Analysis of the Variable Lightspeed (c-Decay) Theory of Barry Setterfield

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Preface

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Researching and refuting creationist claims is a thankless job for scientists. The contributions of those who expose the distortions of "creation scientists" are often buried in obscure Internet sites and discussion groups. The links, if they can be found at all, are sometimes inoperative. As a result, unfortunately, it can be difficult to trace the originator of a particular argument or calculation. The authors commend all those who have pointed out the deficiencies of creationist cosmology, and apologize to those whose contributions may have been overlooked in this document. We would be glad to receive notice of such omissions, so they can be acknowledged in a later edition of this paper.

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1 Introduction

How old is the Earth? How old is the Universe?

These questions – themselves very old – have been answered through the collaborative, cumulative efforts of scientists. Multiple consistent lines of evidence demonstrate, to the satisfaction of virtually all scientists, that the Earth is 4.6 billion years old, and that the expanding Universe began as a highly-compressed primordial fireball between 13 and 14 billion years ago.[1]

Young-earth creationists have a different answer. Influenced by a literal reading of the Bible, they are committed to the idea that the world began in an act of Creation 6,000 to 8,000 years ago.

The Universe is very big – a fact disputed by no one, including creationists. Traveling at 186,000 miles per second (2.998×10^5 km/s), a beam of light takes billions of years to reach us from the most distant visible objects in space. And so the creationist is faced with a seemingly insurmountable problem: we can see the vastness of the cosmos with our telescopes, or even with our own eyes, and the photons of light with which we do so must be very old. The Old Testament Universe is not the Universe of astronomers. What to do?

The creationist could claim that the Universe was created with the light photons already in space, radiating away from astronomical objects that were only "apparently" their points of origin. The obvious problem is that God then appears deceitful, engineering a cosmos that appears to be much older than it is, with artificial images of distant events that never happened. Although at times creationists have tried to advance this contrived argument,[2,3] they've probably never felt comfortable with it.

A seemingly more attractive possibility is the bounded cosmology invented by D. Russell Humphreys, in which gravitational time dilation allows distant galaxies to be much older than the Earth.[4] However, this cosmological model has been subject to convincing attack.[5]

A third possibility is the "*c*-decay" or ("variable light speed") theory developed by Barry Setterfield. If Setterfield is right, the speed of light, along with several other physical "constants," has undergone tremendous changes over the course of time. Because light traveled millions of times faster when the Universe was created, the visibility of distant astronomical objects is supposedly explained. Likewise, because atomic processes operated on a faster timescale in past ages, the radioisotope ratios pointing to an old Earth are allegedly brought into agreement with the Old Testament timescale.

In this report, we show why Setterfield is wrong.

According to his website biography,[6] Barry Setterfield was born in 1942. He attended Adelaide University in Australia, studying physics and geology. Health and family obligations forced him to drop out of college, and he worked for a time as a geologist for a mining company. He had a continuing interest in astronomy, and lectured for the Astronomical Society of South Australia for six years.

Around this time, Setterfield became a committed Christian (of the Biblical literalist variety). Discomfort with secular academic culture, combined with continuing family obligations, prevented him from resuming his formal education, and he never

obtained an academic degree. He is forthright about this, and admonishes admirers not to refer to him as "Dr. Setterfield."

As he pondered the discrepancies between the scientific and Old Testament views of creation, Setterfield found data that seemed to suggest variations in the fundamental constants of physics. He developed the idea that c, the speed of light, has declined or decayed over the centuries, and in 1981 published his first article on c-decay in the creationist journal *Ex Nihilo*.[7] From 1985 to 1987 he collaborated with Flinders University mathematician Trevor Norman in a survey of observational and experimental data on fundamental constants. The document that resulted, "Atomic Constants, Light, and Time," contained tables of all of the historical data used to formulate his theory.[8] The report (which didn't mention creationism or the Bible) was written at the request of Lambert Dolphin, a physicist at Stanford Research Institute (SRI). It's not clear from Setterfield's online material how much corporate involvement SRI had in this work. Setterfield also says that Flinders University "had reviewed the paper initially and accepted the research and results as valid." It's hard to tell exactly what this means.

Setterfield's ideas were controversial among creationists, and were attacked by the Institute for Creation Research in the U.S. and the Creation Science Foundation in Australia. Other "scientific" creationists were supportive. For example, Dr. Walt Brown of the Center for Scientific Creation wrote approvingly about Setterfield's work and added nonsensical suggestions of his own.[9]

The mainstream scientific community, of course, remained oblivious to this challenge to orthodox physics. Setterfield says he submitted a later paper on the cosmological redshift to four scientific journals, who rejected it because of its speculative character, Setterfield's lack of institutional affiliation, and because one of his references was a university text rather than an original research paper. He has published nothing in mainstream refereed journals. All of his writings are online or in creationist journals.

As we shall see, neglect of Setterfield's work by the scientific community is appropriate because it is obviously and outrageously incorrect.

Setterfield now lives in California with his wife Helen, who assists him in promoting and explaining his ideas. He is still actively involved with heterodox astronomy and physics, incorporating newly-announced research results into his theoretical framework and awaiting the day when the scientists of the world open their minds and acknowledge his remarkable discoveries.

From his life story and public activities, Barry Setterfield can be judged to be a man of powerful religious conviction, deep family ties, and inquiring spirit. His claims would change the world if they were true. It would be tempting to leave him and his theories alone, but he has unfortunately put himself in the position of misleading large numbers of sincere people with ideas that put them on a collision course with scientific truth.

In this document, we describe Setterfield's ideas, explain the inconsistencies and theoretical errors we have found in his writings, and demonstrate the blatant disagreement between his model and reality. As we proceed, it will become clear that Setterfield's theory of light is not the scientific revolution he wants it to be. At best, it is a light comedy.

2 Description of Setterfield's Theory and Assumptions

2.1 The Varying Constants

Setterfield maintains that the Universe was initially "stretched out" (a Biblical phrase) about 8,000 years ago. Since then, the Universe has allegedly been static (not expanding) with a "gentle oscillation."[10]

The cornerstone of Setterfield's theory is a radical change in c, the speed of light, over the lifetime of the Universe. Due to this "c decay," the speed of light was allegedly at least 10 million times greater at the time of Creation. However, the specific function that describes the decay is difficult to discern clearly from Setterfield's writings.

For clarity, we'll describe the variation by the time-dependent function $\zeta(t)$, which we'll call the "c-decay factor".[*] We then write the speed of light as

$$c(t) = \overline{c}\,\zeta(t) \tag{1}$$

where $\overline{c}$ is the current speed of light (299,792 km/s).[**] In past eras, when Setterfield claims the speed of light was greater than its present value, we would have $\zeta(t) > 1$.

But Setterfield doesn't change only the speed of light.[***] To maintain the invariance of $E = mc^2$, he also posits a gradual increase in the masses of elementary particles over time, with a variation proportional to the square of the c-decay factor:

$$m(t) = \overline{m}\,\zeta^{-2}(t). \tag{2}$$

Setterfield varies the gravitational constant too:

$$G(t) = \overline{G}\,\zeta^{2}(t). \tag{3}$$

It follows that ζ cancels out in the gravitational acceleration Gm/R^2. Objects in Setterfield's universe fall at the same rate, even as the masses of particles change by many orders of magnitude. Orbits of astronomical objects do not change, orbital periods remain constant, and Kepler's laws always apply in their familiar form.

Planck's constant increases with time, according to Setterfield:

$$h(t) = \overline{h}\,\zeta^{-1}(t). \tag{4}$$

Finally, the characteristic frequencies of atomic and nuclear processes were allegedly greater in the past:

$$f(t) = \overline{f}\,\zeta(t). \tag{5}$$

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[*] For those who like to read out loud, ζ is the Greek letter "zeta."

[**] The time coordinate t is what Setterfield calls "dynamical" time. It is what is marked out by pendulum clocks, orbital motions in gravitational fields, etc. Setterfield distinguishes it from "atomic" time, since he maintains that atomic processes operated more rapidly in the past (cf. Equation (5)).

[***] We discuss only those parameter variations that enter directly into our analysis. However, Setterfield varies additional parameters, such as the electric permittivity constant and the electron charge.

A consequence of this, according to Setterfield, is that nuclear reactions proceeded more rapidly in the early history of the Earth. Unlike many young-earth creationists, he does not cast doubt on radiometric dating by claiming that the atomic clocks have been "reset" by the Flood, or that geochronologists make invalid assumptions about the initial composition of the rocks they study. Rather, he maintains that geologists have, perhaps understandably, been fooled by the accelerated half-lives of the atomic clocks in past eras. (This deviation from creationist orthodoxy may help explain why many other creationists have rejected Setterfield's work.[11,12])

According to Setterfield, the combined effect of Equations (1) and (5) is to render modern measurements of c irrelevant for the study of c-decay. Because the most precise measurements of the speed of light involve atomic transitions, the change in atomic behavior allegedly cancels out the variation in c, explaining the lack of systematic decline in c in contemporary laboratory measurements. (In addition, Setterfield claims that the decline in c has virtually stopped since the 1960's.)

2.2 The Slowing-Down Effect

This may be an appropriate place to describe the astronomical "slowing-down effect" that follows from Setterfield's assumptions. This effect will be important in later sections of this monograph, and helps illustrate the way in which multiple time-varying constants sometimes cancel each other out, and sometimes do not.

Figure 1 illustrates emission of a pulse of light from a star. To be specific, let's say the light is emitted during a 1-second interval. If the speed of light is constant at 186,000 miles per second, the total length of the light pulse, from front to back, is 186,000 miles, since this is how far the front of the pulse has traveled at the time emission ends. Seven cycles of the wave are shown (this is for illustrative purposes only – a one-second pulse of visible light would actually contain more than 10^{14} cycles).

Figure 2 shows a different situation, this time with a c-decay factor of two (but with no frequency difference) at the time of emission. Since the light is moving twice as fast, the wave pulse is 2 x 186,000 = 372,000 miles long. Since the wave contains the same number of cycles, the wavelength is also greater by a factor of two. If, due to c-decay, the speed of light is reduced to 186,000 miles per second when the light reaches Earth, the light pulse will last for two seconds, as seen by a terrestrial observer. There will therefore be a slowing-down effect; physical processes observed by means of such a light signal will be seen stretched out in time – in slow motion. Since the changing speed of light won't change the number of cycles, the wavelength will be greater by a factor of two. There will therefore be a "redshift": the wavelength will be seen as shifted toward the red end of the spectrum – *if* the frequency of the emitted light is the same as in the scenario of Figure 1.

Subsequent changes in c, if they occur simultaneously at all points in space, won't affect the spatial extent or modulation structure of a light signal. While the light is in transit, its wavelength also remains constant, since even if c changes, it will affect the entire wave train, and will cause no "stretching" or "squashing" of the wave. The slowing-down effect doesn't depend on the behavior of $c(t)$ during the time the light is traveling through space. In principle, the light could speed up, slow down, or even stop or go backwards for a while…all that matters is the ratio between $c(t)$ at the time of emission and $c(t)$ at the time of reception.
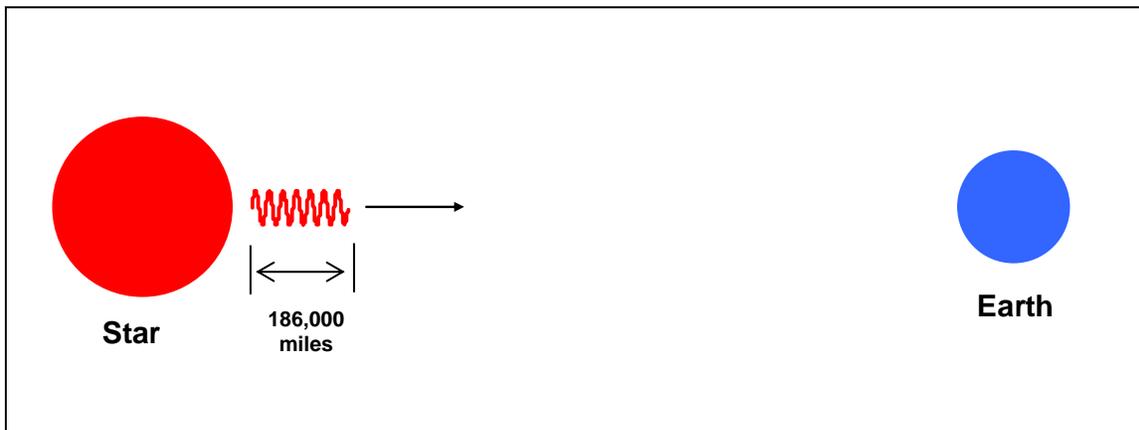
Figure 1. A star emits a one-second pulse of light toward the Earth (*c* assumed constant).
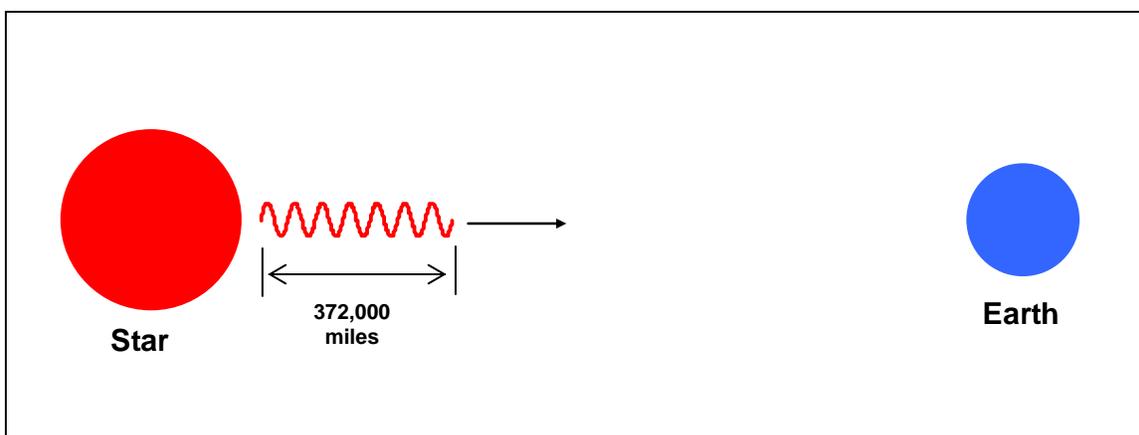

Figure 2. Emission of light with a 2x greater value of *c*.
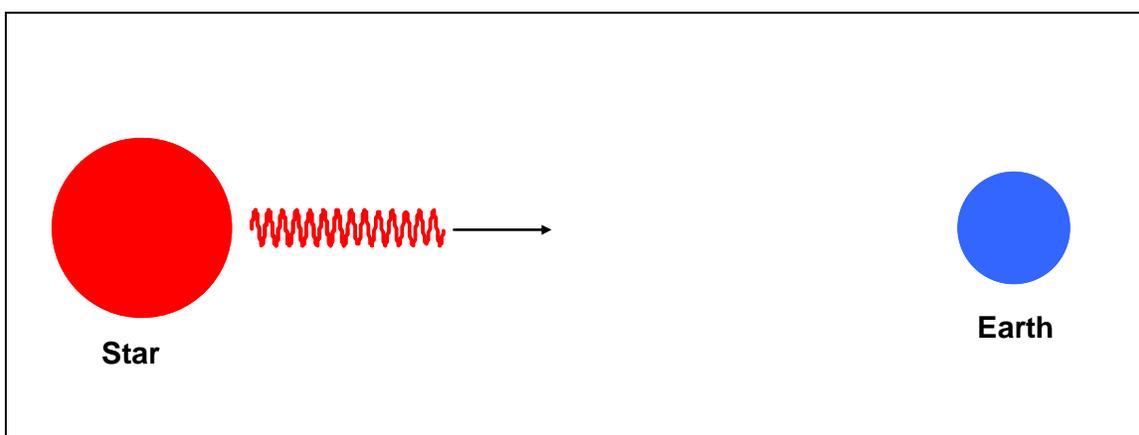

Figure 3. Setterfield's complete scenario: 2x greater value of *c*, and a compensating increase in atomic frequencies.

