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One-way Speed of Light Using Interplanetary Tracking Technology

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Author's contribution

This whole work was carried out by author SJGG.

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ABSTRACT

Light transmission in the Sun-Centered Inertial (SCI) frame is considered within a flat space-time metric of relativity theory. It is shown that this metric which is used to derive the Langevin metric that generates the accurate clock synchronization algorithm used in the Global Positioning System (GPS), also predicts one-way light speed anisotropy in an inertial frame that contradicts the principle of light speed constancy. This finding is tested and confirmed in the SCI frame using the range equations employed in the tracking of planets and spacecrafts moving within our solar system. These equations are based on the observation that light travels in the SCI frame at a constant speed *c* and have been extensively tested and rigorously verified. The results suggest a modification of the Lorentz Transformations that yields new transformations that are consistent with the observed light speed anisotropy and which better accord with the physical world.

Keywords: One-way speed of light; range equations; postulate of light speed constancy; Llorentz transformations, Selleri transformations, sun-centered inertial frame.

1. INTRODUCTION

The idea that light travels at a constant speed in all inertial frames is central to modern physics and metrology [1]. Following the famous Michelson-Morley experiment [2], numerous experiments have been conducted to test this postulate [3-7]. These experiments,

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conducted in the non-inertial frame of the rotating Earth, have progressively lowered the limit on light speed anisotropy to a value of $\delta c/c < 10^{-17}$ where δc is the measured change in light speed. There are published cases of Michelson-Morley type experiments which imply light speed anisotropy [8,9] but these have generally been ignored. Instead the preponderance of negative tests has resulted in the speed of light being declared a constant in the 1983 SI definition of the unit of length applicable in the frame of the rotating Earth. This accepted principle of light speed constancy is used to derive the Lorentz transformations which relate two relatively moving inertial frames and form the basis of modern space-time physics.

Zhang [3] has shown however that what these many experiments have established is two-way light speed constancy and that one-way light speed constancy remains unconfirmed. Recently Spavieri [10] reviewed this situation and suggested an indirect method for one-way light speed determination. A better approach is a direct one-way light speed test on the surface of the Earth which can be conducted using the accurate synchronized atomic clock technology now available in the global positioning system (GPS) [11,12]. Marmet [13] observed that time measurements using these synchronized clocks reveal that light signals take 28 nanoseconds longer travelling eastward from San Francisco to New York as compared with the signals traveling westward from New York to San Francisco. Also using GPS time measurements Kelley [14] noted that a light signal takes 414 nanoseconds longer to circumnavigate the Earth eastward at the equator than a light signal travelling westward around the same path. Unequal travel times for electromagnetic signals travelling in opposite directions around the Earth were first directly demonstrated by Allan et al. using signal reflections off orbiting satellites [15]. From these recorded differences in light travel times Marmet and Kelley deduced light speeds $c-w$ eastward and $c+w$ westward relative to the surface of the Earth where w is the speed of rotation of the Earth's surface at the particular latitude. Hayden [16] arrived at this same conclusion after considering several experiments including Sagnac, Michelson-Gale and Brillet-Hall. These findings are strengthened by the fact that a generalized East-West light speed anisotropy $c \pm w$ is predicted by general relativity [17,18] and this generalized result has been directly confirmed by Gift using the CCIR clock synchronization algorithm [18,19] as well as the GPS range equation [18,20].

In addition to the evidence of light speed anisotropy in frames on or close to the surface of the Earth arising from its rotation, there is strong evidence of light speed variation resulting from the Earth's orbital motion for light travelling in space beyond the terrestrial frame. In research done more than 40 years ago, Wallace [21] analyzed published interplanetary data and presented evidence for the classical composition of light speed c in space and Earth's orbital speed v giving light speed $c+v$ .relative to the moving Earth. The same result was obtained by Tolchel'nikova in 1991 [22]. Light speed variation arising from orbital motion was recently demonstrated for light from planetary satellites in the Roemer experiment [23] and for light from stars on the ecliptic in the Doppler experiment [24]. Such light speed anisotropy has also been reported in a laser diffraction experiment [25], for light propagation over cosmological distances [26] and in the Shtyrkov experiment involving the tracking of a geostationary satellite [27].

