Role of the Universe's Background Gravitational Potential in Relativity Concepts

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February 10, 2014

Abstract

This paper reconciles General Relativity (GR) and Mach's Principle into a consistent, simple and intuitive alternative theory of gravitation. The background gravitational potential from the Universe's matter distribution plays an important role in relativity. This potential far from massive bodies is c^2, and determines *unit* rest mass/energy, which is the essence behind $E = mc^2$. The matter distribution creates a local inertial rest frame at every location, in which the Universe gravitational potential is a minimum. A velocity in this frame increases gravitational potential through net blue shift of Universal gravity, causing velocity time dilation, which is a gravitational effect identical to gravitational time dilation. Time dilation increases with velocity, but does not become boundless in general rectilinear motion. The Lorentz factor is the appropriate metric for time dilation only in certain constrained motions. The low velocity approximation of the Lorentz factor scales for all velocities in general rectilinear motion, and speed of light is not the maximum possible speed in such situations. Gravitational time dilation is derived first, and velocity time dilation is derived from it. The mathematics becomes simpler and more intuitive than GR, while remaining consistent with existing experiments. Some experiments are suggested that will show this theory to be more accurate than GR.

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

PACS: 03.30.+p; 04.25.D-; 04.50.-h; 04.50.Kd

1 Introduction

This paper reconciles the General Theory of Relativity (GR)[1] and Mach's Principle to create an intuitive and simple alternative theory of gravitation.

The Universe has a large background gravitational potential at every point in space, created by its homogeneous and isotropic matter distribution. The magnitude of this potential far from large masses is c^2, and it plays an important role in relativity, especially in the concepts of *rest*

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mass/energy and *velocity (Special Relativity(SR))*[2] *time dilation.* An understanding of this allows us to obtain a much deeper insight into relativity concepts, and correct certain misconceptions.

While the existing predictions and experimental proofs of General Relativity remain valid, we achieve the following understanding from the theory in this paper:

- *Local constancy* of speed of light (c) is physically explained, and need not be a postulate
- *Velocity time dilation* is the same phenomenon as *gravitational time dilation*[3, 4], caused by differential gravitational potential. The former is caused by a velocity-induced blue-shift of Universal gravity, while the latter by relative proximity to large masses
- *Time dilation* or *differential aging* is a simple manifestation of the *relative difference between local energy speeds* (c) at different locations
- *Space* and *Time dimensions* can be separated, and all relativistic physical phenomena may be easily and intuitively described without having to resort to mathematical interpretations
- *Matter*, which can travel slower than speed of light, *can also travel faster than* c, excepting certain specific circumstances (though speeds $\geq c$ cannot be achieved in particle accelerators, where the *force-carrier particles* themselves travel at c)
- Relativity provides many advantages for making realistic interstellar exploration feasible

These conclusions will be reached based on the following principles and concepts:

- *Unit rest energy* of matter is identical to the Universe background gravitational potential (c^2). *Mass* (amount of inertia) of matter increases with velocity (relativistic mass), and by extension, also with increase of magnitude of gravitational potential (since it is equivalent to a velocity as shown in Einstein's derivation of GR). Therefore, *mass* is a gravitational phenomenon, and the Universe gravitational potential accounts for the *unit mass* of matter at rest (i.e. *unit rest mass*)
- Gravity from the Universe's mass distribution creates a *preferred rest frame* at every location in space. We will refer to this as the Universe Inertial Reference Frame (UIF). This frame is sidereal (i.e. does not rotate with regard to distant stars) and local, and not a universally static reference frame like an *ether*
- *Total gravitational potential* at a location (including Universe's background potential) determines the speed of all energy (not just light) at that location. This is an inverse relationship. A larger magnitude of gravitational potential results in a lower energy speed
- The speed of physical processes, from *sub-atomic* to *observable events*, is determined by local speed of energy. *Time dilation* or *differential aging* reflects the difference of energy speed between locations, which results in proportionate but different spacing between an otherwise identical sequence of events (process)

- Velocity of a body in the UIF results in a net blue-shift of Universal gravity, increasing the magnitude of gravitational potential the body experiences. This causes energy within the body to slow down, resulting in velocity time dilation

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

The concepts of 'length contraction' and 'relativity of simultaneity' are not required in this theory, and should not be applied to judge the logic in this paper.

Some new experiments are suggested where the results will differ from existing Relativity Theory.

2 Motivation behind this paper

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

There are good reasons to consider an alternative theory:

- Inseparability of space and time dimensions in GR creates a perception that physical laws of the Universe are so strange that we *cannot* use our intuition to understand them. This need not be so, as the more natural explanations of relativity phenomena in this paper will show. A more intuitive understanding of relativity will help develop this fundamental area of physics further

- Interpretation of physical phenomena only through mathematical models in GR has led to certain unwarranted conclusions about laws of physics (e.g. light speed as a *universal* speed limit)

- A fundamental quantity like 'mass' does not have one consistent definition within GR

- Velocities that satisfy equations of motion (Newtonian or relativistic) need to be measured from *sidereal frames* in practice (e.g. satellite velocities, Hafele-Keating experiment[5, 6]). This shows a rest frame *orientation* imposed by Universe's background gravity, which is not established in GR

- Local constancy of light speed is a *postulate* (Principle of Invariance) in existing theory. Understanding the physical principles behind this postulate will further scientific research. Not only do we establish that matter can travel faster than c, relativity provides many advantages that will encourage research on practical interstellar exploration

- An intuitive theory of gravitation will facilitate the development of a quantum theory of gravity

Apart from this, there are questions and contradictions that do not have satisfactory resolutions within GR. Examples include:

- An in-falling observer into a black hole can cross the event horizon in finite time by her/his clock, but never even reach the event horizon according to an outside observer's clock. This implies there is a time by the clock of the in-falling observer that has no equivalent clock reading for the external observer, no matter how long (s)he waits

- The *singularity* at the center of a black hole defies any definition within GR

- Bailey et. al. experiment[7] (muon lifetime extension) may be considered as orbital free fall under central 'gravitational' acceleration. Lifetimes are compared between (a) muons in an inertial frame, and (b) muons in a strongly accelerated frame (and therefore in a massive 'gravitational' potential by equivalence principle). Why is the time dilation then given only by the Lorentz factor, instead of the Schwarzschild metric[8, 9] (used for GPS satellites[10])? (The Earth's gravitational potential is unimportant here, as the acceleration in the muon ring sets up a much more massive 'gravitational' potential)

Much of this will become clear based on the simple principles established in this paper, and we will obtain a much better understanding of how relativity applies to our Universe.

3 Meaning and usage of specific terms

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

- **Time dilation/Differential Aging:** The term 'time dilation' is used interchangeably with 'differential aging', not including any *coordinate/observer dependent* reciprocal time dilation from Doppler effects. 'Time dilation'/ 'differential aging' terms will stand for the *invariant* difference of clock rates at different locations/velocities (experimentally measurable clock drift)

- **Gravitational potential:** A 'higher' or 'increased' gravitational potential implies an increase in magnitude of potential, as when closer to a large mass. Gravitational potential is treated as a positive energy quantity per unit mass, and not negative as often considered by convention.

- **Location:** Since there is no absolute location in space, the term 'location' in this paper, in general, signifies a small *material body and its immediate surroundings*, which may be assumed to be at a *uniform gravitational potential (i.e. 'local')*. Since bodies may have different velocities, two 'locations' need not be at rest with respect to each other

- **Propagation Speed of light/energy:** Speed of light/energy from source

- **Total speed of light/energy:** Speed of light in UIF (*speed of source+propagation speed*)

- **Local:** What is 'local' depends on the accuracy of measurement desired for considering a location to have a uniform gravitational potential. Higher the measurement accuracy, smaller the volume of space that may be considered 'local'

4 Difference in derivation from existing Relativity Theory

The main differences in derivation of this theory compared to existing theory are noted below.

Gravitational potential difference is the sole cause of time dilation. *Gravitational time dilation* is caused by differential proximity from large masses, while *velocity (SR) time dilation* is caused by velocity-induced blue shift of Universal background gravity (which increases the background gravitational potential).

In this paper, *gravitational time dilation* is derived first, and *velocity time dilation* from it. In existing theory, GR is derived based on SR by generalization to accelerated frames of reference, with *gravitational potential difference* derived as being equivalent to a *velocity difference* between bodies.