Figure 2 might tempt us to explain the observed cosmological redshift by means of *c*-decay. It's well known that the spectra we receive from distant galaxies and quasars show a shift toward the long-wavelength end of the spectrum, with the shift more or less proportional to the distance to the object. But Figure 2 doesn't include all of Setterfield's assumptions. As Figure 3 shows, Setterfield's complete scenario causes the redshift to cancel out. Since, by Equation (5), he assumes an increase in the frequencies of atomic transitions, the number of cycles in the wave would be 14 if $\zeta(t) = 2$, as we've assumed. Hence, the frequency observed at Earth would be the same as in the scenario of Figure 1. However, the *duration* of the light pulse would still be increased by a factor of two, so the slowing-down effect would occur for any phenomenon that is not increased in speed by Equation (5). Hence we can conclude (in agreement with Setterfield) that spectroscopically-observed atomic and nuclear phenomena in space would present the same characteristic frequencies as found in Earthbound laboratories, whereas gravitational phenomena, such as orbits of binary stars, would be seen in slow motion.

2.3 The Redshift

We now must ask: if the cosmic redshift is not due to changes in *c*, how does Setterfield explain it? In his early work, Setterfield apparently did claim that *c*-decay was the direct cause of the redshift.[13] More recently, he has made written comments that make it look as though he still holds such a view.[14,15] But he elsewhere describes the redshift as being due to a change in the intrinsic properties of atoms in the early years of the cosmos, rather than being directly caused by the *c*-decay.[16,17,18]

His most recent writings make it clear that this is his current interpretation.[19] This notion goes beyond the simple increase in atomic frequencies posited in Equation (5), and to understand it we must look at Setterfield's model in more detail.

Setterfield believes that, when the heavens were "stretched out," God filled the Universe with extremely tiny particles called Planck Particle Pairs (PPPs), which, being positive or negative, can be created in "ionization" processes or undergo recombination, causing them to disappear. The annihilation of PPPs adds to the Universe's Zero Point Energy (ZPE) content. The enormous energy present in the ZPE causes the rapid creation and annihilation of virtual particles. It is the interaction of photons with the virtual particles that causes *c*-decay; since the number of these particles increases with time, the speed of light supposedly decreases as a function of time. Increase in ZPE also allegedly causes electrons to increase in size, which leads to a discontinuous *decrease* in electron mass during "quantum jumps," as discussed further in Appendix C.[*]

In addition, ZPE is absorbed by atomic electrons, preventing them from spiraling into the nucleus. (This idea, which has been published by the controversial[**] physicist Harold Puthoff,[20] provides a classical alternative to the conventional quantum explanation that electrons stay in their orbitals because there's no lower quantum state for them to fall into.) As the amount of ZPE increases, Setterfield says, the mass of the electron and the energy levels of atoms change causing atomic spectra to shift to shorter

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[*] As we shall see in Appendix C, the claim of a mass decrease was based on Setterfield's misunderstanding of basic atomic physics. Setterfield has acknowledged this crucial error in this reasoning; for details on recent developments see Appendix D.

[**] Puthoff is well-known for publishing what he regarded as scientific verification of paranormal abilities on the part of Uri Geller and other psychics.

wavelengths (cf. Appendix C). Looking at distant objects, he claims, we see light emitted at an earlier time, when the spectra were redshifted relative to what we measure in our immediate environment.

Setterfield is convinced that astronomical data show this redshift to be "quantized" – that it does not change continuously, but undergoes "jumps" as we look further out into space. This idea (which did not originate with Setterfield) is rejected by the great majority of astronomers, who explain the phenomenon as an artifact of small datasets, galaxy clustering, etc.[21,22,23] Setterfield believes the quantization is due to "resistance" on the part of atoms to changes in their energy levels.[24] Thus, although the variation in *c* and the other constants is continuous, the redshift, being due to a different physical phenomenon, is allegedly quantized.

This completes our overview of Setterfield's main ideas, insofar as they can be understood from his publications. However, his work unfortunately contains many ambiguities and contradictions, which can interfere with attempts to understand, not to mention critically evaluate, his work. The next section explores some of these issues.

3 Ambiguities and Contradictions – The Search for Zeta

To compare Setterfield's theory with experimental and astronomical data we need to know how the physical constants are supposed to change as a function of time. What functional form does $\zeta(t)$ take?

Setterfield changes the values of physical constants *in a manner that is itself time-varying*. As we'll see in this section, he asserts that *c*-decay has occurred at different rates during various historical epochs, without explaining how the various functions are to be reconciled with each other. He has also presented tables and charts[25,26,27] that map "atomic radioisotope time" into "dynamical" (real) time (see Appendix B), but never explains or justifies his numbers.

Setterfield's verbal descriptions of *c*-decay behavior are sometimes confusing. For example, he has referred to *c*-decay as following a Lorentzian function with a superimposed ripple.[28] (The term "Lorentzian function" here probably refers to the "relativistic" denominator of his redshift equation, rather than to the lineshape function physicists think of as "Lorentzian.") We read elsewhere of a square law function.[29]

Setterfield also speaks of a smooth exponential decline with a small superimposed oscillation.[30] Setterfield says that the oscillation "bottomed out" around 1980, and that *c* may soon enter an increasing phase.[31] But as we'll see below, his proposed mathematical functions are *not* exponentials, and they show no sign of oscillations.

In his early work, Setterfield proposed log-sine and cosecant-squared curves.[32] These were extrapolated to ancient times, giving enormous values for the speed of light at the time of Creation and providing the astronomical visibility needed to support the young-earth creationist position. In more recent publications, Setterfield seems to take a piecemeal approach, abandoning the idea that one function can describe the behavior of light over the entire span of cosmic history (all 8,000 years of it) .We'll now present several of his more recent *c*-decay functions:

(1) For times earlier than 3005 B.C.E, Setterfield has stated that "atomic age" d (the age recorded by atomic clocks) is related to true elapsed time (as measured by macroscopic time-keeping processes) by the equation:

$$d = 1905t_s^{\,2} + 6.3 \times 10^7 \qquad (6)$$

where t_s is "true" (dynamical) time in years B.C.E. minus 3005. [33] This relation can be used to calculate $\zeta(t)$, as shown in Appendix A. The result is

$$\zeta(t) = -3810t + 1.14 \times 10^7 \qquad (7)$$

with t expressed in years since the Creation.

(2) For long time spans, such as are involved when we look at distant astronomical objects, Setterfield also proposes a function that is essentially the same as the equation for the cosmological redshift. Translated into our terminology, this function is[34]

$$\zeta(t) = k\left[\frac{(1+T)}{\sqrt{1-T^2}} - 1\right] \qquad (8)$$

where k is a constant and T is a time variable that equals 0 today, and 1 at the time of Creation 8,000 years ago. Bridgman has calculated that, based on a correct analysis of Setterfield's model, 1.14×10^6 can be taken as a likely value for k;[35] Setterfield has more recently published a value that is in rough agreement.[36] For comparison purposes, we can write (8) in terms of t and $t_{max} = 8,000$ years:

$$\zeta(t) = k\left[\frac{\left(1+\dfrac{t_{max}-t}{t_{max}}\right)}{\sqrt{1-\left(\dfrac{t_{max}-t}{t_{max}}\right)^2}} - 1\right] \qquad (9)$$

This function has some bizarre features, as noted in an earlier report by Bridgman.[37] First, its derivation is erroneous, as we'll see in Section 5. Furthermore, by substituting $t = t_{max}$ in (9), we observe that the function claims the speed of light today is zero! Finally, it yields enormous values for $c(t)$ in the very recent past: 100 times its present value just one year ago, and 14,000 times its current value in the year 1908! Clearly, a different function must be found to describe the recent past.

(3) For changes in c over the past 250 years, the statistician Alan Montgomery, a Setterfield supporter, claims the data are well-fit by the function (translated into our notation)[38]

$$\zeta(t) = 1 + 1.034 \times 10^{-7}(1967.5 - t_G)^2 \tag{10}$$

where t_G is the Gregorian year. Expressed in terms of the time since Creation (assumed to have occurred in 6000 B.C.E.), Equation (6) is

$$\zeta(t) = 1 + 1.034 \times 10^{-7}(7967.5 - t)^2 \tag{11}$$

Thus, we have the three c-decay functions plotted logarithmically in Figure 4. Setterfield doesn't explain whether these different functions are supposed to be connected to each other, or whether the earlier-presented ones have simply been abandoned. Equation (9) seems to be his current favorite. We might suggest (although here are doing Setterfield's work for him) that Equations (7) and (9) might be spliced together in the vicinity of $t = 1500$ years. Unfortunately, there is still the problem of integrating Equation (11) with the others. It nowhere comes near the other functions. It can't extend all the way back, since even at the Creation it only reaches a value of 7.5 – useless to explain the visibility of the Universe. And Equations (7) and (9) don't work for recent times; Equation (9) gives ridiculously high ζ values for the recent past, and (7) yields negative values for $t > 3005$ years (causing atomic time to run backward). In fairness, it's not clear whether Setterfield has ever endorsed the use of Montgomery's formula Equation (11), but he has spoken glowingly of Montgomery's analysis, and if (11) doesn't describe c-decay in the years after 3005 B.C.E., what function does? Setterfield hasn't put his earlier papers on his website, so it's possible that he no longer endorses the models described in those writings.
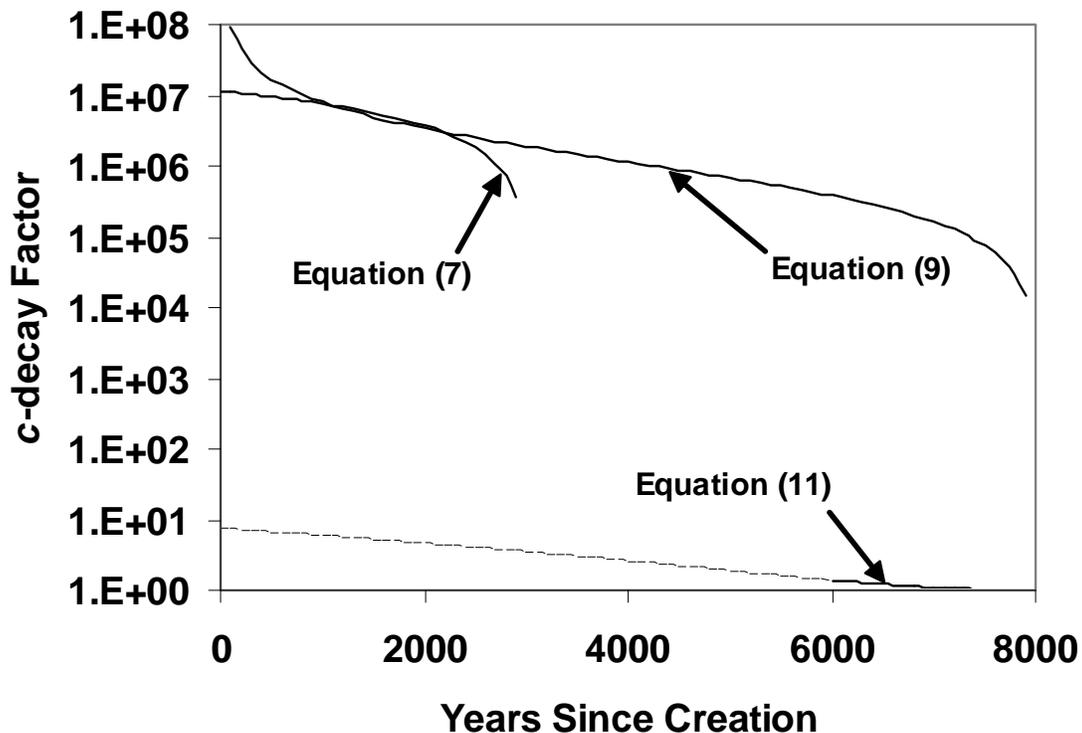

Figure 4. Postulated c-decay functions $\zeta(t)$.

At this point, we abandon the attempt to stitch together a consistent description of *c*-decay from Setterfield's writings. In Section 6, we study astronomical data using ζ values we derive ourselves by requiring that objects in space be visible on Earth. But first, we must confront Setterfield's data (Section 4) and his theoretical work (Section 5).

4 Setterfield's Data
4.1 The Speed of Light

Setterfield bases his theory primarily on astronomical and laboratory measurements of the speed of light and other physical constants. Of course, such measurements were not made in ancient times, so the database is recent, relative to the postulated 8,000-year history of the Universe. Setterfield also attempts to document an oscillation in physical constants, going back to the year 2250 B.C.E., by reference to errors in Carbon-14-derived ages.[39] Scientists, however, generally attribute this effect to variations in the Earth's magnetic field.[40] Furthermore, the *c* variations derived from Carbon-14 data are inconsistent with Setterfield's Biblical timeline (Appendix B), and the C-14 anomalies are, at best, extremely indirect evidence for *c*-decay. Therefore, we won't discuss this "data" source further.

Setterfield and Norman developed the original version of the *c*-decay theory on the basis of historical measurements of the speed of light. Their data were given in detail in their 1987 report.[41]

Setterfield's data plots[42,43] indicate a decrease in *c* beginning with the first data points in the late 17th century. Of course, the validity and accuracy of the data are crucial, and are the basis for a good deal of controversy (largely within the creationist community). Because of the involved claims and counterclaims involved, we won't attempt a complete analysis of these matters, but we will make a few observations.[44]

Setterfield did not use all of the available historical data. Some points were discarded, because they were judged of low quality. Questions were raised about his statistical techniques,[45,46] but Setterfield and others have claimed that Setterfield's and Montgomery's data analysis[47] has withstood such attacks.[48,49]

In Figures 5 and 6, we display the complete set of historical *c* measurements (raw data). Note that many of the points Setterfield ignores (black) would create serious disagreements with the curves of some of his functions for *c*(*t*). In Figure 6, the plotted points with error bars from years 1890-1910, if taken at face value, would suggest a dramatic decline in the speed of light, far more dramatic that any of Setterfield's claims.

