Reconciling Mach's Principle and General Relativity into a simple alternative Theory of Gravity

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Abstract

A theory of gravity reconciling Mach's Principle and General Relativity (GR) is proposed. Background gravitational potential from the Universe's matter distribution is c^2. This potential constitutes unit rest energy of matter and provides its unit rest mass, which is the essence behind $E = mc^2$. The background gravity creates a local sidereal inertial frame. A velocity increases gravitational potential through net blue-shift of Universal gravity, causing velocity time dilation, which is a form of gravitational time dilation. Time dilation does not become boundless in general, and matter may exceed the speed of light. The Lorentz factor applies only under specific circumstances. The theory is consistent with existing relativity experiments, and is falsifiable based on experiments whose predictions differ from GR.

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

Universal gravity creates a *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[1].

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[2, 3], GPS Satellites[4]) need to be measured from sidereal CG frames in practice. This phenomenon, along with the Milky Way galaxy's gravitational

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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[5, 6] type experiments.

The term 'location' in this paper signifies a *small body* and *its immediate surroundings* at a uniform gravitational potential. Two locations need not be at mutual rest.

A simple alternative theory of gravity is derived by reconciling Mach's Principle and General Relativity[7], showing that speed of matter can exceed speed of light.

2 Difference in derivation from current relativity theory

'Time dilation' is *invariant clock rate difference* between locations. It is a manifestation of the difference in local energy speeds, caused by differential gravitational potential. Gravitational potential is treated as a *positive* energy in this paper.

Speed of energy within matter determines the pace of local processes (from subatomic to observable events), and defines speed of local time or *proper time*. Clock-ticks 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.

Gravitational time dilation[8, 9] is a manifestation of difference in local energy speeds, caused by differential gravitational potential arising from relative proximity to a large body.

Velocity time dilation is caused by gravitational potential increase through a velocity-induced net blue-shift of Universe's background gravity.

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 denote *coordinate speed* of light/energy as c_U, and *local speed* as c_I. 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.

Deriving velocity time dilation without gravitational considerations (Special Relativity[10]) requires 'length contraction' and 'relativity of simultaneity'. These concepts are not required, and should not be applied to judge the theory presented.

3 Gravitational potential of light/energy

Light traveling transverse to a large body has *twice* the gravitational potential of stationary matter, since acceleration is double (Eddington[11] and others[12, 13, 14, 15]). This is because relative velocity of light with respect to the body's gravity is $\sqrt{2}c_U$, and acceleration is proportional to the square of incident velocity. We will see that this is also true for energy traveling in any direction in UIF, including energy *which is part of matter.*

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:

$$\hat{\Phi}_U = {c_U}^2 \tag{1}$$

Rest energy of matter is the sum total of the energy-potential of its constituent energy. Time dilation depends on difference in energy-potential, which affects speed of energy within matter. (Potential of matter itself is $\Phi_U = \hat{\Phi}_U/2 = {c_U}^2/2$).

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

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

4 Gravitational potential and mass

Unit rest energy of matter is ${c_U}^2$ (as per $E = mc^2$), 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 $E = \mu m_0 {c_U}^2 = m{c_U}^2$.

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 $E = m_0{c_U}^2$.

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, 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:

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

5 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, increase of $\hat{\Phi}$ must be exactly compensated for by reduction of ${c_I}^2$.

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

At rest far from all masses, $\hat{\Phi} = \hat{\Phi}_U$ and $c_I = c_U$, so we derive an important conclusion:

$$\hat{\Phi}{c_I}^2 = \hat{\Phi}_U{c_U}^2 \tag{4}$$

6 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[16] (Figure 1). Energy-potential is $\hat{\Phi}_U = {c_U}^2$ (and potential of matter itself is $\Phi_U = \hat{\Phi}_U/2 = {c_U}^2/2$).

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.

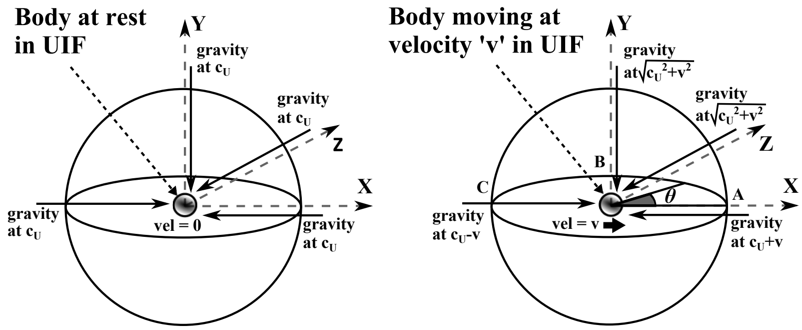

Figure 1: Universe background gravitational potential change with velocity.