The issue with deriving *velocity time dilation* without gravitational considerations is that concepts like 'length contraction' (a *directional* artifact) and 'relativity of simultaneity' (observer dependency) need to be introduced to first create a consistent theory of velocity time dilation (SR). When this is later used to derive gravitational time dilation in GR, these counterintuitive concepts get carried over.

We will first derive *gravitational time dilation* as a manifestation of uniform *change of local energy speed* equally in all spatial dimensions, caused by a *change in gravitational potential.* Such a change in local energy speed determines the speed of local physical processes, and therefore the spacing of events (i.e. time).

Velocity *increases gravitational potential* through a blue-shift of Universe background gravity, causing *velocity time dilation*, which is essentially gravitational time dilation caused by a different mechanism. No additional concepts are required, and *we do not need 'length contraction' and 'relativity of simultaneity'* in this paper. The mathematics and understanding gets much simpler.

5 Explanation of the *Principle of Invariance of c* postulate

Postulate: *The speed of light in free space has the same value c in all inertial frames of reference.*
Explanation: Two different phenomena together make c a local constant in all experiments:

- *Speed of energy* at a location determines the *pace of local physical processes*, including local clock-tick rates, which in turn are used to measure the local speed of light (energy), leading to a numerical constant 'c' ($299,792,458m/s$). Any change of gravitational potential at the location causes both *speed of light* and *speed of physical processes (including clocks)* to change equally, such that the change of c cannot be detected locally

- *Velocity of a light source* causes a change of gravitational potential (Doppler shift of background gravity), resulting in a corresponding change of light *propagation speed* which compensates for source velocity almost exactly, to a very high degree of accuracy. A source velocity (in UIF) of $1m/s$ has an impact of $< 4 \times 10^{-18} m/s$ on the *total speed of light.* The mathematical derivation will be shown when discussing the de Sitter double star experiment[11, 12].

6 Role of the Universe's gravitational potential

The background gravity of the Universe creates the local reference frame for velocities, and defines the rest mass of objects. These phenomena need to be well understood to obtain a clear understanding of the physics behind relativity concepts.

6.1 The local Universe Inertial Reference Frame (UIF)

The background gravitational potential of the Universe is overwhelmingly larger at any location than that of single celestial objects. For example on Earth's surface, the Sun's gravitational potential on the surface of Earth ($900MJ/kg$) is 15 times that of the Earth's own ($60MJ/kg$), that of the Milky Way galaxy ($\geq 130GJ/kg$) is over 2000 times, and even the distant Andromeda galaxy's potential is 7 times. Still, all these are insignificant compared to the background gravitational potential of c^2 ($9 \times 10^7 GJ/kg$).

Gravity from the Universe's mass distribution creates a *preferred rest frame* at every location in space, which gives meaning to velocity and orientation. This is a *sidereal* frame (i.e. does not rotate with respect to fixed stars). We will refer to this 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[13], and there is no rotation in regard to the distant objects.

This is not a universally static reference frame like an *ether*. Far from all large masses, this rest frame is static with regard to the distant matter of the Universe (i.e. fixed stars). Presence of massive bodies influences the nature of this rest frame. Empirical evidence shows that the rest frame coincides with the Center of Gravity (CG) of a body or a gravitationally bound system in free fall, though the sidereal nature remains. This is evident from the below facts.

Velocities that satisfy orbital equations ($v = \sqrt{GM/R}$) are *measured from sidereal frames* in practice. For example, satellite orbital velocities, and velocity of planets around stars are all measured from a sidereal axis through the CG of the local gravitational system. Even velocities of planes in Hafele-Keating (H-K) experiment have to be measured from a sidereal axis through Earth's CG, for relativistic time dilation computations of GR to match experimental results. The velocities of the westbound planes in H-K are effectively a *reduction in velocity*, since the velocities used in relativity computations need to take into account the Earth's rotational velocity around the CG sidereal axis.

The reason the CG of a single body or a gravitationally bound system largely coincides with the local rest frame is that matter drags the gravitational energy associated with it. That is why we can analyze an independent gravitational system in free fall based on potentials and velocities *within the system alone*, for time dilation computations. For example, to compute time dilation of GPS clocks, we do not need to consider the gravitational potential of the Sun or the orbital velocity of Earth, even though they are much larger than the potential and velocity within the Earth-GPS system.

The apparent ***absence of any preferred frame***, as postulated in SR and considered proven to high accuracy in experiments like Hughes-Drever[14, 15], is created by two facts:

- The large size of the background potential overwhelms any small anisotropy of mass or space created by local masses, making it harder to detect
- The preferred rest frame's coincidence with the CG of Earth precludes detection of such a preferred frame in Earth-based experiments. The experiments therefore show strong agreement with local Lorentz Invariance (LLI) and the *Principle of Relativity*

Planetary bodies are able to revolve around one another only because of the *sidereal orientation* of the externally imposed UIF. Same holds for rotation.

The Sagnac effect[16, 17] is seen experimentally on Earth in ring interferometers, and requires corrections for it in the use of GPS system. This effect would be seen even in deep space far from all masses. The effect is not local to Earth or to any particular planetary body. This further shows the role the UIF plays in relativity phenomena.

6.2 Rest mass/energy and inertia

Unit rest energy of matter is defined by and identical to the Universe background gravitational potential far from all massive bodies (c^2).

From SR, we know that *mass* (amount of inertia) and *energy* of matter increase with velocity (relativistic mass). By extension, mass must also increase with a higher magnitude of gravitational potential, since it is equivalent to a velocity as shown in Einstein's derivation of GR.

Since mass increases with gravitational potential, it must be a gravitational phenomenon. Therefore the Universe background potential must account for the *unit mass* of matter at rest (i.e. *unit rest mass*) as postulated in Mach's Principle.

By mass-energy equivalence, the *unit rest energy* of matter must then be c^2, as per the equation $E = mc^2$, m being *unity.*

If γ stands for the *unit mass* of matter (at an arbitrary velocity and potential) and m_0 stands for the *amount of matter* in a body, then γm_0 always represents the total mass (m) of the body. At rest we have $\gamma = 1$, and *unit mass* is the same as *unit rest mass.* The total energy of the body will be given by the equation $E = \gamma m_0 c^2 = mc^2$. At rest, *amount of matter* (m_0) and *rest mass* (γm_0,with $\gamma = 1$) are numerically identical, and the energy equation becomes $E = m_0 c^2 = mc^2$.

A velocity in UIF, or an increase in gravitational potential raises the *unit mass* (γ), resulting in what we call *relativistic* mass. This is in fact just the increase of potential (unit energy), which increases the *unit amount of inertia*, without any change of the *amount of matter.*

The *total gravitational potential* at a location is the sum of the Universe gravitational potential (including any velocity-induced increase) and the potential of any proximal large bodies.

Analogy of inertia: A somewhat crude analogy helps understand how gravity causes inertia. Consider a small body at rest, with numerous invisible stretched strings pulling it 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, this is not a complete analogy for gravitation, but serves to demonstrate the principle.

6.3 Coordinate time and clock

A body *at rest in UIF* at a location *far from all massive bodies* will experience the lowest possible gravitational potential in the Universe. Any velocity or proximity to large masses would increase gravitational potential and slow down energy/time.

Therefore the speed of light/energy (and time) at such a location is the highest possible in the Universe. This is *coordinate time*, since this is the best approximation to infinity we can have in the real Universe.

A clock at rest in such a location will be referred to as the *coordinate clock*.

6.4 Speed of light/energy received by moving objects

We have observed that speed of light/energy emitted from a source at rest in UIF is c_U. Even if the source has a velocity, it does not affect the *total speed* of such light/energy, though red-/blue-shifts will be observed by a distant observer stationary in UIF. This applies to all energy, including gravity.

However, when a body moving in UIF *receives* such energy (including gravity) from another source, the velocity of that would not be c_U, but the relative velocity as computed using the receiving body's velocity and c_U.

If the body is moving at a velocity of v (by coordinate clock) towards or away from the source, the velocity at which such energy/gravity would be received would be $c_U + v$ and $c_U - v$ respectively. For transverse motion, it will be $\sqrt{c_U{}^2 + v^2}$.

