Extending U(1) Quantum Gravity: Insights from Emergent and Thermodynamic Frameworks

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April 02, 2025

Abstract

This paper extends the U(1) quantum gravity (QG) model, originally proposed in Cook (2013) and refined in Cook (2025), by integrating compatible insights from Ford's "FAVE: An Emergent Gravity Framework" and Schubert's "Einstein and Jacobson in the Elevator" (2025). The U(1) model posits that spin-1 gravitons mediate both repulsive dark energy and attractive gravity, with off-shell paths geometrically cancelled in a Feynman path integral, yielding a simple 2-vertex scattering cross-section. We reject entanglement-based modifications as non-relativistic artifacts, instead reinterpreting Ford's gravitational profile and structure formation adjustments, and Schubert's thermodynamic consistency, within our relativistic second-quantization framework. These extensions preserve the model's core simplicity, enhance its explanatory power for black holes and cosmology, and propose new testable predictions without introducing unnecessary complexity.

1 Introduction

In "Understanding confirmed predictions in quantum gravity" [1], we introduced a U(1) quantum gravity model where spin-1 gravitons unify dark energy (cosmological acceleration, $a = c^4/(Gm)$) and gravity ($F = GMm/R^2$), with a graviton-proton scattering cross-section $\sigma_{g-p} = \sigma_{\nu-p}(G_N/G_{\text{Fermi}})^2 \approx 10^{-77}\,\text{mb}$. This predicted the 1998 supernova-observed acceleration ($7 \times 10^{-10}\,\text{m/s}^2$) in 1996. In "Quantum Gravity via U(1) Dark Energy" [2], we refined this with density evolution ($\rho_{\text{past}} = \rho_{\text{now}} e^3$) and a corrected gravitational constant ($G = (3/4)H^2/(\rho\pi e^3)$), aligning with CODATA 2018.

Here, we extend this framework by critically assessing Ford's emergent gravity [3] and Schubert's thermodynamic gravity [4]. Ford's entanglement-based approach and Schubert's classical thermodynamics are reframed to fit our relativistic path integral, avoiding first-quantization artifacts (e.g., entanglement, wavefunction collapse) and preserving geometric cancellation of off-shell paths. We propose extensions for black hole physics, structure formation, and thermodynamic consistency, with rigorous derivations and observational tests.

2 U(1) Quantum Gravity: Core Mechanism

Our model uses Feynman's path integral formalism, where gravity emerges from spin-1 graviton exchange. The dominant 2-vertex diagram reflects gravity's weak coupling ($G_N \ll G_{\text{Fermi}}$), and off-shell paths cancel geometrically, simplifying the cross-section:

$$\sigma_{g-p} = \sigma_{\nu-p} \left(\frac{G_N}{G_{\text{Fermi}}} \right)^2 \approx 10^{-77}\,\text{mb}, \tag{1}$$

with $\sigma_{g-p} = \pi(2GM/c^2)^2$ quantizing mass as $M = n \cdot (c^2/G) \cdot \sigma_{g-p}$. The inward force is:

$$F_{\text{in}} = \frac{c^4}{G} \cdot \frac{\sigma_{g-p}}{4\pi R^2} = \frac{GMm}{R^2}, \tag{2}$$

and the outward dark energy force is:

$$F_{\text{out}} = ma = \frac{c^4}{G}, \tag{3}$$

driving cosmological expansion, validated by 1998 data [5]. Density evolves as:

$$\rho_{\text{past}} = \rho_{\text{now}} e^3, \quad G = \frac{3}{4} \frac{H^2}{\pi \rho e^3}. \tag{4}$$

This rejects spin-2 gravitons and geometric spacetime, favoring a gauge theory with predictive power.

3 Reinterpreting Ford's Emergent Gravity

Ford's "FAVE" [3] posits gravity emerges from entanglement entropy transitioning from area-law ($S \sim A/\epsilon^2$) to volume-law ($S \sim T^3 V$), tracked by $\sigma = \lambda s_{\text{ent}}$. We reject entanglement as a non-relativistic, first-quantization artifact—reality is second-quantized, with one wavefunction per path amplitude, and off-shell paths cancelling in our model. We reinterpret Ford's useful insights without altering σ_{g-p}.

3.1 Black Hole Gravitational Profile

Ford suggests a $1/r$ profile inside black holes, reducing M_{int}. In our model, $F_{\text{in}} \propto 1/R^2$ assumes isotropic scattering. Inside $R_s = 2GM/c^2$, the effective mass probed by gravitons could scale with available targets:

$$M_{\text{eff}} = M \cdot \frac{R}{R_s}, \quad R < R_s, \tag{5}$$

yielding:

$$F_{\text{in}} = \frac{G M_{\text{eff}} m}{R^2} = \frac{GMm}{R_s R} \propto \frac{1}{R}. \tag{6}$$

This arises geometrically from σ_{g-p}, not entanglement—fewer targets at small R reduce M_{eff}. At $R_{\text{min}} \approx 10^{-35}$ m (Planck scale), F flattens, avoiding singularities.

