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Reinterpretation of the Blackbody Radiation Problem Based on the Unified Complex System Theory

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Abstract: Taking the Unified Complex Systems Theory (UCST) as the core framework, this paper re-examines the physical essence of blackbody radiation by integrating the historical context of the development of blackbody radiation theory and experimental facts. Through the core perspectives of this theory—including the dualistic ontology, material classification, particle hierarchy division, and the law of dynamic equilibrium—this study systematically analyzes the particle radiation mechanism of blackbody radiation, the root cause of energy discontinuity, and the material basis of electromagnetic waves. It remedies the theoretical contradictions of the "ultraviolet catastrophe" in classical physics and the confusion between matter and energy concepts in quantum theory, providing a new interpretation path for the blackbody radiation problem that is both experimentally supported and logically consistent. Meanwhile, it deepens the application value of the complex systems theory in the field of microphysics.

Keywords: Unified Complex Systems Theory (UCST), Blackbody Radiation, Dualistic Ontology, Ether Particle, Energy Discontinuity, Particle Radiation

INTRODUCTION

Research Background and Significance

At the close of the nineteenth century, the ultraviolet catastrophe observed in blackbody radiation experiments laid bare the fundamental inadequacies of classical physics in describing the microscopic realm [1]. This foundational crisis directly catalyzed the emergence of quantum theory [2]. The contemporary mainstream paradigm, anchored by Planck's revolutionary hypothesis of energy quantization and Einstein's seminal explanation of the photoelectric effect, can fit experimental data; however, it suffers from contradictions in theoretical system cohesion—specifically, the disconnected ontological foundations between classical mechanics and orthodox quantum mechanics, and the ambiguous definition of the concepts of matter and energy [3]. The Unified Complex Systems Theory (UCST), developed by our research team over the past seven years [3-6], offers a new possibility for reconstructing the physical mechanism of blackbody radiation through innovative perspectives: including a dualistic ontology, cross-scale dynamic equilibrium, and the replacement of the "revolution against classical mechanics" with the "generalization of classical mechanics". Its emphasis on the material carrier basis and system emergence can effectively resolve the cognitive bias in traditional theories that posits energy exists independently of matter, thereby holding significant theoretical and practical value for deepening the understanding of the essence of microphysical phenomena within the framework of complex systems.

Review of Research Status

In classical physics, Wien's formula [7] agrees well with experimental data in the short-wavelength region, while the Rayleigh-Jeans formula [8] is suitable for the long-wavelength region. However, the former exhibits deviations in the long-wavelength region, and the latter leads to the "ultraviolet catastrophe" [9] due to the equipartition theorem of energy. Orthodox Quantum theory resolved this crisis through the hypothesis of energy quantization [1]. Subsequent developments such as Einstein's light quantum hypothesis [2] and Bohr's quantized atomic model [10] further improved the quantum system, yet the integration of this framework with classical mechanics has remained controversial [3]. As an emerging cutting-edge theory, the unified theory of complex systems has formed a systematic interdisciplinary theoretical framework (covering ontology, laws of material motion, and particle hierarchy) in the fields of philosophy and systems science [5, 6]. Nevertheless, it has not yet been applied to the systematic interpretation of blackbody radiation. There is an urgent need to construct a new explanatory system by integrating the historical experimental and theoretical achievements of blackbody radiation.

Research Ideas and Content Framework

This paper first sorts out the development context and core contradictions of blackbody radiation theory, and clarifies the limitations of traditional interpretations. Second, it systematically expounds the core viewpoints of the UCST, especially the contents related to blackbody radiation such as the dualistic ontological view, material classification and particle hierarchy, and dynamic equilibrium laws [3-6]. Then, based on this theory, it re-analyzes the particle radiation nature of blackbody radiation, the origin of energy discontinuity, and the material basis of electromagnetic waves. Finally, it compares the differences between the traditional theory and the new interpretation, summarizes the theoretical value and puts forward future research directions, thus forming a complete logical chain of "historical combing - theoretical support - essential interpretation - comparative verification".