In the face of these many positive indications of light speed variation but recognizing the importance of the principle of light speed constancy to modern physics, we have in this paper again examined the phenomenon of speed variation for light travelling through space.

We first use a flat spacetime metric to evaluate light speed in a frame moving uniformly relative to the solar barycentric or Sun Centered Inertial (SCI) frame. This light speed prediction is then tested using a new approach involving interplanetary tracking technology. In this method the radar technology used in tracking planets and spacecrafts is used to determine the one-way speed of light reflected from a planet or spacecraft and observed from the orbiting Earth moving in the solar barycentric frame. A full discussion of the results and the implications for space-time physics are then presented.

2. LIGHT SPEED ON A UNIFORMLY MOVING PLATFORM USING RELATIVITY THEORY

In this section for a light pulse travelling in the SCI frame, we derive the light speed on a uniformly moving platform. From relativity theory the invariant line element in an inertial frame with Cartesian coordinates (t, x, y, z) where space-time is Minkowskian is given by [1]

$$ds^2 = (cdt)^2 - dx^2 - dy^2 - dz^2 \tag{1}$$

Line element (1) can be expressed in cylindrical coordinates (t, r, ϕ, z) given by [28]

$$-ds^2 = -(cdt)^2 + dr^2 + r^2 d\phi^2 + dz^2 \tag{2}$$

In the very successful GPS system, transformation of line element (2) from a coordinate system (t, r, ϕ, z) in the Earth Centered Inertial (ECI) frame to a coordinate system (t', r', ϕ', z') in a rotating frame corresponding to the Earth Centered Earth Fixed (ECEF) frame which is rotating at the uniform angular speed ω_E using the transformations

$$t = t' ,\ r = r' ,\ \phi = \phi' + \omega_E t' ,\ z = z' \tag{3}$$

yields the well-known Langevin metric in the rotating frame given by

$$-ds^2 = -(1 - \frac{\omega_E{}^2 r'^2}{c^2})(cdt')^2 + 2\omega_E r'^2 d\phi' dt' + d\sigma'^2 \tag{4}$$

Where;

$$d\sigma'^2 = dr'^2 + r'^2 d\phi'^2 + dz'^2 \tag{5}$$

is the square of the coordinate distance. Applying equation (4) to the propagation of light in the rotating frame by setting $ds^2 = 0$ yields a quadratic equation for dt' given by

$$(1 - \frac{\omega_E{}^2 r'^2}{c^2})(cdt')^2 - \frac{2\omega_E r'^2 d\phi'}{c}(cdt') - d\sigma'^2 = 0 \tag{6}$$

the solution of which leads to the extensively tested and rigorously verified CCIR clock synchronization algorithm [12,18] given by

$$\int_{path} dt' = \int_{path} \frac{d\sigma'}{c} + \frac{2\omega_E}{c^2} \int_{path} dA'_z \tag{7}$$

where dA'_z is the infinitesimal area in the rotating frame that is swept out by a line connecting the axis of rotation to the light pulse and projected onto a plane parallel to the equatorial plane [12]. Equation (6) also predicts east-west light speed anisotropy $c \pm v$ in the frame of the rotating Earth as recently demonstrated by Gift [18] and this encouraged a team of researchers to mount a search for such asymmetrical light speeds in the 1980s [17]. This east-west light speed anisotropy has since been confirmed using GPS technology [13,14], [18-20] and was first observed by Allan et al. [15] even though they did not so interpret their measurement.

