. Rather than solving equation (6), I will estimate the speed of light in the Galactic plane by using a simple model for the Galactic mass distribution (McMillan 2011) and a model for c that is calibrated to give $c = c_0$ at $R = 8.5$ kpc:

$$c = c_0(\rho/\rho_0)^{-2/3},\ \rho_0 = 0.083\ M_\odot\ \mathrm{pc}^{-3}. \tag{7}$$

The rest mass of a particle in the theory of Dicke (1957) scales with the speed of light as $m \sim c^{-3/2}$ (this scaling is required in order to satisfy the weak equivalence principle, see Dicke 1957), so that expression (7) is a plausible model for c, but the only requirement for solving the distant starlight problem is a model in which c varies inversely with mass and/or gravitational potential. The model for the Galactic mass distribution consists of a sum of simple functions, one that captures the inner bulge and one that captures the outer disk:

$$\rho_b = \frac{94.1}{(1+r'/0.075)^{1.8}}\, e^{-(r'/2.1)^2}\, M_\odot \mathrm{pc}^{-3},\ r' = \sqrt{R^2 + 4z^2}, \tag{8}$$

$$\rho_d = 1.255\, e^{-(|z|/0.3+R/3)} + 0.101 e^{-(|z|/0.9+R/3.5)}\, M_\odot\ \mathrm{pc}^{-3}, \tag{9}$$

where z and R are cylindrical coordinates in kpc. A plot of the speed of light normalized to c_0 using the sum of (8) and (9) in (7) is shown in Figure 1. In this model, $c \sim 100c_0$ in the outskirts of the Galaxy. Extrapolating this result much beyond that is not warranted due to the fact that the Galaxy is embedded within larger structures, although it seems clear that c will attain a value much larger than c_0 in galactic voids because of the absence of any massive gravitating objects there. The gravitational potential in voids, which make up 80% of the volume of the universe, is many orders of magnitude smaller than the gravitational potential in galaxies, so that the speed of light could easily be large enough there to put the entire universe in causal contact with Earth on the Biblical time scale.

Notice that expression (7) exacerbates the light travel time problem for signals emanating from the Galactic Center, since $c \sim 0.01c_0$ at $r = 0$. The light travel time,

$$t = \int dR/c, \tag{10}$$

can be numerically calculated from (7) and is found to be 10^5 years. The stellar density distribution modeled by expressions (8) and (9), however, is an average density distribution, and the actual stellar distribution is inhomogeneous, with significantly fewer stars in between the spiral arms of the Galaxy. If the interarm stellar density were lower by a factor of 10 the speed of light would be larger by a factor 5 of based upon (7). The fact that the Solar System is located in the fourth spiral arm of the Milky Way would reduce the light travel time by another factor of 4 since light signals from the Galactic Center propagate through 4 interarm regions as they travel to Earth. The combination of these factors reduces the light travel time from the Galactic Center to 8 x 10^3 years, a result that is remarkably close to the Biblical time scale of 6 x 10^3 years.

A final indication that the model described here is based in physical reality can be seen by considering the Tolman test for the redshift evolution of the surface brightness (luminosity per surface area) of galaxies (Hubble and Tolman 1935). This quantity can be used to test the reality of an expanding universe, since in such a universe the surface brightness of galaxies should vary with redshift as $(1 + z)^4$. One factor of $1 + z$ arises from the decrease in photon energy with redshift, two factors come from an apparent increase in galactic surface area due to aberration, and one factor comes from a decrease in the flux of photons with time (Sandage and Lubin 2001). The first factor is present in any self-consistent model for the redshifts since photon energy is coupled to wavelength through the conservation of wave action (Whitham 1965). It is the only factor present in the tired light model, which assumes that redshifts are due to light interacting with matter during propagation (Sandage and Lubin 2001). The next two factors are present in both an expanding universe model and the model described here, although for different reasons. Rather than being due to aberration, in a gravity dependent speed of light model they are due to the variation in atomic length scale with c, with a surface area (length squared) giving rise to two factors of $1 + z$. The final factor is present only in an expanding universe. The present model thus predicts a total Tolman surface brightness factor of $(1 + z)^3$ rather than $(1 + z)^4$. Results for this test found an exponent of 2.28 - 3.55 (Lubin and Sandage 2001), values that are consistent with the result predicted by a spatially varying speed of light model (three) and inconsistent

