Relativity and the Universe Gravitational Potential

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Abstract

This paper reconciles Mach's Principle and General Relativity (GR) into a consistent, simple and intuitive alternative theory of gravitation. The Universe has a large and ubiquitous background gravitational potential from matter distribution. This gravitational potential far from all massive bodies is established to be c^2, which determines unit rest mass/energy. The Universal matter distribution creates a preferred inertial rest frame at every location, in which vector sum of velocity of distant masses in all directions is zero. A velocity in this frame increases the Universe gravitational potential because of net blue shift of Universal gravity. This increase is the same as computed from the low velocity approximation of Lorentz factor. Velocity time dilation is a gravitational effect identical to gravitational time dilation on this basis. The Lorentz Factor is applicable only in situations where local potential is dominant compared to Universe potential. Gravitational time dilation is derived first, and velocity time dilation formulation follows in a natural way. While time dilation increases with velocity, it does not become boundless for general rectilinear motion in the Universe. Speed of light is not the maximum possible speed in such situations, but only in specific circumstances where the Lorentz Factor is the appropriate metric. The mathematics becomes much simpler and more intuitive than GR, but remains consistent with existing experiments. New experiments are suggested that will show this theory to be more accurate than GR. Many advantages for interstellar travel are seen based on relativity concepts.

Keywords: Alternative theory of gravitation; General Relativity; Mach's Principle; Special Relativity; time dilation; intuitive relativity; Universe gravitational potential; interstellar exploration

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1 Introduction

This paper proposes a modification to The General Theory of Relativity (GR)[1] to create an intuitive and simpler alternative theory of gravitation. The important role played by the ubiquitous background gravitational potential of the Universe is not adequately incorporated into GR. Taking that into account helps remove all counterintuitive notions from relativity, and the physics behind relativity phenomena becomes easily understandable.

The Universes potential defines the rest mass/energy of objects, as well as an inertial rest frame at every location in space. A velocity causes a net blue shift of this gravitational energy, increasing the gravitational potential and resulting in mass increase of objects (relativistic mass). The corresponding slowdown of local energy of objects is observed as velocity time dilation. Gravitational time dilation is also caused by increased gravitational potential, though because of proximity to a large body instead of a blue shift of the Universe gravitational potential.

This understanding that velocity and gravitational time dilation are both identical gravitational effects, and are manifestations of difference in local energy speeds, allows us to separate space and time dimensions. This makes understanding of relativity extremely simple, intuitively and logical.

Difference in derivation from current Theory of Relativity: GR is derived based on Special Theory of Relativity (SR)[2] in accelerated frames of reference, with a *gravitational potential difference being equivalent to a velocity difference* between bodies. Therefore, a higher gravitational potential causes time dilation and increase of mass/energy just as a velocity does. In this paper, *we derive the theory the other way round*, which is more intuitive and natural. A higher gravitational potential causes time dilation and mass/energy increase. A *velocity in the Universe background potential is equivalent to a higher gravitational potential*, and therefore also causes time dilation and mass/energy increase.

The mathematical formulation in this paper is consistent with results of all experimental tests of relativity to date, and in some cases explains the results better and in a more intuitive manner than GR does. This is discussed in appropriate sections on the key experiments in relativity.

Some new experiments are also suggested later in this paper where the results will differ from existing Relativity Theory.

Let us consider why we need to look at a modification to the current Theory of Relativity at all, since it appears to have been working so well for nearly a century.

1.1 Motivation behind this paper

Some of the main reasons for looking at a simpler and more intuitive theory of relativity are:

- The counter-intuitiveness of the existing Theory of Relativity limits the ability to make progress in this very fundamental area of physics. It is more difficult to improve what we cannot understand or visualize intuitively, or to explore possible realistic applications. A theory like relativity may have many practical productive uses, as long as it can be understood intuitively by a broad population. In this paper we will see that a very intuitive understanding of relativity can be developed though separation of space and time dimensions, and the mathematics becomes much simpler (no tensors necessary). Concepts like relativity of simultaneity and length contraction would not be required to understand relativity.

- A scientific impossibility of traveling faster than speed of light discourages research on making interstellar travel practical. An intuitive understanding of the physics of relativity helps us establish whether the phenomenon is really universal, or only true under certain circumstances. As it turns out, this restriction is limited to orbital motion (from which considerations existing GR Theory is largely developed), and to remote accelerations from a stationary source only. Relativity also provides many unexplored advantages for interstellar travel, as will be explained.

- While the existing Theory of Relativity has worked well for most situations, there are questions that demand further investigation. Some of these are listed below.

1.2 Questions and Areas of Investigation

Some of the main questions that need to be asked are:

- Mass of a body increases because of velocity (relativistic mass), and by extension, also because of gravitational potential (which is seen as equivalent to a velocity). Does the large background gravitational potential of the Universe then constitute some or all of the rest mass of a body?

- What is mass, and why does it not have one consistent definition in General Theory of Relativity?

- Light speed invariance postulate (local in GR, universal in SR) appears to associate an almost magical property to light. What is the physics behind this? [Existing Theory of Relativity is not supposed to explain this, as it is a postulate. However, investigating possible physical reasons behind this phenomenon provides valuable new insights]

- GPS satellite clock synchronization[3] and Bailey et. al. experiment[4] (muon lifetime extension) may both be considered as orbital free fall motion under transverse (central) acceleration. Why is the time dilation factor for GPS satellites given by the Schwarzschild metric[5, 6], while that of the Bailey experiment given by the Lorentz factor of SR? Why does the SR time dilation formula appear to be the correct one in the Bailey experiment which uses a strongly accelerated frame?
- Travel at or above the speed of light is impossible as per current theory. Is this something that can be generalized to all motion, or is it an artifact of orbital motion under transverse acceleration, based on which GR theory has been largely derived? This needs to be examined.
- Mathematical formulation of current theory leads to the concept of a singularity within black holes, where all known laws of physics break down. Is it the result of applying the current mathematical formulation beyond the domain of applicability of the theory?

We will find satisfactory answers to these questions in this paper.

With the advantage of hindsight of a century of experiments and observations, we reassess some of the assumptions and conclusions of the Special and General Theories of Relativity. This allows us to refine the theory further, and get a very intuitive understanding of how relativity applies to our Universe.

1.3 Overview of this paper

We will define the role of the Universes gravitational potential and how it relates to some important concepts in relativity. Based on this we will derive gravitational time dilation formulation first. Velocity time dilation formulation will then be derived from the above, as modification of gravitational potential, and shown to be a gravitational effect consistent with all relativity experiments.

1.3.1 Role of the Universes Gravitational Potential

The Universe's mass distribution creates a large and ubiquitous gravitational potential. For example on Earth's surface, the Sun's gravitational potential on the surface of Earth (900 MJ/kg) is 15 times that of the Earth's own (60 MJ/kg), that of the Milky Way galaxy ($\geq 130GJ/kg$) is over 2000 times, and even the distant Andromeda galaxy's potential is 7 times, not to mention the trillions of other celestial bodies.

The Universe's background gravitational potential plays an important role in relativity concepts like rest mass, time dilation (differential aging) and local constancy of the speed of light.

This gravitation from the distribution of the matter in space creates a 'local' inertial rest frame at every location in space, and gives meaning to velocity and orientation. This inertial frame is sidereal (i.e. does not rotate in relation to distant fixed stars, or mass distribution of the Universe). The sidereal frame provides the reference orientation to rotation and revolution of objects like stars and galaxies in space.

All velocities, from orbital velocity of satellites to velocities of aircraft in the Hafele-Keating[7, 8], experiment to compute differential clock rates, are in practice computed from such sidereal axes, to satisfy the equations of Newtonian and relativity theories.

We will call this local inertial frame at any location as the Universe Inertial Reference Frame (UIF). The 'rest state' in the UIF corresponds to Einstein's description of being in a situation where velocities of all other distant Universal objects may be considered eliminated[9], and there is no rotation in regard to the distant objects. The gravitational potential at the location determines the local speed of light/energy c. This c, in turn defines the 'local' speed or rate of passage of time.

The UIF is not just a reference frame like an aether. Interaction of matter and energy with the gravitational potential that creates the UIF is an integral part of the concept of relativity.

We will see that the Universe gravitational potential (potential energy per unit mass) at a point far from all massive bodies is exactly c^2, and defines the *unit mass of matter*. This is reflected in the mass energy equivalence equation $E = mc^2$, where m is the amount of matter.

1.3.2 Matter, Energy and Time Dilation

Matter needs to be understood as a spatially stable configuration of constantly moving energy. In the least, all processes that happen within matter (like electrons orbiting the nucleus of an atom) need to be seen as manifestations of movement of energy within matter. Speed of such processes is thus proportional to the local speed of energy.

Time dilation/differential aging between two locations arises because of the difference in local energy speeds, caused by difference in gravitational potentials. This applies to both 'gravitational' and 'velocity' time dilations as will be explained shortly.

We will see that local rate of passage of time and local speed of energy are fundamentally the same thing, and this results in speed of energy being a local constant. Time dilation is a manifestation of difference in energy speed, and therefore time speed, between locations.

[Note: In this paper, we use the term "time dilation" interchangeably with "differential aging", not including the 'apparent' coordinate/observer dependent reciprocal time dilation based on Doppler effects. Reciprocal time dilation based on Doppler effects is equally valid even in Newtonian mechanics, but does not ultimately result in any actual differential clocks rates. The "time dilation"/"differential aging" term in this paper stands for the 'invariant' difference of clock rates at different locations/velocities.]

1.3.3 Speed of light

As is well known from the current GR Theory, speed of light (and all energy) is a local constant. However, to explain time dilation, we need to compare local speeds of light across locations. Therefore we will need suitable terminology and notations for this.

We will denote the **speed of light in vacuum**, far from all massive objects, **as** c_U. This is the base speed of light in the UIF, as determined by the Universe's background gravitational potential. The **reduced speed of light/energy** caused by any increase in gravitational potential (in space or within matter) will be denoted **as** c_I ('local' or 'internal' speed of light).

'Light speed invariance postulate' is a manifestation of slowdown of light propagation velocity from a moving source, which exactly compensates for source velocity. The slowdown occurs because of blue shift of Universe gravitational potential in the direction of light propagation. This will be described in detail mathematically when the de Sitter double star experiment[10, 11] is discussed.

1.3.4 Gravitational Time Dilation

Proximity to large masses augments the ubiquitous Universe gravitational potential. Speed of light/energy at a location slows down with this increase of gravitational potential. This is the reason behind gravitational time dilation[12, 13] between locations, known to be caused by gravitational potential difference, as demonstrated by the Shapiro Delay[14, 15] effect (radar signals passing near a massive object travel slower than they would in its absence), and also otherwise verified in experiments.

Gravitational time dilation is typically small even near very large masses, as the potential difference is small compared to the base potential of the Universe. Gravitational time dilation is intuitively understandable, as the differential of gravitational potential between clocks at different altitudes provides the necessary asymmetry (intuitive physical justification) for observable "differential aging"/"time dilation" between clocks.

At a point near a massive body of mass M, the total potential including the Universe background and the massive body becomes $c^2 + 2GM/R$ or $c^2\,(1 + 2GM/Rc^2)$. This increased potential causes a corresponding reduction of local energy speed at the point, causing gravitational time dilation by a factor of $\sqrt{1 + \frac{2GM}{Rc^2}}$. (The factor 2 appears because it is the potential of energy, which is double the potential of matter. Energy experiences twice the acceleration of matter because of its velocity of c, as seen in light deviation by the Sun, and thus has twice the potential. This will be discussed in detail later.)

1.3.5 Velocity Time Dilation

Velocity time dilation is caused by increased gravitational potential because of a body's velocity in the UIF, which results in a net blue shift of the Universe gravitational energy.

Even small velocities cause time dilations comparable to gravitational time dilation, since the Universe's gravitational potential is large compared to that of any single massive body. Velocity time dilation appears unrelated to gravitational time dilation because of this, and has led to certain counterintuitive concepts. These concepts have hindered an intuitive understanding of time and time dilation. We will link velocity time dilation and gravitational time dilation in this paper.

Far from massive bodies, a velocity v in UIF increases the Universe's base gravitational potential to $c^2 + v^2$ or $c^2\,(1 + v^2/c^2)$. This causes the local energy speed of the traveling body to be correspondingly reduced by a factor of $\sqrt{1 + \frac{v^2}{c^2}}$, causing velocity time dilation. This fact will lead us to existing relativity theory formulas simply and intuitively.

This understanding of velocity time dilation also provides the necessary condition of physical asymmetry between clocks where actual differential clock rates are seen in experiments. Experiments and observations have clearly shown that actual clock rate differences arise from velocity only when two objects in question have differential velocities as measured from a single sidereal inertial frame (e.g. Hafele-Keating experiment and GPS clock synchronization computations depend on measurements from a sidereal inertial frame through the center of Earth). The relative velocities between the objects are immaterial.

Moreover, this single inertial frame in question coincides with the gravitational sidereal reference frame in all practical cases, showing that it is not a locally determined phenomenon, and in itself hints at a gravitational origin of velocity time dilation.

Concepts like 'relativity of simultaneity' and 'length contraction', which today make relativity counterintuitive and overly complex, are not needed to explain time dilation. Time dilation becomes an intuitively understandable and simple phenomenon.

1.3.6 Important insights

Some of the important insights that will be covered in this paper based on the above understanding are stated below.

1.3.6.1 Lorentz Factor and the maximum speed of objects. One of the key insights we obtain is that the nonlinear nature of the Lorentz factor $(1/\sqrt{1-v^2/c^2})$ is derived from orbital motion under transverse acceleration. The local transverse acceleration in an orbital trajectory has to account for not only the transverse momentum of the rest mass/energy of the orbiting body, but the mass/energy increase created by the potential of the local acceleration itself, which increases exponentially with orbital velocity. The derivation of this formula later will clarify this understanding, when it is discussed in the context of the Bailey muon lifetime extension experiment.

The speed of light is a maximum speed limit only in those situations where the Lorentz factor applies. For general rectilinear motion in the Universe's background potential, the low velocity approximation of the Lorentz factor is found to be the correct metric at all velocities, and local speed of light may be exceeded by matter.

1.3.6.2 Understanding of terms in relativity equations. As mentioned, the Universe gravitational potential for matter at rest is c^2. This constitutes the rest mass/energy of matter. We will see that the term $\frac{2GM}{Rc^2}$ which occurs frequently in relativity equations is the ratio of the potential of a proximal large body and the Universe background potential. Similarly the ratio $\frac{v^2}{c^2}$ is the ratio between increase in background potential because of velocity and of background potential at rest. These will be used to show how gravitational time dilation and velocity time dilation are related and that both arise as effects of gravitational potential difference between locations.

1.3.6.3 Separation of space and time dimensions. Space and time dimensions can be separated, since speed of energy (and therefore speed of time) is a local phenomenon depending on gravitational potential alone. As a consequence relativity becomes extremely intuitive to understand and mathematically simple. There would be no need for tensors.

1.3.6.4 Implications for interstellar travel. One of the most important practical conclusions we will see is that time dilation does not become boundless in general rectilinear motion in the Universe, though it does increase with velocity. While this allows practical interstellar exploration as local speed of light may be exceeded in such motion, it provides additional advantages like free-fall gravitational acceleration boost in the direction of travel.

1.4 Note on Special Relativity and gravitational origin of velocity time dilation

Special Theory of Relativity (SR) was conceived by Einstein on the basis of kinematics. One of the consequences has been that velocity time dilation is an 'all or none' phenomenon between bodies, since mass plays no role. It therefore appears that only one of the two bodies can undergo a clock slowdown, by an amount computed based on their relative velocities.

Experiments over the years have indicated that in real-life situations dynamics plays its part in velocity time dilation, and clock rate difference between two bodies cannot be predicted without taking into account the gravitational background, implicitly or explicitly. Both bodies involved may undergo different amounts of measurable velocity time dilation, as would be the case in the Earth-Moon system or binary stars.

