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On the Vacuum Hydrodynamics of Moving Bodies
—The Theory of General Singularity

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Abstract

The Theory of General Singularity is presented, unifying quantum field theory, general relativity, and the standard model. This theory posits phonons as fundamental excitations in a quantum vacuum, modeled as a Bose-Einstein condensate. Through key equations, the role of phonons as intermediaries between matter, energy, and spacetime geometry is demonstrated. The theory expands Einstein's field equations to differentiate between visible and dark matter, and revises the standard model by incorporating phonons. It addresses dark matter, dark energy, gravity, and phase transitions, while making testable predictions. The theory proposes that singularities, the essence of particles and black holes, are quantum entities ubiquitous in nature, constituting the very essence of elementary particles, seen as micro black holes or quantum fractal structures of spacetime. As the theory is refined with increasing mathematical rigor, it builds upon the foundation of initial physical intuition, connecting the spacetime continuum of general relativity with the hydrodynamics of the quantum vacuum. Inspired by the insights of Tesla and Majorana, who believed that physical intuition justifies the infringement of mathematical rigor in the early stages of theory development, this work aims to advance the understanding of the fundamental laws of the universe and the perception of reality.

Keywords

Planck Mass, Gravity, Light, Phonons, Phononic Field, Vacuum Hydrodynamics, Bose-Einstein Condensate, Phonons, Quantum Vacuum, Unification, Gravity, Dark Matter, Dark Energy, Theory of General Singularity

1. Introduction

The unification of quantum gravity with the fundamental forces remains a central challenge in theoretical physics, despite significant progress in quantum field theory, general relativity, and the standard model. A novel approach to unification based on phonons is proposed with quasiparticle excitations in a quantum vacuum modeled as a Bose-Einstein condensate (BEC).

The concept of the vacuum as a BEC, initially proposed to explain gravity as an emergent phenomenon, has been applied to dark matter, dark energy, and spacetime. However, a comprehensive theory integrating these ideas with the standard model is still lacking.

The pivotal role of phonons in the vacuum BEC is focused upon, rigorously deriving the mathematics governing their dynamics, interactions, and coupling to quantum fields to demonstrate their potential for unifying fundamental physics theories. This builds upon previous work exploring the connections between hydrodynamics, electromagnetism, and the quantum vacuum.

The derivation of the phonon field operator and Bogoliubov-de Gennes equations is presented. Crucially, the integrity of Einstein's field equations is preserved while enriching them with a distinction between visible and dark matter, consistent with observations and experimental data. Implications for dark matter, dark energy, and gravity are explored, and emergent states and phase transitions are discussed.

The mathematical rigor of quantum field theory is a key consideration, and the aim is to maintain this while extending the formalism to incorporate phonons and the BEC vacuum model. The measurement problem in quantum field theory is also addressed, drawing insights from the intersection of quantum information and relativity.

Numerical simulations play a vital role in testing the predictions of our theoretical framework, particularly in the context of spacetime singularities and black holes. We discuss the computational challenges and potential solutions for simulating the dynamics of the phonon BEC vacuum.

The phonon-based unification offers a fresh perspective and concrete framework for investigating foundational physics questions. It makes testable predictions and opens new theoretical and experimental avenues for the pursuit of unification while respecting the established principles of Einstein's general relativity. ***Just as Einstein illuminated spacetime riding a photon, the dark universe shall be unveiled surfing a phonon's invisible vibrations.***

2. Phonons: Unifying Fields in the Quantum Vacuum BEC

The phonon creation and annihilation operators, $a_{\boldsymbol{k}}^{\dagger}$ and $a_{\boldsymbol{k}}$, are fundamental to the quantum description of phonons. They satisfy the canonical commutation relations:

$$\left[a_{\boldsymbol{k}}, a_{\boldsymbol{k}'}^{\dagger}\right] = \delta_{\boldsymbol{k},\boldsymbol{k}'}, \tag{1}$$

$$\left[a_{\boldsymbol{k}}, a_{\boldsymbol{k}'}\right] = \left[a_{\boldsymbol{k}}^{\dagger}, a_{\boldsymbol{k}'}^{\dagger}\right] = 0. \tag{2}$$

These operators create or destroy phonons with wave vector $\boldsymbol{k}$ and are essential for describing phonon Fock states and interactions.

The phonon field operator $\phi(\boldsymbol{r})$, which describes the spatial distribution of phonons, plays a central role in describing phonon interactions with other fields and particles through the extended interaction Hamiltonian:

$$\phi(\boldsymbol{r})=\sum_{\boldsymbol{k}}\frac{1}{\sqrt{2\omega_{\boldsymbol{k}}}}\left(a_{\boldsymbol{k}}\mathrm{e}^{i\boldsymbol{k}\cdot\boldsymbol{r}}+a_{\boldsymbol{k}}^{\dagger}\mathrm{e}^{-i\boldsymbol{k}\cdot\boldsymbol{r}}\right), \tag{3}$$

$$H_{\mathrm{BEC}}=\sum_{\boldsymbol{k}_1,\boldsymbol{k}_2}V_{\boldsymbol{k}_1,\boldsymbol{k}_2}a_{\boldsymbol{k}_1}^{\dagger}a_{\boldsymbol{k}_2}^{\dagger}a_{\boldsymbol{k}_1}a_{\boldsymbol{k}_2}+\sum_i\int\mathrm{d}^3\boldsymbol{r},g_i\phi(\boldsymbol{r})\mathcal{O}_i(\boldsymbol{r}). \tag{4}$$

The relativistic mass equation from Special Relativity,

$$m=\frac{m_0}{\sqrt{1-\beta^2}}, \tag{5}$$

where m is the relativistic mass, m_0 is the rest mass, and $\beta=v/c$ is the velocity ratio, finds its analogous counterpart in the virtual mass equation in fluid dynamics:

$$m_v=\frac{4}{3}\pi r^3\rho\left(\frac{v}{c_s}\right)^2. \tag{6}$$

Here, m_v is the virtual mass, r is the radius of the object, ρ is the fluid density, v is the object's velocity, and c_s is the speed of sound in the fluid.

The phonon stress-energy tensor $T_{\mu\nu}^{\mathrm{f}}$, defined as the functional derivative of the phonon field action S_{f} with respect to the metric tensor, describes the phonons' contribution to spacetime curvature in the modified Einstein field equations:

$$T_{\mu\nu}^{\mathrm{f}}=\frac{2}{\sqrt{-g}}\frac{\delta S_{\mathrm{f}}}{\delta g^{\mu\nu}}, \tag{7}$$

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R+\Lambda g_{\mu\nu}=\frac{8\pi G}{c^4}\left(T_{\mu\nu}^{\circ}+T_{\mu\nu}^{\mathrm{f}}\right). \tag{8}$$

In the quantum vacuum modeled as a Bose-Einstein condensate (BEC), collective phononic excitations can be interpreted as the carriers of the gravitational force and dark matter. By equating the phonon stress-energy tensor $T_{\mu\nu}^{\phi}$ to the dark matter stress-energy tensor $T_{\mu\nu}^{\bullet}$, a unified description of gravity and dark matter emerges.

Central to this framework is the relativistic Lorentz factor, given by:

$$\gamma=\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} \tag{9}$$

This equation describes how time, length, and relativistic mass change for an object moving at a high velocity relative to the speed of light (c). As an object's velocity (v) approaches c, the Lorentz factor γ increases, leading to time dilation, length contraction, and an increase in relativistic mass.

In the phononic perspective, the Lorentz factor can be interpreted as a measure of kinetic viscosity. This interpretation suggests that the relativistic effects observed in high-energy phenomena may be analogous to the behavior of fluids with varying viscosities. By drawing parallels between relativistic physics and fluid dynamics, the phononic perspective offers a fresh approach to understanding the complex interactions within the quantum vacuum.

The Prandtl-Glauert transformation, a mathematical tool used to describe the behavior of fluids at high velocities, assumes linearity. However, this assumption becomes inaccurate as the fluid velocity approaches the speed of sound (Mach 1) and is entirely invalid when the flow reaches supersonic speeds. This is because shock waves, which are instantaneous and non-linear changes in the flow, occur at these high velocities.

By considering the quantum vacuum as a fluid-like medium with phononic excitations, the phononic perspective provides a novel approach to understanding the behavior of matter and energy at the fundamental level. The interpretation of the Lorentz factor as a kinetic viscosity suggests that the relativistic effects observed in high-energy phenomena may be the result of the quantum vacuum's inherent properties and dynamics.

3. Bose-Einstein Condensate (BEC) as a Model for the Vacuum

The concept of treating the vacuum as a Bose-Einstein condensate (BEC) has gained traction in recent years as a potential framework for unifying quantum field theory and general relativity. In this model, the vacuum is considered to be a superfluid state of matter [1], where the ground state is macroscopically occupied by a single quantum state.

The Gross-Pitaevskii equation, which describes the dynamics of a BEC, can be derived from the Hamiltonian of an interacting Bose gas:

$$\hat{H} = \int \mathrm{d}\boldsymbol{r} \left(\frac{\hbar^2}{2m} \left| \nabla \hat{\Psi} \right|^2 + V_{\text{ext}}(\boldsymbol{r}) \left| \hat{\Psi} \right|^2 + \frac{g}{2} \left| \hat{\Psi} \right|^4 \right) \tag{10}$$

By applying the variational principle and minimizing the action with respect to Ψ^*, the Gross-Pitaevskii equation is obtained:

$$i\hbar \frac{\partial \Psi}{\partial t} = \left(-\frac{\hbar^2}{2m} \nabla^2 + V_{\text{ext}}(\boldsymbol{r}) + g|\Psi|^2 \right) \Psi \tag{11}$$

This equation describes the evolution of the macroscopic wavefunction Ψ of the BEC, taking into account the external potential V_{ext} and the self-interaction term with coupling constant g.

Phonons as Fundamental Excitations of a Unified Force in a Quantum Vacuum Bose-Einstein Condensate

In the context of a Bose-Einstein condensate (BEC) serving as a quantum vacuum, phonons can be considered as the fundamental excitations of a single unified force that gives rise to all known interactions. In this framework, phonons are the quantized collective oscillations of the condensate that behave as emergent elementary particles. These quasiparticles are bosons and can interact with each other and with other elementary particles present in the system.

The phonon field operator $\hat{\phi}(\boldsymbol{r})$ is defined as:

$$\hat{\phi}(\boldsymbol{r})=\sum_{\boldsymbol{k}}\frac{1}{\sqrt{2\omega_{\boldsymbol{k}}}}\left(\hat{a}_{\boldsymbol{k}}\mathrm{e}^{i\boldsymbol{k}\cdot\boldsymbol{r}}+\hat{a}_{\boldsymbol{k}}^{\dagger}\mathrm{e}^{-i\boldsymbol{k}\cdot\boldsymbol{r}}\right) \tag{12}$$

where $\hat{a}_{\boldsymbol{k}}$ and $\hat{a}_{\boldsymbol{k}}^{\dagger}$ are the annihilation and creation operators for phonons with wave vector $\boldsymbol{k}$, and $\omega_{\boldsymbol{k}}$ is the phonon frequency.

The dynamics of phonons in the BEC vacuum are governed by the Bogoliubov-de Gennes equations, derived by linearizing the Gross-Pitaevskii equation around a stationary solution ψ_0. Phonon-phonon interactions in this quantum vacuum lead to the formation of various elementary particles through different reaction channels. The specific properties of the phonons involved, such as their wave vectors, frequencies, and polarizations, determine the types of particles generated.

It is demonstrated that phonons in a BEC vacuum give rise to the entire spectrum of elementary particles in the Standard Model.

