

A Unified Model for Gravitational and Velocity Time Dilation

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Abstract

This paper builds on the work from two previous papers. *Quantum Fluctuations as the Substrate of Spacetime* establishes the Fundamental Energy Field (FEF) as the mechanism for forming particles, gravitational time dilation, and potentially dark matter. *Velocity Time Dilation and Spacetime Frame Dragging* explores velocity time dilation, frame dragging, potential warp bubbles, and crucially, the proposition that time dilation is equal to the average delay of quantum “Cause and Effect” propagation across the x, y, and z axes relative to the direction of motion. This paper argues that without factoring the total time dilation of individual areas of the cosmos at different times in history, there is a possibility that we are interpreting observations without the full picture of the underlying reality. This requires the introduction of a comprehensive total time dilation factor (Γ), which integrates static gravitational field density (γ_g), velocity-induced field compression (γ_ξ), and kinematic velocity (Γ_v). The resulting model offers a more comprehensive view of cosmological phenomena and proposes new time dilation maps. These can be overlaid and combined with existing cosmological models to potentially shed light on many current mysteries of the universe.

Keywords: Velocity Time Dilation, Gravitational Time Dilation, Universe Models, Lorentz Transformations, Vacuum Energy Density, Spacetime Fluid Dynamics, Fundamental Energy Field.

Introduction:

Standard cosmological models describe spacetime regions moving relative to one another. This mechanism explains how areas separated by vast causality distances, such as those involved in Baryon Acoustic Oscillations,¹ could interact before inflation and before cosmological objects receded from one another faster than light. This allowed light emitted approximately 13 billion years ago to finally reach observers today.² Scientific consensus describes how light propagates through spacetime,^{3,4} and observations confirm that gravitational and velocity time dilation are physical realities.⁵ Quantum mechanics describes waves as oscillations where pressure builds tension away from minimal energy conditions. These waves return to the zero-energy point but overshoot due to momentum, creating a cycle of peaks and troughs analogous to elasticity. Furthermore, changes in spacetime geometry affect adjacent volumes which allows effects to be passed from coordinate to coordinate for propagation.⁶

These are typically described as effects of geometric curvature.⁷ But as established in the previous paper on the substrate of spacetime, this geometry may be more than abstract math. It proposes that vacuum energy², defined as the Fundamental Energy Field (FEF), is the medium through which light propagates, forming field lines as geodesics, and the FEF is also the foundation of matter and dark matter (dark energy will be covered in a subsequent paper). With this proposal established, this paper explores how these mechanisms unify.

The previous papers established that the speed of light is constant for any observer, as long as they are not traveling at velocity relative to the local, potentially co-moving FEF, and as long as the density of the FEF (higher in strong gravity) is practically physically isotropic with negligible curvature. This does not require Lorentz Transformations^{2,8} to convert between frames to maintain c . It was also established that at velocity, c will remain constant as long as the clock's time measurement axis is aligned to the axis of the arm that's being observed.

It is proposed that the time it takes light to travel distance L_0 is slowed by the exact same amount that the clock is slowed if the clock is aligned in the same frame of reference. We know clocks tick slower in higher gravity, therefore, for light to travel the exact same physical distance at c , it must slow by the exact same amount to keep c constant. Otherwise, physical length must be altered by changes in spacetime paths. However, gravity is ≈ 36 orders of magnitude weaker than the atomic forces^{1,9} maintaining physical distance. LIGO utilizes suspension wires to allow mirrors to move with gravity waves because if they were fixed to the rigid underlying structure, the mirrors would not move relative to each other^{10,11} (tidal forces notwithstanding).² It is therefore reasonable to conclude that physical length contraction of solid matter due to spacetime geometry^{2,8} is not the primary mechanism. However, this remains a theoretical distinction to be rigorously tested.

With velocity, the scenario changes. The actual distance light travels across an interferometer in a moving ship is not the rest distance. Moving a spaceship at high velocity does not “pull” the spacetime medium along with it perfectly like an Alcubierre drive warp bubble.¹² Therefore, light must travel at an angle to intercept the moving mirror. The actual path is L_0 plus the distance the detector travels during propagation. This means light travels a longer path parallel to the direction of movement compared to the perpendicular path.^{8,13} These are not equivalent to paths in flat, stationary (relative to the moving interferometer) spacetime, therefore, standard physics uses Lorentz transformations to equate them. This means both axes are not really local because they require transformations.

The speed of light over 1 meter perpendicular is different than 1 meter parallel because that “1 meter” is not the true distance the light is traversing in the background medium. Dictating that the measured 1 meter is the “true” distance creates a skewed perception of reality. The reality is that velocity slows the clock. A slow clock aligned with a skewed perception of distance may mathematically balance to c , but it obscures the underlying mechanics.

