Relativity: a pillar of modern physics or a stumbling block

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ABSTRACT

Currently, the theory of Relativity is being regarded as one of the main pillars of Modern Physics, essentially due to its perceived role in high energy physics, particle accelerators, relativistic quantum mechanics, and cosmology. Since the founding assumptions or postulates of Relativity and some of the resulting consequences confound the logic and common sense, a growing number of scientists are now questioning the validity of Relativity. The advent of Relativity has also ruled out the existence of the 19th century notion of ether medium or physical space as the container of physical reality. Thereby, the Newtonian notions of absolute motion, absolute time, and absolute reference frame have been replaced with the Einsteinian notions of relative motion, relative time, and inertial reference frames in relative motion. This relativity dominated viewpoint has effectively abandoned any critical study or advanced research in the detailed properties and processes of physical space for advancement of Fundamental Physics. In this paper both special theory of relativity and general relativity have been critically examined for their current relevance and future potential. We find that even though Relativity appears to be a major stumbling block in the progress of Modern Physics, the issue needs to be finally settled by a viable experiment [Phys. Essays 23, 442 (2010)] that can detect absolute motion and establish a universal reference frame.

Keywords: Relativity, Reference frame, Absolute motion, Spacetime, Continuum, Mass-energy equivalence.

1 INTRODUCTION

Twentieth century Physics witnessed a gradual shift in our focus from physical reality to abstract mathematical formulations, which are supposed to describe physical reality. Theory of Relativity played a dominant role in creating such abstract mathematical representations to describe physical reality. In the process however, we have lost our intuitive guide, the common sense, to judge whether these abstract representations do really describe physical reality or simply lead us to a world of fantasy. In this paper, we aim to critically examine the role of Relativity to see whether it constitutes a pillar of modern physics or it has inadvertently become a stumbling block in the progress of modern physics. For the special theory of relativity (SR), it is the founding postulates and associated ad-hoc assumptions regarding the relativity of time that need to be examined afresh. In the general theory of relativity (GR), it is the founding concept of spacetime as a physical entity that needs to be critically examined. Most of the practical applications of relativity are however, based on the principle of mass-energy equivalence and the associated notions of dynamic or relativistic mass and momentum. We need to examine whether the principle of mass-energy equivalence could be treated as a stand-alone concept, independent of SR.

In the process of creating abstract mathematical representations to describe physical reality, quite often there occurs a subtle mix-up between the notions of coordinate space and physical space. An essential feature of a three-dimensional (3D) coordinate space is the concept of one-to-one correspondence of points in space with the ordered triplet of numbers. The predefined notion of unit length or scale for different coordinate axes, constitutes the metric of space for quantifying the notion of distance and position measurements of the sets of points in this coordinate space. The notion of physical space implies the spatial extension of the universe wherein all material particles and all fields are embedded or contained. The true void between material points is in essence the physical space, or free space. It is important to note here that the coordinate space, along with its unit scale or metric, is our human creation intended to facilitate the quantification of relative positions of material particles and fields. The existence of physical space does not depend in any way on the existence or nonexistence of coordinate systems and coordinate spaces. Of course, for the study and analysis of physical space and the material particles and fields embedded in it, we do need the structure of coordinate systems and coordinate spaces as a quantification tool. The most significant point to be highlighted here is that whereas the metric scaling property is only associated with coordinate space, the physical properties of permittivity, permeability and intrinsic impedance are only associated with physical space.

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2 RELATIVITY AND MASS-ENERGY EQUIVALENCE

Currently, quantum mechanics (QM) and Theory of Relativity constitute two main pillars of Modern Physics. Even though, at most fundamental level, QM and General Relativity appear to be mutually incompatible, yet it does not seem possible that we could afford to discard any one of these theories. Main applications of the theory of Relativity are:

- High Energy Physics
- Particle Accelerators
- Relativistic Quantum Mechanics
- Cosmology

The first three of these applications are based on the principle of mass-energy equivalence and the associated notion of dynamic or 'relativistic mass' in SR. The last application critically depends on treating the 4D spacetime continuum as a physical entity.

2.1 Origin of mass-energy equivalence

In physics, mass–energy equivalence is the concept that the mass of a body is a measure of its energy content. Mass is also a measure of Inertia of all forms of energy.

$$\mathrm{dm} = \frac{\mathrm{dE}}{\mathrm{c}^2} \tag{1}$$

The origin of the concept of mass-energy equivalence is generally attributed to Albert Einstein.[1] He integrated this concept with SR in such a way that now it seems impossible to think of it as an independent stand-alone concept. Yet it is a documented fact that the concept of mass-energy equivalence, in one form or the other, was already in existence prior to Einstein's 1905 paper. Nikolay Umov, in his ether based studies of 'Energy in Moving Bodies', had alluded to the inertial property of the energy as $dE/dm = c^2$ in 1873. In 1900, Henri Poincaré had deduced that the electromagnetic field energy of an electromagnetic wave behaves like a fictitious fluid with a mass density of E/c^2. Olinto De Pretto, a native of the Veneto region of Italy, studied nuclear physics and the prevailing ether theory from 1899 to 1903. As a result of his research, on November 29, 1903 De Pretto published a 62-page paper in the *Procedings of the Royal Veneto Institute of Science, Letters and Arts*, vol LXIII , entitled "*Hypothesis of Aether in the Life of the Universe*". He wrote, "*Matter uses and stores energy as inertia, just like a steam engine that uses the energy in steam and stores energy in inertia as potential energy ... All components of a body are animated by infinitesimal but rapid movements equal to perhaps the vibration of the ether*". De Pretto used the expression mv^2 for the "*vis viva*" and the energy store within matter, where he identified v with the speed of light.[2]

It is interesting to note that all previous attempts to develop the concept of mass-energy equivalence, originated in the study of either electromagnetic waves or the assumed relationship of the matter and ether. Einstein too, developed his notion of mass-energy equivalence from the analysis of energy carried by the light waves from the emitting body.[1] The mass-energy concept, when originally introduced in the framework of ether, did not require the framework of SR; when the same mass-energy concept was introduced in the framework of SR, it did not require the framework of ether. Therefore, we need to examine if it could be sustained as a stand-alone concept. For this we need to establish the mass-energy concept in an absolute or universal reference frame, independent of the notion of inertial reference frames (IRF) in relative motion.