Consider now a transformation from the coordinate system (t, x, y, z) in the SCI frame where light speed is c to a coordinate system (t', x', y', z') in a frame moving uniformly relative to the SCI frame. One such moving frame is the Earth centered non-rotating frame of the orbiting Earth which is moving at the (approximately uniform) orbital speed v relative to the SCI frame. This transformation to the uniformly moving frame analogous to the transformation (3) to the rotating frame was considered by Weber [29] and is given by

$$t = t',\ x = x' + vt',\ y = y',\ z = z' \tag{8}$$

The time transformation $t = t'$ in (8) is the same as that in (3) used in the GPS [12] and means that time t' in the uniformly moving frame Earth-fixed frame is the same as the time t in the underlying SCI frame where the measuring clocks can be Einstein synchronized since light speed there is known to be *c*. Such global clock synchronization realizing $t = t'$ is today routinely accomplished in the GPS and therefore the coordinate time t' in the uniformly moving frame is directly measurable using GPS clocks. The space transformation $x' = x - vt$ in (8) means as Weber has stated “that every fixed point x' of the new frame travels with velocity v with respect to the original frame” as required in the uniformly moving frame.

Transformation (8) in line element (1) results in the line element in the moving frame given by

$$ds^2 = (c^2 - v^2)dt'^2 - dx'^2 - dy'^2 - dz'^2 - 2v dx' dt' \tag{9}$$

Applying equation (9) to the propagation of light along the x' axis on the moving platform by setting $ds^2 = 0, dy' = 0, dz' = 0$ yields a quadratic equation for $(\frac{dt'}{dx'})$ given by

$$(c^2 - v^2)(\frac{dt'}{dx'})^2 - 2v(\frac{dt'}{dx'}) - 1 = 0 \tag{10}$$

Solving for $(\frac{dt'}{dx'})$ gives

$$\frac{dt'}{dx'} = \frac{v \pm c}{(c^2 - v^2)} \tag{11}$$

from which

$$dt' = \frac{v \pm c}{(c^2 - v^2)} dx' \tag{12}$$

2.1 Light Travelling from Right to Left

For light travelling in the direction opposite to the motion of the platform corresponding to the Earth moving towards the light source, dx' is negative such that $dx' = -|dx'|$. Since dt' is positive, then the negative sign in $(v \pm c)$ in (12) is chosen giving

$$dt' = \frac{|dx'|(c - v)}{(c + v)(c - v)} = \frac{|dx'|}{(c + v)} \tag{13}$$

Now $|dx'| = d$ is the distance travelled by the light pulse in time dt'. Hence

$$dt' = \frac{d}{(c + v)} \tag{14}$$

Therefore the coordinate light speed c^- on the advancing Earth is given by

$$c^- = \frac{d}{dt'} = \frac{d}{d/(c + v)} = c + v \tag{15}$$

If the Earth is receding from the light source then $v \to -v$ in the transformation (8) and equation (15) becomes

$$c^- = \frac{d}{dt'} = \frac{d}{d/(c - v)} = c - v \tag{16}$$

2.2 Light Travelling from Left to Right

For the original transformation (8), if the light is travelling in the direction of motion of the platform corresponding to the Earth moving away from the light source, dx' is positive and therefore $dx' = |dx'|$. Since dt' is positive, then the positive sign in $(v \pm c)$ in (12) is chosen giving

$$dt' = \frac{|dx'|(c+v)}{(c+v)(c-v)} = \frac{|dx'|}{(c-v)} \tag{17}$$

This reduces to

$$dt' = \frac{d}{(c-v)} \tag{18}$$

Therefore the coordinate light speed c^+ on the receding earth is given by

$$c^+ = \frac{d}{dt'} = \frac{d}{d/(c-v)} = c - v \tag{19}$$

If the Earth is moving towards the light source then $v \to -v$ in the transformation (8) and equation (19) becomes

$$c^+ = \frac{d}{dt'} = \frac{d}{d/(c+v)} = c + v \tag{20}$$

Thus at any point on the uniformly moving platform, the calculation using line element (1) and transformation (8) produces coordinate light speed $c+v$ for motion towards the light source and coordinate light speed $c-v$ for motion away from the light source. This light speed anisotropy in the inertial frame of the orbiting Earth predicted by the flat space-time metric of relativity theory is inconsistent with the principle of light speed constancy postulated to hold in all inertial frames. It however corroborates the findings of Wallace [21] and Tolchel'nikova [22] as well as the light speed variation arising from the Earth's orbital motion demonstrated in [23] and [24]. In the next section in order to verify the predicted light speeds, a new one-way light speed test on the orbiting Earth for light travelling through space is described.