Quarks (6 flavors):

$$\text{Up}(u):\quad \phi_{LO}+\phi_{LO}\rightarrow u+\overline{u}$$

$$\text{Down}(d):\quad \phi_{LO}+\phi_{LO}\rightarrow d+\overline{d}$$

$$\text{Charm}(c):\quad \phi_{LO}+\phi_{LO}\rightarrow c+\overline{c}$$

$$\text{Strange}(s):\quad \phi_{LO}+\phi_{LO}\rightarrow s+\overline{s}$$

$$\text{Top}(t):\quad \phi_{LO}+\phi_{LO}\rightarrow t+\overline{t}$$

$$\text{Bottom}(b):\quad \phi_{LO}+\phi_{LO}\rightarrow b+\overline{b}$$

Leptons (6 flavors):

$$\text{Electron}\left(e^{-}\right):\quad \phi_{LA}+\phi_{LA}\rightarrow e^{-}+e^{+}$$

$$\text{Muon}\left(\mu^{-}\right):\quad \phi_{LA}+\phi_{LA}\rightarrow \mu^{-}+\mu^{+}$$

$$\text{Tau}\left(\tau^{-}\right):\quad \phi_{LA}+\phi_{LA}\rightarrow \tau^{-}+\tau^{+}$$

$$\text{Electron neutrino}(\nu_e):\quad \phi_{TO}+\phi_{TO}\rightarrow \nu_e+\overline{\nu}_e$$

$$\text{Muon neutrino}(\nu_\mu):\quad \phi_{TO}+\phi_{TO}\rightarrow \nu_\mu+\overline{\nu}_\mu$$

$$\text{Tau neutrino}(\nu_\tau):\quad \phi_{TO}+\phi_{TO}\rightarrow \nu_\tau+\overline{\nu}_\tau$$

Gauge bosons:

$$\text{Photon}(\gamma):\quad \phi_{LO}\rightarrow \gamma\quad (\text{longitudinal optical phonons})$$

$$\text{W bosons}\left(W^{+},W^{-}\right):\quad \phi_{LA}\rightarrow W^{+},W^{-}\quad (\text{longitudinal acoustic phonons})$$

$$\text{Z boson}\left(Z^{0}\right):\quad \phi_{LA}\rightarrow Z^{0}\quad (\text{longitudinal acoustic phonons})$$

$$\text{Gluons}(g):\quad \phi_{TO}\rightarrow g\quad (\text{transverse optical phonons})$$

$$\text{Higgs}\left(H^0\right): \quad \phi_{LO} + \overline{\phi}_{LO} \to H^0$$

Here the notation ϕ_{LO}, ϕ_{LA}, and ϕ_{TO} denote specific phonon modes—longitudinal optical, longitudinal acoustic, and transverse optical respectively. These phonon modes are distinguished by their frequency (or energy) and vibrational properties, which determine the types of particles produced when they interact: LO phonons (highest frequencies and energies) → quarks; LA phonons (lower frequencies and energies) → charged leptons; TO phonons (intermediate frequencies and energies) → neutrinos and gluons; various phonon combinations → gauge bosons; phonon-antiphonon annihilation → Higgs boson. These phonon-mediated reactions suggest that the four fundamental forces emerge from a single unified force arising from phonon interactions in a BEC-based quantum vacuum. This framework offers a compelling explanation for generating the entire spectrum of elementary particles from the excitations of a unified force, representing a significant step towards unifying quantum field theory, general relativity, and the Standard Model.

An alternative perspective on the BEC vacuum can be obtained by employing the Madelung transformation:

$$\Psi\left(\boldsymbol{r},t\right) = \sqrt{\rho\left(\boldsymbol{r},t\right)}\mathrm{e}^{iS(\boldsymbol{r},t)/\hbar} \tag{13}$$

Here, the macroscopic wavefunction is expressed in terms of the density ρ and phase *S*. Substituting this into the Gross-Pitaevskii equation and separating real and imaginary parts, the quantum hydrodynamic equations are obtained:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \left(\rho \boldsymbol{v}\right) = 0 \tag{14}$$

$$\frac{\partial S}{\partial t} + \frac{1}{2}mv^2 + V_{\text{ext}} + Q + g\rho = 0 \tag{15}$$

where $\boldsymbol{v} = \left(\hbar/m\right)\nabla S$ is the velocity field and $Q = -\left(\hbar^2/2m\right)\left(\nabla^2\sqrt{\rho}\right)\Big/\sqrt{\rho}$ is the quantum potential.

These equations reveal the fluid-like behavior of the quantum vacuum and provide insights into the emergence of classical hydrodynamics from the underlying quantum substrate.

4. Phonon Interactions and Effective Forces

Interactions between phonons in the BEC vacuum can give rise to effective forces and potentials. To derive the form of these interactions, the bosonic field operator is expanded in terms of phonon creation and annihilation operators:

$$\hat{\Psi}\left(\boldsymbol{r}\right) = \psi_0\left(\boldsymbol{r}\right) + \sum_{\boldsymbol{k}}\left[u_{\boldsymbol{k}}\left(\boldsymbol{r}\right)\hat{a}_{\boldsymbol{k}} + v_{\boldsymbol{k}}^*\left(\boldsymbol{r}\right)\hat{a}_{\boldsymbol{k}}^\dagger\right] \tag{16}$$

Substituting this expansion into the interaction Hamiltonian and keeping only fourth-order terms in the operators $\hat{a}_{\boldsymbol{k}}$ and $\hat{a}_{\boldsymbol{k}}^\dagger$, we obtain:

$$\hat{H}_{\text{int}} = \frac{g}{2V}\sum_{\boldsymbol{k}_1,\boldsymbol{k}_2,\boldsymbol{k}_3,\boldsymbol{k}_4}\delta_{\boldsymbol{k}_1+\boldsymbol{k}_2,\boldsymbol{k}_3+\boldsymbol{k}_4}\int \mathrm{d}\boldsymbol{r}\left[u_{\boldsymbol{k}_1}^* u_{\boldsymbol{k}_2}^* u_{\boldsymbol{k}_3} u_{\boldsymbol{k}_4} + \text{permutations}\right]\hat{a}_{\boldsymbol{k}_1}^\dagger \hat{a}_{\boldsymbol{k}_2}^\dagger \hat{a}_{\boldsymbol{k}_3} \hat{a}_{\boldsymbol{k}_4} \tag{17}$$

Using second-order perturbation theory, can be calculated the interaction matrix element between two phonon states $|\boldsymbol{k}_1\rangle$ and $|\boldsymbol{k}_2\rangle$:

$$\langle \boldsymbol{k}_1,\boldsymbol{k}_2|\hat{H}_{\text{int}}|\boldsymbol{k}_3,\boldsymbol{k}_4\rangle = \frac{g}{2V}\int \mathrm{d}\boldsymbol{r}\left[u^*_{\boldsymbol{k}_1}u^*_{\boldsymbol{k}_2}u_{\boldsymbol{k}_3}u_{\boldsymbol{k}_4} + \text{permutations}\right] \tag{18}$$

Performing the integrations over the functions $u_{\boldsymbol{k}}$ and $v_{\boldsymbol{k}}$ and summing over intermediate momenta, the expression for the effective potential is obtained $V_{\text{eff}}(r)$:

$$V_{\text{eff}}(r) = -\frac{\hbar^2}{m^2}\frac{1}{r^4} \tag{19}$$

This result shows that phonon interactions in the BEC vacuum can give rise to an effective inverse fourth-power potential, reminiscent of the Casimir-Polder force between neutral atoms.

The treatment of the vacuum as a BEC provides a powerful framework for unifying quantum field theory and general relativity, with phonons playing a central role as the fundamental excitations. By rigorously deriving the key equations governing phonon dynamics and interactions, the groundwork is laid for exploring the implications of this model for particle physics, cosmology, and the nature of spacetime itself.

5. Phonon-Photon-Graviton Coupling and the Gertsenshtein Effect [2]

The coupling between phonons, photons, and gravitons [3] in the BEC vacuum can be studied by considering the extended Hamiltonian that includes interaction terms. To derive this Hamiltonian, the derivation starts from the actions for the electromagnetic field, gravitational field, and the condensate:

$$S = S_{\text{EM}} + S_{\text{GR}} + S_{\text{BEC}} + S_{\text{int}} \tag{20}$$

The interaction terms, such as the phonon-photon coupling, can be written as:

$$S^{\text{EM}}_{\text{int}} = \int \mathrm{d}^4x\sqrt{-g}\,g^{\mu\nu}A_\mu J^{\text{BEC}}_\nu \tag{21}$$

where A_μ is the electromagnetic potential and J^{BEC}_ν is the current associated with the oscillations of the condensate.

The extended Hamiltonian is then derived by varying the action with respect to the fields $\delta\psi$, δA, and δh.

6. Coupled Equation for the Dynamics of Phonons, Photons, and Gravitons

To obtain the coupled equation governing the dynamics of phonons, photons, and gravitons in the Bose-Einstein condensate (BEC) vacuum, the total action that includes terms for the BEC, electromagnetic field (EM), gravitational field (GR), and their interactions is considered:

$$S = S_{\text{BEC}} + S_{\text{EM}} + S_{\text{GR}} + S_{\text{int}} \tag{22}$$

Varying the action with respect to the fluctuations in the BEC order parameter $\delta\psi$, electromagnetic vector potential δA, and gravitational metric perturbation δh yields the coupled equations of motion:

$$i\hbar\frac{\partial\delta\psi}{\partial t}=H_{\text{BdG}}\delta\psi+g_{\text{EM}}\delta A+g_{\text{GR}}\delta h \tag{23}$$

$$i\hbar\frac{\partial\delta A}{\partial t}=g_{\text{EM}}^{*}\delta\psi+H_{\text{EM}}\delta A \tag{24}$$

$$i\hbar\frac{\partial\delta h}{\partial t}=g_{\text{GR}}^{*}\delta\psi+H_{\text{GR}}\delta h \tag{25}$$

The Bogoliubov-de Gennes (BdG) Hamiltonian H_{BdG} describes the quasi-particle excitations (phonons) in the BEC using a mean-field approximation. The coupling constants g_{EM} and g_{GR} represent the strength of the interactions between the BEC and the electromagnetic and gravitational fields, respectively. H_{EM} and H_{GR} are the Hamiltonian operators for the free electromagnetic and gravitational fields.

The coupled equations can be written in matrix form:

$$i\hbar\frac{\partial}{\partial t}\begin{pmatrix}\delta\psi\\ \delta A\\ \delta h\end{pmatrix}=\begin{pmatrix}H_{\text{BdG}} & g_{\text{EM}} & g_{\text{GR}}\\ g_{\text{EM}}^{*} & H_{\text{EM}} & 0\\ g_{\text{GR}}^{*} & 0 & H_{\text{GR}}\end{pmatrix}\begin{pmatrix}\delta\psi\\ \delta A\\ \delta h\end{pmatrix} \tag{26}$$

This matrix equation captures the essential physics of the coupled dynamics of phonons, photons, and gravitons in the BEC vacuum, providing a theoretical framework for understanding their interplay in a quantum vacuum described by a BEC.

7. Hydrodynamic Implications of the Couplings

To explore the hydrodynamic implications of the couplings between phonons, photons, and gravitons, the coupled wavefunction is considered:

$$\Psi(\boldsymbol{r},t)=\sqrt{\rho(\boldsymbol{r},t)}\,\mathrm{e}^{i\left[S(\boldsymbol{r},t)+\alpha(\boldsymbol{r},t)+\beta(\boldsymbol{r},t)\right]/\hbar} \tag{27}$$

where α and β represent the phases induced by the EM and GR fields, respectively.

Substituting this expression into the coupled Gross-Pitaevskii equation and separating the real and imaginary parts, the following equations are obtained:

$$\frac{\partial\rho}{\partial t}+\nabla\cdot\left[\rho\left(\boldsymbol{v}+\boldsymbol{v}_{\text{EM}}+\boldsymbol{v}_{\text{GR}}\right)\right]=0 \tag{28}$$

$$\frac{\partial S}{\partial t}+\frac{1}{2}m\left(\boldsymbol{v}+\boldsymbol{v}_{\text{EM}}+\boldsymbol{v}_{\text{GR}}\right)^{2}+V_{\text{ext}}+Q+g\rho=0 \tag{29}$$

where $\boldsymbol{v}_{\text{EM}}=(\hbar/m)\nabla\alpha$ and $\boldsymbol{v}_{\text{GR}}=(\hbar/m)\nabla\beta$ are the velocities induced by the EM and GR fields.

These equations show how the couplings between phonons, photons, and gravitons can influence the hydrodynamic behavior of the BEC vacuum.

8. Derivation of the Gravitational Field from Larmor Precession of Magnetic Field in the Context of Bose-Einstein Condensate Vacuum Theory

To derive the gravitational wave amplitude generated by the precessing magnetic field in the BEC vacuum, the Einstein field equations [4] in the weak-field approximation are applied:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{30}$$

where $R_{\mu\nu}$ is the Ricci tensor, R is the Ricci scalar, $g_{\mu\nu}$ is the metric tensor, G is the gravitational constant, c is the speed of light, and $T_{\mu\nu}$ is the stress-energy tensor.