2.2 Notion of dynamic or relativistic mass

From the inertial property of all forms of entrapped energy (equation 1), we can derive the notion of dynamic mass and develop its quantitative relationship with the rest mass. Let a material particle P be at rest in some center of mass (CoM) fixed reference frame and let its rest mass in this frame be m_0. When at rest, the kinetic energy of this particle P will obviously be zero. Now let us assume that the particle P is set in motion through application of a constant force **F**. Further, at an instant of time t, let the instantaneous velocity of P be **v**, with corresponding kinetic energy content E. Since the energy content E will also exhibit the inertial property, let the quantitative measure of total inertia of P, at the instant t, be given by m, the dynamic mass of the particle. If during a small interval of time dt the particle traverses a small distance **ds** and gains a small amount of kinetic energy dE then the following relations will hold.

$$\mathbf{v} = \mathbf{ds}/\mathrm{dt} \tag{2}$$

$$dE = \mathbf{F}.\mathbf{ds} \tag{3}$$

From Newton's second law of motion,

$$\mathbf{F} = d(m\mathbf{v}) / dt$$

$$= m.\ \mathbf{dv}/dt + \mathbf{v}.\ dm/dt \tag{4}$$

From equations (3) and (4),

$$dE = m.\ (\mathbf{dv}/dt)\ \mathbf{.}\ \mathbf{ds} + \mathbf{v}.(dm/dt)\ \mathbf{.}\ \mathbf{ds}$$

$$= m\mathbf{v}\ .\ \mathbf{dv} + v^2.\ dm \tag{5}$$

And from equations (1) and (5) we get,

$$dm = (mv/c^2)\ .\ dv + (v^2/c^2).\ dm \tag{6}$$

Let us make a substitution x= v/c in equation (6) so that dx = dv/c and

$$dm = mx\ .\ dx + x^2\ .\ dm \tag{7}$$

or, $$(1-x^2)\ dm = mx\ .\ dx$$

or, $$\frac{dm}{m} = \frac{x\,dx}{(1-x^2)} \tag{8}$$

On integration this equation yields,

$$\frac{m}{m_0} = \frac{1}{\sqrt{(1-x^2)}}$$

or, replacing x by v/c, $$m = \frac{m_0}{\sqrt{(1-v^2/c^2)}}. \tag{9}$$

This is a standard relation for the dynamic or relativistic mass of a particle in motion. Here, it is important to note that the derivation of dynamic mass m, in terms of rest mass m_0, did not involve special relativity. Instead, this derivation is entirely based on the inertial property of all forms of energy, including kinetic energy. Further, to deduce a separate relation for the kinetic energy E, in terms of m and m0, we may rewrite equation (5) as,

$$dE = \frac{d(mv)}{dt}.ds = v.d(mv), \tag{10}$$

and using equation (9), $$E = \int_0^v v.\,d\left(\frac{m_0 v}{\sqrt{(1-v^2/c^2)}}\right) \tag{11}$$

or, $$E = m_0\left[\int_0^v v.\,d\left(\frac{v}{\sqrt{(1-v^2/c^2)}}\right)\right]$$

$$= m_0\left[\frac{v^2}{\sqrt{(1-v^2/c^2)}} - \int_0^v \frac{v.dv}{\sqrt{(1-v^2/c^2)}}\right]$$

$$= m_0\left[\frac{v^2}{\sqrt{(1-v^2/c^2)}} + c^2\sqrt{(1-v^2/c^2)}\ - c^2\right]$$

$$= \frac{m_0\,c^2}{\sqrt{(1-v^2/c^2)}} - m_0\,c^2 \ = \ mc^2 - m_0\,c^2 \tag{12}$$

This shows that the kinetic energy of a body in motion is given by the difference between its dynamic mass and rest mass ($m-m_0$) times c^2. Similarly, all other dynamic or relativistic relations of SR can be shown to be resulting from the inertial property of all forms of energy represented by equation (1). It may therefore, be asserted that the mass-energy equivalence can be treated as a stand-alone concept, independent of the postulates and assumptions of Relativity. Hence, all practical applications of SR in the fields of high energy physics and relativistic quantum mechanics, can be sustained on the basis of mass-energy equivalence, without using the framework of SR.

3 REFERENCE FRAMES

A reference frame is a set of space coordinates, fixed in some defined way. The terms 'coordinate systems' and 'reference frames' used here specifically refer to reference systems which can be physically established and used for taking physical measurements. We do not imply to refer to similar abstract mathematical terms like coordinate spaces, coordinate manifolds and their metric representations used in abstract mathematical analysis. Quite often, a subtle mix up between abstract mathematical notions and real physical concepts can become a source of confusion.

3.1 Center of Mass Reference Frame

Let us consider a closed volume V of space containing a system of N particles of matter. We consider a closed volume of space in the sense that there is no transfer of mass or energy across the boundary surface of this volume. Let K be a non-rotating Cartesian coordinate reference frame with its origin located at the center of mass (CoM) of these N particles. In the CoM reference frame K, the total momentum of all of its domain particles is zero. Out of all other inertial reference frames which could be constructed for referring the positions and velocities of given N particles within a closed volume V, the total mass-energy content measured in a CoM reference frame is the minimum. Hence, a CoM reference frame may be considered as an absolute or fixed reference frame for the given N particles contained within a closed volume V. Since the domain particles of the CoM reference frame K do not experience any significant force or interaction from outside its domain volume, the center of mass of reference frame K will continue to remain in its state of rest or of uniform motion in the external space outside its domain volume. Hence the reference frame K can also be regarded as a unique fixed inertial reference frame (IRF) for the system of N particles under consideration.

The International Celestial Reference System (ICRS) consists of the Barycentric Celestial Reference Frame (BCRF) and the Geocentric Celestial Reference Frame (GCRF), both kinematically defined by the position of same extragalactic radio sources. The origin of space coordinates defining BCRF is located at the barycenter or the CoM of our solar system. The origin of space coordinates defining GCRF is located at the geocenter or the CoM of the Earth system. The physical domain volume of BCRF can be defined as the volume of the whole solar system within which all material particles that are co-moving with the solar system, are located. Similarly, the domain volume of GCRF can be defined as the volume of the earth-moon system within which all particles that are co-moving with the earth system, are located. Here BCRF can be regarded as an absolute or fixed reference frame in relation to the solar system whereas the GCRF, being a subset of BCRF, can be regarded as a local reference frame in relation to the solar system. The task of establishing and maintaining the ICRS and its components has been assigned to the International Earth Rotation and Reference Systems Service (IERS).

3.2 Group of Inertial Reference Frames

As per the Relativity Principle: "If a system of coordinates K is chosen so that, in relation to it, physical laws hold good in their simplest form, the same laws hold good in relation to any other system of coordinates K' moving in uniform translation relatively to K." All non-rotating reference frames that move with uniform velocity with respect to one another, are defined as Inertial Reference Frames. The origins of all inertial reference frames are in a state of constant, rectilinear motion with respect to one another and are not accelerating. All inertial reference frames constitute a group and no particular member of this group can be considered a preferred reference frame. To examine the practical relevance of the notion of IRF in relative motion, we need to consider the following points in physical context.