For example, in Earth based experiments, small moving objects have shown clock slowdown effects, with Earth implicitly acting as the 'second body'. Given the many orders of magnitude difference in masses, the small objects have practically had all the velocity, and the 'all or none' computation of velocity time dilation using the Lorentz factor has worked (though the mass ratio has decided which clock is time dilated in experiments).

Even clocks on Earth's surface slow down because of the Earth's rotation velocity, compared to clocks fixed to the sidereal (non-rotating) axis around which Earth rotates, as shown by the Hafele-Keating experiment. This sidereal axis, called the Earth Centered Inertial Frame (ECIF), is the frame from which all velocities are measured in practice for computing velocity time dilation for Earth-based experiments. This is the same velocity as used in momentum conservation and satellite orbital velocity calculations.

The inference we can draw from results of experiments like Hafele-Keating, GPS satellite time dilation and Bailey et. al. muon lifetime experiment is that time dilation computations need to be based on *velocities from the center of gravity* of the local gravitational system, rather than any relative velocities between objects. This in itself is a strong indicator of the gravitational origin of velocity time dilation.

2 Matter, Energy and Time Dilation

As a first step, we need to visualize the relationship between matter and energy, and how the speed of energy relates to time dilation and time.

2.1 Matter as a stable configuration of Energy

Matter is a spatially stable configuration of constantly moving energy. The equivalence of matter and energy is well established by experiment. We may consider matter to be an aggregate of energy, with equal parts of constituent energy travelling in all spatial directions at a given time, preserving the spatially stable structure of the aggregates (like electrons, protons, sub-atomic particles or even atoms). While these spatially stable aggregates which we call matter may remain at rest or, move at any velocity, the energy within continues to move at c.

The vector sum of velocity of energy constituting matter is zero in every direction at the aggregate level, allowing matter to be at rest as opposed to energy which does not have a rest state.

All processes that happen within matter (like electrons orbiting the nucleus of an atom) need to be seen as manifestations of movement of energy within matter. Speed of such processes is thus proportional to the local speed of energy.

Energy never stops moving, whether it is energy comprising matter or free energy. Events are observable outcomes of energy movements at the fundamental level.

Gravitational potential (energy density) at a location inversely affects the speed of all energy at the location even energy which is part of matter. This is what leads to time dilation.

2.2 Time Dilation

2.2.1 Meaning of time dilation

Consider two identical configurations of matter as described below, so we can establish a clear understanding of time dilation and time.

Each configuration consists of a light-clock and a mechanical clock. The only difference we stipulate is that the first configuration (left side in Figure 1) is in a higher gravitational potential. It does not matter whether the difference is caused by large mass proximity or velocity. The impact on local energy velocities depends only on the gravitational potential and not on the specific mechanism that caused it.

The light ray in the left side light-clock moves slower compared to light ray in the right side light-clock, being in a higher gravitational potential.

Now, it is not just the light in the light clock alone that will be so affected, but all energy, including that which comprises the matter of the mechanical clock. Since events

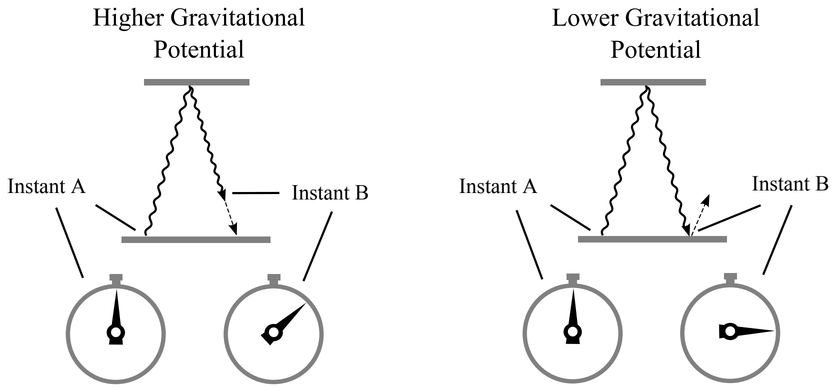

Figure 1: Light clocks and mechanical clocks at different potentials.

or movements happen at the basic level because of movement of such energy, even the mechanical clock on the left must be moving slower in the same proportion as the light clock. The energy within the atoms are moving slower, leading to the electrons moving slower, leading to less number of transitions of the atoms compared to the right side configuration. This goes all the way down to base energy, and all the way up to all observable events, and thus all movement within the left side configuration is slower proportionally compared to the right side configuration.

This gives rise to time dilation between the two locations. An observer at the left location will consider the clock of the right location faster, and in reverse the right location observer will consider the left side clocks slower.

2.2.2 Local constancy of speed of light c

Importantly, observers at the two locations will obtain the same numerical value of $c(299, 792, 458m/s)$ when they measure the speed of light locally. Since a 'second' is defined locally as one tick of either local clock, the relative size of a local 'second' depends on the local speed of light/energy, which also determines the rate at which events happen. This makes c a 'local' constant, in spite of a comparative difference in light/energy speed between the two locations.

Local speed of time (relative spacing between observable events) is determined by the local speed of energy movement. In effect, speed of energy at a location is ultimately used to measure the speed of light at that location, naturally giving a constant numerical value depending on the choice of units alone.

This is the intuitive reason behind why c is a 'local' constant in the current GR theory.

The definition of the term 'local' depends on the accuracy of clock measurement desired. Higher the measurement accuracy needed, smaller the volume of space that may be considered 'local'.

2.2.3 Interpreting time dilation observations

Two real life examples will make this clearer and demonstrate some important concepts.

- **GPS Satellites:** Light/energy travels a little faster in atomic clocks of GPS satellites compared to Earth, a combined effect of both reduced gravitational and increased velocity time dilation. Therefore the 'local' GPS second is a little shorter than that on Earth surface. In effect, the cesium atoms in the atomic clocks on board GPS satellites have slightly faster transitions compared to on Earth (along with all other matter and energy in the GPS satellite, of course). This is the reason GPS clocks are a little faster than Earth clocks, and need a small adjustment to keep in synch with Earth clocks. Note that there is no differential aging between clocks of different GPS satellites, although they travel in six different orbital planes and have significant proper relative velocities between themselves.

- **Cosmic muons**[16]**:** Cosmic muons show some lifetime extension, without which they would not have been able to reach Earth surface in the quantities they do. Their high velocities cause them to face a significantly higher Universe gravitational potential, slowing down their internal energy speed in the process. Thus, the 'clock' of the cosmic muon is much slower, it's 'seconds' being much longer than Earth surface seconds. Therefore, a muon will consider itself traveling at a much higher velocity than someone on Earth would, given the same distance being traveled in less number of seconds.

This visualization removes the necessity of concepts like relativity of simultaneity and length contraction, and paves the way to an intuitive understanding of relativity. Lengths remain a constant for all observers, while the size of the local second may vary.

Time dilation/differential aging is a ratio, not an absolute difference, and therefore cannot be infinite unless energy comes to a complete stop at a location (requiring gravitational potential to be infinite). The problem is that gravitational energy needs to move to create such a potential in the first place, which leads to a contradiction with all energy being stopped. This is another counterintuitive concept, as applied to black hole event horizons, which will be resolved in this paper.

3 Time

Based on the above discussion of time dilation, we can create a clear understanding of time itself.

Time, after all, is just the relative spacing between observable events. Each tick of the light clock or the mechanical clock's 'second' hand, for example, is an observable event.

The rate of passage of time at a location is exactly proportional to the rate at which all energy moves at that location (free energy as well as that comprising matter). Time gets a meaning only in the context of observable events caused by such movement of energy.

For two locations A and B with different gravitational potentials, we have:

$$\frac{T_A}{c_A} = \frac{T_B}{c_B} \quad \textit{and} \quad \frac{T_A}{T_B} = \frac{\Delta T_B}{\Delta T_A} \tag{1}$$

where

$T_A, T_B =$ rate of passage of time at A and B respectively
$c_A, c_B =$ speed of energy at A and B respectively
$\Delta T_A, \Delta T_B =$ the same period of time as observed at A and B respectively

[Note: Local rate of passage of time is inversely proportional to the elapsed local time, so $\frac{T_A}{T_B} = \frac{\Delta T_B}{\Delta T_A}$]

No other physical meaning of time and time dilation is reasonable or possible. The reader should not proceed to read the rest of the paper without first intuitively understanding this explanation fully, which is summarized below at the risk of repetition:

- Differential Aging/Time Dilation between locations is caused by a relative difference of energy speeds (and therefore different comparative spacing of otherwise identical events).

- This time dilation between two locations is caused by difference of gravitational potential, with time/energy speed being inversely proportional to relative gravitational potentials.

- Such gravitational potential difference may arise because of differential proximity to a large mass ('gravitational' time dilation) or differential velocity in the Universe's background gravitational potential ('velocity' time dilation), but the time dilation effects are physically indistinguishable.

- Time speed at a location is directly dependent on energy speed at that location, and hence energy speed (time-dependent displacement) is a local constant.

Whether we consider time to be something real, based on whose flow energy velocity is measured, or whether we consider time itself to be defined and measured based on a certain arbitrary unit distance of energy movement, is a difference of philosophical point of view only.

This explanation of energy speed and time speed equivalence ties in extremely well with the existing notion of gravitational time dilation. The conceptual difficulty in understanding time in this simple manner arises today from the counterintuitive concepts of 'relativity of simultaneity' and 'length contraction' from Special Relativity. Once we establish velocity time dilation also as a gravitational effect, in no way different from gravitational time dilation, these counterintuitive concepts and the corresponding philosophical difficulties disappear.

4 Universe gravitational potential, Mass and Inertia

4.1 Unit mass, Unit energy and Gravitational Potential

We start with the assumption that the Universe's mass distribution may be considered homogeneous and isotropic at a large scale. This is a well accepted assumption in relativity and cosmology.

From SR, we know that velocity increases the 'mass' of matter (compared to its 'rest mass'). This 'relativistic mass' is not a measure of the 'amount of matter' in a body (which does not change), but is a measure of the 'amount of inertia'.

A 'higher gravitational potential' is equivalent to a 'higher velocity', as derived by Einstein in his formulation of GR. Gravitational potential also causes time dilation just as velocity does. Therefore a higher gravitational potential must also increase the 'relativistic mass' of matter.

Now, if gravitational potential affects the 'relativistic mass' of matter, then the Universe's large background gravitational potential must have a contribution even in the 'rest mass' of matter (which in itself is then a 'relativistic mass', even though at rest). Since this is the 'amount of inertia' of such matter, we may argue that the 'rest mass' of matter is nothing but the 'total amount of inertia' matter has because of the Universe's background gravitational potential.

Since gravitational potential does not increase the 'amount of matter' of a body, what it increases is the 'unit mass' or 'unit amount of inertia'. Thus, we can see that 'unit mass' itself is not an inherent property of matter, but a gravitationally defined property depending on the potential (as postulated in Mach's Principle).

For any matter at rest far from all massive bodies, the 'unit mass' is also its 'unit energy', as expressed in mass-energy equivalence in the equation $E = mc^2$:

$$Unit\ Mass = Unit\ Energy = E/m = c^2 \left(or c_U{}^2\right) \tag{2}$$

This is the essence of mass-energy equivalence. **The 'unit mass' of matter is the same thing as the 'gravitational potential energy per unit matter' or simply 'gravitational potential', as obtained from the matter distribution of the Universe**. This is also why it is the same as its 'unit energy', since the potential is all the energy it has.

The 'total mass/energy' of an object is thus the 'unit mass/energy' multiplied by the 'amount of matter' (m) in the object.

$$Total\ Energy\,(Mass) = m c_U{}^2 \tag{3}$$

Since gravity defines the 'total amount of inertia' of matter, 'gravitational mass' of matter is the same thing as its 'inertial mass', as is well established from experiments.

'Amount of matter' and 'mass' must therefore be clearly understood as separate concepts. Everything that *exists*, including light/energy and physical bodies, is made up of something physical. We will call this as 'material content' to differentiate from the term 'matter' which describes an 'aggregate of spatially constrained energy' as described earlier. Amount of 'material content' of either energy or matter does not change because of any changes in gravitational potential, as it is an inherent property.

4.2 Rest Mass as gravitational potential of constituent energy

To clarify the understanding from the above discussion on the relationship between mass and gravitational potential, we look at the same phenomena from a different angle here.

Energy by itself is known to be massless, and therefore matter, which consists of only energy, should have been massless as well. Where does the rest mass of matter come from then?

Energy has some 'material content', however little. Its 'mass' depends on the UIF gravitational potential it obtains at its velocity of c.

Physical matter contains energy in spatially stable configuration where the vector sum of the velocities of its (constantly moving) constituent energy is zero, but the mass of such energy remains intact. The aggregate of the masses of its constituent energy gives matter its 'rest mass' or 'base mass'.

Mass is not an inherent property of either energy or matter, but a derived property that is obtained by interaction with gravity.

The **total energy/mass** of an object is thus **equal to its total gravitational potential** from all other matter in the Universe, or as we will see later, all other matter whose potential reaches the object in question, given the expansion of the Universe. We will call this the 'sphere of influence' for the object.

4.3 Analogy of inertia

A somewhat crude analogy helps understand how gravity causes inertia.

Consider a small body at rest, with numerous invisible stretched strings tied to it and pulling if uniformly from all directions, in an otherwise gravity-less Universe. If a force tries to move the body in any direction, it will have to work against the resistance of some of the strings, giving an impression that the body is resisting movement. We may think of this resistance as inertia or mass.

Of course, in case of gravity the resisting force will not increase, and there will be no tendency for the body to come back to the original position. While the strings create a stable equilibrium, with an acceleration towards the body's rest position, gravity creates an unstable equilibrium with an acceleration in the direction of motion. At low velocities the acceleration is negligible, and it would appear to be almost a neutral equilibrium. Therefore, in gravity, a body will continue to move away from its rest position with the imparted velocity, and over time gain further velocity (though extremely small at low velocities).

5 Gravitational potential of Energy vs. Matter

From our visualization of matter as a spatially stable configuration of moving energy, we need to draw a distinction here between the potential of light/energy and potential of matter. This distinction is important for our understanding of the concepts and deriving mathematical formulas in relativity.

The potential a small test body of matter obtains, when at rest, from a nearby large body of mass M at a distance R is given by the formula GM/R. The speed at which gravity reaches the body is c_U. **Light/energy** which itself travels at c_U will **have a potential of** $2GM/R$ when traveling in a transverse direction at a distance R from the large body. This also applies to energy which is part of matter, even if the matter itself is at rest.

The reason for this is that light's transverse velocity of c_U results in a relative velocity of $\sqrt{2}c_U$ with respect to the gravitational energy from the large body. The gravitational potential (which is dependent on the gravitational acceleration) is proportional to the square of this relative velocity (this will be explained below). This makes the potential of light/energy 2 times that of matter at rest. We see evidence of this doubling of acceleration (which also doubles the potential) in the experiments on bending or deviation of star light by the Sun. As verified experimentally by Eddigton et. al.[17] and others[18, 19, 20, 21] the deviation amount is double the Newtonian value, showing that acceleration is double. While the energy which constitutes matter is part of the 'rest energy/mass' of matter, it does not play a direct role in the movement of matter as a whole, since on aggregate the energy velocities cancel out, leaving only the mass (which is the gravitational potential of the constituent energy). Therefore, for matter as a whole, the potential is GM/R, considering its 'potential for movement' under acceleration.

To elaborate this, consider a bit of matter at rest in UIF. It has no kinetic energy of its own. This is not true of its constituent energy, which keeps moving inside the atoms. However, while within the atom, this may be considered as potential energy, since there is no outside evidence of this energy while the atom remains whole. If the atoms are split up to release the constituent energy, this potential will become observable as kinetic energy based on its impact on other objects. This is the difference we have to keep in mind for our considerations.

If the overall matter were to be given a velocity, it will attain some kinetic energy as a whole, which then adds on to its total energy content.

When we look at time dilation, it is an effect of the slowdown of the internal energy of matter caused by increased gravitational potential, and that is why we need to use $2GM/R$ as the relevant potential.