3. ONE-WAY LIGHT SPEED IN THE SCI FRAME USING TRACKING TECHNOLOGY

While position on or near the Earth can be precisely determined using the range equation of the GPS operating in the Earth-Centered Inertial (ECI) frame, the orbital ephemerides of the planets and other bodies in the solar system are determined using a different set of range equations operating within the solar barycentric or sun-centered inertial (SCI) frame [30], [31,32]. The SCI frame is a frame that moves with the Sun but does not rotate with it and provides a convenient reference frame for many astronomical events. The associated range equations are used to determine round-trip time of an electromagnetic signal that emanates from a transmitting antenna on Earth and is reflected by a spacecraft transponder or planetary body back to the same antenna on Earth. Time measurement is effected using atomic clocks based on Coordinated Universal Time (UTC) and the spatial coordinates are relative to the solar-system barycenter of the SCI frame. The relevant range equations are given by [30-32]

$$c\tau_u = \left| r_B(t_R - \tau_d) - r_A(t_R - \tau_d - \tau_u) \right| \tag{21}$$

$$c\tau_d = \left| r_A(t_R) - r_B(t_R - \tau_d) \right| \tag{22}$$

where t_R is the time of reception of the signal, τ_u and τ_d are the up-leg and down-leg times respectively, r_A is the solar-system barycentric position of the receiving antenna on the Earth's surface, r_B is the solar-system barycentric position of the reflector which is either a responding spacecraft or the reflection point on the planet's surface and c is the speed of light in the SCI frame. These equations are based on the observation that light travels in the SCI frame at a constant speed and have been rigorously tested and verified. They are derived using data sets acquired over more than half a century of measurement. In order to obtain values for τ_u and τ_d, the two equations are solved iteratively. In practice time corrections must be made to τ_u and τ_d because of relativistic effects, the electron content of the solar corona and the Earth's troposphere [31,32].

In determining one-way light speed using this system, consider a transmitting/receiving antenna A fixed on the surface of the Earth which is moving in the SCI frame at orbital speed *v* relative to the SCI frame and a reflecting spacecraft B stationary or moving relative to the SCI frame. On an axis fixed in the SCI frame along the line joining antenna A and spacecraft B at the instant of signal reflection with antenna A closer to the origin O than spacecraft B and taking positive values, let r_A be the coordinate along the axis of the position in the SCI frame of antenna A and r_B be the coordinate along the axis of the position of spacecraft B. At the time of reflection of the signal from B, let the distance between A and B be L given by

$$r_B(t_R - \tau_d) - r_A(t_R - \tau_d) = L \tag{23}$$

3.1 Antenna Moving toward Reflector

At the instant of reflection of the electromagnetic signal at reflector B let antenna A move directly toward the reflector B at orbital speed *v* relative to the SCI frame. Then using the range equation (22),

$$c\tau_d = r_B(t_R - \tau_d) - r_A(t_R) \tag{24}$$

Since (for sufficiently small L) antenna A is moving uniformly toward reflector B at speed *v* relative to the SCI frame, it follows that the relation between the position $r_A(t_R)$ of antenna A at the time of reception of the signal and its position $r_A(t_R - \tau_d)$ at the time of reflection of the signal at reflector B is given by

$$r_A(t_R) = r_A(t_R - \tau_d) + \tau_d v \tag{25}$$

Substituting for $r_A(t_R)$ from (25) in (24) yields

$$c\tau_d = r_B(t_R - \tau_d) - r_A(t_R - \tau_d)) - \tau_d v \tag{26}$$

Using (23) this becomes

$$r_B(t_R - \tau_d) - r_A(t_R - \tau_d) = L = (c+v)\tau_d \tag{27}$$

Hence from equation (27) for an observer on Earth, the range equation (22) yields the down-leg time as

$$\tau_d = \frac{L}{c+v} \tag{28}$$

Therefore the speed c_{BA} of the electromagnetic signal relative to antenna A traveling from the reflector B to the moving antenna A is given by the separation L at the time of reflection divided by the down-leg time τ_d which using (28) is

$$c_{BA} = \frac{L}{\tau_d} = \frac{L}{L/(c+v)} = c+v \tag{29}$$

This speed is the same as that in (15) and (20) predicted by the flat space-time metric but is different from the light speed *c* that is required by the postulate of light speed constancy.

