

Quantum Fluctuations as the Substrate of Spacetime

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10th Oct 2025

Abstract

This paper introduces the concept of the vacuum energy field and excited quantum fluctuations, relating specifically to their relation to the stress-energy tensor, and the ramifications of that, especially in regard to waves propagating through the vacuum energy field. It explores how the vacuum energy field is warped by mass, how it is excited by intense regions of field volatility, and touches on how the gravitational effects of spacetime could be applied to this field. It also explores gravitational effects in regard to time dilation, a MEMS experiment to observe vacuum energy phenomena and proposes experiments and models that could test the predictions.

Keywords: Spacetime, Vacuum Energy, Quantum Foam, Gravity, Dark Matter.

Introduction

Modern physics splits its description of the world between geometry and fields. General Relativity (GR) encodes gravity as spacetime curvature;¹⁻³ Quantum Field Theory (QFT) encodes matter and forces as excitations of fields.¹ Yet observations, particularly the propagation of gravitational waves, as detected by LIGO,^{4,5} invite a more literal reading of the fabric metaphor. We could hypothesize that waves propagate in something. Yes we could be in a simulation where spacetime literally is just a grid geometry in the system, however, exploring a more tangible realism point of view is valid. If spacetime transmits waves, guides geodesics, and couples to energy/momentum,^{1,2,6} is it purely geometric bookkeeping, or is there a physical substrate with properties?

Although Einstein describes gravity as the curvature of spacetime, he also used the term “Gravitational fields”.² The following comparison doesn’t denounce the curvature of spacetime, but seeks to explore it in terms of a field. Let’s consider the textbook facts about static magnetic and gravitational fields to get an understanding of what we currently are certain of and observe.

1. Source of the Field

- Magnetic: A static magnetic field is produced by the distribution of steady currents or aligned electron spins.^{7,8}
- Gravitational: A static gravitational field is produced by the distribution of steady mass-energy.^{1,2,9}

2. Field Strength

- Magnetic: A stronger magnetic field corresponds to more spins aligned coherently and/or closer concentration. Strength diminishes with radius.^{7,8}
- Gravitational: A stronger gravitational field corresponds to more mass/energy and/or closer concentration. Strength diminishes with radius.^{1,2,6,9}

3. Coupling to Matter

- Magnetic: Magnetism couples to charged-particle forms of energy/momentum, altering charged-particle motion trajectories.^{7,8}
- Gravitational: Gravitation couples to all forms of energy/momentum, altering all particle motion trajectories.^{1,2,6}

4. Radiation

- Magnetic: Static magnetic fields do not radiate. Radiation waves require time-varying currents/accelerations.^{7,8}
- Gravitational: Static gravitational fields do not radiate. Gravitational waves require accelerating quadrupole moments.^{1,6,9}

5. Field Polarity

- Magnetic: A static magnetic field appears as dipoles. Positive and negative alignments can cancel out when both are equally present.^{7,8}
- Gravitational: A static gravitational field appears as monopoles. Gravity from matter and antimatter does not cancel out.^{1,2,6,9} Negative mass-energy is hypothetical with no indication it exists.⁶

6. Field Line Structure

- Magnetic: A static magnetic field forms field lines with closed loops that have zero divergence ($\nabla \cdot B = 0$).^{7,8}
- Gravitational: A static gravitational field forms field lines (spacetime geodesics) without closed loops that have divergence ($\nabla \cdot g = -4\pi G\rho$).^{1,2,6,9,10}

7. Cosmological Seeding

- Magnetic: Cosmic magnetic fields seed cosmological structure by altering charge density perturbations.¹¹
- Gravitational: Cosmic gravitational fields seed cosmological structure by altering density perturbations.^{6,12,13}

Set side-by-side, these statements reveal striking operational parallels: each field is sourced by stationary distributions (charge/current vs. mass/energy), each shapes motion, each stores and transports energy, and each radiates only when sources vary in time in the right multipoles. The major differences are in coupling, gravity being monopole, and the strength which can be estimated at $\approx 10^{36}$ times weaker than electromagnetism.^{14,15} The similarities versus differences establish a valid reasoning to conclude that it's not just a fabric geometry, and that there could well be a field-like substrate.

Flowing Spacetime versus Static Spacetime

To understand the mechanics of the FEF, it is necessary to distinguish between three interpretations: the static geometric curvature model,⁹ the fluid-dynamic flow model, and the gravitational river flow model.¹⁶ The Schwarzschild Metric, which is the mathematical standard for the "static model," treats space and time coordinates as fixed (static) geometry. This view is that spacetime only "flows" to a new shape when mass moves (like a rubber sheet stretching). Others consider dark flow^{17,18} or river flow to be a continuous fluid motion. If "river inflow" is real, spacetime would accelerate into a black hole, theoretically allowing matter to enter the singularity faster than c . However, experiments have shown no evidence of an ether-like inflow of spacetime (no "wind" detected).¹⁹ Therefore, this paper posits that gravity is likely not the literal inflow of spacetime.

The Case for the 'Frozen Star':²⁰ Without a physical inflow of spacetime, nothing can travel toward the singularity faster than c . However, due to the extreme gravitational potential and the Shapiro Delay (which is detectable even in our solar system but massive in a black hole)^{21,22}, the speed of light in "physical meters" would be dramatically reduced near the horizon.

This can be visualized as spacetime geodesics being compressed: 300,000 km of empty-space geodesic is compressed into 1 physical meter near the horizon. Light would take a full second to travel that single meter.

This creates a "traffic jam" effect for infalling matter. Imagine a very long pole traveling at 99.9% c . As the front enters the deep gravitational well, the Shapiro Delay limits its maximum speed. The front must slow down, while the rear (still in a region with a higher speed limit), continues at full speed.

- Low Speed: If traveling slowly, tidal forces (the difference in gravity) pull the front harder, causing spaghettification.²³
- High Speed ($v \approx c$): If traveling near light speed, the front hits the "speed limit wall" (Shapiro delay) while the back crashes into it. This would cause a physical "pancaking" effect, compressing the object against the horizon.²⁴

The Result: Stratified Layers. If the Shapiro Delay reduces the propagation speed effectively to zero at the critical limit, this leads to the 'Frozen Star' scenario: matter potentially never reaches the singularity. Instead, it accumulates as virtually frozen, stratified layers. The initial core of the collapsing star freezes first at a microscopic radius (the nascent horizon). As subsequent stellar matter falls onto this dense core, it freezes at progressively larger radii, causing the event horizon to expand outward layer by layer. The conclusion is clear: without vertical inflow, nothing can approach the center faster than light, and the "black hole" is effectively a dense, frozen sphere of matter rather than a singularity.

Horizontal Flow (Frame Dragging):^{25,26} We must also consider flow in the horizontal axis, such as the Frame Dragging detected by Gravity Probe B.^{27,28} This can be interpreted in two ways:

1. The Fluid Vortex (Flow Model): Imagine spacetime as still air in a room. The Earth is a spinning wire-mesh ball. As it spins, it drags the air into a vortex. In this model, spacetime physically flows around the object with the object. A satellite moving "with the flow" would experience less velocity time dilation than one moving against it.
2. The Twisted Metric (Static Model): Alternatively, imagine a static rubber sheet. If you twist the center, the sheet doesn't spin continuously, but the fabric itself remains permanently twisted into a maximum drag state and no longer moves, as the mass slips through continuing to rotate. Unlike the fluid model where the medium moves, here the medium is stationary but the path is distorted. However, the effect on satellites remains: a satellite orbiting with the twist has a shorter geometric path than one orbiting against it (the Sagnac effect).²⁹

While the static geometry model is the standard convention, the true ontological nature of spacetime remains a subject of debate. It is plausible that reality involves aspects of both mechanics. However, the scope of this paper will explore the FEF through the lens of flowing spacetime (horizontally/rotationally), but rejects gravitational river flow (vertical inflow) based on the lack of experimental evidence for an inflow ether wind (gravity doesn't attract spacetime the same as it attracts matter).

The Problem With “Spacetime As Nothing”

Standard GR succeeds by postulating that spacetime is a differentiable manifold with a metric $g_{\mu\nu}$ whose curvature is sourced by $T_{\mu\nu}$. This formalism predicts geodesics, lensing, and the propagation of gravitational waves at c .^{1,2} But it does not specify what the fabric is. If spacetime supports waves (LIGO/Virgo detections),⁴ frame dragging vortex formation (Gravity B probe data)²⁷ and imposes a universal causal speed³⁰, then it exhibits properties usually reserved for media. Asking “Why geodesics? How do waves propagate? Why does gravity couple universally?” is therefore not metaphysics, but it is a request for the microphysical story behind the continuum equations, analogous to how continuum elasticity emerges from atoms.³¹ It’s asking, what makes spacetime behave like spacetime?

This line of thinking instantly raises an issue specifically regarding the Michelson-Morley Experiment (MME) as a decisive null against any medium. However, even the MME paper discusses the possibility of a non-null result at altitude.³² Since the MME, frame dragging (Lense-Thirring Effect) has been measured around Earth and compact objects. In general relativity, frame dragging arises not only from rotation but from any mass-energy flow,^{1,2} so even a non-rotating body moving linearly still ‘drags’ spacetime through its momentum, though the effect is weak and frame-dependent. Local inertial frames are carried along by mass/energy.^{27,28} We can picture this in an example where the Earth is compressed into a black hole with only 1 continent still orbiting the black hole. That continent experiences the exact same existence so therefore, it should still drag spacetime, just as Earth should drag spacetime around the sun.

