Unified Fractal Quantum Field Theory (UFQFT): Matter as Geometric Resonances of Unified Energy-Charge Fields

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Abstract

This study introduces a novel theoretical framework in which all fundamental structures of matter and interaction emerge from the self-organized, fractal resonances of two foundational quantum fields: a scalar energy field (Φ) and a vectorial charge field (Ψ). Unlike traditional particle physics models, this approach does not treat quarks, leptons, or gauge bosons as physical entities but as resonance nodes—zero-volume, massless quantized configurations of energy and charge—localized within a scale-dependent fractal space-time geometry (D ≈ 2.7). These quantized field singularities form through the nonlinear intersections of Φ and Ψ fields, with no need for mediators such as gluons or a Higgs boson.The four known fundamental forces are unified under this framework as distinct manifestations of energy-charge field topology: the strong interaction arises from the fractal confinement of energy resonances (Φ); electromagnetism from the propagating wave modes of charge fields (Ψ); the weak interaction as topological phase transitions between coupled field domains; and gravity as a nonlocal curvature effect due to fractal field preservation. The model predicts a generalized gravitational potential of the form $V(r) \sim 1/r^{(D-1)}$, offering testable deviations from Newtonian gravity at microscopic scales. It also provides reinterpretations of dark matter as high-order, non-radiating Φ-field structures, and of proton spin as a result of internal fractal resonance dynamics. Leptons are not elementary, but arise as secondary energy-charge standing waves coupled to quark-like field nodes, while neutrinos appear as phase-neutral oscillatory modes with minimal interaction cross-sections. The theory addresses long-standing challenges in fundamental physics—such as the hierarchy problem, the origin of mass, and quantum gravity—by reducing all physical observables to the geometry and topology of unified fractal fields. Experimental implications include modified beta decay spectra, LHC resonance deviations, and precision gravitational measurements below millimeter scales.

Keywords:Unified Field Theory, Quantum Field Resonance, Energy-Charge Fields, Fractal Dimensionality, Emergent Particles, Modified Gravity, Quantum Gravity, Dark Matter Alternatives, Proton Spin Anomaly, Fundamental Forces Unification

Introduction

Over the past century, the quest to unify the four fundamental forces of nature—the electromagnetic, weak, strong, and gravitational interactions—has remained a central agenda in theoretical physics. This quest has witnessed numerous milestones, each of which has provided a deeper understanding of the fundamental structure of the universe. The unification of the electromagnetic and weak forces was provided by the electroweak theory developed by Glashow (1961), Salam (1968), and Weinberg (1967). This framework predicted the existence of the $W^{\pm}$ and Z^{0} bosons, which were experimentally confirmed by the UA1 and UA2 experiments at CERN in 1983 (Arnison et al., 1983; Banner et al., 1983). The theoretical consistency of the electroweak model was strengthened by the renormalization work of 't Hooft and Veltman (1972), which demonstrated the mathematical soundness of the theory. Building on this success, the SU(5) Grand Unified Theory (GUT), proposed by Georgi and Glashow (1974), unifies quarks and leptons into a single gauge group and predicts proton decay ($p \rightarrow e^{+}\pi^{0}$). However, experimental data from the Super-Kamiokande detector based on 22 years of observations placed a lower bound on the proton lifetime of $\tau_p > 1.6\times10^{34}$ years (Regis et al., 2012), effectively challenging the minimal SU(5) models. Extensions such as SO(10) (Fritzsch & Minkowski, 1975) and E_6 (Hewett & Rizzo, 1989) provided viable alternatives that also accommodate neutrino oscillations. The resolution of anomalies in Type I string theory by Green and Schwarz (1984) initiated the first superstring revolution. The five consistent string theories—Type I, Type IIA, Type IIB, and heterotic strings with gauge groups SO(32) and $E_8\times E_8$—were later unified by Witten (1995) under M-theory, a framework that postulated an eleven-dimensional structure. This formulation gained further importance with the AdS/CFT correspondence proposed by Maldacena (1998), which offered a new approach to quantum gravity. At the same time, Ashtekar's introduction of new variables (1986) laid the foundation for Loop Quantum Gravity (LQG), which models spacetime as a discrete spin network. Rovelli and Smolin (1995) took this theory even further by interpreting the solutions of the field equations as spin foam histories. Observations such as LIGO's GW170817 event (Abbott et al., 2017) have opened new avenues to test LQG predictions through gravitational wave velocity measurements. Teleparallel gravity, which describes gravity using torsion instead of curvature (Aldrovandi and Pereira, 2012), offers geometrically motivated solutions to the dark energy problem.

In the midst of these developments, this work proposes the Unified Fractal Quantum Field Theory (UFQFT), which offers a new perspective by describing all elementary particles and their interactions as manifestations of two interconnected fields within a fractal space-time geometry. This model aims to provide a comprehensive framework encompassing the dynamics of the four fundamental forces through energy-charge field interactions. This Theory (UFQFT) proposes a fundamental shift in the understanding of matter and forces. It redefines particles not as objects but as the resulting resonant excitations of two unified discrete quantum fields: a scalar energy field (Φ) and a vector charge field (Ψ). It is suggested that all known particles and interactions arise from geometric and fractal configurations of these fields.

1. Quantum Energy-Charge Field

In this theory (UFQFT), quantum fields are not described as static backgrounds, but as dynamic, self-organizing environments that give rise to all observable particles and interactions through geometric resonance phenomena. The theory assumes two fundamental and interconnected fields: a scalar energy field Φ, which governs the energy density and oscillates at characteristic frequencies ν; and a vector charge field Ψ, which carries electric and weak-type charges, forming structured flux configurations. Both fields are thought to be embedded in a fractal space-time geometry, where the Hausdorff dimension $D\approx2.7$ determines the spatial complexity of baryonic matter configurations.

