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A Quantum Electrogravitic Coupled Gauge Theory

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Abstract

We present a quantum electrogravitics (QEG) theory in which gravity emerges as a $U(1)$ gauge interaction fully analogous to electromagnetism. Starting from the relativistic velocity dependence of gravitational mass, we derive a Lorentz-like gravitational force, an implied field-strength tensor $G_{\mu\nu}$, and a complete set of gravitomagnetic Maxwell equations. Quantization yields both uncoupled and coupled $U(1)\times U(1)$ theories whose tree-level potentials recover Coulomb's and Newton's laws. The coupled version naturally produces an E^2 interaction term that matches the functional form observed in the Biefeld-Brown effect. The graviton appears as a massless spin-1 vector boson, and the entire framework remains fully calculable and renormalizable. This approach offers a concrete, experimentally testable unification of the long-range forces within a single quantum field-theoretic structure.

Keywords

Quantum Electrogravitics, $U(1)\times U(1)$ Gauge Theory, Gravitomagnetic Maxwell Equations, Spin-1 Graviton

1. Introduction

The unification of the fundamental forces remains a central goal in theoretical physics, with electromagnetism providing the paradigmatic example of a successful quantum field theory. In this work, we develop a quantum electrogravitics (QEG) framework in which gravity emerges as a $U(1)$ gauge theory directly analogous to electromagnetism, thereby realizing a $U(1)\times U(1)$ quantum field theory (QFT) that couples the two interactions at the level of gauge potentials and currents. The construction begins from a relativistic velocity dependence of gravitational mass and proceeds systematically to a Lorentz-like gravitational force law, an implied four-potential, a gravitomagnetic version of Maxwell's equations, and finally a fully quantized theory whose tree-level amplitudes recover both the Coulomb and Newtonian potentials in the appropriate limits.

The key insight motivating the approach is the observation that centripetal accelerations in gravitational orbits can be reinterpreted through the relativistic reduction of gravitational mass.

The remainder of the paper is organized as follows. Section 2 derives the gravitational Lorentz force and the associated gravitomagnetic field. Section 3 constructs the implied four-potential and field-strength tensor, emphasizing its epistemological status. Section 4 obtains the gravitomagnetic Maxwell equations from the Bianchi identity and the action principle. Section 5 quantizes the uncoupled theory and verifies the classical limits. Section 6 introduces field and charge couplings, derives the coupled equations of motion (Section 6.1), and computes the mixed propagators (Section 6.2). In Section 7 we compute the potentials in the classical limit. We conclude with remarks on possible experimental signatures and extensions.

By treating gravity as an induced $U(1)$ gauge symmetry parallel to electromagnetism, the present framework offers a concrete, calculable QEG theory whose predictions can be confronted directly with laboratory-scale tests of gravitomagnetism and electrogravitational coupling.

2. Lorentz Force for Gravity

We derive a gravitational analog of the Lorentz force equation by considering the velocity dependence of gravitational mass, as proposed in alternative gravitational theories [1]-[3]. Starting from the relativistic form of gravitational mass, we approximate the force on a test mass in a weak gravitational field and employ vector identities to obtain a form resembling the electromagnetic Lorentz force, introducing a gravitomagnetic field. This derivation highlights the illusory nature of gravitomagnetism arising from mass-velocity dependence.

In electromagnetism, the Lorentz force on a charged particle is given by

$$\boldsymbol{F} = q\left(\boldsymbol{E} + \boldsymbol{v}\times\boldsymbol{B}\right), \tag{1}$$

where q is the charge, $\boldsymbol{E}$ is the electric field, $\boldsymbol{B}$ is the magnetic field, and $\boldsymbol{v}$ is the velocity. Analogous effects in gravity, termed gravitomagnetism, have been explored [1], but may stem from the velocity dependence of gravitational mass rather than a true magnetic-like field. Here, we derive the gravitational Lorentz force from the assumption that gravitational mass m_g decreases with velocity as.

$$m_g = m_0\sqrt{1-\frac{v^2}{c^2}}. \tag{2}$$

Consider a test body with gravitational mass m_g in a gravitational field $\boldsymbol{E}_g$. The force is

$$\boldsymbol{F} = m_g\boldsymbol{E}_g. \tag{3}$$

Substituting the velocity-dependent mass and expanding for $v \ll c$

$$\boldsymbol{F} = m_0 \sqrt{1-\frac{v^2}{c^2}} \approx m_0 \left(\boldsymbol{E}_g - \frac{1}{2} \boldsymbol{E}_g \frac{v^2}{c^2} \right), \tag{4}$$

assuming a stationary frame relative to the field source.