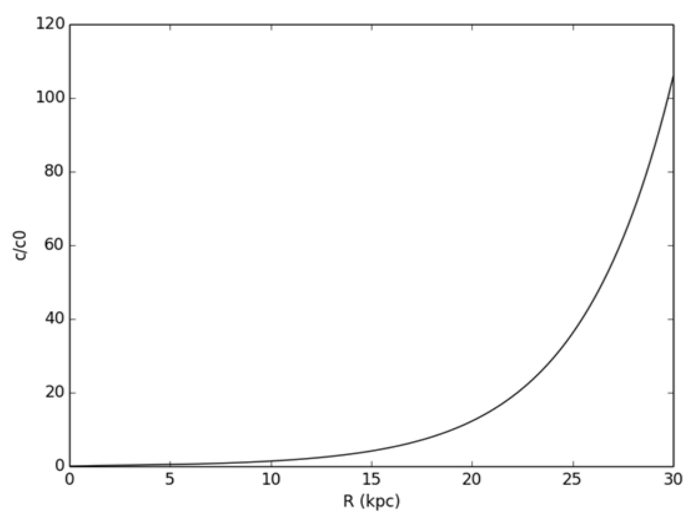

Figure 1. The variation of the speed of light within the Galaxy based upon expression (7).

with the result predicted by an expanding universe model (four). Lubin and Sandage (2001) account for the discrepancy with a model for the evolution of galactic luminosity with redshift. From the perspective of a non-evolutionary cosmological model such as the one proposed here, the match to observations without additional considerations is a highly satisfactory result.

In addition to resolving the distant starlight problem, such a model would have the potential to explain the anomalous rotation curves of galaxies without the need for either dark matter or a modification of Newtonian dynamics. The rotational velocities of stars are determined by the Doppler shift of the 21 cm hydrogen line, and as discussed above, a variation in c will result in a wavelength shift that would be falsely attributed to a Doppler shift if c is assumed to be constant. The gradients in the two effects have the same sign (both the velocity and the speed of light increase away from the center of the Galaxy), so it is quite likely that the combination of the two effects could be modeled using a Keplerian stellar velocity profile. Any mass estimates that are based on velocity measurements, such as the dynamical mass of clusters, would be similarly affected by a variation in the speed of light. An increase in c in expression (2) would imply a corresponding decrease in v for a given red or blue shift, thus reducing the dynamical mass estimate.

A separate possibility for resolving the distant starlight problem is that light travels faster in regions of extremely low particle density. It is well known that the speed of light varies inversely with density (the apparent bending of a straw in a glass of water is due to light moving slower in the denser water than in air). The slowing down of light in dense materials is due to interactions between the light and the atoms or molecules making up the material. It may be that in the low density media where c has been measured there are residual interactions that determine the value of $c_0 = 3 \times 10^{10}$ cm/s, and that these interactions are greatly reduced for the extremely low number of particles that are present in the interstellar medium (ISM) and galactic voids. While the physics of such hypothetical interactions would need to be elucidated, it is certainly the case that the application of c_0 to the speed of light in such low density media is an extrapolation that has not been confirmed by experiment. It would not be the first time that new physics understanding has been required for an unexplored regime of matter. Assuming the astronomical measurements of the speed of light that take place within the Solar System are valid, a change in c would only be noticed at densities lower than that of the interplanetary medium (IPM). A typical particle density in the IPM is 1cm^{-3}, whereas in galactic voids it is 10^{-6} cm^{-3}, or 1 m^{-3}. If the speed of light varies inversely with density,

$$c = c_0(1 + 1/n), \tag{11}$$

where n is particle number density in cm^{-3}, the speed of light in galactic voids would be $10^6 c_0$. In principle other functional forms for $c(n)$ could be chosen to give arbitrarily large values for c.