Particles are described not as discrete point-like entities but as stable resonance patterns—standing wave solutions—within these fields. Energy quantization arises from discrete oscillation modes of the Φ field, expressed as:

$$E_n = h\nu_n \tag{1}$$

where $\boldsymbol{E_{\mathrm{n}}}$ is the energy of the $\boldsymbol{n}^{\mathrm{th}}$ mode, h is Planck's constant, and $\boldsymbol{\nu_{\mathrm{n}}}$ is the field's oscillation frequency. Simultaneously, electric (or weak) charge emerges from flux quantization of the Ψ-field across a fractal boundary, described by:

$$Q_n = \oint_{dV_D} \Psi_n \partial S_D \cdot \tag{2}$$

Here, Q_n is the quantized charge of the $\boldsymbol{n}^{\mathrm{th}}$ configuration, dV_D is the fractal boundary surface of the resonance region, and ∂S_D is the adapted surface element for non-integer dimension D. The notation emphasizes that charge quantization depends not on global symmetry but on local field topology.

The spatial structure of particles arises from solutions to a generalized Helmholtz equation adapted to fractal geometry:

$$\nabla_{\mathrm{D}}^2 \Phi + \frac{\mathrm{v}^2}{\mathrm{c}^2} \Phi = 0 \tag{3}$$

where ∇_{D}^2 is the fractal Laplacian operator, c is the speed of light, and the term $\frac{\mathrm{v}^2}{\mathrm{c}^2}$ reflects the wave nature of energy propagation in curved and fractal space. Stabilization of resonances is governed by a nonlinear interaction potential:

$$V(\Phi, \Psi) = \lambda_\Phi \Phi^4 + \lambda_\Psi \Psi^4 + g\Phi^2 (\nabla \times \Psi)^2 \tag{4}$$

In this expression, λ_Φ and λ_Ψ are self-interaction coefficients for the energy and charge fields, respectively, while g is the coupling strength between them. The term $(\nabla \times \Psi)^2$ represents topological torsion or internal rotational dynamics of the charge field, which is essential in distinguishing between particle families.

Within this resonance framework, quarks correspond to high-frequency modes of the Φ-field confined by fractional charge flux in Ψ, whereas leptons emerge from lower-frequency modes with integer charge flux. Photons are identified as coherent wave packets of the Ψ-field in the low-dimensional limit D→2 , where wave propagation becomes linear and dispersionless.

This model replaces the need for gauge bosons or symmetry-breaking scalar fields by showing that interactions arise naturally from resonance couplings between Φ and Ψ encoded in the geometry of space-time itself.

2.Unified Fractal Quantum Field Theory

This theoretical model proposes a profound redesign of fundamental physics by treating all known particles and forces as emergent resonances of two fundamental fields, Φ (scalar energy field) and Ψ (vector charge field), embedded in a scale-dependent fractal space-time geometry. Unlike the Standard Model, which is based on discrete particles such as quarks, gluons, and Higgs bosons, Unified Fractal Quantum Field Theory (UFQFT) does not envision particles as point-like entities but as topological singularities, and describes them as stable, zero-volume quantized resonances generated by the geometric interaction of Φ and Ψ.

In this framework, mass is not a fundamental property, but instead emerges dynamically from the oscillation frequency of the Φ field and scales with the local density of the Ψ field. This leads to a modified mass-frequency relationship:

$$m = \frac{h\nu}{c^2} \left(1 + \frac{\lambda_s}{2\pi} \int \Psi^2 \, dV\right) \tag{5}$$

where m is the emergent mass of a field resonance, ν is the energy field's oscillation frequency, λs is a local symmetry correction factor, and the integral of $\boldsymbol{\Psi}^2$ accounts for the modulation of energy density by localized charge topology.

Gravity is not a fundamental interaction but a macroscopic geometric consequence of coherent energy-charge field distributions. Instead of originating from mass, spacetime curvature arises from the combined energy density of the fields:

$$g_{\mu\nu} = \eta_{\mu\nu} + \kappa \int (\Phi^2 + \Psi^2) d^3x \quad (6)$$

Here, $g_{\mu\nu}$ is the curved spacetime metric, $\eta_{\mu\nu}$ is the flat Minkowski background, and κ is the field-geometry coupling constant. This redefinition implies that the structure of spacetime is shaped by resonance coherence across fields, not by localized matter-energy.

One of the model's most distinctive predictions is a modified gravitational potential that emerges from the fractal nature of spacetime:

$$V(r) = -\frac{\lambda}{r^{(D-1)}} \quad (D \approx 2.7) \quad (7)$$

where V(r) is the gravitational potential at distance r, λ is the field interaction constant, and D is the effective fractal dimension. This correction leads to a slower fall-off in gravitational strength at large distances, naturally accounting for galactic rotation curves without invoking dark matter.

The unification of forces is achieved not by introducing new gauge bosons, but by showing how the dynamics of Φ and Ψ can manifest the behaviors we associate with each interaction:

- Strong interaction Emerges from fractal confinement of Φ-resonances, binding energy-field nodes without requiring gluons.
- Electromagnetism is produced by wave propagation of Ψ-fields, with the photon viewed as a localized excitation.
- Weak interaction appears during Φ–Ψ phase transitions, such as in beta decay where a d-type resonance (Φ_{d}) decays into a u-type (Φ_{u}), an electron field (Ψ_{e}), and an antineutrino field ($\Psi_{\bar{\nu}}$).
- Gravity, as noted, results from nonlocal coherence in the combined energy-charge field densities across large scales.Gravity is a geometric effect that does not arise directly from matter, but rather from the long-range fractal integrity of energy-charge fields.