We will also see that the formula for this potential of energy from the Universe gravitation is identical to transverse velocity near a large mass, providing the same $2GM/R$ formulation for light/energy potential in UIF as well, and not just for gravity coming from one direction.

All of this will be amply substantiated in the sections below when we derive the velocity time dilation formula.

In this paper, we will use different terms and notations for the potential of energy and matter, where that distinction is necessary. We will refer to the potential of light/energy as 'energy-potential' and use the notation $\hat{\Phi}$, to distinguish from Φ, which is the potential of matter, which we will call 'matter-potential'.

6 Quantifying Universe Gravitational Potential

We need to visualize how potential from the rest of the Universe affects a small body to understand how such potential will change because of proximity to large masses or velocity in UIF.

We do not know how large the Universe is. Nor does all the mass of the Universe necessarily contribute to gravitational potential at any particular location in an expanding Universe.

For a small body at any location in the Universe, the total potential is a sum of the potentials created by all the matter within a 'sphere of influence', which includes all matter whose gravitation reaches the body. This may or may not coincide with the Hubble[22] sphere, but the exact limit of this sphere is not important for our considerations. It is sufficient that there is a finite amount of matter within that sphere, uniformly expanding away, which creates a certain total potential at the location under consideration.

Gravitational potential contribution of farther away spherical layers of matter is greater than closer to, up to a point. While gravitation from closer bodies would be least red shifted, the amount of matter grows as a square of the distance R (under assumptions of homogeneity and isotropy of the Universe). Therefore gravitational potential ($\sim 1/R$) would grow with increasing R, but will be tempered by increasingly larger red shifts. At the edge of the 'sphere of influence', the potential will be red shifted out of existence, and gravitational potential of matter beyond that does not affect our small body.

We need to make one important assumption at this point. Whatever the red shift from a particular source of gravity, the gravitational energy that reaches the location of the small body under consideration from all Universal matter does so at c_U, which is the speed of energy in the base gravitational potential of the Universe far from massive bodies. Considering the large distances from bodies that have any appreciable away velocity, extinction[23] will ensure that all energy reaches the UIF rest position of all locations at a speed of c_U.

The total gravitational energy-potential contribution of a single body of mass M, at a distance R, moving away from the center of the 'sphere of influence' at a velocity v may be represented as:

$$\hat{\Phi}_M = 2\Phi_M = \frac{2GM}{R} \times \left(\frac{c_U - v}{c_U}\right)^2 \tag{4}$$

where

$\hat{\Phi}_M =$ gravitational energy-potential of body of mass M
$\Phi_M =$ Newtonian gravitational potential (matter-potential) of mass M, i.e. GM/R
$G =$ Gravitational constant ($6.6738410^{-11} m^3 kg^{-1} s^{-2}$)

For time dilation considerations, the total gravitational potential of a body needs to be considered as the energy-potential, which is two times the Newtonian potential, as discussed in Section 5.

The reduction factor $((c_U - v)/c_U)^2$ takes into account (a) the reduced gravitational energy conveyed by each quantum of gravity (i.e. gravitons) by the factor $(c_U - v)/c_U$, and (b) the reduced rate of gravitons reaching per unit time by an identical factor of $(c_U - v)/c_U$, compared to source being at rest. Thus, the overall gravitational energy from far away objects moving away from a location because of the expansion of the Universe is decreased by a factor of $((c_U - v)/c_U)^2$.

Therefore, considering all bodies within the 'sphere of influence', the total potential of the small body will be:

$$\hat{\Phi}_M = \sum_{i=1}^{i=n} \frac{2GM_i}{R_i} \left(\frac{c_U - v_i}{c_U} \right)^2 \tag{5}$$

where

$\hat{\Phi}_M =$ total gravitational potential at rest in UIF at the location
$n =$ number of bodies in Universe that affect potential at the location
$G =$ Gravitational constant $(6.6738410^{-11} m^3 kg^{-1} s^{-2})$
$M_i =$ mass of the i^{th} body
$v_i =$ radial velocity of the i^{th} body because of expansion of the Universe
$R_i =$ distance of the i^{th} body from the location under consideration

We may actually consider the distant masses to be adjusted by the red shift factor, and the gravity traveling from them to be reaching a location at c_U, with the below equation:

$$\hat{\Phi}_M = \sum_{i=1}^{i=n} \frac{2GM_i'}{R_i} \tag{6}$$

where $M_i' =$ adjusted mass of the i^{th} body $= M_i \left(\frac{c_U - v_i}{c_U} \right)^2$

Since this is the **total energy of a body of unit mass** at this location, this is equal to **energy per unit mass** as per $E/m = c^2$, so we have:

$$\hat{\Phi}_M = \sum_{i=1}^{i=n} \frac{2GM_i'}{R_i} = {c_U}^2 \tag{7}$$

The total **Universe gravitational energy-potential at any point**, far away from all masses, is then **exactly** ${c_U}^2$.

This is also the minimum energy-potential possible for matter at any point in the Universe. The local speed of light/energy c_U in this situation (UIF rest) is the same as the speed of the gravitational energy received, since in this situation all energy travels at the same speed in vacuum (i.e. velocity of external gravity and velocity of local energy are the same). We can state in this situation that $c_I = c_U$. Proximity to a large body or a velocity in any direction can only increase the potential, which will lead to a reduction of the local speed of light/energy, making $c_I < c_U$, as we will see in the next section.

The above is valid for unit amount of matter. For any arbitrary 'amount of matter' m, the total energy of course would be:

$$Energy = m\hat{\Phi}_M = m{c_U}^2 \tag{8}$$

One important point we must understand from this is that gravity is not a form of energy inherent to matter, created and emitted through conversion of some part of the matter itself.

Gravity is energy **that comes from other matter in the Universe, interacts with a body, and is retransmitted out** (and the same holds for all matter in the Universe). There must be equilibrium between the incoming and outgoing gravity for all bodies, as there is no change of mass of objects in a stable state. This could change very slowly over time as the Universe expands and distances become larger, but that does not affect our considerations.

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

The relationship between 'gravitational energy-potential' ($\hat{\Phi}$) and 'local speed of energy' (c_I) needs to be established. Since the local speed of energy defines the local speed of time, this relationship helps us compute time dilation between locations. It is a very important concept, as this also allows us to separate 'space' and 'time' dimensions.

The product (*energy potential*) $\times$ (*local energy speed*)^2 or $\hat{\Phi} \times {c_I}^2$ turns out to be a constant, as we will see from the considerations in this section. This simple relationship helps us compute time dilation between locations, as well as derive the formulations of gravitational and velocity time dilations.

Consider a relatively sparse distribution of matter (as in a lightly packed body) of mass M in spherical symmetry with radius r. We call this body X. The gravitational energy-potential created by X at a point P at a distance R from the center of gravity (CG) of X can be computed using the gravitational energy-potential formula ($2GM/R$).

If we now compressed all this material and created a denser sphere (radius r'') without changing the CG, X's total mass would have to increase, as each bit of matter within X

will get a higher potential (and therefore mass) from all the rest, through increased average mass proximity. Therefore X's gravitational energy-potential at the distant point P will also increase. However, that would be a potential increase without any matter/energy being added to the gravity source X! Considering that no additional gravity is flowing into that volume of space, such an increase of gravitational potential would be equivalent of 'creation' of energy from nothing! This is, of course, impossible.

The situation is depicted in Figure 2.

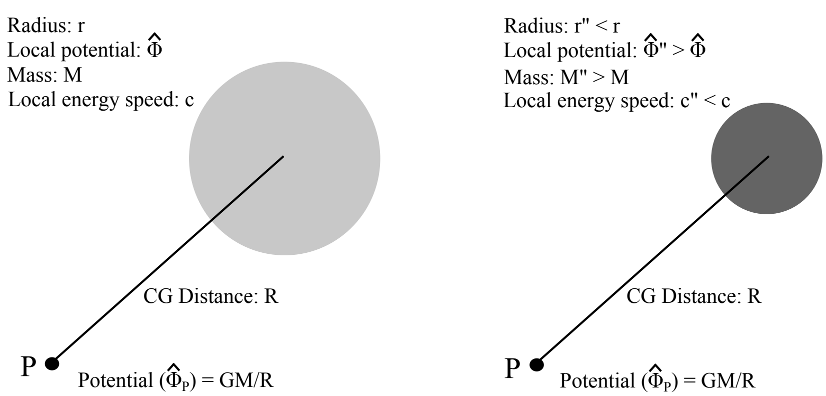

Figure 2: Potential at a distance when a body is compressed.

We come to the conclusion then that the potential at P must remain the same before and after compaction of X. How would that happen?

We know from gravitational time dilation experiments that as the potential increases at a location, the local energy velocity is reduced (i.e. time slows down). Since, nothing else has changed, the above consideration implies that the mass/potential increase of X must be exactly offset by reduction in energy velocity c_I within X, implying an equivalent slowdown of rate of gravity flowing out per unit mass.

However, the local energy velocity c_I does not explicitly appear in the potential formula $2GM/R$. Since R is unchanged and M has increased, the offsetting factor c_I must be part of the Gravitational Constant G.

We noted in the previous section that the potential at a location is affected not only by M and R, but also the square of the velocity of gravitational energy (c^2). Since c varies very little in a locality, this factor remains hidden within the gravitational constant G (and partly explains its curious units $m^3kg^{-1}s^{-2}$, which becomes mkg^{-1} when we take out the c^2 explicitly). We can define a reduced gravitational constant $\not{G}$ as:

$$\not{G} = \frac{G}{c^2} \tag{9}$$

Considering the original mass as M and original energy velocity as c, we can write X's original energy-potential $\hat{\Phi}_P$ at point P as:

$$\hat{\Phi}_P = \frac{2\not{G}M}{R}c^2 \tag{10}$$

When the matter in X is made more compact, the increased mass (M'') and reduced energy velocity (c'') must still give the same energy-potential $\hat{\Phi}_P$ at P:

$$\hat{\Phi}_P = \frac{2\not{G}M''}{R}c''^2 \tag{11}$$

Equating the RHS of (10) and (11), we can derive that:

$$Mc^2 = M''c''^2 \tag{12}$$

Now, mass itself is nothing but the unit energy-potential density of the body, multiplied by the 'material amount'. Therefore we can also write this as:

$$\hat{\Phi}c^2 = \hat{\Phi}''c''^2 \tag{13}$$

where $\hat{\Phi}$ is the original energy-potential *within the gravity source* X (i.e. not at P), and $\hat{\Phi}$ is the increased potential within X after it is compacted.

We need to take careful note of the following to understand the implications of this clearly:

- It is the local energy-potential $\hat{\Phi}$ within the body X that increased because of the compaction. The energy-potential at P ($\hat{\Phi}_P$) from X's gravity stayed the same as it must.
- The local energy velocity c within the body was reduced on compaction (to c''). In effect, greater potential/energy density within the body reduces the speed of energy in such a way that the energy-potential at a distance R outside the body would not change.
- The reduction of c inside X would translate into a slight red shift of gravity for an observer at point P, if one could measure gravity wavelength. This is similar to the slight red shift of sunlight as observed from Earth, because of the slightly slower light velocity on Sun's surface because of its higher potential. The slightly increased mass M'' will compensate for this reduction, such that the gravitational flux that reaches point P would remain the same.

In effect, the increase of potential slows down energy in that volume of space such that the emission rate of gravitational energy per unit time remains the same as the absorption rate (which has not changed).

Noting that c and c'' are the before and after values of internal speed of energy (c_I) within the body X, we can conclude by (13) that the product of (a) internal energy-potential (or unit mass) of a body and (b) square of the internal energy velocity is always a constant, i.e.:

$$\hat{\Phi}{c_I}^2 = constant \tag{14}$$

We can also equate this to the energy-potential and velocity of free energy in UIF (where $c_I = c_U$) as:

$$\hat{\Phi}{c_I}^2 = \hat{\Phi}_U {c_U}^2 \tag{15}$$

This is a very important conclusion for understanding a lot of phenomena in relativity (like time dilation computations) and observations about the Universe's physical laws, as will be discussed in the below sections. Note that since this is an equation for potential per unit matter, it will remain valid even when the total amount of gravity absorbed/emitted per unit time changes, as would be the case when a body obtains higher velocity in UIF.

The other point to note is that c_U is the value of c_I only for light or free energy in UIF. Within matter, the potential is higher because of the high energy density within the matter itself, such that the energy velocity within matter would be somewhat lower than c_U. This is seen in refraction of light in transparent mediums. However, as long as we compare with the UIF energy state and equate $\hat{\Phi}{c_I}^2 = \hat{\Phi}_U {c_U}^2$, our considerations are not adversely affected.

This discussion also demonstrates that our earlier assumption about the homogeneous and isotropic distribution of matter in the Universe (as it affects a bodys potential) is almost literally true. Whether the Universe has matter in large clumps (stars etc.) or is a uniform distribution of energy (as visualized by Einstein in his derivation of GR), the gravitational potential set up at a distant point in space will be the same. This would apply to everything including black holes.

8 Effect of proximity of a large body on gravitational potential

In this section, we consider what the energy-potential ($\hat{\Phi}_M$) of a massive body of mass M should be from the UIF point of view at a distance R from the CG of the body.

8.1 Potential of a nearby large body

As has been indicated earlier, the Newtonian matter-potential being GM/R, the energy-potential for relativistic purposes is twice that. We may state this potential $\hat{\Phi}_M$ as:

$$\hat{\Phi}_M = \frac{2GM}{R} \tag{16}$$

The base gravitational potential of the Universe has been established earlier as $\hat{\Phi}_U = {c_U}^2$. The total potential including that of the proximal mass M (for a small test mass at distance R) would be given by:

$$\hat{\Phi}_{Total} = \hat{\Phi}_U + \hat{\Phi}_M = {c_U}^2 + \frac{2GM}{R} = {c_U}^2 \left(1 + \frac{2GM}{R{c_U}^2}\right) = \hat{\Phi}_U \left(1 + \frac{2GM}{R{c_U}^2}\right) \tag{17}$$

There are several things to be noted from this derivation:

- The mass per unit matter (or relativistic mass of unit matter) is increased by the factor $\left(1 + \frac{2GM}{R{c_U}^2}\right)$
- Since $\hat{\Phi}{c_I}^2$ of a body is constant, the reduced velocity of energy at this location, c_I, can be obtained from:

$$\hat{\Phi}_{Total}{c_I}^2 = \hat{\Phi}_U{c_U}^2 \tag{18}$$

$$\therefore c_U = c_I\sqrt{\frac{\hat{\Phi}_{Total}}{\hat{\Phi}_U}} = c_I\sqrt{1 + \frac{2GM}{R{c_U}^2}} \tag{19}$$

- We can derive the gravitational time dilation factor γ from (19), as used to compute the time dilation near a large mass (e.g. surface of Earth) compared to infinity (i.e. far from all large masses) as:

$$\gamma = \frac{c_U}{c_I} = \sqrt{1 + \frac{2GM}{R{c_U}^2}} \tag{20}$$

- If $\frac{2GM}{R} \ll {c_U}^2$ (which is practically true for all situations expect very near black holes) we may use the approximation:

$$c_U \cong c_I\left(1 + \frac{GM}{R{c_U}^2}\right) = c_I\left(1 + \frac{\Phi_M}{{c_U}^2}\right) \tag{21}$$

  Equation (21) is analogous to the equation derived by Einstein in his 1911 paper "On the Influence of Gravity on the Propagation of Light"):

$$c = c_0\left(1 + \frac{\Phi}{{c_U}^2}\right) \tag{22}$$

[Note: We will use the notation γ for both gravitational and velocity time dilation factor, as it is essentially the same thing.]

8.2 Gravitational Time Dilation

The concept of **Gravitational Time Dilation** can be very intuitively understood based on the above discussion.

