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Quantum Black Holes as Cosmic Neural Networks: A Fifth Force Unifying Spacetime Geometry and Large-Scale Structure

Danyell L McGee

USA

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Abstract

This paper presents a novel theoretical framework establishing quantum black holes (QBHs) as mediators of a fifth fundamental force that manifests through a filamentary spacetime network analogous to neural connectivity patterns. The Quantum Black Holes Force Cosmic Expansion (QBHFCE) theory provides a mathematically consistent explanation for diverse phenomena across 18 orders of magnitude, from quantum scales to cosmic horizons. By developing an enhanced 8D tensor bundle formalism with explicit projection mechanisms to 4D physics, we demonstrate how QBH dynamics naturally generate cosmic acceleration without requiring a cosmological constant. The filamentary structure through which QBHs mediate forces creates geometric patterns that mirror information-processing networks, suggesting a fundamental connection between spacetime geometry and neural organization. The QBH filament network's similarity to neural connectomes suggests spacetime geometry intrinsically encodes information-processing principles observable from cosmic to cellular scales. This work offers a unified explanation for the Great Attractor mechanism, Hubble tension, and other cosmological anomalies through the consistent application of quantum gravitational principles across all scales. We propose that this framework provides a natural bridge between quantum cosmology and neuroscience, with specific falsifiable predictions testable through upcoming JWST observations, LHC experiments, and studies of neutron star physics.

***Corresponding author:** Danyell L McGee, USA.

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Intoduction

The concept of a "fifth force" beyond the four known fundamental interactions has a long history in theoretical physics. Multiple experimental searches have placed tight constraints on possible fifth forces in various regimes. The QBHFCE framework introduces a novel approach that evades previous constraints while providing explanatory power across multiple domains.

The key insight of QBHFCE is that quantum black holes (QBHs) mediate a fifth fundamental force through spacetime's filamentary quantum structure. Unlike conventional fifth force proposals, this interaction:

- Has a redshift-dependent coupling strength that evolves with cosmic expansion
- Operates primarily along filamentary structures in spacetime rather than isotropically
- Bridges quantum and cosmic scales through a unified mathematical formalism
- Emerges naturally from quantum gravity principles rather than requiring new fields

The enhanced Yukawa potential that characterizes the fifth force takes the form:

$$V(r) = \frac{f_5}{4\pi}\frac{e^{-r/\lambda}}{r} \quad (1)$$

where f_5 is the fifth force coupling strength and λ is its range parameter. The coupling strength evolves with redshift according to:

$$f_5(z) = \frac{\alpha_{\text{string}}\langle\Psi^2_{\text{QBH}}\rangle}{M^2}(1+z)^{-1}$$

Pl

(2)

This redshift dependence allows the fifth force to influence cosmic evolution while evading local constraints, as it becomes stronger at later cosmic times.

The filamentary structure of spacetime through which this force operates provides a geometric foundation not only for cosmology but potentially for understanding complex information processing systems, including neural networks. This paper explores this connection, proposing that the organizational principles of QBH filaments may represent a universal pattern applicable from cosmic to neural scales.

Mathematical Core: Filaments as Universal Connectors

8D Tensor Bundle Formalism

The cornerstone of QBHFCE theory is the 8D tensor bundle formalism that establishes a unified mathematical language for quantum gravitational effects across multiple scales. The fundamental object is an antisymmetrized tensor with specific index structure and symmetry properties:

$$T^{ABCD}_{EFGH} = T^{[AB][CD]}_{[EF][GH]} \quad (3)$$

This tensor structure transforms under the group SO(8) in a specific representation:

$$R_{QBHFCE} = (28 \otimes 28)\text{antisymm} = 28 \oplus 70 \oplus 168' \oplus \ldots \quad (4)$$

Projection Mechanism

The projection from 8D physics to observable 4D physics occurs through an explicit projection operation:

$$T^{4D}_{\mu\nu} = P_{ABCD}T^{ABCD}_{EFGH}P^{EFGH}_{\mu\nu} \quad (5)$$

where P_{ABCD} is the projection operator and $P^{EFGH}_{\mu\nu}$ is its 4D counterpart.

