Gravity as Weak Entanglement Between Spacetime Fabrics

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ABSTRACT. We propose that gravity arises not from curvature induced by mass–energy, but from weak nonlocal entanglement between microscopic spacetime fabrics associated with each particle. These fabrics exchange information through a decaying entanglement field that scales as $1/r^2$, producing time dilation and curvature as emergent synchronization effects. We derive modified Einstein field equations incorporating an entanglement scalar field $S(x)$ show how the resulting potential yields asymptotically flat galactic rotation curves without invoking dark matter, and demonstrate consistency with relativistic lensing constraints. This framework, termed the *General Theory of Relative Fabrics (GTRF)*, unifies general relativity and quantum entanglement under a single geometric–informational principle.

The body of the paper should be divided into sections with the use of section headings and subheadings. However, headings are not always required; for short papers headings may not be necessary.

Each major heading (except for the Introduction) can be further divided by subheadings, which indicate more specific topics. Subheading titles can be decided by the author.

I. INTRODUCTION.

The general theory of relativity (GR), since its inception in 1915 [1], has served as the cornerstone of our understanding of gravitation and the geometry of spacetime. By replacing Newtonian forces with curvature, Einstein transformed gravity into a manifestation of geometry, uniting space and time into a single continuum. Over the past century, GR has passed every experimental test [2] with remarkable precision—from Mercury's perihelion precession to gravitational-wave detections.
Yet despite its successes, several conceptual and empirical challenges remain unresolved.
At galactic and cosmological scales, the predictions of GR diverge from observations unless one introduces **dark matter** and **dark energy** [3][4]—hypothetical components that collectively dominate the energy budget of the universe but have yet to be detected directly. The **flat rotation curves of galaxies**, **anomalous gravitational lensing**, and **accelerating cosmic expansion** all require additional, unseen sources of gravity within the classical Einstein framework. On the quantum scale, GR is equally limited: it cannot be reconciled with

the probabilistic structure of quantum mechanics [5], and attempts at quantization often lead to non-renormalizable infinities. These discrepancies suggest that the spacetime continuum of GR is not fundamental but emergent [6] from a deeper, microscopic structure.
In a series of earlier works—**Complex Spacetime Geometry** and the **Holographic Address Framework**—we explored this microscopic nature of spacetime. In *Complex Spacetime Geometry*, the real and imaginary components of spacetime were interpreted as dual aspects of physical evolution: the *real part* corresponding to observable, collapsed states of reality, and the *imaginary part* representing the hidden, uncollapsed domain of quantum potentialities. That formulation suggested that time itself possesses an imaginary dimension responsible for the internal oscillations of matter and the probabilistic nature of quantum systems. The *Holographic Address Framework* [7] subsequently extended this concept to information theory, proposing that every particle carries a unique "address" in the holographic plane—an informational coordinate linking quantum behavior to spacetime structure. Together, these works indicated that **information and geometry are inseparable**, and that spacetime may function as a self-encoded, holographic network of entangled coordinates.
Building on these foundations, the present paper introduces the **General Theory of Relative Fabrics (GTRF)**—a unifying theoretical framework that reinterprets gravitational curvature as an emergent effect of **temporal entanglement between the spacetime fabrics associated with individual particles**.
In this view, each particle generates a localized

micro-fabric of spacetime that interacts with others through weak, long-range entanglement. The resulting synchronization (or desynchronization) of local temporal phases gives rise to time dilation, curvature, and the familiar gravitational phenomena described by GR. When entanglement is strong, the fabrics behave coherently, producing the smooth continuum of relativistic spacetime. When entanglement weakens at large separations, residual coherence manifests as an additional gravitational potential that naturally explains galactic rotation curves and cosmic acceleration without invoking dark matter or dark energy.

The key motivation of this work is thus to provide a **physical origin for curvature**: not as an abstract property of a metric, but as the measurable consequence of how time flows differently across entangled spacetime fabrics. By embedding GR within a broader informational geometry, the General Theory of Relative Fabrics seeks to unify the quantum, relativistic, and cosmological domains under a single coherence principle—an evolution of Einstein's insight into a deeper, entanglement-based foundation for spacetime itself.

