A simple Theory of Relativity based on Mach's Principle

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Abstract

A simple and intuitive alternative theory of relativity based on Mach's Principle is proposed. At any location, total gravitational potential from the Universe's matter distribution is c^2. This Universal background potential constitutes unit rest energy of matter and provides its unit mass, which is the essence behind $E = mc^2$. The background gravity creates a local sidereal inertial frame at every location. A velocity increases gravitational potential through net blue-shift of Universe's background gravity, causing kinematic time dilation, which is a form of gravitational time dilation. Matter and energy follow different rules of motion, and speed of matter may exceed the speed of light. The theory is consistent with existing relativity experiments, and is falsifiable based on experiments whose predictions differ from General Relativity. The theory also explains why all the ICARUS and corrected OPERA experiments still show mean neutrino velocities slightly above speed of light (early arrival of neutrinos by $0.1 - 6.5ns$), even after correcting the issues that had led to the original OPERA experiments to erroneously report faster than light neutrinos (early arrival by $\sim 60ns$).

Keywords: Alternative theory of gravitation; General Relativity; Mach's Principle; time dilation; Universe gravitational potential

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1 Introduction

Unit rest energy of matter (c^2) is the gravitational potential of the Universe's homogeneous and isotropic matter distribution (background potential). This is the important concept which forms the basis of this paper.

Mass (amount of inertia) of matter is a gravitational phenomenon, and the Universe's background potential provides the *unit energy/mass* of a body at rest.

From Special Relativity[1], we know that *energy/mass* of matter increases with velocity, causing increased (relativistic) energy/mass and time dilation. A higher magnitude of gravitational potential being equivalent to an increased velocity (as shown in Einstein's derivation of GR), it also increases energy/mass, and causes time dilation.

The Universe has a large background gravitational potential at all locations from its matter distribution. Since energy/mass increases with gravitational potential, this background potential *must contribute* to the *rest* energy/mass of matter. Energy/mass of matter then is a gravitational phenomenon, and the Universe's background potential must constitute *unit rest energy* of matter, i.e. c^2. This is the essence of Mach's principle.

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In this paper, this is the starting point, and the derivations follow the reverse direction of current theory. *Gravitational time dilation*[2, 3] at a location is caused by additional gravitational potential from nearby massive bodies. A velocity causes gravitational potential increase through a net blue-shift of the Universe background gravity, causing *kinematic (special relativistic) time dilation*, which is another form of gravitational time dilation. *Kinetic energy* is a measure of this increased potential energy, as will be explained in detail later.

Deriving kinematic time dilation without gravitational considerations (SR) requires 'length contraction' and 'relativity of simultaneity'. These concepts are not required, and should not be applied to judge the theory presented. Lengths of objects or distances between objects do not change with velocity or gravitational potential change. Each instant or period of time on a clock at any location corresponds to a specific unique instant or period of time on a 'coordinate clock'.

Universe's background gravity creates a local *sidereal rest frame* at every location, which we will call Universe Inertial Reference Frame (UIF). The *rest state* in UIF, far from massive bodies, corresponds to having no rotation or velocity with regard to distant Universal objects[4].

Empirical evidence shows that near massive bodies the UIF coincides and moves with the local Center of Gravity (CG). For example, velocities satisfying orbital equation ($v = \sqrt{GM/R}$) or used to compute time dilation (e.g. Hafele-Keating[5, 6], GPS Satellites[7]) need to be measured from sidereal CG frames in practice. We also see evidence of this in the Sagnac effect[8, 9], where the Earth's rotational velocity around its sidereal axis has to be allowed for in computing speed of light in time-of-flight experiments and applications. This phenomenon, along with the Milky Way galaxy's gravitational potential at Earth being negligible compared to the Universe gravitational potential c^2, precludes detection of any preferred frame or mass anisotropy in Hughes-Drever[10, 11] type experiments.

A simple alternative theory of gravity is derived by reconciling Mach's Principle and General Relativity[12], showing that matter and energy/light follow different rules of motion, and that speed of matter can exceed speed of light. This does not affect GR predictions except in extreme cases, but demonstrates that practical interstellar exploration is possible. The theory is consistent with existing relativity experiments.

2 Meaning and usage of specific terms

In this paper, certain terms are used with a specific meaning:

- **Time dilation:** 'Time dilation' is the same as 'differential aging'. It stands for *invariant clock rate difference* between locations (experimentally measurable clock drift)
- **Gravitational potential:** We use the positive astronomical sign convention for gravitational potentials, such that it is a *positive* energy quantity per unit mass. A larger magnitude (e.g. closer to a large mass) indicates a *higher* or *increased* gravitational potential
- **Propagation Speed of light/energy:** Speed of light/energy from source
- **Total speed of light/energy:** Speed of light in UIF (*speed of source+propagation speed*)
- **Local:** What is 'local' depends on the accuracy of measurement desired for considering a location to have a uniform gravitational potential. Higher the measurement accuracy, smaller the volume of space that may be considered 'local'

3 Motivation behind this paper

Why do we need an alternative theory of gravity, since GR has been so successful in explaining and predicting numerous observational phenomena?

There are good reasons:

- Local constancy of light speed is a *postulate* in existing theory. Understanding the physical principles behind this postulate provides new insights
- Understanding of light speed as a *universal* speed limit needs refinement. Matter and energy follow different rules of motion, since matter does not undergo Shapiro delay[13, 14] (slowdown because of increased gravitational potential). Matter may exceed the speed of light, except in certain constrained motion. This does not affect GR predictions, except in the most extreme cases, but shows that practical interstellar exploration is possible
- A fundamental quantity such as 'mass' does not have one consistent definition within GR. A simple and comprehensive definition of mass is developed in this paper
- Current formulation of GR creates a perception that physical laws of the Universe are so strange that we *cannot* use our intuition to understand them. This need not be so, as the more natural explanations of relativity phenomena in this paper will show. An intuitive understanding of relativity concepts will help develop this fundamental area of physics further
- A simpler classical theory of gravity will facilitate development of a quantum theory of gravity

Apart from this, there are questions that do not have satisfactory resolution within GR, e.g.:

- The *singularity* at the center of a black hole defies any definition within GR
- Bailey et. al. experiment[15] (muon lifetime extension) may be considered as muons in orbital free fall under a central 'gravitational' acceleration towards the center of the muon ring. Lifetimes are compared between (a) stationary/slow muons in an inertial frame in Earth's weak gravitational potential, and (b) near-light-speed muons in a strongly accelerated frame (and therefore, by equivalence principle, in a massive 'gravitational' potential compared to Earth's). Why does no gravitational time dilation appear and why are the observations consistent only with kinematic time dilation?
- The recent OPERA[16, 17] and ICARUS[18, 19] neutrino velocity measurement experiments concluded that the velocity of high-energy neutrinos is 'consistent with the speed of light c', and refuted earlier erroneous OPERA results that neutrino velocities exceeded the speed of light (arrived earlier by $\sim 60ns$). Notably though, each experiment still reported a *mean* neutrino velocity of slightly higher than c (early arrival by $0.1 - 6.5ns$). While this is consistent with speed of light within experimental error for each individual experiment, across four experiments the results become significant. Current relativity theory predicts a statistical mean velocity below c for neutrinos (which have rest mass), at least across multiple experiments. What is the explanation behind this anomaly?

These questions will be answered by the theory in this paper, and we will obtain a much better understanding of how relativity applies to our Universe.

4 Gravitational and non-gravitational energy

In the context of gravitational potential comprising unit energy/mass of matter, it is important to distinguish between gravitational energy and other types of energy, and what the term 'energy' stands for in this paper.

We need to classify energy into two types 'gravitational' and 'non-gravitational'.

