in Yellowstone National Park, and the Glen Rose Texas footprint controversy.

Rev. James W. Skehan, the Director of the Weston Observatory for Boston College, lectured on the interaction of science and the Bible. Picturing Darwin as essentially a religious man, he went on to serve what is a popular NCSE menu of evolution and Biblical criticism. Even though embellished by some beautiful slides, the presentation contained some questionable facts (for example, the number of species and there was an expressed lack of understanding of Genesis.

By far the best of the papers presented at the NCSE was by Craig Nelson from the Department of Zoology, Indiana University. His presentation was the only one which truly dealt with the stated aims of the NCSE itself—namely the improvement of science education. He summarized the salient features of a teaching method he has been using in his evolution course at Indiana University. He attempts to teach students critical thinking. This is a controversial, but much-superior method to the "stuff-and-regurgitation" (KPW term: "stuff as much stuff into the head of a student as possible and have him regurgitate as much of it as possible on a test") used in most classrooms today. Nelson claims that he has seen marked improvement in the reasoning abilities of his students as a result of his method of teaching. The drawbacks are that the students take some time to adjust and in fact object to a teaching method where they have to "work." In addition, it takes much time and effort for a teacher to develop material and change the way they were taught themselves for the sake of the students.

We would like to see more material along the lines of Craig Nelson's presentation from NCSE. This type of material is more honest to the stated aim of NCSE, and more useful to students nationwide. We all are interested in better science instruction.

Contributed by Kurt P. Wise and Wayne Frair

MINISYMPOSIUM ON THE SPEED OF LIGHT—PART II

THE SPEED OF LIGHT AND PULSARS

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Abstract

The consistency of pulsar signals provides unique constraints on the hypothesis that the speed of light has decayed in the past. The model of decay in the speed of light proposed by Norman and Setterfield is found to be an inaccurate description of reality. The data and theory strongly suggest that if the speed of light has decayed, it has done so in a very obscure manner.

Introduction

Seeing light from distant stars in a short creation time frame is a well-known point of confrontation in creation/evolution discussions on cosmology. Creation explanations have generally been to suggest that the light was created in transit, the universe exists in Riemann space or that the speed of light was much faster in the past. It is the purpose of this paper to examine the last explanation and the model recently proposed by Norman and Setterfield (1987).

If the speed of light has changed, hopefully, there is some way we can detect it. A change might be found by examining the speed of light measurements over the last 300 years or by measurements of light from distant stars in the last two decades. An excellent review of speed of light measurements prior to 1941 was completed by Dorsey (1945). Dorsey's conclusion was that the speed of light was a constant.

During the past decade Setterfield and others have advocated that the speed of light is not a constant and that it has decreased by many orders of magnitude. They support this position by attempting to document a small decrease in the speed of light from historical data (Norman and Setterfield, 1987). Other contributors to this symposium have shown that measurements during the last 300 years support a constant, not a decreasing, value for the speed of light. Though the speed of light has been constant in recent history, perhaps it was faster prior to 300 years ago.

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Pulsars behave as very consistent clocks and may provide a unique way of measuring changes in the speed of light in the past. Any changes in the speed of light during the emission of pulsar signals or during the transit of the signals through space should affect the timing of these signals. If the speed of light is changing, the length of time between pulses should be increasing at the same rate that the speed of light is decreasing.

Pulsars

Pulsars are thought to be spinning neutron stars that are surrounded by a co-rotating magnetosphere by which they generate periodic signals. In 1984, 368 pulsars were known and more have been discovered.