These differences in propagation speed between perpendicular and parallel paths must also apply to atomic quantum information propagation. For instance, the decay of a muon^{2,14,15} takes longer because the information transfer driving the decay must travel a longer path to effect the change. Where quantum probability does not rely on a single axis, it is possible to average these paths over all axes to derive an average value for the numerous information transfers occurring within an atom every second. This means that an astronaut (with average time dilation and an ability to register the difference in light speed) could look at both arms of a perpendicular light clock and see a pulse of light running faster in the perpendicular arm and slower in the parallel arm. The brain doesn't use math to transform what it sees.

There is also the concept of frame dragging.¹⁶ While the precise mechanics of spacetime flow¹⁷⁻¹⁹ remain a subject of debate, this paper proceeds under the hypothesis that the FEF exhibits fluid-dynamic properties^{2,20}, allowing us to explore the resulting implications for time dilation. It was previously established that in an FEF capable of flow, the field might be entrained with Earth as it moves around the sun, much like a dense wire-mesh ball dragging air with it at extremely low velocities. While rotation creates a vortex (Lense-Thirring effect),¹⁶ linear movement might create a linear drag. If most of Earth was crushed into a black hole except for a single continent, that continent should still contribute to the Lense-Thirring effect even though it is now orbiting a mass. This near-perfect entrainment would mean the Michelson-Morley Experiment²¹ yields a null result because the medium is locally bound to the Earth. A dense wire-mesh ball would also create a “bow wave” effect,²² like a gravitational pulse in front of a merging black hole detected by LIGO.^{10,11}

While calculating the precise pressure buildup in the FEF “bow wave” is complex (incorporating mass, density, and interaction time with a specific volume of the FEF, as well as $1/r^3$ decay and the fundamental properties of propagation and elasticity), the effect could be estimated effectively. For instance we know the effect is small since we can compare the energy of the entire Earth as a ratio to the total vacuum energy in the same volume. It takes all of Earth to make a minuscule change. Density means a cubic millimeter of neutron star would have significantly more impact than a cubic millimeter of Earth’s crust. Interaction time is also key. A solar sail would be minuscule compared to if the same mass was converted into an extremely long spear. Faster velocity means less interaction time. Additionally, the dragging effect at the plank length would be vastly stronger than at a 100km altitude. Velocity in this unified equation is relative to the local FEF field, meaning if the field is 100% entrained, the velocity is effectively zero. Earth could be in its own warp-like bubble.¹²

To analyze these effects, this paper utilizes a key conceptual tool: the Stable Frame of Reference (SFR), defined by Heat Death²³ conditions and velocity relative to the CMB²⁴ in a non-flowing FEF. This provides an overview perspective of the underlying mechanics. This work expands on the velocity time dilation formula by adding Γ_g to form a novel unified time dilation factor:

$$\Gamma = \frac{\Gamma_g \cdot (\gamma_{\perp}^2 + 2\gamma_{\perp})}{3}$$

where Γ_g represents static field density γ_g multiplied by the induced density γ_{ξ} due to the “bow wave” effect and

$$\gamma_{\perp} = \frac{1}{\sqrt{1 - \left(\frac{v \cdot \Gamma_g}{c}\right)^2}}$$

incorporates velocity v (Note: for a clearer definition of symbols, see Appendix A).

For the purpose of this discussion, this paper will focus on actual clock rate differences, termed *Instant Observed Time*, as opposed to dealing with the complexities of light-signal travel time (*Light Observed Time*). Light Observed Time is simply how a spaceship traveling away from Earth increases the distance every second, meaning 1 light second becomes 2, and therefore, the observer sees the clock as it was in the past rather than its current state. Focusing on Instant Observed Time allows us to isolate the fundamental dilation effects.

Time Dilation: Standard Effects and the SFR Perspective

From the SFR perspective, observed time dilation variations^{5,25} are seen as absolute changes in the local rate of time flow. The slowing of stationary clocks is due to local energy field density (gravitational field) with the Static Time Dilation Factor, γ_g . By definition, $\gamma_g = 1$ in the SFR (which corresponds to Heat Death conditions of minimal field density). In any region with a field density greater than this absolute minimum, $\gamma_g > 1$, meaning local stationary clocks run slower than SFR clocks. This factor γ_g is analogous to and consistent with the gravitational time dilation predicted by General Relativity (e.g.,

$$\gamma_g = \frac{1}{\sqrt{1 - \frac{2GM}{rc^2}}}$$

for a spherical mass,^{2,7} an effect experimentally verified to high precision.^{14,26} This framework allows for the conceptualization of a *time dilation map* of the universe based on γ_g (and eventually, the total dilation Γ when velocity is included), which could aid in developing more accurate cosmological models. With the universe being extremely dense in the early universe, the transfer of quantum information would have been extremely slow compared to what we observe on Earth. This implies that chemical reactions throughout the universe occur at different rates. Supernovae chemical reaction rates are not consistent.

