The Nature of Redshifts and an Argument by Gentry

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Abstract

Robert Gentry's New Redshift Interpretation (NRI) is one of several proposed creationary cosmologies. In defending the NRI, Gentry claims that the standard interpretation of cosmic redshifts is badly in error. In particular, he argues that cosmologists' purported "cessation assumption" is falsified by operation of the GPS. This article examines the nature of various types of redshifts in order to evaluate his claim. It concludes that his claim is incorrect.

Introduction

Much of the work to date in scientific creationism has focused on biology and geology, for the simple reason that some of the most direct evolutionary attacks on the biblical record have come from these fields. Creationists have done much less work in astronomy and cosmology, as noted by Faulkner and DeYoung (1991, p. 87). One exception is Robert Gentry, who in 1997 proposed a creationary cosmology which he called the "New Redshift Interpretation" (NRI). The NRI universe is roughly spherically symmetric about the Milky Way galaxy, finite in extent, static in geometry, and surrounded by a shell of hot hydrogen. The model attempts to explain the galactic redshifts and the cosmic microwave background radiation, two facts often cited in support of the evolutionary Big Bang Model (BBM). The NRI interprets the galactic redshifts as the result of both gravitational and kinematic effects rather than as evidence for cosmological expansion.

Gentry later wrote ten articles defending the NRI and attacking the BBM. He originally posted them on the electronic archive maintained by Los Alamos National Laboratories (www.arXiv.org), but they were deleted from the server, presumably due to the articles' creationary content. They are now available on the internet at http://www.orionfdn.org/PosterSession.

Gentry is to be commended for attempting to construct a cosmology that integrates scientific observations and revealed truth. Nevertheless, I Thessalonians 5:21 commands us, "Prove all things; hold fast that which is good." Thus, creationary scientists have the responsibility of critiquing this theory both scientifically and biblically. Cooperstock, Faraoni, and Vollick (1998), and Carlip and Scranton (1999), proponents of the BBM, address various aspects of the NRI; they include specific calculations in support of their arguments. Creationists, with the higher motivation of a biblical mandate, must do the same.

In fulfillment of this mandate, this paper seeks to evaluate the fifth article (Gentry, 2001) in Gentry's poster session series. In his article, Gentry attacks the idea of cosmological expansion, pointing to what he calls "the fatal flaw in the spacetime expansion postulate" (p. 2). His argument is summarized (largely in his own words) as follows:

1. BBM cosmologists believe that the cosmic expansion causes "wavelength expansion while a photon is in-flight, with complete cessation of expansion's effects during the emission and absorption process" (p. 3). Gentry calls this assumption the "cessation assumption" (p. 3) and asserts that "it is absolutely essential that it be invoked" (p. 3) by defenders of the BBM.
2. In contradiction to this "cessation assumption," Einstein's theory "predicts gravity affecting light during emission, *in contrast to causing in-flight wavelength change, as required by the expansion hypothesis*" (p. 4, emphasis in the original).
3. GPS operation shows "unambiguously that gravity operates during photon emission, without producing any in-flight change in λ whatsoever" (p. 5). Gentry specifically denies that photons "exchange energy with the gravitational field when passing through a potential gradient" (p. 5).
4. Therefore, both Einstein's theory and the operation of the GPS falsify the cosmic expansion hypothesis.

Gentry concludes that acceptance of cosmic expansion as evidence for the BBM "ranks as one of the greatest faux pas in the history of science" (p. 7).

This article contends that Gentry is mistaken. In the following sections I argue that, measured from the proper ref-

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erence, photons *do* lose energy in flight when traveling against a gravitational potential; that BBM theorists make, in fact, no "cessation assumption"; and (most damagingly to his position) that Gentry confuses the operation of gravity (as a mechanism for producing redshifts) with the effects of cosmic expansion. The intent of this article is not to criticize a fellow believer, nor to appear to support the BBM, but to follow the biblical mandate of I Thessalonians 5:21.