Pulsar timing is characterized by its period P, period time derivative $\dot{P}$ (the rate of increase in the period), and stability. Pulsar stability is a measure of irregularities in pulsar timing after taking into account the period derivative $\dot{P}$

All pulsars measured have periods between 0.0015 and 4.3 seconds. The average pulsar period is about 0.7 second. For 268 pulsars where $\dot{P}$ is known, $\dot{P}$ ranges from 10^{-12} to 10^{-18} s/s with an average at 3×10^{-15} s/s. Stability of pulsar timing is better than 10^{-10} (Hewish, 1980; Dewey *et al.*, 1984; Cordes and Downs, 1985). A notable exception is PSR 1937+21 (sometimes referred to as 1937+214) with a $\dot{P}$ at 10^{-20} s/s and a stability of better than 6×10^{-14}. The stability of this pulsar has been shown to rival that of atomic clocks (Rawley *et al.*, 1987).

Pulsars are randomly distributed about a 10 kpc radius from our galactic center (Lyne, 1980). The low signal level of pulsars precludes their detection from extra-galactic sources. Velocity vectors of pulsars also appear to be random in direction and magnitude, with a mean velocity of 180 km / s and a maximum at about 500 km / s (Lyne, 1980).

Pulsar timing stability and consistency must be very good to measure any variation in the speed of light, preferably much better than any alleged variation. Period stabilities and consistencies of pulsars measured, as mentioned above, are better than the decay in the speed of light alleged by the Norman-Setterfield model. This stability and consistency of timing have strong implications for any model proposing a decay of the speed of light.

The Norman-Setterfield Model

The Norman-Setterfield model (1987) for the decay of the speed of light refers to two types of time or ways by which time is measured.

> One is atomic time that is governed by the period taken for an electron to move around once in its orbit. In essence, it is electromagnetic in character. The other is dynamical time whose units are subdivisions of the period that the earth takes to make one complete orbit of the sun. Obviously, this clock is governed by gravitation. (p. 4)

Atomic time is measured with respect to atomic clocks and according to the model varies inversely proportional to the speed of light (p. 5). Atomic time will be designated by t.

Dynamic time is related only to earths orbital period and not to its spin rotational period; that is, dynamic time is related to the length of earths year and not the length of earth's day. This distinction is very important. Dynamic time will be designated by T.

In their model, Norman and Setterfield propose the following relationships:

$$m \propto 1/c(T)^2 \tag{1}$$

where m is mass and c(T) is the speed of light as a function of dynamic time (p. 31) and

$$v \propto 1/c(T) \tag{2}$$

where v is the velocity of any mass (p. 33). Distance is time invariant in the Norman-Setterfield model (pp. 4, 45).

From equations 1 and 2 it is obvious that linear momentum (mv), and consequently angular momentum, varies as 1/c(T) and is not conserved in the Norman-Setterfield model. Momentum is not mentioned in the model and violation of this conservation law is never discussed.

Though not explicitly stated, the model appears to have been developed with the intent to conserve kinetic energy independent of the speed of light. Kinetic energy can be divided into two types, linear and rotational kinetic energy. Linear kinetic energy is the energy of an object associated with its instantaneous velocity, e.g., the energy of a falling rock or a moving automobile. Linear kinetic energy ($mv^2/2$) is conserved independent of the speed of light in the model, (p. 33).

Rotational kinetic energy is the energy of an object associated with its spin about its axis, e.g., the energy of a spinning top or a rotating planet. Norman and Setterfield did not directly address the conservation of rotational kinetic energy with a change in the speed of light and were silent about any implications this might have. To avoid a misreading of the model, the implications of conserving and not conserving rotational kinetic energy will be developed here.

For a sphere of uniform density with a mass m, radius R, and angular velocity, w, the rotational kinetic energy is given by

$$KE = \frac{mR^2\omega^2}{5}. \tag{3}$$

(In this article ω is used only to denote the spin angular velocity of an object and not its orbital angular velocity. For the earth, ω is related to the length of the day and not the length of the year.) Using equation 1 we may rewrite 3 as

$$KE = \frac{M_i R^2\omega^2}{5c(T)^2}. \tag{4}$$

where $m = M_i/c(T)^2$ and M_i is a constant independent of the speed of light. If we stop at this point, assuming R and ω are constants independent of the speed of light, we see that rotational kinetic energy is not conserved in the Norman-Setterfield model, but increases in time. This violation of the first law of thermodynamics would certainly have been noticed and has implications for pulsar timing.

