**Geometric Origin of Fundamental Particle Properties: A Unified Field Theory Based on Coupling of A (Wave), B (Charge), and C (Mass) Vortex Fields**  
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 **Abstract**  
This paper proposes a novel unified theoretical framework to explain the microscopic origin of fundamental particle properties (wave nature, charge, mass). We postulate the existence of three fundamental background fields in the universe: the A-field (responsible for wave nature and phase), the B-field (responsible for electric and color charge), and the C-field (responsible for mass and inertia). By constructing a unified action in a high-dimensional spacetime (e.g., 26 dimensions), we demonstrate that all observable properties of particles arise from their specific coupling modes with these background fields. Specifically:  
i) The particle wavefunction is interpreted as the quantum excitation of its A-field component, and the Schrödinger equation naturally emerges as the low-energy limit of A-field dynamics.  
ii) Charge quantization and fractional values are determined by the topological coupling number of the particle with the color-charge branch of the B-field, satisfying (), perfectly explaining the charge spectra of quarks and leptons.  
iii) The sign and magnitude of mass are governed by Yukawa coupling with the vacuum expectation value (VEV) of the C-field. The double vacuum structure of the C-field () provides a natural mechanism for explaining ordinary matter and potential negative-mass dark matter. This theory unifies wave-particle duality, charge quantization, and mass generation within a single geometric framework, offering a clear path beyond the Standard Model.  
**Keywords:** Unified Field Theory; Charge Quantization; Mass Generation; Wavefunction Origin; Topological Coupling; High-Dimensional Spacetime  
**1. Introduction**  
While the Standard Model (SM) has achieved great success, it treats fundamental issues such as charge quantization and mass distribution as input parameters rather than derived results. At a deeper level, the essence of the wavefunction in quantum mechanics and its statistical interpretation remain conceptually unresolved. This paper aims to provide a unified geometric origin for these fundamental properties from first principles.  
We propose the “ABC mechanism”: The universe consists of three fundamental vortex fields:  
- **A-field ()**: An electromagnetic vortex field carrying wave nature, phase, and interference phenomena, directly linked to de Broglie waves.  
- **B-field ()**: A color-charge vortex field with intrinsic gauge structure, whose topological branches (color and anti-color) directly correlate with charge quantization.  
- **C-field ()**: A Higgs-like vortex field associated with vacuum symmetry breaking and mass generation, whose vacuum degeneracy may imply matter-dark matter asymmetry.  
The paper is structured as follows: Section 2 constructs the high-dimensional unified action ; Sections 3–5 elaborate on how the A, B, and C fields generate wave nature, charge, and mass, respectively; Section 6 discusses the unified description and particle spectrum; Section 7 concludes with future outlook.  
 **2. ABC Unified Theoretical Framework**  
To accommodate rich field structures, spacetime is assumed to be (e.g., , inspired by the critical dimension in string theory). The unified action is defined as:

**Kinetic Term:**

where and are the field strength tensors of the A-field and B-field, respectively, and is the covariant derivative.  
**Interaction Term (Core of the Theory):**

Here, is the quantum operator of background field , is the coupling constant, and is the **property operator** characterizing the coupling mode between the particle field and the background field. This form ensures particle properties emerge dynamically from coupling, rather than being pre-assigned.  
 **3. Origin of Wave Nature from the A-Field**  
The particle wavefunction is not a fundamental entity but an effective description of the quantum excitation of its A-field component at low energies:

The wavefunction phase is determined by the quantized circulation of the A-field:

This mechanism directly explains quantum phase phenomena such as the Aharonov-Bohm effect and double-slit interference. In the non-relativistic limit, the equation of motion for the A-field reduces to the Schrödinger equation:

Thus, quantum mechanical wave nature is rooted in the classical geometric dynamics of the A-field.  
**4. Origin of Charge from the B-Field and Quantization**  
Charge originates from the topological properties of the B-field . The B-field has six branches (red, green, blue, and their anticolors). Define the **branch selection operator** , whose eigenvalue represents the net number of branches coupled to the particle ( for color, for anticolor).  
**Core Postulate:** Particle charge is determined by:

The charge operator is defined as , with the eigenvalue equation:

- : singlet (e.g., neutrino, photon), charge .  
- : triplet (e.g., quarks ), charge .  
- : anti-triplet (e.g., quarks ), charge .  
- : singlet (e.g., electron, muon, tau), charge .  
Charge quantization arises from the discreteness of and topological quantization of B-field flux.  
 **5. Origin of Mass from the C-Field and Sign Differentiation**  
Mass is generated via Yukawa coupling with the C-field :

When the C-field acquires a vacuum expectation value (VEV) , the particle mass is .  
**Innovation:** Assume the C-field potential admits two degenerate vacua:  
- **Positive-mass vacuum ()**:   
- **Negative-mass vacuum ()**:   
Thus:  
- Particles primarily coupled to acquire positive mass (), forming visible matter.  
- Particles primarily coupled to acquire negative mass (), becoming dark matter candidates.  
Mass hierarchies are determined by the Yukawa coupling constant , which may correlate with the coupling geometry between the particle field and the C-field.  
 **6. Unified Description and Particle Spectrum**  
A fundamental particle state is viewed as an entangled state of ABC field components:

Physical properties are determined by eigenvalues of corresponding operators:  
- **Momentum/Wavelength**: (from excitation)  
- **Charge**: (from topological number )  
- **Mass**: (from Yukawa coupling)

**ABC Classification of Standard Model Particles:**

| **Particle Type** | **A-Field Excitation** | **B-Field Topology** | **C-Field Vacuum** | **Mass** | **Charge** |
| --- | --- | --- | --- | --- | --- |
| Electron () | Strong |  |  |  |  |
| Up Quark () | Medium |  |  |  |  |
| Down Quark () | Medium |  |  |  |  |
| Neutrino () | Weak |  |  |  |  |
| Dark Matter Particle | Weak |  |  |  |  |

| **7. Conclusion and Outlook** This paper proposes a unified origin theory based on the coupling of three fundamental fields (A, B, C), attributing particle wave nature, charge, and mass to geometric and topological mechanisms. The framework naturally explains charge quantization, the mass sign problem, and geometrizes the wavefunction. **Future Research Directions:** 1. **Mathematical Rigor**: Derive the reduction from high-dimensional to 4D effective theory, proving consistency with the Standard Model Lagrangian. 2. **Phenomenological Predictions**: Calculate new effects on observables (e.g., lepton charge violation, dark matter distribution) to guide experimental tests. 3. **Quantum Gravity Extension**: Explore unification of ABC fields with gravity (as a “D-field”), advancing toward a theory of everything. |
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