

Part I: Time dilation factor obtained from spherical wave propagation geometry and light-speed limit.

Abstract: I derive the standard Lorentz time-dilation factor $\gamma = 1/\sqrt{1-\beta^2}$ from the spherical wave propagation geometry combined with light-speed limit c . This reproduces SR's empirical time dilation without invoking length contraction. It reframes time-dilation as a wave-propagation geometry, not as a postulate-level statement.

Logic and calculations:

The basic logic assumed that the considered waves propagate spherically with speed of light c . If the object/clock is moving with an exemplary speed $0.9c$, then the combined chase and meet propagation geometry should produce an invariant frequency-distortion factor. In the present model, frequency sets the fundamental rate at which complete propagation cycles can be closed - since clock ticks are assumed to correspond to such cycles, the invariant frequency-distortion factor directly determines the observed time-dilation factor (as frequency defines the minimal energy packages necessary to detect an event - and thus record any time-flow at all).

What is more, the fact that any cycle-time measurement requires both an outgoing and a returning propagation path, naturally motivates the use of geometric mean, which emerges from the reciprocal structure of the propagation geometry for opposite directions. In standard wave physics, a standing wave arises from the superposition of counter-propagating wave components. Stable wave patterns therefore depend on the combined behavior of opposite propagation directions rather than on a single traveling wave alone. The presented construction shows a mathematically similar structure - for opposite propagation directions ("there/chase" and "back/meet"), motion produces complementary propagation distortions: one direction increases the propagation overlap time and is associated with lower received frequency (redshift-like behavior), the opposite direction decreases the propagation overlap time and is associated with higher received frequency (blueshift-like behavior). These opposite directions are treated here not as independent additive events, but as reciprocal components of a single propagation geometry. Mathematically, the opposite directions form a multiplicative invariant pair. Because the relationship is multiplicative and symmetric between those opposite directions, the geometric mean naturally extracts the invariant propagation factor from them. This resembles many wave and oscillatory systems in which reciprocal amplification and attenuation processes combine multiplicatively. The argument presented here should therefore be understood as a propagation-based derivation of the Lorentz factor. In this interpretation, the geometric mean is used because opposite propagation directions form a reciprocal multiplicative structure whose invariant quantity is naturally recovered through geometric averaging.

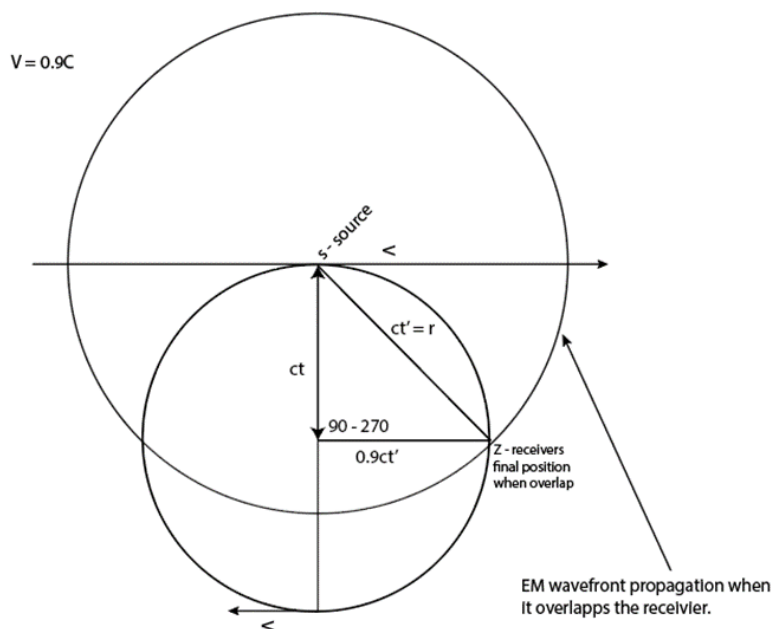
In the model that I built the Lorentz factor arises from the geometry of a closed propagation cycle ("there-and-back") and of course each cycle must start from the same underlying frequency. Otherwise, if every new cycle inherited the already-dilated result of the previous one, the dilation would accumulate from cycle to cycle, leading to an ever-slower process. Thus a moving or gravitating system is a set of self-consistent "eigenmodes". This is strongly reminiscent of eigenstates in quantum mechanics. A quantum eigenstate does not "remember" previous oscillations. Quantum-mechanical eigenstates provide at least an

analogy for the idea that time dilation and gravity may correspond to a transition into a different stable propagation mode in the way presented in my calculations and logic. Here it is worth noting that the formation length (mentioned and explained later) arises from the geometry of a single propagation cycle itself and remains present when the cycle is treated as a stable, separate eigenmode. Likewise, orbital precession emerges because the local propagation geometry changes continuously as a phase shift along a gravitational orbit at every step of there-back "eigenmodes" cycle - a global effect accumulates over a complete orbit (this is explained in detail later on).

This brings us to the proper calculation:

1. The 90°/270° angle pair scenario setup:

- Source: Emits an EM pulse at $t=0$.
- Receiver: Initially located 1 light-second from the source, moving laterally at $v=0.9c$.
- Emission wavefront: Expands spherically at speed c in all directions (properly for EM propagation pattern) - this can be illustrated as below:



Key Geometry:

- At $t=1s$, the EM wavefront has radius $r=ct=1$ light-second.

- The original receiver position is exactly on this circle (perpendicular to emission direction).
 - But during the signal's journey the receiver itself has moved sideways by $vt=0.9$ light-second ($0.9c$).
- b) The EM wavefront continues to expand spherically and the receiver continues escaping laterally (covering a distance of vt' where v is $0.9c$ and t' is the time needed to cross the receiver by the expanding EM-signal-sphere).
- At any later time $t' > 1$ s, the radius is $r=ct'$
 - The receiver's position is $(1, 0.9ct')$ in coordinates (x,y) where $x=1$ is the initial separation.
- c) The receiver detects the signal when its position lies on the expanding sphere:

$$c^2t^2 + v^2t'^2 = c^2t'^2$$

$$c^2t^2 = (c^2 - v^2) t'^2$$

$$t^2 = t'^2(1 - v^2/c^2)$$

$$t = t'\sqrt{(1 - v^2/c^2)}$$

$$t' = t / \sqrt{(1 - v^2/c^2)}$$

$$t' = 1 / \sqrt{(1 - 0.81/1)}$$

$$t' = 1 / \sqrt{(0.19)}$$

$$t' = 2.2941573387$$

The wavefront catches up with the moving receiver after ≈ 2.3 seconds (exactly 2.294157339) because the spherical shell curvature expands and eventually overlaps its new position. Conclusion:

- The receiver does not get the signal after 1 second because it moved away from the initial intercept point.
- However, the spherical curvature of the wavefront expands and eventually reaches the receiver at 2.294157339 seconds, exactly as expected.
- The delay is governed by the Pythagorean relationship between initial separation and relative motion.

The above gives a geometric mean of $\sqrt{2.294157339 \times 2.294157339} = 2.294157339$ for 90° and 270° degree pairs of ticks.

2. 0°/180° angle pair scenario setup:

When we calculate the geometric mean for the pair 0° and 180° we get, as per attached .xlsx file, exactly the same geometric mean $\sqrt{10 \times 0.5263157895} = 2.294157339$ for this pair of opposite ticks.

3. For all other angle-pairs and their geometric mean:

- A source emits a photon (or EM pulse) at $t=0$.
- A receiver is located 1 light-second away in some direction θ (angle measured from the direction of motion of the receiver).
- The receiver moves with speed $v=0.9c$ along the x-axis while the photon (EM) propagates outward spherically at speed $c=1$.
- We want to know how long the expanding light sphere takes to overlap the receiver.

To calculate, we need to use the logic presented below:

After time t' , the distance the light travels is: $r = ct' = t'$ (as we operate in light-seconds for simplification).

The receiver's position:

$$x = \cos\theta + vt' \text{ (shifted by covered distance)}$$

$$y = \sin\theta \text{ (it is constant)}$$

So the light covers a diagonal:

$$t'^2 = (\cos\theta + v t')^2 + \sin^2\theta$$

Now we can calculate the outgoing ("there") and returning ("back") propagation frequencies for all propagation angles. For each pair of opposite directions, θ and $\theta + 180^\circ$, the invariant there-and-back tick frequency is then recovered by taking the geometric mean. This averaging preserves the reciprocal symmetry of the two propagation directions, allowing the invariant propagation factor associated with a complete cycle to be extracted. Calculations can be found in column R of the attached file ("dilation_speed" tab).

Note - in the 360_clock.xlsx file we are using the positive solution of the quadratic equation of $t'^2 = (\cos\theta + v t')^2 + \sin^2\theta$ derived as below:

$$t'^2 = (\cos\theta + v t')^2 + \sin^2\theta$$

Expand:

$$t'^2 = \cos^2\theta + 2 v t' \cos\theta + v^2 t'^2 + \sin^2\theta$$

Use: $\cos^2 \theta + \sin^2 \theta = 1$

$$t'^2 = 1 + 2 v t' \cos \theta + v^2 t'^2$$

Collect terms (quadratic in t'):

$$(1 - v^2) t'^2 - 2 v \cos \theta \cdot t' - 1 = 0$$

Quadratic formula:

$$t' = [2 v \cos \theta \pm \sqrt{4 v^2 \cos^2 \theta + 4(1 - v^2)}] / [2(1 - v^2)]$$

Equivalently (since $v^2 \cos^2 \theta + 1 - v^2 = 1 - v^2 \sin^2 \theta$):

$$t' = [v \cos \theta \pm \sqrt{1 - v^2 \sin^2 \theta}] / (1 - v^2)$$

so:

$$t' = [v \cos \theta \pm \sqrt{v^2 \cos^2 \theta + 1 - v^2}] / (1 - v^2)$$

Pick the positive root - here we have our formula:

$$t' = [v \cos \theta + \sqrt{v^2 \cos^2 \theta + 1 - v^2}] / (1 - v^2)$$

All the formulas are available in the attached file. The geometric mean across all opposite angles yields the same overall time dilation factor as SR predicts, purely from spherical wave geometry and speed limit c , without invoking length contraction.

An independent result also emerges from the there-and-back propagation framework used to derive the relativistic time-dilation factor.