For two bodies A and B at distances R_A and R_B from a massive body (M), the relationship between their internal energy speeds c_I (and therefore corresponding time rates/speeds T) can be found (using (1) and (21)) as:

$$c_U = c_{I:A}\left(1 + \frac{GM}{R_A {c_U}^2}\right) = c_{I:B}\left(1 + \frac{GM}{R_B {c_U}^2}\right) \tag{23}$$

$$\therefore \frac{c_{I:A}}{c_{I:B}} = \frac{1 + \frac{GM}{R_B {c_U}^2}}{1 + \frac{GM}{R_A {c_U}^2}} = \frac{T_A}{T_B} = \frac{\Delta T_B}{\Delta T_A} = \frac{\lambda_A \nu_A}{\lambda_B \nu_B} \cong 1 + \frac{GM}{R_B {c_U}^2} - \frac{GM}{R_A {c_U}^2} \; when \; \frac{GM}{R} \ll {c_U}^2 \tag{24}$$

where λ, ν stand for wavelength and frequency of light respectively.

Gravitational time dilation is this ratio of local energy/time speeds (within matter and outside), or local clock tick rates, as applied in Hafele-Keating experiment and GPS clock time dilation computations. The velocity time dilation part of these observations/experiments will be covered shortly.

8.3 Red-shift of sunlight

The red-shift of Sunlight, or gravitational red shift, as predicted by Einstein in his 1911 paper ("On the Influence of Gravity on the Propagation of Light"), and experimentally proven later[24, 25, 26, 27] is dependent on the relative value of local light speed c_I at two locations Sun surface and Earth surface. The light/energy speed at the Sun surface is slightly lower than that on Earth surface, because of the Sun's higher potential on its surface. Therefore, any light leaving atoms on the Sun's surface would be doing so at a slightly lower rate, or 'frequency' (according to Earth clocks, which have slightly shorter seconds).

When light leaves the Sun, it attains a slightly higher velocity during travel to Earth, as gravitational potential decreases. The wavelength gets stretched a bit because of this (as frequency cannot change as per Earth clocks). When it arrives on Earth, it is slightly red-shifted.

The amount of red-shift may be computed from (24) putting ν_E=ν_S (i.e. frequencies are measured as per Earth clocks). On the surface of the Sun, we have to consider only the potential of the Sun itself, as that of the Earth is negligible. On the surface of Earth, we have to consider the potentials of both the Sun and the Earth, as the Sun's is in fact significantly larger than Earth's own. Using the subscripts S for Sun and E for Earth, and denoting the Sun-Earth distance as $S_{S:E}$, we have:

$$\frac{c_{I:E}}{c_{I:S}} = \frac{\lambda_E \nu_E}{\lambda_S \nu_S} = \frac{\lambda_E}{\lambda_S} = \frac{1 + \frac{GM_S}{R_S c_U{}^2}}{1 + \frac{GM_S}{S_{S:E} c_U{}^2} + \frac{GM_E}{R_E c_U{}^2}}$$

Using known values, we find $\frac{GM_S}{S_{S:E} c_U{}^2} + \frac{GM_E}{R_E c_U{}^2} \ll \frac{GM_S}{R_S c_U{}^2}$. Therefore we may approximate this as:

$$\frac{\lambda_E}{\lambda_S} = 1 + \frac{GM_S}{R_S c_U{}^2}$$

$$\therefore RedShift = \frac{\lambda_E - \lambda_S}{\lambda_S} = \frac{GM_S}{R_S c_U{}^2} = 2 \times 10^{-6}$$

This is the same value as predicted by Einstein in his 1911 paper and verified experimentally later.

9 Effect of velocity on gravitational potential

A velocity in the UIF creates a change in the gravitational potential experienced by a body because of the blue-shift of Universe gravitational energy caused by such a velocity.

9.1 Potential increase from a velocity in UIF

When a body initially at rest in UIF begins to move in any direction at a velocity v, the overall Doppler Effect on the gravitational energy from other Universal matter is independent of direction, considering the symmetry of the gravitational field in all directions in the rest state. This is what gives velocity time dilation an appearance of being independent of direction of velocity.

We can consider the body to be at the center of the 'sphere of influence' of Universal matter symmetric in all directions. As mentioned earlier, the gravitational energy is received from all directions radially in equal quantities at uniform speed c_U.

We may depict this situation as in Figure 3.

When the body moves at velocity v, the gravitational energy undergoes a Doppler shift in every direction. While there is a maximal blue-shift in the direction of motion, there is a maximal red-shift in the reverse direction. Intermediate values apply in other directions.

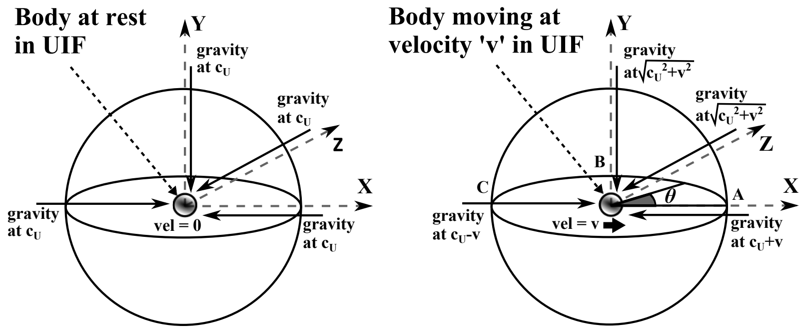

Figure 3: Universe background gravitational potential change with velocity.

The gravitational acceleration is dependent on the square of the incident velocity and the gravitational potential (adjusted for red shift) of all Universal matter within the sphere of influence (as discussed in Section 6). We need to integrate over the entire sphere in all directions to see the overall change in gravitational potential. However, by reason of symmetry, we do not need to integrate along 3-dimensions, but can integrate along the semicircle ABC shown in Figure 3, and obtain the same results.

The relative velocity of the body with respect to the uniform gravitational field in different directions will be given by $\sqrt{c_U{}^2 + v^2 + 2c_U v\cos\theta}$, where θ is the angle between direction of travel and uniformly surrounding gravity sources (i.e other matter within the sphere of influence).

The gravitational energy-potential from an infinitesimal angle $d\theta$ may be represented as:

$$\hat{\Phi}_U \frac{c_U{}^2 + v^2 + 2c_U v\cos\theta}{c_U{}^2} \times \frac{d\theta}{\pi} \tag{25}$$

We can obtain the total potential by integrating this value of θ from 0 to π (by reason of symmetry) as:

$$\hat{\Phi}_{Total} = \int_0^{\pi} \hat{\Phi}_U \frac{c_U{}^2 + v^2 + 2c_U v\cos\theta}{c_U{}^2} \times \frac{d\theta}{\pi} \tag{26}$$

The integration gives us:

$$\hat{\Phi}_{Total} = \frac{1}{\pi}\frac{\hat{\Phi}_U}{c_U{}^2}\left[c_U{}^2\theta + v^2\theta - 2c_U v\sin\theta\right]_0^{\pi} = \frac{\hat{\Phi}_U}{c_U{}^2}\left(c_U{}^2 + v^2\right) = \hat{\Phi}_U\left(1 + \frac{v^2}{c_U{}^2}\right) \tag{27}$$

Since $\hat{\Phi}_U = c_U{}^2$, we can also write this in other useful forms:

$$\hat{\Phi}_{Total} = c_U{}^2\left(1 + \frac{v^2}{c_U{}^2}\right) = c_U{}^2 + v^2 = \hat{\Phi}_U + v^2 \tag{28}$$

For reference in later sections, we will use the notation $\hat{\Phi}_{U,v}$ to denote this total potential in UIF when there is a velocity v:

$$\hat{\Phi}_{U,v} = \hat{\Phi}_U + v^2 = {c_U}^2 + v^2 \tag{29}$$

This is a very important result. It shows that the change in the base UIF gravitational energy-potential (${c_U}^2$) created by a small velocity v in UIF is simply v^2, or equivalently a factor of $(1+\frac{v^2}{{c_U}^2})$. This simple relationship between an **UIF velocity** and **energy-potential** will help us establish that **velocity time dilation**:

- can be derived intuitively from purely gravitational considerations, without need for concepts like 'length contraction' or 'relativity of simultaneity'.
- has the same root cause (gravitational potential difference) as gravitational time dilation.
- current mathematical formulation applicability under different situations needs to be reexamined (i.e. the Lorentz factor applies only to orbital motion under transverse acceleration).
- does not restrict objects to a maximum possible velocity of c in general, but only in cases where the Lorentz factor is applicable.

These will be the topics for discussion in the next few sections.

9.2 Velocity time dilation

Since $\hat{\Phi}{c_I}^2$ is a constant for a body, we get the time dilation factor (γ) from (29) as:

$$\hat{\Phi}_{U,v}{c_I}^2 = \hat{\Phi}_U{c_U}^2 \tag{30}$$

$$\therefore \gamma = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{U,v}}{\hat{\Phi}_U}} = \sqrt{1 + \frac{v^2}{{c_U}^2}} \tag{31}$$

For small velocities v such that $v^2 \ll {c_U}^2$, we can approximate this as:

$$\therefore \gamma = \frac{c_U}{c_I} \cong \left(1 + \frac{v^2}{2{c_U}^2}\right) \tag{32}$$

9.3 Maximum velocity of objects

This metric $\sqrt{1 + v^2/c_U{}^2}$ in (31) for velocity time dilation is different from the currently used *Lorentz factor* $(1/\sqrt{1 - v^2/c_U{}^2})$, though both have the same low velocity approximation $(1 + v^2/2c_U{}^2)$.

For high velocities, the Lorentz factor dictates an absolute maximum possible velocity of c for all motion. That is not the case with the above metric $(\sqrt{1 + v^2/c_U{}^2})$, which shows that while time dilation does increase with velocity, *c does not put an unconditional limit to the maximum possible velocity in space.*

Objects *can exceed the local value of c in UIF*, except for certain situations where the Lorentz factor is the appropriate metric. We will see shortly that the **Lorentz factor and a speed limit of** c **applies only to certain types of motion**, and when specific conditions are met, and **not for any velocity in UIF in general**.

Equation (31) provides the correct time dilation factor for unconstrained rectilinear motion in UIF.

10 Effect of gravity on light, and the invariance postulate of SR

As much as 'gravitational instantaneous action at a distance' is absurd, so is the concept of velocity of light being completely independent of the velocity of the source and of observers. Yet there are many experiments that appear to have validated this 'light speed invariance postulate' of Special Relativity to great accuracy.

In this section we will take a close look at how energy-potential affects the velocity of light in UIF. The equations derived will show us how speed of light changes with potential, and why the 'invariance postulate' appears to be experimentally vindicated. A much more intuitive understanding of this phenomenon will emerge.

10.1 Potential of light/free energy

Light (or any energy) is not immune to the effects of change in gravitational potential, and slows down relatively when the potential increases. That, after all, is the physics behind time dilation, as is well established in existing GR theory for gravitational time dilation.

What is different for movement of light (compared to movement of matter) is that the UIF potential increase because of any source velocity will result in a light 'propagation velocity'

slowdown in the direction of movement of the source. Time dilation within matter does not affect the velocity of the overall matter, but time dilation of light does so affect, since **time dilation itself is nothing but a slowdown of energy speed** (naturally in the direction of travel) in higher potential.

Note that this is fundamentally the same phenomenon as Shapiro delay.

In other words, the potential itself determines the velocity of light, though not of matter. This is an essential difference between movement of matter and light that we must take into account, and at normal light velocities the invariance postulate will be mathematically seen to be very close to correct.

This difference in the behavior of matter and energy, in response to increased gravitational potential because of a velocity in UIF, is represented in Figure 4. Recognizing this difference is the first step in understanding why the 'light speed invariance postulate' works.

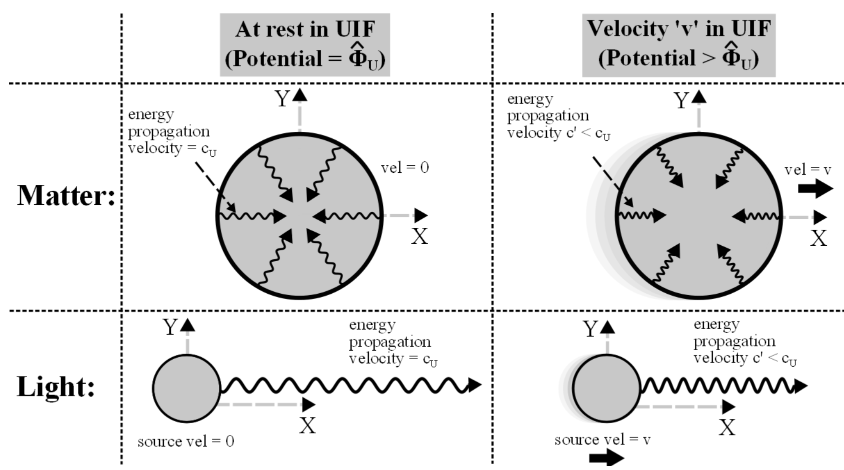

Figure 4: Time dilation of matter and light.

We observe that light has a characteristic velocity in a given potential but matter does not. While velocity of light must slow down in a predictable way in higher potential, matter is not similarly affected (though energy comprising it is). This is why matter can be at rest or move slower than light at a given potential, while light must travel at the local c. On the other hand, if light is slowed down by a significantly higher energy density (as in a medium like water or glass), matter can travel faster than light, as seen in Cherenkov effect[28]. These will be discussed in greater detail once we develop the mathematical model in this section.

If it were possible for light (or photons) to remain stationary in the UIF, it would receive gravitational potential equally from all directions, just as matter does, at uniform c_U. This allows us to compute the base potential in such a situation as:

$$\Phi_U = \sum_{i=1}^{i=n} \frac{GM'_i}{R_i} \tag{33}$$

using the same conventions as earlier.

Noting that light is not stationary but is constantly moving at c_U, we can compute the potential for such light using (27) as:

$$\hat{\Phi}_U = \sum_{i=1}^{i=n} \frac{GM'_i}{R_i} \times \left(1 + \frac{v^2}{{c_U}^2}\right) = \sum_{i=1}^{i=n} \frac{2GM'_i}{R_i} = 2\Phi_U \tag{34}$$

since for light $v = c_U$.

10.2 Relationship of potentials of light/energy and matter

Having established this understanding of potential for light, we can extend this to matter as well, since matter is essentially a spatially stable configuration of light/energy moving at c_U. **This is why matter at rest must have a total energy-potential $\hat{\Phi}_U = 2\Phi_U$, double the Newtonian value, as specified earlier.** This is a measure of the total potential of the all the energy within matter, which is what affects speed of internal energy and therefore time dilation. However, this potential does not play a direct role in the movement of the overall matter as a whole under some acceleration. It is not even in evidence unless we split up atoms and release the energy, except for its contribution to the 'mass' of the matter.

The potential of matter overall will still be only $\Phi_U = \sum_{i=1}^{i=n} \frac{GM'_i}{R_i}$ in UIF, or simply $\Phi = \frac{GM}{R}$ at a distance of R from a proximal body of mass M. This 'matter-potential' defines how the overall matter will move subject to the accelerations that set up this potential.

This gives us the basis for considering how the velocity of light emitted from a moving source will change compared to light emitted from a source at rest in UIF.

10.3 Effect of source velocity on light velocity

10.3.1 Light potential change because of source velocity

When light is emitted from a stationary source, it will travel at c_U, and its potential is simply $\hat{\Phi}_U$.

Now consider this scenario at a location where an observer is at rest in UIF, far from all massive bodies, observing a small light source moving away from the observer while emitting light in all directions, as shown in Figure 5.

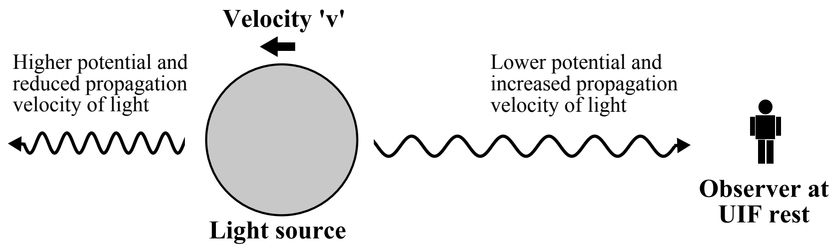

Figure 5: Potential and propagation speed change of light with source velocity.