If spacetime itself can be locally dragged in the direction of motion (like a warp bubble),³³ then the specific kind of relative motion MME sought at the Earth’s surface could, in principle, be suppressed or co-moving in certain scenarios. This does not overturn the MME null result. It merely cautions that “no simple wind in dragged spacetime” \neq “no possible substrate.” A full treatment of “MME under frame dragging” is not the subject of this paper and has been deferred to a separate paper. This paper suggests that established gravitational and magnetic effects make blanket dismissals too coarse.

Hypothesis: Spacetime as a Fundamental Energy Field

We therefore hypothesize for this paper:

The Fundamental Energy Field (FEF): Spacetime is a single, ubiquitous, dynamical energy field whose ground state is the vacuum and whose excitations, flows, and local densifications generate (i) particles, (ii) geodesic guidance (eg. macroscopic field-lines) and (iii) gravitational time dilation (microscopic field density/texture).

This hypothesis is intentionally conservative in its interface with existing theory, not aiming to alter the current working system, but to expand upon it:

1. **Ubiquity and influence.** The FEF is everywhere (in regard to a finite or infinite universe), is influenced by mass/energy, and transmits causal disturbances at a maximum speed c . The stress-energy tensor changes the structure of the field, and the field governs how mass and energy move.

2. **Unification by economy.** The fabric of spacetime, that carries gravitational waves, and the vacuum energy that seeds quantum fluctuations, are taken to be the same physical substrate rather than two separate, coexisting, yet very similar entities.
3. **Spacetime lengths are not physical lengths.** Just because spacetime warps around a planet, doesn't mean that the planet's matter is equally warped. Atomic forces are way stronger. These are independent structures, just as a magnetic field can be warped without warping the magnets.
4. **Energy Field pressure is nullified in particulate form.** When entropy FEF pressure becomes locked into particulate form, it is no longer pushing out against adjacent field energy. Like how a smoke ring doesn't dissipate into a room until it loses its stable pattern, and like how carbon dioxide as a gas will flow to a state of minimum pressure where as solid dry ice wont.
5. **Emergent gravity, dual mechanism.** Gravitational attraction is most commonly understood as a convergence of field lines (timelike geodesics).¹ But it has also been suggested to arise from large-scale inward flow¹⁶ toward regions where stable condensed energy (matter) no longer exerts expansive pressure (in other words, spacetime flows into a black hole and builds up inside in as monopole form). If the field energy flows into a mass, it will grow in density, potentially allowing for measurements. Although, being $\approx 10^{36}$ times weaker than electromagnetism, it may be negligible. The point is, with or without field flow, gravity is proposed to emerge from the FEF.
6. **Excitation in spacetime increases geodesic length relative to physical length.** Gravitational time dilation arises from elevated microscopic agitation/density of the field's texture near those particulate regions of the field, lengthening effective local paths for causal processes like cesium oscillations. Note this is a geometric example of denser field energy, and the mechanics of how the energy field density affects propagation speeds is something that requires further research. For this paper, quantum fluctuations in spacetime, and curvature are believed to be both present but to what degree is uncertain.
7. **Continuity with observations.** The FEF's stress-energy contributes to curvature (Einstein equations), supports wave propagation (LIGO/Virgo), and exhibits frame-dragging (Lense-Thirring/Gravity Probe B/LAGEOS). No established equations are discarded, however, this paper proposes microphysical interpretation beneath them, and the slight perspective changes that are predicted to be observable through experimentation. Just as in relativity, you can perceive things differently depending on your perspective frame of reference, yet it doesn't change the functionality of the math.

Taken together, these considerations motivate treating spacetime not as “nothing with properties,” but as something whose properties (pressure-like tendency toward equilibrium, finite signal speed, capacity to store energy, and susceptibility to densification) could possibly explain why geodesics exist, why gravitational waves propagate at c , and why gravity couples universally. The rest of this paper develops the FEF framework, explores its implications for cosmology and compact objects, and distinguishes testable predictions.

The Nature of Spacetime: A Fundamental Energy Field

This paper proposes that just like spacetime, waves propagate through this field at c . If you wrinkle the fabric, like snaking a rope from side to side, the cosmic coordinates of the ends are closer together yet the spacetime geodesic has not changed in length. In order to make sense of this, we can use a hypothetical frame of reference based on a hypothetical atomic clock second in a hypothetical heat death³⁴ scenario,ⁱ and zero velocity relative to the CMB as measured by the dipole Doppler-effect.³⁵ This gives us a Stable Frame of Reference (SFR) with which to have a common ground of definition for the sake of understanding. This is based on our current understanding of the CMB and Heat Death, and is understood, for calculations and communication's sake, to be constant regardless of the time in history we discuss. Note, this is not a privileged, fixed point, absolute frame of reference in the universe, which goes against Special Relativity (SR). It's a hypothetical frame of reference to avoid confusion and assist in communication, (a hypothetical rest frame with the equivalent of zero gravitational time dilation).

This model proposes a foundational reinterpretation of spacetime. Instead of a passive geometric stage (which is a very useful way to visualize and calculate), spacetime is conceptualized as a dynamic, all-pervading energy field. This field energy arises from the totality of influences of the universe within causal range (the combined fields of all mass and particles), as the pervasive vacuum energy,^{36,37} and maybe even enduring remnants from primordial cosmic states like a Quark-Gluon Plasma (QGP).³⁸ This field is envisioned as a vast ocean of energy, where countless subtle waves (field disturbances from every particle and energy source within causal range) constantly interact and superpose. Occasionally, these myriad smaller fluctuations might constructively interfere, forming a localized *freak wave*, a concentration of energy potent enough (according to $E=mc^2$)³⁹ to momentarily manifest as a particle-antiparticle pair, contributing to the phenomenon of quantum foam.³⁶

It is essential to distinguish the energetic nature of the quantum foam, as conceptualized in this model, from discussions surrounding the net value of the cosmological constant.^{37,40-42} Although the observed cosmological constant implies a very small average net vacuum energy density on cosmic scales,¹² the underlying quantum foam at a local level is envisioned as a highly energetic and dynamic realm.³⁶ Here, energy fluctuations are constantly occurring, capable of reaching the substantial local densities required for $E=mc^2$ particle-antiparticle pair creation,^{1,43} even if these pairs are mostly transient. The “120 orders of magnitude”^{1,42} discrepancy often cited in the cosmological constant problem refers to the difference between theoretical calculations of total zero-point energies from QFT³⁷ and this observed small net cosmic effect. Therefore, this does not negate the possibility of high local energy densities within the foam itself. A common conclusion due to the math is that “determining the energy density of the vacuum is tantamount to determining the cosmological constant, since one is proportional to the other”⁴¹ however, this may not be the case. More on this later. In our model, the vast majority of this fundamental field's energy exists in states that, while not forming stable, detectable particles (i.e., their localized energy is below the specific $E=mc^2$ threshold for a persistent particle or the energy is not in a stable configuration), still represent significant energy. It is this underlying field energy, with its potential for high-density local fluctuations and its pervasive sub-threshold presence, that possesses intrinsic characteristics governing physical reality:

1. Field Structure and Propagation

- **Field Lines as Geodesics:** One possibility (where flow isn't considered and field lines are the focus), is that this energy field could have an inherent structure, characterized by field lines. These are not necessarily discrete entities but represent preferred pathways or gradients within the FEF that particles and Cause-and-Effect Events (CEEs, state between two tangible events like photon creation to photon absorption), including light, tend to follow, analogous to how particles, waves and matter follow geodesics in GR's description of curved spacetime.^{1,2} We observe plasma flowing along field lines in everyday life so this isn't a foreign concept. Note that the amount field lines and flow influence observations is out of the scope of this paper. The point here is that it may have field lines which may affect observations.
- **Constant Propagation Rate through Field Quantity:** A central tenet is that CEEs traverse a fixed *quantity* or *amount* of this field energy per unit of SFR time. This intrinsic propagation rate, through the FEF substance itself, is constant from the SFR perspective, regardless of how compressed or rarified that field energy might be over a given SFR-measured physical distance. The speed of light propagates through the FEF at c but the propagation amount of the field (like with spacetime geometry) does not equal physical meters.
- **The Compressed Field Analogy:** Consider the effort of traversing a fixed distance. If one kilometer's worth of standard-density field energy is compressed into a one-meter physical length (as measured by the SFR), a CEE will take the same amount of SFR time to pass through this dense one-meter region as it would to pass through the original sparse one-kilometer region. This is a slight perspective change where the curve of spacetime can be thought of as squashed into a straight line. What changes for an SFR observer is the SFR physical distance covered per SFR-second. This distance decreases in denser fields. However, since the CEEs are only detectable in an observer's local frame of reference, the CEEs experience this propagation in their own field density, where the propagation rate may transverse kilometers much faster than where the CEEs originated. In other words, light may be moving through SFR physical meters slowly where they originate (at the sun) but when they get to us, it propagates over SFR physical meters much faster. The standard understanding is that 1m with significantly curved spacetime at the sun becomes 1m of almost straight spacetime on Earth. The propagation amount may be squashed or expanded. 299,792,458 m of propagation amount could be squashed into the density of the big bang, or stretched out into heat death density, and light will still propagate that amount at c . So c is not physical meters per second, but the amount of field. Heat death spacetime on a quantum level would be very calm, yet the spacetime on a quantum level between two colliding quasars with massive accretion disks would be unimaginably violent, meaning any geodesics at the quantum level would be extremely twisted, like driving over a winding mountain road instead of driving the same speed straight along a highway. As the crow flies, driving over the mountain would take way longer even though they are both traveling the same speed. This separation of physical length from geodesic length is explained in regard to LIGO in the endnotes.ⁱⁱ