DISCUSSION

This paper proposes the simple postulate that light travels faster in regions of low gravity or extremely low particle density as a solution to the distant starlight problem. I have only explored the bare outlines of a theory based on this idea, and much work remains to be done. The analogy between gravity and a spatially varying speed of light discussed above suggests that a robust physical model for c could be constructed in which c traces the gravitational potential of the visible matter in the universe. Such a model would remove the need for dark energy and has the potential to remove the need for dark matter as well. Future work along these lines should solve equation (6), or a related model based upon the ideas outlined in Barceló et al. (2011) and Dicke (1957), to determine the speed of light for actual observed (baryonic) stellar density distributions. A separate but related task would be to calculate redshifts based upon these speed of light variations and subtract their effect from dynamical mass estimates.

Whether or not the speed of light varies in regions of extremely low density can in principle be experimentally tested. Assuming it is not technically feasible to achieve a sufficiently low density to see an increase in the speed of light in a terrestrial experiment, the most readily apparent opportunity for observing it would be to perform a light travel time measurement between a pair of space-based probes such as the Voyager space craft after they pass the solar bow shock and enter the ISM. The Voyager probes themselves are only about half-way to the bow shock, however, so such an experiment is not feasible in the near future.

I will close with a final philosophical point. Attributing the cosmological redshift to a variation in the speed of light alone implies that Earth is near $r = 0$. This result clearly contradicts the Copernican Principle that is foundational to modern astronomy. Hubble (1937) himself noticed our apparent central location relative to the redshift distribution and rejected it as untenable (emphasis mine):

> Thus the density of the nebular distribution increases outwards, symmetrically in all directions, leaving the observer in a unique position. *Such a favoured position, of course, is intolerable*; moreover, it represents a discrepancy with the theory, because the theory postulates homogeneity. Therefore, in order to restore homogeneity, and to *escape the horror of a unique position*, the departures from uniformity, which are introduced by the recession factors, must be compensated by the second term representing effects of spatial curvature. There seems to be no other escape… Well, perhaps the interpretation is correct and we do inhabit a rapidly expanding universe.

Attributing the cosmological redshifts to a spatial variation in the speed of light thus entails a rejection of the expansion of the universe, dark energy, possibly dark matter, and the Copernican Principle. That is a lot to swallow, even for a creationist. As I discussed above, both effects (expansion and speed of light variation) could in principle be operating simultaneously. I have focused solely on a variation in the speed of light both for simplicity and for its relevance to the distant starlight problem, but one could imagine constructing a cosmological model that included both the Hubble expansion and a variation in the speed of light. There are several reasons to think that such a complication is not necessary, however, and that the simple model outlined above is preferable. 1) Reducing our level of ignorance regarding the contents of the universe from 96% to 23% (or possibly 0%) by removing the need for dark energy (and possibly dark matter) should speak for

itself. We would improve in the "what stuff is made of" department from a woefully bad F to a barely respectable C+ (or possibly an A+). 2) The Copernican Principle, for all the weight it carries in the modern mind, is an unproven assumption, and a handful of researchers have recently set out to prove it (Caldwell and Stebbins 2008). In the words of Hubble (1937):

> [T]he statement that all observers, regardless of their location, will see the same general picture of the universe… is a sheer assumption.

3) Accepting the apparent spherical redshift distribution as real does not require a return to the medieval picture with the Earth stationary at the precise center of the universe. The vast scale of the universe implies that if the center of the redshift distribution were as far away as the nearest galaxy, for example, we would still be at the "center" of the universe to within one part in a million. 4) Our unsavory association with a special space-time event is an unavoidable fact of nature. Postulating an expanding universe in order to remain consistent with the Copernican Principle simply substitutes a unique location in space with a unique point in time (the so-called Coincidence Problem). Of course neither choice should pose a particular philosophical problem for a creationist, whether young universe or otherwise.

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