3.2.1 **Why should reference frames be required to move at all?** Logically it is the particles of matter that are expected to move in a reference frame. Primarily the reference frames are required for quantifying the positions of various particles located in a given region of space. A reference frame with its origin fixed at the CoM of all the particles in the given region of space, is sufficient to quantify the positions of all such particles. A large number of reference frames, in relative uniform motion, are just not required to quantify the positions of a given set of particles. It would be quite illogical and misleading if the IERS is asked to create many more celestial reference frames in relative uniform motion with respect to the BCRF.

3.2.2 **Why do we need very many reference frames?** For studying the kinematic motion and dynamic interactions of a large number of particles located in a given region of space, we need to reference their positions to a single CoM reference frame, like BCRF for the solar system. If we create a separate reference frame for each particle, the very objective of creating a reference frame will be lost. However, some local reference frames (like GCRF in the solar system) could always be created for the convenience of practical measurements of positions and velocities, provided such local measurements could ultimately be transformed to the fixed CoM reference frame.

3.2.3 **Can multiple IRF in relative motion be established in BCRF?** To establish an IRF in relative uniform motion with respect to the BCRF, we need to first establish a point O for the origin of that IRF, which is moving at a uniform velocity with respect to the barycenter of our solar system. But practically, we cannot find any material particle or body which could move with a uniform velocity within our solar system. We can only define a hypothetical point O, moving at uniform velocity with respect to the barycenter. With that the very notion of inertial reference frames in uniform relative motion becomes hypothetical because they can only be 'defined' but cannot be practically established within BCRF. Apparently this notion was introduced just for conducting hypothetical thought experiments.

3.2.4 **Can relative measurements alone yield correct information?** No, relative measurements alone cannot yield true information regarding position and velocity of particles in the relevant region of space under consideration. To illustrate this point, let us consider two space ships S_1 and S_2 moving in the solar system. Let their position vectors in BCRF be $\mathbf{R_1}, \mathbf{R_2}$ and their velocity vectors be $\mathbf{V_1}, \mathbf{V_2}$ respectively. The dynamic motion of these space ships will obviously be governed by the parameters $\mathbf{R_1}, \mathbf{R_2}$ and $\mathbf{V_1}, \mathbf{V_2}$. The relative separation between S_1 and S_2 will be given by $\mathbf{R_{12}} = \mathbf{R_2} - \mathbf{R_1}$ and their relative velocity will be given by $\mathbf{V_{12}} = \mathbf{V_2} - \mathbf{V_1}$. If we use only relative coordinates and measure only the relative parameters $\mathbf{R_{12}}$ and $\mathbf{V_{12}}$ (without using BCRF) we find that the dynamic motion of the two space ships is not governed by the relative parameters $\mathbf{R_{12}}$ and $\mathbf{V_{12}}$. Hence it is quite obvious that the relative measurements alone do not provide complete information required for depiction of the physical situation.

Finally we may conclude that a CoM reference frame may be considered as an absolute or **preferred** reference frame for the given set of N particles contained within a closed volume of space. The measurements in a convenient local reference frame constitute a necessary step for establishing the absolute measurements in a relevant CoM fixed reference frame. Relative measurements alone, without reference to a CoM fixed reference frame can give misleading results. For example, relative measurement of position and velocity of a uniformly moving spacecraft, from the ground stations may indicate as if the spacecraft is periodically accelerating towards or away from the ground stations, which is highly misleading. Purely relative inertial reference frames in SR can only be defined or assumed, but cannot be practically established. These are only useful for conducting hypothetical thought experiments.

4 LOGICAL FLAWS IN POSTULATES OF SR

There are two main founding postulates of SR. The first postulate enunciates the special 'Principle of Relativity' in which it has been assumed that the laws of physics are the same in any inertial frame, regardless of its position or velocity. Physically, this means that all IRF in relative uniform motion are equivalent for the description of the laws of Nature and that there is no absolute or preferred frame of reference. Only relative positions and velocities between objects are meaningful. The second postulate enunciates the constancy of the speed of light in all IRF in relative uniform motion. It assumes that the speed of light is independent of the speed of light source, and that the light speed c is an isotropic constant in all IRF.

4.1 Principle of Relativity

Albert Einstein, in his 1905 paper 'On the Electrodynamics of Moving Bodies' compares the representations in two IRF by terming one of them as a "stationary system" and the other one as a "coordinate system in uniform motion".[3] "If a system of coordinates K is chosen so that, in relation to it, physical laws hold good in their simplest form, the same laws hold good in relation to any other system of coordinates K' moving in uniform translation relatively to K." Let the solar system reference frame BCRF represent the system of coordinates K, and let K' be any other IRF moving in uniform translation relative to BCRF. We know that in BCRF, being a CoM reference frame, the total linear momentum of all particles within the solar system will be zero; but in IRF K', which is in motion relative to BCRF, the total momentum of all particles within the solar system will not be zero. Further, the total kinetic energy of all particles within the solar system will be a minimum, say E, in BCRF, whereas the total kinetic energy E' of all particles within the solar system will be greater than E in all IRF K', which are in relative motion with respect to BCRF. This fundamental difference between their total momentum and total kinetic energies, becomes a distinguishing feature between IRF K and K' and sets the reference frame K or the BCRF as the unique, preferred reference frame for our solar system. With this the principle of relativity stands violated and a logical flaw in the first postulate of SR is established.

Basically, all laws of Nature will remain valid and operative independent of reference frames. However, in physics we quantify the laws of Nature, so as to represent them through certain mathematical equations involving various dimensional physical parameters. If certain mathematical equation representing a law of physics is written in terms of parameters measured or defined in a particular coordinate reference frame, then we can say that the law of physics is expressed or represented in that reference frame. Laws of Nature depend on the characteristic interactions among material particles and fields in a given region of space and depict the causal evolution of the physical state of such particles and fields. The characteristic interactions among material particles and fields cannot be influenced by the arbitrarily defined human artifacts like coordinate systems and reference frames. Similarly the laws of Nature too cannot be influenced by the arbitrarily defined coordinate systems and reference frames. Of course, the form of mathematical representation of the laws of Nature can change with the change in coordinate system or reference frame but not the laws themselves. Hence, it is wrong to assume any *linkage* between the laws of Nature and the arbitrarily defined inertial reference frames in relative uniform motion. This establishes second logical flaw in the first postulate of SR.[4]

4.2 Constancy of the speed of light in all IRF

The second postulate of SR depicts an assumption that the speed of light in vacuum is the same isotropic constant c in all inertial reference frames (IRF) in relative uniform motion. It is well known from Maxwell's theory that the speed of light in vacuum depends on the permittivity ε_0 and permeability μ_0 of the physical space ($c = \sqrt{(1/\varepsilon_0 \mu_0)}$). Since permittivity and permeability are properties of the physical space, the speed of light in vacuum is also a property of physical space and cannot be derived from the metric properties of coordinate space. Hence the speed c of light in vacuum cannot be *linked* to the arbitrarily defined coordinate systems or inertial reference frames in relative motion. It is therefore, wrong to assume that the speed of light in physical space could be made to depend upon, or even defined with respect to the state of different inertial reference frames.