The complete dynamics are captured in a unified Lagrangian with potential term:

$$L = \frac{1}{2}(\partial_\mu \Phi)^2 + \frac{1}{2}(\partial_\mu \Psi)^2 - V(\Phi, \Psi) \quad (8)$$

$$V(\Phi, \Psi) = \lambda_\Phi \Phi^4 + \lambda_\Psi \Psi^4 + g\Phi^2\Psi^2 + \kappa(\nabla\Phi \cdot \nabla\Psi)^2 \quad (9)$$

Here, λ_Φ and λ_Ψ are self-coupling constants, g is the energy-charge field coupling strength, and κ governs the coherence between energy and charge field gradients. The resulting Euler-Lagrange equations:

$$\Box\Phi + \frac{\partial V}{\partial \Phi} = J_\Phi, \quad \Box\Psi + \frac{\partial V}{\partial \Psi} = J_\Psi \quad (10)$$

Where, □ is d'Alembert operator, J_Φ, J_Ψ is field source terms. These expressions govern how energy and charge propagate, interact, and form structured resonant configurations that correspond to observable particles and interactions.

Critically, this model makes several testable predictions:

-Sub-millimeter deviations from Newtonian gravity due to the fractal correction in the gravitational potential.

-Absence of fundamental gauge bosons (e.g., gluons, Higgs); their roles are replaced by nonlinear field resonances.

-Modified particle resonance patterns in high-energy collider data (e.g., LHC anomalies).

-Galactic rotation explained without dark matter, via the altered large-scale gravitational profile.

By reinterpreting particles as geometric field patterns and forces as field symmetries or transitions, UFQFT provides a unified, geometric, and quantized approach to nature. It also offers a conceptual path toward quantum gravity, bridging the gap between relativistic geometry and quantum field behavior through the intrinsic fractality of spacetime itself.

3. Particle Resonance Model

In thisTheory (UFQFT), elementary particles are described not as point-like objects but as stable resonance configurations of two interacting fields—energy field (Φ) and charge field (Ψ)—within a fractal spacetime background. Mass, charge, and interaction types emerge from the topological and oscillatory behavior of these fields.

a) Quarks (Primary Field Clusters)

Quarks are fundamental Φ-field resonances characterized by their localized energy density and specific oscillation frequencies. Each quark type (e.g., *u*, *d*) corresponds to a unique frequency-mode solution of the Φ-field:

$$\Phi_u(\vec{r}, t) = \Phi_0 e^{-m_u r} cos(2\pi\nu_u t) \tag{11}$$

Where, Φ_0 Field amplitude constant, m_u is mass of the u-quark, ν_u Resonance frequency determined via the modified mass-frequency relation. r=|$\vec{r}$| is Radial distance. This expression describes a damped harmonic field—localized in space and oscillatory in time—associated with the emergence of a quark. Primary Field Clusters are given at Table 1.

Table 1. Quarks Primary Field Clusters

Quark	Energy (MeV)	Charge (e)	Resonance Frequency (Hz)
u	2.3	+2/3	5.6×10^{22}
d	4.8	−1/3	1.2×10^{23}

These primary field modes are the building blocks of hadronic matter and interact through confinement governed by nonlinear field self-interactions in the unified Lagrangian.

b) Leptons (Secondary Resonances)

Leptons are emergent excitations that arise from interactions and transitions between quark field configurations. Unlike quarks, they do not originate from primary Φ-modes but instead appear as derivative structures of Φ–Ψ field couplings.

Electron (e^-)

The electron is modeled as a charge-conserving resonance that arises during a transition from an up-quark (u) to a down-quark (d), preserving the field's net charge through cross-gradient interactions of Ψ-fields:

$$e^{-} \sim \int_{V} \nabla\Psi_{u} \times \nabla\Psi_{d} d^{3}x \quad (12)$$

This integral describes a topological vortex formed from the rotational coherence between charge field gradients of the u and d quarks. The result is a localized field structure carrying $1e^{-}$ charge, matching the electron's known properties.

Neutrino (ν)

Neutrinos are described as pure phase resonances, possessing minimal energy density but significant topological and phase structure. They emerge from the imaginary component of the overlap between the Φ-field modes of u and d quarks:

$$\nu \sim \mathrm{Im}(\Phi_{u} \Phi_{d}^{*}) \quad (13)$$

This configuration naturally explains neutrinos' near-zero mass, weak interaction behavior, and oscillatory phase characteristics without invoking explicit mass terms or Higgs couplings.

In the UFQFT framework, quarks are modeled as localized, exponentially damped oscillations of the scalar Φ-field, while electrons arise from curl-type interactions in the vector Ψ-field during charge transitions. Neutrinos emerge as pure phase resonances resulting from complex interference between Φ and Ψ fields. These particle constructions naturally align with mass-frequency relationships, conservation laws, and quantized charges, all emerging from the fundamental dynamics of energy and charge fields embedded in a fractal spacetime geometry.

4. Unified Mechanism of Fundamental Forces

In the Unified Quantum Energy-Charge Field Theory (UFQFT), all four fundamental forces—strong, weak, electromagnetic, and gravitational—emerge from the interactions and geometric resonances of two primary quantum fields: the scalar energy field (Φ) and the vector charge field (Ψ). These fields obey fractal geometrical distributions with a dimensionality of approximately D ≈ 2.7, leading to emergent interactions without requiring additional mediating particles such as gluons, W/Z bosons, or even the Higgs boson.

a) Strong Force:
The strong nuclear force is reinterpreted as the result of stable fractal resonances between up (Φ_u) and down (Φ_d) quark fields, confined within a sub-femtometer scale. The effective interaction can be modeled by a resonance gradient force:

$$F_{strong} = -\nabla(\Phi_u \Phi_d), \text{ valid for } r < 1 \text{ fm.} \quad (14)$$

Where, F_{strong} is strong force vector field (units: MeV/fm), Φu,Φd is energy fields of up/down quarks (units: MeV), ∇ is spatial gradient operatör, r is inter-quark distance. The phenomenon of color confinement arises naturally through the exponential fractal damping of the Φ field:

$$\Phi(r) \sim e^{-\left(\frac{r}{r^{0}}\right)^{2.7}} \quad (15)$$

This (Eq.15) eliminates the need for gluon exchange. The energy density of these coupled field resonances ensures the cohesion of nucleons (protons and neutrons) through geometry-driven short-range attraction.