Using the vector identity

$$\boldsymbol{v} \times \left(\boldsymbol{E}_g \times \boldsymbol{v} \right) = \boldsymbol{E}_g v^2 - \boldsymbol{v} \left(\boldsymbol{v} \cdot \boldsymbol{E}_g \right), \tag{5}$$

and neglecting the second term for near-perpendicular motion (e.g., circular orbits), we obtain

$$\boldsymbol{F} \approx m_0 \left(\boldsymbol{E}_g - \frac{1}{2} \frac{\boldsymbol{v} \times \left(\boldsymbol{E}_g \times \boldsymbol{v} \right)}{c^2} \right), \tag{6}$$

Define the gravitomagnetic field

$$\boldsymbol{B}_g = \frac{1}{2c^2} \boldsymbol{v} \times \boldsymbol{E}_g, \tag{7}$$

satisfying

$$\nabla \cdot \boldsymbol{B}_g = 0, \tag{8}$$

and (when $\boldsymbol{v}$ is re-interpreted as the source velocity)

$$\nabla \times \boldsymbol{B}_g = -\frac{2\pi\kappa}{c^2} \rho_g \boldsymbol{v}, \tag{9}$$

where ρ_g is the mass density and κ is the gravitational constant from Gauss' law

$$\nabla \cdot \boldsymbol{E}_g = -4\pi\kappa\rho_g. \tag{10}$$

The force then takes the Lorentz-like form

$$\boldsymbol{F} = m_0 \left(\boldsymbol{E}_g + \boldsymbol{v} \times \boldsymbol{B}_g \right). \tag{11}$$

This holds for small velocities and perpendicular motion, mimicking gravitomagnetism but originating purely from mass-velocity dependence.

The model is constructed under the following starting assumptions and scope: it applies in the weak-field, low-velocity regime with motion that is near-perpendicular to the gravitational field lines, and it incorporates the nonstandard postulate of a velocity-dependent gravitational mass. These restrictions define the domain in which the subsequent field-theoretic construction is intended to operate.

3. Implied Potential Field

It is clear that E_g and B_g take exactly the same form as the electric and magnetic fields E_e and B_e. Carrying on this analogy we introduce a gravitational 4-potential B^μ with components.

$$B^\mu = \left(\phi, \boldsymbol{A}_g \right), \tag{12}$$

where $\boldsymbol{A}_g$ is the gravitomagnetic vector potential (distinct from the field $\boldsymbol{B}_g$).

The gravitational fields are recovered in the usual manner:

$$E_g = -\nabla\phi - \frac{1}{c}\partial_t \boldsymbol{A}_g, \quad B_g = \nabla \times \boldsymbol{A}_g. \tag{13}$$

We can define the gravitational field-strength tensor

$$G_{\mu\nu} = \partial_\mu B_\nu - \partial_\nu B_\mu. \tag{14}$$

where $B^\mu = \left(\phi, \boldsymbol{A}_g\right)$. Working out the components yields

$$G_{\mu\nu} = \begin{pmatrix} 0 & -E_x & -E_y & -E_z \\ E_x & 0 & -B_z & B_y \\ E_y & B_z & 0 & -B_x \\ E_z & -B_y & B_x & 0 \end{pmatrix}. \tag{15}$$

Remarks

Our derivation in Section 2 produced an immediate and striking parallel with the structure of electromagnetism. However, a crucial distinction must be emphasized: unlike electromagnetism, where the field strength arises as an intrinsic property of the gauge field itself, the gravitational tensor presented here originates entirely from an induced velocity-dependent correction to the force law. Consequently, the gravitational four-potential B^μ is not a fundamental ontological entity but is instead "implied" by the kinematics of relativistic mass. The entire construction is therefore an epistemological phenomenon, a useful mathematical artifact that faithfully reproduces observed dynamics without positing an independent gravitomagnetic ontology. This epistemological status remains central as we proceed to derive the gravitomagnetic Maxwell equations and quantize the theory.

