**The Unified Origin of Matter and Interactions: A Rigorous Mathematical Framework Based on ABC Field Theory and the Emergence of Gauge Symmetry**

**Authors:** Li Zhijun, Zhao Guangyao

**Abstract:**

This paper aims to achieve a deep integration of the Yang-Mills gauge field theory and the Li Zhijun ABC Cosmic Vortex Field Theory in both conceptual and mathematical frameworks, thereby constructing a unified theory on the origin of fundamental constituents of matter and fundamental interactions. The core thesis is that the gauge symmetry in the Yang-Mills theory is not the most fundamental starting point of the physical world, but an approximate symmetry that “emerges” from the geometric topological properties of the quantized vortex modes of the color charge vortex field (B-field), the electromagnetic vortex field (A-field), and the Higgs vortex field (C-field) in the ABC field theory. The key advances of this paper are as follows:

1. Rigorous Mathematization: Introducing the vortex winding number, color space winding number, and energy level topological charge as the core topological invariants of the ABC fields, and establishing their direct correspondence with the representations of gauge groups. Through the fiber bundle-vortex correspondence principle, the gauge field is strictly defined as an excitation of the ABC background connection .
2. Derivation of the Standard Model Group: Deriving the group from the inherent three-color nature of the B-field (originating from its symmetry); deriving the group from the chiral duality related to the wave nature of the A-field; and obtaining the group from the symmetry of the A-field phase rotation. This explains why the standard model group is .
3. Calculation and Fitting: Constructing the scattering amplitude calculation formula under the ABC field theory, and taking the process as an example, proving that its results in the low-energy effective theory are completely consistent with the standard model QED calculations, while predicting possible deviations at very high energy scales.
4. Gravitational Unification Mechanism: Extending the ABC field theory further, proposing that universal gravitation originates from the repulsive effect of negative-mass dark matter soup on material particles, which induces an effective attractive force. Material particles in the negative-mass dark matter soup, due to their positive mass, are repelled by the surrounding negative-mass background. The macroscopic statistical average effect of this repulsive force manifests as an effective mutual attraction between material particles, i.e., universal gravitation.

This framework unifies matter particles, force-carrying particles, and gravitational phenomena as dynamic manifestations of the ABC fields and their background environment, providing a solid mathematical foundation and new physical predictions for the ultimate unification of the four fundamental interactions.

Keywords: Gauge field theory; ABC field theory; Topological invariants; Fiber bundle-vortex correspondence; Derivation of gauge groups; Scattering amplitude; Negative-mass dark matter; Induced gravity; Unified theory

1. **Introduction**

Since Yang and Mills proposed non-Abelian gauge field theory in 1954, it has become the cornerstone of the standard model of particle physics, successfully unifying the electromagnetic, weak, and strong fundamental interactions. The standard model, with its astonishing predictive accuracy, represents the pinnacle of human understanding of the microscopic world. However, there remain some fundamental unsolved mysteries in this theory: First, it treats matter (fermions) and interactions (gauge bosons) as two distinct fundamental entities, lacking a deeper unifying principle; second, the origin of its gauge symmetry group and why parameters (such as coupling constants and particle masses) take specific values are still unknown; third, it fails to incorporate gravity into its unified framework.

Professor Li Zhijun’s ABC Cosmic Vortex Field Theory attempts to provide a possible direction for solving these problems from a new ontological perspective. This theory posits that all things in the universe are composed of three more fundamental vortex fields: the electromagnetic vortex field (A-field, dominating wave nature and phase), the color charge vortex field (B-field, dominating charge properties and strong interactions), and the Higgs vortex field (C-field, dominating mass generation and symmetry breaking). In this theory, all elementary particles are “field combination states” formed by the coupling of cosmic energy quanta with specific quantized vortex modes of the A, B, and C fields.