It's also instructive to examine the rates of change Setterfield obtains from his own analysis:

Roemer: 28.3 km/s/yr, 36.35 km/s/yr
Foucault: 1.85 km/s/yr
Fizeau: 164 km/s/yr, 2.17 km/s/yr
Bradley: 5.04 km/s/yr

(multiple values for a given experiment reflect different data selection criteria.) These values vary by nearly two orders of magnitude! Such radical ranges of results strongly suggest a systematic experimental effect, *not* an actual variation in the parameter being
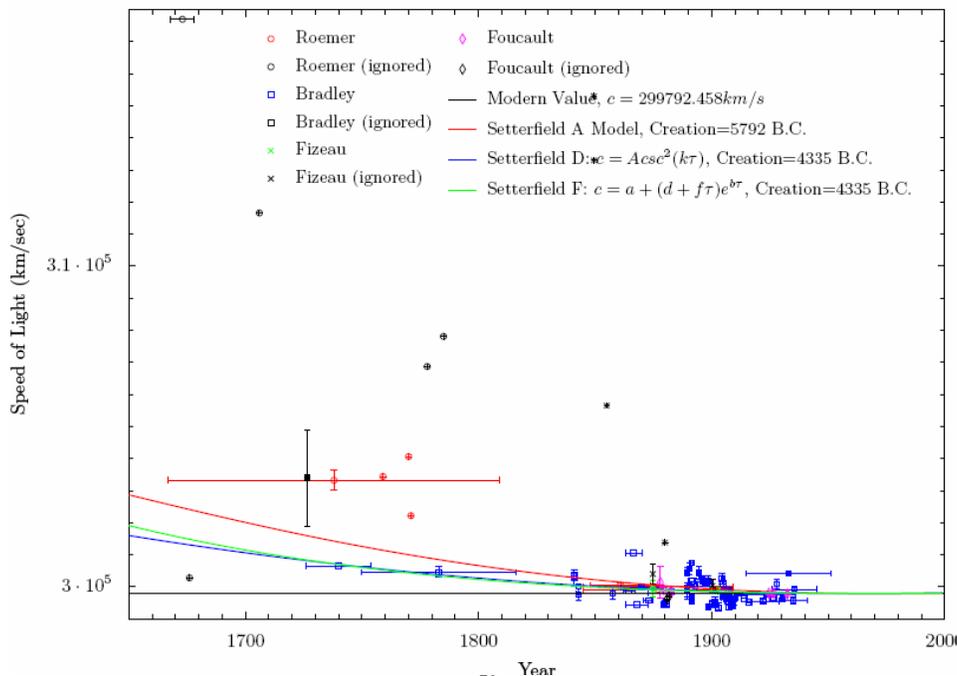
Figure 5. Plot of Setterfield's listed data[50] covering the years 1750-2000 C.E. The symbols separate the data by experiment; color points indicate data Setterfield used while black symbols indicate data Setterfield lists or mentions but are not included in many of his computations. Some of the black (ignored) points occupy the region of the graphic legend. The color curves illustrate several of Setterfield's models.
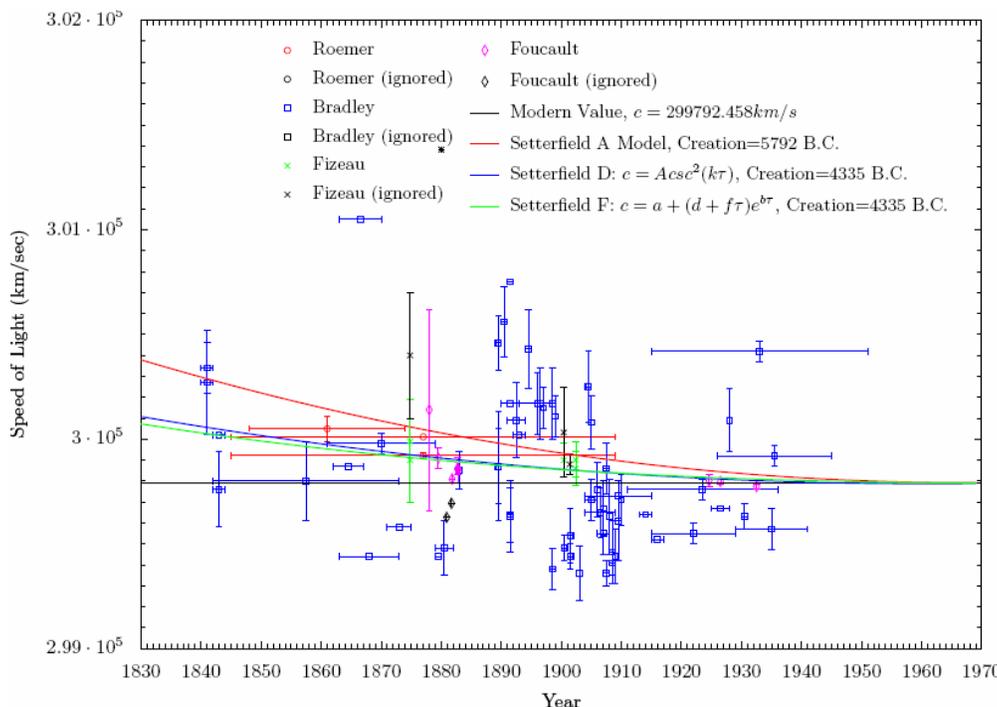

Figure 6. Plot of Setterfield's recent historical data. Same as Figure 5, but an expanded view, covering the years 1830-1970 C.E.

measured. It's also important to recognize for the Roemer- type measurements (timing of eclipses of Jupiter's satellite Io), that the value of the Astronomical Unit used in the speed calculation involved considerable uncertainty, with parallax and transit values obtained that were 10-20% different from the modern values.[51,52] It's interesting that Setterfield has not chosen to interpret the AU experimental errors as an actual variation as well!

Several curve fittings, drawn from Setterfield publications of various vintages, are also shown. Clearly, a number of curves can be drawn through such imprecise data. Most fitting routines will generate curves that satisfy some 'goodness-of-fit' criterion, but this does not mean the resulting curve is truly meaningful. To claim so is to be guilty of over-interpretation. It should be emphasized that the available historical data give no support whatever to claims that c was *millions* of times greater in the distant past. Even if we accept the dubious claim of a change in c over the past 300 years, extrapolating the plot of Figure 5 so far beyond the earliest data point is entirely unjustified.

Basing a radical theory on measurements taken at the dawn of the scientific age is highly questionable. It's impossible to know how much credence to place in 300-year-old data; the problem is especially severe since it is precisely the earliest data points that are most significant for Setterfield's claims. For example, one of the critical data points, dated 1675, has been the subject of controversy, and Setterfield's reference for this point is a personal communication from an astronomer[53] that is, itself, ambiguous.[54]

Setterfield's oldest data points show a speed of light greater than today's accepted value, with a gradual downward trend. But effects like this are sometimes seen with data from the early days of scientific research, when workers were, unfortunately, susceptible to being swayed by illustrious predecessors. In some cases, an experimentalist might discard data that seemed too far away from what he thought was the "right" answer, having honestly convinced himself there was something wrong with the unexpected results. In this way, an earlier mistaken measurement could exert an influence on later reported values. This "intellectual phase locking" is nothing for scientists to be proud of, but it has been known to occur.[55,56]

In any event, it would be most peculiar if c had undergone enormous changes in the prescientific era, experienced relatively small changes in the 17th century, gone on to experience ever-smaller changes that tended to be within the error bars of developing experimental techniques, and settled down to stable values in our own time. Is c-decay leveling off, or are we just getting very good at measuring the speed of light?

It would be excellent, of course, if 21st century technology could settle these questions by detecting (or more likely failing to detect) tiny c variations in the laboratory. Unfortunately, Setterfield maintains that the c-decay has virtually stopped in recent years (without giving any theoretical explanation of why this should be so). Even worse, he says that since today's highly precise physical measurements depend on atomic processes, the c variation is undetectable due to cancellation by the variation in atomic frequencies (Equation (5)).

But there is a way out of this conundrum. Setterfield's theory claims variation in other physical constants besides c, notably the masses of elementary particles and Planck's constant. These constants are measured in the laboratory with high precision. And Setterfield has never argued that variations in these constants are undetectable with modern techniques; indeed, he has claimed that such measurements have shown

variations consistent with his theory as recently as 2004.[57,58] Therefore, it will be instructive to look at the historical measurements of these constants.

4.2 Electron Mass and Planck's Constant

Figure 7 shows the historically-recommended values of electron mass m and Planck's constant h, as given in Setterfield's references[59] as well as some more recent sources.[60,61] In Setterfield's theory, m and h increase with time (Equations (2) and (4)).

In the data, there is a large increase around 1930, and its explanation is instructive. This fluctuation is not "real": it is largely due to an error made by Millikan in his famous oil-drop experiment to measure the charge of the electron.[62] Interpretation of the experimental results required knowledge of the viscosity of air, and Millikan used an erroneous value. What's most important is that this error, in an experiment to measure *electron charge*, caused accompanying errors in the values of *electron mass* and *Planck's constant*. In general, fundamental measurements do not directly yield the value of individual constants. Rather, experimental results depend on some *algebraic combination* of constants; untangling the individual values requires physicists to combine the results of different types of experiments, followed by application of some involved mathematical techniques (as well as occasional educated guesswork).[63,64] Setterfield does not consider this vital fact, and thereby gives the erroneous impression that the fundamental constants are varying together, as his theory predicts. In truth, as the well-documented Millikan example shows, this correlated behavior is a mathematical artifact.

Figure 8 shows the same data as Figure 7, but with expanded vertical scales to allow inspection of more slowly-varying recent values. Here again, some variations are seen. They are understood by physicists, but explaining them involves us in some admittedly mind-numbing technicalities. For example, the changes between 1955 and 1963 are due to a more accurate knowledge of the Faraday constant, a more accurate value of the gyromagnetic ratio of the proton, and elimination of certain x-ray data.[65] Changes between 1963 and 1969 are mostly due to a change in the reported value of the fine-structure constant, and the discarding of some data relating to the proton magnetic moment. But in 1973 it was discovered that the discarding of these data was a mistake, and that, instead, some measurements of the Faraday constant were less accurate than previously thought.[66] The important point here is that the fluctuations in parameter values reflect assessments of analysts after performing detailed studies of *all* reported experimental results. The fact that a parameter changes from one year to the next does not generally signify that someone did an experiment that directly measured that parameter, and got a different value. It often simply reflects the fact that physicists, in reviewing all the data, understood something differently (and usually more correctly).

To get the most useful perspective on this topic, we expand the vertical scales one more time in Figure 9, and also show the error ranges in the values of the two constants.

Here, at last, the story of the "varying" constants reaches its climax. Starting in 1998, we see technology catching up to, and destroying, Setterfield's claims of variations in m and h. The determination of these constants has achieved a phenomenal degree of precision, and as the error ranges fall to less than one part in 10,000,000, the reported values become *rock-steady*. The leveling-off of the variations is testimony to our increasing ability to measure the fundamental parameters of physics. The physical constants are indeed constant.
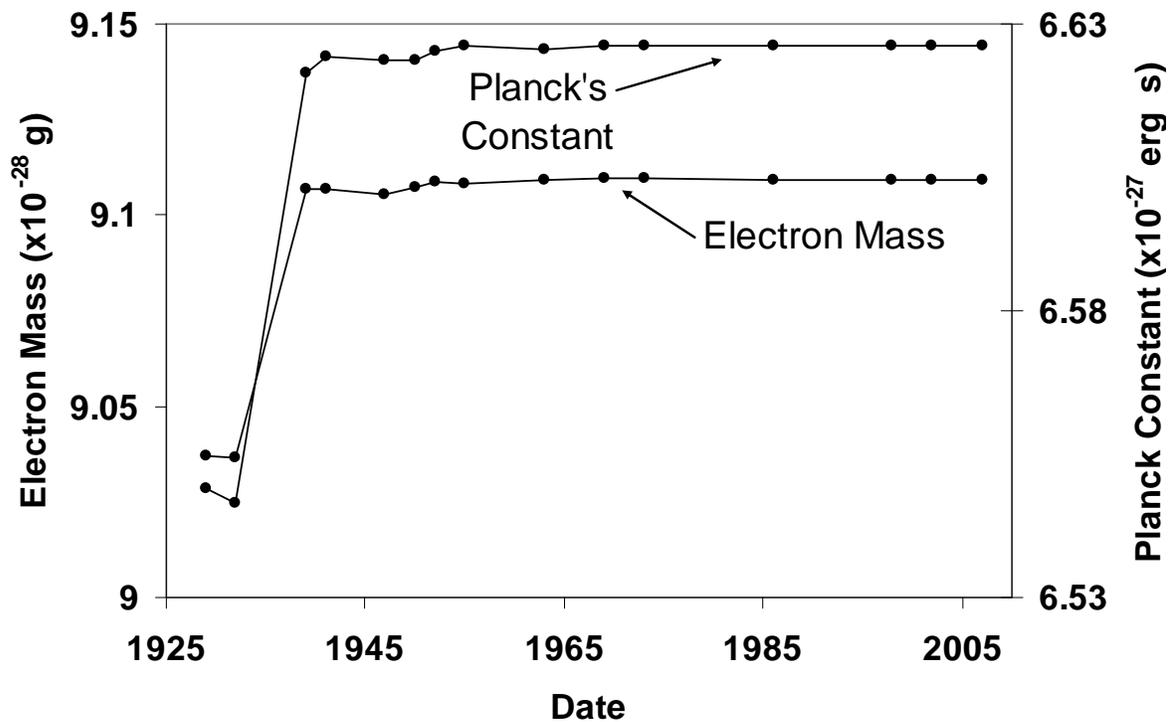
Figure 7. Reported and recommended historic values of electron mass and Planck's constant.
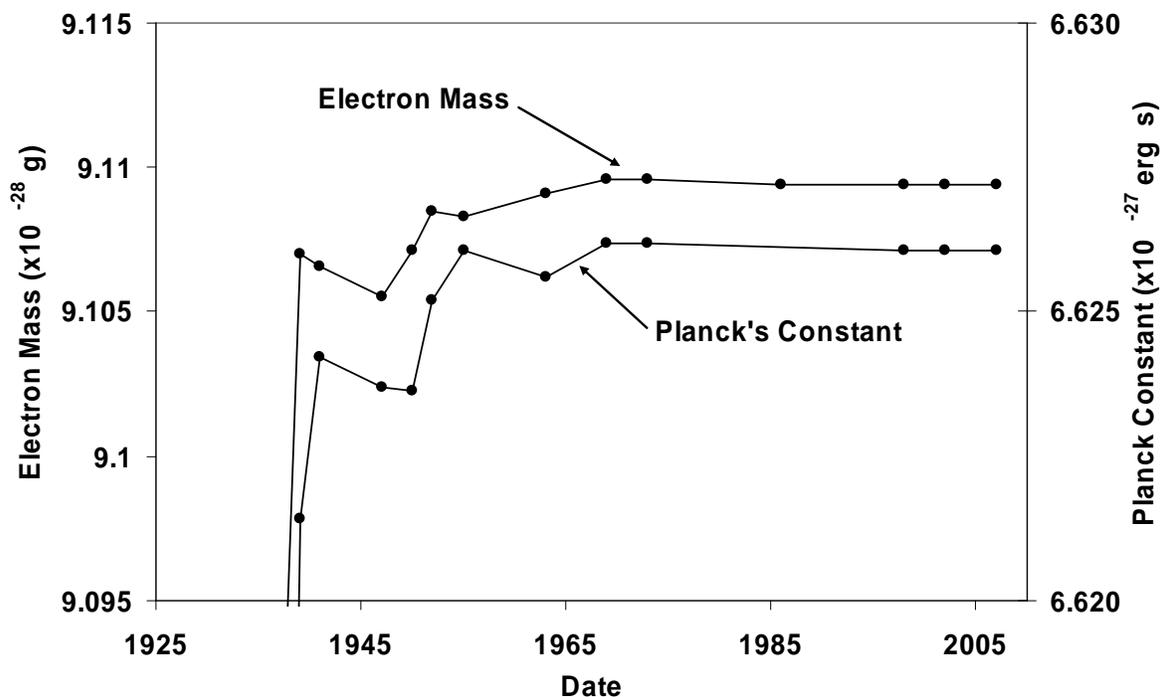

Figure 8. Values of electron mass and Planck's constant (expanded vertical scales to show recent small variations).
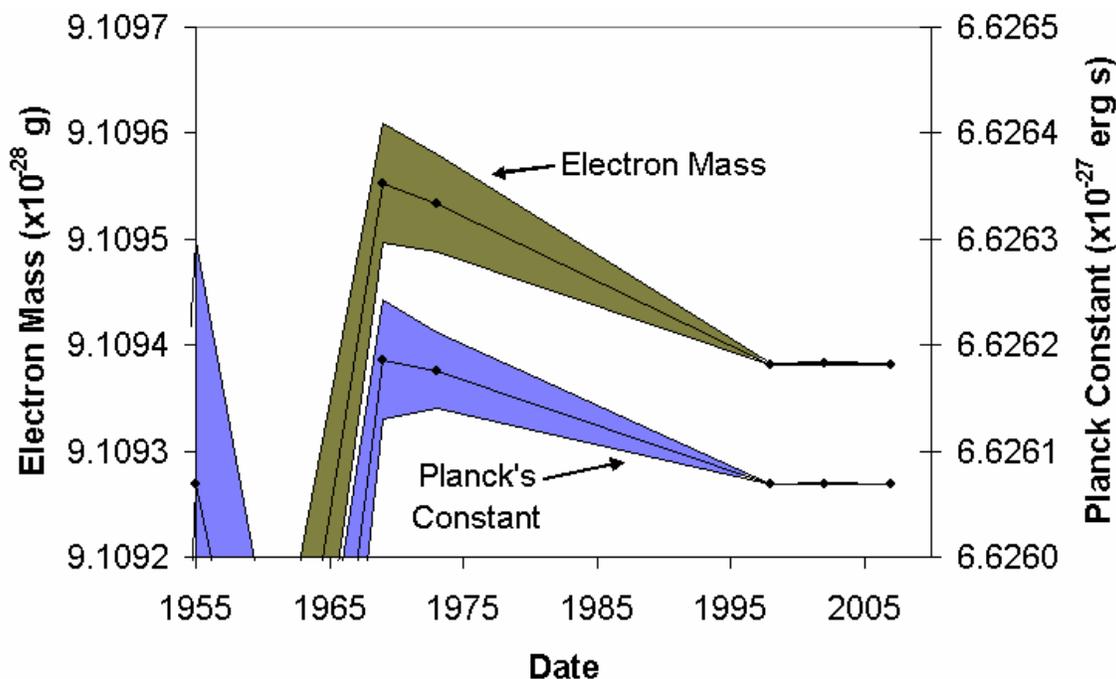
Figure 9. Values of electron mass and Planck's constant (greatly expanded vertical scales) with error ranges.