At present, gravity is modeled classically (based on GR), while the other fundamental forces/ interactions are modeled through quantum theory. However, it is expected that all the four could be modeled as quantum interactions mediated by gravitons (gravity), photons (electromagnetism), gluons (strong nuclear), and W and Z bosons (weak nuclear). Similarly, all four could have classical models where they could be treated as interactions mediated by specific types of radiation/energy.

Although GR defines gravity as a property of spacetime, it may also be defined as an interaction mediated by energy radiation, as we will do in this paper. Why it acts as a 'field' will be shown in a later section.

This paper describes a classical theory in which we will treat all fundamental interactions as being mediated by radiation/energy. Speed of movement of such radiation/energy at a location is always locally the constant c ($299,792,458m/s$), and determines the pace of local processes relative to other locations. References to 'speed of energy' or 'energy speed' in this paper stand for speed of radiation/energy that mediate the fundamental interactions.

Gravitational energy encompasses gravitational potential energy and kinetic energy. As noted earlier, kinetic energy is essentially an increase of potential energy caused by net blue-shift of the Universe background potential, as will become clear later when we develop the mathematical model.

Non-gravitational energy represents the other three types of radiation/energy. It is the radiation/energy that mediates all non-gravitational fundamental forces/interactions, i.e. electromagnetic, strong nuclear and weak nuclear forces.

When not referring to gravitational potential and kinetic energies, the term 'energy' will refer to the other three types of radiation/energy that mediate electromagnetic, strong nuclear and weak nuclear interactions.

Matter itself ultimately consists of non-gravitational energy. Mass of matter is the total mass of non-gravitational energy that it comprises.

5 How gravity differs from other fundamental forces

Gravity is different from all 'non-gravitational energy' in that we see gravity's effect only as mass/inertia of matter (and of non-gravitational energy), rather than gravitational energy itself being part of the matter of a body.

This is an important distinction. Gravitational energy (total of potential and kinetic energy) is essentially a measure of mass/inertia obtained by matter and non-gravitational energy from interaction with gravity.

Elementary particles of fundamental interactions (photons, gluons, W and Z bosons) are massless by themselves. Interaction with gravity provides their unit mass (inertia) and unit energy (gravitational potential). This is the mass carried by such particles. 'Gravitons' are also massless, and it is the interaction that provides the mass, not the gravitons themselves.

The total non-gravitational energy of a body (the energy constituting its matter) is therefore the same as its total gravitational energy (potential and kinetic). Gravitational and non-gravitational energies are not additive, but are two sides of the same coin. Inertial mass and gravitational mass are one and the same thing.

In GR terminology, stress-energy tensor may be considered to represent either the total non-gravitational energy (including energy comprising matter) *or* the total gravitational energy.

6 Model of gravity

The model of gravity that underlies this paper is described in this section.

'Gravity' is quantized radiation (comprising 'gravitons') received by a body from all other matter in the Universe within the body's Hubble sphere[20]. It comes equally from all directions at c, interacts with matter comprising the body (providing its mass/inertia), and is radiated out equally in all directions. The same holds for all matter in the Universe.

There is equilibrium between the incoming and outgoing gravity for all bodies, as there is no change of mass of bodies over time (except in the very long term because of Universe expansion). Gravity, as GR defines, is truly a property of spacetime and not of matter. In fact, we may say gravity is spacetime of GR.

The gravity radiation described above is not the same as what 'gravitational waves' mean in GR. The difference will be highlighted later.

As an analogy for gravity, consider a small body at rest, attached to numerous stretched strings pulling it uniformly in all spatial directions, in an otherwise gravity-less Universe. If a force tries to move the body in any direction, it will have to do work against the resistance of some of the strings, giving an impression that the body is resisting movement. This resistance is inertia or mass. The tension in the strings provides the resistance that needs to be overcome to move the body, although the strings themselves are not part of the matter constituting the body itself. Of course, this is not a complete analogy for gravitation, but serves to demonstrate the principle. The strings in the analogy create a stable equilibrium. Gravity creates a neutral equilibrium, such that a body maintains a constant velocity once the force is removed.

Not all matter in the Universe affects the gravitational potential at a location. Only matter within the Hubble sphere of the location does. Gravitational potential contribution of farther away spherical layers of matter around the location is greater, since gravitational potential ($\sim M/R$) would grow with increasing R, as M grows $\sim R^2$. However, this is tempered by increasingly larger cosmological red-shifts with increasing R, because of Universe expansion. Any gravity from the edge of the Hubble sphere or beyond is red-shifted out of existence.

Whatever the red-shift though, all gravity reaches a location at c, as extinction[21] will ensure this, irrespective of the away-velocities of the distant gravity sources.

Note that the direction of movement of gravity radiated from a source body (point mass) at rest or moving at a constant velocity will always remain pointed directly away from the *current position* of the CG of the source body. Therefore, when such gravity interacts with distant matter, the gravitational acceleration will always be towards the current position of the source body, and not its retarded position, in spite of gravity having a finite speed (c). A receiving body may perceive the acceleration to be in the direction of the retarded position, but that is an artifact of its own relative speed from the source body. There is actually no component of the gravitational acceleration in any direction but towards the current position of the source body's CG. This means that gravitational acceleration will always be 'central' and gravity acts as a 'static field'. This will be explained in greater detail in a later section.

7 Time dilation and coordinate speed of light/energy

All motion is ultimately dependent on movement of energy at the fundamental level. Speed of energy at a location determines the pace of local processes, from subatomic to observable events, and defines speed of local time or *proper time*. Clock-tick rate is one such local process, used in turn to measure the local speed of energy/light, making 'c' ($299,792,458 m/s$) a local constant. (*Source independence* of light velocity is the other aspect of local constancy of c, and will be explained later).

'Time dilation' is a manifestation of the difference in *local* energy speeds between locations, caused by differential gravitational potential.

Gravitational time dilation is caused by proximity to a massive body, whose gravitational potential augments the background gravitational potential or unit rest energy c^2.

Kinematic time dilation (SR time dilation) is caused by gravitational potential increase through a velocity-induced net blue-shift of the Universe's background gravity itself.

At rest in UIF, far from all masses, gravitational potential is a minimum, and this defines a 'coordinate location'. Light here travels at 'coordinate speed', defining 'coordinate time'.

Proper time at different locations may vary, depending on their gravitational potentials, and corresponding local speeds of light/energy.

We will denote *coordinate speed* of light/energy as c_U, and *local speed* of light at non-coordinate locations as c_I. *Locally*, both would be measured as the constant 'c' $(299, 792, 458m/s)$ as explained above.

Time dilation factor (γ) is the ratio between local energy speeds at two locations. Compared to a coordinate location, $\gamma = c_U/c_I$ is the time dilation factor at any other location. If coordinate time is denoted by t, and proper time by τ, then $d\tau/dt = c_I/c_U$.

8 Gravitational potential of light/energy and matter

Light traveling transverse to a large body has *twice* the gravitational potential of stationary matter, since acceleration is double, as experimentally demonstrated by Eddington[22] and others[23, 24, 25, 26].

Gravitational energy flux (energy per unit time) received by a small body is proportional to the *square of the relative velocity* of the small body and the gravity (which travels at c_U) from the large body. Energy flux depends on two factors, (a) the gravitational energy conveyed by each quantum of gravity (i.e. graviton), and (b) the rate of gravitons received per unit time. For transverse motion at a velocity v, the factors would both be $\sqrt{{c_U}^2 + v^2}/c_U$ compared to rest, and the overall gravitational energy flux received would increase by a factor of $\left(1 + v^2/{c_U}^2\right)$. Similar considerations may be used to derive the change in energy flux for motion in other directions.

Gravitational acceleration is proportional to the gravitational energy flux. Relative velocity of transverse light with respect to the large body's gravity being $\sqrt{2}c_U$, the acceleration is double. This also doubles the gravitational potential.