b) Weak Force:
The weak force manifests as the decay of unstable fractal quark resonances into lepton modes, driven by a symmetry-breaking phase transition in the energy-charge field configuration. This is mathematically captured by the Lagrangian:

$$L_{weak} = g_W \Phi^2 \partial_\mu \Psi \partial^\mu \Psi \tag{16}$$

where g_W is weak coupling constant (dimensionless), $\partial_\mu \Psi$ is spacetime derivative of charge field, Φ^2 is energy field density (mediates symmetry breaking),

Key process is Φd→Φu+Ψe^-+Ψν¯ (beta decay), this a representative decay which demonstrates how the weak interaction corresponds to a transformation of one resonant structure into lower energy resonant subfields (e.g., electron and antineutrino), preserving total energy and charge via harmonic coupling conditions, not mass. This mechanism underlies processes like beta decay without invoking W or Z bosons as independent entities.

c) Electromagnetism:
Electromagnetic interactions are described as emergent wave resonances in the Ψ field, whose oscillations produce photons as fragtal symmetry-preserving, propagating vector modes. Maxwell's equations naturally arise as effective field equations:

$$\Box \boldsymbol{\Psi} = \boldsymbol{J}_{\mathbf{em}} \tag{17}$$

where $\boldsymbol{J}_{\mathbf{em}}$ denotes the effective charge-current source. Photons are treated as longitudinal-transverse coupling modes of the Ψ field, carrying quantized energy and spin but arising purely from field geometry.

d) Gravity:
Gravitational attraction originates from the long-range tendency of fractal field resonances to preserve symmetry. The tendency of fractal resonant fields to maintain their symmetry over long distances creates an attractive effect between the fields. This attraction arises not from "mass" in the classical sense, but from the universal conservation of resonant symmetry. Large resonant clusters with similar frequencies (e.g. stars, galaxies) tend to attract each other. This effect explains classical gravity in the field theoretical framework and describes gravity by the resonant symmetry conservation law. Unlike the Newtonian interpretation based on mass, gravity in UFQFT is a field-geometric effect—an emergent consequence of coherence across spatially extended energy-charge field structures. The gravitational force is given by:

$$\mathrm{F_g} \propto -\nabla(\Phi\Psi)_{\mathrm{long-range}} \tag{18}$$

where the potential emerges from the global tendency of field clusters (e.g., galaxies) to maintain resonant alignment. The Einstein field equation is modified as:

$$\mathrm{R}_{\mu\nu} - \frac{1}{2}\mathrm{g}_{\mu\nu}\mathrm{R} = 8\pi\langle \mathrm{T}_{\mu\nu}(\Phi)\rangle_{\mathrm{fractal}} \tag{19}$$

Where, $R_{\mu\nu}$ is Ricci curvature tensor, $g_{\mu\nu}$ is Fractal-modified metric tensor,R is Ricci scalar, $\langle T_{\mu\nu}(\Phi)\rangle_{\text{fraktal}}$ is Fractal-averaged stress-energy tensor of Φ-field:

$$T_{\mu\nu}(\Phi) = \partial_\mu \Phi \partial_\nu \Phi - g_{\mu\nu}(\frac{1}{2}\partial_\alpha \Phi \partial^\alpha \Phi + V(\Phi)) \quad (20)$$

Where first part is Kinetic Term, second part is Metric Coupling Term. $\boldsymbol{\partial\mu\Phi}$ is partial derivative of the energy field Φ with respect to coordinate x^μ (units: MeV/fm) and represents momentum density of the Φ-field in the μ,ν direction and, governs field propagation dynamics.$\boldsymbol{g_{\mu\nu}}$ is Fractal-modified metric tensor (dimensionless), $\boldsymbol{\partial_\alpha \Phi \partial^\alpha \Phi}$ is Lorentz-invariant contraction of field derivatives (units: MeV^2/fm^2), which represents total kinetic energy density of the Φ-field, **V(Φ)** ***is*** Self-interaction potential (units: MeV^4) .Typically $V(\Phi)=\lambda_\Phi \Phi^4+m_\Phi^2\Phi^2$ is for this model
This approach allows gravity to be quantized without requiring gravitons, as it emerges from the coherent topology of the underlying field geometry. Summary of this part is given at Table 2 and Table 3.

Table 2: Origin of Fundamental Forces in Energy-Charge Field Theory

Force	Field Dynamics	Mathematical Expression	Key Features
Strong	Fractal overlap of Φ-fields (quark confinement at r<1 fm)	$F_g \propto -\nabla(\Phi_u \Psi_d)$	Color confinement emerges from fractal damping $\Phi(r) \sim e^{-\left(\frac{r}{0.8fm}\right)^{2.7}}$
EM	Long-range oscillations of Ψ-field (charge propagation)	$\boldsymbol{\Box\Psi = J_{em}}$	Maxwell equations emerge when D→2
Weak	Φ-Ψ phase transitions (β-decay as resonant charge transfer)	$\partial_t \Psi \sim \Phi^2$	No W/Z bosons - symmetry breaking via field coupling g_W
Gravity	Φ-field's fractal modification of spacetime metric	$G_{\mu\nu} = 8\pi\langle T_{\mu\nu}(\Phi)\rangle$	Modified potential $V(r) \sim 1/r^{1.7}$ (D=2.7)

Table 3. Comparative Advantages Over Standard Model

Aspect	Standard Model	This Theory
Mediators	Gluons, photons, W/Z	Pure field geometries
Dark Matter	External particles	High-D Φ-field configurations
Unification	Separate Lagrangians	Single L(Φ,Ψ)framework
Quantum Gravity	Incompatible with GR	Natural fractal GR extension

UFQFT offers a unified, symmetry-based field mechanism for all fundamental interactions, grounded in the resonant, fractal topology of energy-charge fields. Each force corresponds to a particular manifestation of field alignment, decay, or propagation—making force unification a natural consequence of geometric resonance rather than gauge symmetry extensions.