For a propagation process moving with velocity v , the forward and backward propagation times are:

$$t_{\text{chase}} = 1 / (1 - \beta)$$

$$t_{\text{meet}} = 1 / (1 + \beta)$$

where:

$$\beta = v / c$$

The geometric mean of these reciprocal factors gives the standard relativistic time-dilation factor:

$$\sqrt{t_{\text{chase}} \cdot t_{\text{meet}}}$$

$$= \sqrt{[1 / (1 - \beta)] \cdot [1 / (1 + \beta)]}$$

$$= \sqrt{[1 / (1 - \beta^2)]}$$

$$= 1 / \sqrt{1 - \beta^2}$$

$$= \gamma$$

However, if one considers the total spatial extent required to complete the full propagation cycle, the relevant quantity becomes the sum of the two propagation paths:

$$L_f \propto t_{\text{chase}} + t_{\text{meet}}$$

Substituting the expressions above gives:

$$L_f \propto 1 / (1 - \beta) + 1 / (1 + \beta)$$

$$= [(1 + \beta) + (1 - \beta)] / [(1 - \beta)(1 + \beta)]$$

$$= 2 / (1 - \beta^2)$$

Using:

$$\gamma^2 = 1 / (1 - \beta^2)$$

one obtains:

$$L_f = 2\gamma^2$$

This quantity should be interpreted as a formation length: the longitudinal distance required for a complete there-and-back propagation cycle to form. The same propagation geometry therefore produces two different relativistic scalings:

$$\text{time-dilation factor} = \gamma$$

$$\text{formation length} = 2\gamma^2$$

For example, at:

$$v = 0.9c$$

$$\beta = 0.9$$

$$\gamma = 1 / \sqrt{1 - 0.9^2}$$

$$\gamma = 1 / \sqrt{1 - 0.81}$$

$$\gamma = 1 / \sqrt{0.19}$$

$$\gamma \approx 2.294$$

therefore:

$$2\gamma^2 = 2 \times 2.294^2$$

$$2\gamma^2 \approx 2 \times 5.263$$

$$2\gamma^2 \approx 10.53$$

The formation region therefore becomes more than ten times longer than in the rest case, while the observed time-dilation factor increases by only about a factor of 2.3.

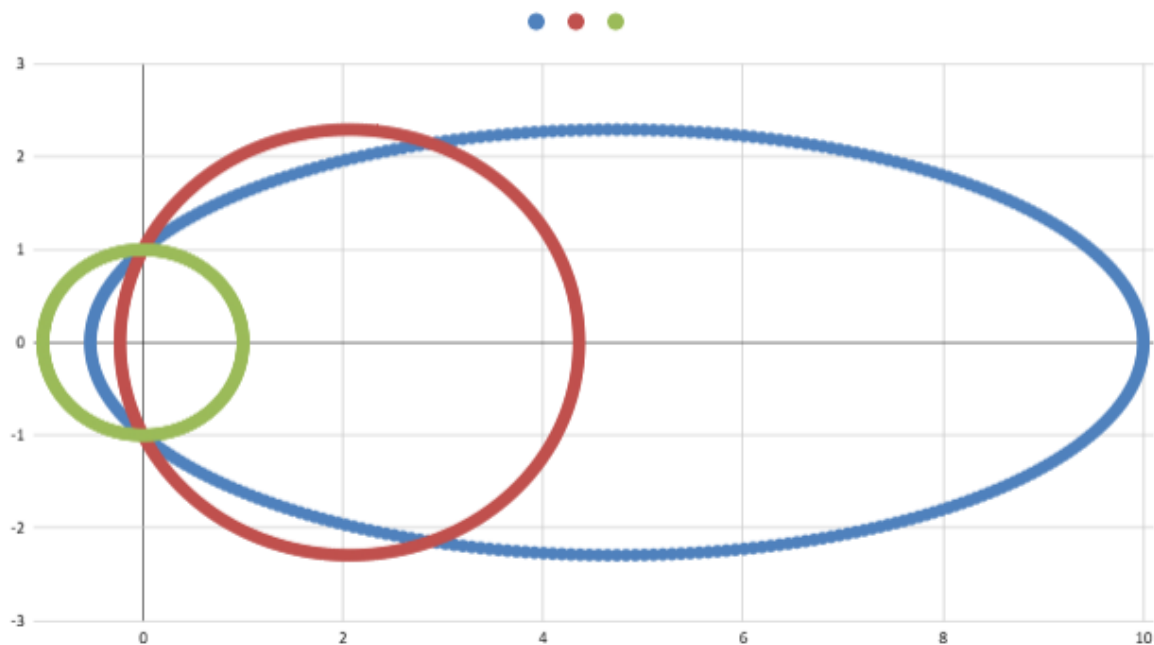
An interesting aspect of this result is that the $2\gamma^2$ scaling appears naturally from the same reciprocal chase/meet structure that generates γ . No additional assumptions are required beyond the there-and-back propagation picture itself.

This suggests that relativistic time dilation and the growth of formation regions may be different manifestations of the same underlying propagation geometry.

To predict the formation region distortion factor for each angle pair we just need to use the $t_{\text{chase}} + t_{\text{meet}}$ formula as in the S column of the attached XLS file (speed dilation tab) - this observation should be the first prediction of the model presented and should give the opportunity to test if this model might explain the true mechanism of time dilation.

For speed $\sim 0.9c$ we arrive to formation region corresponding to a shape presented below:

Energy scale: green base, red = gamma, blue full formation-region geometry ($\beta = 0.9$)



By manipulating the speed number in the attached xls file one can generate proper formation region visualisation for given speed.

Part II: Escape velocity and gravitational time dilation from spherical wave propagation refraction in a static gravitational gradient of a spherical static body

Abstract: I derive the standard escape velocity and gravitational time-dilation factor from

spherical wave propagation in gravity treated as a static refractive gradient. This reproduces the standard gravitational time dilation and escape velocity without invoking spacetime curvature, instead interpreting gravity as a propagation effect arising from wave refraction, while predicting special outcomes in some defined circumstances.

Logic and calculations:

First of all we assume, as in the picture presented in part one (time dilation in fast moving frames), that a frequency-distortion factor directly determines the observed time-dilation phenomenon (as frequency defines the minimal energy packages necessary to detect an event - and thus record any time-flow at all).

The basic logic assumes that gravity acts as a refractive gradient through which spherical waves propagate at speed c . In this model, gravity around a static spherical body is treated as a stationary spatial gradient that continuously modifies the propagation geometry of spherical wavefronts. As a consequence, wave propagation becomes direction-dependent: propagation against the gradient experiences a redshift-like distortion, whereas propagation along the gradient experiences a blueshift-like distortion. The starting point to explain the logic used for further calculations is the observed gravitational redshift (this is a dimensionless observable):

$$GM / rc^2$$

This is the measured frequency difference between clocks located at different gravitational potentials.

The observed value GM / rc^2 represents only the directly visible part of a deeper propagation process. The key idea is that the same dimensionless factor affects both:

the propagating signal,

the local clock used to measure that signal.

If the same first-order factor appears in both places, the observable process contains:

$$(1 + GM / rc^2)(1 + GM / rc^2)$$

$$= (1 + GM / rc^2)^2$$

Expanding gives:

$$1 + 2GM / rc^2 + (GM / rc^2)^2$$

Since GM / rc^2 is very small in ordinary gravitational fields, the quadratic term can be neglected:

$$(1 + GM / rc^2)^2 \approx 1 + 2GM / rc^2$$

The coefficient 2 therefore appears naturally from the multiplication of two identical first-order factors.

In this interpretation - observed one-way redshift effect (distorted by being in gravitational potential):

$$GM / rc^2$$

underlying one-way propagation factor (if observed from outside of gravity influence):

$$2GM / rc^2$$

In this view light passing through a gravitational field experiences two propagation stages:

propagation into the field,

propagation out of the field.

While it is all the time distorted by this gradient, as well going into as going out of the field, so by applying the same underlying factor to both stages we land (if observed from outside of gravity - meaning in gravity that can be neglected) at:

$$2GM / rc^2 + 2GM / rc^2 = 4GM / rc^2$$

which coincides with the observed light-deflection coefficient and couldn't have been obtained without the idea that it is all about refraction of a wave, which happens both on the way in and out, totally cumulating to the effect x2.

Here we come to Newtonian physics, that, thanks to Johan Soldner's (this was the year 1801 - far before Einstein) equation, lets us calculate the deflection of light by mass (treating light as a small particle - "cannonball") as the fast-particle approximation. This before-Einstein equation is:

$$\theta \approx 2GM / (r c^2)$$

This equation was in fact deduced by observations of matter falling into gravity, and so it already contained the x2 factor - this factor is inherent to matter as, in the model presented, matter is assumed to be based on a closed there-and-back propagation cycle rather than a single one-way propagation, so it naturally gives x2 factor.

To make it clear, by applying this logic to propagation of matter into and then out of the field (analogous to light) we should get:

$4GM / rc^2$ (real, underlying one-way propagation factor $2GM / rc^2$ deduced earlier multiplied x2 for there and back cycle constituting matter - way into gravity) + $4GM / rc^2$ (real, underlying one-way propagation factor $2GM / rc^2$ deduced earlier multiplied x2 for there and back cycle constituting matter - way out of gravity) = $8GM / rc^2$

leading to the sequence:

$$GM / rc^2 \rightarrow 2GM / rc^2 \rightarrow 4GM / rc^2 \rightarrow 8GM / rc^2$$

where:

GM / rc^2 is the observed local redshift,

$2GM / rc^2$ is the underlying one-way propagation factor,

$4GM / rc^2$ is the a/ full light propagation effect (in + out of gravity) and b/ the matter effect while just falling into or just going out of gravity or being stationary in gravity (we get 2x underlying $2GM / rc^2$ factor due to the closing of the there and back cycle needed to create matter),

$8GM / rc^2$ is the full matter-cycle effect for matter going in and out of gravity with speed c (so, obviously, it is twice the light effect for there and back needed to constitute matter). Here it is important to note what c speed means in this case. In this view c means the total velocity of a 3D process with a preferred direction equally distributed in a three-dimensional propagation process - such situation naturally introduces the factor:

$$1 / \sqrt{3}$$

because a vector equally distributed among three spatial directions has components:

$$(1 / \sqrt{3}, 1 / \sqrt{3}, 1 / \sqrt{3})$$

satisfying:

$$(1 / \sqrt{3})^2 + (1 / \sqrt{3})^2 + (1 / \sqrt{3})^2 = 1c$$

As gravity provides a preferred direction, the radial direction toward the gravitating body, making such projections is physically meaningful and necessary.

Once a preferred axis exists, it becomes natural to analyze how a three-dimensional propagation process projects onto that axis.

This leads naturally to the velocity defining the $8GM / rc^2$ bending factor:

$$c / \sqrt{3} \approx 0.577c$$

which represents the projection of a full light-speed process onto a single spatial axis in a symmetric three-dimensional geometry.