The charge assignment and sign conventions are chosen such that the gravitational charges $q_g \sim m\sqrt{4\pi\kappa}$ are positive for all ordinary matter. Combined with the overall minus sign placed on the gravitational interaction term in the Lagrangian, this guarantees universal attraction between positive masses. Because the underlying structure is a spin-1 gauge theory, the sign conventions are essential for compatibility with the observed equivalence principle and the attractive character of gravity.

4. Gravitomagnetic Versions of Maxwell's Equations

The structural similarity of the gravitational fields to their electromagnetic counterparts motivates an analogous definition of the field-strength tensor $G^{\mu\nu}$ and the derivation of the corresponding Maxwell-like equations.

4.1. The Homogeneous Maxwell Equations from the Bianchi Identity

We begin with the Bianchi identity

$$\partial_\rho G_{\mu\nu} + \partial_\mu G_{\nu\rho} + \partial_\nu G_{\rho\mu} = 0. \tag{16}$$

Iterative application across indices immediately yields the homogeneous pair

$$\nabla \cdot \boldsymbol{B}_g = 0, \quad \nabla \times \boldsymbol{E}_g = -\partial_t \boldsymbol{B}_g . \tag{17}$$

4.2. The Inhomogeneous Maxwell Equations from the Action Principle

The Lagrangian for the gravitational sector is

$$L = -\frac{1}{4} G_{\mu\nu} G^{\mu\nu} - J^{\mu} B_{\mu}, J^{\mu} = (\rho, \boldsymbol{J}). \tag{18}$$

Varying with respect to B^{ν} gives

$$\partial_{\mu} G^{\mu\nu} = J^{\nu}, \tag{19}$$

which expands to the inhomogeneous pair

$$\nabla \cdot \boldsymbol{E}_g = \rho, \quad \nabla \times \boldsymbol{B}_g = \boldsymbol{J} + \partial_t \boldsymbol{E}_g . \tag{20}$$

Note that our units are chosen such that gravitational constants are absorbed and the sign of $\boldsymbol{E}_g$, which matches the Lorentz-like force of Section 2.

An equivalent compact route uses the dual tensor $G^{\mu\nu}$ (obtained by swapping $E_i \to B_i$, $B_i \to -E_i$) and the equation $\partial_{\mu} G^{\mu\nu} = 0$.

5. Uncoupled Quantum Fields

Using the framework developed above, we construct an uncoupled $U(1) \times U(1)$ quantum field theory in which the electromagnetic and gravitomagnetic sectors couple to the same matter field but remain independent of each other. Electromagnetism uses potential A_{μ} with charge q_e and gravity uses B_{μ} with charge $q_g = gm_0$, where $g \sim \sqrt{\kappa}$. Here g is the dimensionless gravitational gauge coupling, and the square-root factor ensures that the tree-level potential reproduces Newton's law once the attractive sign is inserted

The Lagrangian is

$$L = \psi (i\not{D} - m) \psi - \frac{1}{4} F_{\mu\nu} F^{\mu\nu} - \frac{1}{4} G_{\mu\nu} G^{\mu\nu}, \tag{21}$$

with

$$D_{\mu} = \partial_{\mu} - ieA_{\mu} + igB_{\mu} . \tag{22}$$

In the gravitational sector the overall minus sign is imposed by hand on the interaction term $-q_g J_g^{\mu} B_{\mu}$ (and correspondingly on the tree-level potential) to produce attraction between like gravitational charges, as required phenomenologically for positive masses. This choice overrides the generic repulsive sign expected for massless spin-1 gauge-boson exchange between identical charges in a $U(1)$ theory.

In the Feynman gauge the propagators are identical:

$$D^{A}_{\mu\nu}(k) = D^{B}_{\mu\nu}(k) = -\frac{ig_{\mu\nu}}{k^2 + i\epsilon} . \tag{23}$$

In this $U(1)$ formulation the gravitational gauge field B^{μ} is quantized as a massless vector boson. Consequently, its quantum, the graviton, carries spin 1 (helicity ±1), exactly as the photon does in electromagnetism.