Redshifts

In order to support the assertions made above, we examine the nature of various types of redshifts. The term "redshift" refers to a decrease in the frequency of incoming light; that is, light normally emitted at one frequency is received by us at a lower frequency. (The corresponding term "blueshift" refers to an *increase* in the frequency of incoming light.) It turns out that the light from most galaxies exhibits a redshift roughly proportional to the galaxies' distance from us. Most cosmologists consider this pattern of redshifts to be evidence of cosmic expansion, a conclusion which Gentry disputes. There are three known causes of redshifts; we examine each in the following sections.

Kinematic Redshift

If an emitter of light (or of any kind of wave) is moving away from the observer, then during the time between the emission of two successive wavecrests, the emitter will increase its distance from the observer. As a result, it will take slightly longer for the second wavecrest to reach the observer than the first, resulting in a decrease in the observed frequency. This effect, commonly called the Doppler Effect (although the name is sometimes used for the other types of redshifts), is easily observable with sound waves emitted by automobiles. It is useful in identifying binary stars by means of the periodically shifting spectral lines (Hänsch, 1991).

We derive the classical kinematic Doppler Effect as follows. Suppose an emitter E is moving radially away from a receiver R with relative velocity v. Then in the time Δt that it takes E to emit successive wavecrests, E has increased its distance from R by $\Delta t \cdot v$, so the that time between the two wavecrests, as measured by R, is $\Delta t + \Delta t \cdot v/c$. Hence, the ratio of the wavelength λ_E measured by E and the wavelength λ_R measured by R is

$$D \quad \frac{R}{E} \quad \frac{c \ \ t \qquad t \ \ v \,/\, c}{c \ \ t} \quad 1 \quad \frac{v}{c}. \tag{1}$$

With the advent of special relativity, the classical formula required alteration, as follows, to account for the effects of time dilation. Suppose E is moving radially away from R at a relative speed of v, and suppose E measures the time interval Δt between emission of successive wavecrests. Then R will measure that same interval of time as $\gamma(v)\Delta t$, where $\gamma(v) = 1 - (v^2/c^2)^{-1/2}$ is the "Lorentz factor," the factor by which relative motion dilates time. (this deirvation assumes that the relative motion of E with respect to R is purely radial.) During this time, as measured by R, the distance between E and R increases by $\gamma(v)\Delta t{\cdot}v$, and hence the wavecrests arrive at R separated by a time interval of $\gamma(v)\Delta t + \gamma(v)\Delta t{\cdot}v/c$. Thus the ratio of wavelengths becomes

$$D \quad \frac{R}{E} \quad (v) \ 1 \quad \frac{v}{c} \ , \tag{2}$$

which is simply the classical expression multiplied by the Lorentz factor.

Gravitational Redshift

Einstein's theory of special relativity did not take gravitational forces into account. He expanded it to include gravity (thereby formulating the theory of general relativity) by assuming the following Equivalence Principle (EP): "all local, freely falling, nonrotating laboratories are fully equivalent for the performance of all physical experiments" (Rindler, 1977, p. 18). In other words, Einstein postulated that one could effectively transform gravity away by considering observers to be in free fall.

The resulting theory of general relativity concludes that light emitted within a gravitational field is redshifted when observed by a receiver outside of the field (or, strictly speaking, at a lesser gravitational potential). The reasoning, qualitatively, is as follows. Suppose you have a laboratory falling freely in a gravitational field. Say an emitter on the floor shines a beam of light toward the ceiling. By the EP, the freely falling lab is (locally) equivalent to a lab with no gravity, so a sensor on the ceiling will see the light with the same frequency at which it was emitted. However, an observer outside the lab will see the emitter traveling away from him. Hence, to the observer, the light will be redshifted, as discussed in the section above.