Since ω is proportional to the instantaneous velocity of elements of a solid rotating system, one could infer from equation 2 that ω should vary proportional to c(T) in the Norman-Setterfield model. If this is assumed, rotational kinetic energy is conserved and is independent of the speed of light. However conservation of rotational kinetic energy in the Norman-Setterfield model causes another very significant problem. If the rotating system is the earth and ω slows down in dynamic time proportional to c(T), the length of a day will be constantly increasing. This increase in the day's length will be inversely proportional to the speed of light and very noticeable.

The implication of this for the Norman-Setterfield model is grave. About 6,000 years ago, when the speed of light was allegedly 10 million times its present value, the length of a day would be 0.0086 seconds. This would require 3.7×10^9 days in a dynamic year. just 1,000 years ago when the speed of light was allegedly twice its present value, the day would be 12 hours and there would be 730.5 days in a dynamic year. Historical records do not allow for such an absurdity.

If rotational kinetic energy is conserved in the Norman-Setterfield model, we have an absurdity about the number of days in a year. If rotational kinetic energy is not conserved, the model violates the first law of thermodynamics. These inconsistencies show major errors in the Norman-Setterfield model.

Pulsars and the Speed of Light

Suppose there is some pulsar a distance from earth emitting periodic signals with a distance L_{mn} between wave fronts m and n (Figure 1). In dynamic time the distance between two consecutive wave fronts m and n is given by

$$L_{mn} = \int_{T_m}^{T_n} c(T)\,dT \qquad (5)$$

where T_m and T_n are the *emission* times in dynamic time of pulses m and n respectively. In atomic time the distance is given by

$$l_{mn} = \int_{t_m}^{t_n} \hat{c}(t)\,dt$$

where t_m and t_n are the measured arrival times in atomic time $\hat{c}(t)$ of pulses m and n respectively at earth and where c(t) is the speed of light as a function of atomic time. (Corrections for the relative motion of the earth and pulsar having already been made.)

With distance as an invariant in the Norman-Setterfield model, the distance between wave fronts is the same in both dynamic and atomic time. (Distance need not be an invariant for the conclusions of this analysis to be valid as long as any transformation is linear in space and constant in time.) So we have

$$L_{mn} = l_{mn} \qquad (7)$$

Using this relationship we may write, from 5 and 6,

$$\int_{T_m}^{T_n} c(T)\,dT = \int_{t_m}^{t_n} \hat{c}(t)\,dt. \qquad (8)$$

This gives us a direct comparison between the speed of light in the present and the past.

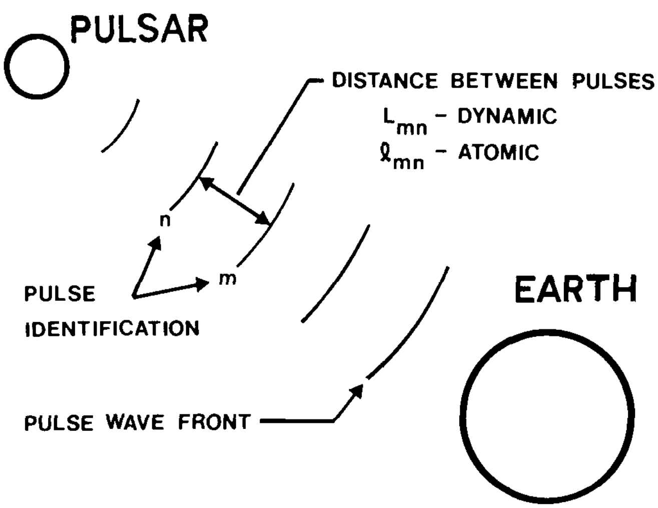

Figure 1. Pulsar signals traveling to earth. Distance variations between a pulsar's signals provide a way to measure any change in the speed of light since the time signals were emitted.