4.3 A Test of $m \propto h^2$

As can be seen from Equations (2) and (4), Setterfield's theory predicts that the time-varying electron mass and Planck's constant obey the proportionality $m(t) \propto h^2(t)$. Specifically, he claims that the data support the equation[67]

$$m(t) = 0.20748h^2(t). \tag{12}$$

The data we have discussed in this section allow us to test this relationship.

Figures 10 and 11 show (at two scales) the historically recommended values of electron mass, along with values predicted from Setterfield's Equation (12). For comparison, we also show values computed from the equation (*not* derived from Setterfield's work)

$$m(t) = 0.13747h(t) \tag{13}$$

that is, a direct proportionality between $m(t)$ and $h(t)$.

The figures show that Setterfield's prediction, Equation (12), is not a good fit to the measured data. Significantly, the direct proportionality relationship, Equation (13), does a much better job of predicting the electron mass over the entire range of dates shown. Thus, Setterfield's claim that the data are in accord with $m(t) \propto h^2(t)$ is not correct. In fact, the data support the interpretation discussed above: measurements yield algebraic combinations of constants, and variations in the recommended value of one constant cause variations in others due to the mathematical techniques used in unscrambling their values.

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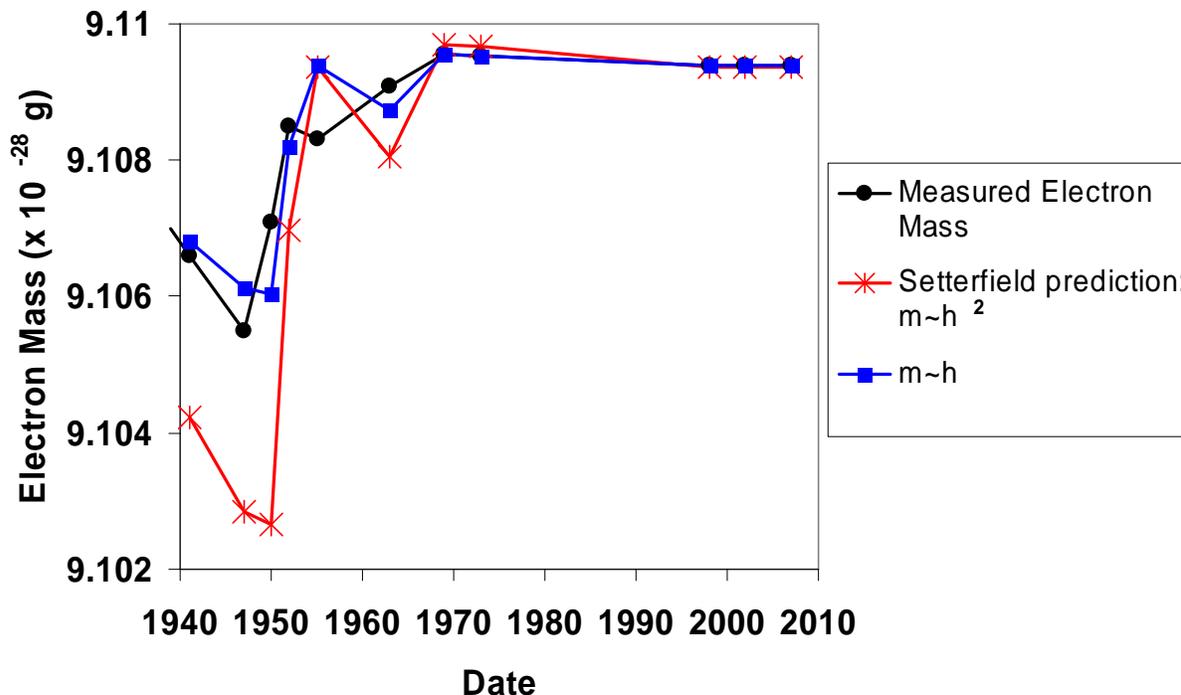
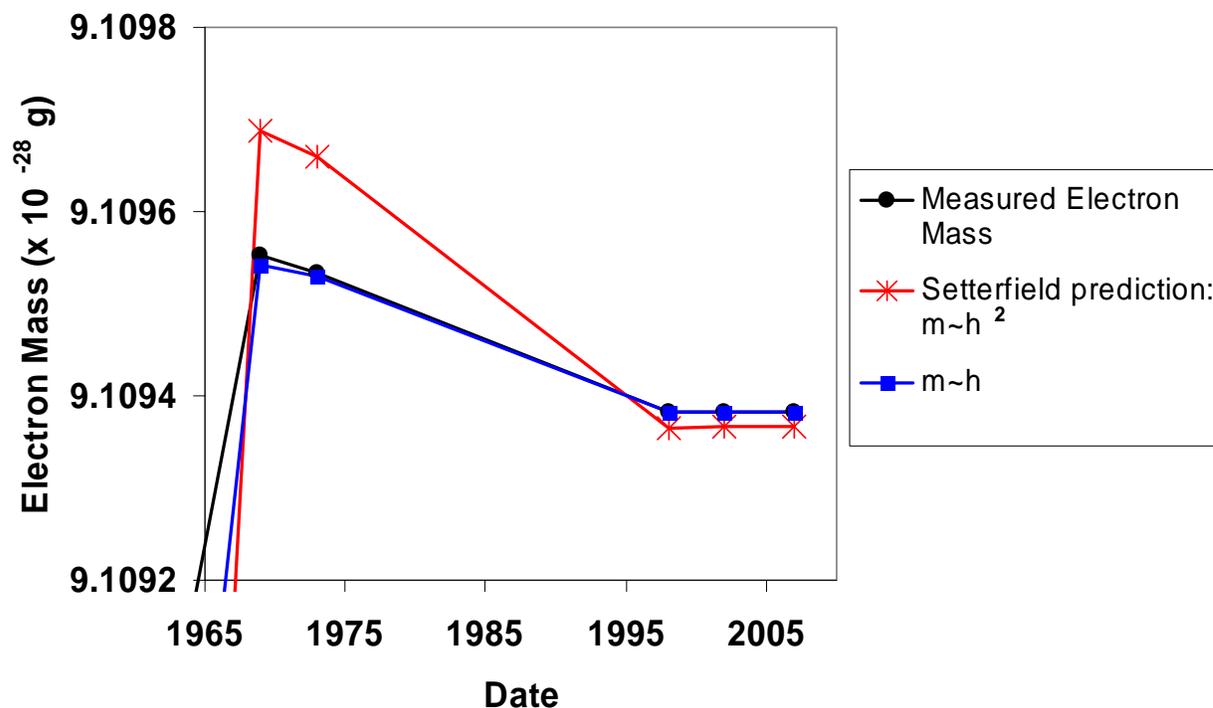**Figure 10. Electron mass from measurement, Setterfield's prediction (12), and non-Setterfield prediction (13), vs. date.**

Figure 11. Electron mass from measurement, Setterfield's prediction (12), and non-Setterfield prediction (13), vs. date (expanded vertical scale).

5 Theory Ex Nihilo: Setterfield's Mathematical Errors

Unlike many creationists who primarily write books for public consumption, Setterfield has produced many writings that, at least outwardly, resemble standard scientific journal papers. The appearance of over a hundred equations in some of these online publications may give the initial impression that his theories have a strong mathematical basis. In truth, Setterfield's theoretical work demonstrates a lack of mathematical understanding, and perhaps an unwillingness or inability to communicate the results of his calculations in a straightforward manner. The theoretical basis for his work is, essentially, nothing. This section discusses a few of these problems; additional issues are complained about in Appendix B.

In his more recent writings, Setterfield places great emphasis on the c-decay function reproduced in our Equation (8). He begins with the standard cosmological equation for redshift z as a function of distance x:

$$1 + z = \frac{1 + x}{\sqrt{1 - x^2}} \qquad (14)$$

Since we look back in time when we look into the distant cosmos, Setterfield equates distance x to time T to obtain[68]

$$1 + z = \frac{1 + T}{\sqrt{1 - T^2}} \qquad (15)$$

The speed of light does not appear explicitly in this substitution because both x and T are normalized to a maximum value of 1. He then claims a relationship between c and redshift to get

$$c(t) = k\frac{1 + T}{\sqrt{1 - T^2}},$$

equivalent to our Equation (8). However, as Bridgman has already pointed out,[69] the only way the transformation from (14) to (15) works is if $x = T$ for all values of x and T. While both x and T will increase as one moves to greater distances, *they will only be directly proportional if the photon speed is constant*. Setterfield has forgotten c variation – the cornerstone of his theory! Although Setterfield is aware of this criticism, he continues to maintain that his calculations are correct.[70]

Setterfield claims to have derived the "quantized redshift" value of 2.67 km/s from his ZPE theory.[71] He starts with an equation from the paper of Puthoff that gives the utilizable power P_u that an atom can absorb from the zero point energy:[72]

$$P_u = \frac{e^2 h \omega^3}{72\pi^2 \varepsilon m c^3} \qquad (16)$$

What Setterfield does next is astonishing. He says that P increases at one of his "quantum jumps" according to

$$P_1 = P_2 + zP_2$$

and, since z is evidently dimensionless, it must equal the dimensionless component of (16), that is $1/72\pi^2$.

This assertion is ridiculous. Would Setterfield say that, since kinetic energy is $\frac{1}{2}mv^2$, and we can write kinetic energy change as $E_1 = E_2 + zE_2$, it follows that kinetic energy can only change by ½?

But Setterfield isn't finished. It seems that z is not equal to $1/72\pi^2$ after all. "That does not exhaust the dimensionless components of P," he asserts. For no apparent reason, he proceeds to equate electron charge e to a proportionality constant d divided by the "surface area of the electron" a to obtain

$$e = \frac{d}{a} = \frac{D}{4\pi}$$

where D is another proportionality constant. Substituting this for e in (16), he obtains the numerical factor $\left(\dfrac{1}{4\pi}\right)^2 \left(\dfrac{1}{72\pi^2}\right) = 8.9 \times 10^{-6}$; after multiplying by c he gets what he's after: the alleged 2.67 km/s quantized redshift.

There is no logic in this procedure. The use of the "surface area of the electron" is entirely arbitrary (why not "cross sectional area"?). And, of course, the dimensionless quantities that appear in Equation (16) result from arbitrary conventions. For example, if he'd written frequency as f instead of angular frequency ω, he'd have picked up three unwanted factors of 2π. Writing (16) in Gaussian cgs units rather than mks would also have changed the dimensionless factors. The fact that he comes close to the desired answer makes one wonder how much time he spent juggling numerical factors!

Having obtained (15), Setterfield wants to derive a population equation for the Planck Particle Pairs (PPPs).[73] He knows the plasma physics equation for the evolution of ion density; as he notes, the time rate of change of the PPP density N should be

$$\frac{dN}{dt} = q - rN^2 \tag{17}$$

where q is the creation rate (by ionization), and r is the recombination coefficient. Thus, the first term on the right hand side of (17) is a "birth rate" and the second term is a "death rate." After two pages of algebra, he obtains

$$\frac{dN}{dt} = k\left(q - rN^2\right), \tag{18}$$

equivalent to (17) except for the easily-overlooked coefficient k. Where did it come from? Half a page earlier, he'd written the equation

$$\frac{dM}{dT} = -\{[1/(2M)] + [M/2]\}, \tag{19}$$

where $\frac{dM}{dT} = -\frac{dN}{dT}$, and followed it with

$$\frac{dM}{dT} = k\{[1/(2M)] + [M/2]\} \tag{20}$$

where k, he says, "is required to be negative." Clearly, k is simply equal to -1. It is inserted between (19) and (20) *for no evident reason*. But substituting -1 for k in (18), we see that his equation is really

$$\frac{dN}{dt} = \left(-q + rN^2 \right) \tag{21}$$

This is the negative of what he needs! Written plainly, it's nonsensical. According to (21), if the birth rate of PPPs is greater than the death rate, $\frac{dN}{dt}$ is negative, that is, the population goes down!

  Setterfield's insertion of the k factor gives his readers the misleading impression that he has successfully derived a population equation of the expected type (17). In fact, his equation (18) has different (and absurd) characteristics, which Setterfield has never acknowledged in his publications.

6 Astronomical Impossibilities

  In this section we'll examine several examples of conflict between predictions of Setterfield's *c*-decay model and astronomical observations. Unfortunately, we are immediately faced with the problem of defining exactly what Setterfield's model is. As noted in Section 3, we have found several different and not-easily-reconciled candidates for the *c*-decay time function, $\zeta(t)$, in Setterfield's writings.

  The specific function is important because we'll be invoking the "slowing-down effect"[74] illustrated in Figs. 1 through 3. As explained in Section 2, the amount of slowing down is simply given by the ratio between $\zeta(t)$ at time of emission and time of reception. For a periodic phenomenon, the period observed is

$$P_{obs} = P_{true}\zeta(t_{em})$$

where P_{true} is the true period of the physical process and t_{em} is the time at which light was emitted (we assume, of course, that the current value of ζ is unity). Since $\zeta(t)$ was greater than one in the distant past, P_{obs} will be greater than the true period. Longer period means that we should observe astronomical events in slow motion. But what shall we assume for $\zeta(t)$?

This question is especially important because Setterfield has tried to dispute astronomical evidence by claiming that *c*-decay does not become noticeable until one gets out past the Magellanic Clouds (hundreds of thousands of light years).[75] In this way, he has dismissed earlier work by Bridgman showing disagreement between various Setterfield *c*-decay functions and variations in rotational and orbital periods of pulsars out to several hundred thousand light years.[76]

We can eliminate the controversy by deriving the *minimum c*-decay factor needed to observe objects at various distances in space. Since Setterfield assumes the Universe to be 8,000 years old, there is no problem with the visibility of objects out to 8,000 light years (to astronomers, of course, this is practically next door). Further out, Setterfield needs to invoke *c*-decay, whether he admits it or not. For example, to see something 16,000 light years away, we would need the *average* speed of light to be twice its current value during the entire time the light was traveling to Earth. Hence, the *minimum* $\zeta(t_{em})$ needed is 2. If *c* decays during the transit of the light, so that the average speed is less than the speed at emission, $\zeta(t_{em})$ would need to be greater.