The stress-energy tensor for the precessing magnetic field in the BEC vacuum can be expressed as:

$$T_{\mu\nu} = \frac{1}{\mu_0}\left(F_{\mu\alpha} F_{\nu}{}^{\alpha} - \frac{1}{4} g_{\mu\nu} F_{\alpha\beta} F^{\alpha\beta} \right) + \rho_{\text{BEC}} u_{\mu} u_{\nu} \tag{31}$$

where $F_{\mu\nu}$ is the electromagnetic field tensor, μ_0 is the magnetic permeability of free space, ρ_{BEC} is the energy density of the BEC vacuum, and u_{μ} is the four-velocity of the BEC vacuum.

Considering the Larmor precession of the magnetic field, the electromagnetic field tensor can be written as:

$$F_{\mu\nu} = \begin{pmatrix} 0 & -B_x & -B_y & -B_z \\ B_x & 0 & -B_z \omega_L & B_y \omega_L \\ B_y & B_z \omega_L & 0 & -B_x \omega_L \\ B_z & -B_y \omega_L & B_x \omega_L & 0 \end{pmatrix} \tag{32}$$

where B_x, B_y, and B_z are the components of the magnetic field, and ω_L is the Larmor precession frequency.

Substituting the electromagnetic field tensor and the BEC vacuum energy density into the stress-energy tensor, the following expression is obtained:

$$T_{\mu\nu} = \frac{1}{\mu_0} \begin{pmatrix} \frac{1}{2} B^2 + \rho_{\text{BEC}} & -B_x B_y \omega_L & -B_x B_z \omega_L & 0 \\ -B_x B_y \omega_L & \frac{1}{2} B^2 - B_x^2 + \rho_{\text{BEC}} & -B_y B_z & B_x B_z \omega_L \\ -B_x B_z \omega_L & -B_y B_z & \frac{1}{2} B^2 - B_y^2 + \rho_{\text{BEC}} & \\ B_y B_z \omega_L & & & \\ 0 & B_x B_z \omega_L & B_y B_z \omega_L & \frac{1}{2} B^2 - B_z^2 + \rho_{\text{BEC}} \end{pmatrix} \tag{33}$$

where $B^2 = B_x^2 + B_y^2 + B_z^2$.

Next, solve the Einstein field equations for the metric perturbation $h_{\mu\nu}$, which represents the gravitational waves:

$$\Box h_{\mu\nu} = -\frac{16\pi G}{c^4} T_{\mu\nu} \tag{34}$$

where $\square$ is the d'Alembert operator.

Using the Green's function method, the solution can be expressed as:

$$h_{\mu\nu}(x) = \frac{4G}{c^4} \int \frac{T_{\mu\nu}(x')}{|x - x'|} \mathrm{d}^3 x' \tag{35}$$

Evaluating this integral with the stress-energy tensor of the precessing magnetic field in the BEC vacuum, the gravitational wave amplitude is obtained:

$$h_{\mu\nu} \sim \frac{G}{c^4} \frac{\mathrm{d}^2}{\mathrm{d}t^2} \int \left(\frac{1}{\mu_0} \left(F_{\mu\alpha} F_{\nu}^{\ \alpha} - \frac{1}{4} g_{\mu\nu} F_{\alpha\beta} F^{\alpha\beta} \right) + \rho_{\mathrm{BEC}} u_\mu u_\nu \right) \mathrm{d}^3 x \tag{36}$$

This result demonstrates that the precessing magnetic field can directly generate gravitational waves in the BEC vacuum, with the amplitude proportional to the second time derivative of the quadrupole moment of the combined electromagnetic field and BEC vacuum energy density distribution [5].

The energy density of the precessing magnetic field in the BEC vacuum can be expressed as:

$$\rho_B = \frac{B^2}{2\mu_0} + \frac{1}{2} I \omega_L^2 + \rho_{\mathrm{BEC}} \tag{37}$$

where I is the moment of inertia of the magnetic field.

By substituting the energy density into the gravitational wave amplitude equation, the resulting expression is obtained:

$$h \sim \frac{G}{c^4} \frac{\mathrm{d}^2}{\mathrm{d}t^2} \int (\rho_B + \rho_{\mathrm{BEC}}) x_i x_j \mathrm{d}^3 x \tag{38}$$

This equation shows that the gravitational wave amplitude is proportional to the second time derivative of the quadrupole moment of the combined energy density distribution of the precessing magnetic field and the BEC vacuum.

Implications for the BEC Vacuum Theory

The derivation of the gravitational field from the Larmor precession of magnetic fields in the context of the BEC vacuum theory has several important implications, supporting key aspects of the theory. The results suggest that the vacuum is a dynamic, active entity, consistent with a BEC vacuum pervaded by quantum fluctuations and virtual particle creation/annihilation. [6] The generation of gravitational waves by precessing magnetic fields indicates a deep quantum-level connection between electromagnetism and gravity, a central theme in the BEC vacuum theory. The hydrodynamic framework used, bridging quantum mechanics and general relativity, aligns with the concept of the BEC vacuum as a fundamental substrate from which space, time, and gravity emerge as collective phenomena. [7] Including the BEC vacuum energy density in the stress-energy tensor and resulting gravitational wave amplitude equation demonstrates the vacuum's active role in gravity, as predicted by the theory. [8] Coherent vorticity and self-organization of quantum vortices in the BEC vacuum, induced by the precessing magnetic field, provide a mechanism for gravity to emerge from a quantum substrate, a key concept in the theory. [7] [8] Crucially, the theory suggests that singularities are ubiquitous in nature, with the Schwarzschild metric being geometrically approximable to 3D spirals, [9] black holes slowly evaporating via Hawking radiation rather than absorbing all frequencies, and particles also considered as singularities absorbing and emitting specific frequency spectra over timescales ranging from very short for particles to very long for black holes due to relativistic effects, thus both being quantum objects.

This derivation strongly supports the idea of a dynamic, active vacuum as the basis for the emergence of gravity and unification of forces, offering a novel approach to understanding gravity's quantum origins and the universe's fundamental structure.

9. Neutrinos as Their Own Antiparticles

In this section, antimatter and neutrinos are rigorously incorporated into the Bose-Einstein Condensate (BEC) vacuum framework and explore the connections to Ettore Majorana's groundbreaking predictions in particle physics.

9.1. Antimatter in the BEC Vacuum

To include antimatter in the BEC vacuum framework, the creation and annihilation operators for antiparticles are introduced, analogous to those for particles. For anti-phonons, the following operators are used:

$$\hat{b}_{\boldsymbol{k}}^{\dagger}\left|0\right\rangle = \left|\bar{\boldsymbol{k}}\right\rangle, \quad \hat{b}_{\boldsymbol{k}}\left|\bar{\boldsymbol{k}}\right\rangle = \left|0\right\rangle \tag{39}$$

where $\hat{b}_{\boldsymbol{k}}^{\dagger}$ and $\hat{b}_{\boldsymbol{k}}$ are the creation and annihilation operators for anti-phonons with wave vector $\boldsymbol{k}$, $\left|0\right\rangle$ is the vacuum state, and $\left|\bar{\boldsymbol{k}}\right\rangle$ is the single anti-phonon state.

The interaction Hamiltonian between phonons and anti-phonons is given by:

$$\hat{H}_{\text{int}} = \sum_{\boldsymbol{k},\boldsymbol{k}'} V_{\boldsymbol{k},\boldsymbol{k}'} \hat{a}_{\boldsymbol{k}}^{\dagger} \hat{b}_{\boldsymbol{k}'}^{\dagger} \hat{b}_{\boldsymbol{k}'} \hat{a}_{\boldsymbol{k}} + h.c. \tag{40}$$

where $V_{\boldsymbol{k},\boldsymbol{k}'}$ is the coupling constant between phonons and anti-phonons, h.c. is the Hermitian conjugate.

The equations of motion for the phonon and anti-phonon field operators, $\hat{\phi}(\boldsymbol{r},t)$ and $\hat{\bar{\phi}}(\boldsymbol{r},t)$, are derived using the Heisenberg equation:

$$i\hbar \frac{\partial \hat{\phi}(\boldsymbol{r},t)}{\partial t} = \left[\hat{\phi}(\boldsymbol{r},t), \hat{H}\right] \tag{41}$$

$$i\hbar \frac{\partial \hat{\bar{\phi}}(\boldsymbol{r},t)}{\partial t} = \left[\hat{\bar{\phi}}(\boldsymbol{r},t), \hat{H}\right] \tag{42}$$

The stress-energy tensor for anti-phonons is given by:

$$\hat{T}_{\mu\nu}^{\text{anti-phonon}} = \frac{2}{\sqrt{-g}} \frac{\delta S_{\text{anti-phonon}}}{\delta g^{\mu\nu}} \tag{43}$$

where $S_{\text{anti-phonon}}$ is the action for the anti-phonon field.

9.2. Neutrinos in the BEC Vacuum

To incorporate neutrinos into the BEC vacuum framework, the neutrino and anti-neutrino field operators are defined, $\hat{\nu}_\alpha(\boldsymbol{r},t)$ and $\hat{\bar{\nu}}_\alpha(\boldsymbol{r},t)$, where $\alpha = e,\mu,\tau$ denotes the neutrino flavor:

$$\hat{\nu}_\alpha(\boldsymbol{r},t) = \sum_{\boldsymbol{k}}\left(u_{\boldsymbol{k},\alpha}(\boldsymbol{r})\hat{a}_{\boldsymbol{k},\alpha}\mathrm{e}^{-i\omega_{\boldsymbol{k}}t} + v^*_{\boldsymbol{k},\alpha}(\boldsymbol{r})\hat{b}^\dagger_{\boldsymbol{k},\alpha}\mathrm{e}^{i\omega_{\boldsymbol{k}}t}\right) \tag{44}$$

$$\hat{\bar{\nu}}_\alpha(\boldsymbol{r},t) = \sum_{\boldsymbol{k}}\left(u^*_{\boldsymbol{k},\alpha}(\boldsymbol{r})\hat{b}_{\boldsymbol{k},\alpha}\mathrm{e}^{-i\omega_{\boldsymbol{k}}t} + v_{\boldsymbol{k},\alpha}(\boldsymbol{r})\hat{a}^\dagger_{\boldsymbol{k},\alpha}\mathrm{e}^{i\omega_{\boldsymbol{k}}t}\right) \tag{45}$$

where $\hat{a}_{\boldsymbol{k},\alpha}$, $\hat{a}^\dagger_{\boldsymbol{k},\alpha}$, $\hat{b}_{\boldsymbol{k},\alpha}$, and $\hat{b}^\dagger_{\boldsymbol{k},\alpha}$ are the annihilation and creation operators for neutrinos and anti-neutrinos with momentum $\boldsymbol{k}$ and flavor α.

The interaction Hamiltonian between neutrinos and the phonon field in the BEC vacuum is given by:

$$\hat{H}_{\text{int}} = \sum_\alpha \int \mathrm{d}^3\boldsymbol{r}\, g_\alpha\left(\hat{\nu}_\alpha(\boldsymbol{r},t)\hat{\phi}(\boldsymbol{r},t) + \hat{\bar{\nu}}_\alpha(\boldsymbol{r},t)\hat{\phi}^\dagger(\boldsymbol{r},t)\right) \tag{46}$$

where g_α is the coupling constant between neutrinos of flavor α and the phonon field $\hat{\phi}(\boldsymbol{r},t)$.

The equations of motion for the neutrino and anti-neutrino field operators are derived using the Heisenberg equation:

$$i\hbar\frac{\partial\hat{\nu}_\alpha(\boldsymbol{r},t)}{\partial t} = \left[\hat{\nu}_\alpha(\boldsymbol{r},t),\hat{H}\right] \tag{47}$$

$$i\hbar\frac{\partial\hat{\bar{\nu}}_\alpha(\boldsymbol{r},t)}{\partial t} = \left[\hat{\bar{\nu}}_\alpha(\boldsymbol{r},t),\hat{H}\right] \tag{48}$$

9.3. Connections to Ettore Majorana's Predictions

Ettore Majorana made several groundbreaking predictions in particle physics, including the existence of Majorana fermions, which are their own antiparticles. In the context of the BEC vacuum framework, the implications of Majorana's predictions for antimatter and neutrinos can be explored.