To quantify the amount of the redshift, let the gravitational field have strength g and let the cabin have length l. The emitter E begins emitting light the instant the cabin is dropped. Let v_E be the frequency of the light as measured inside the freely falling cabin. Now suppose the outside observer R is positioned so that he is even with the ceiling of the lab just as the first light hits the ceiling. The time taken for the light to traverse the lab is l/c, and hence the lab is now moving at a speed of gl/c. Hence, by Equation 1 (we here ignore special relativistic effects), the ratio of the wavelengths will be

$$D \quad \frac{R}{E} \quad 1 \quad \frac{gl}{c^2}.$$

Rewriting the expression in terms of frequency,

$$\frac{\nu_R}{\nu_E} = \frac{c^2}{c^2 + gl},$$

or,

$$1 - \frac{\Delta\nu}{\nu_E} = \frac{\nu_R}{\nu_E} = 1 - \frac{gl}{c^2 + gl}. \tag{3}$$

So we see that the gravitational redshift is indeed, as Gentry (2001, p. 6) claims, the result of the fact that "two observers at different potentials are comparing identical photons in reference frames that have intrinsically different physical characteristics. In essence, if you move to a different potential, you establish a different reference frame for energy measurements of photons originating from outside your new frame." Does this fact imply, then, as Gentry also claims, that it is incorrect to consider a photon to be losing energy as it climbs out of a gravitational potential well? In answer, let us develop a differential version of Equation 3 and perform some integration.

First we replace l with Δr, where r is distance from the center of gravitational attraction. Suppressing the subscript, we have

$$-\frac{\Delta\nu}{\nu} = \frac{g\Delta r}{c^2 + g\Delta r}$$

$$\frac{\Delta\nu}{\Delta r} = -\frac{g\nu}{c^2 + g\Delta r}$$

$$\frac{d\nu}{dr} = -\frac{g\nu}{c^2},$$

letting Δr approach zero, and thus

$$\frac{d\nu}{\nu} = -\frac{g\,dr}{c^2}. \tag{4}$$

Replacing g with GM/r^2 (where G is the gravitational constant and M the mass of the gravitating object) we obtain

$$\frac{d\nu}{\nu} = -\frac{GM\,dr}{c^2 r^2}.$$

Integrating, we obtain

$$\ln \nu = \frac{GM}{rc^2} + C,$$

whence, allowing ν_0 and r_0 to be the initial frequency and distance, respectively, we obtain the following equation for the frequency of the photon as it travels through a gravitational potential gradient:

$$\nu = \nu_0 e^{\frac{GM}{c^2}\left(\frac{1}{r} - \frac{1}{r_0}\right)}. \tag{5}$$

Since ν is a decreasing function of r, one can clearly consider the photon to be losing energy as it climbs out of the gravitational well. Indeed, it is possible to obtain Equation 4 from Planck's relation $E = h\nu$ if one considers the photon to be losing energy to the field as it travels upward (Rindler, 1977, p. 268). One can even use the classical expression for potential energy, namely, $dU = (GmM/r^2)dr$, to do the same, as long as one remembers that the photon cannot change speed and therefore must change frequency to conserve energy.

These calculations show that Gentry on this point is correct in what he affirms and wrong in what he denies. If one constantly changes freely falling reference frames as the photon moves along, we see that the redshift is the result of the change of reference frames. Or, if you watch a photon climbing out of a gravitational potential well, you see it losing energy to the field. The whole point of the EP is that the two ways of looking at the situation are equivalent.

For this cause it is proper to say that Gentry misunderstands what the operation of the GPS tells us. According to Alley (in Gentry, 2001, p. 5),

> If the physical clock adjustments have been made as described above so that all clocks are keeping a common coordinate time, then there is no effect on the frequency of the radiation as measured in that coordinate time. However, the contractor had included in the computer programs to operate the system just such a correction, *effectively correcting twice for the relativistic effects* (emphasis added).

In other words, to correct for frequency change and to correct also for coordinate change is to correct twice for the *same* effects. The operation of the GPS actually reaffirms the EP, which tells us that the two ways of looking at gravitational redshifts are equivalent.

In summary, gravitational redshift is the result of the photon struggling against the gravitational field, losing energy to it. Or, equivalently, it is the result of the effects of gravity on spacetime, causing the need for different reference frames at different potentials.

Expansion Redshift

The third type of redshift is, like the preceding type, a general relativistic effect, but it is completely distinct from both gravitational and kinematic redshifts. It is caused by the expansion of the space through which the wave is traveling, resulting in an "expansion" (redshifting) of the wave itself. The process is analogous to drawing a wave on a sheet of rubber and then stretching the rubber in the direction of the wave's travel. It is the commonly accepted explanation for the redshifts of the distant galaxies (Rindler, 1977, p. 213; Misner, Thorne, and Wheeler, 1973, pp. 776–778; Peebles, 1993, pp. 96–98; Bedran, 2002, p. 406).