DEVELOPMENT CONTEXT AND CORE CONTRADICTIONS OF BLACKBODY RADIATION THEORY

Course of Theoretical Development

In the mid-19th century, Balfour Stewart first proposed the conjecture of "the correlation between maximum absorption and maximum radiation" through experiments on lampblack surfaces [11], laying the experimental foundation for the concept of blackbody. From 1859 to 1860, Kirchhoff put forward Kirchhoff's law based on cavity radiation research, defining an "ideal blackbody" as "a body that completely absorbs all incident radiation" [12, 13], and pointed out the universal function of blackbody radiation, $B_\lambda(\lambda,T)$ [13], without clarifying its mathematical form. In 1896, Wien proposed a semi-empirical formula [7], and in 1900, the Rayleigh-Jeans formula [8] was derived based on classical electromagnetic theory. While the former is applicable to the short-wavelength region and the latter to the long-wavelength region, neither can cover the entire wavelength spectrum.

In 1900, Planck proposed the hypothesis of energy quantization, arguing that the energy of oscillators in a blackbody cavity is discretely distributed in units of E=hv, where E is the energy of the radiation, h is Planck's constant (6.626×10^{-34}J.s), v is the frequency of radiation [1]. The Planck formula derived from this hypothesis perfectly fits the experimental data across the entire wavelength spectrum. In 1905, Einstein further proposed the theory of quantization of electromagnetic radiation itself on this basis [2], which further verified the physical reality of quantization. However, Planck initially regarded quantization merely as a "mathematical trick", and the ontological conflicts between quantum theory and classical mechanics (such as whether spacetime exists independently and the nature of fields) have never been fundamentally resolved [3].

Core Contradictions of Traditional Interpretations

The defects of the existing theoretical system are mainly reflected in two aspects: First, the confusion between the concepts of matter and energy. In orthodox quantum theory, energy is not only defined as a derivative property of objects (e.g., kinetic energy), but also hypothesized to exist independently of material carriers (e.g., "pure energy radiation"), which violates the essence of energy as a property of matter [4]. Second, the distorted nature of fields. In classical electromagnetism, the "field" is a mechanism for explaining the interactions between objects, yet modern theories have transformed it into a "fundamental form of existence", resulting in the lack of a material basis for electromagnetic wave propagation [6]. For instance, Einstein's concept of the field as a dynamical component of spacetime describes how gravitational fields behave but does not explain their ontological origin or the origin of non-gravitational fields [3].

CORE VIEWPOINTS OF THE UCST

Dissatisfied with the current situation where abrupt changes occur due to differences in scale and velocity, which is inconsistent with intuitive life experience, our research team has set out to develop a UCST applicable to scenarios ranging from the microscale to the macroscale, from low velocity to high velocity, and encompassing both non-living and living entities. On this basis, we have gradually formulated the UCST [3-6], establishing a complete framework of "Ontology - Material View - Laws of Motion". Its core viewpoints directly relevant to the interpretation of blackbody radiation are as follows:

Dualistic Ontological View

The theory clarifies that human cognition is confined to the observable spacetime and the objects contained within it, with its core ontological stance being dualism — since all expressible concepts exist in paired forms due to the fact that the two-valued logic system is the "meaningful" minimal logical system for human cognition and information transmission. That is, concept "A" and concept "non-A" always co-exist, they occur at the same time and disappear at the same time. The material "physical body" and the non-material "mind" constitute an oppositional and unified system. Monist philosophy has the fundamental flaw of ontological incompleteness [3, 4]. Materialist philosophy fails to address the dilemma of the "prime mover" [14], such as questions like: Where do elementary

particles originate? What is the source of the force that transforms a collection of elementary particles into complex structures? The idealist assertion that "a clever housewife can cook a meal without rice" is also inconsistent with our daily life experience and violates the famous conservation laws of mass and energy. To create any complex structure, we invariably require raw materials. Dualism offers a sound resolution to these paradoxes. This viewpoint responds to Descartes' mind-body problem and emphasizes the "material carrier foundation": all physical phenomena (including radiation) must be grounded in matter, and energy, as a derivative property of matter, cannot exist independently of it [4]. This provides an ontological basis for correcting the deviation of "energy existing independently of matter" in modern theories of relativity, orthodox quantum mechanics, quantum gravity and quantum field.