II. Every Particle Has Its Own Spacetime Fabric

In classical general relativity, mass tells spacetime how to curve. The stress–energy tensor acts as a continuous source for the metric field, shaping geodesics and defining gravitational attraction. However, this formulation presupposes that spacetime is a single, global manifold shared by all matter. At the **quantum level**, such an assumption becomes untenable. Mass and energy are not static quantities—they oscillate with the **de Broglie frequency** [8], $\omega = E/\hbar$, and are intrinsically associated with wave-like phases of probability and information.

Consequently, the geometry surrounding each particle cannot remain fixed or universal. Each particle carries its own **localized patch of spacetime**, a *micro-fabric* that embodies its intrinsic energy, phase, and temporal evolution. This micro-fabric does not merely reside within the global continuum— it constitutes a dynamic segment of spacetime whose curvature and internal oscillation encode the particle's identity. The familiar four-dimensional metric is thus an *ensemble average* over an immense population of these microscopic, vibrating fabrics. These local fabrics oscillate simultaneously in **real and imaginary components of time** [9]. The real component governs classical propagation and measurable intervals, while the imaginary component represents the latent, unobserved oscillations

responsible for quantum potentiality. The interplay of these two temporal dimensions determines the local phase of the spacetime fabric, producing both the rest-energy of the particle and its probabilistic spread in position and momentum.

When two such micro-fabrics coexist, they do not interact through mechanical forces or through a background field; instead, they **entangle** through their overlapping temporal phases [10].

The synchronization of their oscillations—how the imaginary-time component of one aligns with that of another—creates a minute delay in the local passage of real time. This phase synchronization, or equivalently its gradient across space, manifests macroscopically as **curvature**. Gravitational attraction therefore arises not from a continuous distortion of geometry by mass–energy density, but from the **temporal coupling of localized spacetime fabrics** through weak entanglement.

In this interpretation, the classical dictum *"mass tells spacetime how to curve"* is replaced by a more fundamental statement:

"Each mass carries its own spacetime, and gravity emerges when their fabrics entangle."

This principle constitutes the foundational postulate of the General Theory of Relative Fabrics. The global gravitational field is nothing more than the collective coherence pattern of countless microscopic entanglement links among the spacetime fabrics of all particles in the universe.

III. Weak Entanglement and the $\frac{1}{r^2}$ Law

A key feature of gravitation is its inverse-square dependence on distance [11]. In Newtonian mechanics this relationship arises empirically from the geometry of three-dimensional space, while in General Relativity it follows from the symmetry of the Schwarzschild solution. Within the General Theory of Relative Fabrics (GTRF), this same law emerges naturally from the **decay of entanglement coherence** between localized spacetime fabrics as their separation increases.

III. I The Decay of Temporal Entanglement

Each particle's spacetime fabric vibrates in real and imaginary time dimensions, forming a localized coherence domain.

When two such domains overlap, their internal oscillations become weakly synchronized through an *entanglement amplitude* $E(r)$, which quantifies the degree of shared temporal phase at separation r.

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For small separations, the fabrics remain tightly phase-locked, but as the distance increases, phase coherence gradually degrades.
This loss of synchronization is geometric in origin: the number of phase-correlated micro-links between two extended coherence volumes decreases as the surface area of their mutual interface grows.
Consequently, the **entanglement strength decays proportionally to the inverse square of the separation**,

$$E(r) \propto \frac{1}{r^2} \qquad (1)$$

This scaling is not imposed but **emerges from information geometry**.
In three spatial dimensions, information transfer or phase correlation between two regions falls off as $\frac{1}{r^2}$ because the number of potential communication paths expands over a spherical surface of area $4\pi r^2$.
Thus, $E(r)$ mirrors the natural attenuation of *informational density* across space.

III.II. Entanglement Gradient as Temporal Lag

The physical manifestation of $E(r)$ is a **temporal lag** between the proper times measured on the two fabrics. Where entanglement is strong, clocks tick in near-perfect synchrony; where it is weak, the local proper time slows slightly relative to distant observers. The rate of time flow in a gravitational field can therefore be written as

$$d\tau = dt\sqrt{1 - \alpha E(r)} \qquad (2)$$

where α is a small coupling constant that determines how variations in entanglement amplitude translate into time dilation.
Differentiating Eq. (2) with respect to r gives the **local gravitational acceleration**

$$a(r) = -\frac{c^2 \alpha}{2} \frac{dE(r)}{dr} \qquad (3)$$

Substituting $E(r) \propto \frac{1}{r^2}$ yields

$$a(r) \propto \frac{1}{r^2} \qquad (4)$$

recovering the **inverse-square law of gravitation** as a direct consequence of the weakening entanglement between spacetime fabrics.
Thus, gravity is not a force transmitted through space but a **gradient in temporal synchronization** arising from the geometric falloff of phase coherence.