Thus here a prediction can be made that $8GM/rc^2$ should appear as gravitational deflection formula for matter passing spherical non-rotating mass exactly at:

$$v = c / \sqrt{3}$$

while the deflection should smoothly decrease toward:

$$4GM / bc^2$$

as the one-direction velocity approaches c (this is natural, as finally matter can not be constituted at all, and only a one-way propagating wave “stays alive” moving through space with the speed c).

An interesting consequence of the propagation framework is that Mercury’s perihelion precession can be interpreted as arising from the combination of the gravitational one-way drop component and the tangential orbital-motion component.

In this model, the gravitational drop of one propagation step is described by:

$$2GM/(rc^2)$$

For an orbiting body, the propagation cycle is not purely radial, because the body also has tangential orbital motion. This orbital motion contributes an additional propagation distortion:

$$v_{\text{orb}}^2/c^2$$

For a circular orbit:

$$v_{\text{orb}}^2 = GM/r$$

therefore:

$$v_{\text{orb}}^2/c^2 = GM/(rc^2)$$

The total effective one-way orbital propagation factor is therefore:

$$2GM/(rc^2) + v_{\text{orb}}^2/c^2$$

$$= 2GM/(rc^2) + GM/(rc^2)$$

$$= 3GM/(rc^2)$$

This is the coefficient appearing in the standard relativistic correction responsible for perihelion precession.

For elliptical orbits, the relevant orbital scale is the semilatus rectum:

$$p = a(1 - e^2)$$

where a is the semi-major axis and e is the eccentricity.

Replacing r by p gives:

$$3GM/(pc^2)$$

Over one complete revolution, this accumulated correction gives:

$$\Delta\phi = 2\pi \cdot 3GM/(pc^2)$$

$$= 6\pi GM/(pc^2)$$

$$= 6\pi GM/[a(1 - e^2)c^2]$$

This is the standard General Relativity result for Mercury's perihelion precession.

Here Mercury's precession can be viewed as the orbital analogue of speed-induced formation-length growth. In uniform motion, propagation geometry produces an extended formation length that scales as $2\gamma^2$. In orbital motion, gravity and tangential velocity introduce an analogous formation-length component proportional to $3GM/(pc^2)$. As a result, the propagation cycle does not close perfectly after a single revolution. A small residual cycle-closing offset remains after each orbit, and the accumulation of these offsets over many revolutions appears geometrically as the observed advance of Mercury's perihelion. In this interpretation, perihelion precession is not a separate phenomenon but a direct consequence of a slightly elongated orbital formation cycle.

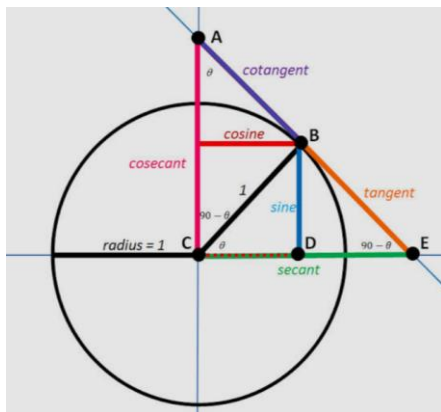
To clarify how this propagation-based interpretation developed it would be good to dig a bit deeper. For uniform motion, the there-and-back propagation geometry gives: $L_f = t_{\text{chase}} + t_{\text{meet}}$ where: $t_{\text{chase}} = 1 / (1 - \beta)$ $t_{\text{meet}} = 1 / (1 + \beta)$. Combining both directions gives: $L_f = 2 / (1 - \beta^2) = 2\gamma^2$. This quantity can be interpreted as the longitudinal formation length required for a complete propagation cycle to form. For small velocities: $2\gamma^2 \approx 2 + 2\beta^2$ so the excess formation length above the rest value is: $\Delta L_f \approx 2\beta^2$. Thus, in uniform motion, relativistic effects can be viewed as arising from a small propagation-cycle elongation proportional to β^2 . A similar structure appears in orbital motion. For an orbiting body: $v_{\text{orb}}^2 = GM / r$ which gives: $\beta_{\text{orb}}^2 = GM / (rc^2)$. In the propagation picture, orbital motion contains two contributions: a gravitational drop component corresponding to the escape-velocity scale: $v_{\text{esc}}^2 / c^2 = 2GM / (rc^2)$ and tangential orbital-motion component: $v_{\text{orb}}^2 / c^2 = GM / (rc^2)$. Adding both contributions gives: $2GM / (rc^2) + GM / (rc^2) = 3GM / (rc^2)$. For elliptical orbits: $3GM / (pc^2)$. This is exactly the coefficient appearing in the standard relativistic correction responsible for Mercury's perihelion precession. The analogy is therefore: Uniform motion: $\Delta L_f \approx 2\beta^2$. Orbital motion: $\Delta L_{\text{orb}} \approx 3\beta^2$. In both cases the effect appears as a small excess propagation-cycle length proportional to β^2 . The difference is that orbital motion contains an additional gravitational contribution, increasing the coefficient from 2 to 3. The key conceptual distinction is that in uniform motion the enlarged formation region does not accumulate any directional offset because the motion is straight. The propagation cycle becomes longer, but it still closes consistently. In orbital motion, however, the cycle is constrained to close around a curved trajectory. The additional propagation length therefore prevents perfect closure after a single revolution. A small residual cycle-closing offset remains after each orbit. The accumulation of these residual offsets over many revolutions appears geometrically as Mercury's observed perihelion advance. In this interpretation, Mercury's precession can be viewed as the orbital analogue of relativistic formation-length growth. Both phenomena originate from the same underlying idea: propagation cycles become slightly longer than their ideal closure condition. In uniform motion this appears as an enlarged formation region scaling at length as $2\gamma^2$, while in orbital motion it appears as a cycle-closing excess proportional to $3GM/(pc^2)$, producing perihelion precession. The

resulting picture suggests that relativistic time dilation, formation-length growth, and orbital precession may all be different manifestations of a common propagation-geometry mechanism based on the elongation and closure properties of there-and-back propagation cycles.

This brings us to one more calculation:

The proper averaged spherical wave redshift (and its downward energy bias due to redshift/blueshift imbalance) can be expressed as a radial elongation (in fact representing the redshift as the path elongation) of the wavefront tilted down - this is obtained from the secant proportion in the right-triangle construction as presented below:

- to know the elongation of the radius we can construct a right triangle,
- where $\sqrt{1-x}$, $\sqrt{x}$, and 1 can form a right triangle because the sum of the squares of the two shorter sides (legs) equals the square of the longest side (hypotenuse) according to the $(a^2 + b^2 = c^2)$.
- In this case, $(\sqrt{1-x})^2 + (\sqrt{x})^2 = (1-x) + x = 1$, which is equal to 1^2 , the square of the hypotenuse, confirming it is a right triangle for any valid value of x . Thus:

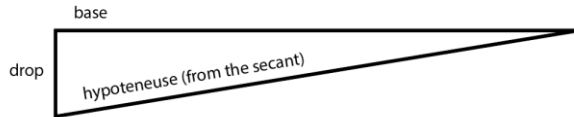


- The adjacent side is $\sqrt{1-2GM / (rc^2)}$ and represents $\cos$;
- The opposite side is $\sqrt{2GM / (rc^2)}$ and represents $\sin$;
- The hypotenuse is 1.
- The dilation factor (effectively averaged photon path elongation understood as redshift) is simply the secant of this angle: $\gamma = 1/\cos = 1/\sqrt{1-2GM / (rc^2)}$.

The stronger blueshift tilts the whole object (wavefront) energetically inward. If we treat matter as having Compton's frequency, then all objects fall with the same acceleration derived from the bending of those wavefronts' energy vectors.

Treating gravity as causing countless tiny light-speed steps to tilt slightly downward gives a picture where their total route-accumulation should meet exactly the standard free-fall acceleration: $g = GM / r^2$.

The escape velocity follows directly from the same construction (proper calculations are also available in the attached xls file):



Let's assume:

$$c = 299\,792\,458 \text{ m/s}$$

$$G = 6.6743 \times 10^{-11}$$

$$M = 1.9885 \times 10^{30} \text{ kg (sun's mass)}$$

$$r = 6\,371\,000 \text{ m (Earth's radius)}$$

Secant:

$$\gamma = 1 / \sqrt{1 - 2GM / rc^2}$$

$$\gamma = 1.00023186400517$$

Light-step time for hypotenuse = 1,000231864005170000000000000000 m:

$$t = 1,000231864005170000000000000000 / c$$

$$t = 0,000000003336414367 \text{ s}$$

Right-triangle drop:

$$\text{drop} = \sqrt{\gamma^2 - 1}$$

$$\text{drop} = 0.02153559313$$

Vertical speed from secant drop:

$$v = \text{drop} / t$$

$$v = 0.02153559313 / 0.000000003336414367$$

$$v = 6\,457\,411.782 \text{ m/s}$$

And this equals escape velocity:

$$v_{\text{esc}} = \sqrt{2GM / r}$$

$$v_{\text{esc}} = 6\,457\,411.782 \text{ m/s}$$

The proposed mechanism assumes that gravity is a spatial gradient that changes wave propagation (refraction). For a stationary receiver, a signal propagating through the

gravitational gradient arrives with a frequency shifted according to the local gravitational potential - the decrease of this frequency equals to elongation of the radius of the spherical wavefront and so the secant construction allows us to estimate the proper value of this distortion. The energy of the wavefront shifts and thus:

- The signal received has less energy (is redshifted) and this frequency-distortion factor directly determines the observed time-dilation factor (as frequency defines the minimal energy packages necessary to detect an event - and thus record any time-flow at all).
- The energy shift points down causing the acceleration.

Given the above the outcome is that the receiver resolves the signal at a different rate, producing the familiar time-dilation effect, while, in this model, the energy-vector bias points inward and is interpreted as the origin of gravitational acceleration. In fact, the redshift / blueshift imbalance occurring under acceleration / deceleration may also explain exactly the values standing behind inertial forces. Assuming that matter is constituted from waves hitting there and back with speed c may explain mechanistically not only the speed time dilation, gravity time dilation, gravity itself, gravitational acceleration and escape velocity but also inertial forces (redshift / blueshift imbalance) and possibly coasting (stable redshift / blueshift relation).

Importantly, all the logic and calculations done above for the gravity part were conducted only by using equations existing before Einstein - those pre-Einstein equations and observations mixed with the idea that matter is constituted by closing of there and back wave cycles yields the proper experimental values thus giving a hint of what the mechanism of the above mentioned phenomena might be.