A Unified Model for Time Dilation

This model proposes a unified understanding of time dilation, stemming from the influence of the local energy field density (static component, γ_g) and an object's velocity (v) through that field, as observed from the Stable Frame of Reference (SFR). The core hypothesis is that the fundamental *clock rate* of an object or physical process, and thus its total time dilation (Γ), is determined by an average of how intrinsic two-way Cause-and-Effect Event (CEE) propagations are kinematically affected along different spatial dimensions relative to its motion. This is also slowed by gravitational time dilation, and there could be induced "bow wave" time dilation γ_ξ .

In an atomic clock, the measured *oscillation* is not a physical vibration confined to a single spatial axis. Although, experimenters define a quantization axis using a static magnetic field,^{27,28} this does not mean the underlying quantum information transfer is restricted to that direction. The quantum evolution is inherently symmetric, with no preferred orientation.²⁹ Quantum information does not have a fixed, singular path it follows each time, but instead spreads and interacts in all directions without repeating the same axis over time. This gives us the average of the time that quantum information takes to transverse all the axes equally over long enough time.

To intuitively grasp how both local field conditions, an analogy can be employed based on a 'light clock' concept.¹³ Two primary orientations are considered within a conceptual 'train': one parallel to its direction of motion (e.g., from caboose along the track to engine and back) and one perpendicular (e.g., from the train's center on the ground to a sidecar and back).

The 'messengers' in this analogy always exert the same 'effort' and the same number of steps per second (analogous to CEEs having an intrinsic propagation rate through the FEF, AKA spacetime).

- **Static Field Density Effect (like γ_g):** If the train is moving through 'mud' (representing a region of high energy field density), the same running effort through the mud results in smaller 'steps.' Consequently, any journey (to the engine or the sidecar and back) requires more steps and takes longer, even if the train is stationary in this mud. Currently, this is not including the effects of frame dragging.
- **Velocity Effect (contributing to Γ_v):** Now, consider the train moving at velocity v . We can think of it as pushed by other runners who can never push faster than the messengers can run toward the front of the train so even a billion pushing the train will never go faster than a messenger, and a billion will have very little increase in speed compared to a million. This echoes why the closer you get to the speed of light, the more energy you need to get an increase in speed. It's not that the train gains mass (which is a great mathematical way to look at it) but it's that the pushing power per SFR seconds decreases as chemical reactions take longer and longer to the point where the it may take a year to output the same power that would be outputted in a second at rest. Currently, this is also not including the effects of frame dragging.

- The messenger running from the caboose (*alongside the train on the ground*) to the engine must cover an actual distance greater than the train's length because the engine is receding. The return trip to the caboose is shorter as the caboose approaches. The total round-trip time is longer than if the train were stationary.
- The messenger running from the train's center to the sidecar and back must also cover a longer diagonal path (again, running on the ground alongside) because the train moves forward during their perpendicular journey. This round trip also takes longer than if the train were stationary.

Crucially, the previous paper showed that the parallel path time dilation factor is the square of the perpendicular time dilation factor.

Core Concepts and Symbols:

The Fundamental Energy Field and Cause and Effect Points (CEPs): With the Universe as an energy field, CEP density is inferred from gravitational time dilation,^{14,26,30} denser packing means CEEs take longer to traverse 1m SFR from SFR view. A value can be assigned to this For instance, 1m SFR, 299,792,458 CEPs per second, 299,792,458m. Double the energy field density, 299,792,458 CEPs are compressed into 149,896,229m SFR, each CEP 0.5m apart. Gravitation time dilation means 1 second local becomes 2 seconds in SFR time since quantum information has double the amount of CEPs to traverse for the same physical length. In standard physics the path bends in a wide curve to double the geodesic length relative to the physical length, however, the Shapiro Delay has been shown to be prominent even in potentially negligible spacetime curvature.³¹

1. The Stable Frame of Reference (SFR) and Static Time Dilation Factor (γ_g):

- Symbol: γ_g
- Meaning: The Static Time Dilation Factor. Quantifies the slowing of local stationary clocks and CEE propagation purely due to the energy field's density, relative to the Heat Death SFR baseline (where $\gamma_g = 1$). For any physical environment with greater field density, $\gamma_g > 1$, approaching ∞ at an event horizon. Consistent with GR's

$$\frac{1}{\sqrt{1 - \frac{2GM}{rc^2}}}$$

7,32

2. Velocity of an Object (v):

- Symbol: v
- Meaning: The velocity of an object relative to the local energy field structure, as measured by an SFR observer.