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

7 Time dilation and speed of light/energy

7.1 A definition of time

We can think of *time* as a *relative spacing between observable events*, with an arbitrary amount of spacing defined as the unit (like a 'second').

Observable events (like the tick of a clock, or radioactive disintegration of atomic nuclei) are outcome of processes that are fundamentally driven by movement of energy, which also drives the movement of matter. Without the presence and movement of energy and matter, time has no meaning.

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.

Consider an atom. Electrons are moving in orbits around the nuclei. This happens because of constant interaction of the electrons with intra-atomic energy, as otherwise they would have travelled in a straight line and left the atom. It is the movement of energy at this fundamental level that determines the pace of events, e.g. the number of electron transitions per second.

Locally, speed of energy is always c, and this is true of all energy which drive processes within an atom. When we look at an assembly of atoms, e.g. a spring wound up within a mechanical clock, the unwinding of the clock spring happens at a certain rate, again driven by movement of energy within the assembly of atoms. This is also driven by the speed of energy. This argument can be extended all the way to macro or observable events at a location.

7.2 Time dilation

When an increased gravitational potential is applied to a location (say X), the speed of energy/light slows down (according to a coordinate clock) uniformly within and outside the atoms. This is locally undetectable, as the standard processes measuring the local process rate (or time), e.g. the unwinding spring within a mechanical clock or the light ray in a light clock, also slows down in the same proportion as all other energy.

However, as measured by clocks at a different location (say Y) where gravitational potential is unchanged (e.g. coordinate clock), all processes at X would have slowed down, which in essence is a slowdown of time speed at X (as per the clock at Y). The difference of time passage rates between X and Y is *time dilation/differential aging.*

This is why 'proper time' between two events may be different for two observers, as their relative gravitational potentials may dictate different clock tick-rates.

Even though speed of time varies from location to location, every *instant* in time by a clock at one location can be mapped to a corresponding specific instant in time by a clock at any other location in the Universe, no matter the potential or velocity differences between them.

Relativity of simultaneity is therefore not necessary in this theory.

7.3 Coordinate and local speeds of light

While speed of light is always locally c, it varies between locations. For time dilation computations, we need to compare local speeds of light/energy across locations. We will need suitable notations for this.

We will denote the **speed of light/energy in vacuum**, far from all massive objects, **as** c_U. This is the coordinate speed of light in the UIF, and has the value $c = 299,792,458 m/s$ by a *coordinate clock*. 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). This has a value $c = 299,792,458 m/s$ by a *local clock*, but a value $< 299,792,458 m/s$ by a *coordinate clock*.

For two locations A and B at different gravitational potentials, we can state:

$$\frac{T_A}{c_A} = \frac{T_B}{c_B} \tag{1}$$

where

$T_A, T_B =$ rate of passage of time at A and B respectively (as per coordinate clock)
$c_A, c_B =$ speed of energy (c_I) at A and B respectively (as per coordinate clock)

Local rate of passage of time and local speed of energy are inversely proportional to the elapsed local time, therefore:

$$\frac{T_A}{T_B} = \frac{c_A}{c_B} = \frac{\Delta T_B}{\Delta T_A} \tag{2}$$

where $\Delta T_A, \Delta T_B =$ a period of coordinate time as measured at A and B (by local clocks)

The *total gravitational potential* at either location is completely determined by the UIF potential including any velocity-induced increase, and potential created by any large bodies in proximity.

Therefore, we do not need the concept of *length contraction* to justify velocity time dilation. Time dilation is not a direction specific phenomenon. *Dimensions of or spacing between objects do not have to be considered changed* because of velocity or gravity, since the total gravitational potential associated with a body determines entirely the energy speed within the body equally in all directions.

Consistency between views of different observers for the same phenomenon is preserved without length contraction, as observers with greater time dilation would naturally consider *all external velocities to be higher* than observers with lesser time dilation. For example, cosmic muons[18] show some lifetime extension, without which they would not be reaching 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, its *seconds* being much longer than Earth surface seconds. A muon will consider itself traveling at a much higher velocity than someone on Earth would, given the same distance being travelled in less number of seconds.

8 Separation of *Space* and *Time* dimensions

Since local time passage rate is a function of local energy speed, we can separate *Space* from *Time* dimensions.

Instantaneous location of objects in space can be completely determined using the three dimensions of space from an arbitrary reference point. Time passage rate at these locations may be different, giving rise to disparity between local clock readings across locations for the same set of events. However, the readings can always be mapped to a coordinate clock, and observers at any location can determine the unique readings of local clocks at all other locations for an event, given gravitational potentials and UIF velocities of all objects are known.

Time is therefore a *local* dimension, and the difference of *speed of time* between two locations is a matter of scale. The locations themselves are determined by the three spatial dimensions alone.

Instantaneous location of objects in space can be completely determined using the three dimensions of space from an arbitrary reference point. Time passage rate at the locations of the objects may be different, and may have different values according to local clocks at any of the objects, providing different readings for any event. However, the readings can always be mapped to a coordinate clock, and observers at any location can determine the unique readings of clocks at all other locations for an event, given the gravitational potentials and UIF velocities of all objects are known.

At each location, speed of light will still be the same numerical constant c by local clocks.

Simultaneity of events, or the lack of it, is as an absolute fact between spatially separated locations.

9 Gravitational potential of energy vs. matter

The *gravitational potential of light/energy*, traveling transverse to a large body of mass M, is *twice* the potential of stationary matter, since the gravitational force is twice the Newtonian value, as shown in experiments by Eddington et. al.[19] and others[20, 21, 22, 23]. 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, as per the relative velocity equation $\sqrt{{c_U}^2 + v^2}$, with ($v = c_U$ for light).

We will shortly see that this is true of energy traveling in *any direction in the UIF* as well. This also applies to energy which is part of matter, even if the matter itself is at rest.

This is an important distinction, as *time dilation computations* depend on the gravitational potential, and therefore *speed*, *of energy* within and outside matter, and not directly on the speed of matter itself (which only modifies the UIF potential).

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'.

The total gravitational *energy-potential* contribution of a single large body of mass M, at a location at distance R from the CG, is given by:

$$\hat{\Phi}_M = 2\Phi_M = \frac{2GM}{R} \tag{3}$$

We will see this is why the terms $2GM/Rc^2$ and v^2/c^2 frequently appear in relativity equations of time dilation, rather than the Newtonian equivalents GM/Rc^2 and $(1/2)\, v^2/c^2$. These are ratios of *local large body potential* or *velocity-induced UIF potential increase* of **energy** ($2GM/R$ and v^2 respectively) to the *Universe background gravitational potential* (c^2).

10 Quantifying Universe's gravitational potential

Not all matter in the Universe affects the gravitational potential at a location. Only matter within the Hubble[24] sphere of the location does.

Gravitational potential contribution of farther away spherical layers of matter around the location is greater, since gravitational potential ($\sim M/R$) would grow with increasing R, as M grows $\sim R^2$. However, this is tempered by increasingly larger gravitational red shifts because of Universal expansion.

Whatever the red shift though, all gravitational energy reaches the location under consideration at c_U, as extinction[25] will ensure this, no matter the away velocities of the distant gravity sources.

The total gravitational *energy-potential* contribution of a single body of mass M, at a distance R, moving radially away from the center of the Hubble sphere 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 $(6.6738410^{-11} m^3 kg^{-1} s^{-2})$

The term $((c_U - v)/c_U)^2$ accounts for reduction of energy from a retreating gravity source, since energy is proportional to square of the relative velocity as shown earlier.

Considering all bodies within the Hubble sphere, the total energy-potential at a location far from all massive bodies is:

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

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
$M_i =$ 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:

$$\hat{\Phi}_U = \sum_{i=1}^{i=n} \frac{2GM'_i}{R_i} \tag{6}$$

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 *unit rest energy* at this location, this is equal to *energy per unit mass* as per $E/m = c^2$, so we have:

$$\hat{\Phi}_U = \sum_{i=1}^{i=n} \frac{2GM'_i}{R_i} = {c_U}^2 \tag{7}$$

One important point to note is that '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 in this paper. Gravity is truly a property of spacetime than of matter, as understood in current relativity theory.