The derivation of the formula for the expansion redshift (also called the "cosmological redshift") is straightforward.

First, we let $R(t)$ be the radius of curvature of the universe at time t. Note that by "radius" we do *not* mean the distance from a central galaxy to an edge galaxy; indeed, the BBM universe is homogeneous (Rindler, 1977, pp. 201–202) and thus has "no edge and no center" (Humphreys, 1994, p. 19). The quantity $R(t)$ refers rather to the amount of curvature of the spacetime continuum of general relativity. (It could in theory be calculated by various geometrical means from observations, but not measured as a physical length in our three-dimensional universe.) As expansion proceeds, $R(t)$ grows; if the universe were to contract, $R(t)$ would shrink.

Now suppose a distant galaxy E emits light of wavelength λ_E at time t_E. Two wavecrests leave E separated in space by a distance of λ_E, and if the path over which they travel does not expand in flight, receiver R will observe them at time t_R with the same separation. However, if their path expands proportionally to $R(t)$ during flight, then the ratio of λ_E and λ_R will be given by

$$D = 1 + z = \frac{\lambda_R}{\lambda_E} = \frac{R(t_R)}{R(t_E)}, \tag{6}$$

where z is the amount of the redshifting that takes place.

Note that Equation 6 contains no velocity terms; z cannot therefore be measuring any sort of kinematic redshift. The only thing that matters is how much the universe expands between emission and reception of the photon. The expansion could have occupied billions of years or a fraction of a second (or a few days of the creation week), and the amount of redshift would be the same. There might have been no relative motion at all when the photon was emitted, nor when it was received (all the expansion having taken place during the intervening time), and the expansion redshift would be the same. Thus the kinematic and expansion redshifts are qualitatively different. One could think of the kinematic redshift as the result of motions through space, whereas the expansion redshift would be the result of the motion of space itself. Quantitative differences between the two types of redshifts are explored by Bedran (2002).

The expansion redshift differs also from the gravitational redshift. As seen in the development of Equation 3, we did not make any assumptions of cosmic expansion, nor, in the development of Equation 6 did we make any assumptions about gravitation. Indeed, in the BBM, there is no large scale pattern of gravitational attraction, the mass distribution being assumed homogeneous; hence it predicts expansion redshifts but no (large scale) gravitational redshifts. Conversely, a static universe could well exhibit gravitational redshifts but would have no expansion redshifts.

Gentry contends that cosmologists assume the expansion effects cease during emission and reception of the light. To show that cosmologists assume no such thing, I will rederive Equation 6 by following the method adopted by Misner *et al.* (1973, pp. 776–778), one of the sources referenced by Gentry. Misner *et al.* use the following *Robertson-Walker metric* for spacetime, which is the standard metric for the BBM:

$$ds^2 = c^2dt^2 - R(t)^2\left[\frac{d\eta^2}{1-k\eta^2} + \eta^2\left(d\theta^2 + \sin^2\theta\, d\phi^2\right)\right], \tag{7}$$

where $R(t)$ is the curvature of space, η is a "comoving" radial coordinate (i.e., a galaxy that starts at a given value of η will remain there as it is carried by the cosmic expansion), k can have the values 1, 0, or –1 (depending on whether the universe is positively curved, flat, or negatively curved, respectively), and θ and ϕ are standard spherical coordinates.