From this, two major problems for the Norman-Setterfield model will become apparent. One problem is the predicted pulsar timing time derivative $\dot{P}$ due to a change in the speed of light. The other problem is a direct implication for the consistency of the speed of light. A change in the speed of light while pulsar signals are being emitted will produce a change in the distance between pulses. This change in distance is equivalent to a change in pulsar timing and can be given by

$$\dot{P} = \frac{L_{mn} - L_{m'n'}}{1/2(L_{mn} + L_{m'n'})}$$

Where L_{mn} and $L_{m'n'}$ are the distances between consecutive pulses at the beginning and ending, respectively, of some observational time interval Δt. Though the derivation is involved, equation 9 can be reduced to

$$\dot{P} \simeq \frac{2S(b + 4dT_m)}{a/T_m + b(T_m + S) + dT_m^6(T_n + 8S)} \qquad (10)$$

if $T_m >> S >> \Delta t$,

where a, b and d are the constants defined by Norman and Setterfield (p. 55) and:

$T_m = T(t_m)$ and is the dynamic time since pulse m was emitted,

t_m = the number of atomic light-years it has taken pulse m to reach the earth,

and $S = T(t_m + \Delta t) - T(t_m)$ and is the dynamic time between the emission of pulse m and n.

To evaluate $\dot{P}$, T(t) must be determined. By changing the limits of integration in equation 8 one can find that

$$t = T + \frac{bT^3}{3a} + \frac{dT^9}{9a} \qquad (11)$$

as Aardsma (1988) has done. The Newton-Raphson method of iteration can be used to find T for specific values of t.

Evaluating 10 for all pulsars within 50 light-years of the earth and assuming a four month (1/3 year) observational period, one finds that P ranges from 6.1 x 10^{-6} to 6.6 x 10^{-4}. For PSR 1937+21 P is 4.4 x 10^{-5}. These values are six to 12 orders of magnitude higher than that actually observed for all pulsars and 15 orders of magnitude higher than that observed for PSR 1937+21. This is a huge difference between observation and prediction. (Allowing the rotation rate of the pulsar to slow in time makes this difference even larger.)

The other problem for the Norman-Setterfield model is with regard to a direct implication for the consistency in the speed of light. Since $\hat{c}(t)$ is a constant in atomic time, the integral on the right side of equation 8 becomes a measure of the period of atomic time between consecutive pulses. For all pulsars observed, excepting "noisy" glitches, this period is constant and stable to better than 10^{-10}.

For pulsar PSR 1937+21 the constant has tighter limits. Its:

> . . . frequency stability is at least as good as 6 x 10^{-14} for averaging times longer than four months, and over the longest intervals the measurements appear to be limited by the stability of the reference atomic clocks. [In addition] The stable rotation and sharp radio pulses of PSR 1937+21 make this pulsar a clock whose long term stability may exceed that of the best atomic clocks (Rawley *et al.,* 1987).

With such stability of atomic time intervals and $\dot{P}$ values less than 10^{-12}, the right side of equation 8 becomes a constant to better than 10^{-10} for all measured pulsars and better than 6×10^{-14} for PSR 1937+21. We have then in dynamic time

$$\int_{T_m}^{T_n} c(T)dT = \text{constant to better than } 10^{-10}. \qquad (12)$$

This represents a situation in which c(T) would normally be labeled as a constant, but other interpretations are possible.

Option for Interpreting Pulsar Timing

There are three options available for interpreting equation 12 that allow a decay in the speed of light. They are:

I. At the time of emission of all the pulses so far measured, the speed of light was constant in dynamic time. We do not know at what value it was constant or if it later changed.
II. The difference between emission times or simply the pulse period of all the pulsars could have varied inversely proportional to c(T) so as to keep each incremental integral from T_m to T_n a constant.
III. It could be imagined that the velocity of pulsars relative to earth could be accelerating in dynamic time inversely proportional to c(T) so as to keep the incremental integral constant.