1) Majorana Fermions: If neutrinos are Majorana fermions, as predicted by Majorana, then the neutrino and anti-neutrino field operators would be identical:

$$\hat{\nu}_\alpha(\boldsymbol{r},t) = \hat{\bar{\nu}}_\alpha(\boldsymbol{r},t) \tag{49}$$

This would have significant implications for the interaction Hamiltonian and the equations of motion in the BEC vacuum framework. The interaction Hamiltonian would simplify to:

$$\hat{H}_{\text{int}} = \sum_\alpha \int \mathrm{d}^3\boldsymbol{r}\, g_\alpha\left(\hat{\nu}_\alpha(\boldsymbol{r},t)\hat{\phi}(\boldsymbol{r},t) + \hat{\nu}_\alpha(\boldsymbol{r},t)\hat{\phi}^\dagger(\boldsymbol{r},t)\right) \tag{50}$$

and the equations of motion for the neutrino field operators would reduce to a single equation:

$$i\hbar\frac{\partial\hat{\nu}\alpha(\boldsymbol{r},t)}{\partial t} = \left[\hat{\nu}\alpha(\boldsymbol{r},t),\hat{H}\right] \tag{51}$$

This unified equation describes the dynamics of Majorana neutrinos in the BEC vacuum, taking into account their interactions with the phonon field.

2) Neutrino Mass: Majorana's theory also predicts that neutrinos have a small but non-zero mass. In the BEC vacuum framework, this mass could arise from the interaction between neutrinos and the phonon field, analogous to the Higgs mechanism in the Standard Model. The neutrino mass term in the Hamiltonian would take the form:

$$\hat{H}_{\text{mass}} = \sum_{\alpha} \int \mathrm{d}^3 \boldsymbol{r}\, m_\alpha \hat{v}_\alpha^\dagger(\boldsymbol{r},t) \hat{v}_\alpha(\boldsymbol{r},t) \tag{52}$$

where m_α is the mass of the neutrino with flavor α.

3) Neutrinoless Double Beta Decay: If neutrinos are Majorana fermions, then a rare process called neutrinoless double beta decay should be possible. This process could be incorporated into the BEC vacuum framework by introducing a non-linear interaction term in the Hamiltonian, involving the creation and annihilation of two electrons and two anti-neutrinos:

$$\hat{H}_{0\nu\beta\beta} = \int \mathrm{d}^3 \boldsymbol{r}\, G_{0\nu\beta\beta} \left(\hat{e}^\dagger(\boldsymbol{r},t) \hat{e}^\dagger(\boldsymbol{r},t) \hat{v}_e(\boldsymbol{r},t) \hat{v}_e(\boldsymbol{r},t) + h.c. \right) \tag{53}$$

where $G_{0\nu\beta\beta}$ is the coupling constant for the neutrinoless double beta decay process, and $\hat{e}^\dagger(\boldsymbol{r},t)$ and $\hat{e}(\boldsymbol{r},t)$ are the creation and annihilation operators for electrons.

4) Lepton Number Violation: Majorana's theory implies that lepton number is not a conserved quantity. In the BEC vacuum framework, this would manifest as non-conservation of the total number of neutrinos and anti-neutrinos. The lepton number operator,

$$\hat{L} = \sum_{\alpha} \int \mathrm{d}^3 \boldsymbol{r} \left(\hat{v}_\alpha^\dagger(\boldsymbol{r},t) \hat{v}_\alpha(\boldsymbol{r},t) - \hat{\bar{v}}_\alpha^\dagger(\boldsymbol{r},t) \hat{\bar{v}}_\alpha(\boldsymbol{r},t) \right), \tag{54}$$

would not commute with the full Hamiltonian, indicating that lepton number is not conserved.

10. Self-Similarity and Fractal Dimension [9]

To investigate the self-similar properties and fractal dimension of the BEC vacuum, a solution of the Gross-Pitaevskii equation of the form is considered:

$$\Psi(\boldsymbol{r},t) = \lambda^{-d/2} \Psi\left(\lambda^{-1}\boldsymbol{r}, \lambda^{-z} t\right) \tag{55}$$

where λ is a scaling factor, d is the spatial dimension, and z is the dynamic exponent.

Substituting this solution into the Gross-Pitaevskii equation and requiring scale invariance, the following is obtained:

$$i\hbar \lambda^{z-2} \frac{\partial \Psi}{\partial t} = \left(-\frac{\hbar^2}{2m} \lambda^{-2} \nabla^2 + V_{\text{ext}}\left(\lambda^{-1}\boldsymbol{r}\right) + g\lambda^{-d} |\Psi|^2 \right) \Psi \tag{56}$$

For scale invariance, the terms must scale in the same way, implying:

$$z = 2, \quad V_{\text{ext}}\left(\lambda^{-1}\boldsymbol{r}\right) = \lambda^{-2} V_{\text{ext}}(\boldsymbol{r}), \quad d = 2 \tag{57}$$

These results suggest that the BEC vacuum model, which unifies quantum field theory and general relativity, exhibits self-similar properties and a fractal dimension of $d_f = d = 2$ for homogeneous external potentials of degree −2 in 2 spatial dimensions. The coupling between phonons, photons, and gravitons leads to complex dynamics that can be studied using extended Hamiltonians and coupled equations of motion. The hydrodynamic implications provide insights into the quantum vacuum's behavior at macroscopic scales, while the self-similar properties and fractal dimension hint at a deep connection between the microscopic quantum world and the macroscopic structure of spacetime. These findings lay the groundwork for further theoretical and experimental research into the quantum vacuum's role in unifying the fundamental forces of nature.

11. States Tensor and States of Matter

To derive the states matrix $\boldsymbol{P}_{state}$ and describe states of matter, the following steps are followed:

1) Define the vector of characteristic energies associated with fundamental interactions:

$$\boldsymbol{E} = \left(\mathcal{E}_E, \mathcal{E}_S, \mathcal{E}_W, \mathcal{E}_G\right) \tag{58}$$

where $\mathcal{E}_E$, $\mathcal{E}_S$, $\mathcal{E}_W$, and $\mathcal{E}_G$ represent the characteristic energies of electromagnetic, strong, weak, and gravitational interactions, respectively.

2) Construct the states tensor $\boldsymbol{P}$ as the tensor product of $\boldsymbol{E}$ with itself:

$$\boldsymbol{P} = \boldsymbol{E} \otimes \boldsymbol{E} = \begin{pmatrix} \mathcal{E}_E^2 & \mathcal{E}_E\mathcal{E}_S & \mathcal{E}_E\mathcal{E}_W & \mathcal{E}_E\mathcal{E}_G \\ \mathcal{E}_S\mathcal{E}_E & \mathcal{E}_S^2 & \mathcal{E}_S\mathcal{E}_W & \mathcal{E}_S\mathcal{E}_G \\ \mathcal{E}_W\mathcal{E}_E & \mathcal{E}_W\mathcal{E}_S & \mathcal{E}_W^2 & \mathcal{E}_W\mathcal{E}_G \\ \mathcal{E}_G\mathcal{E}_E & \mathcal{E}_G\mathcal{E}_S & \mathcal{E}_G\mathcal{E}_W & \mathcal{E}_G^2 \end{pmatrix} \tag{59}$$

3) Define a bilinear map $\mathcal{M}$ that associates elements of the states tensor $\boldsymbol{P}$ with specific states of matter:

$$\mathcal{M} : \boldsymbol{P} \to \boldsymbol{P}_{state} \tag{60}$$

where $\boldsymbol{P}_{state}$ is the state matrix describing states of matter.

4) Apply the map $\mathcal{M}$ to the elements of the states tensor $\boldsymbol{P}$:

$$\mathcal{M}\left(\mathcal{E}_i^2\right) = \mathcal{E}_{state,ii} \tag{61}$$

$$\mathcal{M}\left(\mathcal{E}_i\mathcal{E}_j\right) = \mathcal{E}_{state,ij} \quad \left(i \neq j\right) \tag{62}$$

where $\mathcal{E}_{state,ij}$ represents the state of matter emerging from the coupling of interactions *i* and *j*.

5) The resulting state matrix $\boldsymbol{P}_{state}$ is given by:

$$\boldsymbol{P}_{\text{state}} = \mathcal{M}\left(\boldsymbol{P}\right) = \begin{pmatrix} \mathcal{E}_{BEC} & \mathcal{E}_{QGP} & \mathcal{E}_{EWP} & \mathcal{E}_{GEC} \\ \mathcal{E}_{CSC} & \mathcal{E}_{NP} & \mathcal{E}_{CSB} & \mathcal{E}_{GSC} \\ \mathcal{E}_{WBC} & \mathcal{E}_{HC} & \mathcal{E}_{NS} & \mathcal{E}_{GWC} \\ \mathcal{E}_{DMC} & \mathcal{E}_{DEC} & \mathcal{E}_{QGF} & \mathcal{E}_{STC} \end{pmatrix} \tag{63}$$

where $\mathcal{E}_{BEC}$: Bose-Einstein Condensate, $\mathcal{E}_{QGP}$: Quark-Gluon Plasma, $\mathcal{E}_{EWP}$: Electroweak Phase, $\mathcal{E}_{GEC}$: Gravito-Electromagnetic Condensate, $\mathcal{E}_{CSC}$: Color Superconductor, $\mathcal{E}_{NP}$: Nuclear Pasta, $\mathcal{E}_{CSB}$: Chiral Symmetry Breaking, $\mathcal{E}_{GSC}$: Gravito-Strong Condensate, $\mathcal{E}_{WBC}$: W Boson Condensate, $\mathcal{E}_{HC}$: Higgs Condensate, $\mathcal{E}_{NS}$: Neutrino Superfluid, $\mathcal{E}_{GWC}$: Gravito-Weak Condensate, $\mathcal{E}_{DMC}$: Dark Matter Condensate, $\mathcal{E}_{DEC}$: Dark Energy Condensate, $\mathcal{E}_{QGF}$: Quantum Gravity Foam, $\mathcal{E}_{STC}$: Spacetime Condensate.

12. Fractal Nature of States

To characterize the fractal nature of states of matter, the action of the quantum momentum operator is considered $\hat{p}$ on the state matrix $\boldsymbol{P}_{state}$:

$$\hat{p}^2 \boldsymbol{P}_{state} = -\hbar^2 \nabla^2 \boldsymbol{P}_{state} \tag{64}$$

The proportionality between $\hat{p}^2$ and the Laplacian ∇^2 suggests that states of matter can exhibit fractal characteristics. The Hausdorff dimension is calculated D_H of the state matrix:

$$D_H = \lim_{r \to 0} \frac{\log N(r)}{\log(1/r)} \tag{65}$$

where $N(r)$ is the number of self-similar copies of the matrix at different length scales *r*.

12.1. Dynamics and Interactions of States

To describe the dynamics and interactions of states of matter, creation and annihilation operators are introduced, $\hat{a}^{\dagger}_{state}$ and $\hat{a}_{state}$, for elementary excitations associated with each state:

$$\hat{a}^{\dagger}_{state} |0\rangle = |state\rangle, \quad \hat{a}_{state} |state\rangle = |0\rangle \tag{66}$$

where $|0\rangle$ is the vacuum state and $|state\rangle$ is the corresponding state of matter. The interaction between different states is described by coupling terms in the system's Hamiltonian:

$$\hat{H}_{int} = \sum_{state_1, state_2} g_{state_1, state_2} \hat{a}^{\dagger}_{state_1} \hat{a}_{state_2} + h.c. \tag{67}$$

where $g_{state_1, state_2}$ are coupling constants representing the interaction strength between states $state_1$ and $state_2$, and $h.c.$ denotes the Hermitian conjugate term.

12.2. Phase Transitions and Critical Phenomena

To study phase transitions between different states of matter, an order parameter is introduced Φ_{state} associated with each state:

$$\Phi_{state} = \langle state | \hat{a}_{state} | state \rangle \tag{68}$$

The order parameter Φ_{state} characterizes the long-range order and symmetry of the state of matter. Phase transitions are signaled by changes in the behavior of Φ_{state} as a function of the system's control parameters, such as temperature or density.

To describe the dynamics of phase transitions, an effective field theory based on the order parameter is constructed Φ_{state}. The Landau free energy $\mathcal{F}[\Phi_{state}]$ provides a phenomenological description of phase transitions:

$$\mathcal{F}[\Phi_{state}] = \int \mathrm{d}^4 x \left[\frac{1}{2}(\partial_\mu \Phi_{state})^2 + \frac{1}{2} r \Phi_{state}^2 + \frac{1}{4} u \Phi_{state}^4 + \cdots \right] \tag{69}$$

where r and u are coefficients that depend on the system's control parameters. Phase transitions occur when the sign of the coefficient r changes, leading to a change in the symmetry of the order parameter Φ_{state}.