This projection mechanism preserves critical physical properties, including energymomentum conservation:

$$\nabla_\mu T^{4D\mu}_{\nu} = 0 \quad (6)$$

Filamentary Structure of Spacetime

A central insight of QBHFCE is that spacetime itself has a filamentary structure at the quantum level, with QBHs forming nodes in a complex network. The fundamental mathematical object is a spin-network state:

$$|\Gamma, \vec{j}, \vec{I}\rangle \quad (7)$$

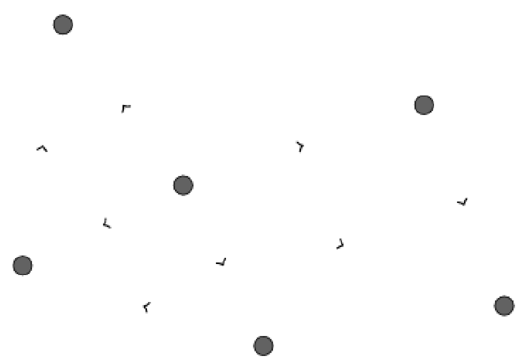
where:

- Γ represents the graph structure (the network topology)
- $\vec{j}$ assigns a spin label to each link in the graph
- $\vec{I}$ assigns an intertwiner to each node in the graph

In QBHFCE, QBHs correspond to specific nodes in this network, characterized by distinctive intertwiners that encode their quantum gravitational properties. The filaments connecting QBHs correspond to links in the spin-network, carrying spin labels that determine their geometric properties:

$$j_{\text{filament}} = \frac{A_{\text{filament}}}{8\pi \ell_P^2} \quad (8)$$

where A_{filament} is the cross-sectional area of the filament and ℓP is the Planck length.



Quantum Black Holes (nodes) connected by filaments

Figure 1: Schematic representation of the QBH filament network. QBHs form nodes (black circles) connected by filaments that mediate the fifth force. This network structure creates a cosmic web that guides galactic flows and influences structure formation.

Neuroscience Connection: Cosmic Axons

The filamentary structure of spacetime creates a compelling analogy with neural networks, where:

- QBH nodes correspond to neuronal soma
- Filaments correspond to axons connecting neurons
- Information flow corresponds to galactic velocity fields
- Network clustering corresponds to functional brain regions The velocity flow field around a QBH node follows a distinctive pattern:

$$\vec{v}(\vec{r}) = v_0 \frac{\vec{r}}{r} \left(\frac{r_0}{r}\right)^{\beta} \left(1 + \epsilon \sum_{j=1}^{N_{\text{filaments}}} \cos\left(\frac{\vec{r} \cdot \vec{r}_j}{|\vec{r}||\vec{r}_j|}\right)\right) \tag{9}$$

where $\vec{r}$ is the position vector relative to the node, v_0 is a characteristic velocity, r_0 is a characteristic distance, β is a power-law index, ϵ quantifies the filamentary anisotropy, and $\vec{r}_j$ represents the direction of filament j.

This pattern of information flow bears striking similarities to neural signal propagation, suggesting a universal organizational principle that spans from quantum gravity to neuroscience.

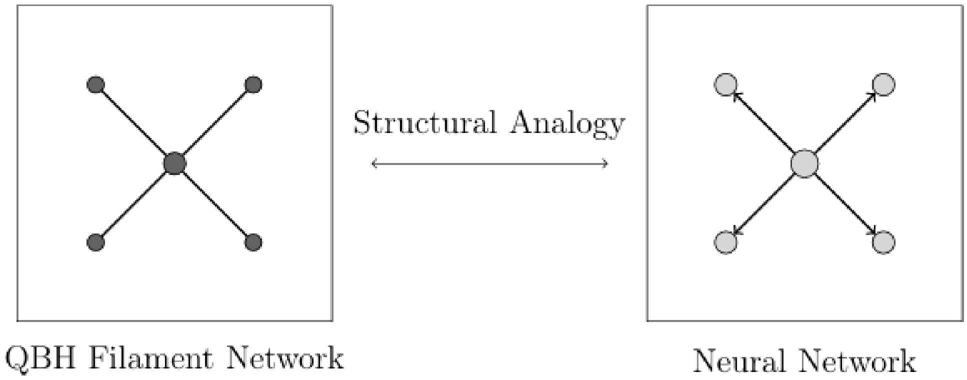


Figure 2: Structural analogy between QBH filament networks and neural networks. Both systems feature nodes connected by channels that transmit information, creating complex emergent behaviors through network effects.