The proposed propagation-based framework may be capable of recovering the full structure of General Relativity because energy, momentum, and stress arise naturally as different directional moments of closed wave - propagation cycles, providing an analogue of the stress-energy tensor. If all physical processes - including matter, light, and clocks - are ultimately manifestations of propagation, then a gravitational field can be interpreted as a modification of the local geometry of propagation rather than as a fundamental curvature of spacetime itself. In such a picture, the Einstein field equations may emerge as an effective macroscopic description of underlying propagation dynamics. At the same time, the model may replace several conceptually difficult elements of standard GR - such as treating time as a fundamental dimension and allowing solutions with closed timelike curves or backwards time evolution - with a framework in which time is an emergent measure of completed propagation cycles, making causality and the arrow of time natural consequences of the underlying physical processes.

Further logic:

The propagation picture can be interpreted using the same geometric logic for both uniform motion and gravity.

In the SR construction, a moving system produces an asymmetry between opposite propagation directions. The forward direction corresponds to a chase configuration, while the

backward direction corresponds to a meet configuration. The combination of these opposite directions produces the relativistic dilation factor.

In the gravitational construction, the escape-velocity scale plays the role of the effective propagation velocity:

$$v_{\text{esc}}^2 = 2GM / r$$

Viewed from far away, the vertical pair of directions becomes a redshift/blueshift pair.

The lower direction corresponds to a deeper gravitational potential and therefore appears more redshifted to a distant observer.

The upper direction corresponds to a shallower gravitational potential and therefore appears relatively blueshifted compared to the lower direction.

Thus:

$270^\circ \rightarrow$ redshift

$90^\circ \rightarrow$ blueshift

The remaining opposite pair:

$0^\circ \leftrightarrow 180^\circ$

plays the role of the $90^\circ/270^\circ$ basic chase/meet pair familiar from the opening SR construction.

In this interpretation, gravity reorganizes the same propagation geometry. The escape-velocity scale therefore acts as the gravitational analogue of the propagation velocity used in the SR model.

Here the propagation-based route to frame dragging can be also written as follows:

Start with a static spherical mass. In the weak-field limit, the natural radial gravitational scale is:

$$2GM / rc^2$$

In the present interpretation, this is the radial propagation-distortion scale produced by a stable spherical mass. A non-rotating mass produces a purely radial effect: the propagation field is distorted inward/outward, but it has no preferred azimuthal direction.

Now let the same mass rotate.

Before Einstein, classical mechanics already had the necessary description of mass in motion. A continuous rotating body is described by a mass density ρ and a velocity field v . The local momentum density is:

$$\rho v$$

The rotational content of the whole body is obtained by integrating this momentum density with the lever arm r :

$$J = \int r \times (\rho v) dV$$

This is the ordinary classical angular momentum. For a rigid rotating sphere:

$$J = I\omega$$

and:

$$I = kMR^2$$

so:

$$J = kMR^2\omega$$

where k describes the mass distribution, R is the radius of the source, and ω is its angular velocity.

The key interpretive step is this:

if a static mass produces a radial propagation distortion $2GM/rc^2$, then a rotating mass should not leave that distortion perfectly radial. The moving mass distribution introduces an azimuthal bias into the same propagation field. In other words, the radial influence is partially “twisted” by the rotational flow of the source.

The natural measure of this rotational bias at distance r is the angular momentum per mass and per area:

$$J / Mr^2$$

This quantity has units of angular frequency. It tells how strongly the source’s mass distribution participates in rotation as seen from distance r .

Therefore the frame-dragging scale is obtained as:

radial gravitational influence $\times$ normalized rotational bias

so:

$$\Omega_{LT} = (2GM / rc^2)(J / Mr^2)$$

Multiplying gives:

$$\Omega_{LT} = 2GJ / c^2r^3$$

This is the weak-field Lense-Thirring frame-dragging result.

In this interpretation, frame dragging is not introduced as a separate phenomenon. It is the rotating-source version of the same propagation distortion that a static mass produces

radially. A static mass changes the radial closure of propagation cycles. A rotating mass adds an azimuthal twist to that closure.

The important point is that the classical ingredients were already known before Einstein:

ρv = local momentum density

$J = \int \mathbf{r} \times (\rho \mathbf{v}) dV$ = total angular momentum

$J = kMR^2\omega$ for a rigid rotating body

What was not present in pre-Einstein physics was the rule that this moving mass distribution also twists the gravitational field. In GR, this rule comes from the energy-momentum tensor and the Kerr/Lense-Thirring solution. In the propagation interpretation, it is introduced as the statement that motion of the source redistributes the radial propagation effect into a directional, azimuthal distortion.

So the structure can be summarized as:

Ω_{LT} = radial GR scale $\times$ rotational redistribution scale

$\Omega_{LT} = (2GM / rc^2)(J / Mr^2)$

$\Omega_{LT} = 2GJ / c^2r^3$

This gives the correct weak-field frame-dragging scale.

An interesting aspect of the frame-dragging construction is that the rotational factor naturally appears in the form $J/(Mr^2)$. The angular momentum J has units:

$\text{kg} \cdot \text{m}^2/\text{s}$

while Mr^2 has units:

$\text{kg} \cdot \text{m}^2$

Therefore:

$J/(Mr^2)$

has units:

$(\text{kg} \cdot \text{m}^2/\text{s})/(\text{kg} \cdot \text{m}^2) = 1/\text{s}$

which is the unit of frequency. More specifically, it corresponds to an angular frequency scale, since angular momentum is intrinsically associated with rotational motion. In standard General Relativity, the Lense-Thirring effect is described by a precession frequency, so the appearance of a quantity with units of $1/\text{s}$ is physically meaningful.

Within the propagation-based interpretation developed here, $J/(Mr^2)$ can therefore be viewed as a local rotational propagation frequency associated with the spinning source. The radial

gravitational factor $2GM/(rc^2)$ describes the strength of the underlying propagation distortion, while $J/(Mr^2)$ describes how that distortion is redistributed azimuthally by rotation. Their product gives:

$$\Omega_{LT} = (2GM/rc^2)(J/Mr^2) = 2GJ/(c^2r^3)$$

The appearance of $J/(Mr^2)$ as a natural frequency scale is particularly noteworthy because frequency already plays a central role throughout the framework, where time, inertia, gravity, and relativistic effects are interpreted as consequences of propagation-cycle geometry and closure.

For a thin ring, where all of the mass is concentrated at radius r , $J/(Mr^2)$ is exactly equal to the physical rotation rate ω . For a real spherical body such as the Earth, much of the mass lies closer to the rotation axis and therefore contributes less to the total angular momentum. As a result, $J/(Mr^2)$ is smaller than the surface rotation rate and represents an average rotational frequency of the entire mass distribution.

An illustrative argument for inertia, to close the intuition part, can also be constructed from the propagation-cycle interpretation.

Assume that acceleration produces a small frequency gradient across a propagation cycle of characteristic length L :

$$\Delta f/f \approx aL/c^2$$

where a is the acceleration and c is the speed of light.

Now consider the Compton frequency associated with a particle of mass m :

$$f_C = mc^2/h$$

The corresponding frequency difference across the cycle is:

$$\Delta f = f_C \cdot aL/c^2$$

Substituting the Compton frequency gives:

$$\Delta f = (mc^2/h) \cdot aL/c^2$$

$$\Delta f = maL/h$$

If momentum is related to frequency through:

$$p = hf/c$$

then the momentum imbalance associated with the frequency imbalance is:

$$\Delta p = h\Delta f/c$$

Substituting the expression above:

$$\Delta p = (h/c) \cdot (maL/h)$$

$$\Delta p = maL/c$$

Assume that the propagation cycle closes with frequency:

$$c/L$$

cycles per second.

The resulting force is then:

$$F = \Delta p \cdot (c/L)$$

Substituting Δp :

$$F = (maL/c) \cdot (c/L)$$

$$F = ma$$

Thus the standard inertial force law emerges directly from the propagation-cycle picture.

As an example, consider an 80 kg passenger in an aircraft accelerating at approximately 0.25 g:

$$a \approx 2.45 \text{ m/s}^2$$

The resulting force is:

$$F = ma$$

$$F = 80 \times 2.45$$

$$F \approx 196 \text{ N}$$

In this interpretation, inertia is not treated as a fundamental property of matter. Instead, acceleration produces a small redshift/blueshift imbalance across the closed propagation cycles constituting matter. This imbalance generates a momentum asymmetry, and maintaining acceleration requires continuously sustaining that asymmetry. The observed inertial force is therefore interpreted as the macroscopic manifestation of the resistance of stable propagation cycles to changes in their propagation geometry.

As the formation-length interpretation follows naturally from the presented propagation geometry itself, **we can construct an explanation of Michelson-Morley interferometer as well as of the Sagnac effect based on this model.**

Let's have at velocity of 0.9c:

Longitudinal propagation:

$$\text{there} = 1 / (1 - 0.9) = 10$$

$$\text{back} = 1 / (1 + 0.9) = 0.526$$

$$\text{there} + \text{back} = 10 + 0.526 = 10.526 = 2\gamma^2$$

Transverse propagation:

$$\text{there} = \gamma = 2.294$$

$$\text{back} = \gamma = 2.294$$

$$\text{there} + \text{back} = 2.294 + 2.294 = 4.588 = 2\gamma$$

Thus, the propagation geometry itself predicts that the complete longitudinal formation region is exactly γ times larger than the transverse one:

$$2\gamma^2 / 2\gamma = \gamma.$$

Considering this fact the observable propagation for longitudinal direction is:

$$\text{there} = 10 / \gamma = 4.359$$

$$\text{back} = 0.526 / \gamma = 0.229$$

$$\text{there} + \text{back} = 4.359 + 0.229 = 4.588 = 2\gamma$$

Therefore:

$$\text{longitudinal: } 4.359 + 0.229 = 4.588 = 2\gamma = t_{\text{first}} \text{ (*or rather } L_{\text{first}} \text{ for length)}$$

$$\text{transverse: } 2.294 + 2.294 = 4.588 = 2\gamma = t_{\text{first}}$$

The above means that both propagation directions produce the first observable event named t_{first} after exactly the same **perceived** propagation length (as the observable longitudinal length/distance is 'consumed' by signal-creation process longer exactly by γ when compared to the transverse signal creation distance).

This formation length is therefore not introduced as an additional assumption. It is a direct consequence of the chase-meet propagation geometry. In this framework, time is not a fundamental quantity. It is an emergent quantity generated only when a propagation process reaches a complete detectable state. Before that point, there is only propagation geometry rather than an independently existing flow of time. The proposal is therefore that detection occurs only after the complete formation region has been completed.

Importantly, both the longitudinal and transverse signals require completion of their full formation regions before any of them becomes observable. So the same completed propagation state occupies different amounts of raw geometric propagation length depending on direction. Along the direction of motion, the same completed propagation state requires γ times more raw propagation than in the transverse direction. Consequently:

$$2\gamma^2 / \gamma = 2\gamma,$$

so both directions correspond to exactly the same observable completed propagation length within the moving frame (while from 'outside' the longitudinal formation lengths scaling like γ are observable).