3. Fundamental CEE Propagation Speed (c):

- Symbol: c
- Meaning: The constant propagation speed of Cause-and-Effect Events (CEEs, including light) in the SFR under minimal field density conditions ($\gamma_g = 1$). In a vacuum of relatively flat spacetime at rest, $c \approx 299,792,458$ m/s.³³

4. Perpendicular Kinematic Velocity Factor (γ_{\perp}):

- **Symbol:** γ_{\perp} (gamma-perp)
- **Meaning:** Arises from analyzing the kinematics of a two-way CEE process (like a light clock) oriented *perpendicular* to the direction of motion v . If only looking at the perpendicular path, γ_g and γ_{ξ} would be included here in the form of Γ_g .
- **Formula:**

$$\gamma_{\perp} = \frac{1}{\sqrt{1 - \left(\frac{v \cdot \Gamma_g}{c}\right)^2}}$$

This factor is mathematically similar in form to the Special Relativistic Lorentz factor,¹³ but here v is scaled by Γ_g . This modification is required because the effective speed of light (c_{eff}) in a dense field is reduced to c/Γ_g . As the object's velocity v approaches this lower limit c_{eff} , the time dilation must approach infinity. Therefore, Γ_g is included within the square root to correctly model the kinematic limit relative to the local field density.

5. Averaged Velocity Dilation Factor (Γ_v):

- **Symbol:** Γ_v

Meaning: The overall time dilation component due purely to velocity v . It is derived by averaging the kinematic dilation effects experienced by two-way CEE processes along three orthogonal spatial dimensions within the moving object (one parallel to the direction of motion, two perpendicular). This is derived from standard relativistic kinematic analysis of two-way light paths as viewed from the SFR.¹³ Notice we aren't incorporating Γ_g here.

Formula:

$$\Gamma_v = \frac{(\gamma_{\perp}^2 + 2\gamma_{\perp})}{3}$$

6. Total Time Dilation (Γ):

- **Symbol:** Γ

Meaning: The overall factor (≥ 1) by which all local physical processes (clocks, reaction rates, etc.) within an object are slowed, as observed from the SFR. It combines the static field density effect (γ_g), the induced density caused by velocity (γ_{ξ}), and the averaged velocity effect (Γ_v).

Formula:

$$\Gamma = \gamma_g \cdot \gamma_{\xi} \cdot \Gamma_v$$

Derivation of the Velocity Time Dilation Component (Γ_v):

To determine how velocity v (relative to the field it's traveling through) affects an object's internal clock rate, we consider fundamental two-way CEE processes (analogous to a light clock of proper length L_0) within the object, as observed from the SFR.

It is instructive to consider how this velocity-dependent dilation component is formulated. If one were to calculate a 'pure' velocity dilation factor assuming the relevant speed of light c was always the universal constant (as in an idealized flat spacetime without considering background field density effects), the kinematic analysis of two-way CEE paths would yield factors related to the standard Lorentz factor,

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

2,8,13

However, in this model, the static field density (γ_g) and induced density (γ_ξ) modify the local environment. The total gravitational density is defined as $\Gamma_g = \gamma_g \cdot \gamma_\xi$. Consequently, the maximum propagation speed for CEEs (and thus for any object) as observed by the SFR in this region is effectively reduced to $c_{eff} = c / \Gamma_g$. This raises an interesting effect of inertia. A spaceship reaching 99% c in the void of space, coasts directly between two black holes (not spinning much, not orbiting, on a direct collision course). The spaceship should slow down as it approaches the high γ_g like the Shapiro Delay,³¹ since the pattern can't propagate through spacetime faster than c_{eff} . Akin to a smoke ring coasting into significantly denser air. However this is based on spacetime without river flow.¹⁸

The crucial consequence is that as Γ_g increases (e.g., near an event horizon where Γ_g approaches infinity), the effective speed limit c_{eff} approaches zero. This means the 'range' of possible velocities v before $v \cdot \Gamma_g / c$ approaches 1 (and thus γ_\perp and Γ_v approach infinity) becomes extremely compressed. Even a small SFR-measured velocity v (e.g., 1 km/s) in a region of immense Γ_g can lead to an enormous velocity-dependent dilation effect, pushing Γ towards infinity much more rapidly than the same v would in a region with negligible Γ_g . This formulation ensures that the combined effects of static field density and velocity correctly approach the limit where all local processes cease from the SFR perspective.

Therefore, the object's velocity v (as measured by SFR) must be assessed relative to this local speed limit c_{eff} , not the absolute c of the Heat Death SFR. The velocity term in the equation becomes $v \cdot \Gamma_g / c$.

- Perpendicular Two-Way CEE Process: For a CEE completing a round trip of $2L_0$ perpendicular to the direction of motion v , the SFR-observed time involves the slowed propagation speed (c_{eff}) and the kinematic dilation factor (γ_\perp):

$$\Delta t_\perp = \left(\frac{2L_0}{c_{eff}} \right) \cdot \gamma_\perp$$

Here, γ_\perp is calculated relative to the effective speed limit, incorporating Γ_g .

- Parallel Two-Way CEE Process: For a CEE completing a round trip of $2L_0$ parallel to the direction of motion v :

$$\Delta t_\parallel = \left(\frac{2L_0}{c_{eff}} \right) \cdot \gamma_\perp^2$$

The purely velocity-induced dilation factor for this orientation is γ_\perp^2 .