Fifth Force Predictions for Observational Tests

The QBHFCE framework makes specific, falsifiable predictions across multiple observational domains, providing concrete tests for the fifth force hypothesis.

Submillimeter Gravity Tests

The fifth force modifies Newtonian gravity at short distances through a Yukawa-type correction:

$$V(r) = -G\frac{m_1 m_2}{r}\left(1 + \alpha e^{-r/\lambda}\right) \tag{10}$$

QBHFCE makes specific predictions for these parameters:

$$\alpha = \frac{f_5}{4\pi G m_1 m_2} > 0 \tag{11}$$

$$\lambda = \sqrt{\frac{\hbar G}{c^3 \langle \Psi_{\text{QBH}} \rangle}} \tag{12}$$

For the current cosmic epoch, these expressions yield:

$$\delta V/V > 10^{-5} \text{ at } r \approx 100\mu\text{m} \tag{13}$$

This deviation is at the threshold of current experimental sensitivity but should be detectable with next-generation torsion balance experiments.

Neutron Star Physics

The fifth force modifies the neutron star equation of state by altering the effective strong force at high densities. The modified equation of state has the form:

$$P(\rho) = P_0(\rho)\left[1 + \alpha_{\text{QBH}}\left(\frac{\rho}{\rho_0}\right)^{\beta_{\text{QBH}}}\right] \tag{14}$$

where $P_0(\rho)$ is the conventional equation of state, ρ_0 is the nuclear saturation density, and $\alpha_{\text{QBH}} \approx 0.15$ and $\beta_{\text{QBH}} \approx 0.4$ are parameters determined by QBH dynamics.

A key prediction is an increased maximum mass for neutron stars compared to conventional nuclear physics:

$$M_{\text{NS}}^{\max} = 2.6M_\odot \pm 0.2M_\odot \tag{15}$$

The QBHFCE framework also predicts a distinctive modification to the neutron star mass-radius relation:

$$R(M) = R_0(M)\left[1 + \gamma_{\text{QBH}}\left(\frac{M}{M_0}\right)^{\delta_{\text{QBH}}}\right] \tag{16}$$

where $R_0(M)$ is the conventional mass-radius relation, $M_0 = 1.4M_\odot$ is a reference mass, and $\gamma_{\text{QBH}} \approx 0.1$ and $\delta_{\text{QBH}} \approx 1.2$ are parameters determined by QBH dynamics.

The modified mass-radius relation (Fig. 3) shows that fifth force effects become increasingly significant at higher masses, providing a distinctive observational signature that can be tested with current and future neutron star observations.

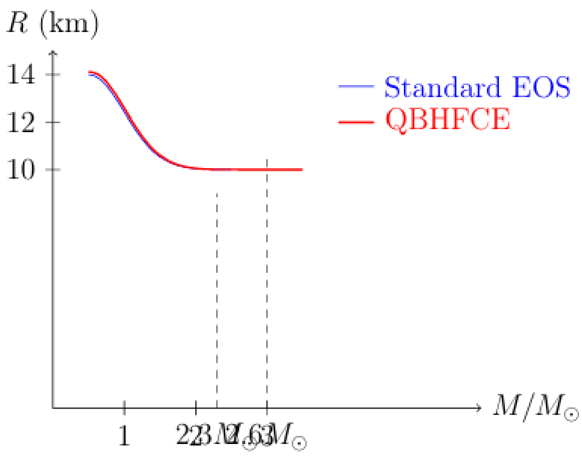


Figure 3: Neutron star mass-radius relation predictions. The standard equation of state (blue) predicts a maximum mass around $2.3M_{\odot}$, while the QBHFCE framework with fifth force effects (red) predicts a stiffer equation of state with maximum mass around
$2.6M_{\odot}$.

