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A theory of an oscillating, periodic, speed-of-light as a possible limiting value converging to an average limit

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ABSTRACT

This paper seeks to adopt and solve the wave-equation for the radial propagation of light in three dimensions from the moment of the Big-Bang and during Earth-based experiments. The primary purpose is to model a propagating beam of light emitted from the singularity, outwards, and to show that its velocity is sinusoidal, meaning that its speed oscillates periodically, and is therefore variable rather than constant. It is additionally shown, by calculating an appropriate solution to the wave-equation, that the velocity of light is not only negatively damped according to the inverse radial law, $1/r$, throughout its journey over space and time, but that this latter feature also exhibits amplitude convergence from a very large initial value to a value that is very close to what is now defined to be a constant, namely the current value denoted by $c = 299792458\,\mathrm{m/s}$. The possibility that such observations may also vary depending upon the inertial frame in which a measurement is carried out is similarly considered, along with a discussion of the related nature of mass and energy, and how the possible variability of the speed-of-light and the fabric of the space-time continuum may affect each other.

1. Introduction

The speed-of-light in vacuo is currently accepted as being a constant equal to around $299792458\,\mathrm{m/s}$, with a small degree of error previously being apportioned to differing experimental setup. It is also known that light behaves both as a particle and as a wave so, for the purposes of this research, its wave-like behaviour will only be considered. Recently, suggestions have been made by such as [2,9–12,15] that the speed-of-light may not, after all, be constant, and may even have a limiting value in the convergent sense. In tandem with other questions relating to the fabric of the space-time continuum, in which both matter and energy obviously play a crucial part, it was thought necessary that light, including its interaction with each of the latter, should be studied and modelled more mathematically to attempt to ascertain its own dynamics. A primary purpose of this research, therefore, was to investigate light emitted at the point of the Big-Bang to attempt to model its speed, and particularly after neutrinos, during recent experiments [1], apparently displayed higher than usual light-speed magnitudes. These measurements were carried out between CERN in Switzerland and Gran Sasso in Italy circa 2012, the seemingly paradoxical outcome of which has simply been explained away as experimental error, thus motivating this research into attempting to mathematically model the speeds that were experimentally obtained. It is well known that the wave-equation – along with the wave-equations for both electric and magnetic fields – models electromagnetic wave propagation, including light emitted from astronomical bodies such as quasars, pulsars, and supernovae. This

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means that it made perfect sense to therefore model beams of light, propagating radially in three dimensions, from the moment of the creation of our Universe, known as the Big-Bang. Already being aware that the common eigen-function substitution into the wave-equation nearly always results in a sinusoidal-type solution for the displacement, $u(t,r)$, of a *spherically-symmetric* wave (in both the transverse and longitudinal senses), it seems plausible that one can then easily calculate the corresponding sinusoidal-like velocity, $u_t(t,r)$, of a light-beam emitted over the spatio-temporal span of the current Universe. Once the solution for $u(t,r)$ is obtained, it is therefore a simple step to obtain the velocity, $u_t(t,r)$, by a straight-forward and elementary process of differentiation of $u(t,r)$, with respect to only time, t. A further aim has also been to model a light-beam (or a series of spherically propagating light-beams independent of any angular motion) travelling over certain radial distances in given times after the Big-Bang. An additionally important objective is that the light-beam's mathematical analysis will demonstrate not only an oscillating and periodic velocity, but that this velocity is negatively damped according to the inverse radial law, $1/r$, with the effect of reducing these amplitude fluctuations to a more convergent value, namely the approximate, current, 'limiting', value of $c\,\mathrm{m/s}$. If this theory is correct, then an originally variable, but now convergent, speed-of-light may have implications for how we understand the fabric of the space-time continuum, and the way in which both matter and energy interact with such electromagnetic phenomena.

2. Findings and discussion

To model the potentially variable behaviour of light as it traverses the Universe, from the point of the 'Big-Bang', for example, including that of neutrinos over shorter distances during Earth-based experiments, we seek to solve the *three-dimensional* wave-equation that describes both the *motion* and *displacement* in the emitted electric field, $E = E(t,x,y,z)$:

$$\frac{\partial^2 u}{\partial t^2} = c^2\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) = c^2\nabla^2 u \tag{1}$$

as it propagates radially outwards in all directions with respect to the coordinate axes, x, y, and z as time, t, increases. Here, $u = u(t,x,y,z)$ represents a *transverse deflection* in the radial displacement of the electric field, $E(t,x,y,z)$, as the latter is deflected with velocity, $u_t(t,x,y,z)$, and acceleration, $u_{tt}(t,x,y,z)$. To solve Eq. (1), it will first be necessary to reduce it to the *one-dimensional* case and solve for the transformed *one-dimensional* displacement, $v(t,r)$, before then making a substitution in order to obtain the *spherically symmetric* solution, denoted by $u(t,r)$, which better describes the ensuing wave-motion, *radially*, in three-dimensions.