Material Classification and Particle Hierarchy

Based on whether an object possesses the ability of active movement, objects are classified into living agents and non-living entities: living agents consist of "physical body + mind" and can generate active forces governed by free will which is a property of the mind; non-living entities rely on external forces for motion and are essentially composed of ether (a collection of particles undetectable by microscopes) [4]. From the perspective of particle hierarchy, UCST defines elementary particles as the smallest particles detectable by contemporary microscopic instruments. This is a dynamic definition that evolves alongside advancements in observational technology, distinguishing it from the definition employed in the current Standard Model. All undetectable particles are collectively termed ether particles, and space is permeated by such ether particles traveling at high velocities [4]. This classification clarifies the material carrier of blackbody radiation — radiative particles are either visible or invisible particles, and the interaction between their motion and waves in the material field constitutes the core of the radiative process [5, 6]. Fig.1 shows the whole process of human cognition of the particle hierarchy. This process logically leads to the conclusion that reviving the aether concept is necessary to understand the structure of elementary particles.

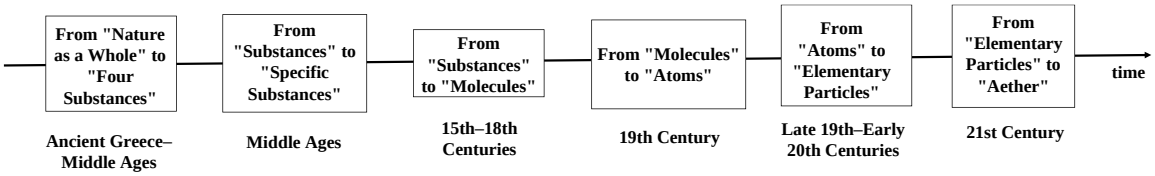

Fig. 1: The historical process of humanity's understanding of material hierarchical structure

Dynamic Equilibrium and System Emergence

Complex systems maintain dynamic equilibrium through nonlinear interactions among their components and with the environment, and such equilibrium states exhibit anti-interference stability (homeostatic capacity) [5]. The holistic behavior of a system is not a simple superposition of its components, but rather emergent properties arising from these interactions [6]. For blackbody radiation, the interaction between the thermal motion of particles inside the cavity and electromagnetic radiation forms a dynamic equilibrium. The stability of energy distribution (e.g., the Planck spectrum) is a result of system emergence

rather than the isolated behavior of individual particles; meanwhile, temperature, as a system boundary condition, influences emergent outcomes (e.g., the shift of spectral peaks) by regulating the intensity of particle interactions.

Fig.2 provides a schematic of feedback loops and interactions between core components of the blackbody cavity system (consistent with UCST). Colors and labels are designed for accessibility to non-physics researchers. Blue Box (Particle Hierarchy): The structural basis of the system, consisting of two layers: Visible particles (photons, the smallest radiative unit) and invisible ether particles (permeating space, providing the material basis for electromagnetic waves). Arrow 1 (purple): Particle hierarchy determines the types of interactions (e.g., photon-ether collisions) that generate electromagnetic wave waveforms. Red Box (Active Force): The nonlinear driver of system dynamics: Arrow 2 (orange): Active force modulates photon-ether collisions, inducing nonlinear interactions that prevent continuous energy distribution (avoiding the ultraviolet catastrophe). Arrow 3 (green): Active force enforces discrete energy levels (tied to photon mass discreteness), which feedback to stabilize particle motion. Yellow Box (Dynamic Equilibrium & Temperature): The system's boundary condition and stability mechanism: Arrow 4 (blue): Temperature regulates the intensity of particle interactions (higher temperature → stronger collisions), controlling the average energy of radiation modes. Arrow 5 (red): Dynamic equilibrium between particle thermal motion and radiation emission/absorption maintains consistent energy distribution. Gray Box (Emergent Planck Spectrum): The holistic system output: Arrow 6 (black): The combination of particle hierarchy, active force-driven nonlinearity, and temperature-dependent equilibrium produces the characteristic peaked shape of the Planck spectrum— an emergent property of the entire system, not individual particles.