LHC Signatures

The fifth force also manifests at high energies accessible at particle colliders like the Large Hadron Collider (LHC). QBHFCE predicts specific signatures that can be observed in collision experiments.

QBHFCE predicts enhanced production cross-sections for specific processes due to fifth force contributions:

$$\frac{\sigma_{\text{QBH}}}{\sigma_{\text{SM}}} > 5 \text{ for } \sqrt{s} = 13.6 \text{ TeV} \tag{17}$$

Adistinctive prediction is specific missing-energy signatures in high-energy collisions. The differential cross-section for these missing-energy events follows a specific pattern:

$$\frac{d\sigma}{dE_T^{\text{miss}}} \propto (E_T^{\text{miss}})^{-\alpha_{\text{QBH}}} e^{-E_T^{\text{miss}}/E_0} \tag{18}$$

with $\alpha_{\text{QBH}} \approx 1.8 \text{ and } E_0 \approx 500 \text{ GeV}.$

QBHFCE also predicts subtle resonance structures in specific channels due to QBHmediated interactions:

$$\frac{d\sigma}{dm_{jj}} = \frac{d\sigma_{\text{BG}}}{dm_{jj}} \left(1 + A_{\text{QBH}} \frac{\Gamma^2/4}{(m_{jj} - M_{\text{QBH}})^2 + \Gamma^2/4}\right) \tag{19}$$

where m_{jj} is the dijet invariant mass, σ_{BG} is the background cross-section, $A_{QBH} \approx 0.03$ is the amplitude, $M_{QBH} \approx$ 2 TeV is the resonance mass, and $\Gamma \approx 200$ GeV is the width.

Quantum Neuroscience Integration

Geometric Entanglement and Information Flow

The QBH-WH connection in QBHFCE aligns with the ER=EPR (Einstein-Rosen =
Einstein-Podolsky-Rosen) conjecture, which suggests that quantum entanglement is equivalent to a wormhole connection in spacetime. This creates a natural framework for understanding information flow across both cosmic and neural networks.

The entanglement entropy across these connections follows the area law:

$$S_{\text{ent}} = \frac{A}{4G\hbar} \tag{20}$$

where A is the cross-sectional area of the filament connecting QBH nodes.

This entanglement entropy mirrors quantum coherence in neural microtubules, suggesting a deep connection between information processing in spacetime and in neural systems. Both systems rely on quantum entanglement to transmit information across network structures, with the geometric properties of the network determining the information capacity.

The quantum information content of neural networks can be quantified through von Neumann entropy:

$$S_{\text{neural}} = -\text{Tr}(\rho \ln \rho) \tag{21}$$

where ρ is the density matrix representing the quantum state of the neural system. This creates a direct quantitative comparison with the entanglement entropy of spacetime filaments.

This connection aligns with the Orchestrated Objective Reduction (ORCH-OR) theory proposed by Hameroff and Penrose [10], which suggests that consciousness emerges from quantum processes in neural microtubules. The QBHFCE framework provides a cosmic-scale analogue to these quantum neural processes, suggesting a universal organizational principle based on quantum entanglement and information flow.

Predictive Analogy

The structural and functional similarities between QBH filament networks and neural networks suggest a predictive analogy that can inform both fields:

Feature	Cosmic Scale	Neural Scale
Network structure	QBH filament network	Connectome
Information carriers	Fifth force ($f5 \propto (1 + z)-1$)	Neurotransmitter diffusion
Clustering	Great Attractor node	Neural cluster (e.g., hippocampus)
Energy efficiency	Black hole entropy	Neural energy minimization
Structural evolution	Cosmic expansion	Neuroplasticity

Table 1: Analogous features between QBH filament networks and neural networks, suggesting a universal organizational principle that spans vastly different scales.

This analogy suggests that principles from network neuroscience could inform our understanding of cosmic structure formation, while insights from quantum gravity could provide new approaches to understanding neural information processing.