Physical objects are three-dimensional, and their intrinsic *clock* mechanisms (atomic oscillations, chemical reaction rates, biological processes) likely depend on CEEs propagating isotropically in their own rest frame. A directional lock for these processes would imply anisotropic aging or function, which is not observed, however, any atomic structures that are specifically aligned would be affected. This could be tested in decay times of atomic structures that are specifically aligned in a distinct direction, and comparing their decay rates under velocity. If atomic structures are specifically aligned then the math becomes too complex for the scope of this paper. Each distinct aligned atomic structure would have to be calculated individually. Therefore, in this proposed formula, we are working on a non aligned atomic structure where all quantum information traverses in equally random directions. This allows for the analysis of an object's overall velocity-dependent time dilation component, Γ_v , as an average of these kinematic effects across three spatial dimensions. Assuming one dimension aligns with v (experiencing γ_{\parallel}^2) and two are perpendicular (experiencing γ_{\perp}):

$$\Gamma_v = \frac{(\gamma_{\parallel}^2 + \gamma_{\perp} + \gamma_{\perp})}{3} = \frac{(\gamma_{\parallel}^2 + 2 \cdot \gamma_{\perp})}{3}$$

Therefore, to model the total time dilation experienced by the atom, it is necessary to average the kinematic effects across all spatial dimensions. The arithmetic mean is proposed as the most direct mathematical representation of this underlying isotropic quantum reality, averaged over the three orthogonal axes of the macroscopic experience. For multi atom objects, where the numerous atoms are randomly aligned, this is consistent even if the individual atoms may have aligned quantum structures.

The Combined Time Dilation Formula (Γ):

The total time dilation Γ is the product of the total effective gravitational density Γ_g (which combines static field density γ_g and induced density γ_{ξ}) and the averaged velocity-dependent dilation component Γ_v :

$$\Gamma = \Gamma_g \cdot \Gamma_v = \frac{\Gamma_g \cdot (\gamma_{\parallel}^2 + 2 \gamma_{\perp})}{3}$$

How the Formula Works:

- **Static Component (Γ_g):** This factor (≥ 1) establishes the baseline slowing due to the local field density relative to the Heat Death SFR. If the object is stationary ($v=0$), then $\gamma_{\perp} = 1$. Consequently, the velocity component becomes:

$$\Gamma_v = \frac{1+2}{3} = 1$$

In this case, $\Gamma = \Gamma_g \cdot 1 = \Gamma_g$, correctly reducing the total dilation to the static field density alone.

- **Velocity Component (Γ_v):** This term, $(\gamma_{\perp}^2 + 2\gamma_{\parallel})/3$, quantifies the additional average dilation due to velocity v . It incorporates the more extreme effect along the direction of motion (γ_{\parallel}^2) and the less extreme effect along perpendicular directions (γ_{\perp}). As the ratio of velocity to the effective speed limit ($v \cdot \Gamma_g / c$) approaches 1, γ_{\perp} tends towards infinity. Consequently, both γ_{\parallel}^2 and γ_{\perp} tend towards infinity, causing Γ_v and thus Γ to also approach infinity. This signifies that all local processes effectively halt from the SFR perspective as this limit is approached.
- **Field Flow Note:** It is important to remember that the field energy itself may be flowing relative to an object that is considered stationary within the SFR's coordinate system (e.g., due to frame dragging, cosmic flows, or a river model of space).^{18,19} For the application of this formula, v is understood as the velocity of the object relative to the immediate local structure or flow of the energy field it is traversing.

What This Formula Is Good For & Why We Should Use It:

This unified formula for Γ offers a framework to:

1. **Quantify Combined Dilation:** It provides a single equation to calculate the total time dilation when strong gravitational fields (high γ_g), high velocities (v), and/or significant induced “bow wave” densities (γ_{ξ}) are present (such as for matter orbiting close to black holes^{2,13,16,32,34,35} or for particles in high-energy environments, like quasar jets, where relativistic effects are prominent).³⁴ Note that γ_{ξ} could potentially vary with velocity, as seen in FEF entrainment scenarios discussed in previous works.
2. **Model Limits on Speed and Reaction Rates:** It inherently shows how Γ imposes a limit on the rate of internal processes. The closer the effective velocity term $v \cdot \Gamma_g$ gets to c (approaching the local speed limit), the more pronounced the slowing of chemical reactions (like nuclear decay) or any cause-and-effect sequence within the object. This is particularly relevant for understanding particle stability under extreme conditions.
3. **Investigate Frame Dragging Effects in a Spacetime Flow Scenario:** While not explicitly detailed here, the concept of a background field (γ_g) that can be influenced by mass-energy suggests that if this field itself is *dragged* or set into motion by a rotating massive body, the v term in the formula might need to be considered relative to this moving field, potentially offering a new way to model frame dragging's impact on local clocks, an effect predicted by General Relativity and experimentally confirmed.^{2,16,36} Mapping this potential flow of spacetime may yield interesting possibilities.
4. **Velocity Induced “Bow Wave” Time Dilation:** The potential for an induced field density, created by velocity, may also lead to fundamental new models that explore subtle possible effects. Mapping out galactic objects of varying sizes, mass, shape and spin and their velocity induced pressure differentials could be added to the frame dragging models to complete a mass velocity/spacetime interaction model. Overlaying these models even in a small cosmological scale (like stars and accretion disks, orbiting and being absorbed by a super massive black hole), could allow for some averaging of the system’s cause and effect rates that could be then applied to larger models for a velocity time dilation map of average velocity time dilations for varying orbits in galaxies.

