The Consequences of Assuming that the Speed of Light is not Constant

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The speed of light is the mortar that holds together the 20th century physics paradigm, which we have inherited in the 21st century. Many different functions of physics use the speed of light as a proportionality constant, a necessary component, or a limiting condition. Examples abound: special relativity, general relativity, mass-energy equivalence, fine structure constant, Rydberg number, Stefan-Boltzmann constant, uncertainty principle, electromagnetic spectrum, Maxwell equations, Compton wavelength, properties of free space, Planck scale and many others. Some functions, that will be described, are new to the accepted physics paradigm, such as a specific superforce and the constant gravitation potential of light. The objective of this paper is to show how much of physics is dependent upon the speed of light and to indicate how disastrous the consequences would be if the speed of light were not constant. The constant speed of light must be retained in the 21st century physics paradigm.

Introduction

During my training as a chemical engineer, one of my professors would frequently remind us students that "Water is the universal solvent." My experience in reading and studying physics for over a half century makes me believe that physicists surely were taught that "The speed of light is the universal constant." The speed of light appears to be ubiquitous in physics. In fact, the constant speed of light could very well have been the mortar that held together the 20th century physics paradigm.

Several of the papers that I have read that have been submitted (both in person and *in absentia*) at the last two or three conferences of the Natural Philosophy Alliance (NPA) and related comments that I have heard at the conferences convinced me that I needed to learn more about the speed of light. Four questions have piqued me.

- What is light anyway?
- If the speed of light is not constant, in what way does it vary?
- How did Einstein influence our understanding of the speed of light?
- What if the speed of light were not constant?

As I started searching for answers to the above questions, I was led astray from my task by another question: "What is a paradigm?

In Search of a Paradigm

Somewhere I read that **The Structure of Scientific Revolutions** by Thomas S. Kuhn [1] was the most popular philosophy of science book during the 20th century. I have underlined key concepts in the following excerpts from this book. Kuhn gave the word "paradigm" a significance and a specific connotation that was never known before. As he stated in his book, "Paradigms . . . [are] universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners (p. viii—page numbers in Kuhn's book in this section)." The lectures we hear, the textbooks we read and the experiments we perform in school and the *modus operandi* we follow in our chosen professions are components of the paradigm—the "party line" of reality. The reason why a particular paradigm is adopted is because "Paradigms gain their status because they are more successful than their competitors in solving a few problems that a group of practitioners have come to recognize as acute (p. 23). Mopping-up operations are what engage most scientists throughout their careers. … No part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are often not seen at all. Nor do scientists normally aim to invent new theories, and they are often intolerant of those invented by others. There are … only three normal foci for factual scientific investigation (p. 25). These three classes of problems—determination of significant fact, matching of facts with theory, and articulation of theory—exhaust … the literature of normal science, both empirical and theoretical (p. 34)."

Kuhn continues with a discussion of conditions that may demand an adjustment, revision, or overhaul of the existing paradigm. "Discovery commences with the awareness of anomaly, i.e., with the recognition that nature has somehow violated the paradigm-induced expectations that govern science (p. 52). Crises are a necessary precondition for the emergence of novel theories. … The decision to reject one paradigm is always simultaneously the decision to accept another, and the judgment leading to that decision involves the comparison of both paradigms with nature *and* with each other (p. 77). [Scientists] will devise numerous articulations and ad hoc modifications of their theory in order to eliminate any apparent conflict (p. 78). [There is an] "essential tension" implicit in scientific research. … All crises begin with a blurring of a paradigm and the consequent loosening of the rules for normal research. …All crises close in one of three ways. Sometimes normal science ultimately proves able to handle the crisis-provoking problem despite the despair of those who have seen it as the end of an existing paradigm. … Scientists may conclude that no solution will be forthcoming in the present state of their field. … Or a crisis may end with the emergence of a new candidate for paradigm and with the ensuing battle over its acceptance (p. 84). In periods of acknowledged crisis … scientists have turned to philosophical analysis as a device for unlocking the riddles of their field … (p. 88). The resulting transition is scientific revolution (p. 90)."