To comply with this assumption, the notion of time as an absolute measure of change has been sacrificed in SR, leading to the notions of relative time and consequent length contractions. According to SR, the time interval dt of a standard atomic clock and a length segment dx of a standard meter rod, will be *seen to be different* in each of the infinitely many inertial reference frames in relative uniform motion. This is built in to the following relation involving space-time interval dS which is treated as an invariant in all IRF.

$$(dS)^2 = (dx)^2 + (dy)^2 + (dz)^2 - (c.dt)^2 \tag{13}$$

Thus the Newtonian notion of time and length as absolute measures has been replaced by the Einsteinian notion of relative time and length in SR. However, the notions of length contraction and time dilation are not physical but only apparent or hypothetical effects, resulting from hypothetical measurements made by fictitious observers from IRF in relative motion.

4.2.1 **Notion of Length Contraction.** Notion of length contraction appears in SR as a consequence of assumed constancy of the speed of light 'c' in all IRF in relative motion. A rod of length L_0 at rest in BCRF will be found to be of length L when 'hypothetically measured' in an IRF (K') moving parallel to the length of the rod, at a uniform velocity 'v' with respect to BCRF. We say 'hypothetically measured' because as per the prescribed method of measurement, the measuring rods are supposed to be carried in the moving IRF (K') while the rod to be measured is located in the BCRF, and the measurements are to be carried out through exchange of light signals.

$$\mathrm{L} = \mathrm{L}_0\sqrt{1 - (\mathrm{v}^2/\mathrm{c}^2)} \tag{14}$$

Let us consider a thin spherical glass shell of diameter L_0 in BCRF. It will not be seen broken when viewed from the moving IRF (K'), even though its size in the direction of motion of K' will appear contracted. Normally, the glass shell is bound to break when its diameter physically contracts, even slightly. This shows that the length contraction in SR is not physical but apparent or hypothetical effect. Further, a rod of length L_0 will be seen to be of different lengths L_1, L_2, etc. when viewed from different IRF moving parallel to the length at different velocities. Hence, we may conclude that the length contraction in SR is an apparent effect, induced by the assumed constancy of the speed of light 'c' in all IRF in relative motion.

4.2.2 **Notion of Time Dilation.** Quoting Albert Einstein, from his 1905 paper,[3] "…*We have so far defined only an 'A time' and a 'B time'. We have not defined a common 'time' for A and B, for the latter cannot be defined at all unless we establish by definition that the 'time' required by light to travel from A to B equals the 'time' it requires to travel from B to A.*" This arbitrary definition of 'common time' constitutes a fundamental departure from the Newtonian notion of absolute time. Of course, this departure was required to support the assumed constancy of light speed 'c' in all IRF in relative motion. Consequent to this arbitrary definition, which became Einstein's famous clock synchronization convention, clock times in different IRF in relative motion, had to be readjusted by introducing time rate dilation and time offset as a function of position and velocity, as given by Lorentz transformation (for frames in standard configuration).

$$t' = \frac{(t - vx/c^2)}{\left(\sqrt{1 - v^2/c^2}\right)} \tag{15}$$

Consider an IRF (K'), moving with a relative uniform velocity **v** with respect to the solar system frame BCRF. Let us position one precision clock in BCRF and another identical clock in the moving frame K'. Now a small time interval Δt of the BCRF clock will appear to be longer when observed from the moving frame K'.

$$\Delta t' = \frac{\Delta t}{\left(\sqrt{1 - v^2/c^2}\right)} \tag{16}$$

This shows that the period of a clock in BCRF appears to be 'time dilated' when 'observed' from the moving IRF (K') in comparison to the period in the frame of the clock itself. That is, any observer moving with respect to BCRF will find the clock in BCRF to be running slow. Therefore, this 'time dilation' is not physical but an apparent effect because different observers, moving with respect to BCRF at different relative velocities, will find the same clock in BCRF to be running slow by different amounts.

Thus the notions of 'Length Contraction' and 'Time Dilation' in SR, are just the props required to support the assumed constancy of the speed of light 'c' in all IRF in relative motion.

5 ERRONEOUS CONCEPT OF SPACETIME IN GR

Our dynamic universe is embedded in a three-dimensional (3D) Euclidean space and its dynamic behavior or characteristic changes can be represented with an independent time coordinate. However, there appears to be a subtle mix-up between the notions of coordinate space and physical space in the abstract mathematical representations of GR. Relativity has extended the notion of 3D coordinate space to 4D spacetime continuum to facilitate geometrical representations of dynamic phenomenon. But the *geometrical interpretation of gravitation* in GR implies the spacetime continuum to be a physical entity which can even be deformed and curved. This misconception is quite deep rooted in the metaphysical eternalist viewpoint of existence in contrast to the logical presentist viewpoint.

As per the eternalist viewpoint, a so-called material object in a spacetime world is a continuous series of spacetime events, each of which exists eternally as a distinct part of the world. There is no distinction between the past, present and future. This is a block view of spacetime, in which the universe pre-exists at all future instants of time. As per the presentist viewpoint, the present moment is different from the past and future and that physical entities exist only in the present. The physical phenomenon does not exist in the past and the future regions of time. The foundations of GR are critically dependent on the integrity of the notion of spacetime as a physical entity. Albert Einstein had asserted in a matter of fact way, —*the world in which we live is a four-dimensional space-time continuum*.[5] According to GR, —*mass curves space-time, and space-time tells the mass how to move*.[6]

5.1 Geometrical representation of deformation in 3D Space Continuum

Let us consider a 3D continuum of space points representing the points of an ideal rigid material medium. All points in this space will be considered as invariant. A triply infinite set of points, constituting a rigid 3D space continuum, may also be considered invariant if an infinitesimal separation distance ds between any pair of neighboring points remains invariant under admissible coordinate transformations. The notion of invariance of the arc element ds in all admissible coordinate transformations is most crucial in the representation of a rigid 3D continuum. Since representation of vectors and tensors in the Euclidean geometry rely on the invariance of arc element ds,[7] it implies that the Euclidean 3D space is effectively treated as a rigid 3D space continuum. This invariance of an arc element ds, is given by,

$$(ds)^2 = a_i a_j \, dx^i dx^j = g_{ij}(x) \, dx^i dx^j = g_{\alpha\beta}(y) \, dy^\alpha dy^\beta \, . \tag{17}$$

where $g_{ij}(x)$ are the metric tensor components in X coordinate system and $g_{\alpha\beta}(y)$ are the metric tensor components in Y coordinate system. In an orthogonal coordinate systems, the value of a metric coefficients g_{ii} determines the magnitude of corresponding base vector $\mathbf{a_i}$ as, $a_i = \sqrt{g_{ii}}$.