This paper aims to deeply integrate these two theoretical systems. We propose a core hypothesis: the gauge fields, gauge symmetries, and even gravitational phenomena in the standard model are “emergent phenomena” resulting from the more fundamental field dynamics of the ABC fields and their interaction with the background environment. Our goal is to construct a mathematically self-consistent framework in which:  
\* Fermions and gauge bosons are uniformly described as different “field combination excitation states” of the ABC fields.  
\* Gauge symmetry is interpreted as the continuous transformation symmetry of these field combination states in their configuration space that preserves their topological invariants.  
\* Universal gravitation is explained as a statistically induced effect arising from the repulsion of positive-mass material particles by the pervasive negative-mass dark matter background.

This paper will first strictly define the topological invariants of the ABC fields and explain how gauge symmetry emerges from them; then derive the structure of the standard model gauge group; subsequently demonstrate consistency with the standard model through specific scattering processes; and finally propose the induction mechanism of gravity, outlining a blueprint for the unification of the four forces.

1. **Theoretical Framework: From ABC Fields to Gauge Symmetry**

This chapter establishes the mathematical foundation of the entire theory by introducing topological invariants and fiber bundle theory, rigorously explaining how gauge symmetry emerges from the geometric structure of the ABC fields.

**2.1 Basic Definitions and Topological Invariants of the ABC Fields**

We introduce a core, discrete topological invariant for each field. These invariants are more fundamental than continuous gauge symmetries and are the root of quantization.

* A-field (Electromagnetic Vortex Field): Its core topological invariant is the winding number It describes the net change of the A-field phase along a closed path in spacetime:

where C is a closed loop. This winding number is directly related to charge quantization. The fact that is an integer is the topological origin of charge quantization. Its gauge group is the group of all continuous phase transformations that preserve

* B-field (Color Charge Vortex Field): Its core topological invariant is related to a discrete symmetry. The fundamental space of the B-field (color space) consists of three basis vectors (R, G, B), and its most natural symmetry is cyclic permutation which constitutes a cyclic group. We define the color winding number which is related to this structure and describes how the B-field “winds” in color space. The continuous group is the smallest continuous Lie group containing this discrete symmetry, and the center of the group is exactly This perfectly explains color confinement: all observable hadron states must be in the trivial representation of (color singlet).
* C-field (Higgs Vortex Field): Its core topological invariant is the energy level topological charge related to mass generation and chirality. The weak interaction gauge group can be understood as the continuous symmetry describing chiral (left-handed/right-handed) transformations coupled to the C-field, which preserves the topological invariant associated with the chiral charge.

A fundamental particle state is the tensor product of these field states, labeled by their topological quantum numbers:

**2.2 Emergence of Gauge Symmetry: Fiber Bundle-Vortex Correspondence Principle**

We propose the “fiber bundle-vortex correspondence” principle to establish a rigorous bridge between the ABC fields and the mathematics of gauge fields.

* Standard Formulation: Mathematically, a gauge theory is described by a principal fiber bundle. Its base space is the spacetime manifold M, the fiber is the gauge group G, and the connection (i.e., the gauge field) defines parallel transport on the fiber.
* ABC Field Formulation: We posit that this mathematical structure is a continuous approximation of the physics of the ABC fields.
  + The base space is similarly spacetime M.
  + The “fiber” is not an abstract group G, but the physical local vortex configuration space of the ABC fields at each point in spacetime. This configuration space consists of internal degrees of freedom such as field direction, phase, energy level, etc., and itself has non-trivial topology (e.g., for the A-field, is similar to a circle ; for the B-field, is related to the discrete set ).
  + The gauge connection is interpreted as the geometric connection of this physical vortex configuration space. It describes how the local ABC vortex configuration is “parallel transported” as we move in spacetime. is no longer a fundamental field but a derived quantity from the background geometry of the ABC fields.
  + A gauge transformation corresponds to a continuous deformation of the vortex configuration space but this deformation must preserve the topological invariants (such as ) at that point. The set of all such topology-preserving continuous deformations forms a continuous group—this is the gauge group G.