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

The inverse relationship between *gravitational potential* and *energy speed* turns out to be the constant (*gravitational potential*) $\times$ (*local energy speed*)^2 or $\hat{\Phi} \times {c_I}^2$. 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 (a lightly packed body X) of mass M in spherical symmetry with radius r. The gravitational energy-potential created by X at a point P at a distance R from the center of gravity (CG) of X is $2GM/R$.

If we now compressed X to create 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 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.

The situation is depicted in Figure 1. Since no additional gravity is flowing into that volume of space, such a gravitational potential increase is equivalent to *creation of energy* from nothing. This is, of course, impossible. Potential at P must remain the same before and after compaction of X. How would that happen?

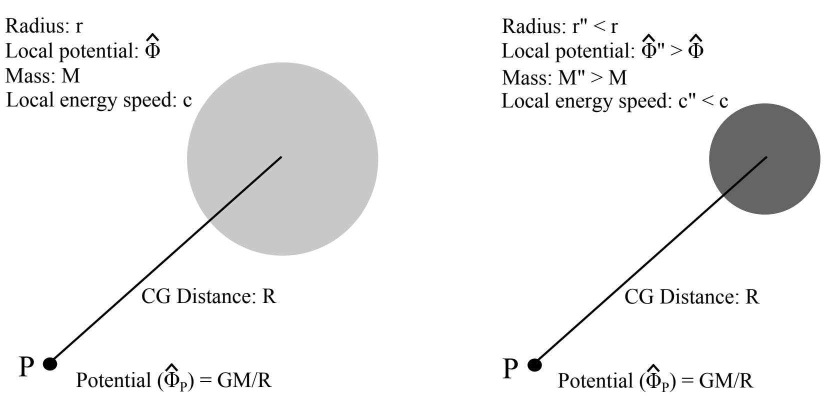

Figure 1: Potential at a distance when a body is compressed.

As potential increases at a location, local energy speed is reduced. Since, nothing else has changed, the mass 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.*

The local energy speed 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 earlier 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). Variation of the value of c is generally very small even across locations, and therefore this factor remains hidden within the gravitational constant G.

We define a reduced Gravitational Constant $\cancel{G} = G/c^2$. 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:

$$\hat{\Phi}_P = \frac{2\cancel{G}M}{R}c^2 \tag{8}$$

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:

$$\hat{\Phi}_P = \frac{2\cancel{G}M''}{R}c''^2 \tag{9}$$

Equating the RHS of (8) and (9), we derive:

$$Mc^2 = M''c''^2 \tag{10}$$

Mass of the *same amount of matter* is proportional to the *energy-potential* (i.e. $M = M_0(\hat{\phi}/{c_U}^2)$ and $M'' = M_0(\hat{\phi}''/{c_U}^2)$ where M_0 is the amount of matter), so we can derive:

$$\hat{\Phi}c^2 = \hat{\Phi}''c''^2 \tag{11}$$

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.

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 (11) 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.:

$$\hat{\Phi}{c_I}^2 = constant \tag{12}$$

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

$$\hat{\Phi}{c_I}^2 = \hat{\Phi}_U{c_U}^2 \tag{13}$$

This is important for understanding a lot of phenomena in relativity, like time dilation computations.

Since this relationship is true for *energy per unit mass*, it is valid even when the amount of gravity absorbed/emitted per unit time changes, as would be the case when a body obtains higher velocity in UIF.

12 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.

12.1 Potential of a nearby large body

The *energy-potential* of a large body of mass M at a distance R is given by:

$$\hat{\Phi}_M = \frac{2GM}{R} \tag{14}$$

The base gravitational potential of the Universe has been established earlier as $\hat{\Phi}_U = {c_U}^2$. The *total gravitational potential* at a location at a distance R from M would be:

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

There are several things to be noted from this derivation:

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

$$\hat{\Phi}_{Total}{c_I}^2 = \hat{\Phi}_U{c_U}^2 \tag{16}$$

- We can derive the *gravitational time dilation factor* γ_g from (2) and (16), 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:

$$\gamma_g = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{Total}}{\hat{\Phi}_U}} = \sqrt{1 + \frac{2GM}{R{c_U}^2}} = \frac{T_U}{T_I} = \frac{\Delta T_I}{\Delta T_U} \tag{17}$$

  where

  $T_U =$ rate of passage of time far from all masses by a coordinate clock

  $T_I =$ rate of passage of time at the location under consideration by a coordinate clock

- If $\frac{2GM}{R} \ll {c_U}^2$ (practically true for most situations) we may use the approximation:

$$\gamma_g = \frac{\Delta T_I}{\Delta T_U} \cong \left(1 + \frac{GM}{R{c_U}^2}\right) \tag{18}$$

This is the same as the low-gravity approximation from current relativity theory.

We will use the notation γ for both *gravitational* and *velocity* time dilation factors, as they are essentially the same thing.

12.2 Gravitational time dilation

Gravitational Time Dilation can be explained and quantified 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 speeds T compared to coordinate time) can be found (using (2) and (18)) as:

$$c_U = c_{I:A}\left(1 + \frac{GM}{R_A {c_U}^2}\right) = c_{I:B}\left(1 + \frac{GM}{R_B {c_U}^2}\right) \tag{19}$$

$$\therefore \frac{c_{I:A}}{c_{I:B}} = \frac{1 + \frac{GM}{R_B {c_U}^2}}{1 + \frac{GM}{R_A {c_U}^2}} = \frac{T_A}{T_B} = \frac{\Delta T_B}{\Delta T_A} = \frac{\lambda_A \nu_A}{\lambda_B \nu_B} \cong 1 + \frac{GM}{R_B {c_U}^2} - \frac{GM}{R_A {c_U}^2} \; when \; \frac{GM}{R} \ll {c_U}^2 \tag{20}$$

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

Gravitational time dilation is this ratio of local energy/time speeds (by coordinate clocks) between two locations. The above formula has been proven in Hafele-Keating experiment and GPS time dilation.

The reduction of speed of light associated with gravitational time dilation near massive bodies has been demonstrated by the Shapiro Delay[26, 27] effect (radar signals passing near a massive body travel slower than they would in its absence).

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.

12.3 Red-shift of sunlight

Red-shift of Sunlight, or gravitational red-shift, as predicted by Einstein and experimentally proven later[28, 29, 30, 31] depends on local light speed c_I at two locations - Sun surface and Earth surface. Light/energy speed at the Sun surface is slightly lower than that on Earth surface, because of the Sun's higher surface potential on its surface. Any light leaving atoms on Sun's surface would be doing so at a slightly lower rate, or 'frequency' (according to Earth clocks, which have slightly shorter seconds).

Light from the Sun attains a higher velocity during travel to Earth, as gravitational potential decreases. The wavelength gets stretched a bit (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 (20) 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:

$$\frac{c_{I:E}}{c_{I:S}} = \frac{\lambda_E \nu_E}{\lambda_S \nu_S} = \frac{\lambda_E}{\lambda_S} = \frac{1 + \frac{GM_S}{R_S {c_U}^2}}{1 + \frac{GM_S}{S_{S:E} {c_U}^2} + \frac{GM_E}{R_E {c_U}^2}} \tag{21}$$

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:

$$\frac{\lambda_E}{\lambda_S} = 1 + \frac{GM_S}{R_S{c_U}^2} \tag{22}$$

$$\therefore RedShift = \frac{\lambda_E - \lambda_S}{\lambda_S} = \frac{GM_S}{R_S{c_U}^2} = 2 \times 10^{-6} \tag{23}$$

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

13 Effect of velocity on gravitational potential

This section develops a mathematical model for the gravitational potential increase from velocity.

13.1 Potential increase from a velocity in UIF

When a body has a velocity v in UIF, the Doppler effect on gravitational energy 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.

The body is at the center of its Hubble sphere. At rest, gravitational energy is received from all directions radially in equal quantities at uniform speed c_U, as in Figure 2.

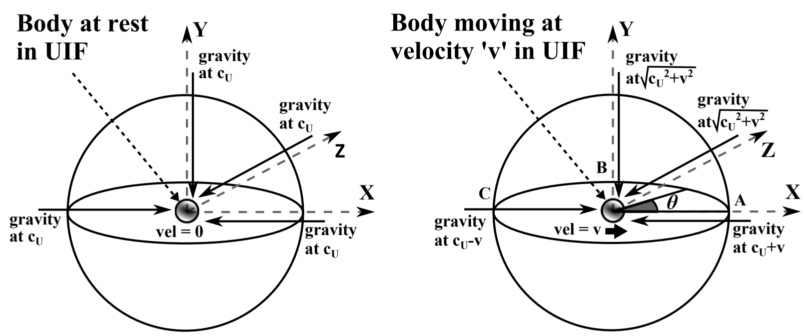

Figure 2: Universe background gravitational potential change with velocity.