Now let us consider the deformed state of a continuum of space points. In this state let the point P from the initial un-deformed state get shifted to point P' and the neighborhood point Q shifted to the point Q'. This shift in position of neighborhood points P and Q to the positions P' and Q' is termed as displacement of these points and essentially constitutes the deformation of the continuum under consideration. An infinitesimal deformed state of the continuum can be described as its strained state. The strained state is represented by a strain tensor E with its components e_{ij} defined at every point P of the continuum. In the linear or infinitesimal theory of deformation, the strain tensor components are computed from the covariant derivatives of the displacement vector. However, the strained state of the continuum can also be represented by the metric h_{ij} of the deformed sate.

$$(ds')^2 = b_i b_j dx^i dx^j = h_{ij}(x)\, dx^i dx^j \, . \tag{18}$$

We can say that the deformable continuum is strained whenever arc element ds' given by equation (18) is different from the arc element ds given by equation (17). The covariant strain tensor components e_{ij} are related to this difference through following relations.[7]

$$(ds')^2 - (ds)^2 = (h_{ij}-g_{ij})\, dx^i dx^j = 2e_{ij}\, dx^i dx^j \, . \tag{19}$$

$$e_{ij} = \tfrac{1}{2}\{h_{ij} - g_{ij}\}. \tag{20}$$

Ideally speaking, we should first obtain the displacement vector for the strained state of the continuum and then compute the components of the strain tensor and the modified metric. However, on physical considerations we may first specify the components of strain tensor or the modified metric, and then work out the displacement vector components. Physical constraints demand that the displacement vector components must be finite, continuous, and single valued functions of coordinates, for which the strain components must satisfy a set of compatibility conditions.

The spacetime continuum of the General Theory of Relativity is not a Euclidean Continuum.[5] In GR, the coefficients of metric tensor $[h_{ij}]$ of the pseudo-Riemannian spacetime manifold are obtained from Einstein's Field Equations (EFE) and the Riemann curvature tensor R_{ijkl} computed from $[h_{ij}]$ is non-zero. It can be shown that the Riemann tensor R_{ijkl} computed from the metric h_{ij} of the Riemannian 3D space, associated with the pseudo-Riemannian spacetime manifold, is also non-zero. On the other hand, the Riemann tensor computed from the metric tensor g_{ij} of the Euclidean space, is always zero. As such the Riemannian 3D space of GR is *defined* to be a deformable space which is generally *perceived* as curved space.

Let us now examine whether the strain components e_{ij} induced in the Riemannian 3D 'curved' space of GR, satisfy the standard compatibility conditions. It can be shown from the Saint Venant's integrability or compatibility conditions for a continuous media, that the Riemann tensor composed from strain components e_{ij} must be a zero tensor to ensure that the displacement vector components, obtained from integration of these strain components, are finite, continuous, and single valued. This can be true only if both metrics of equation (20), namely g_{ij} and h_{ij} are Euclidean, which however contradicts the basic postulate of curved spacetime in GR. Hence, all strain components in the space continuum, induced by the Riemannian metric, will fail to satisfy the integrability or compatibility conditions, leading to discontinuities in the induced displacements.[8] Therefore, if we treat the 4D spacetime manifold to be a physical entity, we end up with physically invalid discontinuities in the space continuum. Hence the 4D spacetime cannot be a physical entity.

5.2 Spacetime Continuum treated as a Block Universe

Let us consider a 2D (thin) metal sheet located in the XY plane of a rectangular Cartesian coordinate system XYT. Let the time axis extend from zero to infinity and let t_p depict the present time on the time axis.[9] The time zone $t<t_p$ represent the past and the time zone $t>t_p$ represent the future. The body of the metal sheet is physically located at $t= t_p$ and is not located anywhere in the past or the future time zones. That is, the XY plane representing a section of the XYT manifold at $t=t_p$ can be said to be physically occupied with the thin metal sheet and all other XY planes representing sections of the XYT manifold at $t<>t_p$ are physically empty. This is the standard presentist view of the XYT manifold as per which only the present ($t=t_p$) section of the manifold represent the physical entities and not the whole manifold. As per this viewpoint, the physical state of the thin metal sheet at the next future instant ($t=t_p+\delta t$), evolves from its present ($t=t_p$) state through the operation of physical laws of nature, through the operation of cause and effect. On the contrary, as per the eternalist view of the XYT manifold, all XY sections of the manifold are supposed to be physically occupied with thin metal sheets. This eternalist viewpoint represents a situation where in the physical state of all matter particles and their interaction fields, is *predetermined* at all future locations of the metal sheet, or at all XY plane sections for $t>t_p$ of the XYT manifold. This predetermined physical state at all future locations of the metal sheet does not permit a causal evolution of the physical state. That is, the notion of predetermined physical state of all matter particles and their interaction fields violates the fundamental principle of cause and effect which is the basis of all scientific study of the universe. Thus the eternalist viewpoint, depicting whole XYT manifold as a physical entity, is fallacious on the grounds of causality violation.

Similarly we may consider the physical space of our solar system located in a particular spatial section of a Cartesian space-time manifold XYZ-T. Let t_p depict the present instant on the time axis. As per the standard presentist view of the XYZ-T space-time manifold only the present ($t=t_p$) section of the manifold represent the physical entities and not the whole manifold. As per this viewpoint, the physical state of the solar system at the next future instant ($t=t_p+\delta t$), evolves from its present ($t=t_p$) state through the operation of physical laws of nature, through the operation of cause and effect. On the contrary, as per the eternalist view of the spacetime, all 3D XYZ sections of the manifold are supposed to be physically occupied with our solar system. This eternalist viewpoint represents a situation where in the physical state of all matter particles and their interaction fields, is *predetermined* at all future locations of the solar system, or at all 3D XYZ spatial sections for $t>t_p$ of the 4D XYZ-T spacetime manifold. This predetermined physical state of the 'Block Universe' does not permit a causal evolution of the physical state. Further, the notion of predetermined physical state of all matter particles and their interaction fields violates the fundamental principle of cause and effect which is the basis of all scientific study of the universe. Thus, the eternalist viewpoint, depicting whole 4D XYZ-T spacetime manifold as a physical entity, a 'Block Universe', is fallacious on the grounds of causality violation in the predetermined physical state of the solar system at all future instants of time. Hence, the spacetime continuum is not a physical entity but just an abstract mathematical notion.

5.3 Geometrical representation of dynamic trajectories

As is well known, a parabolic curve can be represented as a straight line on a log-log or differential scale graph or coordinate system. Any single-valued open curve can be represented as a straight line in a suitable coordinate system with appropriate differential scale or the base vectors. Hence any change in the differential scale, or the metric, along different coordinate axes results in corresponding change in the shape of geometric curves.