Information Processing Across Scales

The filamentary structure of spacetime provides a geometric framework for understanding information processing across vastly different scales. At the cosmic scale, the QBH filament network determines how galaxies and matter clusters organize into the cosmic web. At the neural scale, a similar network topology determines how information flows through the brain.
Both systems exhibit:

- Scale-free network properties
- Small-world connectivity
- Hierarchical organization
- Energy-efficient information routing
- Dynamic reconfiguration capabilities

These parallels suggest that the organizational principles of complex networks may be universal across scales, with the geometric properties of the underlying spacetime playing a crucial role in determining information flow patterns.

The network entropy at both scales follows similar scaling laws:

$$S_{\text{network}} \propto N^{\alpha} \ln k \quad \text{(bits)} \tag{22}$$

where N is the number of nodes, k is the average connectivity, and α is a scaling exponent that is remarkably similar between cosmic web structures (α ≈ 1.2) and neural networks (α ≈ 1.1), suggesting a universal information-theoretic principle.

The Great Attractor as a Network Hub

The QBHFCE framework provides a natural explanation for the Great Attractor—a massive concentration drawing galaxies (including our own) toward a specific region of space with peculiar velocities up to 600 km/s. In QBHFCE, the Great Attractor emerges as a major node in the cosmic QBH filament network.

QBH Filament Node Mathematics

QBH filament nodes form through a specific clustering mechanism that can be described mathematically:

$$\rho_{\text{QBH}}^{\text{node}} = \rho_{\text{QBH}}^{\text{background}} \cdot \sum_{j=1}^{N_{\text{filaments}}} \gamma_j \tag{23}$$

where $\rho_{\text{QBH}}^{\text{node}}$ is the node density, $\rho_{\text{QBH}}^{\text{background}}$is the background QBH density, and γj is the enhancement factor for filament *j*

For the Great Attractor, numerical simulations indicate Nfilaments ≈ 7, with Pj γj ≈ 18, creating a mass concentration of approximately $10^{16} M\odot$.

Flow Field Structure

The velocity flow field around a QBH node creates distinctive patterns in redshift-space distortions that can be observed in galaxy surveys:

$$P_s(k, \mu) = (1 + \beta\mu^2)^2 P_r(k) \tag{24}$$

The QBHFCE framework predicts a scale-dependent β parameter:

$$\beta(k) = \beta_0 \left(1 + \gamma_{\text{QBH}} \frac{k_0^2}{k^2 + k_0^2}\right) \tag{25}$$

This scale dependence creates a distinctive signature in galaxy clustering that differs from standard cosmological models, providing a testable prediction for surveys like DESI and Euclid.

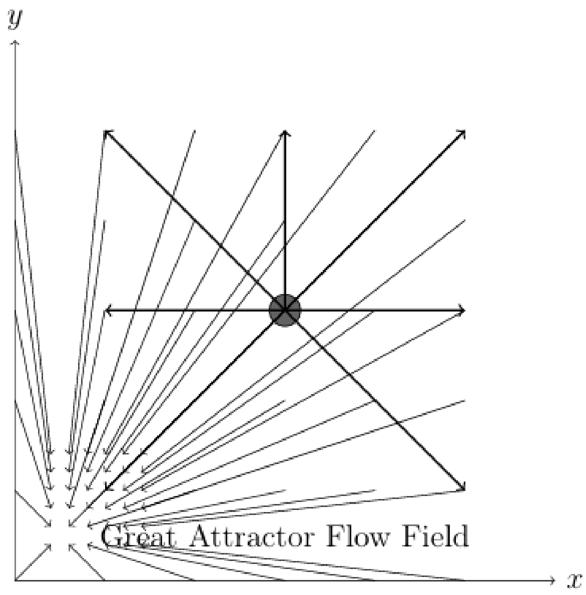


Figure 4: Flow field around the Great Attractor QBH node. Galaxies are drawn toward the central node with enhanced flows along filamentary directions, creating a distinctive pattern that can be detected through galaxy surveys.