Therefore, the gauge symmetry is the maximum continuous symmetry group possessed by the vortex configuration spaces of the B-field, C-field, and A-field, respectively, that preserves their discrete topological quantum numbers. Gauge symmetry is a continuous approximation and emergent phenomenon of a deeper discrete topological structure.

1. **Unified Description of Matter and Interactions**

In this chapter, based on the ABC field theory, we provide a unified description of matter particles (fermions) and force-carrying particles (gauge bosons) as field combinations. Special attention: The following key corrections are made to the description of color charge properties of quarks and leptons:

**3.1 Fermions (Matter) as “Ground State” Field Combinations**

All elementary particles (fermions) are uniformly regarded as specific “ground state” combination excitations of the ABC fields. Their quantum numbers are determined by the topological properties of the combinations.

* Up quark (): Carries two positive color charge.
  + : A-field winding number, determining its fractional charge.
  + : Any two of the red, green, blue positive color charges of the field. The up quark exists in the fundamental representation (triplet) of the color space.
  + : Coupled to a specific energy level of the C-field, giving it mass.
* Down quark (): Carries anti-color charge.
  + : Fractional charge.
  + : Any one of the anti-red, anti-green, anti-blue anti-color charges of the field. The down quark exists in the conjugate representation (anti-triplet) of the color space.
* Electron (): Is a color singlet (colorless).
  + : Charge of .
  + : The symmetric combination of the anti-red, anti-green, anti-blue three components of the field, forming a color singlet, hence the electron does not participate in strong interactions.
  + : Coupled to the ground state of the C-field, giving it mass.
* Positron (): Is a color singlet (colorless).
  + : Charge of .
  + : The symmetric combination of the red, green, blue three components of the field, forming a color singlet.

Summary of Key Correction: The up quark carries positive color charge ( field), the down quark carries anti-color charge ( field), the electron is a singlet of anti-color charge ( field singlet), and the positron is a singlet of positive color charge ( field singlet). This correction ensures that quarks are in color triplets while leptons are in color singlets, fully consistent with standard model observations.

**3.2 Gauge Bosons (Interactions) as “Excited” Field Combinations**

Gauge bosons are interpreted as non-local “excited states” of the ABC fields, whose function is to mediate transformations between field combination states.

* Photon (): Pure A-field excitation. Corresponds to the quantum exchanged in gauge transformations (A-field phase rotations).
* Gluon (): Coupled excitation of the A-field and the color octet of the B-field. Corresponds to the quantum exchanged in gauge transformations.
* W/Z Bosons: Coupled excitation of the A-field, B-field (components related to weak charge), and C-field. Corresponds to the quantum exchanged in gauge transformations.

In this picture, the boundary between fermions (stable matter states) and gauge bosons (unstable interaction states) becomes blurred; they are all excitations of the ABC fields, differing in their combination patterns, stability, and functions.

1. **Mathematical Realization: Dynamics and Scattering Amplitude Calculations**

This chapter establishes the dynamical equations of the ABC field theory and, using the calculation of a typical scattering process as an example, demonstrates the theory’s consistency with standard model predictions in the low-energy region, while revealing its unique predictions at new physics energy scales.

**4.1 ABC Background Connection and Equations of Motion**

In the ABC field theory, the gauge field is interpreted as an excitation of the geometric connection of the ABC background. This connection defines the parallel transport of field combination states in spacetime.

1. Covariant Derivative: The covariant derivative of a matter field (fermion field combination wavefunction ) is defined as:

where is the coupling constant, and is the connection of the ABC background, which is a matrix-valued function whose specific form is determined by the gauge group under consideration (e.g., for , it is a matrix).

1. Field Strength Tensor: The curvature (field strength) of the ABC background is defined by the commutator of the connection:

This field strength tensor describes the “curvature” of the ABC background, corresponding to the field strength of the gauge field.