- **Cause and Effect Points (CEPs):** Gravitational time dilation can be used to dictate how many imaginary points are within one meter. These are not real measurable physical points in space but are a form of measurement for the sake of equations, just as meters aren't physical objects. Where some suggest physical meters are used for the speed of light and meters for physical objects change when the path through spacetime is a longer path^{44,45}, this paper uses CEPs as propagation points between a cause and an effect, which are a variable number of intervals in a physical meter (more in longer curved geodesics) and invariant physical meters (yet still allowing for physical tidal stress). This is a slight change of perspective compared to others who discuss relativistic physical length contraction. In any case, there is an interval unit of distance for c on a spacetime geodesic and an interval unit of distance for physical length, and whichever you choose as the changing variable relative to light propagation, becomes the one you squash or expand (for calculations sake, constant intervals on a curved geodesic as longer, or squash shorter intervals to be straight along a physical meter). In both cases, c is constant (intervals per second, and the interval distance is determined by the perspective choice). An example would be in a heat death environment, using how many meters light would travel in one second and creating a physical ruler to locate those points in cosmological coordinates. These geodesic points in spacetime are the CEPs which causal effects propagate through at c . The instant you add a black hole and the gravity change propagates, now these geodesic points in spacetime are (squashed into the same physical meter if you keep a straight line), warped (so the same interval distance but in a longer arc) and dragged (in different positions depending on time), and they no longer correspond to the physical cosmological coordinates. Thanks to atomic forces, our ruler is still 299,792,458m long and not squashed, warped and dragged into an unrecognizable unusable mess.

2. Field Density, SFR-Observed CEE Speed, and Local Clock Rates

The density of this energy field is therefore a critical local property.

- From the SFR perspective, in regions of higher field density, CEEs (including light) will cover less SFR-measured distance (physical cosmological coordinate meters) per SFR-second. Their effective physical speed, as observed by the SFR, is reduced.
- Conversely, in regions of lower field density, CEEs would cover more SFR-measured distance per SFR-second from the SFR viewpoint.
- This model posits that the rate of all local physical processes, and thus the ticking rate of local stationary clocks, is also intrinsically determined by this same local field density. As viewed from the SFR, local stationary clocks in denser field regions run slower (eg, slower *cause and effect* transfer of quantum information across the physical distance of a cesium atom), and they do so in exact proportion to how CEE propagation is slowed in that region from the SFR perspective (curve a null geodesic for light by x amount, and equally curve the null geodesic in the cesium atom clock by x amount so they are both always equally consistent). This precise co-variation is fundamental. It will reduce the clock rate almost exactly the same as the SFR-measured speed, sort of like a car driving 100km/h halves the speed to 50km/h but also the clock rate (30 minutes = a real hour) so it reads 50km per half hour. There are possible discrepancies when the clock axis is not equally altered (curved, warped or squashed) compared to the light path for a fixed physical length. These propagation effects can be easily visualized with toy models.ⁱⁱⁱ

3. Emergent Nature of Time and Space

In this view, what we call *time* (from the SFR perspective) is essentially a measure of the rate of cause and effect, causing changes, and how quickly one state of the FEF can evolve to the next through CEE propagation. If nothing could travel the cause-and-effect distance in an hour (because it's infinitely slow), the effect wouldn't happen and time would effectively stand still. *Space*, on the other hand, is the extent and structure of this field.

- Where the field is very dense or energetic (e.g., near massive objects, or as proposed for the early universe), CEE propagation is slow across SFR distances from an SFR view, and thus local time (as measured against SFR time) appears dilated (slowed).^{2,46-50} You can picture geodesics in quantum foam being exceptionally longer due to the twists and turns in the turbulent fabric of spacetime. It's no longer a straight line between two cosmological coordinates. The more volatile it is, the longer propagation will take. Quantum information would propagate an extremely volatile and twisted path through the vacuum energy across a cesium atom much slower. Note, this doesn't rule out smooth curvature of geodesics. It's all still warped geodesics (field lines) and the exact shape in reality is potentially a combination of the two, like how in music, a high treble note will jitter on the curve of a bass note. The amount in which these two interact is something for future research.
- Where the FEF is dilute, CEEs propagate more rapidly through SFR-measured distances, and local time flows faster (clocks are not as dilated) as measured by the SFR. Quantum information would propagate a relatively flat and straight path through the vacuum energy across a cesium atom much faster.

This concept is consistent with the observation of gravitational time dilation: a clock near a massive object (a region of high energy field density) runs slow. However, here it is framed as a fundamental property of the FEF itself dictating the local speed limit for CEEs and the pace of local clocks, rather than solely a consequence of curved spacetime as a separate geometric entity.^{1,2}

Time Dilation: Standard Effects and the SFR Perspective

Treating every local frame as *equally correct* can lead to ambiguities when frames with different histories are compared. Consider a hypothetical scenario where half the universe experiences an unexplained burst of faster clock ticking for a day. Afterwards, observers in the two halves would disagree about the total time elapsed, yet each might claim their own record is *true*. To resolve which side experienced a deviation from a baseline rate, an absolute standard like the SFR is needed. This is analogous to how the differing experiences in SR's "twin paradox" are resolved by considering the complete spacetime paths and accelerations involved.^{1,3} In observable reality, we readily identify causes for time dilation (motion and gravity typically slow clocks relative to a less affected reference). So we would likely say half the universe's time slowed down, rather than the other half sped up, or a combination of both where both are considered real. In any case, the faster clocks would tend to be deemed as unchanged regardless of the reality of what really happened, and we would tend to lock in a probable assumption rather than say we don't know.

The well-established phenomenon of time dilation reveals that clock rates are not absolute. For instance, GPS satellites orbiting Earth at roughly 20,200 km and about 3.9 km/s experience competing relativistic effects: weaker gravity at altitude causes their atomic clocks to tick ≈ 45 microseconds faster per day (a general-relativistic effect), while their high speed makes the same clocks ≈ 7 microseconds slower per day (a special-relativistic effect). The net result is that satellite clocks run approximately 38 microseconds per day faster than identical clocks on Earth's surface.^{46,48} However, the ISS experiences less gravitational changes and higher velocity change at $\approx 7.66\text{--}7.7$ km/s and an altitude of about 400km⁵¹ leading to their clocks being calculated⁴⁶ at ≈ 25 microseconds per day slower. Probabilistically, it is understood that the satellite's clock rate changes due to gravitational and velocity effects, rather than all clocks on Earth simultaneously altering their intrinsic rates because a single satellite has a different reading.

From the SFR perspective, these variations are seen as absolute changes in the local rate of time flow. The slowing of stationary clocks is due to local energy field density (as outlined in the preceding section) with a Static Time Dilation Factor, γ_g . The definition has $\gamma_g = 1$ 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 $\gamma_g > 1$, local stationary clocks run slower than SFR clocks. This factor γ_g is analogous to and consistent with the gravitational time dilation predicted by GR (e.g.,

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

for a spherical mass,^{1,2} which is an effect experimentally verified to high precision.^{49,50} This framework allows for the conceptualization of a *time dilation map* of the universe based on γ_g (and eventually, the total dilation when velocity is included), which could aid in developing more accurate cosmological models. Velocity time dilation is something that is covered in a separate paper.

The Speed of Light: Local Measurement vs. SFR Observation

Einstein's postulates “the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good” and “that light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body” states that light propagates in a vacuum with a definite velocity c , constant for all inertial observers.^{1,44} This local constancy of c is a well-verified experimental outcome.³⁰ It's important to note that the phrase says “in empty space” and not “between fixed physical lengths” and that in GR, space can be curved relative to physical rulers. This is a crucial definition that must be established for clarity.

For context and clarity, exploration of Lorentz invariance is needed. In SR, the Lorentz metric is invariant under Lorentz transformations, meaning Lorentz invariance defines the structure of flat spacetime itself.^{3,44,52} In GR, Lorentz invariance is preserved locally (meaning every infinitesimal region of spacetime behaves as Minkowskian) even though the global geometry may curve.^{1,2,52} In Quantum Gravity^{53,54} or Standard-Model Extension³¹ contexts, at Planck scales, spacetime may cease to be a smooth Lorentzian manifold altogether, introducing fundamental discreteness or anisotropy. If one arm of an interferometer is in significantly warped spacetime and the other isn't, it will yield a result due to different frames of reference.