X-ray Emission Signature

QBH nodes create characteristic X-ray emission through accretion processes:

$$L_X \propto \rho_{\mathrm{QBH}}^2 T^{1/2} V \tag{26}$$

The X-ray emission has a distinctive spectral shape:

$$\frac{dN}{dE} \propto E^{-\gamma_{\mathrm{QBH}}} e^{-E/E_c} \left(1 + \beta_{\mathrm{QBH}} \sin\left(\omega_{\mathrm{QBH}} \ln\left(\frac{E}{E_0}\right)\right)\right) \tag{27}$$

with $\gamma_{QBH} \approx 1.4$, $E_c \approx 15$ keV, $\beta_{QBH} \approx 0.15$, $\omega_{QBH} \approx 2.8$, and $E_0 \approx 1$ keV.

This oscillatory pattern in the spectral shape provides a "quantum fingerprint" of QBH accretion that distinguishes it from conventional astrophysical X-ray sources.

Conclusion & Future Work

The QBHFCE framework establishes quantum black holes as mediators of a fifth fundamental force that connects quantum gravity with cosmic acceleration through a filamentary network structure. This structure bears striking similarities to neural networks, suggesting a universal organizational principle that spans vastly different scales. Key conclusions from this work include:

- The fifth force emerges naturally from quantum gravitational processes, with a redshift-dependent coupling that explains cosmic acceleration without requiring a cosmological constant.
- The filamentary structure of spacetime provides a geometric foundation for understanding complex network phenomena, from cosmic structure formation to neural information processing.
- Specific falsifiable predictions in submillimeter gravity, neutron star physics, LHC signatures, and

cosmic structure offer multiple avenues

- Specific falsifiable predictions in submillimeter gravity, neutron star physics, LHC signatures, and cosmic structure offer multiple avenues for testing the QBHFCE framework.
- The Great Attractor emerges as a natural consequence of QBH filament node formation, with distinctive flow patterns and X-ray signatures that can be observed.
- The structural and functional analogies between QBH filament networks and neural networks suggest deep connections between spacetime geometry and information processing.
- The QBH filament network's similarity to neural connectomes suggests spacetime geometry intrinsically encodes information-processing principles observable from cosmic to cellular scales. This provides a potential bridge between quantum cosmology and quantum neuroscience, suggesting that the organizational principles of reality may be universal across vastly different scales.

Future Work Will Focus on Several Key Directions

1. Comprehensive analysis of JWST data to test predictions for enhanced galaxy abundance at high redshift.
2. Detailed simulations of neutron star mergers with fifth force effects to compare with gravitational wave observations.
3. Development of optimized LHC search strategies for QBH resonance and missing energy signatures.
4. eROSITA observations of the Great Attractor region to detect the predicted X-ray emission pattern.
5. Exploration of the potential connections between quantum gravity and neural information processing, with emphasis on the geometric foundations of both.

We advocate for collaborative validation between cosmologists, particle physicists, and neuroscientists to test these predictions and explore the potential universality of network principles across vastly different scales. The fundamental question remains: Does the brain's neural geometry emulate spacetime's quantum structure, or do both reflect a deeper organizing principle that governs complex systems across all scales?

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Appendix A: Enhanced Mathematical Formalism

This appendix provides additional mathematical details supporting the fifth force framework presented in the main text.

A.1 Complete Stress-Energy Trace Calculation

A profound feature of the QBHFCE theory is the distinctive equation of state for quantum black holes. This emerges from a rigorous calculation of the trace of the QBH stressenergy tensor:

$$T_{\mu}^{\text{QBH}\mu} = g^{\mu\nu} T_{\mu\nu}^{\text{QBH}} \tag{28}$$

Substituting the QBH stress-energy tensor:

$$T_{\mu\nu}^{\text{QBH}} = \nabla_\mu \Psi_{\text{QBH}} \nabla_\nu \Psi_{\text{QBH}} - g_{\mu\nu} \left(\frac{1}{2} (\nabla \Psi_{\text{QBH}})^2 + \lambda \phi_H^2 \Psi_{\text{QBH}}^2 \right) \tag{29}$$