The increased gravitational acceleration remains central, i.e. directed towards the CG of the large body, since locally the UIF coincides with this CG, and the gravitational acceleration has no component in any other direction.

We will shortly see that energy traveling in any direction in UIF also has double the gravitational potential of stationary matter. This includes all energy at a location, including that which directly drives the pace of local processes.

We will call this gravitational potential of energy as 'energy-potential' (denoted $\hat{\Phi}$), to distinguish from potential of matter (Φ). By earlier definition, Universe's energy-potential ($\hat{\Phi}_U$) at a location is:

$$\hat{\Phi}_U = \sum_{i=1}^{i=n} \frac{2GM_i}{R_i} = {c_U}^2 \tag{1}$$

where

$n =$ number of Universal bodies within the Hubble sphere of the location considered
$G =$ Gravitational constant
$M_i =$ mass of the i^{th} body, adjusted for cosmological red-shift
$R_i =$ distance of the i^{th} body from the location considered

Rest energy of matter is the sum total of the 'energy-potential' of its constituent energy. This is the amount of energy that would be released if unit amount of matter were to be completely converted to energy.

The background gravitational potential of matter itself is $\Phi_U = \hat{\Phi}_U/2 = {c_U}^2/2$, when at rest in UIF.

Gravitational energy-potential from a body of mass M, at distance R, is:

$$\hat{\Phi}_M = 2\Phi_M = \frac{2GM}{R} \tag{2}$$

We may use either energy-potentials ($\hat{\Phi}_U = c_U{}^2$, $\hat{\Phi}_M = 2GM/R$) or potentials ($\Phi_U = c_U{}^2/2$, $\Phi_M = GM/R$) for deriving time dilation equations, as long as they are used consistently. In this paper we adopt the energy-potential as the convention to be used.

9 Gravitational potential and mass

Unit rest energy of matter is $c_U{}^2$, as per $E = mc^2$ with m being unity.

If μ stands for *unit mass* of matter (at an arbitrary velocity and potential) and m_0 stands for the *amount of matter* in a body, then μm_0 represents total mass (m) of the body. The total energy of the body is $E = \mu m_0 c_U{}^2 = mc_U{}^2$.

At rest far from massive bodies $\mu = 1$, and mass is the same as rest mass. Amount of matter (m_0) and rest mass (μm_0) are numerically identical, and the energy equation becomes $E = m_0 c_U{}^2$. Therefore *unit energy* of a body may be defined as 'energy per unit amount of matter' or 'energy per unit rest mass'.

Any increase in potential (through a velocity, or proximity to large body) raises the unit mass (μ), resulting in *relativistic* mass. This is simply an increase of unit energy (potential), which increases the *unit amount of inertia*, without any change in the amount of matter.

In terms of total energy-potential ($\hat{\Phi}_{Total}$) at a location, *unit mass* is:

$$\mu = \frac{\hat{\Phi}_{Total}}{\hat{\Phi}_U} = \frac{\hat{\Phi}_{Total}}{c_U{}^2} = \frac{(E/m_0)}{c_U{}^2} \qquad (3)$$

In the above, $\mu c_U{}^2$ stands for total gravitational potential of the body, including any unit kinetic energy.

E may be considered as either the total non-gravitational energy (including matter) of a body, or the total gravitational energy, as the latter defines the former and the two are equivalent.

10 Effect of velocity on gravitational potential

A body at rest receives gravity from all directions at speed c_U, from matter within its Hubble sphere (Figure 1). Energy-potential is $\hat{\Phi}_U = c_U{}^2$ (and potential of matter itself is $\Phi_U = \hat{\Phi}_U/2 = c_U{}^2/2$).

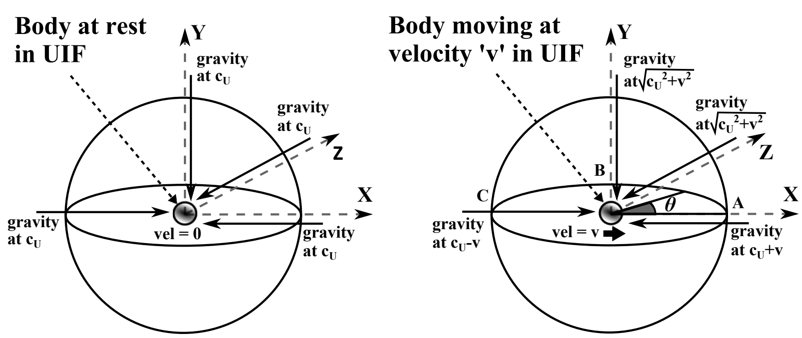

Figure 1: Universe background gravitational potential change with velocity.

A velocity v causes maximal blue-shift of gravitational energy in the direction of motion, and a maximal red-shift in the reverse direction. Intermediate values apply in other directions.

Gravitational acceleration and potential depend on the square of incident gravitational energy velocity. By symmetry, we compute the acceleration/potential change by integrating along the semicircle ABC.

Relative velocity of the body is $\sqrt{{c_U}^2 + v^2 + 2c_U v\cos\theta}$, where θ is the angle between direction of travel and gravity sources.

Gravitational energy-potential from an infinitesimal angle $d\theta$ is:

$$\hat{\Phi}_U \frac{{c_U}^2 + v^2 + 2c_U v\cos\theta}{{c_U}^2} \times \frac{d\theta}{\pi} \tag{4}$$

Total gravitational energy-potential ($\hat{\Phi}_{U,v}$), integrating over θ from 0 to π, is:

$$\hat{\Phi}_{U,v} = \int_0^\pi \hat{\Phi}_U \frac{{c_U}^2 + v^2 + 2c_U v\cos\theta}{{c_U}^2} \times \frac{d\theta}{\pi} = \frac{\hat{\Phi}_U}{{c_U}^2}\left({c_U}^2 + v^2\right) = \hat{\Phi}_U\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{5}$$

Since $\hat{\Phi}_U = {c_U}^2$, we may also write:

$$\hat{\Phi}_{U,v} = {c_U}^2\left(1 + \frac{v^2}{{c_U}^2}\right) = {c_U}^2 + v^2 = \hat{\Phi}_U + v^2 \tag{6}$$

Change in energy-potential of a body, because of a velocity v in UIF, is simply v^2, or a factor of $(1 + v^2/{c_U}^2)$.

Potential of matter becomes $\Phi_{U,v} = \hat{\Phi}_{U,v}/2 = {c_U}^2/2 + v^2/2$, where $v^2/2$ is the *specific kinetic energy.* Kinetic energy is an increase of potential energy from net blue-shift of Universe background potential.

Also, light which travels at $v = c_U$ must have *twice* the potential of stationary matter in UIF, as stated earlier.

A net free-fall acceleration also develops in the direction of motion (though negligible at low velocities). This may alleviate fuel needs for interstellar missions, and explain excessive energies of some cosmic muons[27, 28].

11 Constancy of the product $\hat{\Phi}{c_I}^2$

Gravitational acceleration/potential from *a given amount of matter* at a distant point (X) remains the same, whether the matter is loosely or tightly packed.

In the latter case, $\hat{\Phi}$ within the matter is higher because of closer proximity of different parts. For acceleration/potential at X to remain constant, the energy flux at X must remain the same. Increase of unit mass ($\hat{\Phi}/{c_U}^2$) must then be exactly compensated for by reduction in gravity flux, which is proportional to ${c_I}^2$.

Of course, the gravitational energy will speed up as it leaves the body, and at X the speed of gravity will be c_U, with the gravity being slightly red-shifted as a result. This is analogous to red-shift of sunlight (gravitational red-shift) as predicted by Einstein and experimentally proven later[29, 30, 31, 32].

Therefore (*energy potential*) $\times$ (*local energy speed*)^2 or $\hat{\Phi} \times {c_I}^2$ is a constant.

