**Regulation of Temperature and Pressure on the Formation of Superconducting State: A Thermodynamic Field Theory Model Based on the Synergistic Effect of ABC Vortex Fields**

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**Abstract:**  
Based on Li Zhijun’s ABC cosmic vortex field theory, this paper proposes a comprehensive microscopic quantum field theory model for superconductivity that incorporates the effects of temperature () and pressure (). The core argument is that the superconducting phase transition is a quantum dynamical process in which electrons (as composite excitations of the electromagnetic vortex field (A-field), chromoelectric charge vortex field (B-field), and Higgs vortex field (C-field)) undergo energy level fusion through the exchange of virtual B-field excitations under the regulation of external thermodynamic parameters (), ultimately forming a global phase-coherent state dominated by the C-field. Through rigorous derivation, we demonstrate:

1. Field combination state in a thermodynamic environment: The occupancy of the electron state is determined by temperature through the generalized Fermi-Dirac distribution , where the chemical potential explicitly depends on pressure .
2. Pressure-modulated interactions: Pressure linearly modulates the Debye frequency of B-field excitations and the electron-B-field coupling strength by altering the lattice constant, making the interaction Hamiltonian a function of .
3. Quantum amplitude and effective potential: The scattering amplitude of the energy level fusion process explicitly depends on and , leading to the derivation of the effective attractive potential .
4. Explicit expression of critical conditions: The critical temperature formula is rigorously derived, fully revealing the dependence of on pressure .
5. Self-consistent equation of the order parameter: A self-consistent equation for the energy gap that depends on both temperature and pressure is constructed:

fully describing the formation and evolution of the superconducting state. This model, for the first time, integrates and as intrinsic variables into the quantum field theory framework of superconducting energy level fusion, providing a powerful theoretical tool for understanding and predicting the behavior of superconducting materials under external fields.

**Keywords:** ABC vortex field theory; superconductivity; temperature effect; pressure effect; energy level fusion; quantum amplitude; effective interaction; critical temperature; self-consistent equation

1. **Introduction**

Superconductivity, as a macroscopic quantum phenomenon, and its microscopic mechanism and response to external fields such as temperature () and pressure () are core issues in condensed matter physics. Li Zhijun’s ABC theory posits that all things in the universe are composed of three fundamental vortex fields: the electromagnetic vortex field (A-field), the chromoelectric charge vortex field (B-field), and the Higgs vortex field (C-field). This paper aims to build upon this theory to construct a thermodynamically complete quantum field theory model that naturally incorporates and into the dynamics of ABC field combinations, revealing the physical mechanisms by which they regulate the superconducting phase transition at the microscopic level.

1. **Theoretical Framework: ABC Field Combinations under Temperature and Pressure**

2.1 Basic Field Definitions

In Li Zhijun’s ABC theory:  
\* Electromagnetic vortex field (A-field): Corresponds to the gauge group. Its quantum excitations are photons, determining electromagnetic interactions. Its excitation state carries energy, momentum, and charge, with the quantum number labeling its energy level.

* Chromoelectric charge vortex field (B-field): Corresponds to the gauge group. Its excitations determine the chromoelectric charge and charge attributes of particles. Its negative branch provides the negative charge attribute for electrons.
* Higgs vortex field (C-field): Corresponds to the gauge group. Its positive mass branch couples with particles, providing rest mass and stabilizing their structure.

An electron is a specific composite excitation of these three fields, whose state vector can be expressed as:

This indicates that the energy level of an electron is determined by the excitation mode of the A-field, its charge attribute is determined by the branch of the B-field, and its mass is determined by coupling with the branch of the C-field. The normal metallic state is a mixture of such combination states with different .

2.2 Temperature Effect: Finite Temperature Occupancy

At finite temperature , the electron field combination state follows the grand canonical ensemble distribution, and its average occupancy is determined by the Fermi-Dirac distribution:

where is the Boltzmann constant. The chemical potential is a function of pressure , as pressure alters the electron gas density, thereby shifting the Fermi level . Temperature directly determines the availability and energy distribution of the initial electron pairs participating in the energy level fusion process. At high temperatures, the distribution broadens, dispersing electron energy levels and hindering consistent energy level fusion.

2.3 Pressure Effect: Interaction Modulator

Pressure directly affects the properties of the B-field excitations (whose low-energy excitations correspond to phonons), which serve as the interaction medium, by altering the lattice constant :

1. Debye frequency modulation: Phonon frequency is related to interatomic force constants and generally increases with pressure. We introduce a pressure-modulated Debye frequency:

where is the Grüneisen parameter, is the bulk modulus, and is the volume.

1. Coupling strength modulation: The electron-B-field coupling strength is also related to lattice dynamics. Based on a microscopic model, its pressure dependence can be derived:

where is a coefficient characterizing the sensitivity of the coupling to pressure.

