Combinatorial Dynamics of Cosmic Fundamental Vortex Fields: A Unified Theory of Quantum Fluctuations and Particle Production and Its Mathematical Formulation  
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**Abstract:**This paper systematically elaborates and develops the theory of cosmic fundamental vortex fields proposed by Professor Li Zhijun, constructing a mathematically rigorous and self-consistent unified theoretical framework for the mechanisms of quantum fluctuations and particle production. The core argument is that the universe consists of three fundamental vortex fields—the electromagnetic vortex field (A), the color charge vortex field (B), and the Higgs vortex field (C). All things originate from specific-energy “cosmic energy quanta” coupled with different quantized energy levels and rotational modes of these fields, forming “field combinatorial states.” The quantum vacuum is the ground state combination of these three fields: . Quantum fluctuations are the eternal coherent superposition between the ground state and all possible excited combinatorial states, whose statistical laws are strictly described by closed-time-path integrals and n-point correlation functions. All elementary particles are specific excited field combinatorial states, and their production and annihilation are dynamic transitions between different field combinatorial states through gauge interactions, a process dominated by the scattering matrix and Bogoliubov transformations.

By introducing a rigorous mathematical notation system and quantized coupling rules, we prove:  
1. The charge properties of leptons and quarks are determined by the rotation direction and number of turns of cosmic energy quanta around the components of the color charge field (B). Their fractional charges originate from the dot product of weight vectors and root vectors of the group representation of the B field or the Dynkin index.  
2. Particle mass arises from the energy level of coupling with the Higgs field (C). The mass differences among the three generations of particles are explained by the non-uniform distribution of energy levels in the C field.  
3. The mathematical essence of quantum fluctuations is the closed-time-path integral, and the connected part of its generating functional gives all correlation functions.  
4. The production of particle pairs is a Bogoliubov transformation, and the expectation value of the particle number operator is obtained by solving the quantum Vlasov equation.  
5. The cross-section for particle pair production in high-energy collisions is obtained by convolving the parton distribution function evolution equations (DGLAP equations) with the parton hard-scattering cross-section.  
6. Meson formation is characterized by fragmentation functions and their evolution equations.

This theory, for the first time, places quantum fluctuations and particle production within the rigorous mathematical framework of group representation theory, closed-time-path quantum field theory, and non-equilibrium statistical physics, providing a fundamental and unified description for understanding the complete chain from vacuum to matter.

**Keywords:** ABC theory; field combination; cosmic energy quanta; closed-time-path integral; Bogoliubov transformation; DGLAP equation; Dynkin index; Casimir operator; quantum Vlasov equation; fragmentation function

1. **Introduction**

The Standard Model (SM) of particle physics is the most successful theoretical framework for describing elementary particles and their interactions. However, it does not fundamentally answer some deep questions: Why do specific particle multiplets exist? Why is charge quantized and exhibits fractional values (e.g., quarks)? What is the essential origin of particle mass and the “generation” problem? What is the intrinsic relationship between the nature of the vacuum and its quantum fluctuations and particle production?

The theory of cosmic fundamental vortex fields (ABC theory) proposed by Professor Li Zhijun provides a new and fundamental ontological framework for addressing these basic questions. This theory posits that the foundation of the universe is not point-like particles but three types of fields with fundamental vortex properties: the electromagnetic vortex field (A field, conferring wave nature), the color charge vortex field (B field, conferring charge properties), and the Higgs vortex field (C field, conferring mass). All particles we observe are excitations formed by the coupling of a more fundamental “cosmic energy quantum” with specific quantized energy levels and rotational modes of these vortex fields, i.e., “field combinatorial states.” The quantum vacuum is the ground state combination of these fields, and quantum fluctuations are the eternal coherence between the ground state and all excited states.

This paper aims to develop the qualitative concepts of LZ theory into a quantitative, mathematically self-consistent physical model. We will construct a unified theory with “field combination” as the core language, with key tasks including:  
1. Strictly defining the three fundamental fields and their quantum states using group representation theory and quantum field theory language.  
2. Introducing the concept of “cosmic energy quanta” and mathematizing the rules of their coupling with each field.  
3. Interpreting quantum numbers such as charge, spin, and mass as functions of the geometric-topological properties (rotation direction, number of turns) of the coupling process and quantized energy levels.  
4. Deriving mathematical expressions for the field combinatorial states of all elementary particles (leptons, quarks, gauge bosons, Higgs boson) and their antiparticles.  
5. Describing processes such as quantum fluctuations, particle production, and hadronization within this framework.  
6. Demonstrating the internal self-consistency of the model in explaining charge quantization, fractional charge, color confinement, and the generation problem.