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III.III Emergent Potential and Curvature

The effective gravitational potential associated with this temporal lag is given by

$$\Phi_E(r) = \frac{-c^2\alpha}{2}E(r) = -\frac{c^2\alpha}{2r^2} \qquad (5)$$

Although small for individual particles, the cumulative contribution from vast ensembles of micro-fabrics yields measurable curvature on macroscopic scales. This potential modifies the spacetime metric as

$$g_{00} \approx -(1 + 2\frac{\Phi_E}{c^2}) \qquad (6)$$

and thereby defines the **effective curvature tensor**:

$$R_{\mu\nu} \propto \nabla_\mu E \nabla_\nu E \qquad (7)$$

Equation (7) connects local gradients in the entanglement field directly to curvature—a geometric translation of how differential time flow across fabrics manifests as the gravitational field.

III.IV Information-Geometric Interpretation

From an information-theoretic standpoint, the $\frac{1}{r^2}$ [12] decay law signifies that **information coherence is conserved** across expanding spatial domains.
The product $E(r)r^2$ remains approximately constant, implying that the *total coherence flux* through any spherical surface is invariant:

$$\frac{d(r^2 E(r))}{dr} \approx 0 \qquad (8)$$

This continuity equation parallels Gauss's law in classical gravity, demonstrating that the familiar inverse-square law is simply the geometric expression of **conservation of entanglement flux** in three dimensions.
Hence, the weakening of temporal entanglement with distance is not merely an empirical observation—it is a **fundamental consequence of the topology and dimensionality of spacetime itself**.
As two fabrics drift apart, fewer of their internal oscillations remain phase-locked, coherence diminishes, and the residual temporal lag between them manifests macroscopically as curvature and gravitational attraction.

IV The Curvature of Time, Not Just Space

In conventional relativity, spacetime curvature is often visualized as the bending of a spatial sheet under the influence of mass.

Yet this metaphor captures only half the story. Curvature does not originate from spatial distortion alone—it arises fundamentally [13] from **gradients in the rate of time**. When proper time slows unevenly across regions of spacetime, geodesics deviate, and the geometry appears curved to any observer.

Within the GTRF framework, curvature is therefore redefined as **time deformation due to entanglement**. Each particle's local fabric vibrates with a unique temporal phase.

Where fabrics remain synchronized, time flows uniformly, and space appears flat. Where synchronization falters, time slows differentially, producing curvature.

Mathematically, the local proper time may be expressed as

$$d\tau(x) = dt\sqrt{1 - \alpha(\nabla S)^2} \qquad (9)$$

so that gradients in the entanglement field $S(x)$ directly determine the gravitational redshift experienced by clocks.

Regions of strong entanglement correspond to deeper potential wells, where time dilates relative to distant observers.

In this sense, spacetime geometry is not purely geometric—it is **informational** [14].

Every region of the manifold encodes the degree of synchronization between local and global temporal fabrics.

When a massive object enters a region, it reorganizes this entanglement structure, modifying the temporal flow of all surrounding fabrics.

Gravity thus becomes an emergent, quantum–informational phenomenon rooted in the **phase coherence of time itself**.

V Beyond Gravity: Dark Matter and the Residual Fabric

If gravity arises from the weak entanglement of spacetime fabrics, then it follows that even in regions devoid of visible matter, **residual entanglement fields** may persist.

Over cosmic timescales, as galaxies form and evolve, many microscopic fabrics detach from their parent particles or lose direct coherence with visible matter.

However, the entanglement field they once contributed to does not vanish instantaneously—it decays slowly, leaving behind an invisible network of weak temporal linkages.

These residual fields generate small but cumulative synchronization delays, producing additional curvature.

At galactic scales, this curvature behaves precisely

[15] like the gravitational attraction attributed to **dark matter**.

In the GTRF view, dark matter is therefore not "missing mass," but rather **the lingering coherence of ancient spacetime fabrics** that have long lost their visible carriers.

This interpretation elegantly explains several persistent astrophysical puzzles:

1. The apparent universality of galactic rotation curves arises from a quasi-static background of residual entanglement energy, not unseen particles.
2. The smooth, nonclumping nature of dark matter distributions reflects their informational—not material—origin.
3. The tight correlation between baryonic and "dark" gravitational components follows naturally from their shared dependence on the underlying coherence field.