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.

The gravitational acceleration and potential are dependent on the square of the incident velocity. We need to integrate over the entire sphere to see the overall change in gravitational potential. However, by reason of symmetry, we obtain the same results by integrating along the semicircle ABC in the Figure 2.

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

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

$$\hat{\Phi}_U \frac{{c_U}^2 + v^2 + 2c_U v \cos\theta}{{c_U}^2} \times \frac{d\theta}{\pi} \tag{24}$$

The total potential at velocity v ($\hat{\Phi}_{U,v}$) is given by integrating over θ from 0 to π as:

$$\hat{\Phi}_{U,v} = \int_0^{\pi} \hat{\Phi}_U \frac{{c_U}^2 + v^2 + 2c_U v\cos\theta}{{c_U}^2} \times \frac{d\theta}{\pi} \tag{25}$$

$$\therefore \hat{\Phi}_{U,v} = \frac{1}{\pi}\frac{\hat{\Phi}_U}{{c_U}^2}\left[{c_U}^2\theta + v^2\theta - 2c_U v\sin\theta\right]_0^{\pi} = \frac{\hat{\Phi}_U}{{c_U}^2}\left({c_U}^2 + v^2\right) = \hat{\Phi}_U\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{26}$$

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

$$\hat{\Phi}_{U,v} = {c_U}^2\left(1 + \frac{v^2}{{c_U}^2}\right) = {c_U}^2 + v^2 = \hat{\Phi}_U + v^2 \tag{27}$$

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

13.2 Velocity time dilation

Since $\hat{\Phi}{c_I}^2$ is a constant for a body, we get the time dilation factor (γ) from (27) as:

$$\hat{\Phi}_{U,v}{c_I}^2 = \hat{\Phi}_U{c_U}^2 \tag{28}$$

$$\therefore \gamma = \frac{c_U}{c_I} = \sqrt{\frac{\hat{\Phi}_{U,v}}{\hat{\Phi}_U}} = \sqrt{1 + \frac{v^2}{{c_U}^2}} \tag{29}$$

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

$$\therefore \gamma = \frac{c_U}{c_I} \cong \left(1 + \frac{v^2}{2{c_U}^2}\right) \tag{30}$$

A velocity v in UIF increases the background gravitational potential to $c^2 + v^2$ or $c^2\left(1 + v^2/c^2\right)$. This causes the local energy speed of the traveling body to be correspondingly reduced by a factor of $\sqrt{1 + v^2/c^2}$, causing *velocity time dilation.* Even small velocities cause time dilations comparable to gravitational time dilation near a large body, as the Universe's potential is very large.

This understanding of velocity time dilation provides the necessary condition of physical asymmetry between clocks where actual differential clock rates are seen in experiments, such as Hafele-Keating and GPS satellites. For such Earth-based experiments, the UIF rest frame coincides with the CG of Earth, and all velocities are computed from a sidereal frame through the CG.

13.3 Maximum velocity of objects

This metric $\sqrt{1 + v^2/c_U{}^2}$ in (29) 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 $(1 + v^2/2c_U{}^2)$, and are equally applicable to low velocity relativity experiments.

When we derive the Lorentz factor later, we will see that it applies only in cases of *orbital motion* when a *local 'gravitational' potential* is much larger than the *UIF potential.*

For unconstrained motion in UIF, the metric $\sqrt{1 + v^2/c_U{}^2}$ applies for all velocities, which shows that while time dilation does increase with velocity, c is not 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.

14 Effect of gravity on light

14.1 Motion of energy vs. matter

Increased gravitational potential caused by a velocity reduces the speed of energy within matter, but *does not affect motion of matter itself.* Movement of a body's CG is unaffected.

The effect is different for light, as the *slowdown* of speed of light (propagation speed) because of higher potential occurs *in the direction of movement of light.* This is Shapiro delay.

Gravitational potential (energy density) completely determines the speed of light (in vacuum) at a location, and light cannot travel *higher* or *lower* than c.

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 3. Recognizing this difference is the first step in understanding why the *source velocity independence* of light works.

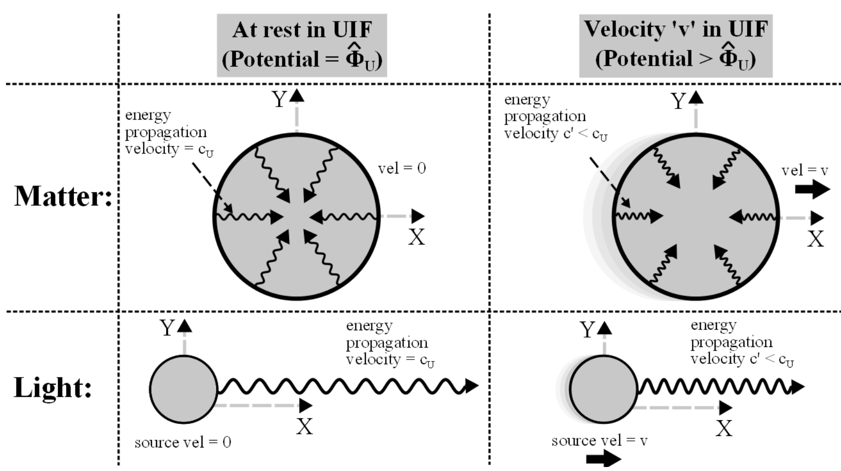

Figure 3: Time dilation of matter and light.

Light has a characteristic velocity in a given potential but matter does not. While 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 at any velocity, while light always travels at the local c. Matter can also travel faster than light under certain circumstances, as seen in Cherenkov effect[32]. We will see later that matter can travel faster than light even in vacuum, as the principles are the same.

14.2 Potential of light/energy

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:

$$\Phi_U = \sum_{i=1}^{i=n} \frac{GM'_i}{R_i} \tag{31}$$

using the same conventions as earlier.

Noting that light is not stationary but is always moving at c_U, we can compute the potential for such light using (26) with $v = c_U$ as:

$$\hat{\Phi}_U = \sum_{i=1}^{i=n} \frac{GM'_i}{R_i} \times \left(1 + \frac{v^2}{{c_U}^2}\right) = \sum_{i=1}^{i=n} \frac{2GM'_i}{R_i} = 2\Phi_U \tag{32}$$

Thus, as stated earlier, *potential of light/energy in UIF is twice the Newtonian potential.*

14.3 Relationship of potentials of light/energy and matter

Matter has been proven to be comprised entirely of energy. *Matter can essentially be considered as a certain amount of energy in a fixed region of space* (e.g. within protons, electrons subatomic particles etc.), such that the vector sum of the energy velocities within any fundamental particle is zero, allowing matter to be at rest.

Thus, *matter at rest* must have *total energy-potential* of $\hat{\Phi}_U = 2\Phi_U = {c_U}^2$, *double the Newtonian value (matter-potential).* This is a measure of total potential of all energy within matter, which determines speed of internal energy and therefore time dilation. This potential does not play a direct role in the movement of matter as a whole. It is not even in evidence unless we split up atoms and release the energy, except for its contribution to the *mass* of matter.

The *matter-potential* of matter at rest is the Newtonian value $\Phi_U = \sum_{i=1}^{i=n} \frac{GM'_i}{R_i}$ in UIF, or $\Phi = \frac{GM}{R}$ at a distance of R from a proximal body of mass M. This determines how the matter will move, when subjected 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.

14.4 Effect of source velocity on light velocity

14.4.1 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 $\hat{\Phi}_U$.

Now consider a location with an observer at rest in UIF, far from massive bodies, observing a light source moving away while emitting light in all directions, as shown in Figure 4.