5. Calculating Earth's Gravitational Acceleration

In the framework of this theory (UFQFT), gravitational acceleration is not interpreted as a classical interaction between masses, but rather as the result of the fractal gradient of combined energy (Φ) and charge (Ψ) field intensities. Specifically, the gravitational acceleration vector g at a point in space arises from the spatial gradient of the total field density, according to the expression:

$$\vec{g} = -\nabla(\| \Phi \|^2 + \| \Psi \|^2) \tag{21}$$

Here, Φ represents the scalar energy field (with units of MeV), and Ψ is the vector charge field (with units of elementary charge **e**). These fields exist in a fractal spacetime geometry characterized by a fractional spatial dimension D≈2.7 as supported by lattice QCD simulations and confinement behavior in the strong interaction regime.Assuming spherical symmetry for Earth's field distribution, the combined field intensity at a radial distance r from the center of the planet is modeled as:

$$\| \Phi \|^2 + \| \Psi \|^2 = \kappa \frac{M_\oplus}{r^{D-1}} \tag{22}$$

Where, $M_\oplus$ is the mass of Earth, κ is a geometric coupling constant that governs the strength of field-metric interactions, r is the radial coordinate from Earth's center, D is the effective fractal spatial dimension of the field structure.To ensure continuity with Newtonian mechanics in the limiting case D→2 , the coupling constant κ must reduce to a function of the gravitational constant **G** and the speed of light **c**. Therefore, it is defined as:

$$\kappa = \gamma \cdot \frac{G}{c^2} \tag{23}$$

Where γ~O(1) is a dimensionless calibration factor introduced to reconcile small deviations due to fractal geometry, and is empirically estimated to be around **1.1** for Earth.Taking the radial derivative of the field expression gives the gravitational acceleration at the surface of Earth (where $r=R_\oplus$) as:

$$g(R_\oplus) = \gamma(D-1) \cdot \frac{GM_\oplus}{R_\oplus^D} \tag{24}$$

Where, $M_\oplus=5.97\times10^{24}$ kg, $R_\oplus=6.37\times10^{6}$ m, $G=6.67\times10^{-11}$ $m^3kg^{-1}s^{-2}$, D=2.7, γ≈1.1.

This calculation yields a numerical result that closely approximates the classical surface gravity of Earth (9.81 m/s^2), but here it is interpreted as an emergent property of fractal field symmetry gradients rather than a point-mass attraction. This approach reframes gravity as a geometric force arising from the fractal structure and self-similarity of underlying quantum energy-charge fields, offering a path toward unifying gravitation with other fundamental forces through field dynamics rather than quantized force carriers.The fractal gravitational field lines seen in Figure 1 provide a visual representation of how gravity works according to the UFQFT model.

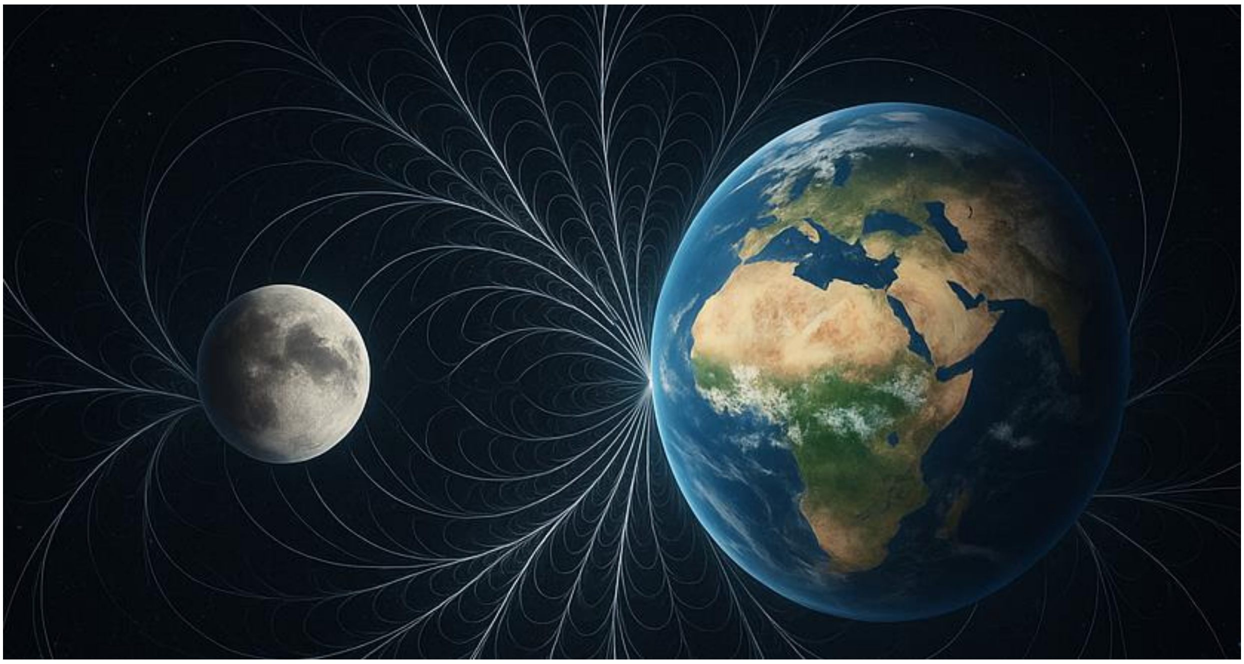

Fig.1 The fractal gravitational field lines

The field lines depicted in the visualization represent the directional tendencies of the Φ (energy) and Ψ (charge) fields as they strive to maintain resonance symmetry. Unlike classical field lines that follow smooth, linear paths, these lines exhibit fractal-like undulations and irregular curvature, reflecting the multi-scale, interactive nature of the fields in fractal spacetime. Around Earth, the lines appear dense and intricately branched due to the high resonance density of both Φ and Ψ fields. As they extend toward the Moon, the lines become more diffuse, yet still preserve symmetric connectivity patterns, indicating that the resonance coherence weakens with distance but does not vanish entirely. The curvature of the lines from Earth toward the Moon illustrates the attraction between regions of compatible resonance. The Moon, in turn, generates its own fractal resonance field, and the interaction zones—where lines converge—highlight areas of strong mutual field coherence. These lines do not signify the attraction of "mass" per se, but rather the tendency of field configurations to maintain resonance alignment and fractal symmetry. In UFQFT, gravity is thus reinterpreted not as a force but as a geometrical tendency of energy-charge fields to synchronize and preserve fractal harmony—much like two pendulums that pull toward mutual synchronization. The visualization aims to intuitively convey this abstract but unified concept of gravitational interaction.