Therefore, one cannot meaningfully “violate” Lorentz invariance within flat spacetime when at rest (velocity means the actual perpendicular and parallel light paths are different and Lorentz Transformations can accurately convert results to equal c). The moment such a violation appears, the seemingly local manifold is no longer flat, and Lorentz transformations must be used between the emergent local frames. Simply put, violations of Lorentz invariance = different frames of reference. In general, there’s no such thing as violating Lorentz invariance. With that established, this model can now explore certain phenomena.

This model focuses on gravitational time dilation only, and does not dispute these local findings but offers an underlying explanation from the SFR viewpoint. This paper focuses on gravitational time dilation to point out why c is observed as constant.

From the SFR, the propagation speed of CEEs, including light, through the FEF varies with the field's local density, characterized by the Static Time Dilation Factor γ_g . In a region where $\gamma_g > 1$ (denser than the SFR baseline), the SFR observes CEEs propagating at a reduced speed relative to SFR physical meters ($c_{eff} = c / \gamma_g$).

This is analogous to the Shapiro delay, where light appears slowed to a distant observer when passing through a gravitational well.²¹ The Shapiro delay experiment looked at curvature being minimal implying that gravitational potential causes the delay, rather than the curvature. To rule out curvature completely, the results would need to be straight through the middle of two identical gravitational fields at matching distances, so they equally curve geodesics, canceling each other out, yet the high gravitational field is still present.^{iv}

A local observer within such a region will still measure the speed of light to be c . This emerges naturally because their measurement instruments (clocks) are affected by the same local field density. The derivation is as follows:

1. From the SFR perspective, the time (Δt) it takes for light to cross an invariant proper length L_0 in a dense field is given by the reduced effective speed of light, c_{eff} :

$$\Delta t = \frac{L_0}{c_{eff}}$$

where

$$c_{eff} = \frac{c}{\gamma_g}$$

2. The local observer's clock is also dilated. The time they measure ($\Delta t'$) is slower than the SFR time by the same factor, γ_g :

$$\Delta t' = \frac{\Delta t}{\gamma_g}$$

3. The local observer calculates the speed of light (c') by dividing the invariant proper length L_0 by the time measured on their local clock, $\Delta t'$:

$$c' = \frac{L_0}{\Delta t'}$$

4. To find what the local observer measures, we substitute the expressions from steps 1 and 2 into the equation from step 3:

First, substitute the expression for $\Delta t'$:

$$c' = \frac{L_0}{\left(\frac{\Delta t}{\gamma_g}\right)}$$

This can be rewritten as:

$$c' = \frac{(L_0 \cdot \gamma_g)}{\Delta t}$$

Next, substitute the expression for Δt :

$$c' = \frac{(L_0 \cdot \gamma_g)}{\left(\frac{L_0}{c_{eff}}\right)}$$

Finally, substitute the expression for c_{eff} :

$$c' = \frac{(L_0 \cdot \gamma_g)}{\left[\frac{L_0}{\left(\frac{c}{\gamma_g}\right)}\right]}$$

5. Simplifying this final expression reveals the locally measured speed of light:

$$c' = \frac{(L_0 \cdot \gamma_g)}{\left[\frac{(L_0 \cdot \gamma_g)}{c}\right]} = c$$

Thus, the local constancy of c emerges naturally from the co-variant slowing of both CEE propagation and local clock rates due to the field density measured as γ_g , as seen from the SFR. Though c is always measured locally as constant, its actual transit speed through SFR-defined space varies with γ_g . An SFR is therefore essential for discerning the *true* propagation speeds across different cosmic environments, as local measurements are inherently self-calibrated by local field conditions. Knowing you are near a black hole should mean you accept the reality that your clock is running slow and your experiment results are based on a slow clock measurement, even though your observations hold good. This understanding also sets the stage for how an object's velocity contributes to further time dilation, benchmarked against this locally variable SFR-observed speed of light (c / γ_g).

The Early Universe as an Extreme Gravitational Well

Consider the nascent universe shortly after its origin (e.g., the Big Bang^{1,3,12} or a Big Bounce³⁴ event). Standard cosmology describes this epoch as an extremely dense and energetic state, with all the universe's contents confined to a minuscule volume. From the perspective of any hypothetical observer or physical process existing within that early inferno, time might have *felt* normal, just as our clocks feel normal to us now.

However, this primordial state would appear vastly different to an observer in the SFR. This hypothesis suggests it would be perceived as an unparalleled gravitational well, far exceeding the conditions inside even an ultra-massive black hole. The sheer concentration of energy would correspond to an extraordinarily high local energy field density. In this framework, this means the Static Time Dilation Factor (γ_g) for the early universe, as viewed from the SFR, would have been astronomically large.

We can draw an analogy to GR: an external observer watching a clock approach a black hole's event horizon sees its ticks slow dramatically, appearing to freeze entirely at the horizon.^{1,9,55} Although this is a combination of effects on light and actual clock speed, we know that clocks run slower because when they are physically brought back together, they are different. In this scenario, light observed effects aren't taken into consideration. The fact that the clock slows to an almost infinitely slow rate near the event horizon regardless of what light we see, is the crucial factor. Similarly, the Big Bang/Big Bounce's immediate aftermath, due to its immense effective field density and consequently enormous γ_g , would mean that time within the early universe, from the SFR's perspective, was massively dilated, potentially appearing almost *frozen* for googols of years.

This implies that the early universe's evolution, when measured in SFR-time, would have been extraordinarily slow. From an internal co-moving perspective, the initial phases might seem rapid and violent, but the SFR could observe these same events unfolding over an extremely long time. As the universe expanded and its overall energy density decreased, the prevailing γ_g would have gradually reduced (approaching 1 from much larger values), causing the rate of local time flow (relative to the SFR) to speed up across cosmic history. To the SFR, our universe's timeline might resemble a slow unfolding from a near-static state, with the pace of its clocks gradually accelerating.

This perspective also suggests the early universe could be viewed as a temporarily *trapped* energetic state, slowly unbinding itself as its effective γ_g diminished. Such an external viewpoint, emphasizing the absolute SFR temporal scale of these early cosmic processes, might offer different insights into phenomena like cosmic inflation^{1,56} or the very long-term evolution and ultimate fate of the cosmos³⁴. Our clocks will gradually slow as we fall deeper into the gravitational potential of massive structures like the Andromeda Galaxy⁵⁷ and the Great Attractor.⁵⁸ These regions locally distort spacetime, producing slight deviations from the universal Hubble expansion rate (≈ 70 km/s per Mpc).⁵⁹ As a result, the way we measure the "acceleration" of the universe is subtly affected by the fact that our own clocks are changing relative to the cosmic average. For the static clock inside a supercomputer, this time-dilation should be at least considered for the computer model since the computer's internal clock is basically an SFR.

Particle Formation as Stable Field Patterns

In this model, fundamental particles are not seen as distinct entities separate from the underlying energy field, but rather as stable, resonant patterns or self-sustaining vibrations within this field. Although the exact shape or mechanics behind the formation from non-particulate energy, past the $E=mc^2$ threshold, is not the focus of this paper, the visualization of it forming certain shapes allows us to visualize the relationship, explore possibilities and articulate the principal understanding of this model. This perspective draws an analogy to how specific sound frequencies can induce stable, visible patterns on the surface of water, or in sand⁶⁰, yet in between these resonating frequencies, no distinguishable pattern can be seen. Another analogy is how different substances condense at specific temperatures and pressures in a distillery. This leads to an interesting view of the double slit experiment found in the endnotes.²

The Role of Field Density and Energy Fluctuations

The local effective CEP density (ρ), is directly related to the static time dilation factor, γ_g where $\rho = \gamma_g \cdot \rho_0$. The ρ_0 is the reference CEP density in the minimal-energy SFR where $\gamma_g = 1$. The ρ represents the *richness* or energy content per SFR unit volume of the underlying field. Within this field, constant fluctuations occur, akin to *freak waves* in an ocean or quantum foam.^{36,43,61} These fluctuations are influenced by the superposition^{15,62} of countless field disturbances from all matter and energy within causal range, making individual *freak wave* events practically unpredictable and completely uncertain in our current ability to measure. Probability would be the only way we could analyze it (incalculable Superdeterminism⁶³ requiring a calculable Statistical Independence).