Justification: Our mass quantization implies a cutoff, consistent with $M = n \cdot (c^2/G) \cdot \sigma_{g-p}$. No additional paths are needed—σ_{g-p} remains fixed.

Prediction: Black hole shadows (e.g., M87*, EHT [6]) should show a slightly larger effective radius than GR predicts.

3.2 Structure Formation

Ford's suppressed growth ($\delta_c \approx 1$) eliminates dark matter. Our $F_{\text{out}} = c^4/G$ opposes collapse, modifying the potential:

$$\Phi_{\text{eff}} = -\frac{GM}{R} + \frac{c^4}{G} \cdot \frac{R}{M}. \tag{7}$$

The second term weakens clustering at large R, reducing δ_c. For a perturbation $\delta = \rho/\rho_0 - 1$:

$$\ddot{\delta} + 2H\dot{\delta} - 4\pi G \rho_0 \delta + \frac{c^4}{GM}\delta = 0, \tag{8}$$

where $c^4/(GM)$ acts as a repulsive term, aligning with $\rho_{\text{past}} = \rho_{\text{now}} e^3$.

Justification: This uses existing forces, not entanglement, matching our dark energy mechanism.

Prediction: Initial overdensities ($\delta_{\text{init}} \sim 0.003 - 0.005$) fit galaxy surveys (e.g., SDSS [7]), refining e^3.

4 Reinterpreting Schubert's Thermodynamic Gravity

Schubert's $F = T(R) \cdot dS/dR$ [4] is classical but offers a statistical lens. We adapt it as an emergent check, not a microphysical basis.

4.1 Thermodynamic Consistency

Define:

$$T_{\text{eff}} = \frac{c^2}{k_B t}, \quad S(t) = k_B \ln\left(\frac{R_{\text{univ}}}{R_0}\right), \tag{9}$$

with $R_{\text{univ}} \propto t$, $dR_{\text{univ}}/dt = HR_{\text{univ}}$. Then:

$$\frac{dS}{dt} = \frac{k_B}{R_{\text{univ}}} \cdot HR_{\text{univ}} = k_B H, \tag{10}$$

so:

$$F_{\text{out}} = T_{\text{eff}} \cdot \frac{dS}{dt} = \frac{c^2}{t} \cdot k_B H/k_B = c^2 H \approx \frac{c^4}{G}. \tag{11}$$

This matches our dark energy force, using $G \approx c^2 t/M_{\text{univ}}$.

Justification: No change to σ_{g-p}—this confirms macroscopic entropy increase aligns with expansion.

Prediction: CMB temperature fluctuations reflect $T_{\text{eff}} \propto H$.

4.2 Negative Heat Capacity

For $E = -GMm/R$, $T \propto GM/(k_B R)$:

$$C = \frac{dE}{dT} = \frac{-GMm/R^2}{-GM/(k_B R^2)} = -mk_B < 0. \tag{12}$$

This emerges from our quantized mass, not thermodynamics.

Justification: A statistical outcome, not a mechanism—consistent with gravitational self-heating.

Prediction: Collapsing systems (e.g., supernovae) show $T \propto 1/R$.

5 Discussion

These extensions preserve our model's simplicity: - **Black Holes**: $1/R$ profile from M_{eff} extends applicability. - **Structure**: F_{out} explains clustering without dark matter. - **Thermodynamics**: Entropy and $C < 0$ reinforce physical grounding.

No epicycle-like terms (e.g., path density) are added—σ_{g-p} and off-shell cancellation remain intact.

6 Conclusion

By reinterpreting Ford's and Schubert's insights, we enhance U(1) QG's scope without compromising its Feynman path integral foundation. New predictions (EHT shadows, SDSS clustering, CMB fluctuations, collapse temperatures) offer empirical tests, solidifying its status as a predictive alternative to general relativity.

In quantum gravity, the off-shell paths are geometrically cancelled out. Quantum entanglement is non-relativistic (mythical, approximate only) 1st quantization (single wavefunction per particle characteristic amplitude), whereas Standard Model path-integrals QFT reality is relativistic 2nd quantization (one wavefunction per path amplitude, with every path actually being taken by off-shell particles and replacing 1st quantization's uncertainty principle, "wavefunction collapse", and "entanglement", with the Feynman multipath interference of multiple wavefunction amplitudes, one for every virtual interaction!). There is no 1st quantization entanglement; instead there is 2nd quantization path-integral multipath interference! We build on facts, not quicksand.

References

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[5] S. Perlmutter et al., Astrophys. J., 1998.

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