The light traveling towards the observer faces a *lower potential* than when the source was at rest. This is most important to understand. With the source at rest, the velocity of the emitted light towards the UIF rest position of the observer was already c_U. When the source is moving away, this light *velocity would tend to decrease* in UIF, thus *resulting in a lower potential* experienced by it. In effect, we are considering a v reduced from c_U in (27).

The total velocity of light would always be given by:

$$c_{Total} = c_I + V \tag{35}$$

where

$c_{Total} =$ total velocity of light in UIF
$c_I =$ *velocity of propagation of light* in a given potential (*local velocity* of light)
$V =$ velocity of light source

The Velocity of Source in the above scenario is negative. Therefore the Velocity of Propagation of Light must **increase** because of the lower potential it now faces.

For the invariance postulate to hold, this means that the 'velocity of light source' must be almost exactly compensated by the increase of the 'propagation velocity', for the stationary observer to see the same 'total velocity' in both cases of stationary and moving source. This is indeed the case when light is traveling at c_U in UIF (which is the usual situation, when emitted from a stationary source), as our derivation below will show.

However, with increasingly larger negative 'velocity of light source', the 'total velocity' will ultimately start decreasing.

Thus, we will be able to determine a situation where the 'velocity of light source' does become exactly equal to the 'propagation velocity of light' in the opposite direction, such that the 'total velocity' of such light would be zero in UIF. This will happen at a negative 'velocity of light source' $> c_U$, since 'propagation velocity' will continue to increase from c_U as lower and lower potentials are encountered. However, at 'total velocity' zero in UIF, we have a situation for light which is analogous to matter being at rest in UIF. This is the 'base potential' of light in UIF (analogous to matter), from which we need to derive all relationships.

10.3.2 Determining the base potential of light

One thing should be clarified here. Although photons may be momentarily at rest as seen in UIF rest frame, this does not constitute a rest frame for photons or light. In fact, light is propagating at a velocity faster than c_U from the source, and is not in any way stationary in regard to the gravity coming from all directions (which is traveling at c_U with regard to the light, or vice versa).

If the negative velocity of source were to increase further beyond this point, then the emitted light would in fact reverse direction, and start increasing with regard to local UIF rest frame, and the situation then would become analogous to matter, where potential would increase in either direction if there is a velocity change.

Let us call the potential faced by light in this UIF rest position as 'base potential', denoted by $\hat{\Phi}_{base}$. The corresponding light propagation velocity will be denoted as c_{base}. The propagation velocity of light in general will be denoted as c_I, as we denote the local velocity of energy, as they are essentially the same thing.

10.3.3 Light potential, source velocity and light velocity relationship

We start our analysis from this *base potential situation* to derive the mathematical formula applicable. Let the velocity of the retreating source be reduced by a small velocity V. The emitted light thus gains a small velocity V towards our observer, as a first approximation.

Using the equation derived for velocity time dilation (27), we can compute the increased energy-potential as a first approximation as:

$$\hat{\Phi}_V = \hat{\Phi}_{base}\left(\frac{{c_U}^2 + V^2}{{c_U}^2}\right) = \hat{\Phi}_{base}\left(1 + \frac{V^2}{{c_U}^2}\right) \tag{36}$$

Note here that the c_U here represents the velocity of external gravity, which remains c_U, no matter how the propagation velocity c_I of light changes based on its source velocity and corresponding potential. The c_I at the base situation had the value c_{base}, which must now decrease because of the higher potential encountered.

We now need to account for the **reduction of the 'propagation velocity' of light** from c_{base}, because of the slightly increased potential. To do that, we break this increase into 'n' very small steps such that the first approximation above may be considered valid, and account for the corresponding potential increase at each small step, using the 'compound interest' formula.

We may then rewrite the equation as:

$$\hat{\Phi}_V = \hat{\Phi}_{base}\left(1 + \frac{(V^2/{c_U}^2)}{n}\right)^n \tag{37}$$

Since this is a continuous increase, we make the number of steps 'n' arbitrarily large, and in the limit get:

$$\hat{\Phi}_V = \hat{\Phi}_{base}\lim_{n\to\infty}\left(1 + \frac{(V^2/{c_U}^2)}{n}\right)^n = \hat{\Phi}_{base}e^{\frac{V^2}{{c_U}^2}} \tag{38}$$

This is the base equation we need for understanding of potential of light and its effect on light velocity, as well as the 'invariance postulate'.

Potential of light increases as an exponential function of velocity, rather than linearly as is the case for matter. This is because the velocity of light in the direction of motion is itself affected by the change of potential. Using $\hat{\Phi}{c_I}^2$ constancy, we are able to see that the total velocity of light will decrease as an inverse exponential function with source velocity. In the next sections on the de Sitter, Fizeau[29, 30], and similar experiments[31], we will do this computation and see why the invariance postulate appears to be true in vacuum, whereas light dragging by a moving medium depends on the refractive index.

For now, it is important to note that velocity of light does not add on to velocity of the source simply as a scalar addition, as we would have expected from classical mechanics or emission theory. The inverse exponential function dictates that the total velocity of light in UIF will increase less and less with faster source velocity. At the speed of light in UIF, c_U, it turns out that the increase of total velocity is negligible (i.e. the decrease in propagation velocity exactly compensates for the increase in source velocity), as we will see in the de Sitter experiment discussion below. This is not a coincidence, but a necessary consequence of the velocity of light in the Universal gravitation potential, as the two are directly related.

When V is c_U, the source of light is at rest in UIF. We then have the usual situation of light/energy traveling at c_U in UIF frame, when emitted from a body at rest. Therefore we can derive from the above equation:

$$\hat{\Phi}_U = \hat{\Phi}_{base}e^{\frac{{c_U}^2}{{c_U}^2}} = \hat{\Phi}_{base}e \tag{39}$$

From $\hat{\Phi}{c_I}^2$ constant, we also get:

$${c_U}^2 = \frac{\hat{\Phi}_{base}}{\hat{\Phi}_U}{c_{base}}^2 = \frac{{c_{base}}^2}{e} \tag{40}$$

These give us the relationship between energy-potential and propagation velocity at the 'base' and 'source at rest' situations in terms of a clock running at c_U.

10.4 Explanations of relativity experiments

The understanding developed in the above section is of extraordinary importance. It provides an intuitive explanation of the invariance postulate without having to ascribe a magical property to light, viz. complete independence of light velocity from source and observer velocity. It also comprehensively and intuitively explains results of many important relativity experiments without the invariance postulate assumption. In this section we look at some of these experiments like **de Sitter** double star experiment, **Michelson-Morley**[32, 33, 34, 35] **Alvager**[36] and **Fizeau** experiments in the light of the above discussions.

The de Sitter experiment, and subsequent repetitions by Kenneth Brecher[37], showed that we do not see apparitions/multiple-images of binary stars, as we would if the velocity of light were dependent on the velocity of the source stars. The conclusion reached is that the velocity of light must be independent of the source velocity.

The question is: *completely independent*, at all velocities of source? The Alvager experiment has been seen to answer this with an emphatic 'Yes'.

We need to look at each of these experiments in some detail in order to understand whether such conclusions are really cast in iron, or if more intuitive yet simple explanations exist that explain the observations just as well or better.

10.4.1 The de Sitter double star experiment

Let us consider the de Sitter experiment first. Two distant binary stars are revolving around their common CG at a velocity v (assuming they are of reasonably similar mass). If the velocity of the source stars were added classically to the velocity of their emitted lights (constant c), the light emitted by one star when moving towards Earth, and light emitted by the same star when moving away from Earth, would ultimately overlap at some point in the journey to Earth. We would then see blurred or multiple images of the stars (de Sitter apparitions) instead of sharply differentiable stars. The experiments have instead established that the stars are seen as sharply differentiable objects, as would be seen if they were not moving relatively at all.

This observation is seen as a confirmation of the invariance postulate (zero effect of source velocity on emitted light velocity) against the ballistic/emission theory (velocity of the source gets added to c). To summarize the two points of view, the equation used is:

$$c' = c + kv \tag{41}$$

where

$c' =$ observed total velocity of light
$c =$ velocity of light from emitting source body
$v =$ velocity of emitting source body
$k =$ 0 (for invariance) or 1 (for ballistic/emission)

Can we take the de Sitter experiment results as incontrovertible proof for the invariance postulate and against the ballistic/emission theory? Not necessarily. In fact, the actual explanation is in between the two, though the invariance postulate turns out to be much closer to the truth. For source velocity $v \ll c$, the invariance postulate is almost exactly true, but that changes somewhat with higher source velocities. Let us see why this must be so, based on the (38) derived in the previous section.

10.4.1.1 Velocity of light from the star moving towards Earth. Light emitted by a stationary star would simply face a potential of (from (39)):

$$\hat{\Phi}_U = \hat{\Phi}_{base} e^{\frac{{c_U}^2}{{c_U}^2}} \tag{42}$$

For light emitted from a star that is moving towards Earth at a velocity v, the total velocity of light would be $v_+ = c_U + v$, as a first approximation. However, the potential faced by such light, denoted $\hat{\Phi}_{v+}$, will also have increased, and that will tend to reduce the propagation velocity of the light. Using Equation (38), we obtain this increased potential as:

$$\hat{\Phi}_{v_+} = \hat{\Phi}_{base} e^{\frac{{v_+}^2}{{c_U}^2}} = \hat{\Phi}_{base} e^{\frac{(c_U+v)^2}{{c_U}^2}} \tag{43}$$

From (42) and (43), keeping $\hat{\Phi}{c_I}^2$ constant, we can write:

$$\hat{\Phi}_{base} e^{\frac{(c_U+v)^2}{{c_U}^2}} \times {c_{I+}}^2 = \hat{\Phi}_{base} e^{\frac{{c_U}^2}{{c_U}^2}} \times {c_U}^2 \tag{44}$$

where c_{I+} is the reduced propagation velocity of light from the star because of the increased Universe gravitational potential.

Solving for c_{I+} we have:

$$ {c_{I+}}^2 = e^{-\left(\frac{2vc_U+v^2}{{c_U}^2}\right)} \times {c_U}^2 \tag{45}$$

$$\therefore c_{I+} = e^{-\left(\frac{v}{c_U}+\frac{v^2}{2{c_U}^2}\right)} \times c_U \tag{46}$$

Expanding the exponential as a Taylor expansion as $e^x = 1 + x + x^2/2! + x^3/3! \cdots$, the equation becomes:

$$c_{I+} = c_U \left(1 - \left(\frac{v}{c_U} + \frac{v^2}{2{c_U}^2} \right) + \frac{\left(\frac{v}{c_U} + \frac{v^2}{2{c_U}^2} \right)^2}{2!} - \frac{\left(\frac{v}{c_U} + \frac{v^2}{2{c_U}^2} \right)^3}{3!} + \cdots \right) \tag{47}$$

Ignoring the small orders above v^3/c^3 (since $v \ll c_U$), we can approximate this as:

$$\therefore c_{I+} \cong c_U \left(1 - \frac{v}{c_U} - \frac{v^2}{2{c_U}^2} + \frac{v^2}{2{c_U}^2} + \frac{v^3}{2{c_U}^3} - \frac{v^2}{6{c_U}^3} \right) = c_U \left(1 + \frac{v^3}{3{c_U}^3} \right) - v \tag{48}$$

$$\therefore c_{Total+} = c_{I+} + v = c_U \left(1 + \frac{v^3}{3{c_U}^3} \right) \cong c_U for\ v \ll c_U \tag{49}$$

In other words, the total light velocity increase from the star moving at velocity v, compared to if it were at rest, is negligible. The change is of the order of $v^3/{c_U}^3$, as opposed to the effects de Sitter was measuring for (order of v/c). This is why the invariance postulate (i.e. $k \cong 0$ in $c' = c + kv$) appears to be vindicated, and we do not see any 'de Sitter apparitions' or blurred images from distant binary stars.

The ballistic/emission theory is never close to correct, but at larger source velocities the total light velocity will be somewhere between the prediction of invariance postulate and emission theory (i.e. $0 < k < 1$ in $c' = c + kv$).

10.4.1.2 Velocity of light from the star moving away from Earth. For the other star in the binary, the one moving away from Earth, the equation will likewise be:

$$\hat{\Phi}_{base} e^{\frac{(c_U - v)^2}{{c_U}^2}} \times {c_{I-}}^2 = \hat{\Phi}_{base} e^{\frac{{c_U}^2}{{c_U}^2}} \times {c_U}^2 \tag{50}$$

where c_{I-} is the increased propagation velocity of light from the star because of the lower potential its emitted light faces.

Solving for c_{I-} in a similar manner as above, we derive:

$$c_{Total-} = c_{I-} - v = c_U \left(1 - \frac{v^3}{3{c_U}^3} \right) \cong c_U for\ v \ll c_U \tag{51}$$

This again shows that the total velocity of light towards Earth, from the star moving away, is also practically the same as c_U, and we do not see any overtaking of one star's light by the other on the way to Earth.

Comparing to the equation $c' = c + kv$, we find that $k \sim v^2/3{c_U}^2$. Since orbital velocity v for binaries is typically of the order of $10 - 100\ km/s$, k is expected to be of the order of 10^{-7} to 10^{-10}. This is consistent with the limits established by the Brecher experiment ($k < 2 \times 10^{-9}$), and well beyond the accuracy of the de Sitter experiment ($k < 0.002$). [Note: Extinction of visible light for the de Sitter experiment, and even partial extinction of X-rays for the Brecher experiment are not accounted for in the k-values reported for the experiments. If they were, the k-values would be even less stringent.]

In the above analysis we have ignored the slight reduction of the internal energy velocity of the stars themselves because of their own velocity. That would lead to a small correction of the initial velocity of the light emitted by the stars (as seen in the Ives Stillwell experiment[38, 39]). However, that change is negligible at small v, and is equally present during all observations. It does not affect our analysis of the de Sitter experiment.

10.4.2 Fizeau Experiment

The experiment of Fizeau which established the formula for light dragging by moving water may also be explained by the effect of gravitational potential on light velocity.

In the experiment, when light was transmitted through water moving at v, the light was dragged to an extent as given by the below equation:

$$w_+ = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right) \tag{52}$$

where

$w_+ =$ velocity of light in water as observed from lab frame
$c =$ velocity of light in vacuum/air (essentially c_U)
$v =$ velocity of water in the same direction as light
$n =$ refractive index of water

In this case, the comparison is between the potential/energy density of stationary water and moving water. The light/energy that travels through water goes through a significantly higher potential/energy density than in vacuum. We may consider such light/energy traveling within the stationary water to be in the equivalent of a significantly increased UIF gravitational potential.

The refractive index of water, n, represents the change of light velocity with the increased potential in water:

$$n = \frac{c_U}{c_w} \tag{53}$$

where c_w is the velocity of light in stationary water.