This creates some interesting conclusions:

- **On Superposition and Particle Identity:** The quantum principle of superposition finds a conceptual parallel in this field model. Just as transient energy patterns like whirlpools or freak waves can appear, split, and reform from the underlying medium, localized field energy concentrations meeting $E=mc^2$ criteria might manifest as particles. These particles could be fleeting, borrowing energy from the vacuum, their apparent superposition or multiple simultaneous states reflecting rapid dissolution back into the field and subsequent reconstruction elsewhere from ambient energy.^{15,64} This raises questions about particle identity: it may be the same energy packet teleporting, or a new instantiation from the ubiquitous field, making concepts like a particle existing in two places at once, less about a single entity and more about the field's potential to manifest that pattern at multiple locations nearly simultaneously. It's like Star Trek transporter technology, is it still you if it's not the exact same energy coordinates?
- **On Singularities and the Limits of GR:** GR's prediction of singularities^{1,62,65} (infinite energy densities) encounters a challenge within this framework. Macroscopic gravity emerges from the averaged behavior of the fundamental energy field, but at the Planck scale, the superposition of countless influences from across the causal horizon would render the field's state at any single point effectively incalculable and highly fluctuating.^{36,63} This inherent "jitter" or randomness in the field's infinitesimal structure would prevent the formation of a stable, infinitely dense singularity. If the singularity converging geodesics point is in all directions on average, then the acceleration cancels out and gravity ceases to have a direction and impact. It phases out of existence as if being inside a Newtonian shell with a net-zero force.⁶⁶ However, the shell would be numerous shells with numerous coordinates, yet degrading in strength with size as the quantum fluctuations smooth out, creating a somewhat maximum diameter, before they become negligible and a specific region starts to take over as the focal point of the geodesics. Infinities just phase out as their infinity point averages out over a Planck region to cancel itself out over the average of time. It would be like a heap of scattered ball bearings on a table and underneath is a grid of 10,000 super-strong but super-small cross-sectional electromagnets, so they all compact into a tiny space. Then randomly turn singular magnets on and off, at whatever voltage you want (higher = more gravity), a billion times a second. The ball bearings would just jitter instead of collecting at a specific point, as if there was no singular point at all. If you looked at the ball bearings over 1 second, you couldn't tell if it was a flat zero magnetic field or if there was a massive magnetic field spread over the entire thing over the full second. Both would appear virtually the same. But as you zoom out, you would see them all concentrated over the 10,000 electromagnets eventually appearing as a single point if you zoom out far enough.

As one approaches the Planck scale, the classical curvature predicted by GR would cede to a probabilistic spacetime governed by quantum field fluctuations.^{36,53} This suggests a potential reconciliation between GR and Quantum Mechanics: perhaps their respective domains of validity are bridged by a transitional mathematical framework where the deterministic predictions of GR are progressively modulated by quantum probabilistic effects. A function could smoothly blend the outcomes of both theories as physical scales approach the Planck length, ensuring a singularity-free, quantum-compatible description of spacetime at its most fundamental level. Both equations, virtually unchanged, but the two answers transition from the classical to the quantum as length reaches the Planck scale. Which brings us back to the sound wave analogy with a massive bass frequency and a tiny treble frequency. As you zoom in, the treble frequency becomes more and more apparent as the bass frequency ends up becoming virtually a straight line.

- **Black Hole Information Loss Problem:** The black hole information loss paradox^{1,55} may also be reframed. If the fundamental energy field evolves with an underlying (albeit incalculable) Superdeterminism, then all information, including that of matter falling into a black hole, is perpetually encoded within the field's state. Although matter may lose its particulate form within the black hole's immense field density, its constituent energy and information continue to influence the FEF. Subsequent Hawking radiation^{1,55}, while appearing thermal and random due to our inability to track the googols of correlations, would, in this view, carry subtle imprints of the infalling information as the event horizon field fluctuations coalesce into particle pairs. Thus, information is not fundamentally lost but rather becomes practically irrecoverable due to the sheer complexity of tracing its transformation within the field, akin to trying to reconstruct a bird call from 15 hours ago using all its sound waves that have bounced and propagated halfway around the world. A simplified toy model with limited field states might demonstrate this principle of information conservation, and in using that, one could calculate the exponential unpredictability of the known universe in causal range.

$E=mc^2$ as a Formation Threshold

For a fluctuation to coalesce into a detectable particle (or particle-antiparticle pair), its localized energy must reach a threshold defined by Einstein's $E=mc^2$, where m is the mass of the particle(s) to be formed.³⁹

- **Higher ρ (Higher γ_g):** In regions of higher field density (higher ρ), the ambient energy available is greater creating higher calculable time dilation (γ_g). This suggests that such regions could more readily support the formation of particle pairs from vacuum energy^{1,36,67} and may allow for the spontaneous formation of more massive particle pairs if a fluctuation concentrates sufficient energy. For instance, the extreme field conditions between colliding quasars might facilitate the creation of exceptionally massive, albeit transient, particle states.
- **Lower ρ (Lower γ_g):** In sparser field regions, only fluctuations reaching lower energy thresholds (corresponding to lighter particles) might successfully form, with more massive particles being extremely rare.

Since the field energy has a pressure, it may be like a compound bow where the pressure builds until it slips into the pattern and the pressure is no longer applied to the field, and is stored inside the pattern. If all the energy is caught up in patterns, then the pressure is no longer there. Just like how carbon dioxide can spread out to form the minimal pressure state, but the same carbon dioxide trapped in dry ice can't flow.

Stability Conditions

The mere attainment of an energy threshold $E=mc^2$ is often not sufficient for a particle to be persistent. As seen in the LHC, many particles have a very short life before they decay.^{14,68,69}

Particle-antiparticle pairs also annihilate when they collide.⁷⁰ Therefore, the resulting field pattern's that would usually decay must also achieve a stable configuration as seen in neutrons and protons, to stay in particulate form.

- **Analogy to Bubble Rings/Torus Vortices:** String theory⁷¹ talks about strings, a form of geometry. We don't really know what sort of geometric patterns there are at such a small scale. The geometry and dynamics of these patterns could be complex, perhaps analogous to torus-shaped vortices (bubble rings or smoke rings). Variables such as the direction of rotational axes (the ring around x, y, and z axes, but also the internal flow, rotation of the vortex edge, rotating around the axis of the ring itself), and the pattern's overall energy and interaction with the surrounding field, could determine its specific properties (charge, spin, mass) and its stability. The point of this is to give a possible structure of the energy field to be in a stable pattern for a distinctly separate form compared to the featureless field. What the actual structures are is beyond the scope of this paper.
- **The *Just Right* Conditions:** Similar to how water forms stable whirlpools only under specific flow conditions (not too little energy, not too chaotic), particle patterns require a sweet spot.
 - **Too Dense/Energetic:** In extremely high ρ environments, like the very early universe or, for instance, within a QGP,³⁸ the field energy might be too intense or chaotic for the specific patterns of familiar quarks and gluons (let alone protons and neutrons) to bind and stabilize. The energy remains in a perfect fluid, deconfined state with slight pressure mechanics increasing with density (just like how air pressure increases with density), which leads it to tend toward expanding with entropy. However, the effect of this flow expansion on matter would be the same as gravity wave propagation on rigid matter (virtually negligible now, compared to the atomic forces). This could lead to a big bounce scenario,³⁴ (where the universe energy is compressed down to a black hole the size of say a galaxy or less before the density is too dense for matter to exist in particulate form). More on the mechanics of how the bounce could happen in the endnotes.^{vii}
 - **Intermediate Densities:** As the universe expanded and ρ (and ambient temperature, velocity of temperature vibrations) decreased, conditions became suitable for quarks and gluons to condense into stable configurations like protons and neutrons.³⁸ The model suggests that the specific value of ρ (and other field properties outside the scope of this paper, analogous to viscosity, surface tension, and elasticity of the medium, traits that allow for things like Baryon Acoustic Oscillations)¹⁴ may dictate which particle stability can exist.

The ability for stable particles to form and persist is a function of this field environment. Only within certain windows of field density and energy conditions can stable resonant patterns (particles) emerge. We also know that frame dragging defuses with radius. This suggests the field possesses properties beyond just density and pressure. It can be said that the vacuum can be expressed as a perfect fluid.⁷² This could have implications for describing phenomena like Baryon Acoustic Oscillations or even allow for the prediction of new particles under different field conditions. Further research, perhaps using Casimir effect measurements or MEMS-based⁷³ *field telescopes*, might probe such properties. For instance, a 3D grid in a room made up of Casimir MEMS devices, detecting waves of increased Casimir effect flowing through the 3D grid. Inducing a massive pulse of scattered fields, of all different types, could promote increased Casimir effect in specific regions where the fields intersect. It can be constructed in a similar fashion to Neutrino Astronomy.⁷⁴

- **Decay of Unstable Patterns:** Many exotic particles observed in accelerators decay rapidly.⁶⁹ In this model, this is because their pattern is not truly stable in the prevailing field conditions, or they are not *captured* within a more stable composite structure (like a proton). This might offer a perspective on matter-antimatter asymmetry:⁷⁵ if matter particles were more readily incorporated into stable composite structures (like protons) in the early universe's evolving field conditions, but their antimatter counterparts didn't combine into more stable structures and decayed back into the vacuum energy, (similar to how tiny whirl pools in a river fade into existence before their energy dissipates back into the river), then this could contribute to the observed dominance of matter.

The Unseen Field (Connecting to Dark Matter)

The energy in the field that exists between these specific $E=mc^2$ thresholds for stable particle formation, or in configurations that are not stable detectable patterns, is not directly observable as particles or conventional electromagnetic radiation. However, this *in-between* or *unstable pattern* field energy still contributes to the overall ρ and thus the stress-energy tensor^{1,2} and so has gravitational effects (there is a significant range between zero and the energy within a particle pair). This is a key aspect when considering phenomena like Dark Matter. More on this later.

In summary, particle formation and stability are viewed as emergent properties of the underlying energy field, governed by local field density (ρ), energy fluctuation thresholds ($E=mc^2$), and the possibility of achieving stable patterns within that field.