3.2 Antenna Moving Away from Reflector

At the instant of reflection of the electromagnetic signal at reflector B let antenna A move directly away from the reflector B at orbital speed *v* relative to the SCI frame. Then using the range equation (22),

$$c\tau_d = r_B(t_R - \tau_d) - r_A(t_R) \tag{30}$$

Since antenna A is moving uniformly away from reflector B at speed *v* relative to the SCI frame, it follows that the relation between the position $r_A(t_R)$ of antenna A at the time of reception of the signal and its position $r_A(t_R - \tau_d)$ at the time of reflection of the signal at reflector B is given by

$$r_A(t_R) = r_A(t_R - \tau_d) - \tau_d v \tag{31}$$

Substituting for $r_A(t_R)$ from (31) in (30) yields

$$c\tau_d = r_B(t_R - \tau_d) - r_A(t_R - \tau_d)) + \tau_d v \tag{32}$$

Using (23) this becomes

$$r_B(t_R-\tau_d)-r_A(t_R-\tau_d)=L=(c-v)\tau_d \tag{33}$$

Hence from equation (33) for an observer on Earth, the range equation (22) yields the down-leg time as

$$\tau_d=\frac{L}{c-v} \tag{34}$$

Therefore the speed c_{BA} of the electromagnetic signal relative to antenna A traveling from the reflector B to the moving antenna A is given by the separation L at the time of reflection divided by the down-leg time τ_d which using (34) is

$$c_{BA}=\frac{L}{\tau_d}=\frac{L}{L/(c-v)}=c-v \tag{35}$$

Again this speed is exactly that predicted by the flat space-time metric in (16) and (19) but is different from the light speed *c* required by the postulate of light speed constancy.

4. DISCUSSION

This research shows that a flat space-time metric predicts anisotropic light speeds $c\pm v$ for light transmission on the Earth moving uniformly in the SCI frame. This contradicts the principle of light speed constancy that is postulated to hold in all inertial frames. Weber [29] in an attempt to reconcile these anisotropic light speeds with the light speed invariance postulate of special relativity argued that "These velocities do not contradict special relativity since, in the traditional view, the clocks reading time t are not synchronized, that is, clocks with larger x' have later times than if they were synchronized." However in the coordinate frames under consideration the clocks reading time t in the underlying SCI frame and those reading time t' in the frame moving uniformly relative to the SCI frame are all synchronized since the transformation $t=t'$ means that all clocks in both coordinate systems carry the same time. Achieving this level of synchronization in practice is not a straightforward matter but it turns out that modern clock technology readily accomplishes this "global synchronization". This is realized for example in the GPS where precise synchronization of hypothetical clocks in the ECI frame and atomic clocks in the rotating ECEF frame according to $t=t'$ is the basis of the success of the system.

This predicted light speed non invariance has been confirmed using interplanetary tracking technology. Thus it was shown in equations (29) and (35) that light travels from a reflector to a receiving antenna on Earth at a speed $c+v$ relative to the antenna for the Earth moving toward the reflector at orbital speed v and light travels at speed $c-v$ relative to the antenna for the Earth moving away from the reflector at orbital speed v. Light speed variation for light traveling in the SCI frame confirms the findings of Wallace [21] and Tolchel'nikova [22] for light travel through space. It is consistent with the light speed changes observed on the orbiting Earth for light from planetary satellites in the Roemer experiment [23] and for light from stars on the ecliptic in the Doppler experiment [24].