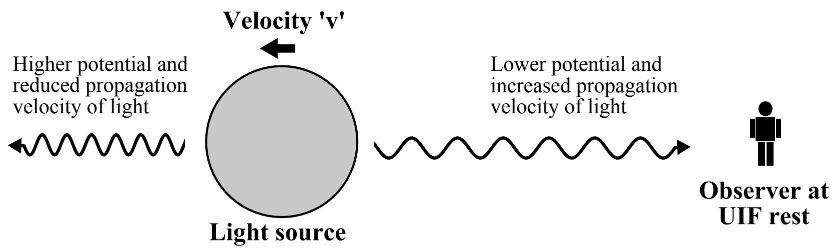

Figure 4: Potential and propagation speed change of light with source velocity.

Light traveling towards the observer faces a *lower potential* than when the source was at rest, since light already had a velocity of c_U with the source at rest, and the away source velocity *would tend to decrease* the light velocity in UIF.

The total velocity of light is given by:

$$c_{Total} = c_I + V \tag{33}$$

where

$c_{Total} =$ total speed of light in UIF
$c_I =$ propagation speed of light in a given potential
$V =$ speed of light source

The source velocity in the above scenario is negative. Therefore *propagation speed* of light must **increase** because of the lower UIF potential it now experiences. The *total speed* of light in UIF would be the *vector addition* of *source velocity* and *propagation speed.*

The mathematical model below will show that the change in propagation speed almost exactly compensates for the source velocity, and change in total speed is negligible (to very high accuracy). This is the reason behind *source velocity independence* of speed of light as seen in experiments.

14.4.2 The base potential of light

With increasingly larger negative source velocity though, the *total speed of light* will start decreasing. When the source velocity becomes exactly equal and opposite to the propagation speed, the total speed of emitted light (c_{Total}) would be zero in UIF.

This situation for light is analogous to matter being at rest in UIF. This provides the 'base potential' (denoted $\hat{\Phi}_{base}$) of light in UIF (analogous to matter), from which we will derive relationships between velocity and potential.

Although photons may be momentarily at rest as seen in UIF rest frame, this does not constitute a *rest frame* for photons or light. Light is still propagating at a non-zero velocity from the source, and also with regard to gravity coming from all directions (which travels at c_U with regard to the light).

14.4.3 Light potential, source velocity and light speed relationship

From the base potential scenario above, if the light source's away velocity is reduced by a small amount V, the potential experienced by emitted light will increase from $\hat{\Phi}_{base}$.

Using considerations of (26), we get the increased potential (as a first approximation):

$$\hat{\Phi}_V = \hat{\Phi}_{base}\left(\frac{{c_U}^2 + V^2}{{c_U}^2}\right) = \hat{\Phi}_{base}\left(1 + \frac{V^2}{{c_U}^2}\right) \tag{34}$$

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.

Since this is a continuous increase over V which changes $\hat{\Phi}_V$ at every small step, we break this increase into 'n' very small steps, and take the limit as $(n \to \infty)$ to replace the first approximation with an exact value.

$$\hat{\Phi}_V = \hat{\Phi}_{base} \lim_{n\to\infty}\left(1 + \frac{\left(V^2/{c_U}^2\right)}{n}\right)^n = \hat{\Phi}_{base} e^{\frac{V^2}{{c_U}^2}} \tag{35}$$

This equation will allow us to find the potential of light/energy at any source velocity, and therefore the propagation speed as well. Potential of light increases as an exponential function of source velocity, rather than linearly as is the case for matter. This is because the speed of light in the direction of motion is itself affected by the change of potential, as discussed earlier.

Using $\hat{\Phi}{c_I}^2$ constancy, we will see that the propagation speed of light decreases as an inverse exponential function of source velocity. In the de Sitter, Fizeau[33, 34] and similar experiments[35], we will do this computation and see why the *source velocity independence* of light appears to be true in vacuum, whereas light-dragging by a moving medium depends on the refractive index.

15 Explanations of relativity experiments

We look at some well known relativity experiments like **de Sitter** double star experiment, **Michelson-Morley**[36, 37, 38, 39], **Alvager**[40] and **Fizeau** experiments in the light of the above discussions.

15.1 The de Sitter double star experiment

The de Sitter experiment, and subsequent repetitions by Kenneth Brecher[41], 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.

Consider two distant binary stars revolving around their common CG at a velocity v. For simplicity, we assume their velocities to be identical, though different velocities (because of different star mass ratios) will not adversely affects the arguments in this section.

If star velocities added on to light speed, light emitted when a star is moving towards Earth would later overtake light emitted when the star is moving away. We would expect to see blurred or multiple images of stars (de Sitter apparitions). No blurring was seen in the experiments.

This observation is seen as a confirmation of the *source velocity independence of light* against the *ballistic/emission theory*. To summarize the two points of view, the equation used is:

$$c' = c + kv \tag{36}$$

where

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

The actual explanation is in between the two, though the *source velocity independence* turns out to be much closer to the truth. For source velocity $v \ll c$, *source velocity independence* is almost exactly true. Let us see why this must be so.

15.1.1 Velocity of light from the star moving towards Earth

Light emitted by a stationary star would simply face a potential of (from (35)):

$$\hat{\Phi}_U = \hat{\Phi}_{base} e^{\frac{c_U{}^2}{c_U{}^2}} \tag{37}$$

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 (35), we obtain this increased potential as:

$$\hat{\Phi}_{v_+} = \hat{\Phi}_{base} e^{\frac{v_+{}^2}{c_U{}^2}} = \hat{\Phi}_{base} e^{\frac{(c_U+v)^2}{c_U{}^2}} \tag{38}$$

From (37) and (38), keeping $\hat{\Phi} c_I{}^2$ constant, we can write:

$$\hat{\Phi}_{base} e^{\frac{(c_U+v)^2}{c_U{}^2}} \times c_{I+}{}^2 = \hat{\Phi}_{base} e^{\frac{c_U{}^2}{c_U{}^2}} \times c_U{}^2 \tag{39}$$

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

Solving for c_{I+} we get:

$$c_{I+} = e^{-\left(\frac{v}{c_U} + \frac{v^2}{2c_U{}^2}\right)} \times c_U \tag{40}$$

Expanding the exponential as a Taylor expansion as ($e^x = 1 + x + x^2/2! + x^3/3! \cdots$), and ignoring small orders above v^3/c^3 (since $v \ll c_U$):

$$c_{I+} \cong c_U \left(1 - \frac{v}{c_U} - \frac{v^2}{2c_U{}^2} + \frac{v^2}{2c_U{}^2} + \frac{v^3}{2c_U{}^3} - \frac{v^2}{6c_U{}^3}\right) = c_U \left(1 + \frac{v^3}{3c_U{}^3}\right) - v \tag{41}$$

$$\therefore c_{Total+} = c_{I+} + v = c_U\left(1 + \frac{v^3}{3{c_U}^3}\right) \cong c_U for\ v \ll c_U \tag{42}$$

In other words, the total light velocity increase 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.

15.1.2 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:

$$\hat{\Phi}_{base} e^{\frac{(c_U - v)^2}{{c_U}^2}} \times {c_{I-}}^2 = \hat{\Phi}_{base} e^{\frac{{c_U}^2}{{c_U}^2}} \times {c_U}^2 \tag{43}$$

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:

$$c_{Total-} = c_{I-} - v = c_U\left(1 - \frac{v^3}{3{c_U}^3}\right) \cong c_U for\ v \ll c_U \tag{44}$$

The total velocity of light towards Earth is again practically the same as c_U.

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 ($k < 0.002$). If *extinction* were taken into consideration, even if partial for the Brecher experiment, even less stringent k-values would apply to the experiments.

The motion of the stars will also cause a small relativistic Doppler effect (as demonstrated by Ives Stilwell experiment[42, 43]) which we have ignored in the above discussion as it is negligible in this case.

15.2 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 (energy density) 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:

$$w_+ = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right) \tag{45}$$

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

The comparison is between the potential/energy density of stationary water and moving water. Light/energy that travels through water goes through a significantly higher potential than in vacuum. This is equivalent to a significantly increased UIF gravitational potential.