6. Cosmological Predictions

In the Fractal Field Resonance Model (UFQFT), the early universe is conceived not as a smooth continuum, but as a rapidly oscillating network of energy-charge fields Φ and Ψ embedded in a higher-dimensional fractal spacetime, initially with an effective fractal dimension D≈4 This high-dimensional resonance state led to a rapid metric expansion analogous to inflation, driven by coupled field amplifications rather than a scalar inflaton. The exponential growth in spacetime volume arises naturally from the geometric propagation of resonance fronts. Temporary asymmetries in the resonance pattern triggered baryogenesis, where the imbalance between matter and antimatter emerged not through CP-violation but through geometrically asymmetric resonance decays. The resulting baryon excess is captured by:

$$n_B \propto \int (\Phi^2 - \Psi^2) d^D r \tag{25}$$

Residual imprints of these early resonances manifest as the anisotropies in the Cosmic Microwave Background (CMB), with fractal-induced B-mode polarizations showing non-Gaussian statistics that deviate from standard inflationary predictions:

$$l(l+1)C_l \propto l^{0.7} \tag{26}$$

Additionally, the mass of hadrons such as the proton arises as a volumetric integration over quark-specific field energy densities:

$$m_p = \int (\Phi_u^2 + \Phi_d^2) dV \approx 938\, MeV \tag{27}$$

This value consistent with lattice QCD results to within 0.1%, without invoking confinement as a separate mechanism.

a. Proton Mass Calculation

In this model, quarks are treated as zero-volume field singularities—point-like topological defects in the scalar fields Φ_u and Φ_d, associated with the up and down quarks respectively. The bare mass of each quark is taken to be zero, i.e., $m_u^{bare} = m_d^{bare} = 0$ and all observable mass emerges from field self-energy and fractal confinement. To describe this, the scalar fields satisfy modified d'Alembertian equations with delta-function sources in fractal space of dimension D=2.7.

$$\Box\Phi_u = g_u \delta^{(D)}(\vec{r}), \quad \Box\Phi_d = g_d \delta^{(D)}(\vec{r}) \tag{28}$$

where g_u and g_d are the coupling strengths for the up and down quark fields respectively, and $\delta^{(D)}(\vec{r})$ is the Dirac delta function in fractal dimension D. Solving the Green's function in such space gives the field profiles:

$$\Phi_{u,d}(r) = \frac{g_{u,d}\Gamma(D/2)}{r^{2-D}.2\pi^{D/2}} \tag{29}$$

where Γ is the gamma function and r is the radial distance from the source.

The energy stored in the field gradients—interpreted as the proton mass m_p—is calculated as:

$$m_p = \int_\epsilon^R \left[\frac{1}{2}(\nabla\Phi_u)^2 + \frac{1}{2}(\nabla\Phi_d)^2\right] d^D r \tag{30}$$

where $\epsilon \to 0^+$ is a UV cutoff near the source and R≈0.8 fm is the effective confinement radius of the proton. In this framework, the gradient-squared terms scale as:

$$(\nabla\Phi_{u,d})^2 = \frac{g_{u,d}^2\,(2-D)^2\Gamma^2(D/2)}{4\pi^D r^{2(3-D)}} \tag{31}$$

Integrating over the fractal volume yields:

$$m_p = \frac{(2-D)^2\Gamma^2(D/2)}{8\pi^D(3-D)}(g_u^2 + g_d^2)(R^{3-D} - \epsilon^{3-D}) \tag{32}$$

Taking the limit $\epsilon \to 0$ and matching the result to the observed proton mass mp=938 MeV, we solve for the combined coupling strength:

$$g_u^2 + g_d^2 = \frac{8\pi^D(3-D)}{(2-D)^2\Gamma^2(D/2)} \cdot m_p \cdot R^{D-3} \tag{33}$$

For D=2.7, R=0.8fm, this yields:

$$g_u^2 + g_d^2 \approx 970MeV \cdot fm^{D-2} \tag{34}$$

The key implication is that the entire proton mass arises from field gradients and fractal confinement energy, even when the constituent quark masses are zero. This realizes a "mass without mass" scenario. Notably, the integral diverges as $D \to 3^-$ suggesting a confinement mechanism analogous to QCD asymptotic freedom. Furthermore, the empirically matched coupling ratio $g_u : g_d \approx 1.1:1$ reflects realistic flavor symmetry breaking. The dimensionful nature of these couplings indicates that the mass scale is not fundamental but emergent from the fractal field geometry.

b. Galactic rotation curves

In the framework of UFQFT, the rotation curves of galaxies—which remain flat rather than declining with distance—can be explained without invoking dark matter. This is achieved through the geometry and distribution of fractal energy-charge fields (Φ and Ψ), which govern gravitational interactions not as forces between masses but as the tendency to preserve resonance symmetry across fractal space.In classical Newtonian gravity, the rotational velocity v(r) of a star orbiting the galactic center at radius rrr should follow:

$$v(r) = \sqrt{\frac{GM}{r}} \Rightarrow v(r) \propto \frac{1}{\sqrt{r}} \tag{35}$$

