A simple Theory of Gravity based on Mach's Principle

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Abstract

A simple and intuitive alternative theory of gravity 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

A mathematical formulation and deeper understanding of the meaning of Mach's Principle provides important insights into some of the fundamental phenomena in physics.

This gives rise to a simple alternative theory of gravity which is consistent with existing experiments and observations including relativistic effects. While the predictions of this theory are identical to General Relativity (GR)[1] except in extreme cases, there are some differences with significant implications.

Among other things, the theory explains:

- An unambiguous physical meaning of mass-energy equivalence, as represented by $E = mc^2$
- Why *gravitational mass* is the same as *inertial mass*
- Why speed of light is a local constant and independent of source velocity
- That matter and energy follow different rules of motion as speed of matter is neither independent of source velocity, nor affected by change of gravitational potential (i.e. no Shapiro delay effect[2, 3])

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- *Kinematic (special relativistic) time dilation*[4] is a form of *gravitational time dilation*[5, 6], caused by net blue-shift of gravity from distant Universal matter (Universe background gravity)

We obtain two important conclusions that indicate practical interstellar exploration is possible:

- Speed of light $c(299,792,458m/s)$ is not the maximum speed limit for 'matter'
- Moving bodies obtain a free-fall acceleration in the direction of motion because of the blue-shift of Universe background gravity, and this can be significant at high velocities

The below interpretations of Mach's principle form the basis of this paper:

- "Mass out there influences inertia here": Total gravitational potential of Universe's homogeneous and isotropic matter distribution is the unit rest energy ($c^2 = E/m$) at any location. Inertia (resistance to movement) is a manifestation of the gravitational attraction of distant matter from all directions, as a force needs to do work against some of this gravitational attraction to provide velocity to a body. Mass is a measure of the amount of inertia, and therefore directly related and equivalent to the gravitational potential energy
- "A physical law relates motion of distant stars to the local inertial frame": Universal matter distribution provides a local sidereal inertial frame at every location, which gives meaning to rotation (orientation) and velocity. We will call this the Universe Inertial Frame (UIF)

This theory may be seen as a mathematical extension of Mach's Principle. It is simple and intuitive, as it allows separation of 'time' and 'space' dimensions, and does not require the concepts of 'length contraction' and 'relativity of simultaneity'. Lengths of objects or distances between objects do not change because of 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'.

2 Overview of the theory

2.1 Universe background gravity defines rest energy (c^2) and rest mass

Inertia is not an intrinsic property of matter, but a property derived from gravity. Since increased gravitational potential increases mass, the ubiquitous large gravitational potential from the Universe's matter distribution must account for at least some of the 'rest mass' (amount of inertia at rest) of matter. Rest mass has to be either an inherent property, or a completely gravitational property, as it cannot be partially both. Since gravity clearly increases mass, it must be a gravitational phenomenon, and in a gravity-less Universe mass of anything would be zero.

As the Universe background potential exists everywhere, matter always has a minimum mass (rest mass) which would have the appearance of being an intrinsic property.

Universal matter distribution provides the 'rest energy' (gravitational potential) of a body at rest in the local inertial frame (UIF). Energy radiation (e.g. electromagnetic radiation) has twice the gravitational potential of stationary matter because of its velocity (c), and that potential is c^2 (as in $E = mc^2$), while matter at rest has a potential of $c^2/2$. Therefore, $c^2/2$ is the minimum energy per unit rest mass that is possible for any matter anywhere in the Universe, while for any energy radiation it is c^2.

2.2 Gravity, matter and energy radiation

We will refer to all energy radiation other than gravitational (i.e. radiation that mediates electromagnetic, strong nuclear and weak nuclear forces from a classical perspective) as 'non-gravitational energy radiation' or just 'non-gravitational energy' in this paper.

Gravity is a type of energy radiation that reaches a body from all other matter in the Universe within the body's Hubble Sphere[7], and is radiated out in all directions at the same rate.

Matter (fermions) is made up entirely of non-gravitational energy, as proven in particle-antiparticle annihilation experiments. Gravity itself is not part of matter, and gravitational energy is not additive to non-gravitational energy as part of the total energy of a body. Interaction with gravity manifests itself as mass (inertia) of all non-gravitational energy radiation, and therefore of matter. The gravitational potential thus derived by non-gravitational energy and matter is the 'energy' in mass-energy equivalence. Non-gravitational energy and matter are otherwise massless by themselves.

