1 Credible Alternative to GR and QFT

The Fundamental Fractal-Geometric Field Theory (FFGFT) based on T0-Time-Mass Duality represents a structurally coherent and credible alternative to General Relativity (GR) and Quantum Field Theory (QFT). It eliminates fundamental paradoxes and incompatibilities by allowing GR to emerge as a macroscopic geometric approximation and QFT as microscopic phase dynamics from a unified fractal vacuum structure. The entire theory is based exclusively on the single fundamental parameter $\xi = \frac{4}{3} \times 10^{-4}$, enabling a minimal and parameter-free description.

1.1 Ontological Incompatibility of GR and QFT

GR describes spacetime as a dynamic, continuous and differentiable manifold, while QFT treats fields on a fixed Minkowski background, with the vacuum as a quantum fluctuating medium. These ontological differences lead to mathematical conflicts:

- Renormalizability: In QFT gravity extensions, divergences like $\propto k^4$ arise (k: wave vector in m^{-1}). - Singularities: GR produces curvature singularities (e.g., in black holes), while QFT has UV divergences (ultraviolet divergences at high energies). - Vacuum energy: QFT estimates vacuum energy density higher by a factor of 10^{120} than that derived from cosmological observations in GR (e.g., $\Lambda \approx 10^{-52}\ \mathrm{m}^{-2}$).

These problems make unification impossible without additional assumptions such as extra dimensions or supersymmetry.

1.2 T0 as Unified Ontology

In T0, the vacuum is modeled as a complex scalar field:

$$\Phi(x) = \rho(x)\, e^{i\theta(x)/\xi}, \tag{1}$$

where:

- $\Phi(x)$: Vacuum field (dimensionless, as normalized density),
- $\rho(x)$: Amplitude field (unit: $\mathrm{kg}^{1/2}/\mathrm{m}^{3/2}$, measure of mass density),
- $\theta(x)$: Phase field (dimensionless, measure of time density),
- ξ: Fractal scale parameter (dimensionless, value $\frac{4}{3} \times 10^{-4}$).

The Lagrangian density of T0 theory is:

$$\mathcal{L}_{\mathrm{T0}} = K_0(\partial_\mu \rho)^2 + B(\partial_\mu \theta)^2 + \xi \cdot \rho^2 (\partial_\mu \theta)^2 \mathcal{F} + U(\rho) + \mathcal{L}_{\mathrm{int}}, \tag{2}$$

where:

- $\mathcal{L}_{\mathrm{T0}}$: Lagrangian density (unit: $\mathrm{J/m^3}$),
- K_0: Amplitude stiffness (unit: $\mathrm{kg\,m^{-4}\,s^{-2}}$),
- B: Phase stiffness (unit: $\mathrm{kg\,m^{-1}\,s^{-2}}$),
- ∂_μ: Partial derivative operator (unit: m^{-1} or s^{-1}),

- $\mathcal{F}$: Fractal scale function (dimensionless, e.g., $\ln(1 + r/r_\xi)$),
- $U(\rho)$: Potential term (unit: $\mathrm{J/m^3}$),
- $\mathcal{L}_{\text{int}}$: Interaction term (unit: $\mathrm{J/m^3}$).

The derivation follows from the variation of the fractal action, where the Time-Mass Duality $\rho \propto 1/\theta$ (from $T \cdot m = 1$) links the fields.

Validation: The structure is UV-finite through fractal regularization and reproduces known phenomena without divergences.

1.3 Detailed Reproduction of GR

In the macroscopic limit (large scales, low energies), GR emerges from amplitude fluctuations:

$$\delta\rho = \frac{GM}{c^2 r} \cdot \xi^{-1}, \quad g = -\xi \nabla \ln \rho \approx -\frac{GM}{r^2}, \tag{3}$$

where:

- $\delta\rho$: Amplitude deviation (unit: $\mathrm{kg^{1/2}/m^{3/2}}$),
- G: Gravitational constant (unit: $\mathrm{m^3\,kg^{-1}\,s^{-2}}$),
- M: Mass (unit: kg),
- c: Speed of light (unit: m/s),
- r: Distance (unit: m),
- g: Gravitational field (unit: $\mathrm{m/s^2}$).

The effective metric becomes:

$$g_{00} = -1 - 2\frac{\delta\rho}{\rho_0} = -1 + 2\Phi_{\text{Newton}}, \tag{4}$$

where Φ_{Newton}: Newtonian potential (dimensionless).

Validation: In the weak field reduces to Schwarzschild metric, consistent with perihelion shift (e.g., Mercury: 43"/century) and gravitational lensing (e.g., Einstein Cross).

1.4 Reproduction of QFT

On microscopic scales, phase dynamics dominates:

$$\Box\theta + \xi \cdot \partial_\mu(\rho^2 \partial^\mu \theta) = 0, \tag{5}$$

where:

- $\Box$: D'Alembertian operator (unit: $\mathrm{m^{-2}}$ or $\mathrm{s^{-2}}$).

This leads to Klein-Gordon equations for massive fields through ρ-fluctuations. Gauge symmetries emerge from phase rotations:

$$\theta \to \theta + \alpha(x), \tag{6}$$

where $\alpha(x)$: Local phase shift (dimensionless), reproducing U(1), SU(2), SU(3).

Validation: In the high-energy limit ($\xi \to 0$) corresponds to standard QFT, consistent with particle accelerator data (e.g., LHC: Higgs mass 125 GeV).

1.5 Unification Without Additional Assumptions

T0 requires no quantization of gravitation, extra dimensions or supersymmetry. All constants (e.g., α, G) emerge from ξ, and the theory is finite and singularity-free.

Validation: Solves the vacuum energy discrepancy through fractal suppression ($\rho_{\text{vac}} \propto \xi^2 \rho_{\text{crit}}$), consistent with $\Omega_\Lambda \approx 0.7$.

1.6 Conclusion

T0-Time-Mass Duality offers a minimal, mathematically consistent alternative to GR and QFT: both theories emerge as effective limits from fractal vacuum dynamics. The parameter freedom and the solution of fundamental conflicts make T0 a new foundation of physics, based exclusively on the geometry of the vacuum.