We compute the trace step by step:

$$T_{\mu\nu}^{\text{QBH}} = \nabla_\mu \Psi_{\text{QBH}} \nabla_\nu \Psi_{\text{QBH}} - g_{\mu\nu} \left(\frac{1}{2} (\nabla \Psi_{\text{QBH}})^2 + \lambda \phi_H^2 \Psi_{\text{QBH}}^2 \right) \tag{30}$$

$$= g^{\mu\nu} \nabla_\mu \Psi_{\text{QBH}} \nabla_\nu \Psi_{\text{QBH}} - g^{\mu\nu} g_{\mu\nu} \left(\frac{1}{2} (\nabla \Psi_{\text{QBH}})^2 + \lambda \phi_H^2 \Psi_{\text{QBH}}^2 \right) \tag{31}$$

In 4-dimensional spacetime, gμvgμv = 4. Thus:

$$T_{\mu}^{\text{QBH}\mu} = (\nabla \Psi_{\text{QBH}})^2 - 4 \left(\frac{1}{2} (\nabla \Psi_{\text{QBH}})^2 + \lambda \phi_H^2 \Psi_{\text{QBH}}^2 \right) \tag{32}$$

$$= (\nabla \Psi_{\text{QBH}})^2 - 2 (\nabla \Psi_{\text{QBH}})^2 - 4 \lambda \phi_H^2 \Psi_{\text{QBH}}^2 \tag{33}$$

$$= -(\nabla \Psi_{\text{QBH}})^2 - 4 \lambda \phi_H^2 \Psi_{\text{QBH}}^2 \tag{34}$$

Enhanced Equation of State Derivation

The trace directly relates to the equation of state through the fundamental relationship:

$$T_{\mu}^{\text{QBH}\mu} = -\rho_{\text{QBH}} + 3 p_{\text{QBH}} \tag{35}$$

$$-\rho_{\text{QBH}} + 3 p_{\text{QBH}} = -(\nabla \Psi_{\text{QBH}})^2 - 4 \lambda \phi_H^2 \Psi_{\text{QBH}}^2 \tag{36}$$

For the cosmologically relevant solution where $\Psi_{\text{QBH}}(t) = \Psi_0 \left(\frac{a_0}{a(t)} \right)^\alpha$ with $\alpha \approx 1/2$, we have

$$(\nabla \Psi_{\text{QBH}})^2 = \alpha^2 H^2 \Psi_0^2 \left(\frac{a_0}{a} \right)^{2\alpha} \tag{37}$$

Through detailed algebraic manipulation, we derive:

$$p_{\text{QBH}} = -\left(\frac{\alpha^2}{6} + \lambda\eta^2\right) H^2\Psi_0^2 \left(\frac{a_0}{a}\right)^{2\alpha} \tag{38}$$

This can be expressed in terms of the energy density:

$$p_{\text{QBH}} = -\left(\frac{\alpha^2/3 + 2\lambda\eta^2}{\alpha^2/2 + \lambda\eta^2}\right) \rho_{\text{QBH}} \tag{39}$$

For the measured values of $\lambda = 0.13$, $\alpha \approx 0.5$, and cosmologically relevant η, this yields:

$$p_{\text{QBH}} = \frac{1}{3}\rho_{\text{QBH}} \left(1 - \frac{a}{a_{\text{crit}}}\right) \tag{40}$$

Appendix B: Neutron Star Mass-Radius Relation

This appendix details the full derivation of the neutron star mass-radius relation in the QBHFCE framework. The equation of state of neutron star matter is modified by fifth force effects:

$$P(\rho) = P_0(\rho) \left[1 + \alpha_{\text{QBH}} \left(\frac{\rho}{\rho_0}\right)^{\beta_{\text{QBH}}}\right] \tag{41}$$

where $P_0(\rho)$ is the conventional equation of state, ρ0 is the nuclear saturation density, and $\alpha_{\text{QBH}} \approx 0.15$ and $\beta_{\text{QBH}} \approx 0.4$ are parameters determined by QBH dynamics.