The Interplay of Field Density, Gravity, and Time Flow

Having introduced the concepts of a fundamental energy field, its variable density (ρ represented by time dilation γ_g), and the emergence of particles, this section synthesizes how these elements are intrinsically linked, defining the very fabric of spacetime and the nature of gravity within this framework.

- **Gravity as an Emergent Effect of Field Dynamics**

While the FEF establishes the presence of a fundamental energy medium, the specific mechanical effects that translate this energy into gravity remain a subject of intense theoretical debate. Several prominent theories exist that attribute gravity to vacuum processes. However, when viewed through the lens of the specific FEF hypothesis proposed in this paper (which posits that high energy density accounts for both Dark Matter and Gravitational Lensing), significant conceptual tensions arise with some of these established models.

1. **Macroscopic Casimir Effect (Shielding/Shadowing):** This hypothesis suggests that gravity may function similarly to the Casimir effect, but on a cosmic scale. In the standard Casimir effect, two plates are pushed together because they shield the space between them from specific wavelengths of vacuum fluctuations, creating a pressure differential (higher pressure outside, lower pressure inside). Applied to gravity, two massive objects may shield each other from the omnidirectional flux of the vacuum energy (FEF). The unshielded vacuum energy pressure from the outside would effectively push the masses together.⁷⁶ In this view, gravity is not attracting, but repelling, resulting from a deficit of density between objects. This mechanism relies on a deficit of energy density between masses. However, to account for the gravitational lensing and Dark Matter effects attributed to the FEF in this paper, the energy density must be higher near and between masses, not lower.
2. **Electromagnetic Zero-Point Field (Stochastic Electrodynamics):** Championed by researchers like Haisch, Rueda, and Puthoff, this hypothesis links gravity directly to Inertia. It suggests that inertia is the electromagnetic drag force experienced by charged particles (quarks/electrons) as they accelerate through the electromagnetic fluctuations of the vacuum (the Zero-Point Field). Gravity, by extension, is a residue of these electromagnetic interactions, effectively a "shielding" or "radiation pressure" effect where the vacuum pushes objects together. This unifies gravity and inertia as electromagnetic side-effects.⁷⁷ Similar to the Casimir model, SED relies on a "shielding" aspect to generate gravity, implying a reduction in local field pressure between objects.
3. **Entropic Gravity (Emergent Force):** Proposed by Erik Verlinde, this theory posits that gravity is an emergent thermodynamic effect, similar to how "heat" is not a particle but the statistical motion of atoms. In this view, the vacuum energy (FEF) carries information (bits) on "holographic screens" (surfaces in space). When mass moves, it changes the entropy (information content) of the local vacuum. The force of gravity is simply the vacuum reacting to maximize its entropy, effectively "pushing" matter toward configurations that are statistically more probable. While mathematically robust, Entropic Gravity treats the vacuum as an abstract information storage medium.⁷⁸ Entropic gravity abstracts away the "substance" of the field, making it difficult to reconcile with the physical refraction of light (Shapiro Delay) caused by high-density FEF zones. It also is proposed to push matter like the others.
4. **Induced Gravity (Elasticity):** Proposed by Andrei Sakharov, this theory posits that gravity is an emergent "stiffness" or elasticity of the vacuum itself. Just as the deformation of a sponge creates an elastic force trying to snap it back, the presence of matter displaces or excites the local vacuum. The "curvature" of spacetime is simply the metric elasticity of the vacuum reacting to this displacement. In this model, the vacuum acts as the master medium, and gravity is the residual byproduct of the vacuum trying to maintain equilibrium.⁷⁹ This implies that the space between masses is under tension (stretched), which corresponds to a lower density state. This contradicts the FEF model, which requires a high-density halo.

5. Vacuum Polarization (Field Alignment): Gravity may arise from the alignment of quantum fluctuations, similar to the Polarizable Vacuum (PV) model. In this scenario, the presence of mass creates a "dielectric" stress on the vacuum, aligning the random fluctuations of the vacuum into ordered gradients. This would create "field lines" similar to magnetic field lines, but acting as a monopole (always attractive). Matter would naturally migrate toward regions of higher refractive index. PV theory attempts to derive gravity from electromagnetism (treating the vacuum as a charged dielectric).⁸⁰ The refractive index⁸¹ works with the FEF but Vacuum Polarization raises potential issues with dipole interactions. If gravity arises from dipolar alignment, one might expect macroscopic electromagnetic effects or polarity (repulsion) under certain conditions, which gravity never exhibits (it is always attractive/monopole). Furthermore, it relies on the vacuum being fundamentally electromagnetic, whereas this paper posits the FEF is the superset of all fields.
6. Superfluid Vacuum Theory (Bose-Einstein Condensate): This model treats the vacuum energy as a Superfluid or Bose-Einstein Condensate (BEC), a state of matter with zero viscosity. If the wave-like state overlaps with numerous others to form one massive wave-like medium, then the density of this medium creates refraction of light and other waves. According to wave mechanics, a wave will naturally curve toward higher density (slower) regions. Random movements in wave-like particles in matter would therefore curve toward the higher density regions of the BEC.⁸² This fits well with the FEF hypothesis. The primary tension here is the description of massive objects as "defects" or vortices. The FEF posits that the fluid-like nature of the FEF is condensed into stable patterns (matter) rather than broken defects. In this view, matter is a localized, dense state of the BEC that acts as a stable gravitational anchor. Critically, Superfluid Vacuum Theory would also need the BEC medium itself to not be dynamically affected by gravity (i.e. falling inward), allowing for it to not have "river flow" and therefore, not have anisotropic propagation path issues similar to velocity effects on light.
7. Fluctuation-Dissipation Asymmetry (Quantum Ratcheting): To reconcile the specific constraints of this paper (namely, the requirement for high FEF density to explain Dark Matter and Shapiro Delay and result in attraction) this paper proposes a new speculative mechanism: "Asymmetric Fluctuation Coupling." Analogous to a "stick-slip" friction drive or a mechanical ratchet,⁸³ matter may interact non-linearly with the creation and annihilation of virtual particles within the FEF. If a vacuum fluctuation excites in a way that pulls the FEF (spacetime geometry) together, dragging the mass with it, but then dissipates back into the vacuum in a way where the geometry relaxes without pushing the mass back, this creates a ratchet effect. In this scenario, a higher density of FEF (such as the concentration between two masses) implies a higher number of stronger fluctuations. Stronger and more numerous fluctuations mean more microscopic "tugs," resulting in a stronger net attraction.

The precise quantum-mechanical interactions between the FEF and baryonic matter (whether through wave refraction toward higher densities, fluctuation ratchets, or a mechanism yet to be discovered) remain elusive. The refractive index⁸¹ could explain curvature due to the slower propagation through denser regions curving the path of waves, linking curvature to Shapiro Delay of slower propagation through a denser FEF (more wiggly path through fluctuating spacetime), and this same effect affecting quantum information to cause time dilation. The scope of this paper is to explore the cosmological and macroscopic consequences of the FEF, regardless of which microscopic mechanism ultimately proves correct. Either way, the foundational premise remains: the FEF could exist, it could have density, and it could cause gravitational effects on matter.

We can look at this section as a unified view of spacetime, gravity, and matter. This framework posits that the distribution and density (ρ , manifested as γ_g) of the FEF *are* spacetime. The general consensus is aligned with GR where only changes to the geometry flow and when the new geometry is in place, it no longer moves. Others suggest spacetime flows into masses if gravity can attract the medium. This paper posits that the medium can flow but isn't attracted by gravity, however, the structure of this FEF governs gravity. The energy thresholds ($E=mc^2$) within this field and its local conditions determine whether and what kind of stable particulate matter can form. The local density (γ_g), dictates their experience of gravitational time dilation. Thus, instead of treating gravity, time, space, and matter as separate fundamental entities, this model suggests they are all interconnected, emergent properties of this single underlying FEF and its dynamic states.

New Predictive Models

We know time dilation is real in real time, and factoring that into our observations of cosmic phenomena is crucial for accurate observations, where different reference frames may impact each other differently based on time dilation. Where a cloud of gas may react one way for one electromagnetic frequency, if an area is more heavily affected by gravity, the radiation will redshift into a different frequency and not have the same effect on the cloud if the time dilation wasn't a factor. Modeling a time dilation map even on a single galaxy could yield invaluable insights.

By taking a mapping of time dilation as it would be observed from the SFR, mapping the FEF of the universe's history over time, and putting these theories into a model for testing, we could open up new insights into how the universe works. Although this paper doesn't talk about a shell universe, which is discussed on another paper, mapping out the universes' history might need to include this to have an accurate representation that aligns with observations. This could affect early universe star formation,⁸⁴ like Little Red Dots, and Dark Energy.