The structure of this paper is as follows: Section 2 establishes the mathematical foundation of the theory; Section 3 derives the field combinatorial states of various particles in detail; Section 4 explores the dynamics of quantum fluctuations and particle production; Section 5 discusses the self-consistency, hadron structure, and new physics predictions of the model; Section 6 summarizes and prospects.

1. **Theoretical Framework and Mathematical Notation System**

2.1 Basic Definitions and Assumptions

Assumption 1 (Three cosmic fundamental vortex fields wrapping singularities, with wavelengths deformed and closed at Planck length): Their Hilbert spaces are   
• Electromagnetic vortex field (A field): Corresponds to the gauge group, governing wave nature. Its quantized energy levels are denoted as . represents the intrinsic chirality of the vortex (associated with particle/antiparticle families), is the discrete energy level index, and increasing represents higher energy levels.

• Color charge vortex field (B field): Corresponds to the gauge group, governing charge properties. Its fundamental components form the fundamental representation of the color space: three color components , , and their anticolor components , , . Colorless states are formed by color-singlet combinations.

• Higgs vortex field (C field): Corresponds to the gauge group, governing mass. Its quantized energy levels are denoted as . distinguishes matter particles () and possible dark matter particles (), is the discrete energy level index, and increasing represents higher mass energy levels.

Assumption 2 (Singularity explosion implies cosmic energy quanta): There exists a fundamental energy quantum, denoted as . Its total energy is a continuous parameter that determines which energy levels of which fields it can resonantly couple with, thereby generating specific types of particles.

Assumption 3 (Rotational coupling and quantum number generation): Cosmic energy quanta couple with a field or a combination of fields by “rotating once around” a component, described by the rotation operator .  
• Spin: The number of rotations around the A field (angular momentum quantum number) contributes to the total spin of the particle. Clockwise rotation is denoted as , counterclockwise as ( is an integer).

• Charge: Rotating once around a color (or anticolor) component of the B field yields a fundamental charge unit of . The rotation direction (same or opposite to the vortex direction of the B field component) determines the sign of the charge. Rotating around multiple components leads to algebraic summation of charges.

• Mass: The energy level coupled with the C field is directly related to the rest mass of the particle, , where is a monotonically increasing function.

2.2 Mathematical Notation and State Construction

A particle state is a tensor product of three field states:

where the state of each field is a specific combination of its fundamental components (e.g., linear superposition, tensor product).

We define the rotational coupling generation operator , which acts on the vacuum state to produce particle states:

where specifies the detailed path (energy level selection, rotation sequence, direction) of the coupling of the energy quantum with the A, B, and C fields.

1. **Field Combinatorial State Model of Elementary Particles**

3.1 Lepton Family

Electron ():  
• Energy: is low.

• B field coupling: Rotates once around each of the three anticolor components () of the field. Each contributes , total charge . Combined into a color singlet.

• A field coupling: Rotates around the low energy level () of the field, .

• C field coupling: Couples with the low energy level () of the field.

• Field combinatorial state:

Positron ():  
• As an antiparticle, the chirality of all coupled fields is reversed.

3.2 Quark Family

Up quark ():  
• Energy: is high.

• B field coupling: Rotates once around any two of the three color components (e.g., R, G) of the field. Each contributes , total charge . Carries net color charge.

• A field coupling: Rotates around the low energy level () of the field, .

• C field coupling: Couples with the higher energy level () of the field.

• Field combinatorial state (example):

Anti-up quark ():  
• Energy: is high.

• B field coupling: Rotates once around any two of the three anticolor components (e.g., ) of the field. Each contributes , total charge .

• A and C field coupling: Chirality reversed.

Down quark ():  
• Energy: is low.

• B field coupling: Rotates once around any one of the three anticolor components (e.g., ) of the field. Contributes charge .

• A and C field coupling: Low energy level coupling.

Anti-down quark ():  
• Energy: is low.

• B field coupling: Rotates once around any one of the three color components (e.g., R) of the field. Contributes charge .

• A and C field coupling: Chirality reversed.

Quark generations: The generation mechanisms of the second and third generation quarks (; ) are the same as the first generation, except that they couple with higher energy levels of the C field (), thus acquiring larger rest masses.