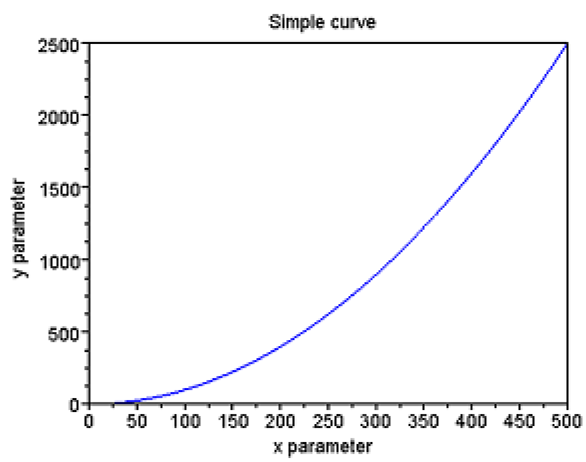

Figure 1. Geometrical representation of a plane curve $y=a\,x^b$ on a uniform scale graph.

To illustrate the influence of metric coefficients g_{ij} on the geometrical representation of space curves, let us consider a plane curve defined by equation,

$$y = a\,x^b \tag{21}$$

An x-y plot of this curve is shown at figure 1. Assuming a unit scale for both x and y coordinate axes, the arc element ds for this curve will be given by,

$$(ds)^2 = (dx)^2 + (dy)^2 \tag{22}$$

which implies that the metric coefficients g_{xx} and g_{yy} are both unity for this coordinate plane. Now if we plot the curve of equation (21) on a log-log scale graph, the curve will take the form of a straight line, as shown at figure 2.

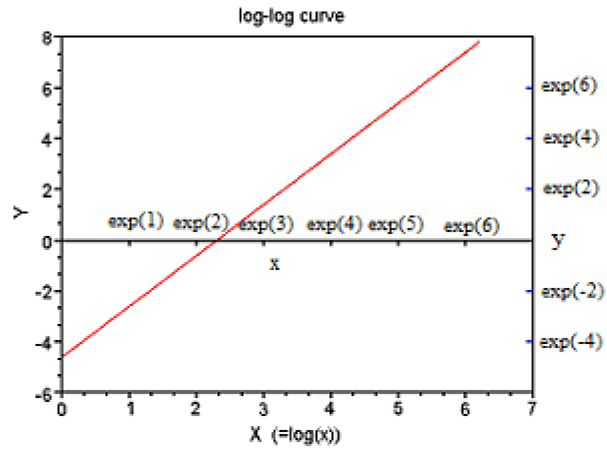

Figure 2. Geometrical representation of a plane curve $y=a\,x^b$ on a log-log scale graph.

Taking natural logarithm on both sides of equation (21), we get,

$$\log(y) = \log(a) + b.\log(x) \tag{23}$$

Let us make following substitutions in Eq. (23):

$$\log(y) = Y\ ;\ \log(x) = X\ ;\ \text{and}\ \ \log(a) = A. \tag{24}$$

Equation (23) will now take the form,

$$Y = A + b\,X \tag{25}$$

Taking differentials of Y and X in equation (24),

$$dY = dy/y \quad \text{or} \quad dy = ydY = e^{Y}dY \tag{26}$$

and

$$dX = dx/x \quad \text{or} \quad dx = xdX = e^{X}dX \tag{27}$$

Substituting values of dy and dx from Eq. (26) and (27) in Eq. (22), we get

$$(ds)^2 = e^{2X}(dX)^2 + e^{2Y}(dY)^2 = g_{XX}(dX)^2 + g_{YY}(dY)^2 \tag{28}$$

This shows that the modified metric coefficients g_{XX} and g_{YY} for the X-Y coordinate space are given by exp(2X) and exp(2Y) respectively. Hence the differential scale factors or the base vectors will be exp(X) along the X coordinate and exp(Y) along the Y coordinate. This illustrates the fact that any single-valued open curve can be represented as a straight line in a suitable coordinate system with appropriate differential scale. It may be stressed here that any change in the differential scale along different coordinate axes results in corresponding change in the shape of geometric curves represented with those coordinates. Therefore, we must not view the metric coefficients in any coordinate system, as some physical entities which could physically influence or change the shape of specified open curves. It is only the *geometrical representation* of such curves in a particular coordinate system that could get influenced by any change in differential scale or metric coefficients of that system.

Let us consider a particle moving in a circular orbit in XY plane. The motion of this particle can be represented as a helical trace in a XY-T coordinate space. The velocity and acceleration characteristics of this particle will be represented by the geometry of helical trace in the XY-T coordinate space. An important point to be noted here is that the helical trace does not physically exist anywhere at any time; it is just a mathematical or graphical representation of the motion of a particle over a period of time. Another important feature of this graphical representation of distance-time data points is that the XY-T coordinate space is not metrized like the Euclidean space to ensure the invariance of space points (equation 17). Here the distance and time *scales*, along their respective coordinates, can be fixed independently without any constraint on the invariance of arc element ds. That is, the metric coefficients g_{ij} of this XY-T coordinate space or manifold are not constrained by the invariance of arc element ds (equation 17). What is invariant in this case is the data point set (x_i,t_i) which is represented by the plot or trace on the distance-time coordinate space. The shape of this data curve can be varied arbitrarily by adjusting the individual coordinate scale or the metric coefficients of the distance and time coordinates independently. Hence, this data curve cannot be regarded as invariant under admissible coordinate transformations. In fact the notion of admissible coordinate transformations itself cannot be valid without some invariance constraint on the arc element ds.

However, it is possible to introduce an important constraint on the metric coefficients of the distance and time coordinates, on the lines of Minkowski space-time manifold as follows,

$$(dS)^2 = g_{tt}\,(c.dt)^2 - \{g_{xx}\,(dx)^2 + g_{yy}\,(dy)^2 + g_{zz}\,(dz)^2\}, \tag{29}$$

where dS is an invariant, g_{tt} is the metric coefficient of the time coordinate and g_{xx}, g_{yy} and g_{zz} are the metric coefficients of the X, Y and Z coordinates respectively. With the introduction of this constraint on metric coefficients, the distance and time scales get interlinked such that the trajectory trace of the data point set (x_i,t_i) in the distance-time coordinate space, could become a geodesic curve in that space with specified metric coefficients. Further the constraint given by equation (29) also puts an upper limit c on the speed computed from any geodesic trace in the distance-time coordinate space or manifold.