In the case where the velocity of the reflecting spacecraft B is such that it is geostationary, then the receiving antenna and reflector are fixed relative to each other as well as to the surface of the moving Earth. In such a case the complete light speed measurement yielding $c \pm v$ is conducted in the frame of the moving Earth, the same frame used in the vast majority of light speed experiments yielding *c*. These results in the SCI frame indicate that the speed v of the uniformly moving Earth is readily detectable with apparatus in which the signal source and receiver are fixed relative to each other and to the moving Earth. This form of the experiment directly corroborates the findings in the Shtyrkov geostationary experiment [27] and succeeds exactly where the Michelson-Morley type experiments fail.

Using an approach similar to that described using tracking technology, it is possible to demonstrate light speed variation relative to the rotating Earth by employing a GPS satellite operating in the ECI frame and transmitting to a receiver on the surface of the Earth. The associated speed variation $c \pm w$ would involve the component w of the rotational velocity of the Earth toward or away from the satellite as pointed out by Phipps [33p42] and demonstrated by Sato [34]. Such a situation with the GPS where light signal from a GPS satellite travels through the ECI frame at speed c and is received on the rotating Earth at speed $c \pm w$ is analogous to that described in this paper where light signal reflected from a space vehicle or planet travels through the SCI frame at speed c and received on the orbiting Earth at speed $c \pm v$.

It follows then that the detection of light speed variation is an objective fact validated by observational experience using atomic clocks in the real-world time measurement of travelling light. This means therefore that the principle of light speed invariance is inapplicable on the surface of the Earth as well as in the immediate surrounding region within the SCI frame. Since the principle directly yields the Lorentz Transformations [1], the inapplicability of the principle implies that these transformations cannot represent the physical world. In an attempt to resolve this difficulty Selleri [35], using experimentally confirmed time dilation [3] and two-way light speed constancy [3] derived the set of "equivalent transformations" which contains all possible space-time transformations that connect two inertial frames under a set of reasonable assumptions. The transformations are "equivalent" in the sense that they have the same space transformations

$$x' = \gamma(x - vt),\; y' = y,\; z' = z \tag{36}$$

but have time transformations that differ only by a clock synchronization parameter e_1 such that

$$t' = t/\gamma + e_1(x - vt) \tag{37}$$

where $\gamma = 1/\sqrt{1 - v^2/c^2}$. Interestingly Selleri has shown that these transformations make the same predictions for a broad range of phenomena despite the synchronization difference. Spavieri [10] discussed the two significant members of this "equivalent" set namely the Lorentz transformations corresponding to $e_1 = -v\gamma/c^2$ and whose time transformation is

$$t'_L = \gamma(t - vx/c^2) = t/\gamma - vx'/c^2 \tag{38}$$

and the Selleri transformations corresponding to $e_1 = 0$ whose time transformation is

$$t'_S = t/\gamma \tag{39}$$

It is evident that the difference between the two transformations is the single term vx'/c^2.

Starting with the classical Galilean transformations, Levy [36] has shown that the introduction of experimentally confirmed clock retardation and length contraction yields the Selleri transformations. Guerra and de Abreu [37] refer to these transformations as Synchronized transformations since the clocks in $S'(t', x', y', z')$ measuring t'_S can be externally synchronized using synchronized clocks in $S(t, x, y, z)$. They properly describe as "true speeds" the speeds calculated in S' using these synchronized clocks and ordinary rulers that measure t'_S and x' respectively. With $dx/dt = c$ in S, the "true speed" of light can be determined by differentiating the Selleri transformations giving light speed $dx'/dt'_S = \gamma^2(c - v)$ in the moving frame [35]. The γ^2 factor arises because of the length contraction and time dilation experienced by the rulers and clocks used in the measurements [36]. This speed $\gamma^2(c - v)$ reduces and generalizes to $c \pm v, v << c$ which accords with the light speeds demonstrated in this paper using the range equations involving Earth's orbital motion and predicted by the flat space-time metric.