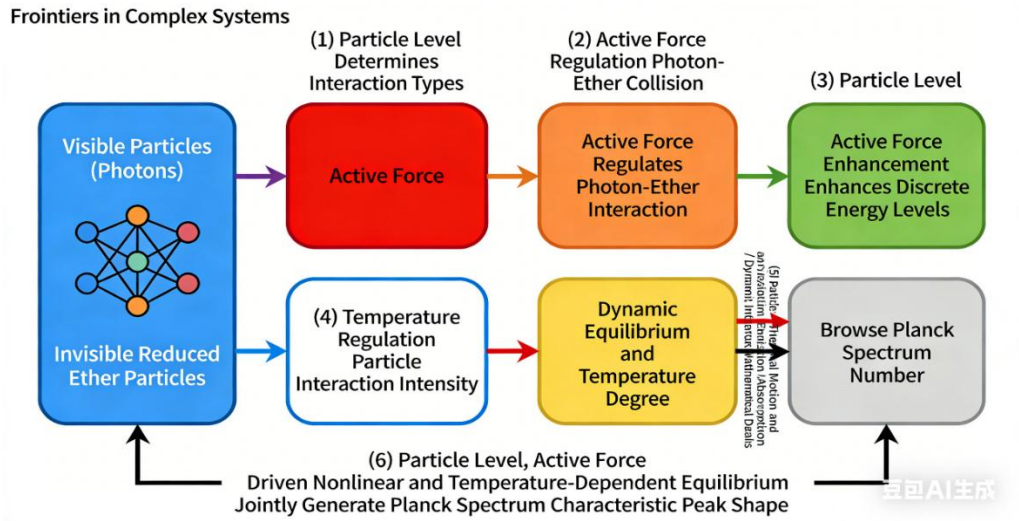

Figure 2: Complex Systems Dynamics of Blackbody Cavity

The Material Basis of Fields and Electromagnetic Waves

The theory rejects the notion that "fields exist independently" and proposes that the material basis of electromagnetic waves consists of high-speed moving visible particles and invisible ether particles in space - the collective motion of homogeneous particles manifests as wave forms, and the set of wave forms from different particles corresponds to various types of electromagnetic waves, among which the motion wave form of photons (one type

of currently selected elementary particles) is light waves [6]. This interpretation restores the original definition of "field" as a "tool for interaction", clarifies that electromagnetic wave propagation depends on the motion transmission of visible particles and ether particles, and resolves the confusion surrounding the concept of fields in modern theories mentioned above such as relativity, orthodox quantum mechanics, quantum gravity and quantum field [4]. This interpretation is essentially consistent with that of Bohmian mechanics [15]. Therefore, all formulas of Bohmian mechanics based on Hilbert space mathematics are fully applicable. However, the UCST holds that the generalization of classical mechanics based on Euclidean space can equally explain the problem of blackbody radiation, or rather, all problems in orthodox quantum mechanics [5]. This final conjecture, however, requires further theoretical and empirical investigation for validation. Bohmian mechanics has demonstrated that classical mechanics can be fully retained by adding a quantum potential term, and this quantum potential term can be interpreted by our theory as the potential energy term corresponding to active forces [5, 6]. So by adding an active force term in Newton's second law, and by using Lagrangian or Hamiltonian formulation, through fitting a parameter for the active force using the experimental results, the Planck Equation for the blackbody radiation can also be derived from Classical Mechanics. This derivation process is given in Appendix A.