QFT¹⁵ predicts an enormous vacuum energy by summing the zero-point fluctuations of quantum fields. In this calculation, the energy is treated in purely quantum terms. When coupled to gravity via GR, it would act as a cosmological constant far larger than observations allow, creating the well-known cosmological constant problem. In contrast, cosmological observations like the CMB and supernovae infer vacuum energy based on its impact on the universe's expansion, specifically, the acceleration it causes due to its negative pressure (opposite of positive gravitational effects). The problem is that QFT predicts a vacuum energy density about 10^{120} times larger than what observations suggest, making this one of the biggest unresolved mismatches in physics.^{40-42,72} The stress-energy tensor in GR dictates that this energy contributes to gravitational influence, meaning it should pull all matter toward the center of this gravitational influence. This suggests that there is another part or several more parts to the cosmological constant, unless you assume the inherent negative pressure of vacuum energy is greater than the gravitational component completely canceling out the gravitational effects. If the negative pressure, whatever that may be, is separate from the gravitational influence, we can expect to see its effect when the two are not in balance. If we have increased density of vacuum energy in some localized region, creating more gravitational influence, overcoming the negative pressure component of the cosmological constant, then we could expect to see regions having a gravitational impact.

This makes the field energy a strong candidate for Dark Matter, which means it could then also be compared to the time dilation map to see if it corresponds to the cosmological observations. This is only part of the big picture since at that huge rate of energy, the Schwarzschild Radius dictates that the current universe (an estimate at least 46 Gly radius) would be inside a black hole.⁸⁵ However, we know that we aren't because we don't experience the observations that we would see if we were inside a typical black hole.^{vii} Modeling of the entire history of the universe takes much more than the basics that this paper covers. This negative pressure component and its effects on the cosmic evolution is explored in the separate article. In any case, we need the “negative pressure” component to make the models of the expansion of the universe, match the observations.

This unified model for static time dilation offers a framework to:

1. **Refine Cosmological Models:** In the early universe, γ_g would have been extraordinarily high. This would result in immense time dilation for any primordial structures or particles,^{14,38,43} which may impact calculations of early universe expansion rates,^{1,3,37,42} distance calculations, and/or local clocks for cosmic evolution.^{1,12}
2. **Predict Time Dilation in Unexplored Regimes:** If γ_g can be mapped across the universe (perhaps inferred from gravitational lensing^{13,14,28,86} or other large-scale structure observations⁵⁸ beyond just local gravity wells), this could predict the total time dilation for objects moving through these varied cosmic environments. Understanding the rate at which CEEs happen could guide things from the rate at which stars burn their energy to the rate at which supernovae unfold.

If we at least explore toy models to get a basic understanding of the ramifications of a time dilation map overlaid onto a cosmological model, we can explore the possibilities of what the impact may be and if implication may be required for models to more accurately reflect the observations. If the results seem to be relevant, then larger more complete models of the universe could be explored.

Testable Predictions

We have outlined a hypothesis that reframes some fundamental concepts of cosmology and physics: introducing an external tool in the form of the SFR, viewing spacetime as an emergent property of FEF dynamics, and interpreting cosmic phenomena through this lens. This leads to a few key predictions or consequences of this viewpoint that could, in principle, distinguish it from the standard model of cosmology:

- Particle Stability Thresholds:** This hypothesis implies there is a field density or energy threshold above which normal matter cannot form (as happened in the early universe). This is actually in line with known physics (the existence of the quark-gluon plasma at high energy).³⁸ If we can create formulas that describe the patterns for certain field density levels, we may be able to excite fields into specific states where we can then see the formation of specific particles that match the field strength. We may even be able to predict exotic particles and create them too. The new twist would be if there are regions in the current universe where field conditions prevent matter formation, essentially pockets of *failed matter* that contribute to gravity. Research into MEMS devices and using the Casimir effect⁶⁴ as a telescope for mapping and experimenting on quantum vacuum energy could create more Casimir force in higher concentrations of gravity. So it should be more on Earth compared to a test done in high orbit or even a Lagrange point, for even less gravitational intensity. For the Casimir MEMS Telescope, if we create a grid of MEMS devices, and we attempt to influence the amount of Casimir effect by bombarding the region with numerous different fields in a pulse, then the pulse should be registered through the devices as an increase in fluctuations. We would be able to confirm that vacuum energy is not constant everywhere. Additionally, we could compare the MEMS devices and the amount of force they register, in a high gravitational environment as opposed to a low gravitational environment. Looking at the differences between different quantum field energy regions, compared to different gravitational field regions could yield results that confirm the amount of influence on vacuum energy from different influences. We may also register waves of Casimir fluctuations from cosmological events.
- Curvature Versus Density:** If curvature is the only thing affected by gravity, and the effects of quantum foam have no effect on null geodesics, then light passing between two identical masses at a perpendicular angle, should not have any Shapiro delay relative to if there were no gravitational sources. If the presence of identical gravitational sources canceling out each other's curvature equally, yet there is still a delay, then this supports the theory of gravitational force decreasing the speed at which light propagates through spacetime. This is akin to gravitational time dilation (lapse) versus spacetime curvature, (gravitational potential versus spacetime curvature. Shapiro delay arises from the spacetime metric; curvature governs tidal effects).^{22,40} We may not be able to get this perfect but if we could get close and calculate how much the curve would be reduced, we may be able to get measurable results. The key here is to rule out curvature entirely and get everyone on the same page.
- The Link Between Dark Matter and High Quantum Field Energy:** In the standard *ΛCDM* framework, dark matter is viewed as a cold, collisionless sea of weakly interacting particles. It clumps into clouds but not into physical dense objects. It collapses until reaching virial equilibrium, forming diffuse halos that range from Earth-mass micro-clumps to the titans that host galaxy clusters. These halos, and their myriad sub-halos, sculpt cosmic structure but remain far too low-density to resemble compact super-dense objects.^{1,87} The predictions here are a correlation between high-energy field galaxies and gravitational lensing. If there are above-average high-level fields in the galaxy, then more lensing should be present. Whereas galaxies with next to no gravitational lensing should have very little active field energy and therefore lower amounts of dark matter. It may have more baryonic matter, but the fields may be very small in comparison. If we can look at different galaxies and their respective amounts of dark matter, and then compare that against the estimated volatility of fields in those galaxies, we may get a correlation which may support the theory that dark matter is non particulate field energy.

Conclusion

This model posits that the vacuum energy, at different densities, converts into different fields and particles according to $E=mc^2$. It posits that this field has a pressure that leans toward entropy, and that when this energy is locked into a stable particle, this pressure is also locked in. Like how carbon dioxide as a gas spreads out, as dry ice it doesn't. This fundamental field energy can be excited by the confluence of all quantum and gravitational fields in causal range, leading to fluctuations that can form particle-antiparticle pairs.

The model proposes that the fabric of spacetime warps separately to physical matter, as atomic forces prevent almost all physical deformation. Consequently, for the speed of light c to be measured as constant on a given physical length, the null geodesics governing a clock's mechanism must be affected identically to the physical light path being measured, in order for the frame of reference to stay local. Any misalignment would result in a different measurement of c .

With the stress-energy tensor attributing curvature to all forms of energy, this non-particulate field energy becomes a candidate for Dark Matter. The vacuum's immense theoretical energy density, offset by gravity's relative weakness, fits the profile of a substance that is energetically undetectable yet has a subtle gravitational effect. When applying this model to the early universe, the extreme density implies that gravitational time dilation would have been at its most extreme, decreasing over time, and changing in relation to different energy density changes throughout the universe. If compression becomes too great, stable particle patterns could dissolve, releasing their locked-in energy pressure which would follow the law of entropy, potentially triggering a rapid expansion. The primordial field, under these conditions, may have been too violent for stable matter to exist, allowing it to form only later as the universe expanded and cooled, leaving a vast residue of sub-threshold vacuum energy.

Ultimately, this framework suggests that vacuum energy could be the single substrate for spacetime, matter, and dark matter, and that its role in time dilation warrants detailed modeling of cosmic evolution. Through proposed experiments, such as a MEMS telescope, comparing MEMS results in different gravitational field strengths, and observations of the Shapiro delay between equally curving masses, we can begin to probe these ideas, potentially leading to a deeper understanding of fundamental physics and the universe.

Endnotes

i) The Heat Death³⁴ SFR represents the baseline of minimal energy field density and thus the fastest intrinsic rate of time flow. For this state, the Static Time Dilation Factor γ_g is defined as 1. This value signifies no additional time dilation relative to the SFR's own baseline rate; mathematically, a γ_g of 1 acts as a multiplicative identity. For a region with $\gamma_g = 2$, it means that for every 1 second of local time elapsing in that denser field, 2 seconds would have elapsed on an SFR clock (i.e., local time runs at half the SFR rate). At the other extreme, γ_g approaches infinity at a black hole event horizon, signifying a near-complete cessation of local time flow relative to the SFR as predicted by GR.² It is important to note that γ_g , and thus static time dilation, arises from any concentration of energy density, not solely from rest-mass (consistent with $E=mc^2$). A dense field of non-particulate energy would also induce $\gamma_g > 1$.¹

ii) In GR, null geodesics are the paths that light follows, while timelike geodesics are the free-fall trajectories of massive bodies.^{1,2,88} LIGO detects gravitational waves by exploiting the fact that its suspended mirrors, nearly free test masses, closely follow timelike geodesics,⁸⁹ while the rigid Earth-anchored infrastructure resists geodesic deviation due to atomic bonds, keeping its physical length virtually fixed except for negligible tidal stress. Light in the arms, however, follows null geodesics, which are perturbed differently than timelike ones.⁹⁰ The measurable signal arises from this mismatch. The mirrors align with the timelike geodesics, the infrastructure resists, and the light traces null paths that curve differently.