At rest far from all masses (i.e., coordinate location) we have $\hat{\Phi} = \hat{\Phi}_U$ and $c_I = c_U$, so we derive an important relationship valid for all values of $\hat{\Phi}$ and corresponding c_I:

$$\hat{\Phi}{c_I}^2 = \hat{\Phi}_U {c_U}^2 \tag{7}$$

12 Kinematic time dilation

We get the kinematic time dilation factor (γ) from (6) and (7) as:

$$\hat{\Phi}_{U,v}{c_I}^2 = \hat{\Phi}_U {c_U}^2 \tag{8}$$

$$\therefore \gamma = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{U,v}}{\hat{\Phi}_U}} = \sqrt{1 + \frac{v^2}{{c_U}^2}} \tag{9}$$

For small $v^2 \ll {c_U}^2$:

$$\gamma = \frac{c_U}{c_I} \cong \left(1 + \frac{v^2}{2{c_U}^2}\right) \tag{10}$$

Potential increase of a body, because of velocity v, reduces local energy speed by a factor of $\sqrt{1 + v^2/c^2}$ ($\cong 1 + v^2/2c^2$), causing *kinematic time dilation.*

Equation (9) also shows that even if matter exceeds the speed of light, time dilation does not become infinite. This is the equation for kinematic time dilation in general rectilinear motion in the Universe background gravity. In high velocity orbital motion, the potential created by the local acceleration becomes important, and the kinematic time dilation metric becomes the Lorentz Factor, as will be shown later.

13 Gravitational time dilation

Energy-potential at a location from Universe matter distribution and a nearby massive body ((1) and (2)) is:

$$\hat{\Phi}_{U,M} = \hat{\Phi}_U + \hat{\Phi}_M = {c_U}^2 + \frac{2GM}{R} = {c_U}^2 \left(1 + \frac{2GM}{R{c_U}^2}\right) = \hat{\Phi}_U \left(1 + \frac{2GM}{R{c_U}^2}\right) \tag{11}$$

Using $\hat{\Phi}{c_I}^2$ constancy:

$$\hat{\Phi}_{U,M}{c_I}^2 = \hat{\Phi}_U {c_U}^2 \tag{12}$$

Gravitational time dilation factor γ_g is:

$$\gamma_g = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{U,M}}{\hat{\Phi}_U}} = \sqrt{1 + \frac{2GM}{R{c_U}^2}} \tag{13}$$

If $2GM/R \ll {c_U}^2$:

$$\gamma_g \cong \left(1 + \frac{GM}{R{c_U}^2}\right) \tag{14}$$

14 Total time dilation from gravity and velocity

From above, total energy-potential at a location from Universe background potential, velocity, and a nearby large body (ignoring any velocity-induced modification of the local large body's potential for simplicity) is:

$$\hat{\Phi}_{Total} = \hat{\Phi}_U + v^2 + \frac{2GM}{R} = \hat{\Phi}_U \left(1 + \frac{2GM}{R{c_U}^2} + \frac{v^2}{{c_U}^2}\right) \tag{15}$$

Correspondingly time dilation factor is:

$$\gamma_{Total} = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{Total}}{\hat{\Phi}_U}} = \sqrt{1 + \frac{2GM}{R{c_U}^2} + \frac{v^2}{{c_U}^2}} \tag{16}$$

For low gravity/velocity, we may approximate:

$$\gamma_{Total} \cong 1 + \frac{GM}{R{c_U}^2} + \frac{v^2}{2{c_U}^2} \tag{17}$$

This is same as Schwarzschild metric[33, 34] low velocity/gravity approximation, except velocity v in (16) and (17) may be in any direction, and not necessarily transverse to a spherical mass.

15 Effect of velocity on speed of light and matter

If c_I is *propagation speed* (speed from source) of light, and v is *speed of source*, total speed of light in UIF is:

$$c_{Total} = c_I + v \tag{18}$$

Velocity of a body of *matter* increases its background gravitational potential as explained earlier, but does not adversely affect speed of *the body itself*. Only *propagation speed* of free energy within the body slows down (causing kinematic time dilation). For *light*, increased (blue-shifted) background gravitational potential because of a source velocity causes a *slowdown* of its propagation speed *in the direction of source velocity*. This is essentially Shapiro delay, and compensates for source velocity (Figure 2).

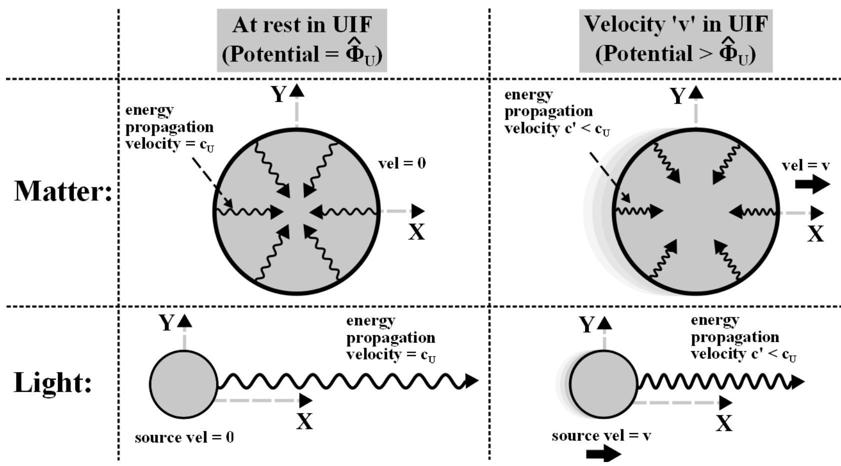

Figure 2: Effect of velocity on light and matter.

Light does not travel faster or slower than local c. Matter can be at rest, or move at any velocity, including faster than light under certain circumstances, as in Cherenkov effect[35].

Matter may travel faster than light even in vacuum, based on the same principles. The only reason we can apply relativistic velocity addition formula in Fizeau[36, 37] and similar experiments[38] is that the *principles involved are the same*. Density of a medium is equivalent to higher gravitational potential. *Refraction* is a Shapiro delay caused by the higher potential within a medium, and the same principles of gravitational potential increase as applied in vacuum may be used to explain phenomena in denser mediums.

Particle accelerators (with force-carrier particles traveling at c from stationary source) or Alvager experiment[39], as will be explained below, cannot achieve $v \geq c$. A practical possibility is described later.

Light travels at c_U in UIF (at a coordinate location), and therefore already faces a higher background potential than it would have had at rest. To understand how a source velocity affects total speed of light in UIF, we must start from the 'base potential' ($\hat{\Phi}_{base}$) light would have had at rest.

If light, theoretically at rest, were to be given a velocity of V, potential would increase from $\hat{\Phi}_{base}$, causing a reduction of the *propagation speed* of the light. Using considerations of (5), the increased potential is (as a first approximation):

$$\hat{\Phi}_V = \hat{\Phi}_{base}\left(\frac{{c_U}^2 + V^2}{{c_U}^2}\right) = \hat{\Phi}_{base}\left(1 + \frac{V^2}{{c_U}^2}\right) \tag{19}$$

Since this increase is continuous over V, we break it into 'n' small steps, and take the limit as $(n \to \infty)$ to get an exact value:

$$\hat{\Phi}_V = \hat{\Phi}_{base} \lim_{n \to \infty} \left(1 + \frac{\left(V^2/{c_U}^2\right)}{n}\right)^n = \hat{\Phi}_{base} e^{\frac{V^2}{{c_U}^2}} \tag{20}$$

From this, we can compute how the speed of light is affected by a source velocity which increases (or decreases) the Universe background gravitational potential for such light.