5. **Refine Cosmological Models:** In the early universe, γ_g would have been extraordinarily high. This formula would describe the immense time dilation for any primordial structures or particles^{1,37,38}, potentially impacting calculations of early universe expansion rates^{2,13,39,40} and event horizons if local process rates define cosmic processes for cosmic evolution.^{2,41}
6. **Predict Time Dilation in Unexplored Regimes:** If γ_g can be mapped across the universe (perhaps inferred from gravitational lensing^{1,16,42,43} or other large-scale structure observations⁴⁴ beyond just local gravity wells), this formula could predict Γ for objects moving through these varied cosmic environments. Some areas in the cosmos may be much older than our region, allowing us to examine what may await us in a more distant future. Cosmological Voids could be a better place to search for things where not enough time has passed in our current location for the events to happen locally, like Hawking Explosions where small primordial black holes have had much more time to evaporate completely.
7. **Provide a Consistent Framework:** It offers a conceptual bridge between gravitational and velocity time dilation, rooting both in the interaction between an object (and its internal CEEs) and the properties of the underlying energy field (Γ_g) and the object's motion (v) through it. This direct connection could allow for alternative exploration of current theories, shedding a more solid light on the concepts and allowing for new mathematical insights into established theories.

By providing a mechanism that directly links an object's experienced time to its motion and the state of the local energy field, this formula aims to offer a more fundamental perspective on relativistic phenomena.

Conclusion:

The universe is composed of interacting elements that span from the cosmic scale down to the atomic level. To fully understand these phenomena, we must account for the totality of these interactions. Focusing too narrowly on a single field (such as quantum mechanics), without considering the broader context of atomic energy history or macroscopic field distortions can lead to incomplete conclusions. Every quantum state is influenced by every bit of energy within causal range. For instance, a LIGO event affects a Bose-Einstein condensate experiment, not just through vibration, but potentially through subtle shifts in time dilation and field density. Science often isolates phenomena to remove overlapping layers, such as the corrections applied in Lunar Laser Ranging (LLR)⁴⁵. However, if we discard the “noise” of global influences without fully understanding them, we risk misinterpreting fundamental realities as anomalies.

In cosmological models, we cannot calculate every particle, so we rely on averages. Yet, if an influence like time dilation becomes non-negligible (effectively stopping time in certain regions), it must be factored into these averages. A cosmological model that overlays a spacetime flow map, a velocity time dilation map, and a static dilation map would provide a far more accurate representation of regional averages. Applying these averaged effects over millions of systems could reveal new insights into galaxy formation and evolution. We must investigate these effects, given their potential to be tremendously impactful.

This paper combines the FEF mechanics of gravitational time dilation with velocity time dilation effects, creating a unified framework to visualize these interactions. This approach offers a clearer understanding of extreme environments, such as the early universe or regions near black holes, and encourages a holistic view of unexplained phenomena.

Science is a journey of exploration where finding an explanation that aligns with all observations is the ultimate goal. With a unified time dilation formula, the exploration of the universe takes on a deeper nuance. Questions like “what happens falling into a black hole” shift from visual speculation to fundamental process analysis. If the chemical processing in an observer's brain slows to one neuron firing per million years, the subjective experience is fundamentally altered. As we aim to explore faster speeds and more massive objects, the total time dilation factor T becomes a critical calculation. We must model these totalities to truly understand the scope of the universe we inhabit.

AI was used to code Toy models, to critically analyze content, to assist in understanding of reference material, and for grammar and spelling. All novel content was created by the author through decades of research and study, with small refinements helping to finish these papers.

These papers take extensive research and time. With so much going into them, and so many new discoveries happening every day, there may be an overlooked issue with the article. If you find something that should be addressed, please get in contact to help the information stay accurate.