This idea is illustrated in Figure 12. Here we see examples of two ζ functions that allow us to see an object 16,000 light years away. We assume, to favor Setterfield as much as possible, that the light emission occurred as early as possible, 8,000 years ago. The minimum requirement is for the integrated area under the function to equal 2 x 8,000 – that is, for the average value of the function from 0 to 8,000 years to be 2. Two functions are shown that satisfy this requirement. The "flat" function is most favorable to Setterfield, as it minimizes ζ at the time of emission (with a value of 2 as opposed to 5 for the other function).
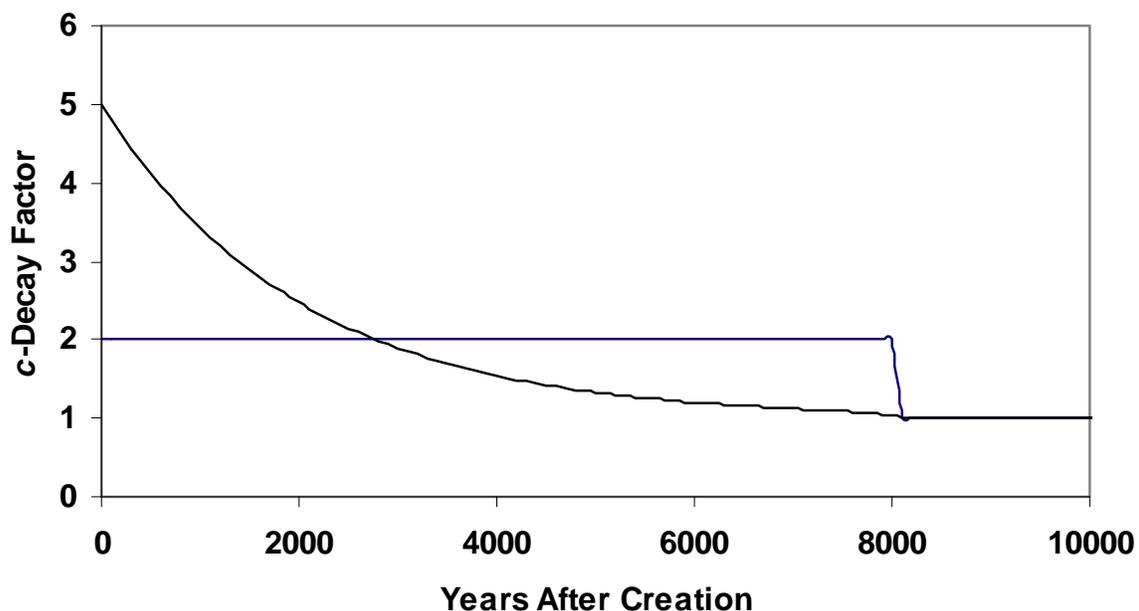

Figure 12. Two possible c-decay (ζ) functions allowing visibility of an object at a distance of 16,000 light years.

Hence, as long as ζ never increases as a function of time, the most conservative value of ζ that allows observation of an object at a given distance is as shown in Figure 13.
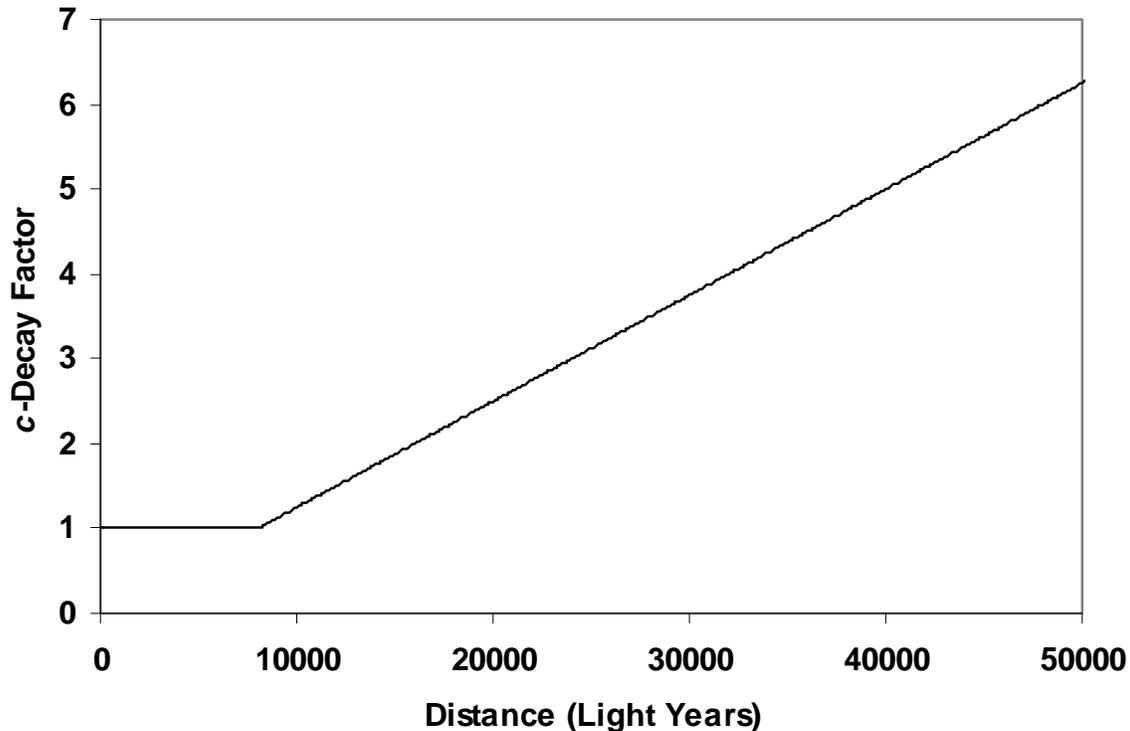

Figure 13. Minimum c-decay (ζ) function at time of emission vs. distance to object.

The minimum $\zeta(t_{em})$ needed, for objects more distant than 8,000 light years, is $D/8,000$, where D is the distance to the object. Clearly, Setterfield is wrong to claim that c-decay is not important within our galaxy, which is 100,000 light years in diameter. To see something on the other side of the galaxy would require a $\zeta(t_{em})$ on the order of 10.

We now present some examples from astronomy that deviate wildly from the deductions we can make from Setterfield's hypothesis. We'll use the minimum $\zeta(t_{em})$ function shown in Figure 13 in our analysis. This minimizes the slowing-down effect to give Setterfield the benefit of every possible doubt.

As the rest of this section shows, we can afford to be generous.

Example 1. Binary Stars. Two stars, orbiting around their common center of mass, have an orbital period P that is related to their mass by Kepler's third law (which still holds in the c-decay scenario because Setterfield needs gravitational acceleration to be a true constant):

$$P^2 = \frac{4\pi^2 a^3}{G(M+m)}$$

where *a* is the semi-major axis of the stars' orbit, and $M + m$ is the total mass of the binary system. If we measure the period, and know the orbital dimensions, we can use this equation to determine the masses of the stars.

Binary stars are observed as far away as the Magellanic Clouds (a distance of over 160,000 light years)[77,78] and M31, the Andromeda Galaxy (2,400,000 light years),[79] and their periods are found to be similar to those observed in the astronomical neighborhood of the Earth.[80] So, if we are seeing these stars in slow motion, they are really orbiting faster than we think, and their masses are greater than those of spectrally similar stars in our galaxy. With a slow-down effect of $2,400,000/8,000 = 300$, the inferred masses of the stars are increased by a factor of $300^2 = 90,000$! But stable stars cannot exist with masses greater than a few hundred times the mass of the Sun.[81] Since Setterfield claims that nuclear reaction cross-sections remain constant (thereby keeping stellar energy production constant), his theoretical assumptions do not contradict this conclusion.

Example 2. Pulsars. Astronomers have detected and studied over a thousand rapidly blinking energy sources, called pulsars, in our galaxy and the Magellanic Clouds. These objects are generally held to be rapidly rotating neutron stars – extremely dense remnants of exploded stars (supernovae). Because they have been compressed by an amazing amount, they have extremely strong magnetic fields that rotate with the rapidly spinning star. The magnetic fields interact with gas in the neighborhood of the star and generate beams of energy, much like the rotating light on top of a police car. We see a flash whenever the beam points in our direction.

Pulsar rotation periods are extremely stable and precise, and for this reason have been extensively studied by astronomers. Periods of over 1,700 pulsars are available for download and study on the website of the Australia Telescope National Facility (ATNF).[82] Figure 14 shows the complete set of pulsar data available from the ATNF. As the figure shows, we have data on many pulsars out to 50,000 light years, and a few even out to 180,000 light years. The Setterfield model predicts a slowing-down effect for these periods, with a maximum effect of $180,000/8,000 = 22.5$. Do we see such an effect in the period vs. distance data?

There doesn't seem to be any upward trend with increasing distance in Figure 14, but the scatter in the plotted data makes it difficult to see whether there is any trend at all. Therefore, in Figure 15 we display a moving average (with a moving interval of 100 points). It's clear that the average pulsar period is constant at about 0.75 over the entire distance range. Figure 15 also shows the prediction that follows from the minimum Setterfield slowing-down effect, as a function of distance. The disagreement is obvious.[83]

The only way for Setterfield to dispute these findings is to claim that pulsar period actually *decreases* (i.e. the rotation speeds up) as a function of distance because of the ζ-function, thereby canceling the slowing-down effect. But there is no reason to think that distant neutron stars rotate more quickly than nearby ones, and such rapid rotation would cause at least some of the pulsars to explode! Setterfield has tried to deflect such issues by claiming that astronomers are wrong about the nature of pulsars. He has suggested that pulsars are not neutron stars, and that neutron stars may not even exist.[84] But imaging of neutron stars and pulsars by the Hubble Space Telescope[85],[86] contradicts such notions, and in any event Setterfield has not explained why *any* proposed pulsar model would have a period that scales with $\zeta(t)$ in the way needed to save his theory.
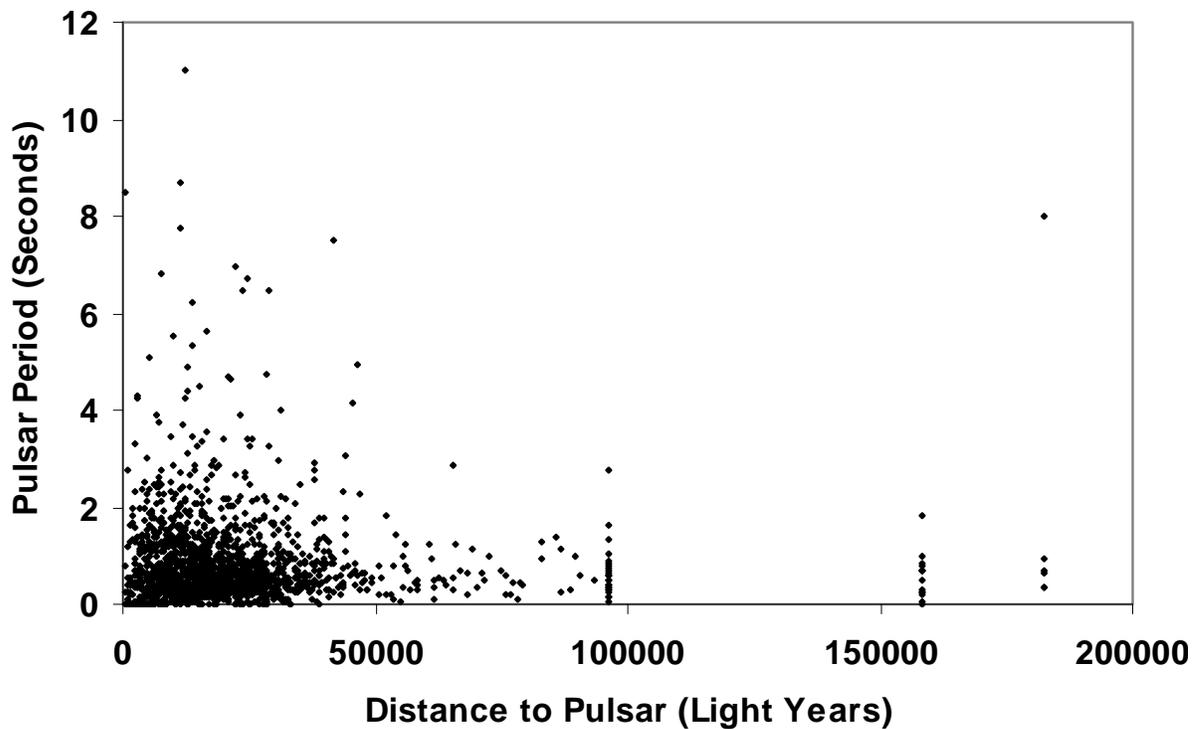
Figure 14. 1,757 pulsars: period vs. distance.
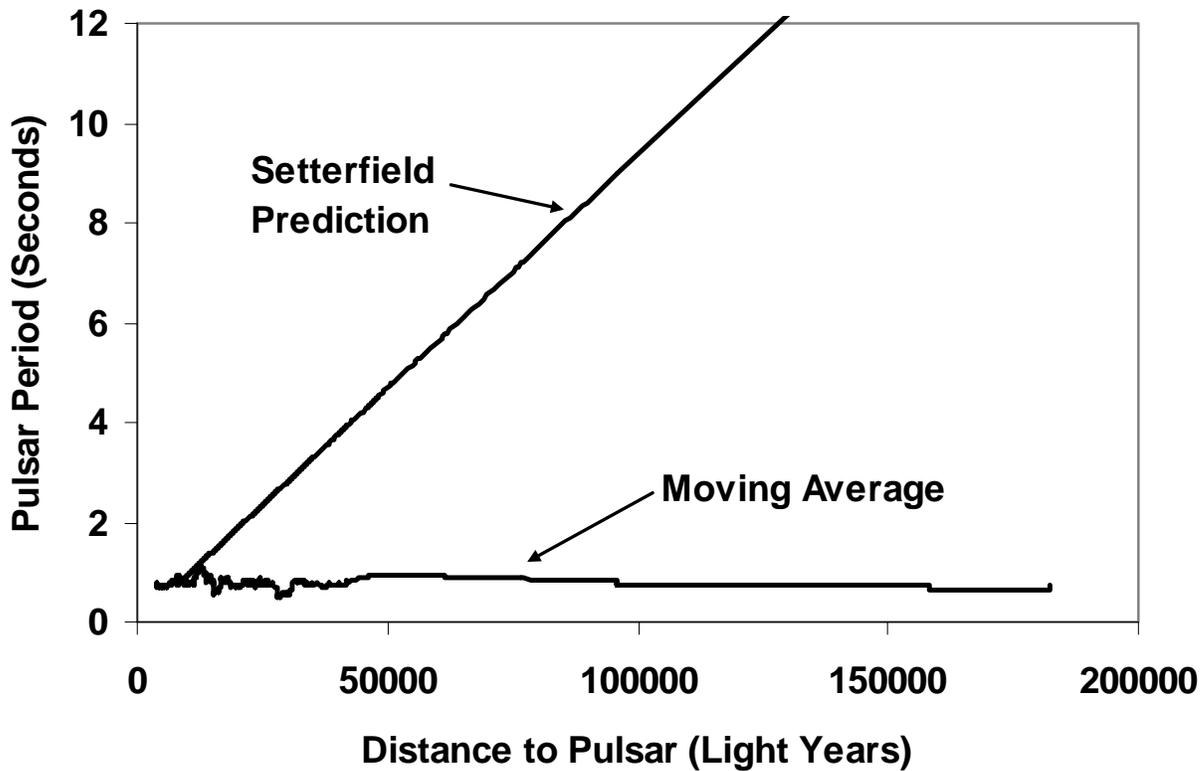
Figure 15. Pulsar period (moving average) vs. distance, compared to Setterfield prediction.