Since gravitational potential itself defines mass, *gravitational mass* and *inertial mass* are identical. They are two sides of the same coin.

The unit rest energy of a body may therefore be seen as either the total gravitational potential *or* the total amount of non-gravitational energy per unit rest mass.

2.3 Gravitational potential, speed of light and time dilation

Gravitational energy encompasses potential and kinetic energy.

Gravitational potential from a nearby massive object increases the total energy/mass of a body beyond its rest energy/mass. Velocity of a body gives it kinetic energy, which is essentially increased gravitational potential because of a net blue-shift of the Universal background gravity, and also increases total energy/mass. These result in increased or relativistic energy/mass, still consistently a gravitational phenomenon and not intrinsic.

A velocity v raises the potential of matter to $(c^2/2 + v^2/2)$ in rectilinear (unaccelerated) motion in the Universe background. The $v^2/2$ is kinetic energy (per unit rest mass), which is a measure of the increased potential energy, and creates increased (relativistic) mass.

If a certain amount of matter is completely converted to energy radiation, all such component energy radiation released would have a velocity of $v = c$. This makes gravitational potential of non-gravitational energy radiation $(c^2/2 + c^2/2) = c^2$.

Speed of light/energy radiation has an inverse relationship to local gravitational potential, as seen from the Shapiro delay effect. 'Proper time' is a manifestation of the local speed of free energy radiation, which drives the speed of local processes, from sub atomic to observable 'events'. Therefore a difference in gravitational potential causes time dilation between two locations. When the gravitational potential difference is caused by a velocity, we get *kinematic (special relativistic)* time dilation. When proximity to massive bodies is the reason, we have *gravitational* time dilation. The term *time dilation* in this paper stands for differential aging of clocks, or experimentally measurable clock drift.

2.4 Constancy of speed of light, and difference of speed of matter

The local constancy of speed of light 'c', along with its independence of source velocity, is a central concept of modern physics, and has been experimentally verified to high accuracy. This concept is provable and understandable intuitively, and need not be a postulate:

- Any local measurement of speed of light is done using a device (clock) whose tick-rate itself is determined by the local speed of light/energy radiation, making 'c' a constant in local measurements. This is easy to see using a 'light clock'. The speed of light is being used to define a local second, and that local second is being used to measure the speed of light. Any reduction in speed of light will increase the size of the local 'second' by definition, exactly in proportion to the change in speed of light. This makes it impossible to detect a change in speed of light locally

- A source velocity causes an increase in gravitational potential because of net blue-shift of background gravity, which results in a Shapiro delay. For small source velocities, this slowdown of speed of light compensates for the source velocity almost exactly, as will be shown mathematically later

Speed of matter, on the other hand, is the speed of its center of gravity (CG). It is neither source dependent, nor does it undergo Shapiro delay. This is why the laws of motion for matter and light are different, and matter may exceed speed of light.

2.5 Kinematic and gravitational time dilation, and the Lorentz Factor

The product of 'gravitational potential' and 'square of the local speed of light' turns out to be a constant. The local speed of light referred here is based on a coordinate clock. This allows us to compute time dilation between bodies at different locations or velocities.

When gravitational potential of a body changes from $c^2/2$ to $(c^2/2 + v^2/2)$ because of a velocity v, the speed of light changes by a factor of $1/\sqrt{1 + v^2/c^2}$, or approximately $(1 - v^2/2c^2)$ at low velocities ($v \ll c$). The time dilation factor then becomes $1/(1 - v^2/2c^2)$ or approximately $(1+v^2/2c^2)$ as observed in kinematic time dilation experiments.

In unaccelerated rectilinear motion in the Universe, the gravitational potential expression $(c^2/2 + v^2/2)$ holds at all values of v, even when $v > c$. Time dilation is never infinite, and c is not the maximum speed limit for matter.