Guerra and de Abreu describe the effect of the introduction of the term vx'/c^2 in the time component of the Selleri transformations (39) resulting in (38) as delaying the synchronized moving clocks "by a factor that is proportional to their distance x' to the reference position $x' = 0$". They appropriately refer to this process as "de-synchronizing" the synchronized measuring clocks which now measure time t'_L in S' and consider the resulting Lorentz transformations as mathematically equivalent to the original Selleri transformations. Their assertion of mathematical equivalence is incorrect since the two transformations predict different light speeds as shown below. We nevertheless agree with their description as "Einstein speeds" the speeds calculated in S' using these "de-synchronized" clocks and ordinary rulers to measure t'_L and x' respectively. This speed of light corresponding to that predicted by the Lorentz transformations can be determined by differentiating the transformations with $dx/dt = c$ giving light speed $dx'/dt'_L = c$ in the moving frame. This result represents light speed constancy. It is different from the anisotropic light speed $dx'/dt'_S = \gamma^2(c - v)$ derived from the Selleri transformations and is directly contradicted by the light speed variation $c \pm v$ detected using range equations (21) and (22) for Earth's orbital motion.

It is clear therefore that the introduction of the "de-synchronizing" term vx'/c^2 results in the invalid prediction of light speed constancy in all moving frames. It is nothing more than an ad hoc mathematical procedure intended to realize light speed constancy which however is artificial and unconnected to the real world. Virtually any "speed" can be similarly obtained by suitably "de-synchronizing" the clocks through variation of e_1 in (37) and Will [38] has pointed out that "a particularly perverse choice of [de-] synchronization can make the apparent speed…infinite"! This particular choice results from $e_1 = -\sqrt{(1+\beta)/(1-\beta)}/c$ which in light speed equation (40) below yields infinite light speed. These "apparent" speeds, represented in general by [35]

$$c(S') = \frac{c}{1+\beta+ce_1\sqrt{1-\beta^2}} \tag{40}$$

where $\beta = v/c$ and $e_1 \neq 0$ are therefore meaningless. They are falsified by the observed light speed $c(S') = c \pm v$ detected using radar tracking technology as reported in this paper and corresponding to $e_1 = 0$ in (40). (For $e_1 = 0$, (40) becomes $c(S') = \gamma^2(c-v)$ which as indicated previously reduces and generalizes to $c(S') = c \pm v, v << c$). These results are fully consistent with the findings of Gift [39] and Selleri [35,40] who identified the Selleri transformations given by

$$x' = \gamma(x - vt), y' = y, z' = z \tag{41a}$$

$$t' = t/\gamma \tag{41b}$$

as those that best accord with the physical world and not the Lorentz transformations represented by

$$x' = \gamma(x - vt), y' = y, z' = z \tag{42a}$$

$$t' = t/\gamma - vx'/c^2 \tag{42b}$$

which are invalid.

Selleri has shown [35] that the transformations (41) contain the "relativistic" phenomena of length contraction and time reduction and it turns out that both of these effects arise as a result of moving electric charge which makes up all matter. Thus consider a stationary system of electric charge whose scalar potential ϕ satisfies Poisson's equation

$$\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2} = -\frac{\rho}{\varepsilon_o} \tag{43}$$

where ρ is the charge density of the system and ε_o is the permittivity of free space. If the system moves in the x direction with velocity v then it can be easily shown [41], [42] that the potential ϕ' on the moving system satisfies

$$\frac{\partial^2\phi'}{\partial x'^2} + \frac{\partial^2\phi'}{\partial y'^2} + \frac{\partial^2\phi'}{\partial z'^2} = -\frac{\rho}{\varepsilon_o} \tag{44}$$

Where;

$$x' = \gamma(x - vt), y' = y, z' = z \tag{45}$$

Relations (45) are the spatial transformation (41a) of the Selleri transformations and represent a contraction of the moving system in the direction of movement.

