Proposed Unification Theory

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1 Introduction

In previous articles, we explored how gravity acts as a quantum background for quantum matter and as a classical background for classical matter. In this article, we aim to go a step further and attempt to unify matter, force, and spacetime. This should be regarded as a proposal rather than a verified theory. Our approach begins with constructing an appropriate conceptual model, followed by a mathematical framework to support this model.

2 Three-Layer Model

As discussed in earlier work, spacetime superpositions can be understood as superpositions of particle fields combined with mass-energy. Now, let us consider matter and force as fields that permeate all of spacetime. We propose that these three components—matter, force, and spacetime—form three interwoven layers, such that an excitation in one layer can randomly affect the other two.

It is understood that massless force carriers do not directly influence spacetime. Based on this, we introduce the three-layer model, which will guide our attempt at unification. Matter and force are already established as fields within quantum field theory (QFT). In this model, we extend that framework by treating spacetime itself as a field—one that not only responds quantum mechanically but also accumulates and integrates the effects of the other fields.

3 Mathematical framework

So, If we say force, matter and spacetime as three layers then mathematically we can write as follow:

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{matter}} + \mathcal{L}_{\text{force}} + \mathcal{L}_{\text{gravity}} + \mathcal{L}_{\text{interaction}} \tag{1}$$

Where:

- $\mathcal{L}_{\text{matter}}$ is the Lagrangian of matter.
- $\mathcal{L}_{\text{force}}$ is the Lagrangian of the force fields.

- $\mathcal{L}_{\text{gravity}}$ is the Lagrangian of spacetime or gravity (e.g., Einstein-Hilbert action).
- $\mathcal{L}_{\text{interaction}}$ represents the interaction terms between different fields.

Where the Lagrangian of matter is:

$$\mathcal{L}_{\text{matter}} = \frac{1}{2}\left(\partial_\mu\phi\partial^\mu\phi - m^2\phi^2\right) + \bar{\psi}(i\gamma^\mu\partial_\mu - m)\psi$$

The Lagrangian of the gauge (force) field is:

$$\mathcal{L}_{\text{force}} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu}$$

The Lagrangian for gravity (Einstein-Hilbert action) is:

$$\mathcal{L}_{\text{gravity}} = \frac{1}{2}\sqrt{-g}\,R$$

In this theory, we preserve both local gauge invariance and general covariance (diffeomorphism invariance). The cross-layer interaction Lagrangian are given below:

1. Gravity–Gauge Field Coupling

$$\mathcal{L}_{\text{int}}^{(1)} = \sqrt{-g}\,\frac{\xi}{M^2}RF_{\mu\nu}F^{\mu\nu}$$

Here, R is the Ricci scalar, $F_{\mu\nu}$ is the field strength tensor of the gauge field, ξ is a dimensionless coupling constant, and M is a high-energy scale (e.g., Planck scale). This term is both gauge-invariant and diffeomorphism-invariant.

2. Gauge Field–Scalar Field Coupling

$$\mathcal{L}_{\text{scalar}} = \sqrt{-g}\left[(D_\mu\phi)^\dagger(D^\mu\phi) - V(\phi)\right]$$

$$D_\mu = \partial_\mu - igA_\mu$$

This is the standard gauge-invariant and generally covariant kinetic term for a scalar field coupled to a gauge field. Optionally, we can add a non-minimal coupling term:

$$\mathcal{L}_{\text{int}}^{(2)} = \sqrt{-g}\,\xi R\phi^\dagger\phi$$

This term can be motivated by conformal symmetry or appear in effective field theory.

3. Gravity–Fermion Coupling

$$\mathcal{L}_{\text{fermion}} = \sqrt{-g}\,\bar{\psi}(i\gamma^\mu\nabla_\mu - m)\psi$$

This is the standard generally covariant Dirac Lagrangian, where ∇_μ includes the spin connection.

Origin of Cross-Layer Coupling Terms

All interaction terms in this theory are constructed to respect local gauge invariance and general covariance. Below we outline the derivation or motivation for each coupling:

1. Gravity–Gauge Field Coupling

The term

$$\mathcal{L}_{\text{int}}^{(1)} = \sqrt{-g}\,\frac{\xi}{M^2} R F_{\mu\nu} F^{\mu\nu}$$

is dimension-6 and appears in the low-energy effective action of quantum gravity and string theory. It respects both diffeomorphism and gauge invariance. It may arise from loop corrections or higher-dimensional operators in compact theories.