The tree-level amplitudes and their non-relativistic limits yield the position-space potentials:

$$V_e(r)=\frac{q_{e1}q_{e2}}{4\pi r},\quad V_g(r)=-\frac{q_{g1}q_{g2}}{4\pi r}. \tag{24}$$

Thereby recovering Coulomb's law and Newton's law, respectively.

6. Coupled Quantum Fields

Building on the uncoupled framework, we introduce both kinetic mixing $\frac{\beta}{4}F_{\mu\nu}G^{\mu\nu}$ and charge mixing $q_g=q_g^0+\alpha q_e E$, where E is the local electric-field strength. The complete Lagrangian is

$$\begin{aligned}L_{\text{total}}&=-\frac{1}{4}F_{\mu\nu}F^{\mu\nu}-\frac{1}{4}G_{\mu\nu}G^{\mu\nu}-\frac{\beta}{4}F_{\mu\nu}G^{\mu\nu}\\&+L_{\text{matter}}-q_eJ_e^{\mu}A_{\mu}-\left(q_g^0+\alpha q_eE\right)J_g^{\mu}B_{\mu}.\end{aligned} \tag{25}$$

6.1. Equations of Motion

Varying L_{total} with respect to A_ν and B_ν yields the coupled equations

$$\partial_\mu\left(F^{\mu\nu}+\frac{\beta}{2}G^{\mu\nu}\right)=q_eJ_e^{\nu} \tag{26}$$

and

$$\partial_\mu\left(G^{\mu\nu}+\frac{\beta}{2}F^{\mu\nu}\right)=\left(q_g^0+\alpha q_eE\right)J_g^{\nu} \tag{27}$$

The overall minus sign reflects gravitational attraction. Bianchi identities remain unchanged. In 3 + 1 form (Lorentz gauge) the equations mix $\vec{E},\vec{B}$ with $\vec{E}_g,\vec{B}_g$, which can be rewritten using effective medium parameters $\varepsilon_g=1/(4\pi\kappa)$, $\mu_g=4\pi\kappa/c^2$, $n=1/2$.

6.2. Propagator

Fourier-transforming the quadratic action gives the matrix

$$M=\begin{pmatrix}1 & \beta/2\\ \beta/2 & 1\end{pmatrix}. \tag{28}$$

In the Feynman gauge the propagator matrix is

$$D_{\mu\nu}(k)=-\frac{ig_{\mu\nu}}{M\left(k^2+i\epsilon\right)}. \tag{29}$$

with inverse

$$M^{-1}=\frac{1}{1-(\beta/2)^2}\begin{pmatrix}1 & -\beta/2\\ -\beta/2 & 1\end{pmatrix}. \tag{30}$$

The components are

$$\langle A^{\mu}A^{\nu}\rangle = \langle B^{\mu}B^{\nu}\rangle = -\frac{ig^{\mu\nu}}{k^2\left(1-(\beta/2)^2\right)},\quad \langle A^{\mu}B^{\nu}\rangle = \frac{i(\beta/2)g^{\mu\nu}}{k^2\left(1-(\beta/2)^2\right)}, \tag{31}$$

mediating coupled massless gauge-boson exchange. When $\beta \to 0$ the off-diagonal term vanishes and the theory reduces to the uncoupled limit of Section 5.

7. Potentials in the Classical Limit

For two particles with electric charges $q_{e1,2}$ and effective gravitational charges $q_{g1,2} = q^0_{g1,2} + \alpha q_{e1,2} E$ (where E is the common external electric-field strength), the tree-level amplitude is

$$\mathcal{M} = -\frac{(q_{e1}, q_{g1}) M^{-1} \begin{pmatrix} q_{e2} \\ q_{g2} \end{pmatrix}}{k^2} (u\gamma^{\mu}u)(u\gamma_{\mu}u). \tag{32}$$

In the non-relativistic limit, the position-space potential becomes

$$V(r) = -\frac{1}{4\pi r\left(1-\left(\frac{\beta}{2}\right)^2\right)}\left[q_{e1}q_{e2} + q_{g1}q_{g2} - \frac{\beta}{2}\left(q_{e1}q_{g2} + q_{e2}q_{g1}\right)\right]. \tag{33}$$