When a local central acceleration constrains a body to move in a circular orbit around a central point/body, the local acceleration's gravitational potential adds to the unit energy/mass of the body, as does the body's velocity. To keep the orbit stable, the local acceleration must then increase to account for the increased transverse momentum of the relativistic mass, and not just the rest mass. This makes the required acceleration (and therefore the gravitational potential) exponential with increasing orbital velocity v. The speed of light reduces by a factor of $\sqrt{1 - v^2/c^2}$ and time dilation is given by the Lorentz factor $(1/\sqrt{1 - v^2/c^2})$, as will be shown mathematically later. At very high orbital velocities, the gravitational potential (and mass) becomes very large, and tends to infinity when the velocity approaches speed of light ($v \approx c$). The Lorentz factor is only applicable to orbital (accelerated) motion.

Gravitational potential of a nearby large body of mass M increases local gravitational potential at a distance R from $c^2/2$ to $(c^2/2 + GM/R)$. Speed of light changes by a factor of $1/\sqrt{1 + 2GM/Rc^2}$, or approximately $(1 - GM/Rc^2)$ at low gravitational potential $GM/R \ll c^2$. The time dilation factor then is $1/(1 - GM/Rc^2)$ or approximately $(1 + GM/Rc^2)$ as proven in gravitational time dilation experiments.

3 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'

4 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 (slowdown because of increased gravitational potential). Matter may exceed the speed of light, except in certain constrained motion
- 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[8] (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[9, 10] and ICARUS[11, 12] 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.

5 The Universe Interital Frame (UIF)

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[13].

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[14, 15], GPS Satellites[16]) need to be measured from sidereal CG frames in practice. We also see evidence of this in the Sagnac effect[17, 18], 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[19, 20] type experiments.

6 Gravitational and non-gravitational energy

In the context of gravitational potential comprising unit energy/mass of matter, we need to classify energy into two types, 'gravitational' and 'non-gravitational', and define the term 'energy' as used in this paper.

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

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 explained later.

This paper describes a classical theory in which we treat all fundamental interactions as being mediated by energy radiation. Speed of movement of such radiation at a location is always *locally* the constant c ($299,792,458 m/s$), 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 such energy radiation.

'Gravitational energy' encompasses gravitational potential energy and kinetic energy. Kinetic energy is the increase of potential energy caused by net blue-shift of the Universe background gravity, as will become clear later when we develop the mathematical model.

'Non-gravitational energy' represents the other three types, i.e. energy radiations that mediate electromagnetic, strong nuclear and weak nuclear forces.

When not referring to gravitational potential and kinetic energies, the term 'energy' represents non-gravitational energy in this paper.

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

7 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 mediating non-gravitational 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. When these particles are part of matter, their mass forms the mass of matter. '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. *Gravitational mass* and *inertial mass* are one and the same thing, as the former defines the latter.

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 of a body.

8 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. 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, or where gravitational potential (i.e. mass) is lost in the form of gravitational waves. 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 quantized 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, and mass is the measure of the amount of inertia a body has. 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 with respect to 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.

9 Time dilation and coordinate speed of light/energy

All motion is ultimately dependent on movement of energy at the fundamental level. Speed of free energy radiation 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' ($299,792,458m/s$) 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 $d\tau/dt = c_I/c_U$.

10 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.

11 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 $E = \mu m_0 {c_U}^2 = m{c_U}^2$.

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 $E = m_0 {c_U}^2$. 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:

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

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.

12 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 $\Phi_U = \hat{\Phi}_U/2 = {c_U}^2/2$).

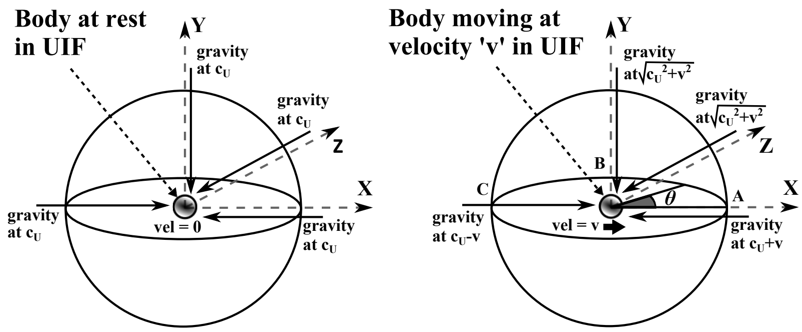

Figure 1: Universe background gravitational potential change with velocity.

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].

13 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 $(\textit{energy potential}) \times (\textit{local energy speed})^2$ 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:

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

14 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.