Option III cannot be maintained in view of the random velocity vectors of the pulsars (Lyne, 1980; Cordes and Weisberg, 1984) and the absence of any corroborating evidence for such a selective distribution of pulsar acceleration. A discontinuous change (option I) would be expected to produce significant effects in stellar phenomena. These effects have not been observed. The only option remaining for a change in the speed of light is II. But is this possible, and what are the implications?

Implications of Pulsar Timing

A decay in the speed of light that is consistent with pulsar timing measurements requires the following proportions:

$$P(T) \propto 1/c(T), \qquad (13)$$

and

$$\omega(T) \propto c(T) \qquad (14)$$

where P(T) is the pulse period (equivalent to a pulsar day) and ω(T) is the angular velocity of the pulsar. The pulse period would be 0.001 of its present value in dynamic time if the speed of light were 1,000 times faster, etc.

This relationship between the length of day, or period, and the speed of light produces the same inconsistency noted earlier in the Norman-Setterfield model. If the period of rotating objects, the earth or pulsars, varied with 1/c(T) to conform to pulsar timing measurements the length of a day in the past would have been absurdly short and the number of days in a year would have decreased enormously. If the period of rotating objects is independent of c(T), pulsar timing measurements show the speed of light is a constant to better than 10^{-10}. The Norman-Setterfield model appears to have little, if any, relevance to the real world.

Conclusion

To assume that the Norman-Setterfield model of the decay of the speed of light is correct requires the negation of history or a violation of the first law of thermodynamics. If one assumes the first law does not hold, pulsar timing measurements indicate the speed of light has been a constant to 10^{-10} since the time light left the pulsars (the pulsars appear to be 30,000 light years and farther away). If one assumes the first law holds, 1,000 years ago a day would only be 12 dynamic hours and there would be 730.5 days in a dynamic year—an historical absurdity. In addition the Norman-Setterfield model gives pulsar $\dot{P}$ values that are six to 15 orders of magnitude different from what is observed. See Table I. These theoretical implications show the Norman-Setterfield model to be an inaccurate description of reality.

Table I. Norman-Setterfield Model Implications for Rotating Objects and the Length of Earth's Day.

Angular velocity	Norman-Setterfield model	Implications
ω = Constant	Rotational KE $\propto$ 1/c(T) (Violation of first law of thermodynamics if c(T) varies.) Predicted pulsar $\dot{P}$ is 10^6 to 10^{15} larger than observed.	Speed of light is constant to 10^{-10} according to pulsar measurements. Predicted pulsar $\dot{P}$ is 10^6 to 10^{15} in error. Day length is constant.
$\omega \propto$ C(T)	Rotational KE conserved Predicted pulsar $\dot{P}$ is > 10^6 to 10^{15} larger than observed.	Day length $\propto$ 1/c(T) (Earth's day was 12 hrs., 1000 yrs. ago- historically absurd.) **Predicted pulsar $\dot{P}$ is > 10^6 to 10^{15} in error.**

The consistency of pulsar signals provides unique constraints on the hypothesis that the speed of light has decayed in the past. The testing times in the past can be greatly extended beyond the time of Roemer's measurements in 1675 by accurate timing measurements of pulsar signals. The constraints implied by pulsar signals will need to be addressed in any serious model that proposes a decay in the speed of light.

One could imagine everything changing with the speed of light in such a way that it would not be detectable, but there would be no way to prove this type of a decay. Such a model would only be speculation. If something cannot be detected and measured, it is not subject to the scientific method.

At this point pulsar data and theory strongly suggest that if the speed of light has decayed, it has done so in a manner that is very obscure. If a decay in the speed of light is the correct explanation for how we can see distant stars in a short creation time frame, perhaps further research will provide a workable model for a decay and identify a test that can verify or falsify such a model.