The refractive index of water, n, represents the change of light velocity with the increased potential in water, where $n = c_U/c_w$, with c_w being 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 (35) to derive the relationship between the base potential and the potential at a light velocity of V:

$$\hat{\Phi}_{V:w} = \hat{\Phi}_{base:w} \lim_{n\to\infty} \left(1 + \frac{\left(V^2/{c_U}^2\right)}{n}\right)^n = \hat{\Phi}_{base:w} e^{\frac{V^2}{{c_U}^2}} \tag{46}$$

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:

$$\hat{\Phi}_w = \hat{\Phi}_{base:w} e^{\frac{{c_w}^2}{{c_U}^2}} \tag{47}$$

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:

$$\hat{\Phi}_{base:w} e^{\frac{{c_w}^2}{{c_U}^2}} \times {c_w}^2 = \hat{\Phi}_{base:w} e^{\frac{(c_w+v)^2}{{c_U}^2}} \times {c_{w'}}^2 \tag{48}$$

$$\therefore {c_{w'}}^2 e^{\frac{(c_w+v)^2}{{c_U}^2}} = {c_w}^2 e^{\frac{{c_w}^2}{{c_U}^2}} \tag{49}$$

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

$$c_{w'} = c_w \sqrt{\frac{e^{\frac{{c_w}^2}{{c_U}^2}}}{e^{\frac{(c_w+v)^2}{{c_U}^2}}}} = c_w \sqrt{e^{\frac{-2c_w v - v^2}{{c_U}^2}}} \cong c_w e^{-\left(\frac{c_w v + v^2/2}{{c_U}^2}\right)} \tag{50}$$

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:

$$w_+ = c_{w'} + v = c_w e^{-\left(\frac{c_w v + v^2/2}{{c_U}^2}\right)} + v \cong c_w \left(1 - \frac{v c_w}{{c_U}^2} - \frac{v^2}{2{c_U}^2}\right) + v \tag{51}$$

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:

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

This is the relationship observed in the Fizeau experiment.

We may treat the presence of a medium (water in this case) simply as an increase in gravitational potential. *Refraction* is a Shapiro delay caused by the higher potential within a medium. This delay becomes greater (i.e. light moves even slower) in moving water because of further increased potential. Of course, this applies only to wavelengths where a medium is *transparent* and does not deflect or stop light itself (where other phenomena come into play).

15.3 Cherenkov effect

That we are able to apply the relativistic velocity computation formula to Fizeau experiment shows that the same principle of *increased gravitational potential* causing *reduced light speed* is applicable within a medium, just like potential increase because of large body proximity or velocity in UIF.

We have seen that while light must slow down in a predictable way with increase in potential, the same does not apply to matter, as the movement of the CG of a body is not affected by potential.

Cherenkov radiation is an example of this difference between matter and energy. While subatomic matter can maintain its incident velocity after entering a denser medium, light slows down to its characteristic velocity as dictated by the refractive index (indicating the increase in potential), allowing matter to travel faster than the local c. This would be true in vacuum as well.

15.4 Michelson-Morley experiment

For Michelson-Morley (and similar experiments like Kennedy-Thorndike[44, 45]), 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.

15.5 Alvager et. al. experiment

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

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

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

However, the following points need to be 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

$3.064 \times 10^8 m/s\,(1.02 c_U)$. 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 γ-rays are not produced *spontaneously* by protons in flight, but through a *collision process*. The protons strike much larger beryllium nuclei in a metal lattice to produce pions. Velocity of the protons at the instant of pion production is certainly reduced. 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.
- Velocity of the source protons should result in increased energy of the γ-rays in the direction of motion, if the source velocity has any bearing on the experiment at all. If equally energetic γ-rays are being scattered in all directions (e.g. perpendicular to proton path), the entire experiment's basis is invalidated. This is not tested. That γ-rays are being scattered in different directions is a certainty, since the experiment measures the velocity of γ-rays at an angle of $6°$ to the proton path. (It is also not clear whether this is accounted for in the experiments reported accuracy/error).

The experiment is inconclusive. It needs to be repeated with measurement of energies of γ-rays in different directions (with a semi-cylindrical Beryllium target) for any reliable conclusions to be drawn.

16 Orbital time dilation and Lorentz Factor

16.1 Acceleration, potential and time dilation in 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.

16.1.1 Acceleration and energy-potential in orbit under transverse acceleration

Consider a small body m (of rest mass m_0) orbiting a massive body M at a distance R with a velocity v. If gravity of M and velocity of m had no impact on *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.

We know from GR 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.

The gravitational acceleration will be multiplied by a factor of $(1 + v^2/{c_U}^2)$, because of the orbital velocity of m in UIF, as 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:

$$\textit{Base acceleration } (A_M) = \frac{GM}{R^2}\left(1 + \frac{v^2}{{c_U}^2}\right) = \frac{v^2}{R} \tag{53}$$

Thus, for increasing v's, lesser gravitational acceleration will be required to maintain the orbit, since the the gravitational acceleration will increase with v.

This 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, (coincident with CG of M), m is moving and M is at 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), as there are no components of M's gravitational acceleration in the direction of m's velocity.

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

The energy-potential of M at m would be $\hat{\Phi}_M = 2GM/R$ at rest. However, the acceleration (A_M) of M on m is slightly higher as shown in (53) because of m's velocity. We may write the actual energy-potential (denoted $\hat{\Phi}_{M,v}$) as:

$$\hat{\Phi}_{M,v} = \hat{\Phi}_M\left(1 + \frac{v^2}{{c_U}^2}\right) = \frac{2GM}{R}\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{54}$$

Taking $\hat{\Phi}_{M,v}$ into account in the unit energy of m, its mass will have increased by $\hat{\Phi}_{M,v}/{c_U}^2$. 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 (since $\hat{\Phi}_U = {c_U}^2$):

$$\Delta A_M = A_M \times \frac{(\hat{\Phi}_{M,v}/{c_U}^2)}{(\hat{\Phi}_U/{c_U}^2)} = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}\right) \tag{55}$$

This increase in the acceleration would, in turn, create a further increase in the potential of m 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 $v^2 < {c_U}^2$):

$$\Delta A_M = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}\left(1 + \frac{v^2}{{c_U}^2}(1 + \cdots)\right)\right) = A_M \frac{\hat{\Phi}_M}{{c_U}^2}\left(\frac{1}{1 - \frac{v^2}{{c_U}^2}}\right) \tag{56}$$

Since the energy-potential would be modified by the same factor as acceleration, the total energy-potential of m from M's gravity (enhanced by m's velocity) will be:

$$\hat{\Phi}_{M,v} = \hat{\Phi}_M \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \tag{57}$$

To get the total energy-potential of m, we add the modified UIF energy-potential $\hat{\Phi}_{U,v}$ (from (27)) to the energy-potential from M:

$$\hat{\Phi}_{Total} = \hat{\Phi}_{U,v} + \hat{\Phi}_{M,v} = \hat{\Phi}_U + v^2 + \hat{\Phi}_M \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) = \hat{\Phi}_U \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2} \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \right) \tag{58}$$

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

$$A_{M,v} = A_M \left(1 + \frac{v^2}{{c_U}^2} \right) \tag{59}$$

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

$$Acc(A) = A_{M,v} + \Delta A_M = A_M \left(1 + \frac{v^2}{{c_U}^2} + \frac{\hat{\Phi}_M}{{c_U}^2} \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \right) \tag{60}$$

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

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

These are the *complete equations for energy-potential* (58) and *acceleration* ((60), (61)) 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/black holes*, and *artificial* gravitational equivalent situations like muons in the muon ring in *Bailey et. al. experiment.*

16.1.2 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 (58) to write:

$$\hat{\Phi}_U {c_U}^2 = \hat{\Phi}_{Total} {c_I}^2 = \hat{\Phi}_U \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2} \left(\frac{1}{1 - \frac{v^2}{{c_U}^2}} \right) \right) {c_I}^2 \tag{62}$$

At *low velocities* ($v \ll c_U$), we have $(1/\left(1 - v^2/{c_U}^2\right) \approx 1)$, and we can approximate as:

$${c_U}^2 = \left(1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2} \right) {c_I}^2 \tag{63}$$

$$\therefore \gamma = \frac{c_U}{c_I} = \sqrt{1 + \frac{v^2}{{c_U}^2} + \frac{2GM}{R{c_U}^2}} \cong 1 + \frac{v^2}{2{c_U}^2} + \frac{GM}{R{c_U}^2} \tag{64}$$

This is the equation that is used for GPS time dilation and Hafele-Keating experiment calculations. Note that this low velocity/weak gravity approximation is exactly the same as that of the Schwarzschild metric near a massive body $\gamma = 1/\sqrt{1 - 2GM/Rc_U{}^2 - v^2/c_U{}^2}$ that is used from GR.