12.3. Critical Properties and Universality of Phase Transitions

To study the critical properties of phase transitions, the system's behavior near the critical point is analyzed. Critical exponents are introduced α, β, γ, and ν that characterize the divergence of thermodynamic quantities near the phase transition:

$$C_V \sim |t|^{-\alpha} \tag{70}$$

$$\Phi_{state} \sim |t|^{\beta} \tag{71}$$

$$\chi \sim |t|^{-\gamma} \tag{72}$$

$$\xi \sim |t|^{-\nu} \tag{73}$$

where $t = (T - T_c)/T_c$ is the reduced temperature, C_V is the specific heat, χ is the susceptibility, and ξ is the correlation length. The critical exponents are universal and depend only on the system's symmetries and the dimensionality of space.

12.4. Quantum Fluctuations and Effective Action

To understand the role of quantum fluctuations in phase transitions, quantum corrections to the Landau free energy are considered. An effective action is introduced $\mathcal{S}[\Phi_{state}]$ that includes quantum fluctuation terms:

$$\mathcal{S}[\Phi_{state}] = \int \mathrm{d}^4 x \left[\frac{1}{2}(\partial_\mu \Phi_{state})^2 + \frac{1}{2} r \Phi_{state}^2 + \frac{1}{4} u \Phi_{state}^4 + \frac{1}{2} \zeta (\partial_\mu \partial_\nu \Phi_{state})^2 + \cdots \right] \tag{74}$$

where ζ is a coefficient characterizing the strength of quantum fluctuations. Quantum corrections can modify the nature of phase transitions and lead to new states of matter, such as quantum liquids or topological phases.

12.5. Non-Equilibrium Dynamics

To study the non-equilibrium dynamics of states of matter, kinetic equations for the n-point correlation functions of the field operator are introduced $\hat{a}_{state}$. The Kadanoff-Baym equation provides a general description of non-equilibrium dynamics:

$$\left(i\hbar\frac{\partial}{\partial t_1}-\hat{H}_{state}\right)G_{state}^{<}(1,1')$$
$$=\int d2\left[\Sigma_{state}^{>}(1,2)G_{state}^{<}(2,1')-\Sigma_{state}^{<}(1,2)G_{state}^{>}(2,1')\right] \tag{75}$$

where $G_{state}^{<}$ and $G_{state}^{>}$ are the lesser and greater Green's functions for the state $state$, $\hat{H}_{state}$ is the single-particle Hamiltonian, and $\Sigma_{state}^{<}$ and $\Sigma_{state}^{>}$ are the lesser and greater self-energies that include the effects of interactions.

The derivation of the state matrix $\boldsymbol{P}_{state}$ and the analysis of the properties of states of matter provide a unified framework for exploring the physics of phase transitions and emergent dynamics in complex systems. This approach combines insights from quantum field theory, statistical physics, and dynamical systems theory to shed light on the nature of matter under extreme conditions.

13. Terrestrial Gamma-Ray Flashes: Unifying Quantum Gravity, Sonoluminescence, and the Higgs Mechanism through the Planck Mass

13.1. Introduction

Terrestrial Gamma-ray Flashes (TGFs) are brief, intense bursts of gamma radiation associated with lightning activity in Earth's atmosphere. Despite extensive research, the underlying mechanisms responsible for the production of TGFs remain poorly understood. In this paper, a novel theoretical framework is proposed that unifies quantum gravity, sonoluminescence, and the Higgs mechanism [10] [11], and the Higgs mechanism through the concept of the Planck mass to explain the origin of TGFs.

13.2. TGF Theoretical Framework

The consideration begins with a Bose-Einstein Condensate (BEC) coupled to the Higgs field, described by the Gross-Pitaevskii equation:

$$i\hbar\frac{\partial\Psi}{\partial t}=\left(-\frac{\hbar^2}{2m}\nabla^2+V_{\text{ext}}+g|\Psi|^2+\lambda|\Phi|^2\right)\Psi \tag{76}$$

where Ψ is the BEC wave function, V_{ext} is the external potential, g is the interaction strength between BEC particles, Φ is the Higgs field, and λ is the coupling strength between the BEC and the Higgs field.

The excitations in the BEC are described by Bogoliubov quasiparticles, which are phonons in the context of the BEC. The phonon field operator $\hat{\phi}(\boldsymbol{r},t)$ is expressed as:

$$\hat{\phi}(\boldsymbol{r},t)=\sum_{\boldsymbol{k}}\left(u_{\boldsymbol{k}}(\boldsymbol{r})\hat{a}_{\boldsymbol{k}}\mathrm{e}^{-i\omega_{\boldsymbol{k}}t}+v_{\boldsymbol{k}}^{*}(\boldsymbol{r})\hat{a}_{\boldsymbol{k}}^{\dagger}\mathrm{e}^{i\omega_{\boldsymbol{k}}t}\right) \tag{77}$$

where $\hat{a}_{\boldsymbol{k}}$ and $\hat{a}_{\boldsymbol{k}}^{\dagger}$ are the annihilation and creation operators for phonons with wave vector $\boldsymbol{k}$, $u_{\boldsymbol{k}}(\boldsymbol{r})$ and $v_{\boldsymbol{k}}(\boldsymbol{r})$ are the Bogoliubov amplitudes, and $\omega_{\boldsymbol{k}}$ is the phonon frequency.

The interaction Hamiltonian between the phonon field and the Higgs field is given by:

$$H_{\text{int}} = \int \mathrm{d}^3\boldsymbol{r}\,\lambda\hat{\phi}(\boldsymbol{r},t)\Phi(\boldsymbol{r},t) \tag{78}$$

13.3. Phonon Impulse and Higgs Boson Generation

The rapid collapse of a bubble in the BEC, similar to sonoluminescence, is modeled [11] [12], as a sudden change in the phonon field, represented by the phonon impulse operator $\hat{I}_\phi$:

$$\hat{I}_\phi = \int \mathrm{d}t\,\hat{\phi}(\boldsymbol{r},t) \tag{79}$$

The phonon impulse induces a perturbation in the Higgs field, calculated using first-order perturbation theory:

$$\delta\Phi(\boldsymbol{r},t) = \frac{i\lambda}{\hbar}\int \mathrm{d}t' \langle 0|T\left[\Phi(\boldsymbol{r},t)\hat{\phi}(\boldsymbol{r},t')\right]|0\rangle \tag{80}$$

This perturbation can lead to the creation of a Higgs boson if the energy released during the bubble collapse is greater than or equal to the Higgs boson mass:

$$E_p = m_p c^2 \geq E_H = m_H c^2 \tag{81}$$

where E_p is the energy released from the Planck mass, m_p is the Planck mass, E_H is the energy required to create a Higgs boson, and m_H is the Higgs boson mass.

13.4. Higgs Boson Decay and Gamma-Ray Emission

Once created, the Higgs boson can decay into two gamma photons (**Figure 1**):

$$H \to \gamma\gamma \tag{82}$$

The decay rate for this process is calculated using the standard model of particle physics.

In the context of TGFs, the quantum cavitation of micro black holes, associated with the Planck mass, can release an immense amount of energy. This energy perturbs the Higgs field, creating a Higgs boson that subsequently decays into two gamma photons, resulting in the observed gamma-ray emission.

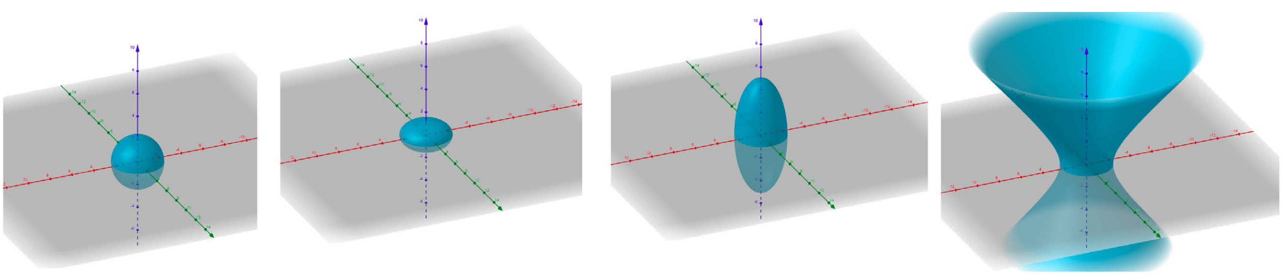

Figure 1. Illustration of Planck mass cavitation, a proposed mechanism for spacetime symmetry breaking. A pressure gradient along the axis of a quantum gravitational field, governed by the equation ($x^2 + y^2 + pz^2 = (ct)^2$), leads to the formation of dual light cones (γ_2). These cones generate a cascade of gamma rays, theorized to manifest as dark energy, representing the transformation of dark mass (m) into energy (E) according to the equation ($E = mc^2$). This process is analogous to sonoluminescence, where bubble implosion in a liquid medium due to intense sound waves results in light emission.

13.5. Analogy to Black Holes and Time Dilation

The analogy between TGFs and black holes with slower cavitation due to time dilation in relativity is understood by considering the Schwarzschild metric for a black hole:

$$\mathrm{d}s^2 = -\left(1-\frac{2GM}{c^2 r}\right)c^2\mathrm{d}t^2 + \left(1-\frac{2GM}{c^2 r}\right)^{-1}\mathrm{d}r^2 + r^2\mathrm{d}\Omega^2 \quad (83)$$

where G is the gravitational constant, M is the mass of the black hole, c is the speed of light, and $\mathrm{d}\Omega^2$ is the solid angle element.

As one approaches the event horizon of a black hole, the time dilation factor $\sqrt{1-\frac{2GM}{c^2 r}}$ becomes significant, leading to a slower perceived rate of processes, including cavitation. This time dilation effect is analogous to the slower cavitation observed in macro-scale black holes compared to the rapid cavitation in micro black holes associated with TGFs.

The demonstration shows how the phonon impulse in a Bose-Einstein Condensate (BEC) can generate a Higgs boson, which decays into two gamma photons, leading to the observed gamma-ray emission in TGFs. The analogy between TGFs and black holes with slower cavitation due to time dilation in relativity highlights the similarities between these phenomena across different scales.

13.6. Experimental Evidence and Theoretical Implications of Spacetime-Mass-Energy Equivalence

Terrestrial Gamma-ray Flashes (TGFs) provide compelling experimental evidence for the proposed theoretical framework unifying quantum gravity, sonoluminescence, and the Higgs mechanism through the Planck mass. TGFs are very short bursts of gamma radiation associated with thunderstorm activity and represent the highest-energy natural particle acceleration phenomena occurring on Earth. The observed gamma-ray emission in TGFs is a direct consequence of the quantum cavitation of spacetime, resulting in the fission of the spacetime continuum and the generation of Higgs bosons, which subsequently decay into gamma photons.

The quantum cavitation process in TGFs bears a striking resemblance to the cavitation of air bubbles in fluid dynamics. Quantum gravity cavitation involves the formation of electromagnetic bubbles or micro black holes within Planck masses in the intermediate region between high and low energy pressure zones. Similarly, fluid cavitation occurs in the intermediate region between a submarine propeller and the propulsion fluid. This analogy highlights the potential for fluid dynamics principles to shed light on complex quantum phenomena, such as the fission of spacetime and the generation of Higgs bosons.

In the context of TGFs, a violent electrical discharge from a lightning strike can trigger the implosion of these quantum gravity bubbles, which are essentially micro black holes undergoing cavitation (**Figure 2**). This process mirrors fluid cavitation, where a rapid change in pressure causes the formation and subsequent implosion of vapor-filled cavities or bubbles. However, in the quantum realm, these bubbles are filled with electromagnetic energy, and their collapse releases Hawking radiation.

The derivation successfully integrates Hawking radiation and black hole evaporation into the TGF framework. The key equation for the Hawking temperature of a black hole of mass M is:

$$T_H = \frac{\hbar c^3}{8\pi G M k_B} \tag{84}$$

For a quantum black hole with a mass equal to the Planck mass m_p, the Hawking temperature is extremely high:

$$T_H\left(m_p\right) \approx 1.4\times 10^{32}\ \text{K} \tag{85}$$

This high temperature implies rapid and intense evaporation of quantum black holes through Hawking radiation, consistent with observations of TGFs and sonoluminescence.