5.4 Spacetime treated as a graphical template

Let us consider the trajectory of an object, falling in a Cartesian XY plane on a gravitating body of mass M. The plot of this trajectory on a 3D XY-T linear scale manifold, will be a parabolic space curve. We can choose a suitable differential scale or the metric coefficients along the X,Y and T axes, in conjunction with the invariance constraint of Eq. (29), such that the parabolic space trajectory on linear scale manifold, changes into a geodesic on the differential scale manifold. Let us make a template of this differential scale manifold. The differential scale or the magnitude of the unit vectors along any particular axis of an orthogonal coordinate system is given by the square-root of the corresponding metric coefficient for that coordinate axis. For obtaining the trajectory of any other object falling in XY plane on a gravitating body of mass M, we just need to set the initial position and velocity of this object on the XY-T differential scale template manifold and compute the geodesic curve of the required trajectory. However, for computing trajectories of objects moving in the gravitational field of a body of different mass M', the differential scaling factor or the metric coefficients of the template manifold must be adjusted accordingly to account for different acceleration profile.

We can extend this methodology for obtaining trajectories of particles moving in 3D physical space, under the gravitational field of a body of mass M. For this we can first obtain a differential scale 4D manifold XYZ-T as a template by correlating its metric coefficients with the mass M, in conjunction with the invariance constraint of Eq. (29), such that the Newtonian trajectories in the given gravitational field appear as geodesic curves in this template manifold. Now, to obtain the trajectory of any other object in the given gravitational field, we can set the initial position and velocity of the object in the template manifold and then compute the trajectory as a geodesic curve through that position. Of course, we need to adjust the differential scale or the metric coefficients of this template manifold according to the mass M of the gravitating body to account for different acceleration profiles. This is precisely what has been attempted through Einstein Field Equations (EFE) in the spacetime model of GR. Further, to ensure a constant speed of light propagation in all coordinates, a pseudo-Riemannian 4D spacetime manifold, with an invariance constraint of Eq. (29), has been used in GR. This feature may be regarded as an improvement over the Newtonian gravitation, whereby the speed of propagation of gravitational influence is limited to the speed of light.[8]

In GR, the pseudo-Riemannian 4D spacetime manifold is used as an abstract mathematical differential scale template manifold for getting the trajectories of particles as geodesic curves. The differential scale or metric coefficients of this 4D template manifold are correlated through EFE with the mass-energy density in the physical space, to simulate the particle trajectories with geodesic curves in a gravitational field. It may be emphasized here that the correlation between the mass-energy density and the metric coefficients of the 4D template manifold as established through EFE, is essentially an empirical correlation. The validity of any particular correlation between the mass-energy density and the metric coefficients of the 4D template manifold as established through EFE, can only be demonstrated through accurate simulation of particle trajectories with geodesic curves in a Newtonian gravitational field.

6. DETECTION OF ABSOLUTE MOTION

As per the Newtonian notion of absolute time and length, we may define a universal reference frame as the one which is at rest with respect to the center of mass of the universe, and is non-rotating with respect to the celestial background. Any motion with respect to such a Universal Celestial Reference Frame (UCRF) will be called ‘absolute motion’. If we assume the isotropy of the speed of light propagation in the universal reference frame, it is possible to detect absolute motion by monitoring the propagation times of light pulses between two co-moving points in absolute space.

6.1 Absolute velocity measurement technique

Consider two space ships A and B, separated by distance D, moving with a uniform common velocity U, along AB, with respect to the universal reference frame. Let a pulse of light be transmitted from A at time t_1 and received at B at time t_2, as illustrated in figure 3, so that the light propagation time from A to B is given by $T_u(=t_2-t_1)$. Let another pulse of light be transmitted from B at time t_3 and received at A at time t_4 so that the light propagation time from B to A is given by $T_d(=t_4-t_3)$. Considering the distance traveled by B during the light propagation time T_u, the up-link light path is given by,

$$D + U * T_u = c * T_u \tag{30}$$

Similarly, considering the distance traveled by A during the light propagation time T_d, the down-link light path is given by,

$$D - U * T_d = c * T_d \tag{31}$$

Eliminating D from equations (30) and (31), we get, $U * (T_u + T_d) = c * (T_u - T_d)$,

or,
$$\frac{U}{c} = \left[\frac{T_u - T_d}{T_u + T_d}\right] \tag{32}$$

The equation (32) implies that the ratio U/c depends on the ratio of the difference between up-link and down-link signal propagation times to the total round trip propagation time. This shows that the common velocity U of two objects A and B, can be determined simply by measuring the to-and-fro signal propagation times between them. On this basis, a simple experimental technique to measure the 'absolute' velocity of two objects A and B, fixed on the surface of earth, can be developed.[10]

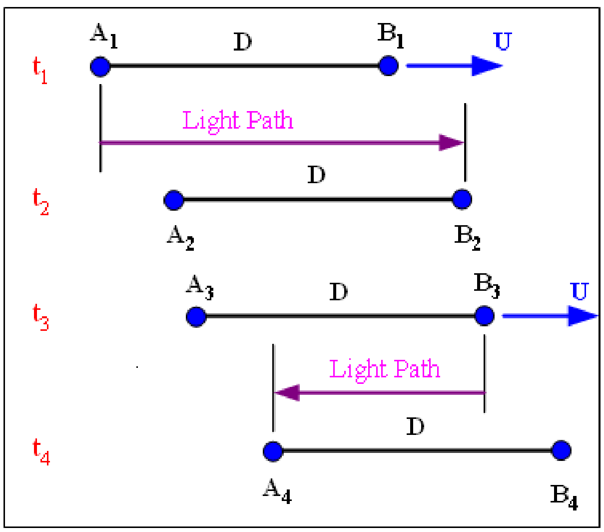

Figure 3. Illustration of Light Path variation for up-link and down-link signal propagation.

6.2 Test equipment layout

For planning this experiment, we need to select two microwave communication towers (or two tall buildings), separated by a distance of about 30 km, as the two objects A and B mentioned above. Exact distance between A and B is not required to be measured. Since the determination of up-link and down-link signal propagation times between A and B will require line of sight communication, we need to position identical sets of test equipment (figure 4) at about 20 m height, on each of the two towers (or buildings). Each set of the test equipment required at both ends, consists of :

- Diode-Pumped Solid State Pulsed Laser – with 1064 nm wavelength, about one mJ pulse energy, one ns pulse width, collimated beam and single shot pulse option.
- Laser Detector with focusing optics – The detector consists of an array of Geiger Mode Avalanche Photo diodes (APDs), each individually coupled to integrated quench electronics.