Place the origin at earth (the Robertson-Walker metric allows one to locate the origin at any point) and consider a galaxy at a radial distance of η_E. It emits two successive wavecrests toward the origin (earth) at times t_{E_1} and t_{E_2}. We neglect any proper motion of the earth relative to space; one could in theory take it into account using an additional kinematic Doppler correction, but our focus is on the effects of the expansion. We first consider the emission of the waves. Clearly

$$\lambda_E = ct_{E_2} - ct_{E_1}. \tag{8}$$

Next consider the propagation of the light. Since the ray is traveling radially toward the origin, $d\theta$ and $d\phi$ in Equation 7 are zero. Since light travels along null geodesics, ds^2 is also zero. This fact necessitates that $-R(t)d\eta/(1-k\eta^2)^{1/2} = c\,dt$, where the negative sign is due to the fact that the light is traveling towards the origin, causing a decrease in η as t increases. Therefore, integrating along the geodesic, we can write

$$\int_0^{\eta_{E_1}} \frac{d\eta}{\left(1-k\eta^2\right)^{1/2}} = \int_{t_{E_1}}^{t_{R_1}} \frac{c\,dt}{R(t)} \tag{9}$$

and

$$\int_0^{\eta_{E_2}} \frac{d\eta}{\left(1-k\eta^2\right)^{1/2}} = \int_{t_{E_2}}^{t_{R_2}} \frac{c\,dt}{R(t)} \tag{10}$$

for the two wavecrests. Since the coordinate η is comoving with the expansion, and since the same galaxy emits both wavecrests, we know $\eta_{E_1} = \eta_{E_2}$, so the left hand sides of Equations 9 and 10 are equal. Now subtracting Equation 9 from Equation 10, we obtain

$$0 = \int_{t_{E_2}}^{t_{R_2}} \frac{c\,dt}{R(t)} - \int_{t_{E_1}}^{t_{R_1}} \frac{c\,dt}{R(t)} \tag{11}$$

$$= \int_{t_{R_1}}^{t_{R_2}} \frac{c\,dt}{R(t)} - \int_{t_{E_1}}^{t_{E_2}} \frac{c\,dt}{R(t)} \tag{12}$$

$$= \frac{ct_{R_2} - ct_{R_1}}{R(t_R)} - \frac{ct_{E_2} - ct_{E_1}}{R(t_E)}. \tag{13}$$

Finally, consider the reception of the light. Once again, it is clear that

$$_R \quad ct_{R_2} \quad ct_{R_1}. \qquad (14)$$

Now combine Equation 13 with Equations 8 and 14 to obtain

$$\frac{_R}{R\ t_R} \quad \frac{_E}{R\ t_E},$$

whence

$$z \quad \frac{_R \quad _E}{_E} \quad \frac{R\ t_R}{R\ t_E} \quad 1,$$

just as in Equation 6. It is clear from the approximation symbol in Equation 13 (which appears in Misner *et al.*) that cosmologists do *not* assume that the expansion effects cease during emission and reception, but only that they assume such effects are negligible.

To see that such an assumption is valid, let us approximate the amount of expansion that takes place during the emission of a photon. Take, for instance, the α line in the hydrogen Balmer series, which has a period of 2.19×10^{-15} seconds. Assign this value to $t_{E_2} \quad t_{E_1}$, which we shall call Δt. To estimate the current speed of expansion, we consider Hubble's constant, which equals $R'(t)/R(t)$; the estimate given by Lang (1991, p. 519) is 50 km s^{-1} Mpc^{-1}. Taylor and Wheeler (1992, p. 297) state that 13.2×10^9 is a value for $R(t)$ that is compatible with observations. Using this value, multiplying, and changing units, we obtain

$$R \quad t \quad 2.025 \quad 10^{10}\,\text{cm/s}. \qquad (15)$$

Hence, the amount of expansion during the emission of an α Balmer line wave is

$$R\ t \quad R\ t \quad t \quad 4.43 \quad 10^{\ 5}\,\text{cm}. \qquad (16)$$

This number is 33 orders of magnitude smaller than the estimate for *R*. Therefore, by Equation 6, the effects of expansion during emission (and, similarly, during reception) are utterly negligible when performing redshift calculations. The estimate obtained in Equation 16 is admittedly crude, but it serves to demonstrate that the "cessation approximation" (*not* assumption!) made by cosmologists is eminently reasonable.

Discussion

In summary, there are at least three distinct possible causes of redshifting:

- Proper motion of the emitter with respect to the receiver,
- Differing gravitational potential at the emitter and the receiver, and
- Expansion of spacetime between emission and reception.