Kuhn relates three approaches to a new theory, "There are, in principle, only three types of phenomena about which a new theory might be developed. The first consists of phenomena already well explained by existing paradigms. . . A second class of phenomena consists of those whose nature is indicated by existing paradigms but whose details can be understood only through further theory articulation. … the third type of phenomena, the recognized anomalies whose characteristic feature is their stubborn refusal to be assimilated to existing paradigms. This type alone gives rise to new theories. … (p. 97)."

The existence of the **Natural Philosophy Alliance** (NPA) fulfills predictions made by Kuhn and offers promise for the future. "History suggests that the road to a firm research consensus is extraordinarily arduous (p. 15). When in the development of a natural science, an individual or group first produces a synthesis able to attract most of the next generation of practitioners, the older schools gradually disappear. In part their disappearance is caused by their members' conversion to the new paradigm (p. 18). In the sciences, . . . the formation of specialized journals [**Galilean Electrodynamics**], the foundation of specialists' societies [**NPA**], and the claim for a special place in the curriculum have usually been associated with a group's first reception of a single paradigm [major corrections of SRT and GRT] (p. 19)."

The Role of Light in the Physics Paradigm

The history of the development of the role of the light in the physics paradigm is briefly outlined in Fig. 1, which is adapted from a figure by G. B. Stroke [2]. The theory of light is divided into two columns that represents two paradigms from the beginning, one by the English and one on the Continent of Europe. Starting with the right side of Fig. 1, Newton believed in a corpuscle or particle structure of light. He studied its characteristics extensively and published his finding in **Optics** in two parts in 1675 and 1679. An interesting statement is made by Newton [3] in the **Optics**, "Do not bodies act upon light at a distance, and by their action bend its rays, and is not this action (*cœteris paribus*) strongest at the least distance."

Almost from the beginning there was a wave-particle argument. Now we move to the left side of Fig. 1. Huygens published his **Treatise on Light** [4] that emphasized that light was a wave. Early wave characteristics of light included rectilinear propagation, refraction, reflection, polarization, and scattering. Early observations on geometric optics were performed by Fresnel, Lord Rayleigh, Descartes, and Fermat. Young developed persuasive arguments favoring a wave theory of light in the early 1800s, but his ideas were not fully accepted into the physics paradigm until the 1850s. A few years later Maxwell put forward the idea that light was an electromagnetic wave propagated in some kind of field that was dubbed the ether. Hertz worked on the propagation of various frequencies and experimentally verified Maxwell's equations. Boltzmann performed experiments on thermal radiation in the late 1800s that lead to the blackbody problem that challenged everyone.

Back to the right side of Fig. 1. Not much was done to advance the particle theory of light until Planck resolved the ultraviolet catastrophe of black body radiation in 1900 by assuming that light was emitted in small discrete bundles of energy leading to a photon theory of light. Einstein gave the name of *quanta* to Planck's bundles of radiation in the Einstein 1905 paper on the photoelectric effect. Planck's equation opened the door and paradoxically defined and explained the electromagnetic spectrum as a continuous spectrum.

Concepts about light, the electromagnetic spectrum, spectroscopy, and quantum phenomena exploded in the 1920s almost simultaneous with observations in 1919 that light does bend in a gravitational field. A paradigm shift was about to begin. Classical physics was ending and quantum physics was beginning. Quantum mechanics began with the Bohr atom, and the particle nature of matter. Wave-particle duality was introduced by de Broglie, followed by the Compton effect and electron diffraction. Schrödinger and Heisenberg put forward different mathematical approaches to wave mechanics that proved identical in meaning.

Einstein did his own thing. He instituted a major change in the physics paradigm concerning light with his *light postulate*. "Light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body." He introduced the light postulate in 1905 into his