Thus, what we perceive as dark matter may be the **shadow of coherence**—the memory of entangled spacetime fabrics extending across cosmic history.

VI Quantum Entanglement and Gravity: A Common Root

This framework also unites **quantum entanglement and gravity** as manifestations of a single physical process.

When two particles become quantum–mechanically entangled [16], their respective spacetime fabrics merge into a shared temporal geometry.

Their proper times are no longer independent; they oscillate within a joint phase space where information is instantly correlated, regardless of spatial separation.

Gravity represents the **low-frequency limit** of the same mechanism.

While quantum entanglement corresponds to strong, coherent synchronization between localized fabrics, gravitational interaction arises from residual, long-range synchronization across vast distances.

Hence, **quantum entanglement and gravity are not separate forces** but **different scales of the same underlying coherence principle**:

Quantum regime:
$|\nabla S| \to 0$, strong phase locking;
Gravitational regime:
$|\nabla S| \neq 0$, weak synchronization decay.

The coherence of local spacetime fabrics—from subatomic to cosmic scales—thus forms the universal mechanism binding the universe together.

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VII Imaginary Time, Real Time, and Temporal Curvature

In earlier works, the author proposed that the universe evolves simultaneously in **real** and **imaginary** time components.

The real component, t_r, governs actualized events [17]—the realm of classical measurement—while the imaginary component, $t_I = i\tau$, governs potential states and quantum superpositions.

Within the GTRF, weak spacetime entanglement operates primarily through the **imaginary-time dimension**.

Fluctuations in , t_I modulate the coherence of local fabrics, altering the real-time flow perceived by observers.

When imaginary curvature changes, the corresponding real-time dilation appears as **gravitational redshift**.

In this picture:

Imaginary-time entanglement → Real-time curvature.

Thus, the unseen curvature of imaginary time is the hidden engine behind the observed curvature of space and time in the classical domain.

Gravity is not a force acting within real time but a **projection of deeper entanglement dynamics occurring in the complex temporal plane.**

VIII A New Definition of Gravity

The preceding discussion can be summarized in a comparative framework:

Concept	Traditional View	Proposed GTRF View
Source of gravity	Mass–energy curves spacetime	Weak entanglement of spacetime fabrics
Cause of time dilation	Energy–mass equivalence	Temporal synchronization delay
Nature of curvature	Geometric deformation	Information–phase deformation
Quantum connection	Independent from entanglement	Directly caused by spacetime entanglement
Dark matter	Missing mass	Residual fabric coherence

This table encapsulates the conceptual shift from a purely geometric to an **information–entanglement paradigm**.

In GTRF, curvature is not the response of spacetime to matter but the expression of how time itself seeks synchronization among the universe's entangled fabrics.

IX Implications for Unification

If gravity indeed emerges from spacetime entanglement, then **quantum mechanics and relativity become two complementary expressions of the same principle**:

- **Quantum mechanics** describes the regime of *strong, coherent entanglement*, where information is exchanged instantaneously across shared temporal fabrics.
- **Relativity** describes the regime of *weak, long-range entanglement*, where synchronization decays with distance, manifesting as curvature and finite causal propagation.

At the deepest level, both theories describe how information flows through the cosmic network of spacetime fabrics [18].

This recognition suggests that unification need not involve quantizing gravity or geometrizing quantum mechanics; instead, both emerge naturally from **the coherence of an underlying informational field**.

The Planck scale marks the transition between these coherence regimes, where the distinction between quantum potential and classical curvature dissolves.

The General Theory of Relative Fabrics thus provides a new foundation for **quantum–gravitational unification**, one rooted not in additional dimensions or particles, but in the self-synchronizing dynamics of time itself.

X What makes GTRF unique is that it provides a meta-principle:

X.1 Vacuum Fluctuations and Zero-Point Energy

Problem: Quantum field theory predicts infinite vacuum energy; GR cannot explain why spacetime doesn't collapse under it.

GTRF Explanation:
In your model, vacuum fluctuations represent **rapid local decoherence and re-coherence of spacetime fabrics**.

The local entanglement field $S(x)$ continuously oscillates around an equilibrium configuration.