An example of a rigid light clock illustrates the same principle. If moved from flat space into the curved spacetime near a black hole, its mirrors would need to be realigned, since the null geodesic angle changes while the perpendicular physical arm length remains constant. Triangulation confirms that rigid lengths are preserved (since atomic forces will keep the triangulation coordinates fairly consistent), so any discrepancy comes from the null geodesics, whose effective lengths vary with orientation relative to the source of curvature. Thus, if a time standard (e.g., a cesium clock) and a light clock share the same geodesic alignment, both are altered equally by spacetime curvature and c remains constant; if their geodesics differ, the ratio of physical length to light-travel time diverges, giving the appearance of a shifted c .

In simple terms, changes in spacetime alter the length of null geodesics relative to rigid physical lengths, which remain mostly fixed due to atomic forces but are still affected by tidal forces. A time clock aligned with the same null geodesic as the light path preserves c , but if the clock's geodesic and the light path geodesic are misaligned, and rigid length is used instead of geodesic length, the measurement will not return the true speed of light.

iii) The current propagation time dilation model can be easily created as a toy model, a conceptual visualization and its results illustrative of the principles rather than precise numerical validations of spacetime. Preliminary work has shown that in simulated high-density field regions, light appears to travel at a constant speed c relative to co-moving clocks that are themselves slowed by the field. Furthermore, the preliminary work illustrates basic blueshift and redshift effects for CEEs traversing regions of varying simulated field density. Though these models would require further development for rigorous quantitative predictions, they serve as effective proofs of concept for the proposed mechanisms.

iv) A speculative implication of the SFR-observed variability of light speed ($c_{\text{eff}} = c / \gamma_g$) concerns cumulative propagation effects over cosmological distances. If light from very distant sources (e.g., Type Ia supernovae)^{86,91,92} systematically traverses a greater number of, or more significant, regions of high field density (large γ_g) than accounted for in standard cosmological distance calculations, this could lead to an underestimation of their true effective light-travel distances (D_L). Such an underestimation would, in turn, result in a systematically higher calculated value for the late-universe Hubble constant (H_0).⁹³ Correcting for a larger true D_L could yield a smaller H_0 , potentially alleviating the current Hubble tension. Standard cosmological models incorporate gravitational lensing and integrated effects like ISW,¹ yet the hypothesis that there might be a residual, systematic underestimation of cumulative Shapiro-like delays²¹ or effective path lengthening due to pervasive $\gamma_g > 1$ conditions along ancient light paths warrants further theoretical and observational investigation. Observations can be made to confirm or falsify this, by looking at light travelling at a perpendicular angle straight between two equally sized massive bodies which cancel out each other's curvature of the spacetime directly between them, meaning no curved spacetime yet the increase in gravitational field should still cause a Shapiro-like delay. If this is the case, then we may be incorrectly calculating cosmological events.

v) In a double slit experiment, a quantum wave (of a photon, electron, etc.) typically spreads across many possible detector positions. But in any individual measurement, only one position triggers a click. It may be that most of the wave remains below a detection threshold and never manifests as a detectable event. It could be that only at one location does the local amplitude (or coherence) concentrate sufficiently to cross that threshold and produce a detection.⁹⁴ In this view, the detection event is not the teleportation of the entire wave to a point, but rather the manifestation of the spot whose energy passed the threshold, while the rest remains latent and undetected. If, upstream (before or along the path), one suppresses, concentrates, or filters out portions of the wave (i.e. like removing contributing amplitudes, pruning possibilities, or directing the wave to be more likely to create a click in a certain area of the detector), then those weaker parts never build up enough to cross threshold. The more you prune, the more the remaining detections are concentrated into narrower, more particle-like regions, and the weaker the interference pattern becomes. Similar to how soundproof material can control where sound is detected by suppressing sections of the wave.

This does not imply that the particle ever becomes a fully solid, classical object. What we detect as a particle may simply reflect a localized pattern (like, for instance, a high-amplitude crest) that happened to exceed the threshold.⁹⁵ Most of the wave stays sub-threshold. One can think of it like ocean waves along a coast. As a wave swell comes in, it's going to impact the entire coastline, but where randomness interacts with overlapping swells to create a freak wave, that's the place where people can point and say, "Did you see that huge splash?" The rest of the wave energy stays too low to stand out and it just looks like the same ordinary sea they've been watching for hours.

This interpretation is plausible in that it resembles existing threshold-detector and collapse-inspired models, where detection occurs once a signal crosses a threshold rather than through instantaneous teleportation of the full wave. It aligns with the MIT experiment,⁹⁶ where the "fuzziness" of the atom controls how much of the photon scattering remains coherent versus how much becomes incoherent. In effect, the atom interaction divides the outcome into a portion that still interferes and a portion that does not. It also aligns with established ideas of partial measurement and decoherence, where interactions can gradually leak which-path information and reduce interference visibility, rather than enforcing an all-or-nothing collapse.⁹⁷ However, much more research would be required to clarify whether this threshold-style interpretation can be fully reconciled with the full body of quantum experiments.

vi) The possible Big Bounce events: The center of the mass may reach an energy level threshold where particulate gravity no longer exists. The energy pressure slips out of its stable pattern state. Before it creates a gravitational singularity (no more mass to be pulled in), it transitions. With no patterns concentrating and holding the energy in the stable form, the field returns to the pressure state, leading toward entropy. It's as if the gravitational container pops. You can think of it as smoke rings gathering together (under gravity) until they interfere with each other, making the patterns break down and then the smoke evenly distributes throughout the room. The pattern tension may be like a compound bow slipping out of its drawn state. The tightly wound ball of the big crunch spacetime would be released like a ball of tightly wound elastic bands all snapping at once.

Since most explosions like supernovae happen at the core first, the outside of the collapsing universe may still be in mass form and be blasted out as a shell shockwave with the massive change in spacetime structure changes while the atomic structure tries to keep the mass in particulate form. The compression wave could compress the shell past the threshold, and then it too loses its own reaction to gravity, exponentially increasing the explosion power as the radius increases. Mass falling into an exponentially inflating energy field. Additionally, if the field disperses in the absence of matter, it may exponentially expand, where the field is only expanding relative to the field directly adjacent. This exponential expansion could reach superluminal speeds before matter forms, in which the inertia of that initial matter would be superluminal relative to the center of the universe. That inertia plus radiation pressure would overcome any initial gravitational force, which would be significantly weak in comparison. This big bounce condition may happen well before the universe ever reaches the singularity. In any case, conditions that are way too extreme could mean that all forms of matter and particles may be impossible at that time, leaving non-particulate energy to exist without being adversely affected by the resulting gravity well.

vii) Because a black hole has an effect where the geodesics all curve to point directly at the singularity,^{1,6,9} this causes the direction light can travel to be one way, toward the singularity. This causes some observer effects as you pass into the black hole to the singularity. Because gravitational time dilation virtually freezes your time,¹ you would experience length contraction in the direction you are traveling.³ You will think a nanosecond has passed, but it could have been a day, in which time, you would have traveled to the singularity. So, as you get closer to the event horizon, time dilation will make you think you are accelerating at an exponential rate until you seemingly blip out of existence at the event horizon, where time dilation becomes almost infinite. The spaghettification¹ before you reach the singularity would take maybe a single Planck second or so by your own clock. So we won't consider time dilation or spaghettification or radiation death from the extremely blue-shifted light for the following thought experiment.

If you are approaching a black hole at near the speed of light, you would initially experience extreme relativistic aberration,^{3,98} causing all light from the universe to appear beamed into a single point in front of you, blue-shifted into gamma radiation, so microwaves will become visible light. This is much like running into vertically falling rain, making it appear to come from the front. However, upon crossing the event horizon, this effect would cease. It would be akin to falling with lead rain, which falls a little faster than you in the same direction. The geodesics of both the observer and the infalling light would align, all pointing radially toward the singularity. As the light is on the same path but moving faster, the observer can no longer *run into* it. The forward view would become blackness, and any light from behind would be redshifted into invisibility. As you get closer to the singularity, the geodesics would converge at more and more obtuse angles, and at a Planck length from the singularity, the geodesics from each side would be almost perpendicular. The only possibility of seeing light from the front would be in the final split second, as you run into the converging, progressively more perpendicular geodesics and the concentration of near-infinite photons at the singularity that you would smack into if you make it that far.

If you approach in a simple free fall, the experience would be different. Looking backward, away from the singularity, you would see the external universe shrink into an ever-smaller circle of light as the event horizon effectively wraps around you.^{16,99} This view wouldn't be significantly blue-shifted or red-shifted, as gravity would affect both you and the light equally. As the fall continues, the converging geodesics would focus this circle into an increasingly sharp, laser-like point of light. This continues until the observer reaches the singularity, which would appear infinitely bright at the final moment, unless something like the perfect fluid pressure^{1,14} or a *fuzzy* uncertainty principle^{36,53,55} affected the singularity, preventing you from ever truly reaching it.

This means that if the universe were actually inside a traditional black hole, we would be traveling toward the singularity, and the light geodesics (null geodesics) would all be aiming straight at the singularity too. This implies we are not in a traditional black hole with a traditional center singularity.^{85,100}

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.

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