Gravitational acceleration and potential depend on the square of incident gravitational energy velocity. By symmetry, we compute the 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:

$$\hat{\Phi}_U \frac{c_U{}^2 + v^2 + 2c_U v \cos\theta}{c_U{}^2} \times \frac{d\theta}{\pi} \tag{5}$$

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

$$\hat{\Phi}_{U,v} = \int_0^\pi \hat{\Phi}_U \frac{c_U{}^2 + v^2 + 2c_U v \cos\theta}{c_U{}^2} \times \frac{d\theta}{\pi} = \frac{\hat{\Phi}_U}{c_U{}^2}\left(c_U{}^2 + v^2\right) = \hat{\Phi}_U \left(1 + \frac{v^2}{c_U{}^2}\right) \tag{6}$$

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

$$\hat{\Phi}_{U,v} = c_U{}^2 \left(1 + \frac{v^2}{c_U{}^2}\right) = c_U{}^2 + v^2 = \hat{\Phi}_U + v^2 \tag{7}$$

Change in energy-potential of a body, because of a small 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*. Also, light which travels at 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. This may alleviate fuel needs for interstellar missions, and explain excessive energies of some cosmic muons[17, 18].

7 Velocity time dilation

We get the velocity time dilation factor (γ) from (4) 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 *velocity time dilation*.

Equation (9) also shows that even if matter exceeds the speed of light, time dilation does not become infinite in unconstrained motion.

8 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 $2GM/R \ll {c_U}^2$:

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

9 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[19, 20] low velocity/gravity approximation, but velocity v in (16) and (17) may be in any direction, and not necessarily transverse to a spherical mass.

10 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 is:

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

Gravitational potential increase does not affect speed of *matter*, though energy within matter slows down. For *light*, a *slowdown* of propagation speed occurs *in the direction of source velocity*. This is Shapiro delay[21, 22], and compensates for source velocity (Figure 2).

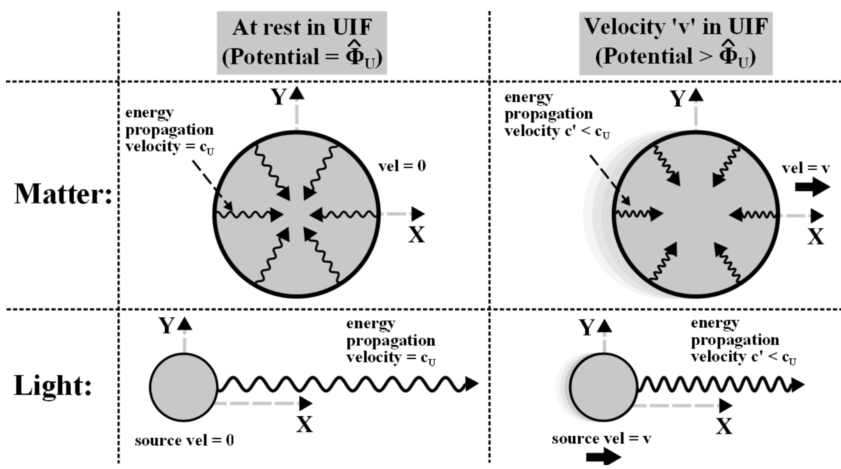

Figure 2: Effect of velocity on light and matter.

Light cannot travel faster or slower than c. Matter can be at rest, or move at any velocity, including faster than light under certain circumstances, as in Cherenkov effect[23].

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[24, 25] and similar experiments[26] is that the *principles involved are the same.* Density of a medium is equivalent to higher gravitational potential.

Particle accelerators (with force-carrier particles traveling at c from stationary source) or Alvager experiment[27] (source protons collide with larger nuclei before emitting gamma rays) cannot achieve $v \geq c$. A possibility is described later.

Consider a situation where a large negative source velocity causes c_{Total} to be zero in UIF (this does not constitute a rest frame for photons). This defines 'base potential' ($\hat{\Phi}_{base}$) of light.

If the negative velocity of source is reduced by a small amount V, speed and potential of light will increase. Using considerations of (6), 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:

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

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 explains *source velocity independence* of light (i.e. $k \cong 0$ in $c' = c + kv$) in experiments like Michelson-Morley[28, 29, 30, 31] and Kennedy-Thorndike[32, 33].

Orbital velocities of binary stars are typically $10 - 100km/s$, giving $k \cong v^2/3{c_U}^2 \sim 10^{-7} - 10^{-10}$. This is consistent with de Sitter[34, 35] ($k < 0.002$) and Kenneth Brecher[36] ($k < 2 \times 10^{-9}$) experiments.

11 Acceleration and potential in orbital motion

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 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 (7)):

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

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:

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

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[37].

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

12 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).

We may take $\hat{\Phi}_{Total} \cong \hat{\Phi}_{M,v}$ 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*.

Lorentz factor is a multiplier of *local energy-potential* $\hat{\Phi}_M$. At low orbital velocities it contributes little, and velocity 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).

13 Suggested Experiment

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 CERN OPERA collaboration experiment[38], 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. Though current supernova theory has a different explanation for this, the observation is expected, as light experiences some Shapiro delay.

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