In the proposed propagation model, the directional formation correction affects the location of the first complete observable event, but it does not permanently change the cadence of the signal generated by the comoving apparatus. Once the first formation event has been completed, all subsequent wave fronts arrive with the steady-state separation imposed by the common moving-system frequency. Let's look at a simple example.

For a source frequency of

$$f_0 = 10 \text{ Hz}$$

and a system velocity of

$$v = 0.9c,$$

the Lorentz factor is

$$\gamma = 2.294.$$

The frequency associated with the moving system is therefore:

$$f_{\text{system}} = f_0 / \gamma = 10 / 2.294 = 4.359 \text{ Hz}.$$

The corresponding separation between successive observable wave fronts is:

$$\Delta t_{\text{system}} = 1 / f_{\text{system}} = \gamma / f_0 = 2.294 / 10 = 0.2294 \text{ s}.$$

Thus, after the first complete signal has been formed and detected, the subsequent observable fronts occur at:

$$t_{\text{first}} (\text{the first complete signal has been formed and detected}) = 4.5883$$

$$t_1 = t_{\text{first}} = 4.5883$$

$$t_2 = t_{\text{first}} + 0.2294 \text{ s} = 4.8177$$

$$t_3 = t_{\text{first}} + 2 \times 0.2294 \text{ s} = t_{\text{first}} + 0.4588 \text{ s} = 5.0471$$

$$t_4 = t_{\text{first}} + 3 \times 0.2294 \text{ s} = t_{\text{first}} + 0.6882 \text{ s} = 5.2765$$

and so on. After that common first event, both branches are assumed to reproduce the same system-imposed signal cadence:

$$\Delta t = 0.2294 \text{ s},$$

or equivalently

$$f = 4.3589 \text{ Hz}.$$

Numerically, the observable sequences would therefore be:

longitudinal: [perceived as $4.359 + 0.229 = 4.5883$] 4.5883, 4.8177, 5.0471, 5.2765, ...

transverse: [$2.294 + 2.294 = 4.5883$] 4.5883, 4.8177, 5.0471, 5.2765, ...

where each successive value differs from the previous one by 0.2294.

Here we can also note:

The effective chase interval is: $C_{\text{observable}} = 4.359$.

The common system interval is: $\Delta t_{\text{system}} = 0.2294$.

Therefore, the chase region contains: $N_C = C_{\text{observable}} / \Delta t_{\text{system}}$ $N_C = 4.359 / 0.2294$ $N_C = 19$ intervals.

The effective meet interval is: $M_{\text{observable}} = 0.2294$.

Therefore: $N_M = M_{\text{observable}} / \Delta t_{\text{system}}$ $N_M = 0.2294 / 0.2294$ $N_M = 1$ interval.

The meet side contains less normalized content but is encountered more quickly: $N_M \times R_M = 1 \times 1.9$ $N_M \times R_M = 1.9$ Therefore: $19 \times 0.1 = 1 \times 1.9$. The same result can be written without normalization:

$$C \times R_C = 10 \times 0.1 = 1$$

$$M \times R_M = 0.5263 \times 1.9 = 1$$

The initial directional geometry determines how much formation length is required to create the first observable event. Once that event has been formed, however, the subsequent fronts are separated by the common frequency interval imposed by the moving apparatus. The formation correction therefore changes the initial offset, while the steady-state wavefront cadence remains the same later on. The encountered phase content is the same on both sides. Chase contains 19 times more front content, but it is encountered 19 times more slowly. Meet contains 19 times less front content, but it is encountered 19 times faster. The larger content and the slower rate cancel each other exactly.

The chase and meet parts have different lengths and different front rates, but their phase closes coherently because the longer part is processed more slowly and the shorter part is processed faster. When their geometric lengths are added, the formation length equals $2 \times \gamma^2$. The number of wavefronts is related to distance through the wavelength:

$$N_{\text{phase}} = L / \lambda$$

So front count and formation length are mathematically connected but they represent different aspects:

Formation length tells us how much distance is occupied.

Front count tells us how many phase cycles fit into that distance.

In this sense, **the formation-length mechanism plays the same observational role as Lorentz length contraction: it removes any measurable difference between the longitudinal and transverse arms in a two-way light experiment while attributing the compensation to signal formation rather than to a contraction of physical distances.**

For the Sagnac interferometer, the two counter-propagating beams are formed simultaneously at the beam splitter and then propagate independently around the loop. Their propagation times therefore remain different throughout the entire path:

$$t_{\text{chase}} = 1 / (1 - 0.9) = 10,$$

$$t_{\text{meet}} = 1 / (1 + 0.9) = 0.526.$$

Hence,

$$\Delta t = t_{\text{chase}} - t_{\text{meet}} = 10 - 0.526 = 9.474.$$

The detector directly measures the propagation-time difference between the independent chase and meet paths.

Explaining further by analyzing the possible route:

Assume acceleration from rest to $\beta = 0.9$, for which: $\gamma = 2.294$. All values below are expressed in units of L/c . Before acceleration, at $\beta = 0$:

$$\text{longitudinal round trip} = 2$$

$$\text{transverse round trip} = 2$$

Therefore, there is no relative shift between the two streams. After acceleration to $\beta = 0.9$:

$$\text{longitudinal round trip} = 2 \gamma^2 = 10.526$$

$$\text{transverse round trip} = 2 \gamma = 4.588$$

The longitudinal stream has therefore been shifted relative to its rest value by:

$$10.526 - 2 = 8.526$$

The transverse stream has been shifted relative to its rest value by:

$$4.588 - 2 = 2.588$$

The difference between these two changes is:

$$8.526 - 2.588 = 5.938$$

In general:

$$(2 \gamma^2 - 2) - (2 \gamma - 2) = 2 \gamma^2 - 2 \gamma = 2 \gamma(\gamma - 1)$$

Acceleration shifts the longitudinal and transverse formation lengths by different amounts. Their relative shift grows from zero at rest to 5.938 at $\beta = 0.9$. Acceleration therefore creates the rearrangement of the two streams. Later uniform motion does not increase it further - it only preserves it. In the established steady state, consider any later event S. The longitudinal front arriving at S originated at:

$$S - 10.526$$

The transverse front arriving at the same S originated at:

$$S - 4.588$$

The difference between their retarded origins is: $(S - 4.588) - (S - 10.526) = 5.938$

5.938 is not the moment when transverse propagation begins. It is the constant distance difference of the longitudinal and transverse contributions that arrive together now. The resulting picture is:

- * Before acceleration, corresponding longitudinal and transverse fronts have the same origin.
- * During acceleration, their propagation structures acquire different shifts.
- * At $\beta = 0.9$, their retarded-origin shift is 5.938.
- * During later coasting, this shift remains constant.

Acceleration from rest to $0.9c$ changes the longitudinal formation length by 8.526 and the transverse formation length by 2.588. Their difference, 5.938, becomes the permanent retarded-origin between the two wavefronts. Uniform coasting preserves this shift.

Imagine two continuously running conveyor loops. At rest, each loop takes 2 units to complete, so packages loaded onto both loops together also return together. After the machine accelerates, the longitudinal loop takes 10.526 units, while the transverse loop takes 4.588 units. Relative to the original 2 units, the longitudinal loop has gained $10.526 - 2 = 8.526$ units of delay, while the transverse loop has gained $4.588 - 2 = 2.588$ units. The additional delay between the two streams is therefore $8.526 - 2.588 = 5.938$ units. Consequently, in the established continuous flow, a longitudinal package arriving now was loaded 10.526 units ago, while the transverse package arriving with it was loaded only 4.588 units ago, meaning that the longitudinal package originated exactly 5.938 units earlier. Despite being loaded at different moments, these two particular packages return to the common endpoint at exactly the same moment.

The geometric mean further explanation and justification:

At $\beta = 0.9$, the asymmetric chase-meet propagation can be represented by an effective ellipse whose two reciprocal directional scales are 10 and 0.526. Their arithmetic round-trip length is 10.526, while the transverse diameter is only 4.588, leaving an excess of 5.938. In classical geometry, an ellipse with effective semiaxes a and b can be replaced by an equal-area circle whose radius is the geometric mean, $R = \sqrt{ab}$. Here, $\sqrt{10 \times 0.526} = 2.294 = \gamma$, and doubling this recovered radius gives 4.588, exactly the transverse diameter.

The geometric mean therefore maps the asymmetric ellipse-like geometry back onto its equivalent base circle and removes the 5.938 arithmetic excess from the symmetrized geometry. This is a classical equal-area-circle construction applied to the effective chase-meet ellipse.

The geometric mean does not destroy the 5.938 excess. It separates the invariant circular base geometry from the additional formation region. That excess region contains the net additional front weight corresponding to kinetic energy, while the asymmetric chase-meet distribution of the complete population carries the directional momentum - as explained below.

The extra longitudinal formation relative to the transverse formation is:

$$(10.526 - 4.588) / 4.588 = 1.294$$

This is exactly $\gamma - 1$.

The physical proposal is that this rearrangement stores energy. If the rest-state formation corresponds to the rest energy mc^2 , then the energy required for the rearrangement is:

$$\text{rearrangement energy} = (\gamma - 1)mc^2$$

This is exactly the relativistic kinetic energy.

In this picture, acceleration does not simply give speed to a point-like object. It forces the object's continuous propagation structure to change. The longitudinal and transverse streams must acquire new formation lengths, new retarded origins, and a new stable relationship. That rearrangement requires energy. The need to supply this energy is experienced as resistance to acceleration. Once acceleration ends, the rearrangement is complete. The system retains its new stable propagation structure, but no additional energy is required. This explains why uniform coasting does not require a force.

During deceleration, the structure must rearrange in the opposite direction. The energy stored during acceleration is released, and the system resists the change by tending to preserve its established motion expressing its propagation structure.

The proposed interpretation is therefore:

Inertia is the reaction of a continuously propagating system to the forced rearrangement of its internal formation structure.

The mathematical connection is unusually direct: the relative excess formation equals $\gamma - 1$, $\gamma - 1$ gives the exact kinetic energy, and the change of that energy gives the correct inertial force.

Here we can come to a **front-counting interpretation of relativistic energy and inertia**.

A physical system is represented by a closed, continuously propagating structure containing oppositely directed wavefronts. Each front carries the same elementary amount of proper energy. Acceleration does not reduce the energy of an individual front. It changes the

geometry in which the fronts are distributed. The proper frequency f_0 remains constant in the comoving system. In an external description, the separation between successive emission events is increased by γ . Thus the external cadence is f_0/γ . The frequency change is geometrical and frame-dependent, not an internal loss of energy by the front.