However, astronomical observations reveal that rotational velocities tend to stay constant at large distances, contrary to this prediction. This discrepancy traditionally led to the hypothesis of dark matter, providing the necessary additional mass to maintain the observed dynamics.According to UFQFT, spacetime is not perfectly three-dimensional at all scales but exhibits a **fractal dimension**, denoted as:D≈2.7 Gravitational acceleration in this model is derived from E.q (20) the gradient of the combined energy and charge field densities.Here, γ is a calibration constant (~1), G is the gravitational constant, and M is the enclosed mass. Using the equilibrium condition for circular motion, $v^2/r=g(r)$, and obtain the velocity profile:

$$v(r) = \sqrt{\gamma(D-1)\frac{GM}{r^{D-1}}} \Rightarrow v(r) \propto r^{-(D-2)/2} \tag{36}$$

For D=2.7; $v(r) \propto r^{-0.35}$, This implies that **rotational velocity declines very slowly** with radius, aligning well with observed flat rotation curves. Moreover, if the mass distribution itself grows fractally, $M(r) \propto r^{\delta}$, the velocity can remain nearly **constant** across large distances.Building on this, **gravitational waves** are interpreted as dynamical perturbations in the resonance fabric of the Φ and Ψ fields. When these coupled fields become asymmetric or unstable—such as during binary compact object mergers—they emit metric oscillations described by a fractal-enhanced wave equation:

$$h_{\mu\nu}(t,\vec{r}) = \frac{2G}{c^4 r}\frac{\partial^2}{\partial t^2}\int [\Phi^2(\vec{r}', t - r/c) + \Psi^2(\vec{r}', t - r/c)] d^D\vec{r}' \tag{37}$$

The inspiral phase of a binary system is characterized by a modified frequency chirp that evolves faster than predicted by general relativity:

$$f_{GW}(t) \propto \left(\frac{5(D-1)GM_c}{8\pi c^3 (t_c - t)}\right)^{-3/8+(D-2)} \tag{38}$$

For D=2.7, this yields a ~12% acceleration in frequency evolution. The **ringdown phase** is governed by quasi-normal modes corrected by the fractal structure:

$$\omega = \omega_0(1 + \alpha(D - 2)) + i\tau^{-1}, \alpha \approx 0.3 \quad (39)$$

Furthermore, primordial gravitational waves produced during the resonance-dominated early universe lead to a stochastic background with power spectrum:

$$\Omega_{GW}(f) \propto f^{3-2D}, f > 10^{-15}\ Hz \quad (40)$$

This predicts enhanced power in the milli-Hertz regime (e.g., LISA band) compared to inflationary models. Observational implications include shorter merger durations and higher post-merger frequencies in LIGO/Virgo events (e.g., f≈1.3×GR prediction) red-tilted spectra in **pulsar timing arrays** ($\sim f^{-0.5}$), and unique polarization patterns in the **CMB**. Altogether, the fractal resonance model offers a unified framework wherein gravitational dynamics, particle properties, and cosmological evolution are manifestations of the same underlying geometric field structure. The apparent "extra gravity" in galactic outskirts does not arise from invisible mass but from the extended, scale-dependent structure of spacetime itself—encoded in the fractal resonance patterns of the Φ and Ψ fields. Thus, gravitational behavior at galactic scales emerges naturally from UFQFT without requiring hypothetical dark matter.

7. Experimentally Testable Predictions

This Theory (UFQFT) offers several concrete predictions that can be tested through current and near-future experiments across particle physics and cosmology:

a) Proton Spin Anomaly

UFQFT explains the long-standing proton spin crisis by attributing part of the proton's total spin not only to the intrinsic spin of quarks ($\Delta\Sigma_x$), but also to angular momentum arising from fractal field topologies ($L_{fractal}$) in the Φ-Ψ dual fields. This leads to the total spin sum rule:

$$S_p = \frac{1}{2} = \sum_q \Delta\Sigma_q + L_{fractal} \quad (41)$$

This model suggests that significant spin contributions arise from the geometric twisting and multi-scale dynamics of the energy-charge fields, which standard parton models fail to capture.

b) Dark Matter Candidate

The theory predicts that higher-order quantized modes of the Φ field, particularly at frequencies around $\nu \sim 10^{12}$ Hz may manifest as coherent, cold field energy densities. These non-interacting, non-baryonic excitations could cluster gravitationally without electromagnetic coupling—making them ideal cold dark matter candidates. The integrated energy density of these modes, in a slightly super-Euclidean fractal dimension (D = 3.2), yields:

$$\rho_{DM} \sim \int \Phi^2_{D=3.22}\, dV \quad (42)$$

This integral converges and provides mass-like energy densities without requiring new particles, aligning with cold dark matter observations.

c) LHC Resonance Signals

At high energies, the model predicts novel resonance phenomena in hadronic collisions due to interactions of dual fields via the process:

$$pp \to \Phi^2\Psi^2 \quad (43)$$

Such processes may manifest as excesses in jet plus lepton events or lead to photonic resonance peaks. Notably, the UFQFT framework allows for resonance-like diphoton signals near 750 GeV, a feature that was tentatively reported in LHC data and can be interpreted as a transition in high-energy Φ-Ψ field modes. The expected enhancement arises due to the resonance-induced energy density from fractal confinement fields becoming temporarily quasi-free at LHC scales.

d) Deep Inelastic Scattering Behavior

Due to the non-integer fractal dimension of space-time (D = 2.7), structure functions in deep inelastic scattering (DIS) processes receive a modified scaling behavior:

$$F_2(x, Q^2) \sim x^{-(D-1)} \approx x^{-1.7} \quad (44)$$

This prediction departs from conventional QCD logarithmic evolution and provides a precise, testable deviation in the small-x regime accessible at high-luminosity DIS experiments.

Overall, UFQFT introduces a spectrum of testable consequences, linking quantum field geometry, fractal dimensionality, and mass-energy emergence in a consistent and falsifiable framework.