With respect to time, it is well known that an accelerating electric charge generates electromagnetic radiation [43]. Consider an oscillating point charge which generates electromagnetic radiation of frequency f with the associated dipole being stationary in free space. If the dipole moves with velocity *v* in free space in any direction perpendicular to the direction of oscillations, then using classical analysis Hazra has shown [44] that the resulting frequency f' of the radiation is given by

$$f' = f / \gamma \tag{46}$$

which represents a frequency reduction. If these oscillations are used to indicate time by counting the number of oscillation cycles (ticks) on a clock, then measured time would be proportional to frequency and (46) yields the time retardation formula

$$t' = t / \gamma \tag{47}$$

Relation (47) is the temporal transformation (41b) of the Selleri transformations.

Therefore with the derivation of (45) and (47) using electrodynamics, a causal agent for the length contraction and time reduction phenomena has been established.

5. CONCLUSION

The main contribution of this paper is the prediction using a flat space-time metric of light speed anisotropy in the non-rotating frame of the orbiting Earth and a demonstration of this light speed variation using interplanetary radar technology. In 1988 Alley and his colleagues [17] used the Langevin metric to derive asymmetrical light speeds in the frame of the rotating Earth and this was also recently demonstrated by Gift [18]. The corresponding flat space-time metric for a uniformly moving frame was used in this paper to derive variable light speed in the non-rotating frame of the orbiting Earth. This variable light speed was then confirmed using interplanetary tracking technology. Specifically the equations used to track planets, interplanetary space probes and other space vehicles involving UTC measurements and spatial coordinates relative to the solar-system barycentric frame were used to determine one-way light speed for light travelling to the orbiting Earth from these bodies moving in our solar system. Based on the fact of the isotropy of the speed of light in the SCI frame, the speed of light reflected from a body and travelling to Earth was found to be $c \pm v$ where v is the orbital speed of the Earth toward or away from the reflecting surface at the time of reflection of the signal.

The light speeds $c \pm v$ relative to the non-rotating frame of the moving Earth computed using modern tracking technology have previously been reported by Wallace [21] and

Tolchel'nikova [22] and were demonstrated in the Roemer [23] and Doppler [24] experiments. These variable speeds are different from the results of the many light speed experiments [2-7] which appear unable to detect such variation [3]. These light speed changes are at variance with the principle of light speed constancy which requires constant light speed *c* for light traveling between the reflector and Earth. They suggest that this principle is inapplicable in the SCI frame and therefore provide a basis for adjusting the Lorentz transformations which are derived from this principle. The modification involves the removal of the "de-synchronizing" term vx'/c^2 from the time component of the transformations. Such a deletion reconciles these transformations with observed and incontrovertible light speed variation while still satisfying all the experimentally confirmed results in special relativity as demonstrated by Selleri [35,40].

The Lorentz transformations and special relativity have been the center of ongoing controversy over the past 100 years [45] and in light of the considerable contradicting evidence now available the continuing use of this theory lacks intellectual integrity and is scientifically indefensible. The statement of the "equivalent" set by Selleri has provided the framework for the examination of all the allowable transformations and the successful identification of the correct one. Thus we believe we have determined the source of the problem and urge the scientific community to consider the easily verified results presented in this paper. They provide a sound basis for the elimination of the offending term vx'/c^2 in the Lorentz transformations and the acceptance of the resulting Selleri transformations. Moreover the associated "relativistic" effects now have classical interpretations in the framework of conventional electrodynamics [41,42,46] which represents a direct causal agency for these phenomena.

The rejection of the falsified Lorentz transformations along with special relativity and the introduction of the confirmed Selleri transformations into mainstream physics are likely to open new vistas in space-time research. For example the relaxation of the Lorentz covariance requirement imposed by a relativistic framework has already led to the development of a promising quantum theory of magnetic interaction that offers plausible explanations for chemical reactivity, the covalent bond and the celebrated Pauli Exclusion Principle [49]. Another interesting development is the provision of a theoretical foundation for the existence of a preferred frame by the new transformations [35], the detection of which has been reported by several researchers [8,9,47,48]. Finally, these new transformations may assist in the development of an improved gravitational theory as attempted by Logunov [50] and earlier by Gift [51] and thereby throw new light on the major problem of the unification of gravity and quantum theory that has remained unsolved for the past 75 years [52].

COMPETING INTERESTS

Author has declared that no competing interests exist.

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