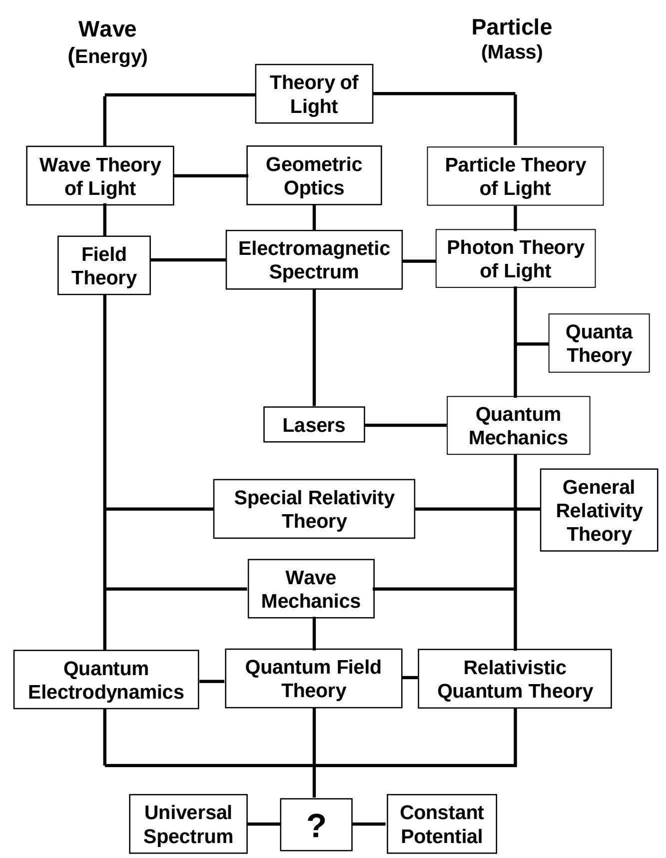

Fig. 1. Developments in the theory of light.

special relativity theory [5] in Fig. 1. Later, in 1916, Einstein adopted the teachings of his mathematics professor Minkowski when Einstein made the following assumption, "The unit of time is to be chosen so that the velocity of light *in vacuo* as measured in the "local" system of co-ordinates is to be equal to unity." This assumption when applied in the general relativity theory [6], had a major impact on the paradigm of physics. This impact is discussed in another paper [7] at this conference.

The three boxes across the bottom of Fig. 1 indicate only a portion of the impact of quantum mechanics on physics. Quantization of the Maxwell equations by Feynman and others resulted in quantum electrodynamics. Quantum field theory, which adapted the Yukawa assumption of particles that mediated forces, led to the standard model. Dirac contributed to both of these areas plus development of relativistic quantum theory.

The future is symbolized by the question mark at the bottom middle of Fig. 1. My two suggestions for advancing the theory of light flank the question mark. The left side of the question mark proposes that the electromagnetic spectrum has a discrete structure that can be extended at both ends to span the universe [8]. On the opposite side is the suggestion by Marquardt and me [9, 10] that light has a constant gravitation potential, which is discussed from a different aspect in another paper at this conference [11].

After 400 years of progress on understanding the theory of light, light is now defined [12] from two perspectives. "Light is electromagnetic radiation with wavelengths capable of causing the sensation of vision, ranging approximately from 4000 (extreme violet) to 7700 angstroms (extreme red). More generally, light is electromagnetic radiation of any wavelength; thus, the term is sometimes applied to infrared and ultraviolet radiation."

Measurements of the Speed of Light

The speed of light "is the most investigated and one of the most accurately measured of all the fundamental constants of nature." According to Halliday and Resnick [13]. An interesting table [14] of early measurements is shown in Fig. 2. The approaches to measuring this speed generally fall into two methods. One approach [15] measures the group velocity: "the average time for a light signal, that is a modulated electromagnetic wave train, to traverse a given distance." Measurements by Roemer, Foucalt, Fizeau, Foucault and Michelson may use differently designed instruments but still measure the group velocity. The other approach measures the phase velocity. If the wavelength of a particular color of light is known, measurements of the frequency are made and the product of frequency and wavelength gives the speed of light. The three laser measurements at the bottom of Fig. 2 are phase velocity measurements. "The phase velocity can also be calculated from the ratio of electromagnetic to electrostatic units." [16].

Date	Experimenter	Country	Method	Speed km/s
1600(?)	Galileo	Italy	Lanterns and shutters	"If not instantaneous, it is extraordinarily rapid"
1676	Roemer	France	Moons of Jupiter	214,000
1729	Bradley	England	Aberration of starlight	304,000
1849	Fizeau	France	Toothed wheel	315,300
1862	Foucault	France	Rotating mirror	298,000
1879	Michelson	USA	Rotating mirror	299,910
1906	Rosa and Dorsey	USA	From $c = 1/\sqrt{\epsilon_0\mu_0}$	299,781
1927	Michelson	USA	Rotating mirror	299,798
1950	Essen	England	Microwave cavity	299,792.5
1950	Bergstrand	Sweden	Geodimeter	299,793.1
1958	Froome	England	Microwave interferometer	299,792.5
1965	Kolibuyev	USSR	Geodimeter	299,792.6
1972	Bay et al.	USA	From $c = \lambda\nu$ (laser light)	299,792.462
1973	Evenson et al.	USA	From $c = \lambda\nu$ (laser light)	299,792.4574
1974	Blaney et al.	England	From $c = \lambda\nu$ (laser light)	299,792.4590