Front counting:

Assume that the complete rest configuration contains 100 front intervals: 50 chase fronts 50 meet fronts. After acceleration, the longitudinal formation length increases by γ^2 , while the separation associated with the source cadence increases only by γ . Therefore:

$$N_{\text{longitudinal}} = 100 \gamma^2 / \gamma = 100 \gamma.$$

For $\beta = 0.9$:

$$N_{\text{longitudinal}} = 229.416.$$

The directional populations are:

$$N_{\text{chase}} = 50 \gamma (1 + \beta) = 217.945$$

$$N_{\text{meet}} = 50 \gamma (1 - \beta) = 11.471.$$

Therefore:

$$N_{\text{chase}} + N_{\text{meet}} = 229.416 = 100 \gamma$$

$$N_{\text{chase}} - N_{\text{meet}} = 206.474 = 100 \gamma \beta.$$

The longitudinal formation structure therefore contains 129.416 more front-equivalents than the rest structure:

$$N_{\text{extra}} = 100(\gamma - 1) = 129.416.$$

The large increase occurs mainly in the chase population, while the meet population becomes smaller.

In this model, the number of front intervals increases only in the longitudinal formation region. At $\beta = 0.9$, $\gamma = 2.294$: the longitudinal formation length grows as γ^2 , while the spacing between fronts grows only as γ , so 100 intervals become 100 $\gamma = 229.4$. Transversely, both the formation length and the front spacing grow by γ , so these factors cancel and the number remains 100. The longitudinal population divides into 217.9 chase fronts and 11.47 meet fronts, giving the 19:1 ratio. This larger, asymmetric longitudinal inventory can coexist with the same later observable cadence in every direction because stored fronts and the rate at which completed fronts emerge are different quantities.

The above is, considering the ratio, equal to $C = 1/(1 - \beta)$ and $M = 1/(1 + \beta)$ and only normalized by γ by the logic:

Start from the definition of the Lorentz factor:

$$\gamma = 1 / \sqrt{1 - \beta^2}$$

Squaring both sides gives:

$$\gamma^2 = 1 / (1 - \beta^2)$$

Therefore:

$$\gamma^2(1 - \beta^2) = 1$$

Dividing both sides by γ gives:

$$1/\gamma = \gamma(1 - \beta^2)$$

Since:

$$1 - \beta^2 = (1 - \beta)(1 + \beta)$$

we obtain:

$$1/\gamma = \gamma(1 - \beta)(1 + \beta)$$

For chase:

$$\begin{aligned} & (1/\gamma) / (1 - \beta) \\ &= \gamma(1 - \beta)(1 + \beta) / (1 - \beta) \\ &= \gamma(1 + \beta) \end{aligned}$$

For meet:

$$\begin{aligned} & (1/\gamma) / (1 + \beta) \\ &= \gamma(1 - \beta)(1 + \beta) / (1 + \beta) \\ &= \gamma(1 - \beta) \end{aligned}$$

Therefore:

$$N_{\text{chase}} = 50\gamma(1 + \beta) = (50/\gamma) / (1 - \beta)$$

$$N_{\text{meet}} = 50\gamma(1 - \beta) = (50/\gamma) / (1 + \beta)$$

Thus, the presented front populations have exactly the same chase–meet proportions as $1/(1 - \beta)$ and $1/(1 + \beta)$, but their common base is normalized from 1 to $1/\gamma$.

Energy and momentum:

Let the rest energy be distributed between the initial 100 fronts:

$$100 \varepsilon = E_0 = mc^2.$$

Because the energy ε of each front remains unchanged, the total energy after acceleration is:

$$E = \varepsilon (N_{\text{chase}} + N_{\text{meet}}) = \gamma E_0 = \gamma mc^2.$$

The energy added during acceleration is:

$$K = E - E_0 = (\gamma - 1)mc^2.$$

For $\beta = 0.9$:

$$K = 1.294157 mc^2.$$

Thus the external work can be interpreted as the energy required to populate the enlarged formation structure with the additional 129.416 front-equivalents. Energy itself has no direction. Direction is encoded by the difference between the two populations. If every chase front carries momentum $+\varepsilon/c$ and every meet front carries momentum $-\varepsilon/c$, then the population difference is:

$$N_{\text{chase}} - N_{\text{meet}} = 50 \gamma (1 + \beta) - 50 \gamma (1 - \beta) = 100 \gamma \beta.$$

The initial 100 fronts contain the rest energy:

$$100 \varepsilon = mc^2,$$

so:

$$\varepsilon = mc^2/100.$$

Substituting this into the momentum equation:

$$p = (\varepsilon/c)(N_{\text{chase}} - N_{\text{meet}}) = (mc^2/100c)(100 \gamma \beta) = \gamma \beta mc$$

as $\beta = v/c$:

$$p = \gamma mv.$$

For $\beta = 0.9$:

$$p = 2.064742 mc.$$

The front counting therefore reproduces:

$$\text{sum of fronts} \rightarrow E = \gamma mc^2$$

additional fronts $\rightarrow K = (\gamma - 1)mc^2$

chase-meet imbalance $\rightarrow p = \gamma mv$.

It also satisfies: $E^2 - p^2 c^2 = m^2 c^4$.

The standard relativistic energy-momentum relation is:

$$E^2 - p^2 c^2 = m^2 c^4.$$

Substituting this expressions from the front-counting model gives:

$$E^2 - p^2 c^2 = \gamma^2 m^2 c^4 - \gamma^2 m^2 v^2 c^2 = \gamma^2 m^2 c^4 (1 - v^2/c^2).$$

Since $\beta = v/c$ and $\gamma^2 = 1/(1 - \beta^2)$:

$$\gamma^2 (1 - v^2/c^2) = 1.$$

Therefore:

$$E^2 - p^2 c^2 = m^2 c^4.$$

Acceleration and inertia:

During acceleration, the propagation structure cannot reorganize everywhere instantaneously because all changes propagate at finite speed. The proposed mechanism is:

The external interaction begins to change the momentum of the system. Fronts temporarily cease to strike the forward and rear parts of the structure coherently. Chase fronts accumulate while the meet population decreases. This produces an internal momentum imbalance. The external force performs work against this reaction. That work populates and reorganizes the enlarged longitudinal formation structure. The final excess energy is exactly $(\gamma - 1)mc^2$, while the final directional imbalance carries momentum $p = \gamma mv$. In this interpretation, inertia is the reaction of a continuously propagating system to a forced rearrangement of its internal formation structure.

Uniform motion:

When acceleration ends, the reorganization also ends. The system settles into a new stable global mode. The enlarged front population and the chase-meet imbalance are preserved, but the internal momentum fluxes again become balanced. Consequently:

- the system retains its energy and momentum;
- no additional 'fronts' need to be added;
- uniform motion requires no additional input of energy.

During deceleration, the reorganization proceeds in the opposite direction. The extra front content is removed or transferred to the braking interaction, and the previously stored kinetic energy is released.

The proposed chain is: External work during acceleration -> temporary front-back momentum imbalance -> creation and redistribution of additional longitudinal front content -> total front count increased by gamma -> total energy increased to γmc^2 -> directional imbalance producing $p = \gamma mv$ -> settlement into a new stable propagation mode -> constant proper frequency during uniform motion.

Here we have arrived at a moment, where in fact mass, energy, momentum, velocity, time, time dilation, inertia, uniform motion all fall out of one spherical wave propagation geometry and speed limit c . As gravitational free-fall in the model presented is described and calculated as the secant-based tick-by-tick drop, **we can come back to the earlier mentioned observation, that a prediction can be made that $8GM/rc^2$ should appear as gravitational deflection formula for matter passing spherical non-rotating mass exactly at:**

$$v = c / \sqrt{3}$$

while the deflection should smoothly decrease toward:

$$4GM / bc^2$$

as the one-direction velocity approaches c (this is natural, as finally matter can not be constituted at all, and only a one-way propagating wave “stays alive” moving through space with the speed c).

The above presented statement connects strongly with the logic presented in the “front counting” part of this writing. To describe it clearly, we have to take one step back and explain one simple fact, later the rest follows.

Let's begin with the step back and remind the part about obtaining the $2GM / rc^2$ coefficient for gravity:

The key idea is that the same dimensionless factor affects both:

the propagating signal,

the local clock used to measure that signal.

If the same first-order factor appears in both places, the observable process contains:

$$(1 + GM / rc^2)(1 + GM / rc^2)$$

$$= (1 + GM / rc^2)^2$$

Expanding gives:

$$1 + 2GM / rc^2 + (GM / rc^2)^2$$

Since GM / rc^2 is very small in ordinary gravitational fields, the quadratic term can be neglected:

$$(1 + GM / rc^2)^2 \approx 1 + 2GM / rc^2$$

This calculation can be also done in analogy to the chase-meet front counting logic presented earlier. Regarding the front counting approach we can add the following additional clarifications. Let's start with the earlier mentioned simple Doppler effect example, which we remind below:

Take:

$$\beta = 0.9$$

The chase time is:

$$C = 1 / (1 - \beta)$$

$$C = 1 / 0.1$$

$$C = 10$$

The meet time is:

$$M = 1 / (1 + \beta)$$

$$M = 1 / 1.9$$

$$M = 0.5263$$

Therefore, the directional ratio is:

$$C / M = 10 / 0.5263 = 19$$

For the same emission rate, the chase region contains 19 times more normalized front content than the meet region.

At the same time, the rates at which the moving system encounters the fronts are:

$$R_C = 1 - \beta = 0.1$$

$$R_M = 1 + \beta = 1.9$$

Normalize the front content so that it is easy to grasp the idea:

$$N_M = 1$$

$$N_C = 19$$

Then, for chase: $N_C \times R_C = 19 \times 0.1 = 1.9$

$$\text{For meet: } N_M \times R_M = 1 \times 1.9 = 1.9$$

$$\text{Therefore: } 19 \times 0.1 = 1 \times 1.9$$

The same result can be written without normalization:

$$C \times R_C = 10 \times 0.1 = 1$$

$$M \times R_M = 0.5263 \times 1.9 = 1$$

As was stated before - chase and meet parts have different lengths and different front rates, but their phase closes coherently because the longer part is processed more slowly and the shorter part is processed faster. Here we can bring back the earlier presented kinetic energy interpretation:

Let the rest energy be distributed between the initial 100 fronts:

$$100 \varepsilon = E0 = mc^2.$$

Because the energy epsilon ε of each front remains unchanged, the total energy after acceleration is:

$$E = \varepsilon (N_chase + N_meet) = \gamma E0 = \gamma mc^2.$$

The energy added during acceleration is:

$$K = E - E0 = (\gamma - 1)mc^2.$$

For beta = 0.9:

$$K = 1.294157 mc^2.$$

That matches exactly $N_chase + N_meet = 229.416 = 100 \gamma$, the normalized excess above initial 100 fronts is $229.416 - 100 = 129.416 / 100 = 1.294$. Thus the C/M ratio reveals the directional kinetic energy scale of the system - and thus here we can proceed to building a simple weak-field gravitational red/blue analogy based on the above presented logic. Firstly let's define the small gravitational parameter: $u = GM / rc^2$.