2. Gauge–Scalar Field Coupling

The minimal coupling term:

$$\mathcal{L} = \sqrt{-g}\,(D_\mu \phi)^\dagger (D^\mu \phi)$$

is derived from demanding invariance under local gauge transformations $\phi \to e^{i\alpha(x)}\phi$. The curvature coupling term $\xi R \phi^\dagger \phi$ arises in conformal scalar field theory and in non-minimal inflation models.

3. Gravity–Fermion Coupling

The Dirac term:

$$\mathcal{L} = \sqrt{-g}\,\bar{\psi}(i\gamma^\mu \nabla_\mu - m)\psi$$

is required by local Lorentz invariance and general covariance. The additional term $\frac{\eta}{M} R \bar{\psi}\psi$ can arise from integrating out heavy fields or as a curvature correction in effective theories.

4 Introduction

In this section, we will derive the Euler-Lagrange equation for a scalar field ϕ from the Lagrangian of the form:

$$\mathcal{L}_{\text{scalar}} = \sqrt{-g}\left[(D_\mu \phi)^\dagger (D^\mu \phi) - V(\phi)\right]$$

where D_μ is the covariant derivative, and $V(\phi)$ is the potential for the scalar field ϕ.

5 Euler-Lagrange equation

The Euler-Lagrange equation for the field ϕ is given by:

$$\frac{\partial \mathcal{L}}{\partial \phi} - \partial_\mu \left(\frac{\partial \mathcal{L}}{\partial(\partial_\mu \phi)} \right) = 0$$

Our goal is to calculate each term in this equation.

6 Step 1: Compute $\frac{\partial \mathcal{L}}{\partial \phi}$

From the Lagrangian $\mathcal{L}_{\text{scalar}}$, we know that ϕ only appears in two places: inside the covariant derivative D_μ and in the potential $V(\phi)$. Thus:

$$\frac{\partial \mathcal{L}}{\partial \phi} = -\sqrt{-g}\, \frac{\partial V(\phi)}{\partial \phi}$$

7 Step 2: Compute $\frac{\partial \mathcal{L}}{\partial(\partial_\mu \phi)}$

Now, we compute the term $\frac{\partial \mathcal{L}}{\partial(\partial_\mu \phi)}$. From the covariant derivative, we know:

$$D_\mu \phi = \partial_\mu \phi - igA_\mu \phi$$

The derivative of the Lagrangian with respect to $\partial_\mu \phi$ is:

$$\frac{\partial \mathcal{L}}{\partial(\partial_\mu \phi)} = \sqrt{-g}\, \left[(D^\mu \phi)^\dagger \right] = \sqrt{-g}\, \partial^\mu \phi$$

8 Step 3: Compute $\partial_\mu \left(\frac{\partial \mathcal{L}}{\partial(\partial_\mu \phi)} \right)$

Next, we calculate the divergence of the term we found in Step 2:

$$\partial_\mu \left(\frac{\partial \mathcal{L}}{\partial(\partial_\mu \phi)} \right) = \partial_\mu \left(\sqrt{-g}\, \partial^\mu \phi \right)$$

This term involves the covariant derivative due to the presence of $\sqrt{-g}$, and can be written as:

$$\partial_\mu \left(\sqrt{-g}\, \partial^\mu \phi \right)$$

9 Step 4: Euler-Lagrange Equation for Scalar Field

Substituting the results of Steps 1 and 2 into the Euler-Lagrange equation, we get:

$$-\sqrt{-g}\,\frac{\partial V(\phi)}{\partial \phi} - \partial_\mu \left(\sqrt{-g}\,\partial^\mu \phi\right) = 0$$

This simplifies to:

$$\partial_\mu \left(\sqrt{-g}\,\partial^\mu \phi\right) = -\sqrt{-g}\,\frac{\partial V(\phi)}{\partial \phi}$$

10 Conclusion

This is the equation of motion for the scalar field ϕ, which describes how the scalar field propagates in spacetime, influenced by the gauge field and the potential $V(\phi)$.

11 Introduction

In this section, we derive the Euler-Lagrange equations for the gravity-gauge field coupling term from the interaction Lagrangian:

$$\mathcal{L}_{\text{int}}^{(1)} = \sqrt{-g}\,\frac{\xi}{M^2} R F_{\mu\nu} F^{\mu\nu}$$

where R is the Ricci scalar, $F_{\mu\nu}$ is the field strength tensor of the gauge field, ξ is a dimensionless coupling constant, and M is a high-energy scale.