- Precision Timing System – Cesium Atomic Clock with a precision Rubidium Oscillator.
- High Precision Event Timer – Measures instant times when events occur.
- Data Acquisition Computer

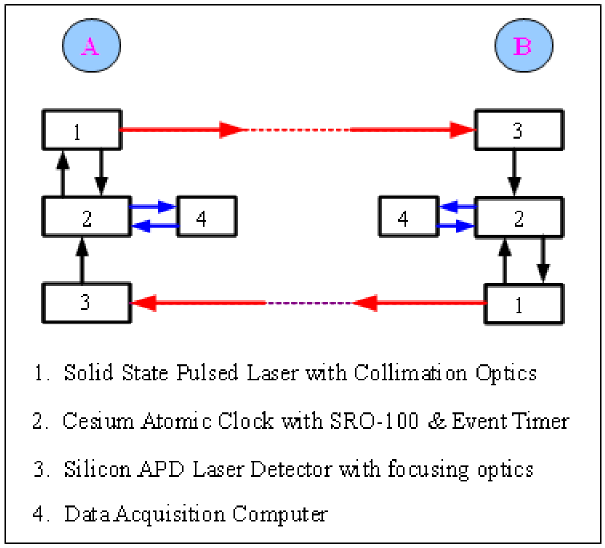

Figure 4. Schematic layout of test equipment for detection of absolute motion

In the proposed test, two high precision, ultra-stable, Cesium atomic clocks will be used as independent primary time standards. The two clocks will be synchronized and calibrated in the close by position and then separated to the selected locations.

6.3 Data acquisition and analysis

For data acquisition in this experiment, the Solid State Pulsed Laser is to be operated in a single shot mode. In this mode the electrical pulse from the controller or Event Timer will trigger the Laser at point A to send out a short laser pulse towards point B. The emission of laser pulse at point A will trigger the clock time readout (T_{a1}) at A. This time readout, will get recorded in the data acquisition computer at A. When the laser pulse transmitted from point A, reaches the photo detector at B, it will be captured by the detector to produce a trigger pulse for the time readout (T_{b2}) at point B. This time readout, will get recorded in the data acquisition computer at B. The two computers located at points A and B, may be inter-connected through a computer network. The difference between these two time readouts will provide the pulse propagation time ($T_u = T_{b2} - T_{a1}$) from points A to B. After a preset time delay from T_{b2}, say one second, an electrical pulse from the Event Timer at B will trigger the Laser at point B to send out a short laser pulse towards point A. The emission of a laser pulse at B will trigger the clock time readout (T_{b3}) at B. This time readout, will get recorded in the data acquisition computer at B. When the laser pulse transmitted from B reaches the photo detector at A, it will be captured by the detector to produce a trigger pulse for the clock time readout (T_{a4}) at point A. This time will get recorded in the data acquisition computer at A. The difference between these two time readouts will provide the pulse propagation time ($T_d = T_{a4} - T_{b3}$) from points B to A.

Similarly, after a preset time delay from T_{a4}, say one second, an electrical pulse from the Event Timer at A will trigger the Laser at point A to send out a short laser pulse towards B. The emission of a laser pulse at A will trigger the clock time readout (T_{a5}) at A. This up-link and down-link pulse propagation process could go on repeating automatically with the corresponding timing data getting stored in the two data acquisition computers at points A and B. As discussed above, the magnitude of U/c will be given by the ratio of the difference between the up-link and down-link signal propagation times to the total round trip signal propagation time as per equation (32). From a 48 hour recorded data of T_u and T_d pairs, obtained from the selected east-west orientation of A and B, a typical diurnal variation of (T_u – T_d), is illustrated at figure 5.

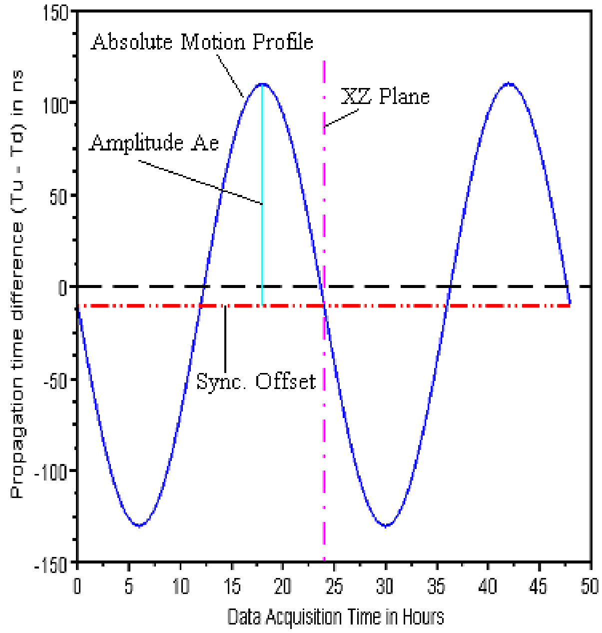

Figure 5. Diurnal variation of 'to and fro' signal timing difference ($T_u - T_d$) in East-West orientation.

Maximum amplitude of the sinusoidal variation of ($T_u–T_d$) curve, will yield a component of absolute velocity U along the selected orientation of A and B. The test is to be repeated with the north-south orientation of A and B. Combined data from these two orientations will yield the absolute velocity vector of the earth. As per SR, this to-and-fro signal time difference $|T_u-T_d|$ must be of the order of zero. On the other hand, if the second postulate is not true, then the maximum difference in the to-and-fro signal times, $|T_u-T_d|$ is expected to be in the range of about 100 to 200 nanoseconds. As such the proposed test for detection of absolute motion of earth in the universal reference frame is surely going to be conclusive and unambiguous. All items of the test equipment are available off the shelf and the experiment is doable by university students/researchers.

7 SUMMARY AND CONCLUSION

Theory of Relativity played a dominant role in creating abstract mathematical representations to describe physical reality. However, due to its rejection of Newtonian notions of absolute space and time, it has inadvertently blocked further research in space physics and become a stumbling block in the progress of modern physics. Practical applications of SR are based on the principle of mass-energy equivalence, which is an independent concept and existed prior to SR. All such applications, in the fields of high energy physics and quantum mechanics, can be sustained on the basis of mass-energy equivalence, without using the framework of SR. To study the motion of a set of particles or bodies enclosed within a closed volume of space, we only need an inertial reference frame fixed with respect to their Center of Mass. Introduction of a set of hypothetical IRF, in relative motion, is unwarranted, misleading and the source of all illogical consequences in SR. Assumption of constant light speed c in all IRF in relative motion, defied logic and abandoned absolute nature of space and time. GR assigned a misleading term 'curved space' for a non-zero value of the Riemann tensor in Riemannian space, when it actually implies 'deformed space'. GR erroneously assumed the spacetime to be physical entity, when truly it is just a mathematical model for computing trajectories. In GR, the pseudo-Riemannian 4D spacetime manifold is used as an abstract mathematical differential scale template manifold for getting the gravitational trajectories of particles as geodesic curves. All GR based speculative models of cosmology rely on the erroneous assumption of treating spacetime as a physical entity. It appears that in the grand maze of the unknown, by adopting the abstract mathematical representations of Relativity, we have somewhere missed the right track and are now approaching a dead end.

The proposed experiment for detection of absolute motion, can finally settle the issue regarding validity of Relativity.

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