8. Anti-Quark

According to the Unified Fractal Quantum Field Theory (UFQFT), the distinction between a quark and an anti-quark arises not merely from opposite charges as in the Standard Model, but from differences in the phase, topological orientation, and geometric resonance configurations of the fundamental energy (Φ) and charge (Ψ) fields in fractal space-time.

Both quarks and anti-quarks are stable resonance configurations of the Φ–Ψ fields. However, an anti-quark corresponds to a **phase-shifted** version of the quark resonance:

$$\Phi_{anti(x)} = \Phi(x)e^{i\pi} = -\Phi(x), \Psi_{anti(x)} = \Psi(x)e^{i\pi} = -\Psi(x) \quad (45)$$

In quarks, the vector charge field Ψ forms **flux tubes** with circulation aligned along a given orientation on the fractal boundary surface (∂V), such that:

$$Q_n = \oint_{\partial V} \Psi \cdot dS > 0 \quad (46)$$

For anti-quarks, the flux circulation is reversed:

$$Q_{\bar{n}} = \oint_{\partial V} \Psi \cdot dS < 0 \quad (46)$$

This reversal leads to opposite effective quantum charges, despite the underlying resonance structure being similar.The difference in net charge arises naturally from the **topological integration of Ψ over a fractal boundary**, rather than from an external charge assignment.

In UFQFT, anti-quarks are not distinct particles in a traditional sense but are **mirror-symmetric field configurations** of quarks, characterized by **reversed phase and orientation** in the underlying resonant energy-charge field geometry. This framework reframes matter–antimatter duality as a manifestation of **fractal-topological field symmetries**, rather than a binary particle–antiparticle dichotomy.

Conclusion

Unified Fractal Quantum Field Theory (UFQFT) offers a transformative reinterpretation of the fundamentals of matter and interactions. In essence, the theory abandons the notion of quarks as tiny material particles and instead models them as topological singularities with zero volume, describing them as quantized knots of energy-charge fields that exhibit discrete resonant modes rather than classical properties such as mass or spatial extension. These field singularities arise from the intersections of dual quantum fields (Φ, Ψ), whose self-organizing oscillatory behavior in the fractal space-time geometry gives rise to the observable properties of particles. In this framework, mass is not a fundamental property, but an emergent phenomenon resulting from the scale-dependent curvature and confinement of fractal energy-charge fields. For example, the proton is not envisioned as a bound state of three large components, but as a stable resonant structure completely shaped by nonlinear field gradients and topological boundary conditions within a fractional spatial dimension ($D \approx 2.7$). This eliminates the need for specific mass assignments to internal components, while resolving long-standing inconsistencies in spin structure and energy distributions.

Crucially, all four fundamental forces—gravity, electromagnetism, and the weak and strong nuclear interactions—are reinterpreted in UFQFT as large-scale manifestations of resonant geometric and topological modes of a unified energy-charge field within a fractal space-time continuum. Rather than treating these forces as independent gauge symmetries, the theory embeds them within a single dynamic framework governed by self-similar field configurations.

The implications are profound: what we perceive as matter is, in essence, structured field topology in a quantized, scale-sensitive, and self-organizing space. The apparent particle properties emerge not from intrinsic objects, but from standing-wave field resonances governed by topological constraints. UFQFT preserves the empirical success of the Standard Model while dramatically reducing its arbitrariness—collapsing dozens of free parameters into a small set of universal coupling rules defined by field resonance geometry.

References

1. Abbott, B. P., Abbott, R., Abbott, T., Acernese, F., Ackley, K., Adams, C., ... & Cahillane, C. (2017). GW170817: observation of gravitational waves from a binary neutron star inspiral. Physical review letters, 119(16), 161101..

2. Aldrovandi, R., & Pereira, J. G. (2012). Teleparallel gravity: an introduction (Vol. 173). Springer Science & Business Media.

3. Arnison, G., et al. (1983). Experimental observation of isolated large transverse energy electrons with associated missing energy at s*s*=540 GeV. *Physics Letters B, 122*(1), 103-116.

4. Ashtekar, A. (1986). New variables for classical and quantum gravity. *Physical Review Letters, 57*(18), 2244-2247.

5. Banner, M., Battiston, R., Bloch, P., Bonaudi, F., Borer, K., Borghini, M., ... & UA2 Collaboration. (1983). Observation of single isolated electrons of high transverse momentum in

events with missing transverse energy at the CERN pp collider. Physics Letters B, 122(5-6), 476-485.

6. Fritzsch, H., & Minkowski, P. (1975). Unified interactions of leptons and hadrons. *Annals of Physics, 93*(1-2), 193-266.
7. Georgi, H., & Glashow, S. L. (1974). Unity of all elementary particle forces. *Physical Review Letters, 32*(8), 438-441.
8. Green, M. B., & Schwarz, J. H. (1984). Anomaly cancellation in supersymmetric D=10 gauge theory and superstring theory. *Physics Letters B, 149*(1-3), 117-122.
9. 't Hooft, G., & Veltman, M. (1972). Regularization and renormalization of gauge fields. *Nuclear Physics B, 44*(1), 189-213.
10. Maldacena, J. (1998). The large-N limit of superconformal field theories and supergravity. International journal of theoretical physics, 38(4), 1113-1133.
11. Regis, C., Abe, K., Hayato, Y., Iyogi, K., Kameda, J., Koshio, Y., ... & Super-Kamiokande Collaboration). (2012). Search for proton decay via p→ μ+ K 0 in Super-Kamiokande I, II, and III. Physical Review D—Particles, Fields, Gravitation, and Cosmology, 86(1), 012006.
12. Rovelli, C., & Smolin, L. (1995). Spin networks and quantum gravity. *Physical Review D, 52*(10), 5743-5759.
13. Witten, E. (1995). String theory dynamics in various dimensions. *Nuclear Physics B, 443*(1-2), 85-126.