Fig. 2. Measurements of the speed of light

The measurements in Fig. 2 ran into a problem in the 1970s. "The speed of light eventually became so well established by experiment that its precision was limited only by the uncertainties involved in the definition of the meter, then based on the wavelength of light emitted by atoms of Krypton-86" [17]. The length of the meter was redefined in 1983 based upon the speed of light. If this standard still exists, any change in the speed of light changes all standards based upon the meter.

Important Equations of Light

As indicated by Fig. 3, the speed of light enters into many equations. Most of the important ones are included. Equations marked with an asterisk are ones that I derived. The little empty square in each equation represents the speed of light in the center square. Many times, the speed of light is raised to an exponent in the equations. The appropriate exponent is noted at the upper right corner of the relevant square. It should be obvious that any significant change in the magnitude of the speed of light will effect a lot of phenomena.

Brief comments will be made for all 18 equations in Fig. 3. The starting point is the top of the circle of equations. Comments will proceed clockwise from the top.

Field Equations of General Relativity. The Einstein field equations can be designated in a mass, momentum, or energy density format depending upon the exponent of the speed of light in the denominator on the right side of his equations. Any change in the magnitude of the speed of light will greatly amplify the effect. Having said this, Einstein used geometrized units where c = 1 in those units. In this case the box in this equation contained unity, and thus was ignored except for the units.

Mass-Energy Equivalence. The amount of energy contained in an amount of mass would vary with the speed of light. Energy balances would be hard to control.

Refractive Index. The refractive index defines the ratio of the speed of light in free space divided by the speed of light in a media. The refractive index would be a meaningless number if the reference standard varies.

Maxwell equations. Maxwell recognized that light was an electromagnetic wave. The speed of light was added into his equations as a reference standard. No standard, no equations?

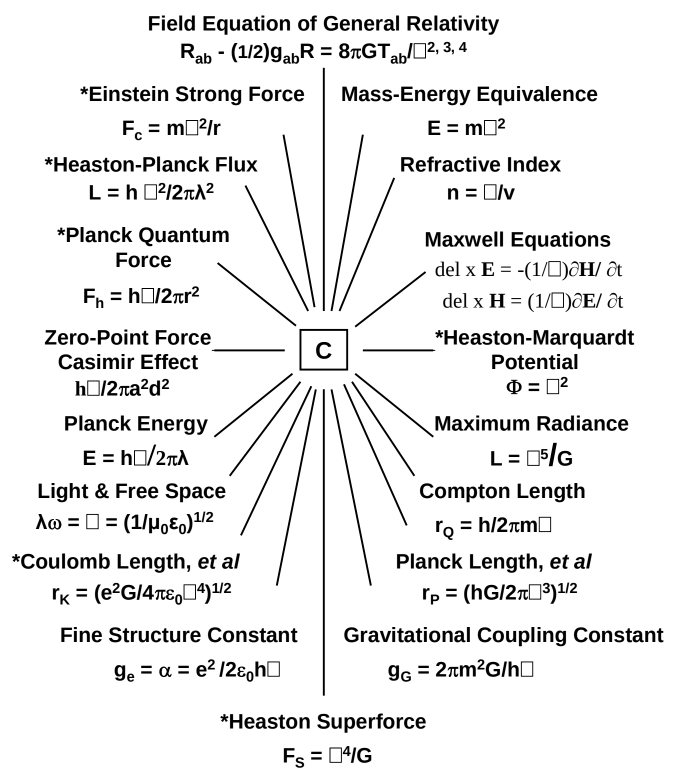

Fig. 3. Important relationships containing the speed of light.

Heaston-Marquardt Potential. Light (and energy) is predicted to have a constant gravitation potential that is defined by the speed of light squared. The bending of light would waver if the speed of light were not constant.