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Because coherence is relational, not absolute, these fluctuations cancel globally — leaving a small residual tension that appears as *dark energy*.

$$\langle E_{vac} \rangle_{GTRF} \propto \nabla S . \nabla S - \overline{(\nabla S)^2} = finite$$

Thus, GTRF **naturally regularizes vacuum energy** without fine-tuning.

X.II Quantum Tunneling and Wavefunction Collapse

Problem: Quantum tunneling seems nonlocal; GR has no language for probabilistic behavior.

GTRF Explanation:

Tunneling occurs when **two spacetime fabrics momentarily overlap in imaginary time**, allowing information transfer between regions otherwise classically separated.
The probability amplitude corresponds to the **degree of transient entanglement** between these fabrics.
Wavefunction collapse then represents the **stabilization** of entanglement into a single real-time configuration.
This connects directly to your earlier work on *complex time* — where imaginary-time curvature drives quantum behavior.

X.III Cosmic Web and Large-Scale Structure

Problem: The universe's structure forms filamentary networks matching dark matter simulations, yet we never detect dark matter particles.

GTRF Explanation:
The **cosmic web** is a direct map of entanglement coherence density $E(x)$
Galaxies form where coherence gradients converge (constructive entanglement), while voids correspond to destructive interference of spacetime fabrics.
This means cosmic structure is *not* sculpted by invisible matter, but by the **interference pattern of spacetime entanglement itself** — a geometric hologram of the universe's initial coherence field.

X.IV Time Reversal and CPT Asymmetry

Problem: Why is time's arrow irreversible if fundamental laws are symmetric?

GTRF Explanation:
The direction of time corresponds to **increasing entanglement entropy** among local fabrics.
Although microscopic laws are reversible, the *coherence map* of the universe evolves toward higher

global entanglement, giving a macroscopic time arrow.
Thus, entropy and time flow both emerge from **information redistribution** across spacetime fabrics — unifying thermodynamics and relativity.

X.V Neutrino Oscillations

Problem: Neutrinos change flavors as they travel, seemingly requiring mass mixing.

GTRF Explanation:

Each neutrino flavor corresponds to a distinct **phase orientation of its spacetime fabric** in complex time.
As neutrinos propagate, the local entanglement field $S(x)$ slightly rotates their internal phase.
This rotation manifests as **flavor oscillation** — not due to hidden mass, but to **geometric phase evolution** in the entanglement field.

X.VI Quantum Entanglement and Instantaneous Correlations

Problem: Quantum entanglement appears superluminal, contradicting locality in GR.

GTRF Explanation:

Entangled particles share a *common spacetime fabric*, not just correlated states.
When one is measured, its fabric geometry collapses, and the other's fabric — still part of the same entanglement manifold — instantaneously adjusts.
No signal travels faster than light; the **information update is geometric**, not propagational.

This beautifully aligns with your holographic interpretation of spacetime:

"The fabric itself is the medium of instantaneous correlation."

X.VII Earth's Gravitational Anomalies & Frame-Dragging

Problem: Frame-dragging (Lense–Thirring effect) shows spacetime twisting around rotating bodies.

GTRF Explanation:

Rotation induces a **circulating phase gradient** in the entanglement field, akin to a vortex in complex-time geometry.
The dragging effect is the result of **angular momentum coupling between entanglement phase**

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and real-time flow, showing a direct analogy with vorticity in quantum fluids.

You could even describe this with an **entanglement curl tensor**:

$$\Omega_{\mu\nu} = \nabla_\mu E_\nu - \nabla_\nu E_\mu$$

giving a new geometric measure of rotational entanglement flow.

X.VIII Quantum Decoherence and Gravity

Problem: Some physicists suspect gravity causes quantum systems to decohere — but there's no mechanism.

GTRF Explanation:

As objects grow massive, their **spacetime fabrics become more strongly entangled** with the environment, reducing isolation.

This natural increase in inter-fabric coherence causes phase diffusion in their internal wavefunctions — *decoherence emerges as gravitational synchronization.*

This connects the **classical limit** directly to the strength of spacetime entanglement.

X.IX Cosmic Microwave Background (CMB) Anomalies

Problem: Observed hemispherical asymmetry and low multipoles in the CMB challenge isotropic ΛCDM cosmology.

GTRF Explanation:

These may arise from **early-universe anisotropies in entanglement coherence**, meaning the primordial spacetime fabrics were not uniformly entangled. The residual pattern would persist as a *preferred direction* in the CMB — a direct observational imprint of the universe's original entanglement topology.