Furthermore, the energy released during the fission of a Planck mass is comparable to that of a lightning strike Table 1, suggesting that TGFs could serve as experimental evidence for the transformation of dark matter (Planck mass) into dark energy. This transformation aligns with the theory of General Singularity and highlights the deep connection between dark matter, dark energy, and the mass-energy equivalence principle.

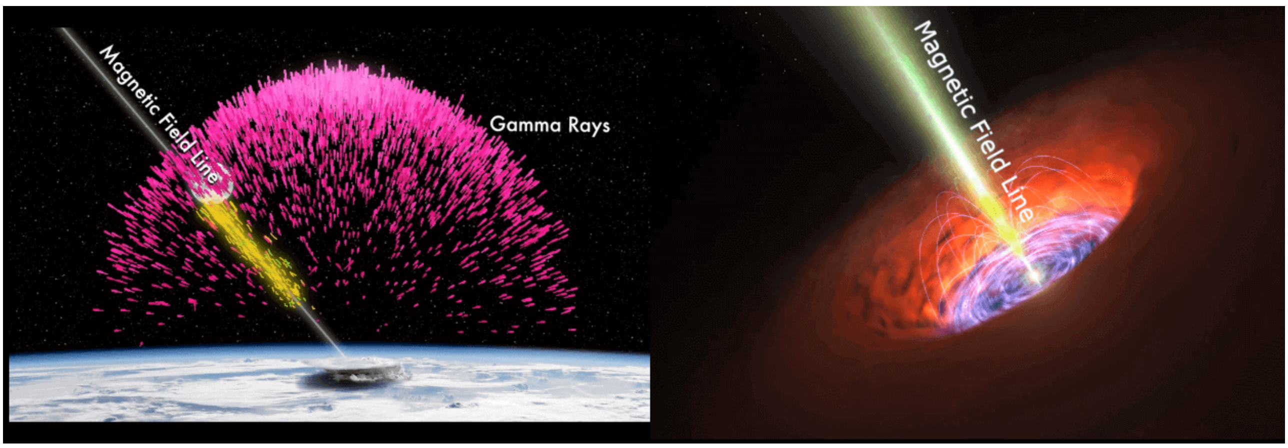

Figure 2. A comparative representation of the magnetic field of a quantum black hole, or Planck mass, induced by Terrestrial Gamma-Ray Flashes (TGFs), alongside a cosmological black hole. The left image illustrates a TGF, showcasing a magnetic jet, a typical feature associated with a black hole, linked with the Planck mass. The right image represents a cosmological black hole for comparison.

Table 1. Comparison of energy released by Planck mass fission and a lightning strike.

Process	Energy (Joules)
Planck Mass Fission	$E_p = m_p c^2 = 1.9561\times 10^9$
Lightning Strike	$\simeq 10^9$

The mathematical derivation presented in this paper, based on the equivalence between spacetime, dark matter, and dark energy, demonstrates the feasibility of this process and provides a solid foundation for understanding the underlying mechanisms responsible for TGFs. The analogy between TGFs and black holes, with slower cavitation due to time dilation in relativity, further strengthens the connection between these seemingly disparate phenomena and highlights the universal nature of the proposed theoretical framework.

13.7. Fractal Matter States and Holographic Principle: Evidence from Sgr A* and Hydrogen Atom

Recent observations of Sagittarius A* (Sgr A*), the supermassive black hole at our galaxy's center, by the Atacama Large Millimeter/submillimeter Array (ALMA) have revealed a hot gas bubble orbiting at 30% the speed of light. This behavior, detailed by ESO researchers, closely resembles the atomic structure of hydrogen, where an electron orbits the proton.

In quantum mechanics, the proton comprises three quarks (two "up" and one "down"), which can be conceptualized as interacting hydrodynamic vortices. Envisioning the quantum vacuum as a hydrodynamic backdrop, quarks interact like vortices in a fluid: a proton is analogous to two "spin up" vortices and one "spin down" vortex, while a neutron has two "spin down" and one "spin up" vortex (**Figure 3**).

This hydrodynamic perspective unifies the behavior of elementary particles and their interactions. Vortex dynamics in superfluids like Bose-Einstein condensates (BECs) [14] [15] [16] mirror the vortex-like behavior of quarks, connecting the macroscopic and microscopic worlds.

The hot gas bubble around Sgr A* can be seen as a cosmic-scale atomic orbital, akin to an electron orbiting a proton. The three luminous halos observed around Sgr A* suggest a tripolar quark structure. Corda's research, correlating black hole quantum behavior with the hydrogen atom [17], supports this view and indicates the universe's fractal, holographic nature.

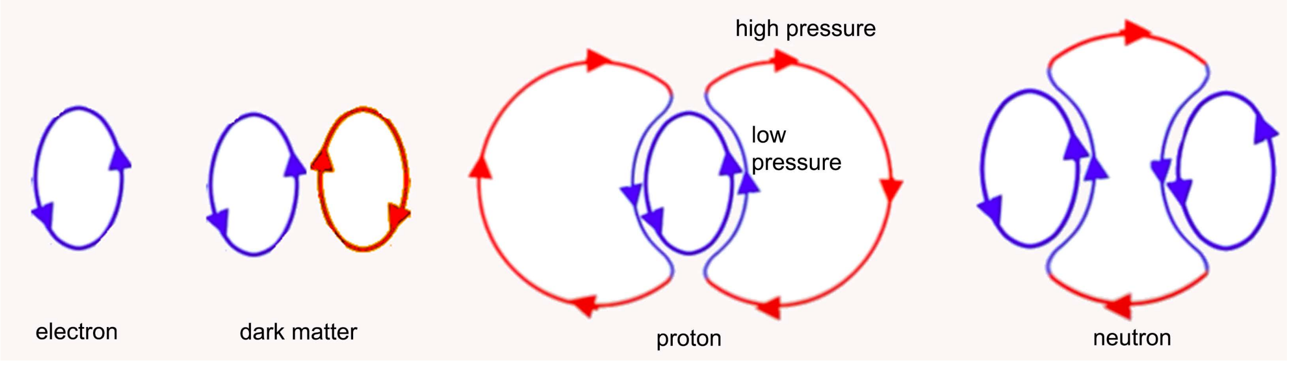

Figure 3. Elementary particles conceptualized through hydrodynamic vortex dynamics, from the electron (monopolar vortex) to dark matter (bipolar vortex pairs following stationary trajectories) to protons and neutrons (tripolar vortices) [13]. The vortex trajectories are constrained to quantized stationary orbits, ensuring compatibility with quantum mechanics.

Fractal states of matter, such as BECs ($\mathcal{E}_{BEC}$), Quark-Gluon Plasma ($\mathcal{E}_{QGP}$), and Dark Matter Condensates ($\mathcal{E}_{DMC}$), exhibit self-similar patterns across scales. The holographic principle, where information within a volume can be represented on its boundary, reinforces the fractal universe.

In summary, quark interactions, electron orbital motion, and gas movement around Sgr A* exemplify similar principles, connecting quantum and cosmic phenomena. Fractal matter states and the holographic principle provide a unifying framework for understanding patterns across scales in the universe (Figure 4).

14. On the Motion of Quantum Particles in a Stationary Liquid Spacetime as Required by the Kinetic Molecular Theory of Gravitational Heat [19]

In the framework of Einstein's theory of relativity, spacetime is elegantly described using the mathematical formalism of Lorentzian geometry. A fundamental concept in this geometric framework is the notion of dual light cones associated with each point in spacetime (Figure 5), which represent the potential future and past trajectories of light emanating from any given event.

A novel quantum-molecular model for the fundamental structure of spacetime at the Planck scale is proposed, where the intersection points of dual light cones trap pairs of virtual "dark photons" with relativistic mass. These dark photon pairs form quantum-entangled bipartite molecules, denoted as γ_2, with a total spin angular momentum of 2. The entanglement between the two dark photons in each γ_2 molecule arises from their simultaneous creation at the light cone intersection via a quantum fluctuation of the vacuum energy. As virtual particles, they are constantly created and annihilated, but their entangled superposition of states persists.

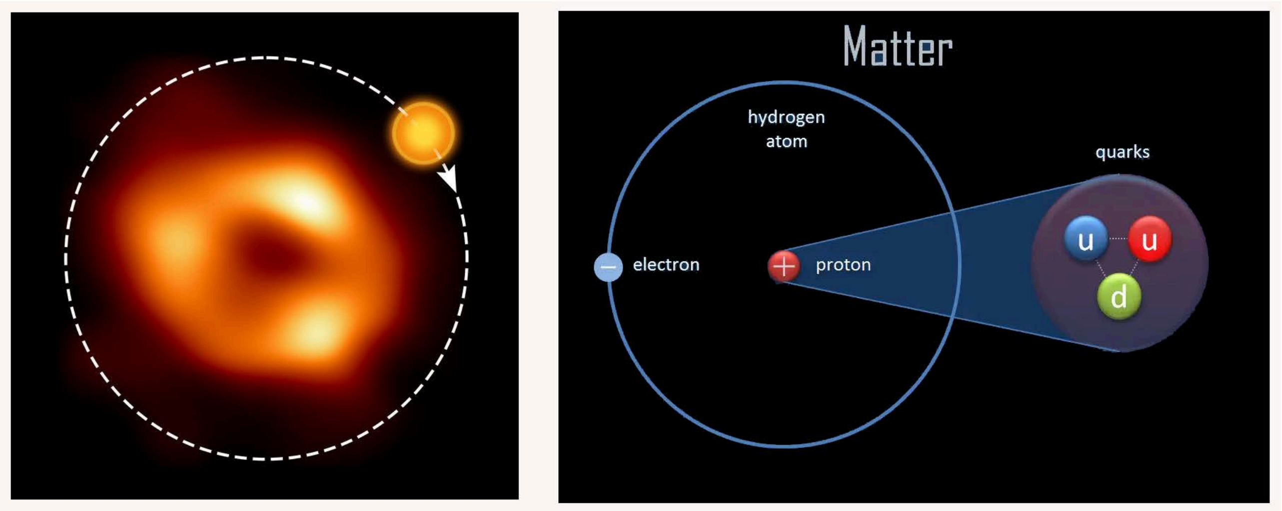

Figure 4. Holographic and fractal principles in the universe, synthesizing a fractal Schrödinger's equation [18]. Sgr A* (left) and the hydrogen atom (right) exhibit similar structures, with luminous halos around the black hole mirroring the tripolar quark structure. The hot spot's orbital path around Sgr A* corroborates Corda's gravitational atom hypothesis. Image Credits: EHT Collaboration and ESO/M. Kornmesser; Special Thanks: M. Wielgus.

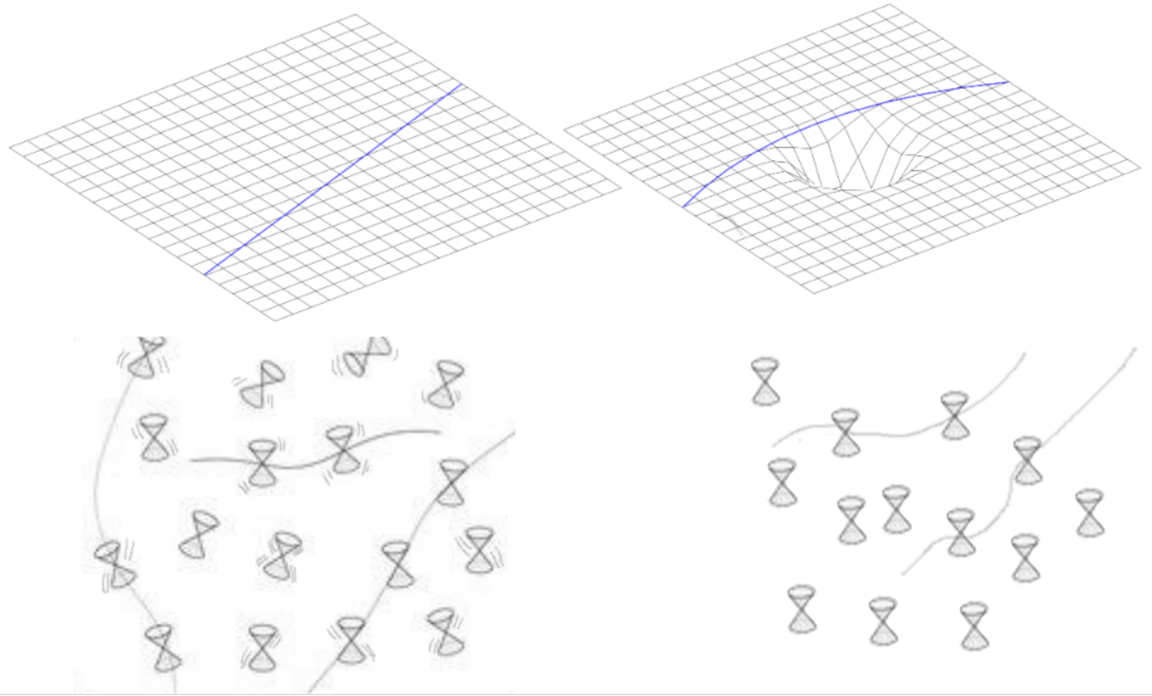

Figure 5. A spacetime diagram illustrating the dual light cones integral to Lorentzian geometry. At the intersection of these cones, a region of pronounced spacetime curvature materializes, pulsating with vibrant energy oscillations akin to "quantum molecules of energy" (γ_2). This vibrational energy manifests as gravitational or spacetime warmth, potentially representing a micro black hole or a focal point of intense gravitational interactions, where the γ_2 molecules condense into a quantum of gravity $\gamma_2\mathcal{G}$.