Light from a stationary star travels at c_U, and has a potential $\hat{\Phi}_U$. From (20):

$$\hat{\Phi}_U = \hat{\Phi}_{base} e^{\frac{{c_U}^2}{{c_U}^2}} \tag{21}$$

Light from a star traveling at v will have speed $c' = c_U + v$, as a first approximation. However, increased potential (denoted $\hat{\Phi}_{c'}$) will reduce the propagation speed c_I. From (20):

$$\hat{\Phi}_{c'} = \hat{\Phi}_{base} e^{\frac{(c_U+v)^2}{{c_U}^2}} \tag{22}$$

From (21) and (22), keeping $\hat{\Phi}{c_I}^2$constant:

$$\hat{\Phi}_{base} e^{\frac{(c_U+v)^2}{{c_U}^2}} \times {c_I}^2 = \hat{\Phi}_{base} e^{\frac{{c_U}^2}{{c_U}^2}} \times {c_U}^2 \tag{23}$$

Solving for c_I:

$$c_I = e^{-\left(\frac{v}{c_U} + \frac{v^2}{2{c_U}^2}\right)} \times c_U \tag{24}$$

Using $e^x = 1 + x + x^2/2! + x^3/3! \cdots$, ignoring orders above v^3/c^3 (since $v \ll c_U$):

$$c_I \cong c_U \left(1 - \frac{v}{c_U} - \frac{v^2}{2{c_U}^2} + \frac{v^2}{2{c_U}^2} + \frac{v^3}{2{c_U}^3} - \frac{v^3}{6{c_U}^3}\right) = c_U \left(1 + \frac{v^3}{3{c_U}^3}\right) - v \tag{25}$$

$$\therefore c_{Total} = c_I + v = c_U \left(1 + \frac{v^3}{3{c_U}^3}\right) \cong c_U \, for \ v \ll c_U \tag{26}$$

Change of total speed of light is *negligible* for small speed of source v. This is why light appears to be *source velocity independent* (i.e. $k \cong 0$ in $c' = c + kv$) in experiments like Michelson-Morley[40, 41, 42, 43] and Kennedy-Thorndike[44, 45].

Orbital velocities of binary stars are typically $10 - 100 km/s$, giving $k \cong v^2/3{c_U}^2 \sim 10^{-7} - 10^{-10}$. This is consistent with de Sitter[46, 47] ($k < 0.002$) and Kenneth Brecher[48] ($k < 2 \times 10^{-9}$) experiments.

The above derivation shows that while light would show the Sagnac effect because of Earth's rotational velocity, matter (e.g. neutrinos) would not. The Sagnac effect from Earth's rotation is essentially a restatement of the (near) source velocity independence of light, as measured from Earth's sidereal axis. Matter is not source velocity independent even at relativistic speeds, as the OPERA/ICARUS experiments demonstrate, with mean neutrino velocities being slightly above c (consistent with the Sagnac effect of $\sim 2.2ns$) across multiple experiments. This is discussed in more detail later.

16 Speed of matter ejected from a moving source

The speed of a small body (m) ejected from a large moving source (M where $M \gg m$) is not affected by the increased background potential. However, the movement of the source itself does have a slowdown effect on the small body's overall speed in UIF.

If the source M is moving at a velocity V, then all energy at its location is slowed by a factor of $\gamma = \sqrt{1 + V^2/{c_U}^2}$. All processes, including the process of ejecting the small body m, are slowed down by the same factor. If the velocity of ejection is v (by M's local clock), the same velocity in UIF will be v/γ. Therefore the velocity of m in UIF will be $V + v/\gamma$.

17 Acceleration and potential in orbital motion

Let us say a small body m is orbiting a massive body M at distance R with velocity v.

Considering m's relative velocity ($\sqrt{{c_U}^2 + v^2}$), M's acceleration on m is:

$$A_M = \frac{GM}{R^2}\left(1 + \frac{v^2}{{c_U}^2}\right) = \frac{v^2}{R} \tag{27}$$

Rest mass of m above accounts only for UIF energy-potential ($\hat{\Phi}_U$). Energy-potential of M (denoted $\hat{\Phi}_{M,v}$) is:

$$\hat{\Phi}_{M,v} = \hat{\Phi}_M\left(1 + \frac{v^2}{{c_U}^2}\right) = \frac{2GM}{R}\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{28}$$

Including this, unit mass of m is higher by $\hat{\Phi}_{M,v}/{c_U}^2$, increasing *transverse momentum*. This will have to be counteracted by an *equal increase in central acceleration* (ΔA_M). Since $\hat{\Phi}_U = {c_U}^2$:

$$\Delta A_M = A_M \times \frac{(\hat{\Phi}_{M,v}/{c_U}^2)}{(\hat{\Phi}_U/{c_U}^2)} = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{29}$$

This incremental acceleration in turn creates further increase in potential, and therefore mass and transverse momentum. The relationship is recursive, and leads to the additional acceleration becoming (for $v^2 < {c_U}^2$):

$$\Delta A_M = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}(1 + \cdots)\right)\right) = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right) \tag{30}$$

Energy-potential of m from M would be modified by the same factor:

$$\hat{\Phi}_{M,v} = \hat{\Phi}_M\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right) = \frac{2GM}{R}\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right) \tag{31}$$

Total energy-potential of m (adding UIF energy-potential $\hat{\Phi}_{U,v}$ from (6)):

$$\hat{\Phi}_{Total} = \hat{\Phi}_{U,v} + \hat{\Phi}_{M,v} = \hat{\Phi}_U + v^2 + \hat{\Phi}_M\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right) = \hat{\Phi}_U\left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2}\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right)\right) \tag{32}$$

M's acceleration also needs to account for this additional UIF transverse momentum:

$$A_{M,v} = A_M\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{33}$$

Therefore, total acceleration (A) is:

$$A = A_{M,v} + \Delta A_M = A_M\left(1 + \frac{v^2}{{c_U}^2} + \frac{\hat{\Phi}_M}{{c_U}^2}\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right)\right) \tag{34}$$

In terms of M's potential and m's orbital velocity, this is:

$$A = \frac{v^2}{R}\left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2}\left(\frac{1}{1-\frac{v^2}{{c_U}^2}}\right)\right) \tag{35}$$

This gives us *energy-potential* (32) and *acceleration* ((34), (35)) for circular *orbit* under *central acceleration.*

By equivalence principle, this applies to both natural gravitational situations like GPS Satellites/black holes, and artificial situations like muons in the muon ring in Bailey et. al. experiment.

Anomalous precession of Mercury's perihelion is caused by the slightly increased acceleration ($\cong v^2/R \times (1 + 3GM/R{c_U}^2)$) for small v in (35).

We also see that although dense objects like black holes may form, there is no event horizon or singularity mandated.

18 The Lorentz Factor

Time dilation factor ($\gamma = c_U/c_I$) in orbital motion can be found from $\hat{\Phi}{c_I}^2$ constancy and (32):

$$\hat{\Phi}_U{c_U}^2 = \hat{\Phi}_{Total}{c_I}^2 = \left(\hat{\Phi}_{U,v} + \hat{\Phi}_{M,v}\right){c_I}^2 = \hat{\Phi}_U\left(1 + \frac{v^2}{{c_U}^2} + \frac{\hat{\Phi}_M}{{c_U}^2}\left(\frac{1}{1-\frac{v^2}{{c_U}^2}}\right)\right){c_I}^2 \tag{36}$$

In *high velocity orbital motion* ($v \approx c_U$), as in Bailey experiment, we get $\hat{\Phi}_M \cong \hat{\Phi}_U$ (by (27) we have $GM/R = v^2/(1 + v^2/{c_U}^2)$, and since $v \approx c_U$, we get $\hat{\Phi}_M = 2GM/R \cong {c_U}^2 = \hat{\Phi}_U$).