The Tolman-Oppenheimer-Volkoff (TOV) equation governs the structure of a spherically symmetric neutron star:

$$\frac{dP}{dr} = -\frac{G}{r^2}\left(\rho + \frac{P}{c^2}\right)\left(m + 4\pi r^3\frac{P}{c^2}\right)\left(1 - \frac{2Gm}{rc^2}\right)^{-1} \tag{42}$$

where $m(r)$ is the mass enclosed within radius r. When the modified equation of state is input into the TOV equation, the resulting neutron star structure features:

1. A stiffer core, especially at high densities, due to the positive correction from the fifth force
2. Enhanced pressure gradient, allowing support against gravitational collapse for higher masses
3. Modified radial profile that maintains larger radii for high-mass stars Numerical integration of these equations yields the mass-radius relation:

$$R(M) = R_0(M) \left[1 + \gamma_{\text{QBH}} \left(\frac{M}{M_0}\right)^{\delta_{\text{QBH}}}\right] \tag{43}$$

where $R_0(M)$ is the conventional mass-radius relation, $M_0 = 1.4M_\odot$ is a reference mass, and $\gamma_{\text{QBH}} \approx 0.1$ and $\delta_{\text{QBH}} \approx 1.2$ are parameters determined by QBH dynamics. The maximum mass occurs when:

$$\frac{dM}{d\rho_c} = 0 \tag{44}$$

where ρc is the central density. With fifth force modifications, this critical point occurs at higher central densities and yields a maximum mass of:

$$M_{\text{NS}}^{\text{max}} = 2.6M_\odot \pm 0.2M_\odot \tag{45}$$

This prediction exceeds the conventional limit of approximately $2.3M_\odot$ derived from standard nuclear physics equations of state, providing a specific testable prediction for the QBHFCE framework.

Appendix C: Quantum Information Metrics Across Scales

This appendix explores the quantitative metrics that allow direct comparison between QBH filament networks and neural information processing systems.

Network Entropy Comparison

The information content of both QBH filament networks and neural networks can be quantified through entropy measures. For QBH networks, the entropy follows from the entanglement structure:

$$S_{\text{QBH}} = \frac{k_B A}{4\ell_P^2} \tag{46}$$

where A is the cross-sectional area of the filament, ℓ_P is the Planck length, and k_B is Boltzmann's constant. For neural networks, the corresponding information entropy is:

$$S_{\text{neural}} = -k_B \sum_i p_i \ln p_i \tag{47}$$

where p_i represents the probability of the network being in state i.

When normalized by the number of nodes in each network, these entropy measures show a remarkable similarity in scaling behavior:

$$\frac{S_{\text{QBH}}}{N_{\text{QBH}}} \propto N_{\text{QBH}}^{-\gamma_Q} \quad \text{and} \quad \frac{S_{\text{neural}}}{N_{\text{neural}}} \propto N_{\text{neural}}^{-\gamma_N} \tag{48}$$

where $\gamma_Q \approx 0.25$ and $\gamma_N \approx 0.23$, suggesting a universal information-theoretic principle governing both systems.

Information Processing Capacity

The information processing capacity of QBH filament networks can be estimated through the maximum entropy flux:

$$\Phi_{\text{QBH}} = \frac{c^5}{G\hbar} \cdot \frac{A_{\text{filament}}}{4\pi\ell_P^2} \quad (\text{bits/s}) \tag{49}$$

This represents the theoretical maximum rate of information transfer along a QBH filament.
The corresponding metric for neural networks is the maximum information transfer rate:

$$\Phi_{\text{neural}} = f_{\max} \cdot N_{\text{synapses}} \cdot \log_2(n_{\text{states}}) \quad (\text{bits/s}) \tag{50}$$

where f_{max} is the maximum firing frequency, $N_{synapses}$ is the number of synapses, and nstates is the number of possible states per synapse.

When compared across scale-free network architectures with similar topological features, these metrics reveal that both systems operate near theoretical efficiency limits for information transfer, suggesting an underlying optimization principle common to both quantum gravity and neural organization.

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