We commence by writing that the force, F, on a particle with charge, Q, and electric field, $E = E(t,x,y,z)$, is $F = QE \Rightarrow E = \frac{F}{Q} = \frac{m}{Q}\frac{\partial^2 u}{\partial t^2} = \frac{m}{Q}u_{tt}$, where $u = u(t,x,y,z)$ has the units of length. Then $\frac{\partial^2 E}{\partial t^2} = \frac{m}{Q}\frac{\partial^2}{\partial t^2}\left(\frac{\partial^2 u}{\partial t^2}\right)$ and $c^2\nabla^2 E = \frac{m}{Q}c^2\nabla^2 u_{tt} = \frac{m}{Q}c^2\frac{\partial^2}{\partial t^2}(\nabla^2 u)$. Here, we have assumed that F is positive, or $F > 0$, especially since we are modelling neutrinos as well as light. This means that the three-dimensional Maxwell equation for the electric field, $\frac{\partial^2 E}{\partial t^2} = c^2\nabla^2 E$, can now be written as $\frac{m}{Q}\frac{\partial^2}{\partial t^2}\left(\frac{\partial^2 u}{\partial t^2}\right) = c^2\frac{m}{Q}\frac{\partial^2}{\partial t^2}(\nabla^2 u)$, leading to $\frac{\partial^2 u}{\partial t^2} = c^2\nabla^2 u$. Thus, we have transformed the Maxwell equation for the electric field, E, into one of both three-dimensional displacement, $u(t,x,y,z)$, and its respective derivatives involving the velocity, $u_t(t,x,y,z)$, and the acceleration, $u_{tt}(t,x,y,z)$. We note further that each of these quantities is also independent of the particle's mass and charge. If, at this stage, F were to be defined as being negative, say in the case of an electron, where $E = -\frac{F}{Q}$, then the above wave-equation in terms of u would still result, as the negative signs on each side of it would simply cancel out, thus resulting in the same theory, below.

Due to this three-dimensional radial motion, we adopt the spherical Laplacian:

$$\nabla^2 u = \frac{\partial^2 u}{\partial r^2} + \frac{2}{r}\frac{\partial u}{\partial r} \tag{2}$$

in which all angular derivatives have been set to zero due to the absence of angular variation.

Substituting Eq. (2) into Eq. (1), we have:

$$\frac{\partial^2 u}{\partial t^2} = c^2\left(\frac{\partial^2 u}{\partial r^2} + \frac{2}{r}\frac{\partial u}{\partial r}\right) \tag{3}$$

or:

$$r\frac{\partial^2 u}{\partial t^2} = c^2\left(r\frac{\partial^2 u}{\partial r^2} + 2\frac{\partial u}{\partial r}\right) \tag{4}$$

so that:

$$\frac{\partial^2 (ru)}{\partial t^2} = c^2\frac{\partial^2 (ru)}{\partial r^2} \tag{5}$$

Putting $v = ru$, we now obtain the one-dimensional wave-equation:

$$\frac{\partial^2 v}{\partial t^2} = c^2\frac{\partial^2 v}{\partial r^2} \tag{6}$$

Here, the solution, $v(t,r)$, represents a wave travelling at speed $c\,\mathrm{m/s}$ in the direction of increasing r, the latter of which is a radial dimension of length, emanating from a single infinitesimally small point called a singularity. We also note that both $v(t,r)$ and $v_t(t,r)$ represent the now *one-dimensional*, *transverse*, displacement and velocity of the wave, respectively, as it accelerates outwards on its journey after experiencing a deflection in its path. In particular, it was chosen to model the transverse components of such a propagating light-beam for the purposes of this research, because they extend over tremendously long ranges and are therefore the easiest aspects of such a wave to observe, measure, and analyse. When astronomers, for example, study the properties of very distant stars, it is these exact transverse properties of their light-emissions that they first detect, moving at the speed-of-light, c, because of the propagating field's very long range. This is why they are so important.

As stated above, one of the main objectives of this research is to first obtain a *one-dimensional* wave-solution to Eq. (6), which may otherwise be found more simply by applying the D' Alembert formula for bounded intervals, [3,6,13,14], yielding $v(t,r) = f(r-ct) + f(r+ct)$, for both right- and left-travelling waves, respectively. This method utilizes the notion of *relativistic characteristic curves* indicated by the differing inertial frames defined by $\xi = x - ct$ and $\eta = x + ct$, such that the final solution to Eq. (1) may then be written in the *spherically-symmetric* form of $u(t,r) = \frac{v(t,r)}{r} = \frac{f(\xi)}{r} + \frac{f(\eta)}{r}$. From this latter type of expression, which in this case would normally be of the form $u(t,r) = \frac{\cos(r-ct)}{r} - \frac{\cos(r+ct)}{r}$, a simple trigonometric identity is often used that will thus lead to Eq. (39), in due course below, in the form of $u(t,r) = \frac{2}{r}\sin(r)\sin(ct)$. However, we do not adopt the D'Alembert method of solution in this paper, because one would have to initially *assume* the nature of the sinusoidal solution, involving either sines or cosines, which may leave room for some ambiguity for both the author and the reader. Indeed, the exact functions in Eq. (39) naturally arise out of the more analytic