A signal moving upward, against the gravitational gradient, is redshifted. Its frequency decreases - analogous to the chase direction in motion. A simple weak-field chase-like representation is: $C_G = 1 / (1 - GM / rc^2)$. A signal moving downward, along the gravitational gradient, is blueshifted - analogous to the meet direction in motion. A simple weak-field meet-like representation is: $M_G = 1 / (1 + GM / rc^2)$.

Now compare the red period factor with the blue period factor:

$$C_G / M_G = [1 / (1 - u)] / [1 / (1 + u)]$$

Because u is very small: $1 / (1 - u) \approx 1 + u$

Therefore: $[1 / (1 - u)] / [1 / (1 + u)] \approx (1 + u)[(1 + u)/1] \approx (1 + u)(1 + u)$

So: $C_G / M_G \approx (1 + u)^2$

Expand the square: $(1 + u)^2 = 1 + 2u + u^2$

In the weak-field approximation, u^2 is extremely small and can be ignored: $(1 + u)^2 \approx 1 + 2u$

Since: $u = GM / rc^2$ we obtain: $C_G / M_G \approx 1 + 2GM / rc^2$

The encountered phase content should not be the same on both sides - analogous to the presented Doppler effect logic we shall assume, that due to the not equal gravity influence at different heights the redshift has less and the blueshift has more value analogous to acceleration thus creating an imbalance felt as the gravitational pull/weight (while in steady motion those balance perfectly as calculated earlier). The downward pull energy scales as $C_G / M_G \approx 1 + 2GM / rc^2$. This approach also matches, as an approximation, the perihelion precession logic as $1 + 2GM / rc^2$ represents $1 + 2\beta^2$ for v_esc^2 / c^2 (and that was calculated above from the 'vertical' scale of pure gravitational effects) + β^2 for v_orb^2 / c^2 (the pure motion part). Intuitively the closing of the phase may explain the "further" closing on the orbit of Merkury as precession.

Now let's explain an idea about momentum - the total momentum presented as energy value is

$$p_1 = E/c = \gamma mc$$

Let the directional momentum be

$$p_2 = p = \gamma mv$$

Now subtract their squares:

$$P^2 = p_1^2 - p_2^2$$

$$P^2 = \gamma^2 m^2 c^2 - \gamma^2 m^2 v^2$$

$$P^2 = \gamma^2 m^2 c^2 (1 - v^2/c^2).$$

Because

$$\gamma^2 = 1/(1 - v^2/c^2),$$

we obtain

$$P^2 = m^2 c^2.$$

Therefore

$$P = mc.$$

Both measured components change with velocity, but their squared difference always recovers the same underlying value, mc . Thus $P^2 = p_1^2 - p_2^2$ recovers the invariant rest scale mc . And so we come back to the front counting picture.

Let the simplified, dimensionless energy scale analogue be the total front count squared, this can also be understood as the sum of momentum regardless of the direction of this momentum. Let also the simplified, dimensionless directional momentum scale be the difference of chase (C) and meet (M) fronts. This can be calculated in a simplified way as:

$$C = 1/(1 - \beta)$$

$$M = 1/(1 + \beta)$$

$$C + M = 1/(1 - \beta) + 1/(1 + \beta) = [(1 + \beta) + (1 - \beta)] / [(1 - \beta)(1 + \beta)] = [1 + \beta + 1 - \beta] / (1 - \beta^2) = 2/(1 - \beta^2)$$

$$C - M = 1/(1 - \beta) - 1/(1 + \beta) = [(1 + \beta) - (1 - \beta)] / [(1 - \beta)(1 + \beta)] = [1 + \beta - 1 + \beta] / (1 - \beta^2) = 2\beta/(1 - \beta^2)$$

Now we can come to the fact that, inside the presented model, gravity changes the direction of the momentum/velocity vector by refraction of the waves. It does so:

- Affecting the total momentum / energy 'ticks' of matter;
- Affecting the directional momentum.

Thus using the total front count squared logic to keep the momentum invariant rest scale mc :

$$\begin{aligned} & [(C + M)^2 + (C - M)^2] / (C - M)^2 = \\ & = [(2/(1 - \beta^2))^2 + (2\beta/(1 - \beta^2))^2] / (2\beta/(1 - \beta^2))^2 \\ & = [4/(1 - \beta^2)^2 + 4\beta^2/(1 - \beta^2)^2] / [4\beta^2/(1 - \beta^2)^2] \\ & = (1 + \beta^2)/\beta^2 \\ & = 1 + 1/\beta^2 \end{aligned}$$

Informs us about:

$(C + M)^2 / (C - M)^2$ - how much of the total momentum-energy is 'stationary' leading to free-fall (shown by the secant logic);

$(C - M)^2 / (C - M)^2$ - how much of the total momentum-energy is 'light-like' leading to pure light deflection.

In this view, $2GM/rc^2$ is the gravitational bending scale evaluated relative to a far-away observer, following the logic presented earlier. The dimensionless momentum factor $(1 + 1/\beta^2)$ is then applied once as the velocity weighting of the complete momentum state. The resulting expression, $2GM/rc^2(1 + 1/\beta^2)$, therefore represents the full deflection from far away on the incoming side to far away on the outgoing side.

At $v = c/\sqrt{3}$, we have $\beta^2 = 1/3$, so the momentum factor equals: $1 + 1/\beta^2 = 1 + 3 = 4$. Therefore, the total deflection is: $2GM/rc^2 \times 4 = 8GM/rc^2$. To understand this geometrically we can also see this accordingly:

take one basic light distance: $L = cT$

Let the object move at: $v = c/\sqrt{3}$

Therefore: $\beta = v/c = 1/\sqrt{3} \approx 0.577$

During the chase, the object moves: $X_{\text{chase}} = \beta L / (1 - \beta)$

$X_{\text{chase}} \approx 1.366L$

During the meet, it moves: $X_{\text{meet}} = \beta L / (1 + \beta)$

$X_{\text{meet}} \approx 0.366L$

Therefore, the directional excess is: $\Delta X = X_{\text{chase}} - X_{\text{meet}}$

Thus: $\Delta X = 1.366L - 0.366L = L = cT$

For example, if $T = 1$ second, then: $L = cT \approx 300,000$ km

Therefore: $X_{\text{chase}} \approx 409,808$ km, $X_{\text{meet}} \approx 109,808$ km and: $\Delta X = 409,808$ km $-$ $109,808$ km $\Delta X = 300,000$ km $= cT$.

During this cycle, the forward velocity vector of the object covers:

$X_{\text{total}} = v \times 3T$

$X_{\text{total}} = (c/\sqrt{3}) \times 3T$

$X_{\text{total}} = \sqrt{3}cT \approx 1.732cT$

This total distance contains exactly three ordinary object-velocity steps:

$X_{\text{total}} / vT = 1.732cT / 0.577cT = 3$

Therefore, gravity acts on the forward material velocity vector through three normalized propagation intervals. This gives the velocity-dependent contribution:

$K_{\text{material}} = 3$

At the same time, the chase–meet asymmetry expressed through the distances travelled by the object is: $X_{\text{directional}} = X_{\text{chase}} - X_{\text{meet}}$
 $X_{\text{directional}} = 1.366cT - 0.366cT$
 $X_{\text{directional}} = cT$.

Thus, after the mutually opposite chase and meet components are compared, one complete light-normalized directional vector remains.

This gives: $K_{\text{directional}} = 1$

This second vector is not an additional physical path travelled by the object. It is the net one-way directional component encoded by the chase–meet difference. Both gravitational deflection contributions point toward the gravitating mass. Therefore, their magnitudes add: $K_{\text{total}} = K_{\text{material}} + K_{\text{directional}}$
 $K_{\text{total}} = 3 + 1 = 4$.

Consequently: $\alpha = 2GM/bc^2 \times 4 \Rightarrow \alpha = 8GM/bc^2$

In this simplified vector picture, matter moving at $c/\sqrt{3}$ carries a forward velocity vector exposed to gravity for three normalized intervals, while its internal chase–meet asymmetry leaves one additional light-normalized directional contribution. Together they produce the factor $3 + 1 = 4$.

In simple words, at $v = c/\sqrt{3}$, the momentum scale in the direction of motion is exactly one complete light-distance unit equaling light momentum scale. Matter at $v = c/\sqrt{3}$ reproduces this unit through its two-directional chase–meet geometry, while light does it one way only. This is not a statement that every massive object at $v = c/\sqrt{3}$ has the same conventional momentum in SI units as every photon. It is an equality between two normalized geometric measures: the direct one-way displacement of light and the chase–meet directional excess of matter. In this precise, model-specific sense, the directional momentum ratio for matter at $v = c/\sqrt{3}$ is equivalent to the one way directional ratio of light.

Regarding $P^2 = p_1^2 - p_2^2$ it is also worth to say, that the above presented approach $[(C + M)^2 + (C - M)^2] / (C - M)^2$ is also equal to:

$$2 + [(C + M)^2 - (C - M)^2] / (C - M)^2$$

because 2 can be written as:

$$2(C - M)^2 / (C - M)^2$$

Therefore:

$$\begin{aligned} & 2 + [(C + M)^2 - (C - M)^2] / (C - M)^2 \\ &= [2(C - M)^2 + (C + M)^2 - (C - M)^2] / (C - M)^2 \\ &= [(C + M)^2 + (C - M)^2] / (C - M)^2. \end{aligned}$$

The only thing happening is:

$$2(C - M)^2 - (C - M)^2 = (C - M)^2$$

This just confirms the equality to $P^2 = p_1^2 - p_2^2$ presented earlier.

In this picture, gravitational bending must depend on the balance between the invariant rest-like part of the system and its directional momentum. At rest, the there-and-back propagation is perfectly balanced: $C = M$ and therefore $C - M = 0$. The system has energy, but no forward momentum preserving a horizontal trajectory. Gravity therefore determines the direction of motion completely. As the directional momentum approaches zero, the weak-deflection coefficient grows without limit and the small-angle description turns into gravity-dominated radial free fall as calculated by the secant constructions and what follows from it. In the opposite situation only the one-way directional lightlike propagation remains. The additional rest-like bending disappears, leaving the light-deflection baseline. The proposed coefficient has the required physical behavior: it diverges toward gravity-dominated free fall when directional momentum vanishes, decreases continuously as directional momentum increases, and reaches the finite light-deflection value when only one-way propagation remains.