The γ_2 molecules can be viewed as a quantum Bose-Einstein condensate (BEC) of geometric spacetime pixels or "qubits" that encode quantum information in their entangled spin states. They form a quantum-molecular lattice or "foam" that underlies the smooth continuum of classical spacetime, analogous to how a superfluid emerges from a BEC of atoms. The entanglement between the γ_2 molecules extends throughout the spacetime lattice, creating a vast quantum network of interconnected spacetime qubits.

The γ_2 molecules are cohered by gravitoelectromagnetic forces—a unification of gravity and electromagnetism that emerges at the Planck scale. These forces induce resonances between the γ_2 spin states and the vibrational harmonics of the quantum spacetime lattice, similar to how phonons propagate through a crystal lattice. The collective excitations and dynamics of the γ_2 BEC give rise to the emergent properties of spacetime, such as curvature, expansion, and the propagation of gravitational waves. (Figure 5)

Mathematically, the γ_2 wavefunction can be modeled as a quantum superposition of two maximally entangled qubits in a Bell-like state:

$$|\gamma_2\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\rangle + |\downarrow\uparrow\rangle\right) \tag{86}$$

where $|\uparrow\rangle$ and $|\downarrow\rangle$ represent the two possible spin states of each dark photon. The spacetime lattice of γ_2 molecules can be described as a quantum many-body system with long-range entanglement and coherence, exhibiting properties analogous to those of a spin-2 BEC.

The quantum-molecular BEC model of spacetime suggests that spacetime has a discrete, entangled substructure at the Planck scale. This approach aims to unify quantum mechanics and general relativity by proposing that quantum gravity effects arise from this substructure. The model may help resolve incompatibilities between current theories, such as the continuous nature of spacetime in general relativity and the discrete, quantized nature of matter and energy in quantum mechanics.

The vacuum is conceived as an electromagnetic fluid or Bose-Einstein condensate (BEC), a dynamic, fluctuating medium exhibiting properties akin to those of a superfluid. The condensation of the electromagnetic vapor state γ_2 into the liquid state quantum of gravity $\gamma_2\mathcal{G}$ at the light cone intersections gives rise to the gravitational field and the curvature of spacetime, unifying the quantum and relativistic descriptions of gravity.

The Planck mass, a fundamental constant in physics, can be expressed as:

$$m_p = \sqrt{\frac{\hbar c}{G}} \tag{87}$$

where $\hbar$ is the reduced Planck constant, c is the speed of light, and G is the gravitational constant [10]. Squaring both sides and multiplying by $4\pi G$ yields the quantized gravitational flux ϕ_g:

$$\phi_g = 4\pi G m_p^2 = 4\pi\hbar c = 2hc \tag{88}$$

This equation suggests a connection between quantum gravity and the quantization of gravitational flux, analogous to the quantization of magnetic flux in superconductors.

In a Bose-Einstein condensate (BEC) vacuum, phonons may describe the energy-momentum tensor for dark matter, with a photon pair (γ_2) proposed as the foundational 'quantum molecule' of spacetime, encapsulated within a quantum of gravity ($\gamma_2\mathcal{G}$) at the liquid state [10]. The reaction $\phi_{LA} + \phi_{LA} \to g$ represents the condensation process $\gamma_2 \to \gamma_2\mathcal{G}$, where longitudinal acoustic phonons (ϕ_{LA}) in the BEC vacuum interact to form a graviton (g), a quantum of gravity $\mathcal{G}$. This suggests gravity emerges from the collective behavior of the quantum vacuum, modeled as a BEC.

The spin alignment in these "quantum molecules" determines spacetime properties—coherent alignment leads to spacetime curvature and gravity, while misaligned spins cause spacetime expansion, identified as light [20]. Gravitons arising as collective excitations in quantum gravity, analogous to phonons in condensed matter, provides a potential framework for unifying gravity with quantum mechanics and other fundamental forces.

The kinetic molecular theory of the quantum vacuum draws parallels with the kinetic theory of gases to elucidate the behavior of the quantum vacuum. A pivotal equation in this theory is:

$$\sqrt{G\varepsilon_o \alpha N} = \phi \left[\frac{\text{Hz}}{\text{Tesla}} \right] \tag{89}$$

where G is the gravitational constant, ε_o is the vacuum permittivity, α is the fine structure constant, N is Avogadro's number (postulated to signify the number of quanta necessary to construct a harmonically structured magnetic field analogous to an electron's spin), and ϕ is the golden ratio. [9]

The ubiquity of spirals and vortices in nature, from the spin of particles at the Planck scale to the swirling motion of galaxies and black holes on a cosmic scale, is a fundamental principle that underlies the fractal and holographic nature of the universe. The presence of the golden ratio ϕ in the equation above suggests that the quantum vacuum, and by extension, the universe itself, is governed by a set of fundamental principles that manifest in the form of spiral patterns and vortices across all scales.

This principle is exemplified by the geometric representation of the relationship between electromagnetic and gravitational fields across scales, visualized through the quantum vortex. At the Planck scale, these fields are tightly converged, while at larger scales they diverge, following the expanding pattern of the vortex. This encapsulates the idea that while nearly indistinguishable at the quantum level, these fields manifest distinct characteristics as they move to cosmological dimensions (**Figure 6**).

The prevalence of spiral patterns in various natural phenomena, from the subatomic to the cosmic, reinforces the universal applicability of this principle, linking the quantum and cosmological realms through the fractal and holographic nature of the universe.

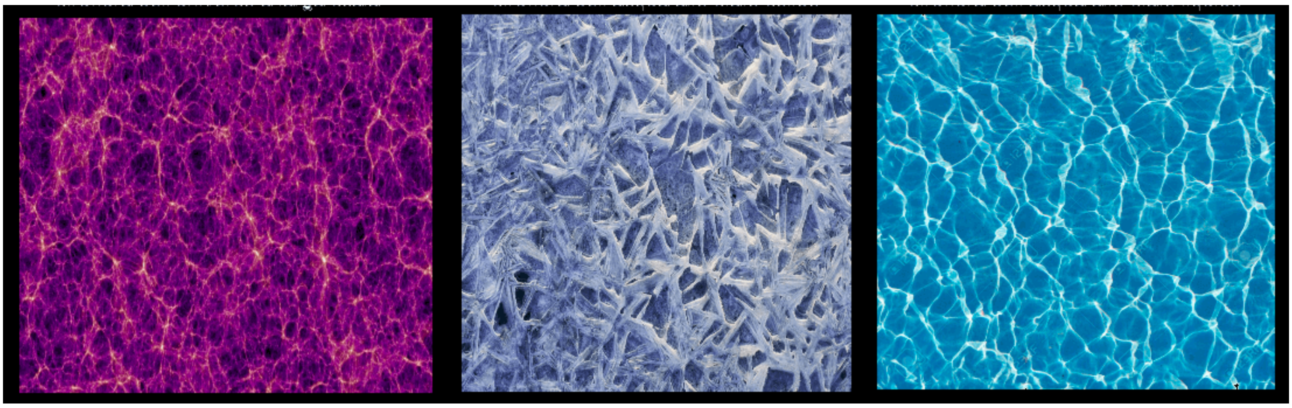

Figure 6. This figure illuminates the remarkable connection between the cosmic structure, dominated by dark matter, and the patterns observed in water across its various states. The cosmic web, a vast network of dark matter, mirrors the hydrodynamic patterns in water, suggesting a fluid-like behavior of the quantum vacuum throughout the universe. This comparison links the immense scale of the cosmos with the dynamics of terrestrial fluids and hints at the quantum vacuum's potential to exhibit hydrodynamic properties. The repeating patterns across scales, from the quantum to the molecular level, suggest that nature operates through self-similar mechanisms, providing a unified perspective on the fundamental workings of the universe. These insights deepen our understanding of the cosmos, highlighting the crucial role of dark matter in shaping the universe's structure and the fluid-like nature of the quantum vacuum, which may arise from the condensation of the electromagnetic vapor state γ_2 into the liquid state quantum of gravity $\gamma_2\mathcal{G}$.

15. Conclusions

In 1905, Albert Einstein introduced the theory of special relativity in his paper "On the Electrodynamics of Moving Bodies [21]." This work seeks to build upon Einstein's approach by examining "On the Vacuum Hydrodynamics of Moving Bodies," which explores the analogy between electrodynamics and hydrodynamics of moving bodies in a vacuum. (Table 2)

The tables included in this document compare hydrodynamic and electromagnetic variables, demonstrating a significant correlation between these two fields.

This analogy is further extended to the equations that describe the dynamics of the Bose-Einstein condensate (BEC) and phonons. (Table 3) The tables provided suggest that the principles of fluid dynamics and electromagnetism could serve as a unifying framework for understanding both quantum and relativistic phenomena.

Table 2. Comparison between hydrodynamic and electromagnetic variables for moving bodies. [22]

Hydrodynamics of moving bodies	Electromagnetics of moving bodies
Fluid velocity, v_f	Magnetic vector potential, A
Fluid acceleration, $\frac{\mathrm{d}v_f}{\mathrm{d}t}$	Induced electric field, $\frac{\mathrm{d}A}{\mathrm{d}t}$
Fluid density, ρ_f	Charge density, ρ_q
Virtual mass, m_{virtual}	Relativistic mass, $m_{\text{relativistic}}$
Acoustic gamma factor, γ_a	Lorentz Gamma factor, γ
Acoustic impedance, Z_a	Electromagnetic impedance, Z_w
Compressibility of fluid, β	Permittivity of vacuum, ε_0
(Surrounding) Fluid density, ρ_f	Permeability of vacuum, μ_0
Inertia Force due to Acceleration, $-\rho_f\left(\frac{\partial v_f}{\partial t}\right)$	Inertia Force due to Acceleration, $-\rho_q\left(\frac{\partial A}{\partial t}\right)$
Virtual mass increase, $-\rho_f\left(v_f\cdot\nabla\right)v_f$	Relativistic mass increase, $-\rho_q\left(v\cdot\nabla\right)A$
Hydrodynamic Inertia Force, $-\rho_f\left(\frac{\mathrm{d}v_f}{\mathrm{d}t}\right)$	Electromagnetic Inertia Force, $-\rho_q\left(\frac{\mathrm{d}A}{\mathrm{d}t}\right)$
Magnus Force, $F_M=\rho_f v_f\times\left(\nabla\times v_f\right)$	Lorentz Force, $F_L=q\left(E+v\times B\right)$
Mach Cone Angle, θ_M	Cherenkov Cone Angle, θ_C
$\sin\left(\theta_M\right)=\frac{c_s}{v}$	$\sin\left(\theta_C\right)=\frac{c}{v_{\text{particle}}}$

Table 3. Comparison between Maxwell's equations and the equations of BEC and phonons in the vacuum. The first row compares Gauss's law for electric fields with the time-dependent Gross-Pitaevskii equation, which describes the dynamics of the BEC wavefunction Ψ. The second row relates the absence of magnetic monopoles in Maxwell's equations to the expansion of the phonon field operator $\hat{\phi}$ in terms of creation and annihilation operators. The third row links Faraday's law to the interaction Hamiltonian $\hat{H}_{\text{int}}$ for phonons, which involves the scattering of phonons. Finally, the fourth row connects Ampère's circuital law with Maxwell's correction to the phonon stress-energy tensor $\hat{T}^{\bullet}_{\mu\nu}$, obtained by varying the phonon action $S_{\bullet}$ with respect to the metric tensor $g^{\mu\nu}$.