As $1/\left(1 - v^2/{c_U}^2\right)$ becomes large, local energy-potential ($\hat{\Phi}_{M,v}$) overwhelms Universe energy-potential ($\hat{\Phi}_{U,v}$) in (36).

Therefore we may consider $\hat{\Phi}_{Total} \cong \hat{\Phi}_{M,v}$ in (36):

$$\hat{\Phi}_U{c_U}^2 \cong \hat{\Phi}_{M,v}{c_I}^2 = \frac{\hat{\Phi}_M}{(1 - v^2/{c_U}^2)}{c_I}^2 \cong \frac{\hat{\Phi}_U}{(1 - v^2/{c_U}^2)}{c_I}^2 \tag{37}$$

This gives us:

$$\gamma = \frac{c_U}{c_I} = \frac{1}{\sqrt{1 - v^2/{c_U}^2}} \tag{38}$$

This is the *Lorentz Factor*, applicable time dilation metric only for *very high velocity orbital motion*, when potential from local acceleration overwhelms Universe background potential.

This is why the Bailey experiment does not show any separate gravitational time dilation. Gravitational and kinematic time dilations are one and the same in this case.

Lorentz factor is a multiplier of *local energy-potential* $\hat{\Phi}_M$. At low orbital velocities it contributes little, and kinematic time dilation predominantly comes from blue-shift of Universe background gravity.

That the Lorentz Factor seems to apply at low velocities is an unfortunate coincidence of its approximation being the same as (10).

We also see why particle accelerators like the Large Hadron Collider (LHC) are able to accelerate particles to very high velocities and energies, though such particles never reach a speed of c.

The strong accelerations used along circular tracks produce extremely high energies (potentials) which slows down the 'clocks' of such particles significantly. Therefore the particles maintain such energies for considerable periods after being ejected from the accelerators, as the very slow movement of energy within them slows down the potential/energy loss process as well.

However, since the force-carrier particles that accelerate subatomic particles are themselves traveling at c from a stationary source (the accelerator magnets), they cannot push the speed of the accelerated particles to c or beyond.

19 Compatibility with existing theories

19.1 Compatibility with Field Theory

The theory developed in this paper is consistent with field theory.

Consider two bodies M and m orbiting each other around the common CG, as in 3. We will examine how the gravity of M affects m, but the argument will hold in the reverse direction as well.

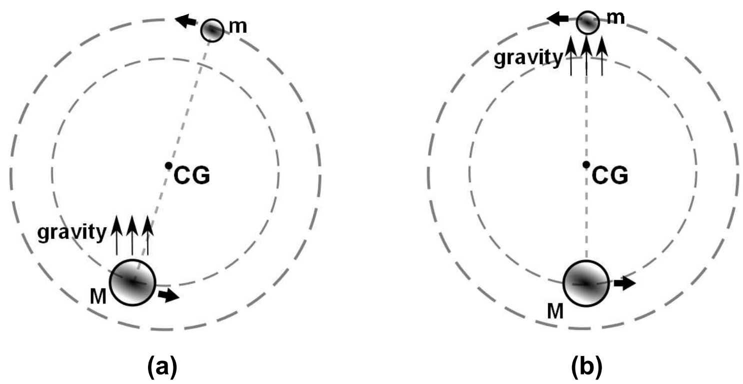

Figure 3: Gravitational field with finite speed of gravity.

Certain amount of gravity (radiation) leaves M in a vertical direction at a point in the orbit of M as shown in 3(a). Assuming M is at rest or moving with a constant velocity v, the direction of this radiation always points directly away from M's current position.

When this gravity reaches m, which is always on the line connecting M to the CG of the system, the acceleration of m is directly towards the current position of M, and not towards its retarded position, as there are no components of the acceleration in any other direction (3(b)). The reverse is also true for M's acceleration because of m's gravity. Therefore, in spite of gravity having a finite speed (c), gravitational acceleration will always be central, i.e. towards the CG of the source body's current position. In other words, gravity acts as a *static field*.

A body receiving gravity from a source may perceive the acceleration to be in the direction of the retarded position, but that is an artifact of its own relative speed with regard to the source body. This is only a projected direction of acceleration, not a true direction. This is similar to a pencil partially dipped in water appearing bent at the waterline, because of the projection back of the light received to form the image. The pencil itself is not really bent, but only appears to be so.

Of course, since in orbit both M and m are accelerating somewhat, the field will be perturbed a bit, but for small orbital velocities $v \ll c$, which is always the case for astronomical bodies, this is a very good approximation to a static field. The approximation is even better when $M \gg m$ as M then is practically at rest in UIF, and m's gravity is largely immaterial. This is seen in the long-term stability of planetary orbits in the Solar System.

19.2 Compatibility with Electrodynamics

The theory also remains consistent with electrodynamics. Since we have seen that local speed of light is always the constant c, and a small velocity ($v \ll c$) of a source does not change the velocity of light, Maxwell's equations and the observations they are based on are not affected in any way.

20 Momentum and energy

While momentum conservation has not been specifically dealt with in this paper for purposes of brevity, it is assumed to remain valid in the same way as in GR. The relativistic masses of colliding bodies need to be considered for momentum conservation computations. The principles outlined in this paper may be used to obtain further insights into momentum conservation.

However, what is important to understand is what loss of kinetic energy in collisions implies.

For example, if two identical bodies, having the same velocity in UIF, collide inelastically with each other and come to rest together, momentum is conserved but kinetic energy is not.

Since kinetic energy is nothing but increased gravitational potential energy, the additional gravity will be released as gravitational waves (or at least one wave) in the above case. This is equivalent to potential or relativistic mass loss of the bodies, and the energy leaves the system.

21 Gravitational waves

'Gravitational waves' are not the same as the gravity radiation discussed above. Gravitational waves carry away excess gravitational potential (which was in the form of kinetic energy) from a body because of its state of motion or changes to the state of motion.

This could take the form of an explosive release/loss as in case of colliding or exploding objects, or continuous release/loss as in the case of orbiting bodies that are slowing down. This is analogous to excess energy release inf the form of light/electromagnetic radiation in case of an explosion in the first case, and continuous release of energy as light from binary stars in the second case.

If the binary stars are observed from a distant rest position (e.g. Earth), the light would appear to be coming in waves of energy alternating between a certain red shift and a blue shift around a mean, as the stars move around in their orbits. This may be thought of as a 'wave of waves'. Gravitational waves are the same when it is gravity that is released instead of light.

Detection of gravitational waves (or at least one wave) should be possible from high speed collisions of large objects, apart from high orbital velocities of compact objects.

22 Explanations of some important experiments

22.1 The OPERA/ICARUS neutrino velocity measurement experiments

ICARUS and OPERA Collaborations recently conducted a number of experiments to very accurately determine velocities of high-energy neutrinos. The purpose was to validate or refute earlier OPERA experiments that indicated neutrino speeds significantly in excess of the speed of light (neutrinos arrived earlier by a computed difference of $\sim 60ns$ compared to light), challenging the basis of current relativity theory.

The ICARUS and corrected OPERA experiments established that the previous OPERA observations resulted from experimental error. However, it is worth noting that each and every one of the new experiments still reported *mean* neutrino velocities slightly exceeding the speed of light (early arrival by $0.1 - 6.5ns$), even though by much smaller amounts compared to the original OPERA experiments.

While the result of each individual experiment in isolation may be considered to validate neutrino velocities being 'consistent with the speed of light' within limits of experimental error, the mean neutrino velocities being measured to be slightly above speed of light across four separate experiments becomes significant. Current relativity theory predicts a statistical mean velocity below c for neutrinos, especially across multiple experiments of such high accuracy.

The results in fact agree very well with the values predicted by the theory proposed in this paper, demonstrating the difference in the rules of motion between light/energy and matter.