Appendix A)

Symbol Definitions:

Symbol	Name	Detailed Explanation
c	Speed of Light	The speed of causality at which it propagates through flat spacetime (FEF) in a vacuum.
v	Velocity	The velocity of an object relative to the local spacetime (FEF) structure or flow.
Γ	Total Time Dilation Factor	The ultimate factor by which all physical processes are slowed for a moving object ($\Gamma = \Gamma_g \cdot \Gamma_v$).
Γ_v	Total Velocity Time Dilation Factor	The averaged dilation factor derived from the 3-axis kinematic analysis.
γ_{\perp}	Perpendicular Kinematic Factor	The time dilation factor for a two-way CEE on a path perpendicular to motion, calculated relative to the effective speed limit c_{eff} .
Γ_g	Total Effective Gravitational Dilation	The complete field density component ($\Gamma_g = \gamma_g \cdot \gamma_{\xi}$), representing the total resistance of the field due to static and induced effects.
γ_g	Background Gravitational Dilation	Time dilation from the static, ambient energy density of the background field (standard gravity).
γ_{ξ}	Induced Gravitational Dilation	A factor quantifying the additional density induced by an object's motion (e.g., "bow wave" or drag).
c_{eff}	Effective CEE Speed	The effective speed limit of CEE propagation in a dense field, defined as c/Γ_g .
L_0	Invariant Proper Length	The absolute, invariant physical length of an object, measured in its own rest frame.
Δt	Time in Stationary Frame	Elapsed time measured by a clock at rest in the stationary frame.
Δt_{\perp}	SFR Time (Perp. Path)	The time measured by the SFR observer for the perpendicular experiment in the moving frame.
Δt_{\parallel}	SFR Time (Para. Path)	The time measured by the SFR observer for the parallel experiment in the moving frame.

References

1. Navas, S. *et al.* Review of Particle Physics. *Phys. Rev. D* **110**, 030001 (2024).
2. Carroll, S. M. Spacetime and Geometry: An Introduction to General Relativity. *Higher Education from Cambridge University Press*
<https://www.cambridge.org/highereducation/books/spacetime-and-geometry/38EDABF9E2BADCE6FBCF2B22DC12BFFE> (2019) doi:10.1017/9781108770385.
3. Maxwell, J. C. VIII. A dynamical theory of the electromagnetic field. *Philos. Trans. R. Soc. Lond.* **155**, 459–512 (1865).
4. Einstein, A. *Autobiographical Notes*. (La Salle ; Chicago : Open Court Pub. Co., 1979).
5. Mungan, C. E. Relativistic Effects on Clocks Aboard GPS Satellites. *Phys. Teach.* **44**, 424–425 (2006).
6. Griffiths, D. J. & Schroeter, D. F. *Introduction to Quantum Mechanics*. (2018).
7. Einstein, A. Die Grundlage der allgemeinen Relativitätstheorie. *Ann. Phys.* **354**, 769–822 (1916).
8. Einstein, A. Zur Elektrodynamik bewegter Körper. *Ann. Phys.* **322**, 891–921 (1905).
9. Dirac, P. A. M. *The Principles of Quantum Mechanics*. (Oxford : Clarendon Press, 1958).
10. LIGO Scientific Collaboration and Virgo Collaboration *et al.* GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral. *Phys. Rev. Lett.* **119**, 161101 (2017).
11. Schumacher, K., Perkins, S. E., Shaw, A., Yagi, K. & Yunes, N. Gravitational wave constraints on Einstein-æther theory with LIGO/Virgo data. *Phys. Rev. D* **108**, 104053 (2023).
12. Alcubierre, M. The warp drive: hyper-fast travel within general relativity. *Class. Quantum Gravity* **11**, L73 (1994).
13. Edwin F. Taylor and John Archibald Wheeler. *Spacetime Physics: Introduction to Special Relativity, Second Edition*. (1992).
14. Vessot, R. F. C. *et al.* Test of Relativistic Gravitation with a Space-Borne Hydrogen Maser. *Phys. Rev. Lett.* **45**, 2081–2084 (1980).
15. Field, J. H. Muon decays in the Earth's atmosphere, time dilatation and relativity of simultaneity. Preprint at <https://doi.org/10.48550/arXiv.physics/0606188> (2009).
16. Overduin, J. M. Spacetime, spin and Gravity Probe B. *Class. Quantum Gravity* **32**, 224003

(2015).