12 Variation of the Lagrangian

The variation of the interaction Lagrangian with respect to the metric $g_{\mu\nu}$ is given by:

$$\delta \left(\sqrt{-g}\,\frac{\xi}{M^2} R F_{\mu\nu} F^{\mu\nu}\right) = \frac{\xi}{M^2}\delta \left(\sqrt{-g} R F_{\mu\nu} F^{\mu\nu}\right)$$

We now compute the variation of the terms involving the Ricci scalar R and the determinant g.

The variation of $\sqrt{-g}$ is:

$$\delta\sqrt{-g} = \frac{1}{2}\sqrt{-g}\,g^{\mu\nu}\delta g_{\mu\nu}$$

The variation of the Ricci scalar R is:

$$\delta R = R^{\mu\nu}\delta g_{\mu\nu} - \nabla_\alpha \nabla_\beta \delta g^{\alpha\beta}$$

Thus, the total variation becomes:

$$\delta\mathcal{L}_{\text{int}}^{(1)} = \frac{\xi}{M^2}\left[\sqrt{-g}\left(R^{\mu\nu}F_{\mu\nu} + RF_{\mu\nu}\delta g^{\mu\nu}\right)\right]$$

13 Field Equations

The field equations corresponding to the variation of the metric $g_{\mu\nu}$ will contain terms involving the Einstein tensor $G_{\mu\nu}$. The resulting equation for the metric will be:

$$G_{\mu\nu} \sim \frac{\xi}{M^2}F_{\mu\nu}F_{\mu\nu}$$

The corresponding equation for the gauge field A_μ can be derived similarly by varying the Lagrangian with respect to A_μ.

14 Embedding General Relativity into the Standard Model Framework

In the Standard Model of particle physics, all known particles are described as excitations of underlying quantum fields. To achieve a unified theoretical framework, we extend this principle to gravity by modeling spacetime itself as a field capable of excitation, rather than as a background geometry composed of discrete particles like gravitons.

This approach allows gravity to emerge naturally from the interaction between the spacetime field and matter-energy distributions, in accordance with the Einstein field equations. For the purpose of integrating General Relativity within the Standard Model, we consider the effect of the lightest known massive particle—the neutrino—on spacetime curvature. Neutrinos have incredibly small but nonzero rest masses, with the lightest eigenstate estimated to be below 0.01 eV. The spacetime curvature induced by such a low-mass excitation provides a practical and theoretically clean test case for quantifying how even minimal mass-energy distributions deform the spacetime field.

In this framework, excitations of the spacetime field correspond to dynamic curvature, and the interplay between the matter field and spacetime curvature becomes fundamental to unification. Just as the Standard Model treats the photon as the smallest excitation of the electromagnetic field, we propose that quantum fluctuations in curvature—while not particle-like—represent the minimal excitations of the spacetime field, and can be described in terms of expectation values in a quantum geometric background. This method respects both general covariance and quantum superposition, and lays the foundation for incorporating gravity as a quantized yet non-particle-based field within the Standard Model.

15 Research and experiment

Recent experimental proposals, such as the Bose–Marletto–Vedral (BMV) scheme, aim to test whether gravity can exhibit quantum superposition by placing two massive particles in spatial superpositions and observing whether they become entangled via their mutual gravitational interaction. This setup effectively tests whether the gravitational field — and by extension, spacetime curvature — can exist in a quantum superposition. While not directly based on the framework proposed here, such experiments serve as potential empirical validation of the central idea in this work: that mass-energy in quantum superposition induces a corresponding superposition in spacetime curvature. The observation of entanglement mediated purely by gravity would strongly support the notion that spacetime itself participates in quantum phenomena.

16 Conclusion

In this work, we have proposed a conceptual and mathematical framework that attempts to unify matter, force, and gravity as interacting quantum fields. Unlike conventional approaches that either quantize gravity via hypothetical gravitons or treat spacetime as a fixed classical background, our model introduces gravity as an excitation of a spacetime field that exists alongside matter and gauge fields. By interpreting the stress-energy tensor and spacetime curvature as superposable quantum quantities, we bridge general relativity with quantum mechanics through expectation values and energy eigenstates.

The core of this proposal is the three-layer model, in which matter, force, and spacetime are treated as dynamically coupled layers. Through a unified Lagrangian that preserves gauge invariance and diffeomorphism symmetry, we establish interaction terms that reflect how excitations in one layer can influence the others. These include non-minimal curvature couplings and quantum corrections that hint at deeper structural relationships.

It is our hope that this layered field-based view of unification offers a conceptually consistent and mathematically extensible step toward reconciling gravity with the Standard Model. [1] [2] [3] [4] [5] [6] [7] [8]

References

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