This equation also applies to *unconstrained (non-orbital) motion* of a small body in UIF, with a transverse velocity near a large mass M. The *Lorentz factor does not appear* as there is no constraint of an orbital trajectory under transverse central acceleration.

In *orbital motion situations where v is close to c_U*, as in the Bailey et. al. experiment, $\hat{\Phi}_M$ becomes nearly $\hat{\Phi}_U$ (by (53) 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 (58) as the $1/\left(1 - v^2/c_U{}^2\right)$ term becomes very large. We can consider the total potential of m to be $\hat{\Phi}_{M,v}$ itself in (58).

From $\hat{\Phi} c_I{}^2$ constancy and (58), we get:

$$\hat{\Phi}_U c_U{}^2 \cong \hat{\Phi}_{M,v} c_I{}^2 = \frac{\hat{\Phi}_M}{(1 - v^2/c_U{}^2)} c_I{}^2 \cong \frac{\hat{\Phi}_U}{(1 - v^2/c_U{}^2)} c_I{}^2 \tag{65}$$

This gives us:

$$\gamma = \frac{c_U}{c_I} = \frac{1}{\sqrt{1 - v^2/c_U{}^2}} \tag{66}$$

This is the *Lorentz factor*, which is the *velocity time dilation metric* in current relativity theory.

16.2 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 other situations, (64) is the appropriate formulation for computing *time dilation (both velocity and gravitational)*.

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

$$\gamma = \frac{c_U}{c_I} \cong 1 + \frac{v^2}{2c_U{}^2} \tag{67}$$

This happens to be the same as the low velocity approximation of the UIF velocity time dilation metric (30), and therefore the Lorentz factor has seemed to work at low velocities too.

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 *very high orbital velocities*, the increased local potential overshadows the UIF potential, and the Lorentz factor then provides the correct time dilation ratio.

When v approaches c_U in orbital motion, both potential and acceleration increase boundlessly ((58)-(61)). If $v \geqslant c$, a *closed orbit is not possible* under a transverse/central acceleration.

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

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

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 transverse acceleration of nearly $10^{18}g$ kept the muons going in a circular orbit along the muon ring. The lifetime of the muons was found to be extended by a factor of 29.327, as computed using the Lorentz factor $(1/\sqrt{1-v^2/c_U{}^2})$, compared to the average lifetime of about $2.2\mu s$ for inertial muons found in unrelated and independent previous experiments.

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

Curiously, only velocity time dilation (Lorentz factor) seems applicable, and 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 $10^{18}g$, which creates a large potential, *equivalent to a gravitational potential.* (The small gravitational potential of Earth plays no role in this experiment.).

Substituting low and high values of v in (62) explains why we see separate gravitational and velocity time dilation terms (from $\hat{\Phi}_{U,v}$) in cases like GPS satellites and Hafele-Keating, but only velocity time dilation (from $\hat{\Phi}_{M,v}$) appears to be present in Bailey experiment.

At low velocities, the Lorentz Factor is nearly 1, and (64) applies. The very high orbital velocity of muons *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* as in (66). In this experiment, *velocity time dilation* is one and the same thing as *gravitational time dilation* from the massive local potential.

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

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

16.4 Energy of relativistic particles

Particles like beta rays are produced as a result of atomic disintegration, and carry away the energy they have within the atom. Particles like electrons are *orbiting* nuclei within atoms at massive speeds close to c, and 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 most of that energy. Initially however, their internal *time* would be extremely slow, and therefore they will retain their energies for considerable periods.

17 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) using (64) as:

$$\gamma_{E:G} = \frac{c_U/c_{I:E}}{c_U/c_{I:G}} = \frac{c_{I:G}}{c_{I:E}} = \sqrt{\frac{1 + \frac{2GM_E}{R_G c_U{}^2} + \frac{v_G{}^2}{c_U{}^2}}{1 + \frac{2GM_E}{R_E c_U{}^2}}} \; since \; v_E \cong 0 \tag{68}$$

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

$$\gamma_{E:G} \cong \frac{1 + \frac{GM_E}{R_G c_U{}^2} + \frac{v_G{}^2}{2c_U{}^2}}{1 + \frac{GM_E}{R_E c_U{}^2}} \cong 1 + \frac{GM_E}{R_G c_U{}^2} + \frac{v_G{}^2}{2c_U{}^2} - \frac{GM_E}{R_E c_U{}^2} \tag{69}$$

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:

$$\gamma_{E:G} - 1 = -4.473 \times 10^{-10} \tag{70}$$

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

$$Difference = -4.473 \times 10^{-10} \times 86400 \times 10^6 \cong -38 \mu s/day \tag{71}$$

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.

18 Velocities higher than local speed of light

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.

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 particle accelerators) accelerate a particle to a velocity of $\geqslant c$, as the force-carrier particles themselves travel at c, no matter how powerful we make particle accelerators.

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 any realistic possibility of creating or observing superluminal speeds in nature.

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, based on our inability to accelerate particles to c or higher locally. As noted earlier, the fact that light slows down in higher potential (energy density), while matter does not, qualifies this as FTL travel.

Can we actually achieve higher than local c (in vacuum) velocities in some way? It is certainly difficult, but not impossible. Suggested experiments are discussed in the next section.

19 Possibilities of FTL experiments

19.1 Neutrinos generated at lower gravitational potentials

One 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[46] 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.

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.

19.2 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 (62). There will be a $15\% - 19\%$ *difference* between this equation and the Lorentz factor in such situations.

The difference between (62) 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 (62). If the muon lifetime extension result is found to be as per (62) rather than the Lorentz factor, it will lend support to the modified equation and the underlying theory developed in this paper as well.

19.3 Spontaneous decay of high-velocity particles

Another 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 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.

A slightly slower source velocity (say $< 0.9c$) would be preferable to high velocities like $0.99975c$, as the reduction of internal energy speed (c_I) would not be that drastic, leading to a possibly more easily observable superluminal speed.

20 Observations on celestial phenomena

20.1 Black Holes and Singularities

The gravitational time dilation formulation in (17) mandates no singularity. 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*. Complete stoppage of time requires a complete stoppage of energy, or infinite gravitational potential, which is not possible.

Since no event horizon exists, all instants in time by the clock of an observer free-falling into a black hole would always have corresponding instants in time by the clock of an outside observer. Since there is no event horizon, we do not have any inconsistency.

20.2 UIF background acceleration

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 large velocities, this may provide an excellent fuel-free source of acceleration for interstellar travel.

This UIF background acceleration may also partially explain the extraordinarily large energies observed of some cosmic muons[47, 48].

21 Significance for interstellar travel

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

- **Practical FTL travel:** Travel through space at higher than speed of light is possible. Even for large speeds (many times c), time dilation (differential aging) does not become boundless.

- **Sustained gravity assist:** Net UIF gravitational acceleration is always in the direction of travel and increases with velocity. This could alleviate some of the fuel needs, as 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.

- **Time dilation advantages:** The time slowdown that will happen provides multiple advantages. Years or months on the home planets could be months or days respectively on a fast spacecraft. Trips will feel shorter, and less provisions need to be carried.

- **Structural strength:** Increased inertia of spacecrafts can be large at high velocities, and provide additional structural strength that may be an advantage against space debris and cosmic radiation.

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

22 Conclusions

We revisited some of the assumptions and concepts underlying current Theory of Relativity, and presented an alternative view of the physics behind relativity. We are able to get a more intuitive and simple understanding, and gain the following insights:

Role of the Universe's gravitational potential in relativity. The Universe's background gravitational potential defines rest mass and energy for matter. It also provides a local inertial frame for orientation and velocity. Though not universally static in an absolute sense, this UIF frame defines the reference frame for any given locality in the Universe.

Simple understanding of time dilation. Velocity time dilation/differential aging that leads to experimentally measurable clock drift is neither reciprocal between observers, nor dependent on their relative velocities. Similar to gravitational time dilation, it is caused by asymmetry of physical conditions (gravitational potential difference), because of differential velocity in local UIF frame. Time dilation between locations is a manifestation of difference in local energy speeds.

Revised understanding of existing relativity concepts. Matter can travel faster than c. *Length contraction* and *Relativity of Simultaneity* are not required for understanding relativity. 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.

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