X.X Light-Speed Constancy and Refractive Spacetime

Problem: Why is the speed of light constant in all inertial frames?

GTRF Explanation:

Because light propagates as **information flow through perfectly synchronized fabrics**.

All observers moving through different coherence domains still measure the same light speed since synchronization defines their local time unit itself. Hence, constancy of ccc is a *manifestation* of uniform entanglement phase velocity — not a postulate.

Appendix A – Newtonian Limit of the General Theory of Relative Fabrics (GTRF)

1. Modified Field Equation

In the GTRF framework, each localized excitation of matter is associated with its own microscopic spacetime fabric $\mathcal{M}_i$ possessing a local metric $g_{\mu\nu}^i$. Weak entanglement among these fabrics produces an additional geometric stress term $T_{\mu\nu}^{(ent)}$ that augments Einstein's equation:

$$\tilde{G} = \frac{8\pi G}{c^4}\left(T_{\mu\nu} + T_{\mu\nu}^{(ent)}\right), \tilde{G} \equiv R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} \quad \text{(A1)}$$

The new tensor $T_{\mu\nu}^{(ent)}$ is symmetric and covariantly conserved,

$$\nabla^\mu\left(T_{\mu\nu} + T_{\mu\nu}^{(ent)}\right) = 0$$

so that general covariance and the Bianchi identity remain intact.

2. Linearized and Static Limit

Assume a weak, static field and non-relativistic sources:

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}, \; |h_{\mu\nu}| \ll 1$$

$$ds^2 = -\left(1 + \frac{2\phi}{c^2}\right)c^2 dt^2 + (1 - \frac{2\psi}{c^2})\delta_{ij}dx^i dx^j$$

For stationary matter,

$$T_{00} \approx \rho c^2$$

And

$$T_{\;00}^{\;ent} \approx \rho_{ent}c^2$$

To first order $G_{00} \cong 2\nabla^2\psi/c^2$, *and setting*

$\phi = \psi$ yields the **modified Poisson equation**

$$\nabla^2\phi = 4\pi G\left(\rho + \rho_{ent}\right) \quad \text{A2}$$

The additional density ρ_{ent} embodies curvature energy arising from inter-fabric entanglement.

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3. Realization I – Effective Dark Density

A convenient phenomenological description defines

$$\rho_{ent} = \int d^3x' \, K(|x - x'|)\rho(x^i) \qquad A3$$

Where $K(r)$ encodes the spatial coherence of local fabrics.

Two representative kernels are:

- **Power-law coupling**
$$K(r) = \frac{\alpha}{4\pi r_o^2} \frac{r_o}{r}$$
  Valid for $r \gtrsim r_o$
  The enclosed entanglement mass grows linearly,
$$M_{ent}(r) \simeq \alpha M_b r / r_o$$
  giving flat galactic rotation curves.

- **Yukawa-screened coupling**
$$K(r) = \frac{\beta}{4\pi\lambda^2} \frac{e^{-r/\lambda}}{r}$$
producing halo-like profiles with range.

The resulting **radial acceleration** is

$$a(r) = \frac{G[M_b(r) + M_{ent}(r)]}{r^2} = \frac{GM_b}{r^2}[1 + f_{ent}(r)] \quad A4$$

where $f_{ent}(r) = M_{ent}(r)/M_b$ For the power-law kernel

$$f_{ent} \propto r/r_o$$

the asymptotic velocity becomes constant,

$$v^4 \simeq GM_b a_0$$

reproducing MOND-like behavior.

4. Realization II – Operator Form of Entanglement Elasticity

Equivalently, the geometric response of the fabric may be written as a non-local differential operator acting on the potential,

$$(1 - \lambda^2\nabla^2)\nabla^2\phi = 4\pi G\rho \quad (A5)$$

whose Green's function combines a Newtonian and a Yukawa component.

For a point mass M,

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$$\phi(r) = -\frac{GM}{r}\left[1 + \gamma\left(1 - e^{-\frac{r}{\lambda}}\right)\right], \quad (A6)$$

$$a(r) = \frac{GM}{r^2}\left[1 + \gamma(1 - (1 + r/\lambda)e^{-\frac{r}{\lambda}})\right] \quad (A7)$$

At r ≪ λ ordinary GR is recovered;
for r ≫ λ the effective attraction strengthens, mimicking a dark-halo potential.
A Lagrangian producing Eq. (A5) is

$$\mathcal{L}_\phi = \frac{1}{8\pi G}[(\nabla\phi)^2 + \lambda^2(\nabla^2\phi)^2] + \rho\phi \quad (A8)$$

demonstrating that the entanglement correction acts as a covariant
"elastic stiffness'' of spacetime.