17. Cembranos, J. A. R., Maroto, A. L. & Villarrubia-Rojo, H. Magnetic fields from cosmological bulk flows. *Mon. Not. R. Astron. Soc.* **497**, 3537–3541 (2020).
18. Hamilton, A. J. S. & Lisle, J. P. The river model of black holes. *Am. J. Phys.* **76**, 519–532 (2008).
19. Atrio-Barandela, F. On the Statistical Significance of the Bulk Flow Measured by the PLANCK Satellite. *Astron. Astrophys.* **557**, A116 (2013).
20. Eling, C. Hydrodynamics of spacetime and vacuum viscosity. *arXiv.org*
<https://arxiv.org/abs/0806.3165v3> (2008) doi:10.1088/1126-6708/2008/11/048.
21. Müller, H., Herrmann, S., Braxmaier, C., Schiller, S. & Peters, A. Modern Michelson-Morley Experiment using Cryogenic Optical Resonators. *Phys. Rev. Lett.* **91**, 020401 (2003).
22. White, F. M. *Fluid Mechanics: Seventh Edition*. (University of Rhode Island).
23. Adams, F. C. & Laughlin, G. A dying universe: the long-term fate and evolution of astrophysical objects. *Rev. Mod. Phys.* **69**, 337–372 (1997).
24. Kogut, A., Lineweaver, C., Smoot, G. F., Bennett, C. L. & Banday, A. Dipole Anisotropy in the COBE DMR First-Year Sky Maps. *Astrophys. J.* **419**, 1 (1993).
25. Ashby, N. Relativity and the Global Positioning System. *Phys. Today* **55**, 41–47 (2002).
26. Pound, R. V. & Snider, J. L. Effect of Gravity on Nuclear Resonance. *Phys. Rev. Lett.* **13**, 539–540 (1964).
27. Nicholson, T. L. *et al.* Systematic evaluation of an atomic clock at $2e-18$ total uncertainty. *Nat. Commun.* **6**, 6896 (2015).
28. 6.5: s Orbitals are Spherically Symmetric. *Chemistry LibreTexts*
[https://chem.libretexts.org/Courses/University_of_California_Davis/UCD_Chem_110A%3A_Physical_Chemistry_I/UCD_Chem_110A%3A_Physical_Chemistry_I_\(Koski\)/Text/06%3A_The_Hydrogen_Atom/6.5%3A_s_Orbitals_are_Spherically_Symmetric](https://chem.libretexts.org/Courses/University_of_California_Davis/UCD_Chem_110A%3A_Physical_Chemistry_I/UCD_Chem_110A%3A_Physical_Chemistry_I_(Koski)/Text/06%3A_The_Hydrogen_Atom/6.5%3A_s_Orbitals_are_Spherically_Symmetric) (2019).
29. Colombo, S., Pedrozo-Peñafiel, E. & Vuletić, V. Entanglement-enhanced optical atomic clocks. *Appl. Phys. Lett.* **121**, 210502 (2022).
30. Hafele, J. C. & Keating, R. E. Around-the-World Atomic Clocks: Predicted Relativistic Time

Gains. *Science* **177**, 166–168 (1972).

31. Shapiro, I. I. *et al.* Fourth Test of General Relativity: New Radar Result. *Phys. Rev. Lett.* **26**, 1132–1135 (1971).
32. Schwarzschild, K. On the gravitational field of a mass point according to Einstein's theory. Preprint at <https://doi.org/10.48550/arXiv.physics/9905030> (1999).
33. Evenson, K. M. *et al.* Speed of Light from Direct Frequency and Wavelength Measurements of the Methane-Stabilized Laser. *Phys. Rev. Lett.* **29**, 1346–1349 (1972).
34. Hossenfelder, S. What Black Holes Can Teach Us. Preprint at <https://doi.org/10.48550/arXiv.hep-ph/0412265> (2004).
35. Biretta, J. A., Sparks, W. B. & Macchetto, F. HUBBLE SPACE TELESCOPE Observations of Superluminal Motion in the M87 Jet. *Astrophys. J.* **520**, 621 (1999).
36. Everitt, C. W. F. *et al.* Gravity Probe B: Final Results of a Space Experiment to Test General Relativity. *Phys. Rev. Lett.* **106**, 221101 (2011).
37. Hossenfelder, S., Schwarz, D. J. & Greiner, W. Particle production in time-dependent gravitational fields: the expanding mass shell. *Class. Quantum Gravity* **20**, 2337–2353 (2003).
38. Witten, E. Cosmic separation of phases. *Phys. Rev. D* **30**, 272–285 (1984).
39. Martin, J. Everything you always wanted to know about the cosmological constant problem (but were afraid to ask). *Comptes Rendus Phys.* **13**, 566–665 (2012).
40. Weinberg, S. The cosmological constant problem. *Rev. Mod. Phys.* **61**, 1–23 (1989).
41. Collaboration, P. *et al.* Planck 2018 results. VI. Cosmological parameters. *Astron. Astrophys.* **641**, A6 (2020).
42. Voit, G. M. Tracing cosmic evolution with clusters of galaxies. *Rev. Mod. Phys.* **77**, 207–258 (2005).
43. Goldhaber, G. *et al.* Observation of Cosmological Time Dilation using Type Ia Supernovae as Clocks. Preprint at <https://doi.org/10.48550/arXiv.astro-ph/9602124> (1996).
44. Lynden-Bell, D. *et al.* Photometry and Spectroscopy of Elliptical Galaxies. V. Galaxy Streaming toward the New Supergalactic Center. *Astrophys. J.* **326**, 19 (1988).
45. Battat, J. B. R., Chandler, J. F. & Stubbs, C. W. Testing for Lorentz Violation: Constraints on Standard-Model-Extension Parameters via Lunar Laser Ranging. *Phys. Rev. Lett.* **99**, 241103

(2007).