In developing the equations for these different types of redshifts, I have also noted the following points:

- One *can* legitimately consider photons to be losing energy in flight as they climb out of a gravitational potential well; alternatively, one can consider the difference in energy to be the result of different coordinate frames;
- Cosmologists do *not* assume that the effects of expansion cease during emission and reception; rather, they assume (correctly) that the effects are small enough to be negligible.

However, we have not yet considered the main problem with Gentry's article, which is that he confuses the gravitational redshift with the expansion redshift. While both are general relativistic effects, we have seen that they are distinct. Gentry seems (correctly) to distinguish them by saying, "Astronomically determined redshifts can be explained by Doppler and gravitational effects, independent of spacetime expansion" (2001, p. 2). Nevertheless, a glance at his argument (summarized at the beginning of this article) shows that it relies on an identification of the two. Even if cosmologists *did* make a "cessation assumption" about the expansion redshift (limiting it to effects on the photon in flight), and even if gravity *did not* (from any point of view) affect the photon in flight, there would be no contradiction, for the gravitational redshift and the expansion redshift are completely distinct. To identify the two is to invalidate any argument that depends on such identification. Hence, while the BBM may yet rank "as one of the greatest faux pas in the history of science," it will not be because of this particular argument by Gentry.

It remains to consider whether there is any evidence for cosmic expansion. Let us first consider biblical evidence. Many passages speak of God "stretching out the heavens," using a variety of words in various contexts to communicate the same idea. Humphreys (1994, p. 66) lists seventeen such verses. While it is perhaps possible that all seventeen references are purely metaphorical (referring to the expansiveness of the sky as seen from the earth), the variety and quantity of the verses lead one to suspect that God literally did "stretch out" the heavens (i.e., space—or spacetime from an Einsteinian viewpoint). Thus a literal reading of Scripture provides evidence for spacetime expansion at some time in the past.

The main scientific evidence for such expansion remains the observed pattern of extragalactic redshifts, wherein the redshift of a galaxy is roughly proportional to its distance from earth. Misner *et al.* state the standard reasoning as follows: "Observed quasar redshifts of $z \sim 1$ to 4 cannot be gravitational in origin; objects with gravitational redshifts larger than $z \approx 0.5$ are unstable against collapse... Nor are the quasar redshifts likely to be Doppler; how could so massive an object be accelerated to $v \approx 1$ without complete disruption? The only remaining possibility is a cosmological redshift" (1973, p. 767). (Note that Misner *et al.* are using units for velocity such that $c = 1$.) This reasoning seems cogent, especially considered in light of the biblical statements mentioned above.

Conclusion

Gentry is to be strongly commended for attempting to formulate a creationary alternative to the BBM. Other creationists have proposed cosmologies and/or cosmogonies consistent with the biblical record. David Harris (1978) outlines a scheme in which a wave of light speed decay propagates outward from the earth at the time of the Fall. Russell Humphreys' White Hole Cosmology (1994) has received much attention. Barry Setterfield continues to refine his theory of light-speed decay (originally proposed in Norman and Setterfield, 1987, and most recently in Setterfield, 2002). These theories must all be developed to the point where they can make quantitative predictions that will distinguish them from each other and from the BBM.

"The works of the Lord are great, sought out of all them that have pleasure therein" (Psalm 111:2). All creationists with the necessary qualifications are urged to "seek out" the works of the Lord in creating and sustaining the cosmos, evaluating current theories and proposing new ones as necessary. The motive for doing so is higher than any apologetic value such efforts might provide; we do it to magnify the greatness of our Creator.

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Survey: Views on Human Life Origins

In the United States, people's views of the origins of human life have varied little over a period of 15 years. The following survey was taken by telephone calls to 1003 adults on November 6–9, 1997.

Which of the following statements comes closest to your views on the origin and development of human beings?

1997	1993	1982	
39%	35%	38%	Human beings have developed over millions of years from less advanced forms of life, but God guides this process.
10	11	9	Human beings have developed over millions of years from less advanced forms of life. God has no part in this process.
44	47	44	God created human beings pretty much in their present form at one time within the last 10 000 years or so.
7	7	9	No opinion.

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