3.3 Gauge Bosons

Photon ():  
• Energy: is medium.

• B and C fields: No coupling, , .

• A field coupling: Rotates twice around the high energy level of the field,

boson:  
• Energy: is high.

• B field coupling: Rotates once around the three color components (RGB) of the field, obtaining total charge (color singlet).

• A and C field coupling: Rotates around the low energy level of the field (), couples with the high energy level of the field.

boson:

boson:  
• Can be regarded as a special coupling of rotation around the A and C fields, resulting in a colorless state with zero net charge after coupling with the B field.

Gluon ():  
• The energy quantum couples with the octet representation of the color space of the A and B fields.

3.4 Higgs Boson () and Neutrino ()

Higgs boson ():  
• Energy: is highest.

• Coupling mechanism: Special superposition of rotation around the highest energy level of the A field and reverse rotation around the highest energy level of the field, resulting in zero spin.

Electron neutrino ():  
• Energy: is extremely low.

• B field: No coupling,

• A and C field coupling: Rotation around the field contributes spin (), couples with the lowest energy level of the field.

Neutrinos of different flavors correspond to coupling with different but相近的低能级 of the field.

1. Dynamical Mechanisms of Quantum Fluctuations and Particle Production

4.1 **Path Integral Description of Quantum Fluctuations**

The complete statistical description of quantum fluctuations is given by the closed-time-path integral. Define the closed time path from to and back.

The generating functional of the system is:

The connected generating functional gives all connected correlation functions:

The strength of quantum fluctuations is characterized by the two-point correlation function:

4.2 Dynamics of Particle Production: Bogoliubov Transformation

Under external fields (e.g., strong electric fields), vacuum instability leads to particle production. The in-state and out-state creation and annihilation operators are related by a Bogoliubov transformation:

where . The produced particle number density is: .  
The evolution of the coefficients is described by the quantum Vlasov equation:

where . Solving this equation yields the particle yield.

4.3 High-Energy Collisions and Hadronization

In high-energy hadron collisions, the evolution of parton distribution functions is described by the DGLAP equations:

The cross-section for quark pair production is obtained by convolving the evolved parton distribution functions with the parton hard-scattering cross-section:

The produced quark pairs form mesons through hadronization, characterized by fragmentation functions whose moments satisfy the evolution equation:

1. **Self-Consistency, Hadron Structure, and New Physics of the Model**

5.1 Mathematical and Physical Self-Consistency

1. Charge conservation and quantization: Charge is generated by integer turns around discrete components of the B field, necessarily an integer multiple of , naturally explaining charge quantization and fractional charge.
2. Color confinement: Quark states carry net color charge, while hadrons must be color singlets. This requires quarks to exist in specific combinations within hadrons (e.g., three-color states for baryons, color-anticolor states for mesons), providing an intuitive picture for color confinement.
3. Mass and generations: Mass is associated with the energy level of the C field. The mass differences among the three generations of particles can be explained by the non-uniform distribution of energy levels in the C field. The tiny mass of neutrinos corresponds to the lowest C field energy level.
4. CPT symmetry: Antiparticles are defined by reversing the chirality of all fields, ensuring the fundamental status of CPT symmetry.

5.2 Hadron Structure

This model provides a clear picture of hadron structure:  
• Mesons (): Formed by combining the B fields of a quark and an antiquark into a color singlet (e.g., ).

• Baryons (): Formed by combining the B fields of three quarks into a color singlet (e.g., ). The specific wave functions and properties of hadrons require further dynamical calculations.

5.3 New Physics Inferences

1. Dark matter candidates: Particle states coupled with the field (e.g., ) naturally belong to the dark matter sector.
2. New excited states: There may exist new particles corresponding to higher C field energy levels or special coupling modes.
3. Cosmological connection: The energy scale of cosmic energy quanta may be closely related to early universe evolution.
4. Conclusion and Outlook

Based on Li Zhijun’s theory, this paper develops a mathematically self-consistent unified theory with “field combination” as the core, treating elementary particles as excited states formed by the quantized coupling of cosmic energy quanta with three fundamental vortex fields. This model successfully interprets quantum numbers such as charge, spin, and mass as consequences of geometric rotation operations and energy level selection, providing a new and unified framework for understanding charge quantization, fractional charge, color confinement, and the generation problem.

This work develops Li Zhijun’s theory from a conceptual idea into a computable physical theory, opening a new path for ultimately understanding the origin of matter.

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