Maxwell's Hydrodynamic Equations	Hydrodynamic Equations of BEC Vacuum and Phonons
$\nabla \cdot \boldsymbol{E} = \rho/\varepsilon_0$	$i\hbar\frac{\partial\Psi}{\partial t} = \left(-\frac{\hbar^2}{2m}\nabla^2 + V_{ext} + g\lvert\Psi\rvert^2\right)\Psi$
$\nabla \cdot \boldsymbol{B} = 0$	$\hat{\phi}(\boldsymbol{r}) = \sum_k \left(u_k(\boldsymbol{r})\hat{a}_k + v_k^*(\boldsymbol{r})\hat{a}_k^\dagger\right)$
$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$	$\hat{H}_{\text{int}} = \sum_{k,k'} V_{k,k'}\hat{a}_k^\dagger\hat{a}_{k'}^\dagger\hat{a}_{k'}\hat{a}_k$
$\nabla \times \boldsymbol{B} = \mu_0\boldsymbol{J} + \mu_0\varepsilon_0\frac{\partial \boldsymbol{E}}{\partial t}$	$\hat{T}^{\bullet}_{\mu\nu} = \frac{2}{\sqrt{-g}}\frac{\delta S_{\bullet}}{\delta g^{\mu\nu}}$

The proposed theory suggests that the energy-momentum tensor for phonons in a Bose-Einstein condensate (BEC) vacuum may describe the energy-momentum tensor for dark matter, implying that dark matter could arise from collective interactions within the quantum vacuum. Phonons in a BEC represent low-energy collective excitations that can lead to the formation of solitons, which may be involved in the formation of dark matter solitons or "acoustic black holes". This connection between phonons, solitons, and dark matter opens up new perspectives for understanding the nature of dark matter itself and could have applications in the development of quantum memory devices and the study of black hole-like phenomena [6] [26].

The general singularity theory proposes that singularities are not endpoints but starting points for describing a universe that includes dark matter, possibly consisting of micro black holes or quantum fractal structures within spacetime. The mathematical parallels between Maxwell's hydrodynamic equations and those describing BEC and phonon dynamics support the idea of a unifying framework for fluid dynamics and electromagnetism.

This fractal nature is evident in the concepts of momentum $p = mc$ and energy $E = pc$, serving as the basis for a physical theory of information with the Planck mass [12] [13]. In the context of Poincaré's idea, where the speed of light is set to unity ($c = 1$) [23], these relations simplify to $p = m$ and $E = p$, highlighting that energy encompasses both rest mass energy and kinetic energy associated with momentum [24] [25]. The correlation allows to define a quantized impulse.

$$\mathrm{P}_p = \frac{m_p c}{2\pi} \approx 1\left[\frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}}\right] \tag{90}$$

At the Planck scale, a quantized impulse corresponds to the transmission of a single bit of physical information at light speed:

$$P_p = \frac{m_p c}{2\pi} = 1\,[\text{Bit}] \tag{91}$$

This equivalence represents the quantized or fractal angular momentum of a photon [26], a dual light particle γ_2 with global spin = 2 trapped in a quantum of gravity *G*, or a quantized mass field manifesting in spatial form, *i.e.*, the Higgs field. Examining the dimensions of this result reveals:

$$P_p = \frac{m_p c}{2\pi} = 1\,[\text{kg}\cdot\text{m}\cdot\text{Hz}] \tag{92}$$

The units of the quantized impulse, [kg·m·Hz], can be understood as follows: kg represents mass, which is related to the Planck mass (m_p), m represents length, which is related to the wavelength of a photon or the Planck length, and Hz represents frequency, which is related to the energy of a photon via Planck's equation ($E = h\nu$).

This quantized impulse is a fundamental unit of information, where one bit of information is associated with a photon's angular momentum at the Planck scale [27]. The photon's angular momentum captures and transmits physical information as a fundamental unit, linking the quantized impulse to the Higgs field, as both are related to the fundamental properties of particles, such as mass and spin.

The Higgs field is a scalar field that permeates all of space and gives particles their mass through interactions with the Higgs boson [11]. The quantized impulse, representing a fundamental unit of angular momentum or spin at the Planck scale, is deeply connected to the fundamental properties of particles and the nature of spacetime.

This theory offers new insights into the nature of dark matter as a massive wave of space, as evidenced by the dimensional analysis. It also sheds light on the origin of the universe and the fabric of spacetime, seeking to bridge the gap between quantum mechanics, general relativity, and information theory.

Derivation of the Standard Model and the Structure of Matter and Space from the Theory of General Singularity

In this section, the standard model of particle physics is rigorously derived from the Theory of General Singularity (TGS) by introducing fermionic and gauge field operators and constructing appropriate interaction Hamiltonians. The phonon field in the Bose-Einstein condensate (BEC) vacuum plays a central role in mediating interactions between fermions and gauge fields, providing a unified description of the fundamental forces and particles.

The phonon field operator is introduced $\hat{\phi}(\boldsymbol{r})$ and the extended interaction Hamiltonian H_{BEC} from the TGS framework:

$$\hat{\phi}(\boldsymbol{r}) = \sum_{\boldsymbol{k}} \frac{1}{\sqrt{2\omega_{\boldsymbol{k}}}} \left(\hat{a}_{\boldsymbol{k}} e^{i\boldsymbol{k}\cdot\boldsymbol{r}} + \hat{a}_{\boldsymbol{k}}^{\dagger} e^{-i\boldsymbol{k}\cdot\boldsymbol{r}} \right) \tag{93}$$

$$H_{\mathrm{BEC}}=\sum_{k_1,k_2}V_{k_1,k_2}\hat{a}_{k_1}^{\dagger}\hat{a}_{k_2}^{\dagger}\hat{a}_{k_1}\hat{a}_{k_2}+\sum_i\int\mathrm{d}^3\boldsymbol{r}\,g_i\hat{\phi}(\boldsymbol{r})\mathcal{O}_i(\boldsymbol{r}) \tag{94}$$

Next, fermionic field operators are introduced $\hat{\psi}_f(\boldsymbol{r})$ for each fermion type f (quarks and leptons) in the standard model:

$$\hat{\psi}_f(\boldsymbol{r})=\sum_{\boldsymbol{p}}\frac{1}{\sqrt{2E_{\boldsymbol{p}}}}\left(\hat{b}_{\boldsymbol{p},f}u_{\boldsymbol{p},f}\mathrm{e}^{i\boldsymbol{p}\cdot\boldsymbol{r}}+\hat{d}_{\boldsymbol{p},f}^{\dagger}v_{\boldsymbol{p},f}\mathrm{e}^{-i\boldsymbol{p}\cdot\boldsymbol{r}}\right) \tag{95}$$

where $\hat{b}_{\boldsymbol{p},f}$ and $\hat{d}_{\boldsymbol{p},f}^{\dagger}$ are the annihilation and creation operators for fermions and antifermions, respectively, and $u_{\boldsymbol{p},f}$ and $v_{\boldsymbol{p},f}$ are the spinor amplitudes.

The interaction Hamiltonian between phonons and fermions is constructed:

$$H_{\mathrm{int}}=\sum_f\int\mathrm{d}^3\boldsymbol{r}\,g_f\hat{\phi}(\boldsymbol{r})\hat{\psi}_f^{\dagger}(\boldsymbol{r})\hat{\psi}_f(\boldsymbol{r}) \tag{96}$$

where g_f is the coupling constant between phonons and fermions of type *f*.

Then introduce gauge field operators $\hat{A}_\mu^a(\boldsymbol{r})$ for each gauge group *a* (U(1), SU(2), and SU(3)) in the standard model:

$$\hat{A}_\mu^a(\boldsymbol{r})=\sum_{\boldsymbol{k}}\frac{1}{\sqrt{2\omega_{\boldsymbol{k}}}}\left(\hat{a}_{\boldsymbol{k},\mu}^{a}\varepsilon_\mu^a\mathrm{e}^{i\boldsymbol{k}\cdot\boldsymbol{r}}+\hat{a}_{\boldsymbol{k},\mu}^{a\dagger}\varepsilon_\mu^{a*}\mathrm{e}^{-i\boldsymbol{k}\cdot\boldsymbol{r}}\right) \tag{97}$$

where $\hat{a}_{\boldsymbol{k},\mu}^{a}$ and $\hat{a}_{\boldsymbol{k},\mu}^{a\dagger}$ are the annihilation and creation operators for gauge bosons, and ε_μ^a are the polarization vectors.

The interaction Hamiltonian between fermions and gauge fields is constructed:

$$H_{\mathrm{gauge}}=\sum_f\int\mathrm{d}^3\boldsymbol{r}\hat{\psi}_f^{\dagger}(\boldsymbol{r})\gamma^\mu\left(g_1Y_f\hat{A}_\mu^1+g_2\boldsymbol{T}_f\cdot\hat{\boldsymbol{A}}_\mu^2+g_3\boldsymbol{l}_f\cdot\hat{\boldsymbol{A}}_\mu^3\right)\hat{\psi}_f(\boldsymbol{r}) \tag{98}$$

where g_1, g_2, and g_3 are the coupling constants for the U (1), SU (2), and SU(3) gauge groups, respectively, Y_f is the hypercharge, $\boldsymbol{T}_f$ are the weak isospin generators, and $\boldsymbol{l}_f$ are the Gell-Mann matrices.

The Higgs field operator is introduced $\hat{\Phi}(\boldsymbol{r})$:

$$\hat{\Phi}(\boldsymbol{r})=\sum_{\boldsymbol{k}}\frac{1}{\sqrt{2\omega_{\boldsymbol{k}}}}\left(\hat{a}_{\boldsymbol{k},\Phi}\mathrm{e}^{i\boldsymbol{k}\cdot\boldsymbol{r}}+\hat{a}_{\boldsymbol{k},\Phi}^{\dagger}\mathrm{e}^{-i\boldsymbol{k}\cdot\boldsymbol{r}}\right) \tag{99}$$

and construct the Higgs-fermion interaction Hamiltonian:

$$H_{\mathrm{Higgs}}=\sum_f\int\mathrm{d}^3\boldsymbol{r}\,y_f\hat{\psi}_f^{\dagger}(\boldsymbol{r})\hat{\Phi}(\boldsymbol{r})\hat{\psi}_f(\boldsymbol{r}) \tag{100}$$

where y_f is the Yukawa coupling constant for fermions of type *f*.

The interaction terms are combined to obtain the total Hamiltonian:

$$H_{\mathrm{total}}=H_{\mathrm{BEC}}+H_{\mathrm{int}}+H_{\mathrm{gauge}}+H_{\mathrm{Higgs}} \tag{101}$$

Finally, the equations of motion for the field operators using the Heisenberg equation are derived:

$$i\hbar\frac{\partial\mathcal{O}(\boldsymbol{r},t)}{\partial t}=\left[\hat{\mathcal{O}}(\boldsymbol{r},t),H_{\mathrm{total}}\right] \tag{102}$$

where $\hat{\mathcal{O}}$ represents any of the field operators ($\hat{\phi}$, $\hat{\psi}_f$, $\hat{A}_\mu^a$, or $\hat{\Phi}$).

The equations of motion derived from the TGS framework reproduce the standard model predictions by capturing the dynamics and interactions of the superconducting order parameter, electromagnetic vector potential, and gravitational metric perturbation. The phonon field in the BEC vacuum plays a central role in mediating these interactions, providing a unified description of the fundamental forces and particles. This derivation demonstrates the potential of the TGS approach to unify quantum field theory, general relativity, and the standard model, offering new insights into the fundamental laws of the universe. The mathematical rigor and physical intuition underpinning the TGS approach contribute to its potential to revolutionize the understanding of reality at its most fundamental level, bridging the gap between quantum mechanics and general relativity, and providing testable predictions connecting seemingly disparate phenomena across different scales.

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Conflicts of Interest

At the time of writing, the author confirms that there are no competing financial interests or personal affiliations that could have swayed the results or interpretations presented in this paper.

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