Since the potential within water is higher than $\hat{\Phi}_U$, we have to compute the base potential in water (denoted $\hat{\Phi}_{base:w}$). We can use the same considerations as in Equation (38) to derive the relationship between the base potential and the potential at a light velocity of V:

$$\hat{\Phi}_{V:w} = \hat{\Phi}_{base:w} \lim_{n\to\infty} \left(1 + \frac{(V^2/{c_U}^2)}{n}\right)^n = \hat{\Phi}_{base:w} e^{\frac{V^2}{{c_U}^2}} \tag{54}$$

When the water is stationary, we denote the potential as $\hat{\Phi}_w$ (stationary in UIF, but in higher potential within water). The light velocity V in this situation is c_w. We can then write the relationship between base potential and UIF rest potential as:

$$\hat{\Phi}_w = \hat{\Phi}_{base:w} e^{\frac{{c_w}^2}{{c_U}^2}} \tag{55}$$

When the water is moving with a velocity v, the potential faced by light traveling through water in the direction of water motion will increase further, resulting in a further reduced velocity of light $c_{w'}$. Using $\hat{\Phi}{c_I}^2$ constancy, we can derive the following relationship between the velocities of light in stationary and moving water:

$$\hat{\Phi}_{base:w} e^{\frac{{c_w}^2}{{c_U}^2}} \times {c_w}^2 = \hat{\Phi}_{base:w} e^{\frac{(c_w+v)^2}{{c_U}^2}} \times {c_{w'}}^2 \tag{56}$$

$$\therefore {c_{w'}}^2 e^{\frac{(c_w+v)^2}{{c_U}^2}} = {c_w}^2 e^{\frac{{c_w}^2}{{c_U}^2}} \tag{57}$$

Solving for $c_{w'}$, we get:

$$c_{w'} = c_w \sqrt{\frac{e^{\frac{{c_w}^2}{{c_U}^2}}}{e^{\frac{(c_w+v)^2}{{c_U}^2}}}} = c_w \sqrt{e^{\frac{-2c_w v - v^2}{{c_U}^2}}} \cong c_w e^{-\left(\frac{c_w v + v^2/2}{{c_U}^2}\right)} \tag{58}$$

Since $\left(c_w v + v^2/2\right)/{c_U}^2 \ll 1$, we can take the approximation $e^x = 1 + x$, and get:

$$w_+ = c_{w'} + v = c_w e^{-\left(\frac{c_w v + v^2/2}{{c_U}^2}\right)} + v \cong c_w \left(1 - \frac{v c_w}{{c_U}^2} - \frac{v^2}{2{c_U}^2}\right) + v \tag{59}$$

Substituting $c_w = c_U/n$, and ignoring the small $v^2/2{c_U}^2$ term, the total light velocity in moving water in the lab frame is given by:

$$w_+ = \frac{c_U}{n}\left(1 - \frac{v}{c_U n}\right) + v = \frac{c_U}{n} + v\left(1 - \frac{1}{n^2}\right) \tag{60}$$

This is the relationship observed in the Fizeau experiment. We derived in this section a very intuitive explanation of this formula, based on relationship between light velocity and energy-potential in a medium (water).

Refraction may be seen as a Shapiro delay caused by the higher energy-potential within water (or any transparent medium denser than vacuum). This delay becomes greater (i.e. light moves even slower) in moving water because of further increased energy-potential.

Of course, this applies only to the wavelengths where a medium is 'transparent' and does not deflect or stop light itself (where other phenomena come into play).

10.4.3 Cherenkov effect

As we have seen above, the velocity of light is slowed in the direction of motion because of the increased potential, resulting in refraction in a transparent medium. Matter is not affected in the same way.

When matter travels in a higher potential, the energy within it is slowed down by the higher potential, but that does not adversely affect the velocity of its CG, which is the velocity of matter.

This allows subatomic matter to maintain its high velocity within a medium, while light must slow down to its characteristic velocity in the medium depending on refractive index (indicating higher potential).

Of course, the physical interaction of the subatomic particles with the medium would cause the subatomic particle to lose energy and slow down or stop over time. This dissipation of energy is seen a Cherenkov radiation. However, for a period of time, the subatomic particle (matter) can move faster than light. This would be true in vacuum as well. Moreover, there would be little slowdown of matter in vacuum of space, as it would not have much interactions with other matter as in a material medium.

10.4.4 Michelson-Morley experiment

For Michelson-Morley (and similar experiments like Kennedy-Thorndike[40, 41]), which were testing for an order of v/c change in light velocity (i.e. $k \sim 1$ in $c' = c + kv$), it is clear from the explanation of the de Sitter experiment that such experiments would provide null results. A difference of the order of $k \sim v^2/c^2$ would have been nearly undetectable given the small Earth rotation velocity.

10.4.5 Alvager et. al. experiment

One experiment that is often taken as strong proof of the invariance postulate is the Alvager et. al. experiment, since it appears to prove that c does not change even when emitted from a high-velocity source. This requires a closer examination in the light of the above discussion.

In the Alvager 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 noted:

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

- The -rays are not produced *spontaneously* by protons in flight, but through a *collision process*. The protons striking the beryllium target interact with much larger beryllium nuclei (themselves part of a much larger metal lattice) in a collision process to produce pions. The process of emitting the pions is preceded by the collision, and the velocity of the protons at the instant of pion production is certainly reduced, even if slightly. Therefore we have no certainty that the source (proton) is moving at all in the original direction at $0.99975c$ at the point of pion production, such that a source velocity of $0.99975c$ may be reliably assumed.

- A presumption is made that high energy γ-rays traveling in the direction of proton path have that energy because of the incident protons' kinetic energy in that direction. Even if the invariance postulate keeps the velocity of the γ-rays same as light, the energy of the protons nonetheless must be reflected in increased energy of the γ-rays. This is necessary for the velocity of the protons to have had any bearing on the experiment at all. This is understandable. What has not been tested though is whether equally energetic γ-rays are being scattered in other directions (say perpendicular to the movement of the protons). If found, they would invalidate the entire experiment's basis, as the velocity/energy of the protons should have no bearing on γ-ray energy in a perpendicular direction. That energetic γ-rays are being scattered in directions other than directly in line with proton movement is a certainty, since Alvager et. al. themselves measure the velocity of these γ-rays at an angle of $6°$ to the proton direction. (It is also not clear whether this last fact is accounted for in the stated accuracy/error, but that is a minor point).

Without these, the experiment is at best inconclusive. The experiment would have to be repeated with energies and velocities of γ-rays in different directions (presumably with at least a semi-cylindrical Beryllium target) for any reliable conclusion at all to be drawn.

11 Time dilation in orbital motion, and the Lorentz Factor

11.1 Deriving the Lorentz Factor from orbital motion

It is important to characterize the current metric of velocity time dilation, Lorentz factor $(1/\sqrt{1-v^2/c^2})$. We need to understand its physical meaning and implications in a gravitational Universe, to see in what situations it is the valid metric. In this section we derive the Lorentz factor based on physical considerations to achieve this.

11.1.1 Acceleration and energy-potential in orbit under transverse acceleration

Consider a small body m (of rest mass m_0) orbiting another massive body (M) at a distance R with a velocity v. If the gravity of M and velocity of m had no impact on the unit mass of m, the Newtonian metric for gravitational acceleration GM/R^2 would be exact. Since mass of m would remain the same as rest mass m_0, the acceleration would be $\left(\frac{GMm_0}{R^2}\right)/m_0 = \frac{GM}{R^2}$. Thus, $Acc(A) = GM/R^2 = v^2/R$ would be satisfied in circular orbit.

However, from GR theory we know that this equation is not exact. The anomalous perihelion precession of Mercury shows that the gravitational acceleration is slightly greater than computed classically from GM/R^2. Investigating the differences allows us to derive both the Schwarzschild metric and the Lorentz factor, and understand the conditions under which one or the other applies.

As a first step, we note that because of the orbital velocity of the small mass m, the gravitational acceleration will be multiplied by a factor of $(1 + v^2/{c_U}^2)$, since the relative velocity of m with respect to the gravity of M is $\sqrt{{c_U}^2 + v^2}$.

Therefore, the Newtonian gravitational equation needs to be modified as:

$$Base\ acceleration\ (A_M) = \frac{GM}{R^2}\left(1 + \frac{v^2}{{c_U}^2}\right) = \frac{v^2}{R} \tag{61}$$

This means that for increasing v's, slightly lesser gravitational acceleration will be required to maintain the orbit, since the relative velocity increase with respect to the source gravity will enhance the gravitational acceleration. For example, for light at $v = c$, we find that the total acceleration doubles. If c had been the orbital velocity under consideration, this would have caused extra inward deviation from the orbit trajectory. Therefore, for c, the base acceleration GM/R^2 required for orbital motion would have to be half the centripetal acceleration v^2/R (as can be computed from the above equation).

This base equation will hold for all velocities. The relativistic modifications discussed below will apply equally to both sides of this equation.

Note that this is an increase in magnitude only, and does not mean that this acceleration is towards the retarded position of the massive body M because of the gravity propagation delay. In the local UIF frame, it is m that is moving and M that is at (nearly) rest. Thus M's gravitational field may be considered a static field. The orbital acceleration is therefore always central (i.e. toward the instantaneous center of M), because there are no components of M's gravitational acceleration in the direction of m's velocity.

Now, in the above discussion, the rest mass accounts only for the UIF energy-potential $\hat{\Phi}_U = {c_U}^2$, and does not consider the additional energy-potential of the local massive body M.

The base energy-potential of M is $\hat{\Phi}_M = 2GM/R$. However, because of the orbital velocity v, the acceleration A_M is slightly higher as shown in (61). Therefore, we may write the actual energy-potential (denoted $\hat{\Phi}_{M,v}$) as:

$$\hat{\Phi}_{M,v} = \hat{\Phi}_M \left(1 + \frac{v^2}{{c_U}^2}\right) = \frac{2GM}{R}\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{62}$$

When we do take $\hat{\Phi}_{M,v}$ into account in the unit mass of the small body m, the mass will have increased by $\hat{\Phi}_{M,v}$. The transverse momentum of m will also have increased accordingly. To counteract this, an equal increase in the central acceleration is required to maintain orbit equilibrium. The acceleration increase required would be:

$$\Delta A_M = A_M \frac{\hat{\Phi}_{M,v}}{\hat{\Phi}_U} = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{63}$$

Now, this increase in the acceleration of M would, in turn, create an increase in energy-potential by the same factor. That is equivalent to a further increase in mass and therefore transverse momentum of m. The relationship between the acceleration and transverse momentum becomes recursive, with increased transverse momentum at each step having to be matched by a corresponding central acceleration increase. This would ultimately lead to the additional acceleration becoming (for $v^2 < {c_U}^2$):

$$\Delta A_M = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}(1 + \cdots)\right)\right) = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right) \tag{64}$$

Thus the total energy-potential of m from M's gravity (enhanced by m's velocity) will be:

$$\hat{\Phi}_{M,v} = \hat{\Phi}_M \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \tag{65}$$

To get the total energy-potential of m, we add the modified UIF energy-potential $\hat{\Phi}_{U,v}$ (from (29)) to the energy-potential from M:

$$\hat{\Phi}_{Total} = \hat{\Phi}_{U,v} + \hat{\Phi}_{M,v} = \hat{\Phi}_U + v^2 + \hat{\Phi}_M \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) = \hat{\Phi}_U \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2} \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \right) \tag{66}$$

Since M's acceleration also needs to take care of the slight additional transverse momentum from the UIF energy-potential, it will also have to increase by the same factor:

$$A_{M,v} = A_M \left(1 + \frac{v^2}{{c_U}^2} \right) \tag{67}$$

The total acceleration (A), taking into account all components would then have to be:

$$Acc(A) = A_{M,v} + \Delta A_M = A_M \left(1 + \frac{v^2}{{c_U}^2} + \frac{\hat{\Phi}_M}{{c_U}^2} \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \right) \tag{68}$$

In terms of M's gravitational potential and m's orbital velocity, this may be stated as:

$$A = \frac{v^2}{R} \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2} \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \right) \tag{69}$$

We have now got the **complete equations for energy-potential** (Eq. (66)) **and acceleration** (Eq. (68), (69)) for a small body in a **circular orbit under a transverse central acceleration**. Note that this description applies to *both natural* gravitational situations like *GPS Satellites* around Earth, and *artificial* gravitational equivalent situations like muons in the muon ring in the *Bailey et. al. experiment.*

11.1.2 Time dilation in orbital motion, and the Lorentz factor

For determining the time dilation factor γ, we can use $\hat{\Phi}{c_I}^2$ constancy and Equation (66) to write:

$$\hat{\Phi}_U {c_U}^2 = \hat{\Phi}_{Total} {c_I}^2 = \hat{\Phi}_U \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2} \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \right) {c_I}^2 \tag{70}$$

At low velocities ($v \ll c_U$), $\hat{\Phi}_M$ is little changed by $1/\left(1 - v^2/{c_U}^2\right)$, and we can approximate this as:

$$ {c_U}^2 = \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2}\right){c_I}^2 \tag{71} $$

$$ \therefore \gamma = \frac{c_U}{c_I} = \sqrt{\left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2}\right)} \cong 1 + \frac{v^2}{2{c_U}^2} + \frac{GM}{R{c_U}^2} \tag{72} $$

This is the equation that is relevant for GPS time dilation and Hafele-Keating experiment calculations. Note that this approximation is exactly the same as that of the Schwarzschild metric $\gamma = 1/\sqrt{(1 - v^2/{c_U}^2 - 2GM/{c_U}^2)}$ that is used from GR. This will be discussed in Section 12.

In situations where v is close to c_U, as in the Bailey et. al. experiment, $\hat{\Phi}_M$ becomes nearly $\hat{\Phi}_U$ (by (61) we have $GM/R = v^2/(1 + v^2/{c_U}^2)$, and since $v \approx c_U$, we get $\hat{\Phi}_M = 2GM/R \approx {c_U}^2 = \hat{\Phi}_U$). Therefore, $\hat{\Phi}_{M,v}$ becomes much larger than $\hat{\Phi}_{U,v}$ in (66) as the $1/\left(1 - v^2/{c_U}^2\right)$ term becomes very large. In this high orbital velocity case, we can then consider the total potential of m to be $\hat{\Phi}_{M,v}$ itself in (66).

From $\hat{\Phi}{c_I}^2$ constancy and (66), we get:

$$ \hat{\Phi}_U {c_U}^2 \cong \hat{\Phi}_{M,v}{c_I}^2 = \frac{\hat{\Phi}_M}{\left(1 - \frac{v^2}{{c_U}^2}\right)}{c_I}^2 = \frac{\hat{\Phi}_U}{\left(1 - \frac{v^2}{{c_U}^2}\right)}{c_I}^2 \tag{73} $$

This gives us:

$$ \therefore \gamma = \frac{c_U}{c_I} = \frac{1}{\sqrt{1 - \frac{v^2}{{c_U}^2}}} \tag{74} $$

This is the **Lorentz factor**, which is used to explain the time dilation of muons in the Bailey et. al. experiment.

11.2 The meaning and applicability of the Lorentz Factor

The derivation above clearly shows us that the Lorentz factor is the appropriate metric for **time dilation** in **very high velocity** ($v \approx c_U$) orbital motion only.

For **low velocities**, (72) is the appropriate formulation for computing **time dilation (both velocity and gravitational)**. Note that it is essentially the Schwarzschild metric approximation that is used to explain GPS satellite and Hafele-Keating time dilations.

The low velocity ($v \ll c_U$) approximation of the Lorentz factor is:

$$ \gamma = \frac{c_U}{c_I} \cong 1 + \frac{v^2}{2{c_U}^2} \tag{75} $$

Coincidentally, this is the same as the low velocity approximation of the correct metric for UIF velocity time dilation (Eq. (32)). Since time dilation computations have always been done at very low velocity (e.g. GPS satellites and Hafele-Keating) or very high velocity (e.g. Bailey et. al.) situations, the Lorentz factor appears to have worked for all cases and is considered to be largely proven as the velocity time dilation factor for all velocities. Experiments on the lines of Bailey et. al. conducted at muon velocities of $0.5 - 0.8c$ will show this is not the case (there will be a $15\% - 19\%$ difference from the Lorentz factor), as time dilation contributions from neither UIF potential nor local potential can be ignored. Equation (70) would have to be used in such cases.

The important difference we need to recognize here is that the Lorentz factor is a multiplier of the local energy-potential $\hat{\Phi}_M$, which for bodies like Earth or any star is very small compared to the UIF potential ($\hat{\Phi}_U$). Thus, **at low orbital velocities** the Lorentz factor contributes little, and the velocity time dilation we see comes from a **body's velocity in the Universe gravitational potential**. At very **high orbital velocities**, the **increased local potential overshadows the UIF potential** and the **Lorentz factor** then provides the **correct time dilation ratio**.

This is why we see separate gravitational and velocity time dilation terms (from $\hat{\Phi}_{U,v}$) in the cases like GPS satellites and Hafele-Keating, but only velocity time dilation (from $\hat{\Phi}_{M,v}$) appears to be present in Bailey et. al. experiment. This will be explained in more detail in the next section.