According to the theory derived in this paper, velocity of neutrinos (matter) is not affected by increased background potential because of source velocity. Therefore they should not show the Sagnac effect, while light would. The Sagnac effect arises from the source laboratory (CERN) moving towards the destination laboratory (Gran Sasso) because of Earth's rotational velocity. Given that Gran Sasso (latitude 42.47°, longitude 13.55°) is approximately 57° SE of CERN (latitude 46.25°, longitude 6.05°), and the Earth's rotational velocity at CERN is about $322m/s$, the Sagnac effect over the distance of about $730km$ is $\sim 2.2ns$, as factored into the experiments. The neutrinos may therefore exceed the speed of light by up to that amount. This is in agreement with the mean neutrino velocities observed in the ICARUS/OPERA experiments.

22.2 Alvager et. al. experiment

The Alvager et al. experiment is taken as strong proof of the invariance postulate, since it appears that c is unaffected even when emitted from a high-velocity source. This requires a closer examination.

In the experiment, γ-rays produced by near-light-speed ($0.99975c$) protons striking a Beryllium target (with an intermediate stage of neutral π-mesons, or pions) do not show a velocity measurably higher than c in a 'time of flight' measurement. The inference drawn is that the high velocity of the source does not affect the speed of light (the γ-rays), which still travels at the speed of light in the lab frame.

In terms of $c' = c + kv$, the conclusion reached is that $k = (-3 \pm 13) \times 10^{-5}$.

However, the following points need to be considered:

- With time dilation factor (γ) of nearly 45, energy within protons (and pions) is moving at $c_I = c_U/\gamma = 6.7 \times 10^6 m/s$ only. Added to proton velocity of $0.99975c$, maximum possible velocity of the γ-rays is $3.064 \times 10^8 m/s\,(1.02c_U)$. This gives $k = 2.2 \times 10^{-2}$, i.e. $\ll 1$. The γ-ray velocity would not have been that noticeably higher than c_U anyway.

- γ-rays are not produced *spontaneously* by protons in flight, but through a *collision process*. Source protons strike much larger beryllium nuclei in a metal lattice to produce pions. We have no certainty that the source protons are moving in the original direction at $0.99975c$ at the point of pion production.

- Velocity of the source protons should increase γ-ray energy in the direction of motion, for it to have any bearing on the experiment at all. If equally energetic γ-rays are being scattered in all directions (e.g. perpendicular to proton path), the entire experiment's basis is invalidated. This is not tested. γ-rays are certainly being scattered in different directions, since the experiment measures velocity of γ-rays at an angle of 6° to the proton path. (It is also not clear why the velocities are measured at this angle rather than along the proton path, and whether this angle deviation is accounted for in the experiment's reported accuracy and error).

This experiment, as a proof of *source velocity independence of light*, is at best inconclusive.

23 Suggested experiments

23.1 Neutrinos generated at lower gravitational potentials

If simultaneous pulses of light and neutrinos are sent from lower to higher gravitational potential (e.g. High-Earth orbit to Low-Earth orbit), neutrinos should arrive earlier than light. Neutrinos generated at a location of higher c would exceed c (in vacuum) at the destination, as they would not undergo Shapiro delay. This is similar to OPERA/ICARUS collaboration experiments, except neutrinos need to be generated at a lower potential and received at a higher potential.

Neutrinos from supernovas arrive at Earth earlier than light, as seen from supernova SN 1987A. Though current supernova theory has a different explanation for this, the observation is expected, as light experiences some Shapiro delay because of the gravitational potential from bodies close to the path of light.

23.2 Intermediate velocity repetition of Bailey experiment

If the Bailey et. al. experiment is repeated at intermediate muon velocities ($v \sim 0.5 - 0.8c$), neither the Schwarzschild metric, nor the Lorentz factor would be adequate by themselves to predict the time dilation. Since the UIF potential would be comparable to the potential created by the local acceleration, we would need the full Equation (36) to compute the time dilation factor. There will be a $15\% - 19\%$ *difference* between this equation and the Lorentz factor in such situations.

If the muon lifetime extension is found to be as per (36) rather than the Lorentz factor, it will validate the modified equation and the underlying theory developed in this paper.

23.3 Spontaneous decay of high-velocity particles

If an unstable particle could be accelerated to a high velocity and then allowed to decay spontaneously (not via collision as in Alvager experiment), the forward velocity of any decay products (preferably particles rather than γ-rays/energy to eliminate any Shapiro delay) should exceed c. A slightly slower source velocity (say $v \sim 0.5 - 0.8c$) would be preferable to high velocities like $0.99975c$, as the reduction of internal energy speed (c_I) would not be that drastic, leading to a more easily measurable superluminal speed.

24 Conclusion

The essence of Mach's Principle is that the Universe's background gravitational potential from its matter distribution defines the unit rest energy/mass of matter (c^2). This understanding of energy/mass as a gravitational phenomenon allows us to derive a simple theory of relativity that provides us a number of important insights.

The Universe background gravitational potential also provides a local inertial reference frame for orientation and velocity at any location. The concept of spacetime in existing relativity theory is a manifestation of this Universal gravity.

Gravitational and kinematic time dilations are shown to be the same phenomenon, caused by increase of gravitational potential, because of proximity to other massive objects or velocity induced net blue-shift of Universe gravitational potential respectively.

This removes the counter-intuitive nature of kinematic time dilation and allows separation of Space and Time dimensions. Time is a local dimension and a function of local energy speed, which is only a comparative measure against energy speed at some other location. Time dilation itself is a manifestation of difference in speed of otherwise identical physical processes between two locations.

There is always a Universal 'now' moment, which can be unequivocally mapped to specific readings on all clocks in the Universe, even if they are running at different rates because of gravitational potential differentials. Simultaneity of spatially separated events is an absolute fact, and any disagreement between relatively moving or distant observers is an apparent effect of the distance to events and limited speed of light as the information carrier.

We achieve an intuitive understanding of the local constancy of c based on simple physical principles, removing the mystique of constancy of c as a postulate.

We reach a very important conclusion that matter and energy follow different rules of motion and matter can exceed the speed of light. This has significant consequences for interstellar exploration. Not only does relativity allow superluminal travel, at high velocities it also provides a mechanism for significant free-fall acceleration in the direction of motion.

References

[1] A. Einstein. Zur Elektrodynamik bewegter Körper (On the Electrodynamics of Moving Bodies). *Ann. Phys. (Berlin)*, 17:891, 1905.

[2] A. Einstein. Über den Einfluss der Schwercraft auf die Ausbreitung des Lichtes (On the Influence of Gravity on the Propagation of Light). *Ann. Phys. (Berlin)*, 35:898–908, 1911.

[3] A. Einstein. *Relativity: The Special & The General Theory.* Methuen & co., London, 1920. Translated by: Lawson, Robert w.

[4] A. Einstein. *The Meaning of Relativity.* Princeton University Press, Princeton, 5th edition, 1955. p.109.

[5] J. C. Hafele and R. E. Keating. Around-the-World Atomic Clocks: Predicted Relativistic Time Gains. *Science*, 177:166–168, 1972.

[6] J. C. Hafele and R. E. Keating. Around-the-World Atomic Clocks: Observed Relativistic Time Gains. *Science*, 177:168–170, 1972.

[7] N. Ashby. Relativity and The Global Positioning System. *Phys. Today*, 55(5):41–46, 2002.

[8] G. Sagnac. The demonstration of the luminiferous aether by an interferometer in uniform rotation. *C. R. Acad. Sci.*, 157:708–710, 1913.

[9] G. Sagnac. On the proof of the reality of the luminiferous aether by the experiment with a rotating interferometer. *C. R. Acad. Sci.*, 157:1410–1413, 1913.