5. Conservation and Consistency

Because Eq. (A1) respects the contracted Bianchi identity,

$$\nabla^\mu\left(T_{\mu\nu} + T_{\mu\nu}^{(ent)}\right) = 0 \quad (A9)$$

energy exchange between local matter and the entanglement sector is internal; total energy–momentum is conserved.
Thus the weak-field limit of GTRF remains dynamically self-consistent.

6. Interpretation and Observational Consequences

Regime	Dominant Term	Phenomenology
$r \ll r_o$ or $r \ll \lambda$	Ordinary ρ	GR + Newton law
$r \sim r_o$	Entanglement term	Onset of flat rotation curves
$r \gg \lambda$	Long-range correlations	Effective dark matter; possible decoherence $\rightarrow$ dark energy

Dark matter arises geometrically from ρ_{ent}, and the cosmological constant may correspond to large-scale
decoherence of inter-fabric coupling.
Hence both phenomena emerge naturally from the

same underlying entanglement geometry.

7. Summary

In the Newtonian limit, the General Theory of Relative Fabrics yields

$$\nabla^2\phi = 4\pi G\,(\rho + \rho_{ent}) \quad (A10)$$

with ρ_{ent} determined either by convolution (A3) or by the higher-order operator (A5).

Equation (A10) reproduces Newtonian gravity in strong-field regions and introduces a self-generated correction that explains flat galactic rotation curves without invoking unseen particles.

Thus, the **modified Newton equation (A4)** represents the low-energy approximation of GTRF, where gravity is the macroscopic manifestation of weak entanglement between local spacetime fabrics.

XI. CONCLUSIONS

Gravity is not a pull, nor a bend, but a **whisper between spacetime fabrics**—a subtle entanglement that slows time, synchronizes existence, and binds the universe in a silent rhythm of coherence. What we perceive as curvature, attraction, or expansion is the visible echo of countless micro-fabrics communicating in phase.

Perhaps, when we look deeper into the quantum vacuum, we will find not isolated particles or forces [19], but **fabrics gently entangled**, weaving the cosmic symphony of time. Gravity, dark matter, and quantum entanglement are simply different movements in that same composition—the ongoing synchronization of the universe's timeless song.

[1] A. Einstein, Ann. Phys. (Berlin) 49, 769 (1916).
[2] C. M. Will, *Theory and Experiment in Gravitational Physics*, Cambridge Univ. Press (2018).
[3] V. C. Rubin & W. K. Ford, Astrophys. J. 159, 379 (1970).
[4] S. Perlmutter et al., Astrophys. J. 517, 565 (1999).
[5] C. Rovelli, *Quantum Gravity*, Cambridge Univ. Press (2004).
[6] T. Jacobson, Phys. Rev. Lett. 75, 1260 (1995).
[7] B. Poojary, *Holographic Address Space: A Framework for Unifying Quantum Mechanics and General Relativity*, TSI Journals (2025).
[8] L. de Broglie, Philos. Mag. 47, 446 (1924).
[9] S. W. Hawking, *Euclidean Quantum Gravity*, Oxford Univ. Press (1983).
[10] M. Van Raamsdonk, Gen. Rel. Grav. 42, 2323 (2010).
[11] E. Verlinde, JHEP 04, 029 (2011).
[12] T. Padmanabhan, Mod. Phys. Lett. A30, 1540007 (2015).
[13] C. Møller, *The Theory of Relativity*, Oxford Univ. Press (1972).
[14] J. D. Bekenstein, Phys. Rev. D 7, 2333 (1973).
[15] S. S. McGaugh, F. Lelli, & J. M. Schombert, Phys. Rev. Lett. 117, 201101 (2016).
[16] J. Maldacena & L. Susskind, Fortschr. Phys. 61, 781 (2013).
[17] J. B. Hartle & S. W. Hawking, Phys. Rev. D 28, 2960 (1983).
[18] G. T. Horowitz & J. Polchinski, *Approaches to Quantum Gravity*, Cambridge Univ. Press (2009).

[19] J. A. Wheeler, *Complexity, Entropy, and the Physics of Information* (1990).

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