Example 3. Distant Supernovae and Gamma Ray Bursts. Since about 1990, the Supernova Cosmology Project has been using supernovae (exploding stars) to study the expansion of the Universe. As a side benefit of this work, we have a better understanding of how the light emitted by supernovae varies in time. The time record of this emission – the "light curve" – typically rises and falls in about 40 days.

The expansion of the Universe is the critical element of the standard Big Bang theory. Spectra of distant galaxies and quasars show a wavelength increase – the famous "redshift" – that is proportional to distance. This is what would be expected in an expanding Universe, in which the distance between galaxies is steadily increasing.

Setterfield, as well as some more eminent scientific dissidents, disputes the Big Bang model. A few astrophysicists have suggested that a "tired light" phenomenon causes the redshift, and that the Universe is not expanding after all.[87] Setterfield says the energy levels of atoms were different in the past, causing a redshift that mimics what we would see in an expanding Universe.

But the Big Bang theory makes another prediction. In addition to the *wavelength* shift, light pulses from a distant light source should be *stretched out in time*. Because the Universe is expanding, the source is receding from us and so is at a greater distance when the last part of the light is emitted. The last part of the pulse takes more time to reach us, causing an increase in the pulse duration. This effect should be proportional to the emitting object's velocity away from us, and thus also to the redshift and distance.

Supernovae, being visible at great distances, make ideal candidates to test this prediction. As Figure 16 illustrates, a supernova light curve that rises and falls in 40 days will appear to take 80 days if it's far enough away to have a redshift $z = 1$. (A redshift of z means the light's wavelength and duration have been stretched by a factor of $z + 1$.) Recent measurements using Supernova Cosmology Project data show exactly the effect predicted by the Big Bang model.[88] Supernova light emission lasts longer for more distant sources, by as much as a factor of 2, and the normalized width is equal to $z + 1$. The data are shown in Figure 17.

What does the Setterfield theory predict? The *c*-decay slowing-down effect (which is conceptually different and quantitatively much larger than the Big-Bang "stretching" depicted in Figure 16) predicts a tremendous width increase at these distances.[*] This is depicted as "Setterfield Prediction #1" in Figure 17. Setterfield might claim that supernova emission, being dominated by nuclear decay processes, scales with $\zeta(t)$, thereby canceling the slowing-down effect. But this would yield the horizontal line in Figure 17 ("Setterfield Prediction #2"), also not in agreement with the data.

There is little likelihood of a Setterfieldian model of supernova light emission that would harmonize with the data shown in Figure 17.[**] And even if this were done, Setterfield would have to perform the same feat for gamma-ray bursts, since their timescales have also been found to agree with the Big Bang predictions.[89]

Astronomical data of time-varying and periodic phenomena are in stark disagreement with the predictions of Setterfield's theory. But as the next section shows, the failures of his model also strike very close to home.

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[*] The slowing-down effect is given by $\zeta(t)$, which at cosmological distances is supposedly given by Equation (8). The redshift is given by Equation (15). Hence the Setterfield-derived width increase in Figure 17 is $w = kz = 1.14 \times 10^6\, z$ (see discussion following Equation (8)).
[**] For additional discussion, see Appendix D.

Low Velocity
Away from
Earth

Supernova

**Narrow
Light
Pulse**
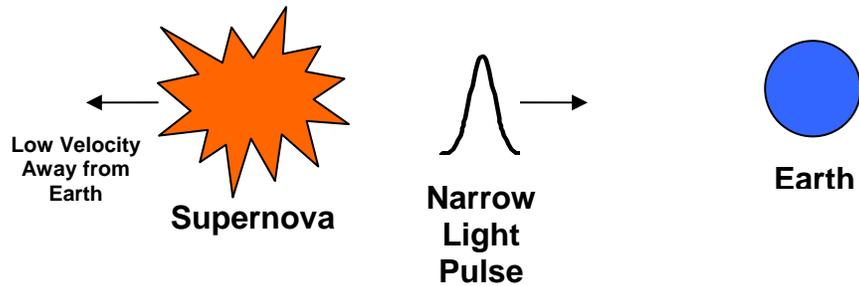
Earth

(a) Nearby supernova, with low velocity away from Earth (low redshift).

High Velocity
Away from
Earth

**Stretched
Light
Pulse**
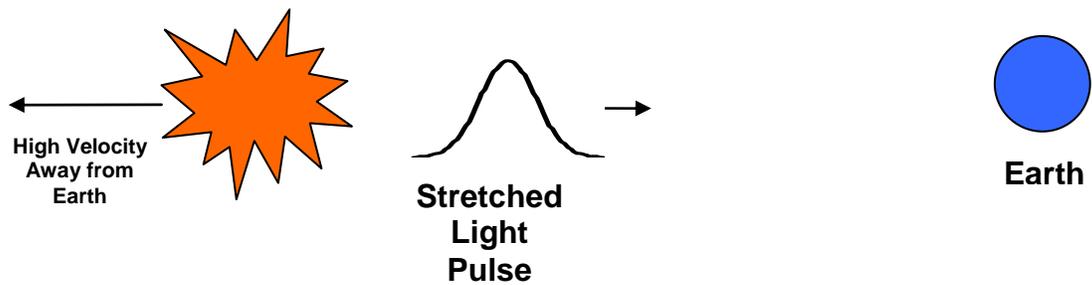
Earth

(b) More distant supernova, with higher velocity away from Earth (high redshift).

**Figure 16. Big-Bang prediction: more distant supernovae will exhibit stretched
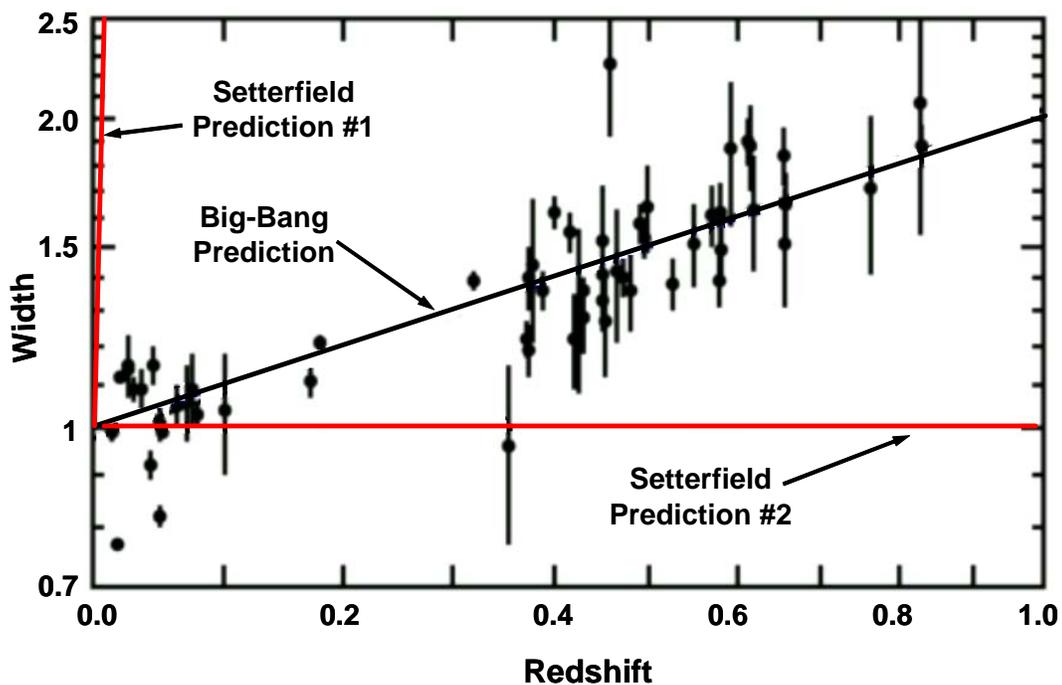(longer duration) light curves.**

Figure 17. Supernova light curve width vs. distance.[90]

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7 The Loss of the Earth's Atmosphere

Setterfield's theory runs into fatal difficulties with the interaction of his atomic and dynamic/gravitational timescales. Gases in gravitational fields, such as stars and planetary atmospheres, provide an excellent "laboratory" for such effects. Here we show, following observations by Kari Tikkanen, that the implications of Setterfield's hypotheses do not always occur in difficult-to-measure distant space.

Molecules in gases do not move at uniform speeds. Through collisions, their speeds are distributed over a wide range in the form of a "Boltzmann distribution." The average molecular velocity is

$$\bar{v} = \sqrt{\frac{8kT}{\pi m}}$$

where k is Boltzmann's constant (1.38×10^{-16} erg K^{-1}), T is temperature, and m is molecular mass. For oxygen ($m = 5.34 \times 10^{-23}$ g) and $T = 270$ K, we find $\bar{v} = 420$ m/s.

The problem occurs when we consider Setterfield's hypothesis that mass varies as $\zeta^2(t)$, according to Equation (2). This means that the average molecular speed was greater in the distant past, varying as (with m as today's value):

$$\bar{v} = \zeta(t)\sqrt{\frac{8kT}{\pi m}}$$

Unfortunately, this creates a severe problem for life on planet Earth. A molecule traveling upward with a velocity greater than the Earth's escape velocity of 11,000 m/s will escape from the planet's gravity, never to return. For oxygen, Figure 18 shows that the average velocity exceeds the escape velocity for ζ values greater than 26.
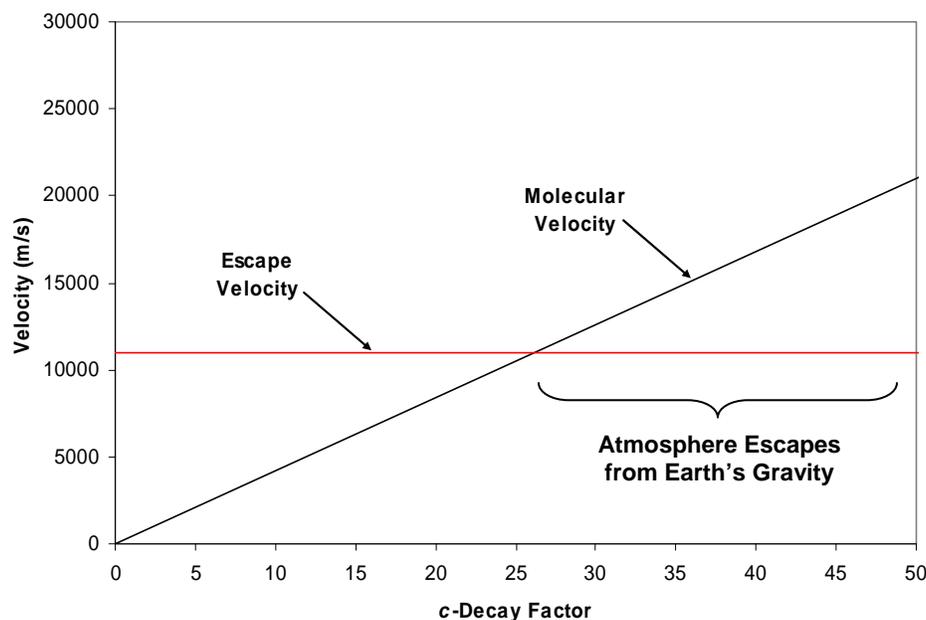

Figure 18. Average molecular velocity of oxygen in the atmosphere vs. *c*-decay factor ζ, compared to escape velocity.

Of course, Setterfield needs ζ to have been vastly greater than this in the past to explain the visibility of distant galaxies in a Universe only 8,000 years old. If $\zeta(t)$ had never exceeded 26 in the past history of his creationist Universe, the most distant object we could see would be at most 26 x 8,000 = 20,800 light years away. We wouldn't even be able to see the nearest galaxies outside our own!

The problem is even more severe than outlined above, because many molecules in the atmosphere have velocities much greater than the average. Hence, the atmosphere would actually leak away to space at *c*-decay factors much less than 26.

To date, Setterfield has not advanced a counterargument to this lethal objection.[91]

8 Summary

Setterfield's published works are scientifically invalid for a number of reasons:

1. Setterfield repeatedly depicts minority or even eccentric scientific viewpoints as well-established or proven. On issues such as the quantized redshift, the effect of ZPE on atomic structure, and calibration of Carbon-14 dating, he rarely acknowledges any evidence in favor of mainstream interpretations.[92] His publications present a distorted view of science, as is so typical of creationist writings.

2. After a quarter-century of work on *c*-decay, Setterfield has not presented a coherent functional form for the change in *c* over the full range of time. This makes it difficult for outsiders to critique his theory, or even to understand exactly what it consists of.

3. Setterfield claims fundamental physical constants to be varying without acknowledging known systematic errors and reinterpretations of data that explain these variations. He generally ignores the error ranges of the measurements. He interprets the leveling-off of the recommended values as a physical effect, rather than acknowledging the correlation between the increasing stability of the values and the improving accuracy of the measurements. He claims to have found variations in m and h that track each other temporally in agreement with his theory, but the data do not support this claim. He ignores the fact that the measurements of these quantities are not independent. Errors in measurement of one quantity affect the others in a way that partially mimics his predictions, but this is a mathematical artifact rather than a physical reality.

4. There are numerous non sequiturs, misstatements, and errors in his mathematical work.

5. Astronomical observations of binary stars, pulsars, distant supernovae, and gamma ray bursts fail to show the slowing-down effect one would expect if his theory were correct. He claims that *c*-decay effects are not observable for objects within our galaxy, but this is inconsistent with his position that the Universe is 8,000 years old.

6. His theory cannot explain the Earth's ability to keep an atmosphere in the past, when atomic masses would have been much less.

The speed of light has not changed.

The visible Universe is enormous. The Andromeda Galaxy, visible to the naked eye, is over two million light years away. We see it as it was when *Homo sapiens* was just about to branch off from our australopithecine ancestors.

We can trust the testimony of our senses, and the extension of our senses provided by technology. The Hubble Space Telescope has shown us images of distant galaxies – images made by capturing photons that have been traveling for billions of years. The Universe really is that old.

Our analysis of c-decay has been a case study in creationist debunking. Setterfield is clearly and spectacularly wrong, and he is not an anomaly. Similar analyses have been done of other creationist claims, with similar results. The work of "creation scientists" is always wrong, because they are trying to prove something that isn't true.

For the first time in history, we understand the spatial and temporal magnitude of the Universe we live in. The discoveries of scientists are our hard-won, common heritage.

Scientists will not be distracted by the errors of Setterfield and others who perform similar creationist "research." But every day, well-funded creationist organizations promote their carefully filtered half-truths to the general public, demanding that religious believers choose between established science and God. Anyone who supports public understanding of science, anyone who is a Christian, or anyone who has come to care about someone who is a Christian, needs to see creationism, and science, for what they really are. We hope this report has helped you to do that.