[10] V. W. Hughes, H. G. Robinson, and V. Beltran-Lopez. Upper Limit for the Anisotropy of Inertial Mass from Nuclear Resonance Experiments. *Phys. Rev. Lett.*, 4(7):342–344, 1960.

[11] R. W. P. Drever. A search for anisotropy of inertial mass using a free precession technique. *Philos. Mag.*, 6(65):683–687, 1961.

[12] A. Einstein. The Foundation of the General Theory of Relativity. *Ann. Phys. (Berlin)*, 49(7):769–822, 1916.

[13] Irwin I. Shapiro. Fourth Test of General Relativity. *Phys. Rev. Lett.*, 13(26):789–791, 1964.

[14] Irwin I. Shapiro, Gordon H. Pettengill, Michael E. Ash, Melvin L. Stone, William B. Smith, Richard P. Ingalls, and Richard A. Brockelman. Fourth Test of General Relativity: Preliminary Results. *Phys. Rev. Lett.*, 20(22):1265–1269, 1968.

[15] H. Bailey, K. Borer, Combley F., Drumm H., Krienen F., Lange F., Picasso E., Ruden W. von, Farley F. J. M., Field J. H., Flegel W., and Hattersley P. M. Measurements of relativistic time dilatation for positive and negative muons in a circular orbit. *Nature*, 268(5618):301–305, 1977.

[16] OPERA Collaboration. Measurement of the neutrino velocity with the OPERA detector at the CNGS beam. *J. High Energ. Phys.*, 2012(10):93, 2012.

[17] OPERA Collaboration. Measurement of the neutrino velocity with the OPERA detector at the CNGS beam using the 2012 dedicated data. *J. High Energ. Phys.*, 2013(1):153, 2013.

[18] ICARUS Collaboration. Measurement of the neutrino velocity with the ICARUS detector at the CNGS beam. *Phys. Lett. B*, 713(1):17–22, 2012.

[19] ICARUS Collaboration. Precision measurement of the neutrino velocity with the ICARUS detector at the CNGS beam. *J. High Energ. Phys.*, 2012(11):49, 2012.

[20] E. Hubble. A Relation between Distance and Radial Velocity among Extra-Galactic Nebulae. *Proc. Natl. Acad. Sci. U. S. A.*, 15 (3):168–173, 1929.

[21] R. J. Trumpler. Preliminary results on the distances, dimensions and space distribution of open star clusters. *Lick Obs. Bull.*, 14(420):154–188, 1930.

[22] F. W. Dyson, A. S. Eddington, and Davidson C. A determination of the deflection of light by the Sun's gravitational field, from observations made at the total eclipse of 29 May 1919. *Philos. Trans. R. Soc., A*, 220:291–333, 1920.

[23] D. Kennefick. Testing relativity from the 1919 eclipse - a question of bias. *Phys. Today*, 62(3):37–42, 2009.

[24] G. van Biesbroeck. The relativity shift at the 1952 February 25 eclipse of the Sun. *Astron. J.*, 58:87–88, 1953.

[25] Texas Mauritanian Eclipse Team. Gravitational deflection of light: solar eclipse of 30 June 1973 I. Description of procedures and final results. *Astron. J.*, 81(6):452–454, 1976.

[26] B. F. Jones. Gravitational deflection of light: solar eclipse of 30 June 1973 II. Plate reductions. *Astron. J.*, 81(6):455–463, 1976.

[27] J. Linsley. Evidence for a Primary Cosmic-Ray Particle with Energy 10^{20} eV. *Phys. Rev. Lett.*, 10(4):146–148, 1963.

[28] D. J. Bird, S. C. Corbató, H. Y. Dai, B. R. Dawson, J. W. Elbert, T. K. Gaisser, K. D. Green, M. A. Huang, D. B. Kieda, S. Ko, C. G. Larsen, E. C. Loh, M. Luo, M. H. Salamon, D. Smith, P. Sokolsky, P. Sommers, T. Stanev, J. K. K. Tang, S. B. Thomas, and S. Tilav. Evidence for correlated changes in the spectrum and composition of cosmic rays at extremely high energies. *Phys. Rev. Lett.*, 71(21):3401–3404, 1993.

[29] W. S. Adams. The Relativity Displacement of the Spectral Lines in the Companion of Sirius. *Proc. Natl. Acad. Sci. U. S. A.*, 11 (7):382–387, 1925.

[30] R. V. Pound and G. A. Rebka Jr. Gravitational Red-Shift in Nuclear Resonance. *Phys. Rev. Lett.*, 3:439–441, 1959.

[31] R. V. Pound and J. L. Snider. Effect of gravity on gamma radiation. *Phys. Rev.*, 140(3B):788–803, 1965.

[32] R. V. Pound. Weighing Photons. *Classical Quant. Grav.*, 17(12):2303–2311, 2000.

[33] K. Schwarzschild. Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie (On the gravitational field of a point mass according to Einstein's theory). In *Sitzungsber. Dtsch. Akad. Wiss. Berlin, Kl. Math., Phys. Tech.*, page 189, Berlin, 1916. Akademie der Wissenschaften.

[34] K. Schwarzschild. Über das Gravitationsfeld einer Kugel aus inkompressibler Flussigkeit nach der Einsteinschen Theorie (On the gravitational field of a sphere of incompressible fluid according to Einstein's theory). In *Sitzungsber. Dtsch. Akad. Wiss. Berlin, Kl. Math., Phys. Tech.*, page 424, Berlin, 1916. Akademie der Wissenschaften.

[35] Pavel A. Cherenkov. Visible emission of clean liquids by action of γ radiation. *Dokl. Akad. Nauk SSSR*, 2:451, 1934.

[36] H. Fizeau. Sur les hypothòses relatives à l'éther lumineux. *C. R. Acad. Sci.*, 33:349–355, 1851.

[37] H. Fizeau. Sur les hypothòses relatives à l'éther lumineux. *Ann. Chim. Phys.*, 57:385–404, 1859.

[38] A. A. Michelson and E. W. Morley. Influence of Motion of the Medium on the Velocity of Light. *Am. J. Sci.*, 31:377–386, 1886.

[39] T. Alväger, F. J. M. Farley, J. Kjellman, and L. Wallin. Test of the second postulate of special relativity in the GeV region. *Phys. Lett.*, 12(3):260–262, 1964.

[40] A. A. Michelson. The Relative Motion of the Earth and the Luminiferous Ether. *Am. J. Sci.*, 22:120–129, 1881.

[41] A. A. Michelson and E. W. Morley. On the Relative Motion of the Earth and the Luminiferous Ether. *Am. J. Sci.*, 34:333–345, 1887.

[42] A. A. Michelson and E. W. Morley. On a method of making the wave-length of sodium light the actual and practical standard of length. *Am. J. Sci.*, 34:427–430, 1887.

[43] A. A. Michelson and E. W. Morley. On the feasibility of establishing a light-wave as the ultimate standard of length. *Am. J. Sci.*, 38:181–186, 1889.

[44] R. J. Kennedy. A Refinement of the Michelson-Morley Experiment. *Proc. Natl. Acad. Sci. U. S. A.*, 12 (11):621–629, 1926.

[45] R. J. Kennedy and E. M. Thorndike. Experimental Establishment of the Relativity of Time. *Phys. Rev.*, 42(3):400–418, 1932.

[46] W. De Sitter. A proof of the constancy of the velocity of light. In *Proc. R. Neth. Acad. Arts Sci.*, volume 15, pages 1297–1298, Amsterdam, 1913. Elsevier.

[47] W. De Sitter. On the constancy of the velocity of light. In *Proc. R. Neth. Acad. Arts Sci.*, volume 16, pages 395–396, Amsterdam, 1913. Elsevier.

[48] K. Brecher. Is the Speed of Light Independent of the Velocity of the Source? *Phys. Rev. Lett.*, 39(17):1051–1054, 1977.