For **unconstrained rectilinear motion** in the UIF, the **Lorentz factor does not appear at all**, as it is an artifact of transverse acceleration in orbital motion.

It is important to understand what the Lorentz factor physically implies, and does not imply, about velocity of light/energy. When v approaches c_U in orbital motion, both potential and acceleration increase boundlessly (Eq. (66)-(69)). **If $v \geqslant c$, a closed orbit is not possible under a transverse/central acceleration**. Conversely, a stable circular orbit must always have $v < c$, no matter how large the potential.

The Lorentz factor **does not imply that a velocity of $v \geqslant c$ is impossible** under non-orbital conditions.

11.3 Explanation of the Bailey et. al. muon lifetime experiment

The Lorentz factor applies to potentials created by local accelerations themselves, irrespective of the UIF potential. The effects are significant only when the local potential is very large. Such potentials may be created artificially as in the case of the Bailey et. al. experiment, or naturally because of massive gravity close to very compact bodies like black holes.

In the Bailey experiment, muons at a velocity of $0.9994c$ were stored in a Muon Storage Ring at CERN for measuring their lifetimes. A black hole like transverse acceleration of nearly $10^{18}g$ (produced using strong electromagnets along the muon storage ring), kept the muons going in a circular orbit. The lifetime of the muons was found to be extended by a factor of 29.327, very close to the value computed using the SR velocity time dilation metric (Lorentz factor) $1/\sqrt{1 - v^2/c_U{}^2}$, compared to the average rest lifetime of about $2.2\mu s$ found in unrelated and independent previous experiments.

The Bailey experiment set-up is exactly equivalent to orbital motion of planets around stars and satellites around planets. Both are orbital motion under transverse (central) accelerations. Therefore, one could expect the same metrics to apply to both.

The curious aspect of the Bailey experiment is that only velocity time dilation formula (Lorentz factor) seems exactly applicable, but no gravitational time dilation term appears (as opposed to the Schwarzschild metric for satellites). This is in spite of a black hole like transverse acceleration of nearly $10^{18}g$. Why does the SR formula alone apply in such a strongly accelerated frame?

From General Relativity we know that gravitational time dilation is co-present with the existence of an accelerated reference frame, and a very strongly accelerated frame was used. How is it that the potential created by such a large acceleration had no impact on time dilation?

Note the difference from other orbital motion observations and experiments (GPS satellites and Hafele Keating), where gravitational and velocity time dilations show up as additive quantities, based on the Schwarzschild metric (or actually the more correct equivalent metric in (66)).

The reason is easy to understand from (70) by substituting low and high v's in the equation. This metric applies to all cases mentioned.

The very high velocity in Bailey experiment **scales the local central acceleration by γ^2 and creates a massive potential**. This **local potential becomes dominant** and overshadows the UIF potential, **leaving only the Lorentz factor** in (70). In this experiment, the 'velocity time dilation' is in fact one and the same thing as the 'gravitational time dilation' from the massive local potential created by the local acceleration.

This is very different from saying that the velocity by itself causes the time dilation, and accelerated frame plays no role at all, as concluded by Bailey et. al. in their paper. That explanation is contradictory to GR and the equivalence principle, when comparing muons lifetimes between non-accelerated and strongly accelerated frames.

The time dilation factor computed using the Lorentz factor was 29.327. If the full Equation (70) had been used, the difference would have been by a factor of only 1 in 1000.

Therefore, the Lorentz factor was the valid time dilation metric in this case.

Note that the time dilation factor of 29.327 simply means that the significantly increased potential reduces energy velocity (c_I) inside the muons by a factor of 29.327. The process of energy movement within muons that causes decay in $2.2\mu s$ at rest is slowed down by this factor, and the muons 'live' that much longer in consequence.

11.4 Energy of relativistic particles

When particles such as beta rays are produced as a result of radioactivity or other atomic disintegration, they must then carry away the energy they have within the atom. Since particles like electrons are moving in orbits within atoms without leaving the spatial configuration of the atoms before atomic disintegration, they are also subject to massive accelerations. This implies that they carry large potentials within the atom (much like the muons in Bailey et. al. experiment), and leave with the same energies when released from atoms.

Thus, they would carry similar energies as computed by the Lorentz factor. Once they leave the atom, they would over time radiate and lose that energy. Initially, their internal 'time' would be extremely slow, and therefore they will retain their energies for considerable periods.

12 Putting Gravitational and Velocity time dilation together

We are now in a position to create the complete picture of the gravitational potential of objects under various conditions.

12.1 Complete potential equation for orbit

For a small body orbiting a massive body, the total potential will have components of all of these: (a) gravitational potential of the Universe, (b) increase of this gravitational potential because of velocity in the UIF, and (c) gravitational potential of the local massive body, enhanced by the velocity. This is described in (66). The complete equation may be written as:

$$\hat{\Phi}_{Total} = \hat{\Phi}_U \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2} \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \right) \tag{76}$$

To compute the time dilation of the orbiting body, we need only apply the $\hat{\Phi}{c_I}^2$ constancy along with the above equation to obtain $\gamma = c_U/c_I$ for any velocity. The usual cases of interest of very low and very high velocities are detailed in subsections (12.3) and (12.4) below.

12.2 Unconstrained rectilinear motion in UIF

For unconstrained rectilinear motion in UIF (i.e. non-orbital motion), where a small body gets significant potential from a number (n) of large proximal bodies (possibly having velocities in different directions), and has a velocity v in UIF, the total potential equation for the small body would be:

$$\hat{\Phi}_{Total} = \hat{\Phi}_U \left(1 + \frac{v^2}{{c_U}^2} + \sum_{i=1}^{i=n} \frac{\hat{\Phi}_{M_i}}{{c_U}^2} \left(\frac{{c_U}^2 + {v_i}^2 + 2c_U v_i cos\theta_i}{{c_U}^2}\right)\right) \tag{77}$$

Here, M_i is the mass of the i^{th} proximal large body, v_i is the velocity of the small body with respect to the i^{th} large body, θ_i is the angle of approach between the small body and the i^{th} large body, and v is the velocity of the small body in UIF.

The Lorentz factor does not appear here as there is no constraint of an orbital trajectory under transverse central acceleration.

In the common case of one single proximal body which may be considered static, the equation simplifies to:

$$\hat{\Phi}_{Total} = \hat{\Phi}_U \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2} \left(\frac{{c_U}^2 + v^2 + 2c_U v cos\theta}{{c_U}^2}\right)\right) \tag{78}$$

12.3 Slow velocity approximation

From Equation (70), at low velocities where $1/\left(1 - v^2/{c_U}^2\right)$ is negligible, as in the case of small velocities involved in satellite (e.g. GPS) or planetary revolution around stars, we may approximate the potential as:

$$\hat{\Phi}_{Total} = \hat{\Phi}_U \left(1 + \frac{\hat{\Phi}_M}{{c_U}^2} + \frac{v^2}{{c_U}^2}\right) = \hat{\Phi}_U \left(1 + \frac{2GM}{R{c_U}^2} + \frac{v^2}{{c_U}^2}\right) \tag{79}$$

Note that this is essentially identical to unconstrained rectilinear motion as in the previous section, when the velocity is exactly transverse to the large proximal mass.

In this case, the local body gravitational time dilation and UIF velocity time dilation effects are of comparable magnitudes and appear as separate effects. This is the same as the low velocity, low gravity approximation of the Schwarzschild metric, as it should be when $GM/R \ll c^2$ and $v^2 \ll c^2$, as proven in numerous experiments. However, this equation is in fact the exact metric and not an approximation, apart from ignoring the small $1/\left(1 - v^2/{c_U}^2\right)$ factor for such situations.

The time dilation factor of the small body (compared to UIF rest) will be given by Equation (79), using $\hat{\Phi}{c_I}^2$ constant as:

$$\gamma = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{Total}}{\hat{\Phi}_U}} = \sqrt{1 + \frac{2GM}{R{c_U}^2} + \frac{v^2}{{c_U}^2}} \tag{80}$$

This equation explains the time dilation results observed in the Hafele Keating experiment (between clocks in airplanes moving in opposite directions and clocks stationary on Earth) and time dilation between GPS satellite and Earth clocks. (For low gravity and velocity, the approximation of this metric is identical to the approximation of the Schwarzschild metric).

12.3.1 GPS time dilation computation

The GPS time dilation is computed as the ratio of c_I's of Earth surface and GPS satellites. This may be written (using subscript E for Earth and G for GPS) as:

$$\gamma_{E:G} = \frac{c_U/c_{I:E}}{c_U/c_{I:G}} = \frac{c_{I:G}}{c_{I:E}} = \sqrt{\frac{1 + \frac{2GM_E}{R_G{c_U}^2} + \frac{{v_G}^2}{{c_U}^2}}{1 + \frac{2GM_E}{R_E{c_U}^2}}} \; since \; v_E \cong 0$$

Since $\frac{GM_E}{R_G}, \frac{GM_E}{R_E}, {v_G}^2 \ll {c_U}^2$, we can use the approximation:

$$\gamma_{E:G} \cong \frac{1 + \frac{GM_E}{R_G{c_U}^2} + \frac{{v_G}^2}{2{c_U}^2}}{1 + \frac{GM_E}{R_E{c_U}^2}} \cong 1 + \frac{GM_E}{R_G{c_U}^2} + \frac{{v_G}^2}{2{c_U}^2} - \frac{GM_E}{R_E{c_U}^2}$$

Substituting known values $M_E = 5.98 \times 10^{24} kg$, $R_E = 6.37 \times 10^6 m$, $R_G = 2.667 \times 10^6 m$ and $v_G = 3868 m/s$, we get the time dilation factor difference as:

$$\gamma_{E:G} - 1 = -4.473 \times 10^{-10}$$

In one day, the total time dilation between Earth clocks and GPS satellite clocks (in μs) will be:

$$Difference = -4.473 \times 10^{-10} \times 86400 \times 10^6 \cong -38 \mu s/day$$

The Earth clocks are therefore $38\mu s/day$ slower than GPS clocks. This is the time dilation computed using the Schwarzschild metric in current relativity theory, and observed in practice.

Time dilations in the Hafele-Keating experiment are computed using the same formula and give the same results as in existing theory. Important thing to note for both GPS satellites and Hafele-Keating experiment is that all velocities used are measure from a sidereal inertial frame through the CG of Earth, and not the relative velocities between the clocks being compared.

12.3.2 Simplified formula for orbital motion

If the small body is in orbit around the local massive body (with velocity $v = \sqrt{GM/R}$, the potential of the small body (compared to UIF rest) will be given by:

$$\hat{\Phi}_{Total} = \hat{\Phi}_U \left(1 + \frac{2GM}{R{c_U}^2} + \frac{v^2}{{c_U}^2}\right) = \hat{\Phi}_U \left(1 + \frac{3GM}{R{c_U}^2}\right) \; since \; v = \sqrt{\frac{GM}{R}} \tag{81}$$

The corresponding time dilation factor may be written as:

$$\gamma = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{Total}}{\hat{\Phi}_U}} = \sqrt{1 + \frac{3GM}{R{c_U}^2}} \tag{82}$$

12.4 High orbital velocity approximation ($v \sim c$)

Where $1/(1 - v^2/{c_U}^2)$ is the predominant factor in (76), as in Bailey et. al. experiment or near black holes, the approximation will become:

$$\hat{\Phi}_{Total} = \hat{\Phi}_U \left(\frac{\hat{\Phi}_M}{{c_U}^2}\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right)\right) = \hat{\Phi}_M \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right) \; since \; \hat{\Phi}_U = {c_U}^2 \tag{83}$$

In this case, the base UIF gravitational potential and UIF velocity time dilation effects are negligible, and gravitational time dilation and velocity time dilation are essentially the same thing, defined by the massive local potential.

In extreme high velocity cases like Bailey et. al. $v \cong 0.9994c_U$, as explained for Equation (73), we would get:

$$\hat{\Phi}_M \cong \hat{\Phi}_U \tag{84}$$

The time dilation factor of the small body in this case will be the Lorentz factor (using $\hat{\Phi}{c_I}^2$ constant):

$$\gamma = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{Total}}{\hat{\Phi}_U}} = \sqrt{\frac{\hat{\Phi}_{Total}}{\hat{\Phi}_M}} = \frac{1}{\sqrt{1 - v^2/{c_U}^2}} \tag{85}$$

This is the domain of Special Relativity, where the Lorentz Factor alone is sufficient to explain the observed time dilations. For other situations, Equation (76) must be used, and that is the domain of General Relativity.

13 Effect on acceleration

13.1 Acceleration in orbital motion

As we have seen, in a stable orbit, the potential created by the local acceleration must be taken into account as part of the mass (and momentum) of an orbiting small body. From Equation (69), we have the complete orbital acceleration as:

$$A = \frac{v^2}{R}\left(1 + \frac{2GM}{R{c_U}^2}\left(\frac{1}{1-\frac{v^2}{{c_U}^2}}\right) + \frac{v^2}{{c_U}^2}\right) \tag{86}$$

For orbital motion in gravitational acceleration in a low velocity situation, we may approximate this (using $v = \sqrt{GM/R}$) as:

$$A = \frac{v^2}{R}\left(1 + \frac{3GM}{R{c_U}^2}\right) \tag{87}$$

This shows us that in a planetary orbit the central gravitational acceleration is slightly greater than the classical Newtonian formulation.

The effect is usually very small for most planets in the solar system, since R is large enough for the $3GM/R{c_U}^2$ factor to be negligible compared to 1. However, in the case of Mercury this factor is significant enough to show an anomaly (compared to classical computation) observable in the planet's orbital precession. The equation from GR (an approximation from the Schwarzschild metric) used to explain this phenomenon is the same as Equation (87) above.

For extremely high orbital velocities ($v \sim c_U$), since $2GM/R \approx {c_U}^2$ the acceleration becomes:

$$A = \frac{v^2}{R}\left(\frac{1}{1-\frac{v^2}{{c_U}^2}}\right) = \gamma^2\frac{v^2}{R} \tag{88}$$

13.2 Acceleration in rectilinear transverse motion near a large mass

For unconstrained (non-orbital) transverse motion near a large mass, from the same considerations used to derive (78), we get:

$$A = \frac{GM}{R^2}\left(1 + \frac{v^2}{{c_U}^2} + \frac{\hat{\Phi}_M}{{c_U}^2}\left(\frac{{c_U}^2 + v^2 + 2c_U v cos\theta}{{c_U}^2}\right)\right) \tag{89}$$

$$\therefore A = \frac{GM}{R^2}\left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}\right)\right) \ \textit{since}\ \theta = \frac{\pi}{2} \tag{90}$$

This formula explains the doubled deviation/bending of light rays near the Sun, compared to Newtonian mechanics, as predicted by GR and proven in experiments by Eddington et. al. and others. Since the light is not in orbit around the Sun, we need to use (78). Given that the transverse velocity of the light $v = c_U$, the total acceleration becomes:

$$A = \frac{GM}{R^2}\left(1 + \frac{{c_U}^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2}\left(1 + \frac{{c_U}^2}{{c_U}^2}\right)\right) = \frac{GM}{R^2}\left(2 + \frac{4GM}{R{c_U}^2}\right) \cong \frac{2GM}{R^2} \tag{91}$$

since $4GM/R{c_U}^2 \ll 1$.

Thus the acceleration, and therefore deviation, of light near the Sun will be double the Newtonian value.

14 Hierarchy of gravitation

Till now, we have considered gravitational and velocity time dilation in situations where a small body is close to a large mass, or has a velocity in the background of the Universe gravitational potential. We have also looked at a combination of the two situations in orbital and rectilinear motion.

We need to now consider the way celestial objects are organized in the Universe in hierarchies, and how we must apply the rules in such situations.

A simplified hierarchy of celestial bodies may be represented as in Figure 6.