Importantly - why does the matter-dependent bending grow as $1/\beta^2$?

The missing square follows directly from the there-and-back cycle geometry. Consider the same gravitational region with a normalized length of 10. Let the faster structure advance 10 directional units per cycle and the slower structure advance only 2 units per cycle. Assume that the same local gravitational gradient produces one normalized unit of transverse momentum change during each cycle. The faster structure crosses the region in one cycle, accumulates one transverse unit, and therefore has the directional-change ratio:

$$1/10 = 0.1.$$

The slower structure requires five cycles to cross the same region. It therefore accumulates five transverse units, while its directional advance per cycle is only 2. Its directional-change ratio is consequently:

$$5/2 = 2.5.$$

The relative increase is:

$$(5/2) / (1/10) = 25.$$

Thus, reducing the directional advance by a factor of five increases the number of gravitationally affected cycles by a factor of five and simultaneously increases the angular effect of each accumulated transverse change by another factor of five:

$$5 \times 5 = 25.$$

In general, the first factor of $1/\beta$ comes from the greater number of cycles required to cross the same gravitational region, while the second factor of $1/\beta$ comes from comparing the accumulated transverse change with the smaller directional component. Therefore:

total matter-dependent bending $\propto (1/\beta)(1/\beta) = 1/\beta^2$.

The values 1, 10 and 2 are only normalized units illustrating the scaling.

Simple summary for energy:

Total kinetic energy corresponds to the excess front content above rest:

$$K \leftrightarrow \gamma N_0 - N_0 = N_0(\gamma - 1)$$

For each opposite angular pair, the normalized factor is:

$$F(\theta) = [C(\theta) + M(\theta)] / 2\gamma$$

The rest chase-plus-meet baseline is 2, and its common scaling when observed from the laboratory frame is 2γ . Dividing by 2γ removes this common scaling and isolates the directional excess. The local excess front content is therefore:

$$\Delta N(\theta) = N_0[F(\theta) - 1]$$

We subtract 1 because it represents the balanced 'one-way' rest-equivalent baseline. The positive growth occurs in the chase direction, while the meet-side decrease is already included in $F(\theta)$ and is not counted as additional positive content (adding the meet-side deficit again as positive content would double-count the same transfer).

Take:

$$\beta = 0.9$$

$$\gamma = 1 / \sqrt{1 - \beta^2}$$

$$\gamma = 1 / \sqrt{0.19}$$

$$\gamma \approx 2.294$$

For the longitudinal chase-meet pair:

$$C = 1 / (1 - 0.9) = 10$$

$$M = 1 / (1 + 0.9) = 0.5263$$

Therefore:

$$F(0^\circ) = (C + M) / 2\gamma$$

$$F(0^\circ) = (10 + 0.5263) / (2 \times 2.294)$$

$$F(0^\circ) = 10.5263 / 4.588$$

$$F(0^\circ) = 2.294 = \gamma$$

Thus:

$$\Delta N(0^\circ) = N_0[F(0^\circ) - 1]$$

$$\Delta N(0^\circ) = N_0(2.294 - 1)$$

$$\Delta N(0^\circ) = 1.294N_0$$

For example, if $N_0 = 100$:

$$\Delta N(0^\circ) = 129.4$$

The normalized total is 229.4. Of this, 100 represents the balanced one-way rest-equivalent baseline, while 129.4 represents the excess.

In the transverse direction:

$$C = M = \gamma = 2.294$$

$$F(90^\circ) = (2.294 + 2.294) / (2 \times 2.294)$$

$$F(90^\circ) = 1$$

Therefore:

$$\Delta N(90^\circ) = N_0(1 - 1) = 0$$

For a spherical surface, this excess represents the normal-equivalent impact energy. It gives $F = \gamma$ and the full kinetic energy along the direction of motion, $F = 1$ and zero excess transversely, and intermediate values at intermediate angles.

$$F(30^\circ) = [C(30^\circ) + M(30^\circ)] / 2\gamma$$

Take the chase and meet values from the xls file:

$$F(30^\circ) = (8.8024 + 0.5979) / 4.5883$$

$$F(30^\circ) = 2.0487$$

Therefore:

$$\Delta N(30^\circ) = N_0[F(30^\circ) - 1]$$

$$\Delta N(30^\circ) = 1.0487N_0$$

This is about 81.0% of the full longitudinal kinetic-energy excess:

$$1.0487 / 1.2942 = 0.810$$

This is algebraically equivalent to the standard relativistic normal-momentum calculation, but provides a simple geometric interpretation once the chase and meet values are known.

The same calculation works at low speeds. For example, take a 100 kg body moving at 100 km/h:

$$v = 100 \text{ km/h} = 27.7778 \text{ m/s}$$

$$\beta = v/c \approx 9.26567 \times 10^{-8}$$

$$\gamma \approx 1.000000000000000429263$$

In the direction of motion:

$$C = 1 / (1 - \beta)$$

$$C \approx 1.000000092656702$$

$$M = 1 / (1 + \beta)$$

$$M \approx 0.999999907343315$$

Therefore:

$$F(0^\circ) = [C + M] / 2\gamma = \gamma$$

The rest energy is:

$$E_0 = mc^2$$

$$E_0 \approx 8.98755 \times 10^{18} \text{ J}$$

The excess energy is therefore:

$$K = E_0[F(0^\circ) - 1]$$

$$K = mc^2(\gamma - 1)$$

$$K \approx 38,580.2469 \text{ J}$$

$$K \approx 38.58 \text{ kJ}$$

At this low speed, this agrees with the familiar classical calculation:

$$K \approx \frac{1}{2}mv^2$$

$$K \approx \frac{1}{2} \times 100 \times 27.7778^2$$

$$K \approx 38.58 \text{ kJ}$$

In the weak-field limit, the kinetic energy gained between heights B and A should correspond analogously to the difference between their excess front contents.

The felt gravitational force arises from the spatial red/blue imbalance and its gradient, analogously to the changing chase/meet imbalance during acceleration.

Potential energy should represent the possible increase in front content that can be realized by falling from B to A.

The total energy grows as γmc^2 because, in this interpretation, the normalized total front count scales by γ . The longitudinal and transverse formation lengths are:

$$L_{\text{longitudinal}} = 2\gamma^2$$

$$L_{\text{transverse}} = 2\gamma$$

Therefore:

$$L_{\text{longitudinal}} / L_{\text{transverse}} = \gamma$$

Accordingly:

$$N / N_0 = \gamma$$

and:

$$E / E_0 = \gamma$$

Since $E_0 = mc^2$:

$$E = \gamma mc^2$$

The kinetic energy is the excess above rest:

$$K = E - E_0 = (\gamma - 1)mc^2.$$

The below presented drawing shows the energy scale, green for the base $E_0 = mc^2$, red for $E = \gamma mc^2$ and the blue one showing the real scaling of a moving frames formation region. So:

The green circle is the rest baseline. The blue ellipse represents the full chase–meet formation geometry. Its longitudinal length is $2\gamma^2$, while the front spacing is enlarged by the common factor gamma. Dividing the formation length by this separation gives the effective front-count scale:

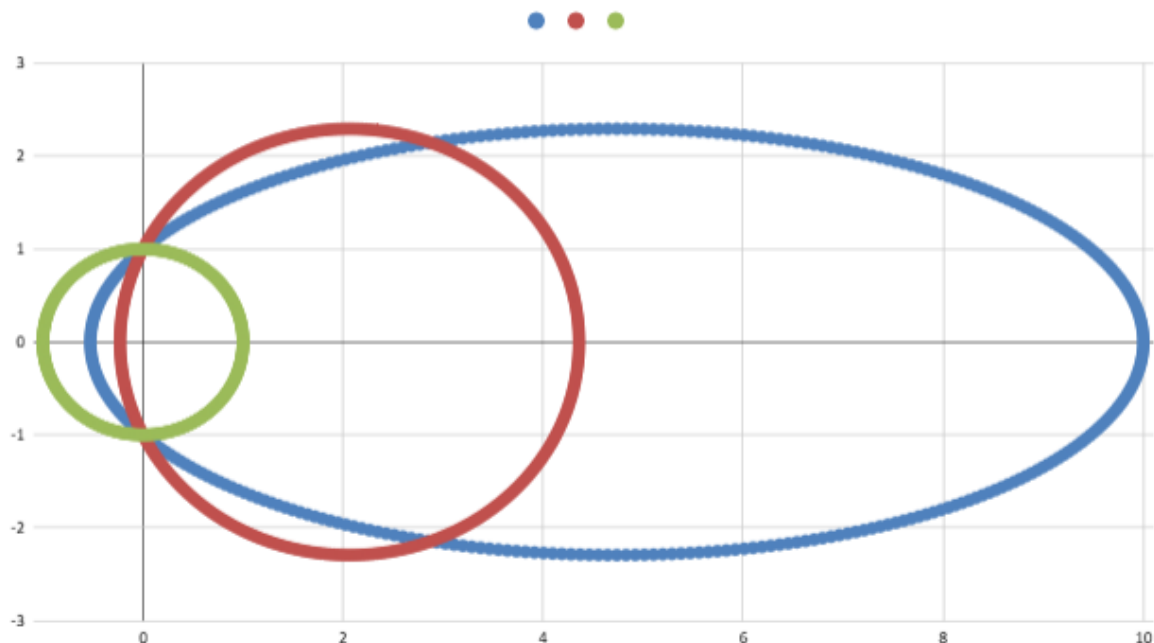
$$2\gamma^2 / \gamma = 2\gamma$$

Relative to the rest scale of 2, this gives the energy factor:

$$2\gamma / 2 = \gamma$$

The red circle represents this energy-equivalent front count compressed back to the original front spacing: its radius is gamma, and its diameter is 2γ .

Energy scale: green base, red = gamma, blue full formation-region geometry ($\beta = 0.9$)



The rest energy is:

$$E_0 = mc^2$$

The kinetic-energy excess produced by motion is:

$$K = (\gamma - 1)mc^2$$

Therefore, the total energy is:

$$E = E_0 + K$$

$$E = mc^2 + (\gamma - 1)mc^2$$

$$E = mc^2 + \gamma mc^2 - mc^2$$

$$E = \gamma mc^2$$

Thus, γmc^2 already includes both the rest energy mc^2 and the kinetic-energy excess $(\gamma - 1)mc^2$.