Thus, the interaction Hamiltonian density becomes a function of pressure:

1. **Quantum Dynamics of the Fusion Process: Amplitude, Effective Potential, and Critical Conditions**

3.1 Medium of Interaction: Virtual B-Field Excitations

The microscopic interaction of the superconducting phase transition is mediated by the chromoelectric charge vortex field (B-field). Its low-energy collective excitations correspond to phonons. Electrons scatter by emitting and absorbing virtual phonons. The interaction Hamiltonian density for this process is:

where is the pressure-modulated electron-phonon coupling constant, and is the B-field excitation (phonon) operator.

3.2 Quantum Scattering Process: Microscopic Image of Emission and Absorption

Consider two electron field combination states at different energy levels:  
\* Initial state:

They scatter by exchanging a virtual phonon transitioning to the final state:  
\* Final state:

This process can be decomposed into two vertex processes:  
1. Emission process: Electron 1 (initial energy level ) emits a virtual phonon transitioning from energy level to an intermediate energy level . This process must satisfy energy-momentum conservation, with the emitted phonon carrying four-momentum .  
2. Absorption process: Electron 2 (initial energy level ) absorbs this virtual phonon transitioning from energy level to the same intermediate energy level . This process must satisfy energy-momentum conservation, with the absorbed phonon’s four-momentum equal to

Final result: Both electrons reach the same energy level . The net effect of the entire process is that two electrons with initial energy levels and fuse into the same energy level through the exchange of a virtual phonon. The energy level is determined by the energy-momentum conservation of the entire system.

3.3 Derivation of Quantum Scattering Amplitude

The scattering amplitude for the above tree-level process, according to Feynman rules, is the product of two vertex factors and one propagator:

where the virtual B-field propagator is:

Thus, the explicit expression for the amplitude is:

This quantitatively describes the probability amplitude of the energy level fusion process and explicitly depends on pressure through and .

3.4 Effective Interaction

Since the phonon is virtual, we need to integrate and average over all possible intermediate states (i.e., all possible phonon momenta and energies ) to obtain the net effective electron-electron interaction. Under the energy level fusion model, we focus on the scattering of electron pairs near the Fermi surface with zero total momentum. After integrating and approximating the propagator, we obtain the effective attractive potential as a function of pressure:

The negative sign clearly indicates the attractive nature of the interaction, which is the fundamental reason energy level fusion can occur.

3.5 Critical Temperature

Starting from the effective potential, the self-consistent equation for the superconducting energy gap can be derived:

At the critical temperature , Solving the above equation yields the critical temperature formula:

This is a core formula of the model. It explicitly shows how depends on pressure through , , and . The rate of change of with is:

This quantitatively predicts the response of to pressure.

3.6 Fusion Rate

The total rate of energy level fusion depends not only on the square of the quantum amplitude but also critically on the statistical distribution of initial and final states (Fermi distribution function and Pauli blocking factor ):

For the superconducting phase transition to occur, must exceed the decoherence rate caused by thermal fluctuations. is the temperature at which .

1. **Self-Consistent Equation of the Order Parameter and Phase Diagram**

4.1 Energy Gap Equation

The superconducting order parameter is characterized by the energy gap parameter whose self-consistent equation is:

This equation depends on both temperature and pressure .  
\* At , , and the equation simplifies to:

Solving this yields:

\* Near :

4.2 T-P Phase Diagram

By solving the equation and the energy gap equation, the phase diagram of the superconducting phase on the plane can be plotted. The characteristics of the phase diagram (whether increases or decreases with ) depend on the specific forms of , , and :  
\* If dominates, generally increases with .

* If or dominates, may decrease with or exhibit a maximum.

1. **Conclusion**

This paper successfully integrates temperature and pressure into the ABC quantum field theory framework, establishing a microscopic, self-consistent, and thermodynamically complete theoretical model for superconductivity:  
1. Role of temperature: Controls the initial energy level distribution and statistical availability of electron field combinations through the Fermi distribution .  
2. Role of pressure: Determines the effective strength, energy scale, and range of interactions by modulating and .  
3. Microscopic mechanism: The quantum amplitude and effective potential clearly reveal that the interaction originates from B-field dynamics.  
4. Macroscopic prediction: The formula and equation directly link macroscopic observables to microscopic parameters, providing powerful predictive capabilities.

This model not only explains superconducting phenomena but also provides a quantitative theoretical framework and computational tool for optimizing the search for higher materials through the combination of pressure and temperature.

**References**

[1] Li, Z. J. (2023). The ABC Vortex Field Theory of the Universe.  
[2] Schrieffer, J. R. (1964). Theory of Superconductivity. Benjamin.  
[3] Griessen, R., et al. (2016). Pressure-induced superconductivity in materials. Reports on Progress in Physics.  
[4] Allen, P. B., & Mitrović, B. (1983). Theory of superconducting Tc. Solid State Physics.