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THE SPECIAL THEORY OF RELATIVITY: ITS ASSUMPTIONS AND IMPLICATIONS

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Abstract

Since Albert Einstein proposed the Special Theory of Relativity in 1905, there has been much discussion, concern, and confusion. This theory is probably the most controversial concept within physics and has been the subject of no little controversy in the origins debate. It is not the intent of this paper to defend or refute the theory, rather to clarify what is and is not assumed and what is and is not implied by it. Thus, hopefully this will reduce the confusion and perhaps some of the unprofitable element of the controversy.

Introduction

There are two basic assumptions underlying Einstein's Special Theory of Relativity (STR): the speed of light in a vacuum appears the same to every observer regardless of their motion and the laws of physics appear the same in every inertial reference frame. To Einstein, the first assumption implied the absence of an ether and any physically measurable absolute reference frame. The second assumption does not per se prescribe what the laws of physics are, just that they be consistent to different observers. Once these two assumptions are made, one can, using calculus, derive the Lorentz contraction, time dilation, change in apparent mass, and the famous energy relationship. It is these derived relationships, and in some cases their misinterpretation, which give rise to the controversies surrounding the STR.

The Unstated Assumptions

Einstein made at least two unstated assumptions in developing the STR: orderliness and causality. Without the assumption of orderliness, there is no point in pursuing the study of physics. If phenomena do not occur in a regular manner, then experiments would not be repeatable and it would be absurd to attempt to apply logic and mathematics to increase our understanding of nature. Even if it is incorrect, the STR, if nothing else, is an attempt to develop mathematical expressions for certain relationships between causes and effects. The notion that the STR somehow assumes or even proves that the cosmos is chaotic and thus cannot be understood is false. On the contrary, in developing the STR, Einstein assumed the very opposite to be the case: an orderly, causal cosmos which could be understood by means of logic mathematics.

The Ether Question

The concept of a ubiquitous ether was the subject of much debate near the end of the nineteenth century. Today it is thought by most physicists to have been as thoroughly discredited by Michelson and Morley as the concept of a flat Earth was discredited by Columbus and Magellan. This, however, is not the case. What Michelson and Morley did obtain was a null result for the motion of an ether with respect to the Earth. What they did not obtain was any result enabling one to distinguish between the at least three remaining logical alternatives: (1) there is no ether, (2) the ether moves with or is attached to the Earth, or (3) the ether, much like a viscous fluid, attaches to whatever body it contacts and is thus entrained or "dragged along" with the Earth.

Many physicists consider the annually varying aberration of fixed stars perpendicular to the Earth's orbit which was reported by Bradley in 1728 (Michelson p. 121) to be evidence that the ether is not entrained by or "dragged along" with the Earth; thus eliminating alternative (3) but not necessarily (2). Michelson investigated a number of tests related to Bradley's aberration beginning with Airy's problem in which the telescope was filled with water rather than air. Airy reasoned that if Bradley's aberration was to be explained by the motion of the telescope relative to the stellar light source as the light traveled through the telescope, then the magnitude of the aberration should depend on the refractive index of media inside the telescope. However, this experiment yielded a negative result which was subsequently explained by Fresnel, "that the luminiferous medium is carried along by the motion of the medium; not, however, by the full amount of this motion, but by a fraction . . ." (Michelson, p. 139). Michelson performed several tests of Fresnel's hypothesis. Michelson, however, did not consider this a satisfying proof as he continued his search for such an experimental test. Had Airy's test been positive without resorting to Fresnel's explanation and thus requiring yet another null hypothesis to be experimentally proven, Bradley's aberration would have been a much stronger test against alternative (3). That Michelson was not convinced by the positive results of Bradley's observation and subsequent negative results obtained by related experiments is illustrated by,

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