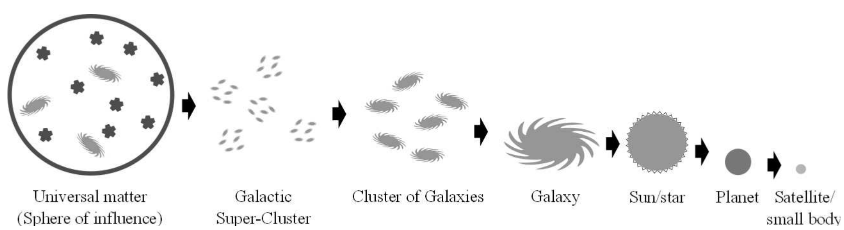

Figure 6: Simplified hierarchy of celestial objects.

Let us consider the gravitational potential and corresponding time dilations at the level of Star/Sun → Planets → Satellites. A planet revolving around a star/Sun is subjected to the gravitational potential of the star/Sun, orbital velocity in UIF, and in addition the gravitational potentials of all objects up the hierarchy. We can ignore the small contributions of other planets in the stellar/Solar system for these considerations.

This goes up the order. We may consider the star/Sun to be similarly subjected to the gravitational potential of the galaxy, and so on. What is important to note is that at each level of hierarchy, a gravitationally bound system may be treated like a single body under the influence of gravitational potential (both proximity and velocity) of the next higher level, as long as the gravitationally bound system is of significantly smaller mass than the next higher level.

Being subject to common gravitational potential of all the higher level objects equally, a gravitational system consisting of a planet and its satellites would not show any difference in energy-potential and time dilation between the different components, except for mass differences and velocities *within the gravitational system itself.* For example, when computing time dilation for GPS satellites with Earth clocks, we do not have to consider the potential of the Sun (though nearly 15 times as strong as the Earth's own in the Earth-satellite system), nor the orbital velocity of the system around the Sun. Those apply equally to the satellites and Earth. This allows us to ignore such much larger but ubiquitous potentials for analysis of time dilation within a system. What difference we see is always based on the local velocity from the Center of Gravity (i.e. a local sidereal axis centered at the CG).

Clearly, a sidereal axis through the CG of the local gravitationally bound system then acts as the local inertial reference frame (UIF), and all velocities within the system must be considered from the CG for computing respective potentials/time dilations of different objects.

This is amply verified in many experimental situations:

- This is how velocities in the Hafele-Keating experiment and GPS time dilation are computed.
- Velocities for artificial satellites that satisfy the Newtonian equation of $GM/R^2 = v^2/R$ are computed from the orientation dictated by the local sidereal axis.

The above discussion gives us a simple way to compute time dilations, both for velocity and proximity, across hierarchies.

For example, we may compute velocity time dilation difference between the Earth and the Moon by simply taking their respective sidereal velocities from the CG of the system. This cannot be done currently using existing relativity theory for bodies of comparable but unequal mass, as it is not clear how the Schwarzschild metric or Lorentz factor may be applied to such situations.

Existing SR theory allows computation of differential aging caused by velocity only in cases where one of the bodies **is orders of magnitude massive compared to the other** (such that velocity from CG is practically the velocity of the small body). It may also trivially be applied to masses **of equal magnitude** like identical binary stars, where the difference is zero. In between lies the situations that cannot be analyzed in existing SR theory, and gives rise to confusion around apparent paradoxes like the twin paradox, where it is not clear which of the two situations above should apply.

This logic can be extended further for comparing time dilations between different levels of hierarchy, e.g. between artificial satellites of Earth and any satellites of Ganymede, Jupiter's moon. Computation of comparative gravitational time dilation due to proximity is obvious, by going up to the common level of hierarchy (Sun in this case) and computing the gravitational time dilations down the hierarchy. For Earth satellites, it will be a combination of the potential of the Sun and that of the Earth, while for satellites of Ganymede we would have to consider 3 levels of Sun, Jupiter and Ganymede.

What is interesting is that the velocity time dilation may be found exactly in the same way between two such objects, as we are able to identify and isolate the gravitational (proximity) time dilation at each level, and velocity time dilation compounds exactly in the same way as proximity time dilation, being basically gravitational in nature.

15 Rotation and revolution in UIF

Without the external gravitational frame of reference (UIF), planetary bodies would not be able to revolve around one another. The Earth could not revolve around the Sun, for if the Sun did not have an externally imposed axis orientation, how could we talk about the Earth 'revolving around the Sun'? The only possible course of action for a Sun-Earth system in an otherwise empty Universe would be for them to be attracted by mutual gravity and ultimately merging together, because in such a scenario an orbital velocity is meaningless. Nor would there be any meaning to the Sun rotating around its axis.

Similarly, rotation and revolution of planets, stars and galaxies would not make sense without the gravitationally determined UIF.

Why should we bother about spatial orientation? We need to do so for an intuitive and simple understanding of motions like rotation and revolution in the larger background of the Universe, understanding the nature of time dilation in various situations, as well as phenomena such as the Sagnac effect[42, 43].

The Sagnac effect is seen experimentally on Earth in ring interferometers, and requires corrections for it in the use of GPS system. Would it be seen in deep space in a ring interferometer, far away from all other matter?

The answer would have to be 'yes'. The effect is not local to Earth or to any particular planetary body. The motion of a ring interferometer has to be seen in regard to the local

UIF sidereal axis, determined by the large potential of the Universe 'sphere of influence'.

Therefore, at any location in the Universe, there is a rest position as well as a rest orientation. Experiments and observations have shown us that this rest orientation is sidereal in nature.

16 Velocities higher than local speed of light

As we have seen, matter should be able to attain faster than light velocities. Why, then, do we not ordinarily see such phenomena, and how can it be achieved? This section discussed the reasons and the possibilities.

16.1 Why we do not see faster than light velocities

Momentum conservation dictates that the velocity of separation of interacting objects cannot exceed the velocity of approach (i.e. coefficient of restitution is $\leqslant 1$).

Therefore, stationary sources of acceleration (like magnetic forces) cannot push a particle to a velocity of c, since the energy/momentum carrying particles themselves travel at c. This is true, no matter how powerful we make particle accelerators. Thus it would be impossible to accelerate particles in accelerators to velocities $\geqslant c$.

Given that most celestial objects move slowly in regard to our Earth position, and the Universe expansion is moving most such objects away from us, any matter or energy arriving from other celestial objects is unlikely to reach us at detectably higher velocities than c.

These factors hinder us from any realistic possibility of creating or even observing superluminal speeds ordinarily in nature.

16.2 Achieving velocities higher than speed of light locally

Note that **Cherenkov radiation** is not considered faster-than-light (FTL) travel, since the velocity of the subatomic particles is lower than that of c in vacuum. This is an unwarranted conclusion.

Light (of a particular wavelength) travels at a characteristic velocity given a particular potential/energy density of a medium. No higher and no lower. As we have seen in the explanation of the Fizeau experiment, this potential can be equated to an increased UIF potential. What we call a 'medium' represents an increased potential, and even the Universe gravity provides one that determines the characteristic velocity of light in vacuum.

Therefore, if any particle can travel at higher than the speed of light in any medium, that is tantamount to FTL travel in that higher potential. This is achieved because matter and energy follow different rules of motion in increased potential, as explained in Section 10 earlier.

Can we actually achieve higher than local c (in vacuum) velocities in some way? It is certainly difficult, but not impossible. Certain possible scenarios are discussed in the next section, where we will also consider other possible experimental results which, if proven, would support the concepts and formulae developed in this paper.

17 Possibilities of FTL experiments

17.1 Intermediate velocity repetition of Bailey experiment

It may be possible to repeat experiments like Bailey et. al. at intermediate muon velocities ($v \sim 0.5 - 0.8c$) where neither the Schwarzschild metric, nor the Lorentz factor are adequate by themselves, and we need the full Equation (76). There will be a $15\% - 19\%$ **difference** between this equation and the Lorentz factor in such situations.

The difference between (76) and the Lorentz factor at very low (say $v < 0.01c$) and very high velocities (say $v > 0.99c$) is negligible as explained earlier. This is the reason that the Lorentz factor appears to work accurately at both extremely low and extremely high velocities (and all previous experiments have been conducted in one situation or the other).

This experiment will not directly prove FTL velocities, but validate Equation (76). If the muon lifetime extension result is found to be as per (76) rather than the Lorentz factor, it will lend support to the modified equation and the underlying theory developed in this paper as well.

17.2 Neutrinos generated at lower gravitational potentials

Another option is to simultaneously send beams of electromagnetic radiation and neutrinos (assuming their velocity is consistent with light) from a lower to a higher gravitational potential location (e.g. from high Earth orbit to near Earth orbit, avoiding Earth's atmosphere), and measuring whether the neutrinos arrive earlier than light. Since the neutrinos would be generated at a location of higher c, they would exceed c (even in vacuum) at the destination, as they would not undergo the Shapiro delay that light would. The concept is similar to the CERN[44] OPERA collaboration neutrino experiments done during 2011-12 except the neutrinos need to be generated at a lower gravitational potential and received at a higher gravitational potential.

[Note: Neutrinos from supernovas have been observed to arrive slightly earlier than light. Though current supernova theory has a different explanation for that, the basis of this experiment predicts this observation, since light experiences some Shapiro delay during the long journey while neutrinos do not].

17.3 Spontaneous decay of high-velocity particles

One possibility would be to accelerate an unstable particle to near c and then allow it to decay spontaneously (not via collision as in Alvager experiment), and measure the velocity of any forward moving decay products (preferably particles rather than γ-rays/energy, as that would eliminate any effect of the 'light speed invariance postulate'/'Shapiro delay'). The velocity achieved would not be anywhere near $2c$, since the internal energy velocity of the unstable particle would by then be much less, but some velocity above c should be achievable. The technical challenge may be in measuring such velocities by mapping specific source particles to their corresponding decay products.

18 Observations on celestial phenomena

18.1 Black Holes and Singularities

As we can see from the formulation of gravitational time dilation in (20), there is no singularity mandated, and no holes in the fabric of space-time. Extremely dense stellar objects can certainly form, with electron degenerate material, or even perhaps something closer to pure energy than matter. Such objects would demonstrate the properties of suspected black holes, without need for a singularity.

What is not possible is an 'event horizon'. As we see from the concepts discussed in this paper, complete stoppage of time at the event horizon is equivalent to a complete stoppage of energy, in which case even gravity could not have 'moved' outward from a black hole (leaving aside explanations like virtual particles which could apply equally well to light). Moreover, complete stoppage of energy requires infinite potential, which is also not possible. The fact that super-massive black holes appear to have an average mass density (within their Schwarzschild radius) less than that of water shows that there is refinement required to the current understanding.

According to interpretation of existing relativity theory, a free falling observer descending into a black hole would pass the event horizon (and not even notice it) in finite proper time by his clock, while an external observer will never see the free falling observer actually reach the event horizon. This also shows (based on our understanding of time and energy relationship) that the same energy must be considered completely stopped at the event horizon for the external observer, but moving for the in-falling observer, which is a physical impossibility.

The gravitational acceleration and potential of black holes are extremely large close to the center of gravity, and few things can escape such gravity. Light would be particularly affected, since the large potential near a black hole would reduce its velocity significantly because of Shapiro delay effect, and that would make it nearly impossible for light that gets close to a black hole to escape. This would make black holes appear 'black'.

Any light that has to escape from close to a black hole must in fact originate within the black hole, which obviously doesnt happen. Gravity escapes because it travels outward from the black hole, and is not similarly affected.

18.2 UIF acceleration, and gravitational repulsion

When a body has a velocity in UIF, it will have a net acceleration in the direction of travel, as bodies in front would attract more strongly and bodies behind less strongly. This is a consequence of the same net blue shift of gravity that causes potential to increase for a moving body.

This acceleration is negligible at low velocities, but can be significant when a body is traveling fast.

At a velocity higher than c, there will be 'apparent' gravitational repulsion from bodies directly behind (since their gravitation would appear to come from the direction of travel). Higher velocity implies stronger acceleration. This increased 'push' from behind is insignificant from a single mass, but half the Universe is a different story.

On the whole, all gravitational sources within the gravitational 'sphere of influence' of a small body would always assist acceleration of the small body in the direction of motion, compared to when it is at rest in UIF. At large velocities, this may provide an excellent fuel-free source of acceleration for interstellar travel.

This UIF acceleration may also at least partially explain the unbelievably large energies observed of some cosmic muons[45, 46]. At present there are no convincing explanations for the extraordinary level of energy seen in the highest energy cosmic rays. The UIF acceleration, which has never been considered till date, may well increase energies of fast particles significantly, given large distances and extended travel times.

19 Significance for Interstellar Travel

The phenomena discussed in this paper have significant implications for interstellar travel. The main ones are:

- **Practical FTL travel:** First and foremost, travel through space at higher than speed of light is possible. Even for travel at very high speeds (many times c) and significant distances (hundreds of light years), the time dilation/differential aging will not *have to* be such that millions of years would pass in an astronaut's home planet after such a journey. It would be practical to do extensive interstellar travel and exploration, without the complications of having generations of human beings pass in travel. Getting up to the high speeds required may have engineering challenges of large accelerations and fuel needs, but it is not a scientific impossibility.

- **Sustained gravity assist:** Net UIF gravitational acceleration is always in the direction of travel. It gets stronger with increasing velocity, and can be significant at large velocities. This could alleviate some of the fuel needs. Interstellar missions can partly use the Universe's own store of energy as fuel. Moreover, this would be free fall acceleration, and even large values would not affect astronauts adversely. In fact, at high velocities, braking against the large acceleration may be a possible engineering problem. Perhaps interstellar matter or stellar radiation pressure of target stars could be used for that.

- **Time dilation advantages:** The time dilation that will happen provides multiple advantages because of the relative slow down of time in a spacecraft. Years or months on the home planets could be months or days respectively on a fast spacecraft. This means carrying less provisions even for long trips (food etc.), trips not being overly long for travelers, and perhaps someday even interstellar commerce in perishables!

- **Structural strength:** The higher mass that a spacecraft obtains can be large at high velocities and provide additional structural strength, and may be an advantage against space debris and cosmic radiation.

Engineering challenges of accelerating to high velocities, collisions with interstellar matter, etc. need to be surmounted still. However, there is no scientific barrier to practical and realistic interstellar travel.

20 Conclusions

Recognizing the role of the Universe's large gravitational potential, we are able to get a much more intuitive and simple understanding of the physics of relativity. We gain the following important insights:

20.1 Physics behind time dilation

- The Universe's gravitational potential plays an active role in defining mass and energy. It provides a local inertial frame for orientation and velocity. It is not an aether, as it interacts with matter and energy and determines their properties and behavior. Though not Universal in an absolute sense, this UIF frame defines the reference frame for any given locality in the Universe.
- Both gravitational and velocity time dilation have the same physical reason behind them, i.e., gravitational potential difference, which is the necessary asymmetry for differential aging.
- Time dilation of both types can be computed based on the celestial hierarchy. For local computations, a sidereal axis through CG of the local system may be considered as UIF.

20.2 Intuitive understanding of relativity

- Space and time dimensions can be separated if the effect of the Universe's gravitational potential is taken into account for velocity time dilation.
- Velocity of light/energy changes in a very well-defined manner with gravitational potential change. This leads to time dilation between locations. Lengths and distances are fixed.
- Velocity time dilation that leads to actual measurable clock differences is neither reciprocal between observers, nor dependent on their relative velocities. Such time dilation occurs because of asymmetry of physical conditions (gravitational potential difference), cause by differential velocity with regard to local UIF sidereal axis. Gravity defines the inertial frame for velocity measurement for time dilation, rotation and revolution.
- Local energy velocity and local speed of time are essentially one and the same thing.
- Counter-intuitive concepts like 'relativity of simultaneity' and 'length contraction' are not necessary for understanding or explaining relativity.

20.3 Revised understanding of existing relativity concepts

- Speed of light is not the maximum velocity in the Universe, except for special trajectories.
- There is 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 gravitational potential variation. 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.

This paper revisits some of the assumptions and concepts underlying the current Theory of Relativity, and presents an alternative and intuitive view of the physics behind it. This includes certain corrections to existing concepts, and simplification of the mathematics.

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