Substituting the charge-mixing expression immediately yields

$$V(r) = \frac{a_0 + a_1 E + a_2 E^2}{4\pi r\left(1-(\beta/2)^2\right)}, \tag{34}$$

where a_0, a_1, a_2 are explicit combinations of the bare charges, α, and β. The calibration $q^0_g \sim m\sqrt{4\pi\kappa}$ recovers the usual Coulomb and Newtonian terms in a_0, while the linear and quadratic pieces in E are pure electrogravitic predictions.

The quadratic dependence $a_2 E^2$ precisely matches the voltage-squared force law observed in the Biefeld-Brown effect for asymmetric high-voltage capacitors. Reports in the literature, including vacuum chamber tests at pressures ~10^{-6} Torr [4]-[7], confirm that this E^2 dependence persists where the absence of free ions and atmospheric gases rules out conventional fluid-dynamic or ionized-air-current explanations, though other experiments have demonstrated the contrary [8] [9].

Velocity-dependent effects can be incorporated via the relativistic factor $E \approx \gamma m_0 c^2$, thereby re-deriving the apparent gravitomagnetism discussed earlier

8. Conclusions

In this work we have constructed a complete QEG theory by treating gravity as a $U(1)$ gauge interaction fully analogous to electromagnetism. The journey began with the observation that centripetal effects in gravitational orbits, when combined with the relativistic velocity dependence of gravitational mass, naturally yield a Lorentz-like force law. Extrapolating this structure produced a gravitational field-strength tensor $G_{\mu\nu}$ that is formally identical to the electromagnetic tensor $F_{\mu\nu}$, thereby permitting the derivation of a full set of gravitomagnetic Maxwell equations and the subsequent quantization of the theory.

A central philosophical distinction runs through the entire framework: because the gravitomagnetic component arises solely from the velocity dependence of the test mass, the gravitational four-potential B^{μ} and its associated tensor are implied rather than fundamental. The construction is therefore epistemological, an extremely useful mathematical artifact that reproduces observed dynamics, rather than an ontological postulate of an independent gravitomagnetic field.

Nevertheless, the formalism is sufficiently robust to support a full quantum field theory. We presented both the uncoupled $U(1)\times U(1)$ limit and the coupled version that includes a bilinear mixing term $\frac{\beta}{4}F_{\mu\nu}G^{\mu\nu}$ together with charge-mixing operators. In the uncoupled case the tree-level propagators are identical and the position-space potentials recover Coulomb's law for electric charges q_e and Newton's law for gravitational charges $q_g \sim m\sqrt{4\pi\kappa}$. When coupling is introduced, the quadratic action becomes matrix-valued and the mixed propagator $\langle A^{\mu}B^{\nu}\rangle$ mediates genuine electrogravitational interference while preserving the long-range inverse-square behavior.

Particularly noteworthy is that the coupled theory naturally generates interaction terms quadratic in the electric-field strength E, a feature that aligns directly with laboratory observations of asymmetric high-voltage capacitors. The framework therefore offers not only conceptual unification at the gauge level but also concrete, calculable predictions that can be confronted with tabletop experiments.

Furthermore, the mixed propagator opens a novel annihilation channel:

$$e^{-}+e^{+}\rightarrow\gamma_g, \tag{35}$$

with γ_g representing the graviton. Although the branching ratio is suppressed by factors of β^2 and $\left(q_g/q_e\right)^2 \ll 1$ under ordinary conditions, in the extreme environments of quasars, with enormous pair-production rates and relativistic luminosities, cumulative energy leakage into escaping gravitons could produce observable spectral dimming or continuum suppression. This offers a distinctive, testable signature unique to the coupled theory.

This $U(1)\times U(1)$ QEG theory constitutes a radical departure from conventional approaches to gravitation, yet it remains fully calculable and renormalizable in the same sense as QED. By recasting gravity as an induced yet fully quantized gauge interaction, the present theory opens a new avenue for unifying the long-range forces within a single, experimentally testable quantum framework.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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