# The Field-Theoretic Essence of Black Holes: A Quantum Gravity Model Based on Color-Charge Field Collapse and Bose-Einstein Condensation

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## Abstract

Based on Li Zhijun’s ABC (Electromagnetic-Color-Charge-Higgs) vortex field theory, this paper proposes a novel theoretical framework for the essence of black holes. We demonstrate that a black hole is not a spacetime singularity, but rather a volumeless Bose-Einstein condensate formed when ordinary matter undergoes color-charge field collapse under extreme gravitational conditions, with its energy transferred to the electromagnetic field component. By constructing the quantum collapse operator for the color-charge field B and the energy transfer tensor , we derive the critical conditions for black hole formation. By establishing a nonlinear Schrödinger-Einstein equation for the special boson field , we describe the properties of the black hole condensate. Finally, we prove the no-hair theorem and the entropy-area formula through the conservation of a topological current. This model, for the first time, fully incorporates black hole physics into the quantum field theory framework, resolves the information paradox and the singularity problem, and provides testable predictions for quantum gravity.  
**Keywords:** ABC Theory; Essence of Black Holes; Color-Charge Field Collapse; Bose-Einstein Condensation; Quantum Gravity; No-Hair Theorem  
 1. Introduction: Rethinking the Essence of Black Holes  
The black hole singularity predicted by general relativity is in fundamental conflict with quantum mechanics. Based on the ABC theory, this paper proposes that a black hole is the product of a quantum phase transition occurring during the gravitational collapse of a matter field. As a star collapses, the color-charge vortex field B of its material constituents is compressed and undergoes quantum tunneling, transferring its energy to the electromagnetic vortex field A, forming an entirely new bosonic condensate.  
 2. Theoretical Framework: Collapse and Energy Transfer of ABC Fields  
 2.1 ABC Representation of the Matter Field  
An ordinary fermion (e.g., a proton) can be represented as a specific combination of ABC fields:

Its energy components are:

2.2 The Collapse Operator of the Color-Charge Field  
Under the critical gravitational potential , the color-charge field collapses, described by the collapse operator:

where is the collapse amplitude, is the energy transfer coefficient, and is the residual state.  
 2.3 The Energy Transfer Equation  
The energy transfer is described by the stress-energy transfer tensor :

The specific form of is:

where is the contribution from the color-charge field.  
 3. Formation and Properties of the Special Boson  
 3.1 The Special Boson Field Equation  
After the energy transfer, a special boson field is formed, satisfying the nonlinear Schrödinger-Einstein equation:

where is the s-wave scattering length and is the boson mass.  
 3.2 The Condensate Wave Function  
The black hole is the ground-state condensate of , with its wave function given by:

where is the boson number, is the Schwarzschild radius, and is the chemical potential.  
 3.3 Mass-Radius Relation  
From the energy minimization condition , we obtain:

Solving for yields:

4. Thermodynamic and Quantum Properties of Black Holes  
 4.1 Statistical Origin of Entropy  
Black hole entropy originates from the number of microscopic states of the bosons:

where is the number of quantum states.  
Using Stirling’s approximation:

4.2 Proof of the Area Law  
When (where A is the horizon area):

This is consistent with the Bekenstein-Hawking entropy formula.  
 4.3 Tunneling Interpretation of Hawking Radiation  
Hawking radiation is a quantum tunneling effect of the boson condensate:

where is the Hawking temperature.  
 5. Topological Proof of the No-Hair Theorem  
5.1 Topological Current Conservation  
The black hole condensate satisfies the conservation of a topological current:

5.2 Field-Theoretic Formulation of the No-Hair Theorem  
The external field of the black hole is uniquely determined by the boundary condition:

This quantitative condition uniquely determines all external field solutions, proving the no-hair theorem.  
 6. Comparison with Existing Theories and Verification  
 6.1 Recovery in the Classical Limit  
As , the boson field equation degenerates to:

which is consistent with the prediction of general relativity in the static, spherically symmetric case.  
 6.2 Quantum Correction Effects  
Our theory predicts the following quantum corrections:  
1. **Quantum Correction to Black Hole Size:**

where is a numerical factor.  
2. **Sub-leading Correction to Entropy:**

3. **Correction to the Hawking Radiation Spectrum:**

7. Experimental Tests and Astronomical Observational Predictions  
 7.1 Constraints from Existing Observations  
- **Gravitational Wave Signals from Black Hole Mergers:** Highly consistent with predictions from general relativity.  
- **Black Hole Shadow Observations:** Consistent with predictions from the Kerr metric.  
 7.2 Predictions of New Physics  
1. **Quantum Black Hole Remnants:** Predicts the existence of stable black hole remnants with a minimum mass .  
2. **Polarization of Hawking Radiation:** Predicts that Hawking radiation has specific polarization properties, distinct from thermal radiation.  
3. **Black Hole Oscillation Modes:** Predicts that black hole quasinormal modes have detectable quantum corrections.  
 8. Conclusion and Outlook  
This paper, based on the ABC theory, proposes a new paradigm for the essence of black holes:  
1. A black hole is a Bose-Einstein condensate, not a spacetime singularity.  
2. Color-charge field collapse and energy transfer are the key mechanisms for black hole formation.  
3. The quantum field theory framework naturally leads to the thermodynamic and quantum properties of black holes.  
4. The no-hair theorem and the entropy formula are proven topologically.  
This theory provides a new approach to resolving the black hole information paradox and the singularity problem, and incorporates black hole physics into a unified quantum field theory framework.  
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