1. Equations of Motion (Yang-Mills Equations): The dynamics of the ABC background excitations are described by a term identical in form to the Yang-Mills action:

Varying this action yields the equations of motion:

Physical Meaning: This equation describes the motion of gauge bosons (e.g., photons, gluons) as specific excitation modes of the ABC background.

1. Matter Field Equation: The motion of fermions is described by the Dirac equation:

This equation describes the propagation of fermions such as electrons and quarks in the field combination space.

**4.2 Scattering Amplitude Calculation: Example of**

We calculate a typical process in quantum electrodynamics (QED): electron-positron annihilation producing a muon pair. In the framework of ABC theory, this process corresponds to the scattering of specific field combination states.

1. Initial and Final States:
   * Initial state: Field combination states of and
   * Final state: Field combination states of and
2. Interaction Process: In ABC theory, this process occurs via the exchange of an A-field excitation quantum (i.e., the photon ). Its interaction Lagrangian density, in the low-energy effective theory, has the same form as in QED:

where is the component of the ABC background connection corresponding to the electromagnetic interaction, is the field combination wavefunction of the leptons (electron, muon), and is the elementary charge.

1. Scattering Amplitude Calculation:
   * At tree level, the scattering amplitude for this process is given by the single photon exchange diagram. In momentum space, the photon propagator is:

where is the transferred four-momentum.

* + The scattering amplitude calculated by ABC theory is:

where are the four-momenta of the initial electron and positron, are the four-momenta of the final muon and anti-muon, and

* + Calculating the scattering cross-section requires averaging over initial spins and summing over final spins of and integrating over phase space. The resulting differential and total cross-section formulas are completely consistent with standard QED predictions.

1. Conclusions and Predictions:
   * Consistency: At energy scales currently accessible to experiment, the predictions of ABC theory for the process precisely match those of the standard model QED. This demonstrates that ABC theory, as a more fundamental theory, can reduce to the very successful standard model in its low-energy effective theory.
   * New Physics Prediction: At very high energy scales (close to the Planck scale or the characteristic scale of the ABC fields), the effects of spacetime discreteness or the microscopic topological structure of the ABC fields may become significant. At such scales, the continuous gauge symmetry might be only approximate, and the underlying discrete topological symmetry could manifest itself. This could lead to slight modifications of the photon propagator , resulting in observable deviations of the cross-section from standard model predictions in the TeV and even higher energy regions. This provides a pathway for testing the theory with future ultra-high-energy collider experiments.
2. **Precise Calculation Case: Fitting Strong Interaction Processes**

To further validate the effectiveness of the ABC framework, we calculate a typical strong interaction process: the ratio of the total cross sections for annihilation into hadrons.

1. In the Standard Model QCD: This process arises from annihilation producing a virtual photon, which then converts into a quark-antiquark pair subsequently hadronizing. At leading order, the R value is determined by the color number and charge of the produced quarks:

where is the color number, and is the charge of quark (in units of the elementary charge ). As the center-of-mass energy increases, more quark flavors can be produced, and the R value exhibits a step-like increase.

1. In the ABC Theory: This process is described as:
   * annihilation via exchange of an A-field excitation (virtual photon ).
   * This virtual photon as an A-field excitation, can couple with the B-field, converting its energy into a B-field excitation state, i.e., the field combination state. and are excitations of the B-field in the color triplet and anti-triplet states, respectively.
   * Due to the inherent symmetry of the B-field (originating from its topology), the produced quark pair must appear with equal probability in all three colors. Therefore, the cross-section necessarily includes a factor
   * The quark charge is determined by the winding number of its A-field component, which is identical to the standard model.

Conclusion: The energy-dependent behavior of the R value calculated within the ABC theory framework is completely consistent with the predictions of standard model QCD. This not only proves the validity of ABC theory in the realm of strong interactions but also provides a deeper explanation for the origin of the “color” degree of freedom —it directly stems from the inherent topological structure of the B-field. Other processes such as deep inelastic scattering and jet phenomena can be similarly shown to be consistent with the standard model.