9 Concluding Words

Usually, even a non-Christian knows something about the earth, the heavens, and the other elements of this world, about the motion and orbit of the stars and even their size and relative positions, about the predictable eclipses of the sun and moon, the cycles of the years and the seasons, about the kinds of animals, shrubs, stones, and so forth, and this knowledge he holds to as being certain from reason and experience. Now, it is a disgraceful and dangerous thing for an infidel to hear a Christian, presumably giving the meaning of Holy Scripture, talking nonsense on these topics; and we should take all means to prevent such an embarrassing situation, in which people show up vast ignorance in a Christian and laugh it to scorn. The shame is not so much that an ignorant individual is derided, but that people outside the household of faith think our sacred writers held such opinions, and, to the great loss of those for whose salvation we toil, the writers of our Scripture are criticized and rejected as unlearned men. If they find a Christian mistaken in a field which they themselves know well and hear him maintaining his foolish opinions about our books, how are they going to believe those books in matters concerning the resurrection of the dead, the hope of eternal life, and the kingdom of heaven, when they think their pages are full of falsehoods and on facts which they themselves have learnt from experience and the light of reason? Reckless and incompetent expounders of Holy Scripture bring untold trouble and sorrow on their wiser brethren when they are caught in one of their mischievous false opinions and are taken to task by those who are not bound by the authority of our sacred books. For then, to defend their utterly foolish and obviously untrue statements, they will try to call upon Holy Scripture for proof and even recite from memory many passages which they think support their position, although *they understand neither what they say nor the things about which they make assertion.* [1 Timothy 1:7] [93]

Appendix A: Derivation of Equation (7)

Setterfield gives our Equation (6):

$$d = 1905 t_s{}^2 + 6.3 \times 10^7$$

where d is "atomic age" (as read by the allegedly fast-running atomic clocks) and t_s is the date B.C.E. minus 3005 years. He doesn't display the $\zeta(t)$ that corresponds to this equation, but it's not too difficult to derive it. First, we note that t_s in the above equation is the date B.C.E., minus 3005 years. Thus, t_s is related to Gregorian time t_G by

$$t_s = t_G + 3005$$

For example, 3005 B.C.E. is equivalent to $t_G = $ -3005, so the corresponding $t_s = 0$. Converting to t, the time in years since the Creation (assumed to have occurred in 6000 B.C.E.), we have

$$t = t_s + 2995$$

We can then write

$$d = 1905(t - 2995)^2 + 6.3 \times 10^7$$

which works out to

$$d = 1905 t^2 - 1.14 \times 10^7 t + 1.715 \times 10^{10}$$

This gives us the *age* registered on an atomic system that originated at a given time. For example, for the Creation itself, $t = 0$ and $d = 17$ billion years. We can convert to σ, the atomic *time coordinate*, by the relation

$$\sigma = 1.715 \times 10^{10} - d$$

so that

$$\sigma = -1905 t^2 + 1.14 \times 10^7 t \tag{22}$$

Since $\zeta(t) = \dfrac{d\sigma}{dt}$ (as explained by Bridgman[94]),

$$\zeta(t) = -3810 t + 1.14 \times 10^7,$$

which is our Equation (7).

Appendix B: A Biblical Timescale

Setterfield's writings refer to "atomic" and "dynamical" time. The former is what an atomic clock would show; it is not "real" time because atomic frequencies have allegedly varied according to Equation (5). Dynamical time is what would be marked by a mechanical clock, an orbiting planetary system, etc., and, as the "true" timescale, is consistent with the 8,000-year-old Biblical story of the Earth's history.

Material on Setterfield's website includes a table mapping "atomic" times onto the truncated "dynamical" or "Biblical" time scale.[95] Values derived from this source are shown below.

Time (Biblical)	Time (Atomic)	c-Decay Factor
0	0.00E+00	
466	3.43E+09	7360515.021
696	4.20E+09	3347826.087
1216	5.50E+09	2500000
2133	7.10E+09	1744820.065
2350	7.40E+09	1382488.479
2392	7.46E+09	1380952.381
2433	7.51E+09	1317073.171
2468	7.56E+09	1285714.286
2489	7.58E+09	1285714.286
2533	7.64E+09	1295454.545
2579	7.70E+09	1304347.826
2628	7.75E+09	979591.8367
2671	7.80E+09	1186046.512
2718	7.85E+09	1148936.17
2787	7.93E+09	1166666.667
2822	7.98E+09	1214285.714
2910	8.00E+09	511382.1138
2946	8.00E+09	170887.0968
3465	8.00E+09	3480.433526

Figure 19 compares these values to Equation (22), the formula we derived from Setterfield's equation in Appendix A. The points and the theoretical curve don't coincide; it's not clear where Setterfield got the numbers above but it apparently wasn't by applying Equation (22)!

We can compute the c-decay factor $\zeta(t)$ from the above values, in the manner explained in Appendix A. Results are shown in Figure 20, and compared to the theoretical models discussed in Section 3.

There is some correlation between Setterfield's tabulated values and Equations (7) and (9). The table allows us to derive one point at approximately 3500 years after Creation (c. 2500 B.C.E.), in the zone uncovered by any of Setterfield's equations. Although this point seems to be making a transition between the "cosmological" and "historical" regimes, it is not explained by any theoretical model, and its origin is unknown. Since Setterfield has claimed, based on Carbon-14 data, that "the speed of light was lower than its current value in BC times," and his C-14 plot shows $\zeta \approx 0.78$ (as opposed to 3,480) in 2550 B.C.E.,[96] the values in the table above are in conflict with his C-14-derived claims.
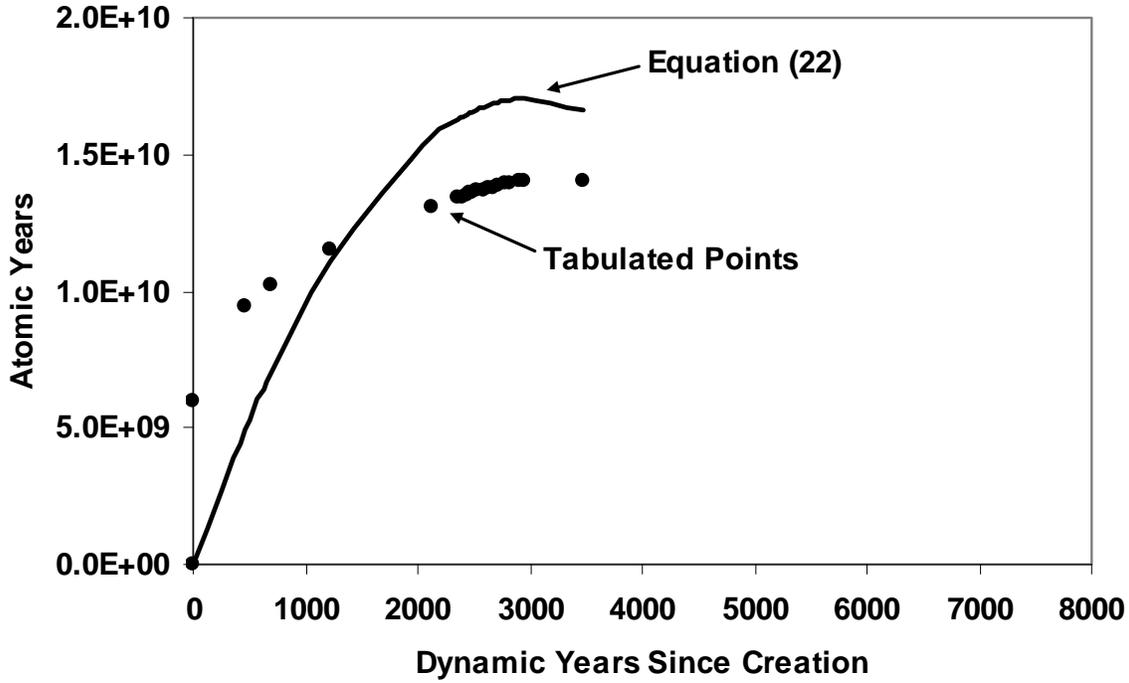
Figure 19. Setterfield's data, converted to "years since Creation" and compared to Equation (22).
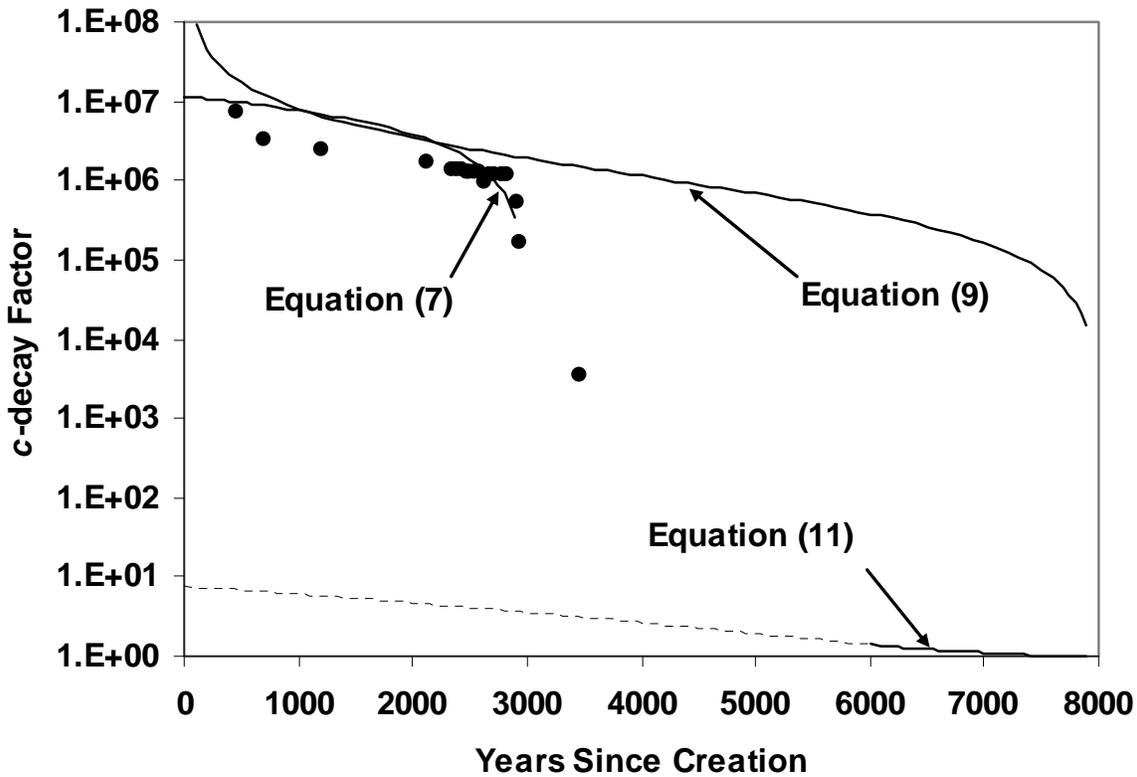
Figure 20. *c*-decay factors derived from tabulated values, compared to theoretical models.

Appendix C: Additional Theoretical Difficulties

The derivation leading up to the equation we reproduce above as (16) contains an error in basic calculus. Setterfield writes[97]

$$M = \frac{\left(1 - T^2\right)^{\frac{1}{2}}}{1 + T} \tag{23}$$

and takes the derivative to obtain

$$\frac{dM}{dT} = \frac{-2T\left(1 - T^2\right)^{-\frac{1}{2}}(1 + T) - 1\left(1 - T^2\right)^{\frac{1}{2}}}{(1 + T)^2} \tag{24}$$

But (24) is *not* the derivative of (23). The correct derivative is

$$\frac{dM}{dT} = \frac{-T\left(1 - T^2\right)^{-\frac{1}{2}}(1 + T) - 1\left(1 - T^2\right)^{\frac{1}{2}}}{(1 + T)^2}$$

Setterfield has acknowledged this error; for discussion see Appendix D.

In the development that follows the calculus error, and that leads to the equation we reproduce as (18), Setterfield performs some outrageous algebraic maneuvers. The introduction of the coefficient *k*, discussed in Section 5, is only part of the story.

Recall that Setterfield is trying to derive a population equation for PPPs:

$$\frac{dN}{dt} = q - rN^2 \tag{25}$$

Since Setterfield is assuming two-body recombination, he correctly assumes the recombination term should include a factor of N^2. Unfortunately, he gets[98]

$$\frac{dN}{dt} = k\left\{\frac{1}{2(A - N)} + \frac{A}{2} - \frac{N}{2}\right\}$$

where *A* is a constant. Not an N^2 in the equation, but that's apparently not enough to stump a creative (creationist) mathematician! Setterfield now multiplies the last term by *N/N* and, after a few substitutions and definitions in the first two terms, gets

$$\frac{dN}{dt} = k\left\{\left[\frac{1}{2M} + B\right] - \left[\frac{1}{2N}\right]\left[\frac{N^2}{1}\right]\right\}$$

The first term in square brackets gets equated to the ionization rate q in (25)…and now for the finishing touch. Setterfield defines r to be $\dfrac{1}{2N}$, yielding, as desired, Equation (25)! Of course, incorporating one of the N's into the recombination coefficient is pure sleight-of-hand. In reality, the second term is still $\dfrac{N}{2}$, meaning that recombination is proportional to the *first* power of N. If this equation were correct, Setterfield would have *disproved* his assertion that the loss of PPPs is due to two-body recombination. But in truth, nothing is established because none of these calculations make any sense.

There is nothing concealed here – Setterfield states exactly what he's doing. And since what he's doing wouldn't fool an alert high-school algebra teacher, it's probably not meant to be deceptive. Similarly, Setterfield's introduction of the k factor that we discussed in Section 5 is probably the result of naiveté, rather than subterfuge. Apparently, Setterfield really does think math is this easy – if you get something you don't like in an equation, just rename it, and everything's fine!

A recent (2007) online publication, "Behavior of the Zero Point Energy and Atomic Constants," discusses some of Setterfield's ideas in a more connected, detailed form than what was formerly available. Unfortunately, clarity of exposition works to Setterfield's disadvantage; the new work reveals new holes in his thinking. To illustrate this, we'll cite his treatment of the physics behind the redshift quantization process.

Recall that m, h, and c allegedly vary continuously with time, as described by Equations (1) through (4). This is caused by a continuous increase in zero point energy (ZPE). There are also discontinuous changes in atomic energy levels, which are triggered when the cumulative ZPE exceeds a certain threshold. These energy level changes allegedly cause the (quantized) cosmological redshift.

Setterfield says that the values of c and h are determined by ZPE strength, which varies slowly and continuously. These quantities experience no sudden changes during "quantum jumps."[99] Since atomic orbit energies change, he then asserts that the particle (parton) mass, m, must be the one thing that changes discontinuously at the jump. This seems a bit arbitrary, and also confusing, since one might attribute the energy changes to the change in orbit-sustaining ZPE input (he quotes Puthoff "…the ground state of the hydrogen atom can be precisely defined as resulting from a dynamic equilibrium between radiation emitted due to acceleration of the electron in its ground state orbit and radiation absorbed from the zero-point fluctuations…").[100] In any event, the redshift is attributed to changes in m, and Setterfield explains this in terms of electron volume, and "jiggling."

Electron size is allegedly determined by the density of ZPE. As ZPE increases with time, so the electron volume increases. Now mass supposedly has its origin in kinetic energy input from the "jiggling" effects of ZPE waves. Larger electrons have *less* mass, because they interact with long-wavelength components of the ZPE, and since ZPE energy density goes down as wavelength goes up, "there are fewer ZPE waves of the longer wavelengths needed to get the parton to resonate or 'jiggle'."[101] A resonance effect like this should depend on particle radius, but Setterfield slips in the assumption that the resonant frequency is proportional to *volume*. (Is there *any* resonance effect in physics that behaves like this?) Setterfield presses on to conclude that, at the quantum

jump, mass increases by a factor of 1.00000878256 (no one can say his theory isn't precise!).

Setterfield says that m has increased continuously during the periods between quantum jumps, in accordance with Equation (2). This variation results in no changes in atomic observables like the Bohr radius and emitted spectra, because of cancellation by the simultaneous changes in the other fundamental parameters. At the quantum jumps, however, m decreases without corresponding changes in c or h. As a result, at each jump the Bohr radius increases by a factor of 1.00000878256.[102] Now, according to Lambert Dolphin, Setterfield has estimated that there have been a total of 500,000 quantum jumps since Creation.[103] Therefore, during the history of the Universe the Bohr radius has increased by a factor of $1.00000878256^{\,500,000} = 80$. It's hard to see how atoms could puff up by almost two orders of magnitude without serious, and observable, consequences in various domains of physics. In particular, if molecules and crystals, and therefore bulk materials, also have increased in size by this factor (as they surely must), we conclude that planets, not to mention people, must have been tiny in the past! (Were Adam and Eve less than an inch tall?)[*] But back to Setterfield's paper…

Now for the atomic energy level changes! Setterfield uses the Bohr atom energy formula, which for hydrogen ($Z = 1$) is:

$$E_n = -\frac{2\pi^2 m e^4}{h^2 n^2} \tag{26}$$

and concludes that, at the quantum jump, m decreases, so $|E_n|$ decreases. But, he says, the minus sign causes atomic energy levels to *increase* (become less negative) at the jump. He says this gives the redshift that is observed; in the past, atomic orbital energies were more negative (smaller), so emitted light had lower energy. As we look into the distant Universe, we see earlier epochs when the electron mass was greater and wavelengths were lengthened, relative to what we observe in the laboratory today.