15 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 $2GM/R \ll {c_U}^2$:

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

16 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.

17 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).

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.

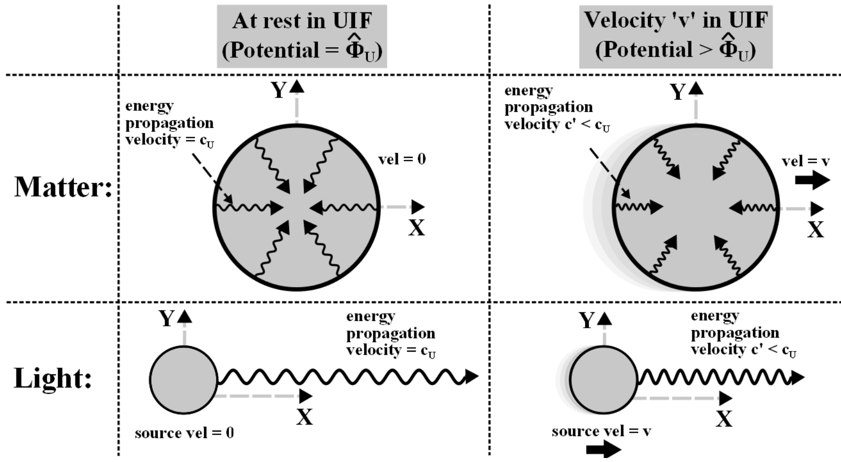

Figure 2: Effect of velocity on light and matter.

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:

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

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 $10 - 100km/s$, 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.

18 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 $V + v/\gamma$.

19 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 ($\hat{\Phi}_U$ or ${c_U}^2$). 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.

20 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.

21 Compatibility with existing theories

21.1 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 Figure 3. We will examine how the gravity of M affects m, but the argument will hold in the reverse direction as well.

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

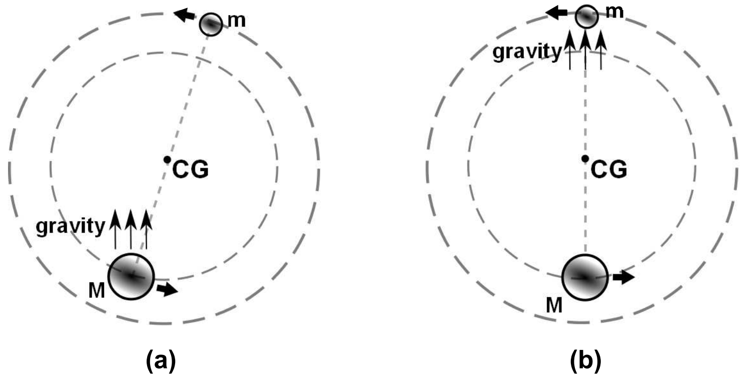

Figure 3: Gravitational field with finite speed of gravity.

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 (Figure 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.

21.2 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 adversely affected in any way.

22 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, with relativistic masses (not rest masses) of colliding bodies being 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 should be released at least partially 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.

23 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.

The case of colliding or exploding objects is analogous to excess energy release in the form of light/electromagnetic radiation in case of an explosion.

The case of continuous release of energy is analogous to light from binary stars.

If 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, as in the case of binary pulsars.

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 like pulsars.

24 Explanations of some important experiments

24.1 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.

24.2 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.

25 Suggested experiments

25.1 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.

25.2 Intermediate velocity repetition of Bailey experiment

If the Bailey et. al. experiment is repeated at intermediate muon velocities ($v \sim 0.5 - 0.8c$), the Lorentz factor would not be adequate 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.

25.3 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.

26 Conclusion

In reconciling Mach's Principle with General Relativity on the basis of the Universe background gravitational potential being identical to the rest energy of matter (c^2), we get a new understanding of mass as a gravitational phenomenon. This provides us a number of important insights.

The Universe background gravitational potential determines unit rest energy/mass. It 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.

General Relativity is a vast subject, and this paper is not intended to go into all aspects of current relativity theory. We have dealt with the basics of relativity to create a consistent theory of gravity based on Mach's Principle. This theory provides us deeper physical insight into relativity phenomena, and predicts certain results that differ from existing relativity theory under extreme conditions. Much further work needs to be done based on the principles formulated to address the numerous other aspects of relativity.

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