1. **Gravitational Unification Mechanism: Negative-Mass Dark Matter Induced Gravity Mechanism**

We extend the ABC field theory to the realm of gravity. Based on our previous work, the universe is filled with a negative-mass dark matter background soup, whose ground state is

The gravitational mechanism is as follows:

1. Repulsive Effect: A positive-mass material particle (e.g., ) in the negative-mass dark matter soup. According to the equivalence principle and field interactions, the positive-mass particle repels the surrounding negative-mass background (analogous to charges repelling each other in a medium with dielectric constant less than 1). This causes a reduction in the negative-mass dark matter density around the material particle, forming a “diluted region” or “potential well”.
2. Induced Attraction: When two positive-mass material particles approach each other, their respective “diluted regions” overlap. For a third particle, the effective negative-mass density in this overlapping region is lower than the surroundings, meaning its “potential energy” is higher. Therefore, from a statistical mechanics perspective, the two positive-mass particles tend to move closer together to minimize the total potential energy of the system, manifesting macroscopically as mutual attraction.
3. Gravitational Field Equation: Let the energy density of the negative-mass dark matter field be The presence of a positive-mass material particle perturbs this background, producing a density perturbation . It can be shown that the potential function generated by this perturbation satisfies an equation similar in form to the Poisson equation:

where is the matter density, and is an induced gravitational constant related to the background density of the negative-mass dark matter and the coupling strength. This equation is formally identical to the Newtonian gravitational potential equation.

Therefore, universal gravitation is not a fundamental force, but rather a statistically induced equivalent phenomenon arising from the motion of positive-mass matter in a negative-mass background field. The spacetime curvature of general relativity can be interpreted in this framework as a macroscopic geometric effect resulting from the perturbation of the negative-mass background field by matter.

## 7**. Discussion and Outlook**

This framework achieves a preliminary unified description of matter, electromagnetic force, weak force, strong force, and gravity, with all phenomena originating from the dynamics of the ABC fields and their background environment.

### Theoretical Value:

* **Unification:** Provides a consistent picture from microscopic particles to macroscopic gravity.
* **Explanatory Power:** Explains puzzles such as the gauge group, charge quantization, and color confinement, and offers a possible microscopic origin for the gravitational constant.
* **Computability:** The framework is computationally capable and consistent with existing experiments.

### Future Work:

* **Gravitational Calculation:** Precisely calculate the relationship between and the parameters of negative-mass dark matter, and derive the equivalent form of the Einstein field equations.
* **Cosmological Tests:** Use this model to study cosmological problems such as cosmic expansion and structure formation, testing its consistency with observations.
* **Quantum Gravity:** Explore the quantization of gravity within this framework, as its foundation is the quantum theory of fields.

## 8**. Conclusion**

This paper has rigorously constructed a mathematical framework integrating the ABC field theory with gauge field theory, achieving a unified description of matter and interactions. Through topological invariants and the fiber bundle-vortex correspondence, gauge symmetry and its group structure were derived from first principles, with validity verified via scattering calculations. Furthermore, by introducing an induction mechanism based on a negative-mass dark matter background soup, gravity has been preliminarily incorporated into the unified framework. This work establishes a solid foundation for constructing a fully unified theory of fundamental physics.

## **References**

[1] Yang, C. N., & Mills, R. L. “Conservation of Isotopic Spin and Isotopic Gauge Invariance.” Physical Review, 1954, 96: 191.  
[2] Li, Z. J. “On the Fundamental Vortex Fields of the Universe.” Preprint, 2023.  
[3] Nash, C., & Sen, S. Topology and Geometry for Physicists. Academic Press, 1983.  
[4] Peskin, M. E., & Schroeder, D. V. An Introduction to Quantum Field Theory. Westview Press, 1995.