Maximum Radiance. Einstein predicted that astronomical bodies give off gravitational waves. Even a small change in this radiation would be noticed because of the large exponent.

Compton Length. The scattering of electrons by radiation has been carefully observed and no change in the speed of radiation has been observed.

Planck Length. All components of the Planck scale (length, mass, time and energy) would change if the speed of light changed. String theory and the standard model employ the Planck scale.

Gravitational Coupling Constant. The relative strength of the gravitational force would change if the speed of light changed.

Heaston Superforce. Since this superforce is hidden in the Einstein field equations directly across from this equation, the superforce would be the cause of changes in the Einstein equations.

Fine Structure Constant. The fine structure constant is prominent in spectroscopy and is also equivalent to the electromagnetic force coupling constant. All things electrical could go awry.

Coulomb length. This is a discovery of mine that identifies a Coulomb scale parallel to the Planck scale. The superforce is submerged in this scale so that the effect of variations in the speed of light escalates exponentially.

Light & Free Space. The phase velocity of light, the relationships of wavelength and frequency, and the link of free space with the Maxwell equations could wreak havoc with changes in the speed of light.

Planck Energy. Quantum mechanics, the electromagnetic spectrum, communications, electronics and a lot of phenomena could become undependable with an unpredictable changing speed of light.

Zero-Point Force Casimir Effect. The vacuum is already gorged with this effect. The addition of a changing light speed would go into the same sump.

Planck Quantum Force. This is another discovery of mine that would change, but so few know about it—why worry?

Heaston-Planck Flux. Another new discovery that describes radiation phenomena that needs more explanation.

Einstein Strong Force. My theoretical explanation of the strong—color force would be directly affected by a change in the speed of light. The bonding strengths of nuclei would be impacted.

Cerenkov Radiation. There are other areas of phenomena where the speed of light enters into the consequences that are not given in Fig. 2. In a "swimming pool" reactor, where water is used as a shield, the decay of Cobalt-60 releases radiation that is going faster than the speed of light in water. The water has a beautiful blue glow as the result of this radiation. Once again, the media is in control of cause and effect.

X-rays in Glass. The velocity of x-rays in glass as well as in some other material is greater than its velocity in free space. This behavior means that the index of refraction for x-rays is less than unity and is bent away from the normal on entry. [18]

Stefan-Boltzmann Equation. The formula for thermal radiation, which contains the speed of light with the temperature to the fourth power, would be effected by any change in the speed of light.

In essence, any phenomena involving electromagnetic waves would be influenced by variations in the speed of light. With changing media, variations are expected and usually predictable. Capricious and unexpected variations could be a threat to the reliability of current expectations.

Anomalies of Light

Most of the anomalies associated with the speed of light are related to the media in which light is moving. The magnitude of the speed of light is usually related to free space according to Maxwell or in *vacuo* according to Einstein. What is free space—free of what? The modern day vacuum has all sorts of virtual stuff in it. The definition of the speed of light needs refining.

A media issue that keeps coming back to torment physicists is the question of the ether. Is there or is there not a special something that permeates all of space and acts as a carrier of light?

An interesting assessment of the velocity of light states [19] this, "The velocity of light is not as constant as it sometimes appears to be. While according to the theory of special relativity, the velocity of light will be the same in any frame of reference, independent of its state of motion, this is true only for frames of the same gravitation potential. Conceivably, local variations of the gravitational potential could lead to variations of the measured velocity of light."

Conclusions

The objective here was to evaluate the consequences of assuming that the speed of light was not constant. Many consequences, mostly not good, occur if the speed of light is not constant. The major lessons learned were that the speed of light in a vacuum/free space . . .

- Was a major component of the 20th century physics paradigm.
- Is a standard fundamental constant of science.
- Is ubiquitous in the equations of physics.
- Has been measured many times and in several different ways.
- Does vary in magnitude depending upon the media in which measured.
- Can be exceeded in magnitude by matter and radiation in motion.
- Has never been proven to violate Einstein's light postulate.
- Would have a disastrous effect if not constant.
- Should be retained in the 21st century physics paradigm and address anomalies.

Even after 400 years of study, there is still something new that we can learn about light. We should not close our minds to the possibility that light does not behave the way that we expect it to.

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