This is completely wrong. The minus sign in Equation (26) has no consequence in spectroscopy, because photon energies depend on the *differences* between energy levels. The frequency associated with a photon resulting from a transition between two atomic states n_1 and n_2 (with $n_1 > n_2$), as shown in Figure 21, is

$$\upsilon_{12} = \frac{E_1 - E_2}{h} = \frac{1}{h}\left(\frac{2\pi^2 m e^4}{h^2 n_2^2} - \frac{2\pi^2 m e^4}{h^2 n_1^2}\right) = \frac{2\pi^2 m e^4}{h^3}\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) \tag{27}$$

Greater particle masses mean greater photon energy and higher frequencies.[**] And, since $\lambda = c/\upsilon$, decreasing m at the quantum jump causes λ to *increase*. As shown in Figure 22, Setterfield asserts that particle mass goes down in a stepwise manner as a function of

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[*] Setterfield has reversed himself on the issue of mass change; he now maintains that mass increases, rather than decreases, at quantum jumps. This means that solid objects, including planets, would have been *bigger* in the past. For a discussion of how this invalidates Setterfield's new version of c-decay, see Appendix D.
[**] This is confirmed by observations of muonic atoms, in which an orbital electron has been replaced by a muon. The muon is 207 times more massive than the electron, and so emitted frequencies from transitions in muonic atoms are much higher, typically in the x-ray part of the spectrum.

time, and from Equation (27) we find a corresponding decrease in photon energy, and an increase in wavelength. Since when we look into space we look back in time, this means that there should be a *blue* shift, rather than a redshift, as we look at distant objects!

Setterfield has acknowledged this error and modified his theory; for discussion see Appendix D.

This discussion has only scratched the surface of Setterfield's errors, ambiguities, and self-contradictions. For example, his 2007 document includes another derivation of the 2.67 km/s redshift factor, using yet another numerological argument using dimensionless numbers, analogous to what we described in Section 5. We spare the reader further description of this work, confident in the belief that we have already made our point in excruciating detail.
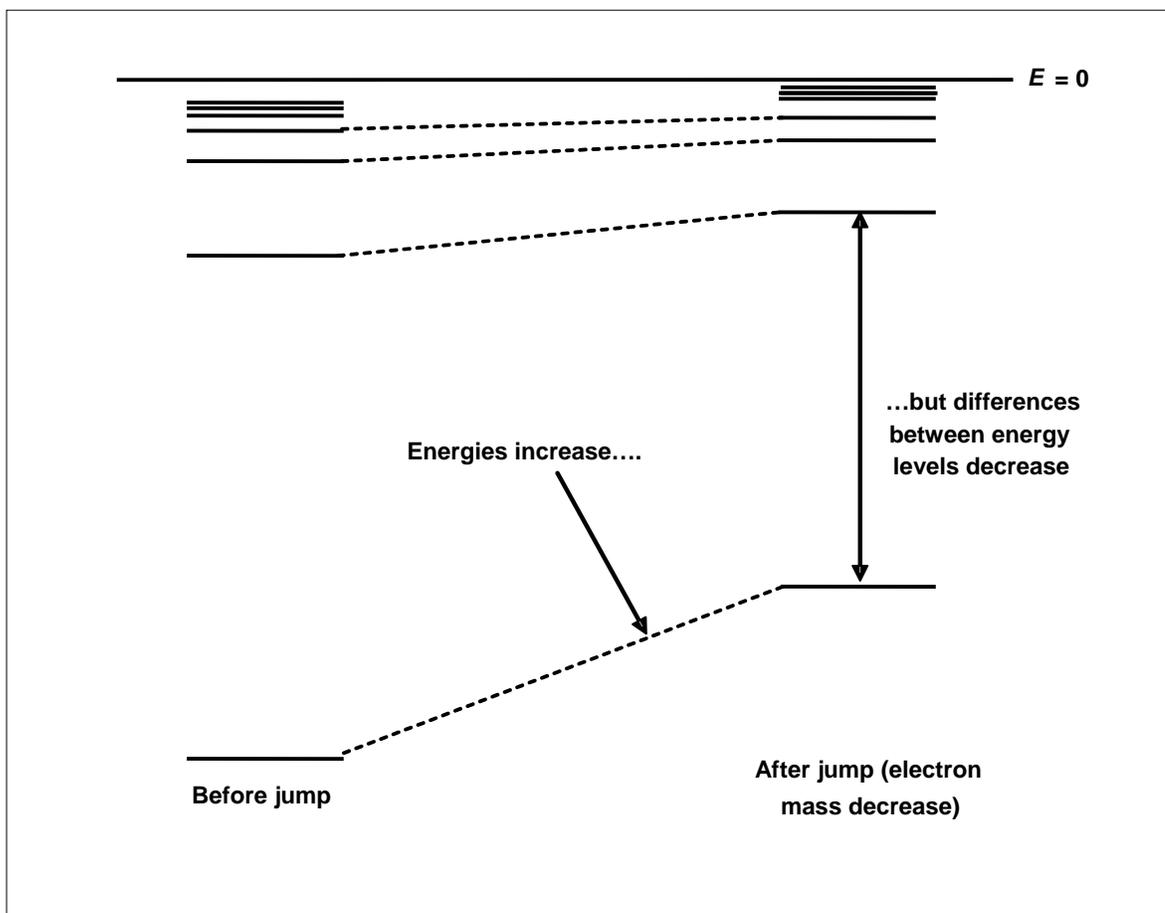

Figure 21. Atomic energy levels before and after speculated "quantum jump."
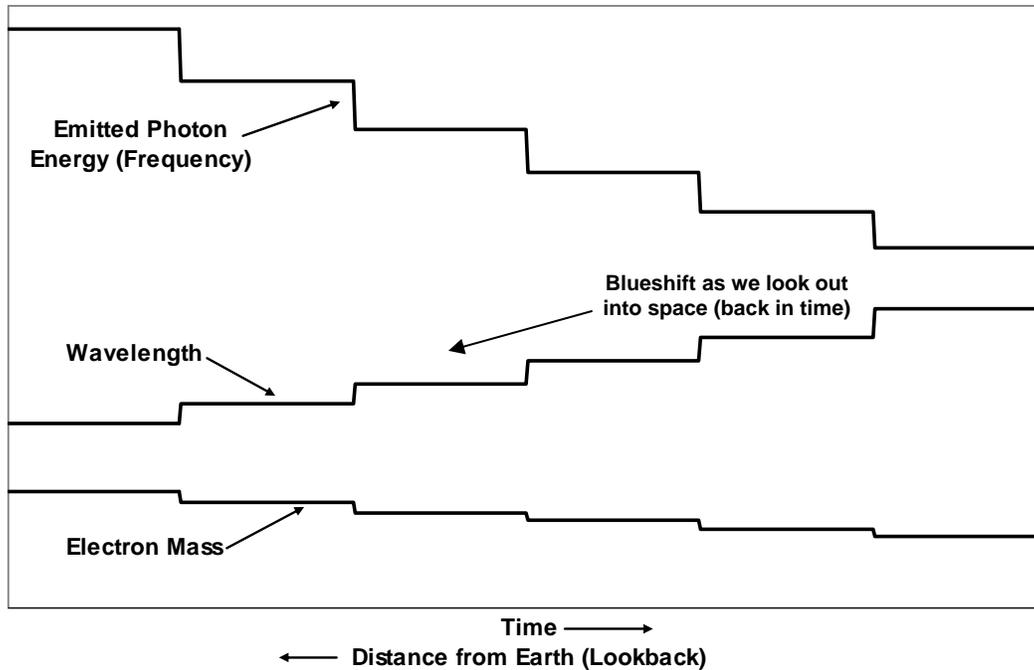
Figure 22. Illustration of changes in electron mass, as deduced from Setterfield's assertions, and photon energy and wavelength from Equation (28). Electron mass decreases in stepwise fashion, with long time intervals between steps. Mass also increases continuously with time; although this effect is greater than the stepwise decrease, it has no observable spectroscopic consequences and so is not shown.

Appendix D: Recent Developments

In June 2007, this document was posted on W. T. Bridgman's "Dealing with Creationism in Astronomy" website (http://homepage.mac.com/cygnusx1). At that time, Salvador Cordova, an Intelligent Design proponent in the Northern Virginia area, was starting up a creationist-oriented site (www.youngcosmos.com) that includes a blog and a discussion forum. Cordova expressed a desire to expose the *c*-decay theory (for which he felt some personal enthusiasm) to critical scrutiny, and he therefore included a link to this document on his youngcosmos site. Over the next several months, Cordova and others posted responses to some of our criticisms of *c*-decay, and one of us (G.P.J.) participated actively in the discussions.

Perhaps because of an existing cordial relationship with Cordova, Barry Setterfield joined the website discussions and engaged in defense of his theory. Although to date he has not shown evidence of having read this monograph, he did attempt to argue with criticisms made in the online posts. To our knowledge, this may represent Setterfield's most extensive and protracted participation in a debate with noncreationist critics about the merits of his work.

Some of the first discussions centered on the calculus error pointed out in our Appendix C. Setterfield at first maintained that he didn't think there was likely to be an

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error, since his work had been checked by a mathematician and a physicist. The precise nature of the error was communicated to him, and an Excel spreadsheet verifying the error was posted on the website by Cordova. Setterfield's response was that "software packages" often fail to "pick up on" certain algebraic identities, and that this was undoubtedly the case here. He also claimed to have re-checked his derivation, and verified that it was correct. However, Cordova expressed the opinion that there really was a problem. At this point, after about a month of arguing the matter, Setterfield acknowledged the error. He said he had worked through the rest of the calculation and found that correcting the error made no significant difference in the derived result.

As noted in Appendix C, the "population" equation that results from this derivation is defective, containing an inappropriate algebraic sign and the factor N raised to the wrong power. In our opinion, it's unfortunate if correcting the calculus error leaves this equation with no significant changes. However, since this population rate equation is arguably not a central feature of Setterfield's theory, the real significance of the experience is to demonstrate how difficult it can be to get Setterfield to acknowledge even an obvious mistake.

The second major dispute with Setterfield centered on interpretation of the cosmological redshift in terms of changing atomic diameter. As discussed in Appendix C, Setterfield's recent writings had claimed that increasing ZPE levels cause electron size to increase, giving rise (via a physically-unreasonable resonance effect) to sudden decreases in particle masses during infrequent "quantum jumps." Setterfield (correctly) deduced that this would cause an increase in atomic dimensions, and (incorrectly) concluded that emitted wavelengths would therefore decrease as time goes on. At great distances, he claimed, we would look back into past epochs, and see redshifted light.

For several weeks, Setterfield posted inane arguments claiming that smaller atoms would emit longer wavelengths. As noted in our Appendix C, this is getting it backwards. Setterfield resisted the evidence from muonic atoms as well as the elementary equations of the Bohr atomic theory. Finally, again after Cordova again expressed support for our argument, Setterfield acknowledged his error.

Setterfield now says that he got it backward; atoms actually get smaller, not larger at quantum jumps! Atoms were larger in the past, and therefore emitted longer wavelengths, giving rise to the observed cosmological redshift. This correction, he says, is due to misreading an equation in an Internet publication by H. E. Puthoff[104] that served as the basis for his model of changing electron dimensions. The increase in ZPE, says Setterfield, actually causes electrons to shrink and increase in mass, leading to a decrease in the Bohr radius as time goes on.

Although this interpretation does seem to be more in line with Puthoff's theory, Setterfield's error was, of course, also due to his misunderstanding of elementary atomic physics (see the energy level diagram of Figure 21 for an explanation of Setterfield's blunder).

In any event, the new version of c-decay has acquired some new problems. If atoms were bigger in the past (as Setterfield now maintains), molecules, crystals, and all solid materials would all have been larger, in proportion to the Bohr radius. We can therefore conclude that the Earth would have been bigger at Creation by a factor of at least two (and probably more, if we accept the need to explain quasar redshifts by this

mechanism). Assuming the number of molecules in the Earth's atmosphere has not changed, air pressure would have been less by at least a factor of 16 when the Earth was twice as large, causing severe breathing difficulties for Adam and Eve. And it seems impossible for the Earth to shrink by a factor of two during 8,000 years without causing catastrophic earthquakes and raising the planet's temperature to intolerable levels.

Setterfield has tried to dispute this conclusion, but we find his arguments absurd. Time will tell whether he will continue to maintain that only atoms, but not molecules, were bigger in the past.

Setterfield's new scenario, involving particle masses that decrease at quantum jumps, adds some new wrinkles to the supernova issues discussed in Section 6. As noted there, supernova light curves show a "time dilation" stretching effect evidently caused by the expansion of the Universe. The effect is in proportion to the cosmological redshift, in agreement with the predictions of the Big Bang theory. As noted in Section 6, nothing in Setterfield's published work provides any c-decay-based explanation for the supernova "time dilation" effect.

However, with the new version of the theory, the situation might be thought to have changed. If particle masses increase at quantum jumps, one might reasonably expect an effect on nuclear reaction rates, and the effect would go in the direction that Setterfield needs. And since the light curves of Type I supernovae evidently result from the decay of ^{56}Ni to ^{56}Co and then to ^{56}Fe, the light curves of these supernovae might scale with the atomic decay constants. The "time dilation" we see would then be due to an actual prolongation of the "life" of the supernova.

This argument has, in fact, been made by Narlikar and Arp in connection with their "variable mass" cosmological model.[105] This is not a creationist model, but it does assume progressive increases in the masses of elementary particles (although on a timescale of billions, rather than thousands of years). Narlikar and Arp claim that the changing masses of particles cause changes in supernova light curves in a way that mimics the expected Big Bang effect. Thus, there is some degree of convergence between their paper and Setterfield's model, and Setterfield finds himself in the rare position of receiving inadvertent support from legitimate scientific researchers. Although Setterfield has shown no awareness of these issues, we might wonder whether the suggestion of Narlikar and Arp provides some relief for his beleaguered theory.

However, Setterfield's theory is now caught in the crossfire of mainstream scientific debate. The claim of Narlikar and Arp has been challenged by data on the evolution of supernova spectral emission features. Foley and coworkers[106] used a technique developed by Riess et al.[107] to determine the spectral-feature age of a Type Ia supernova. The results were within about 1 standard deviation of the Big Bang prediction. The results were inconsistent with the hypothesis of no time dilation with a significance level of 99.0%. The results were also inconsistent with Narlikar and Arp's variable mass theory. The evolution of spectral lines depends on temperature and density and does not scale with mass in the simple manner required by Narlikar and Arp, and Setterfield.

In conclusion, as of September 2007, no criticism in this monograph has been successfully challenged, by Setterfield or anyone else. We stand by all the arguments we

have presented, and are confident that they prove the *c*-decay theory to be scientifically invalid.

Acknowledgments

The decision to write this report was occasioned by Salvador Cordova's expressed willingness to post it on his creationist web site. Mr. Cordova carried through on his promise and, in so doing, exposed Setterfield's theory to what may be its most intense scientific criticism. Although we do not endorse the content of many of Cordova's posts on the youngcosmos.com discussion forum and blog, we do acknowledge his willingness to side with us against Setterfield when he saw the correctness of our arguments. In addition, we acknowledge the role the youngcosmos.com discussions had in our developing understanding of the weaknesses of the *c*-decay theory.

We are grateful to M. Evered for pointing out an error in an earlier version of this report, and for providing copies of some early publications of Setterfield and his critics.

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