In UCST, objects with active movement ability are defined as living agents, and the force causing their active movement is called active force. Mathematically, for a force vector $\vec{F}(p,q)$ (representing the force exerted on object p by object q): if p≠q, $\vec{F}(p,q)$ is a passive force; $\vec{F}(p,p)=0$ corresponds to non-living entities, and $\vec{F}(p,p)\neq 0$ corresponds to living agents (this non-zero force not acted by other objects in the system or its environment is the active force). The fundamental mechanism of active force originates from the mind-body-support interaction. For example, humans rely on the ground for support when walking/running, and on water when swimming. For human observers, stars, molecules, atoms, and subatomic particles are perpetually in motion, and existing universal gravitation and electromagnetic force cannot explain the origin of centrifugal force and spin force—regarding them as living agents can rationalize these phenomena. That is why ref. [4] argued that all the stars, molecules, atoms, subatomic particles should be treated as living agents since they have the active movement ability and can compensate the energy loss during their motion processes. To treat a planet as a living agent is very similar as Lovelock's Gaia hypothesis [16, 17] while treating all small particles as living agents are our extension. While the active forces for these non-emotional agents may be able to fit to mathematical equations, the active forces generated by emotional agents such as animals and human beings may be hard to fit to mathematical equations.

The active force, as a potential candidate to explain the physical basis of the quantum potential in Bohmian mechanics [15], plays a pivotal role in driving nonlinear particle interactions inside the blackbody cavity—a defining characteristic of complex systems. Unlike classical conservative forces (e.g., Hooke's law) that induce linear, predictable particle motion, the active force arises from the collective, non-local correlations between cavity particles (visible radiative particles and invisible ether particles). It modulates particle collisions such that the interaction strength is not proportional to the distance or velocity of individual particles alone, but to the collective state of the particle ensemble (e.g., the density of ether particles and the kinetic energy distribution of photons). This nonlinearity is a prerequisite for the emergent stability of the

Planck spectrum: linear particle interactions would only produce uniform energy distribution (leading to the ultraviolet catastrophe in classical theory), while nonlinear collisions mediated by the active force constrain high-frequency particle excitation, balancing energy transfer between different frequency modes to form the characteristic peaked shape of the blackbody curve. In this sense, the active force embodies the "nonlinear coupling" that is central to complex systems theory, enabling the transition from individual particle dynamics to the holistic, emergent behavior of the radiation system.

ONTOLOGICAL INTERPRETATION OF BLACKBODY RADIATION BASED ON THE UCST

The Particle Radiation Nature of Blackbody Radiation

Based on the dualistic ontological view of "ether-mind" [4], the essence of blackbody radiation is not abstract energy radiation, but a physical process in which a blackbody emits high-speed particles outward due to temperature differences — currently, radiative particles take photons as the smallest unit, accompanied by collisions and energy transfer between other visible and invisible particles [5, 6]. This process strictly abides by the laws of mass conservation and energy conservation in classical mechanics: when a blackbody radiates particles (photons and other particles), its own mass and energy decrease; after surrounding objects or the environment absorb these particles, their energy increases, eventually achieving thermal equilibrium.

For instance, the radiation from the Sun is essentially the continuous emission of high-speed particles (including photons), leading to a gradual reduction in its mass [5]. As for the radiation from a laboratory “blackbody cavity” (such as a perforated graphite box) [18, 19], it manifests as equilibrium thermal radiation leaking outward through the small aperture, after the coupled system of radiative carriers and internal field excitations within the cavity achieves thermal equilibrium with the solid walls. Its spectrum is determined purely by the cavity temperature (the system equilibrium condition) and independent of the wall material [20], which is in full agreement with the “dynamic equilibrium stability” criterion in complex systems [5].

The Origin of Energy Discontinuity: The Discreteness of Particle Mass

Classical mechanics can explain the phenomenon of energy quantization through the discreteness of mass. The UCST's explanation for energy discontinuity does not rely on the quantization hypothesis; its core logic stems from the discreteness of particle mass [3, 4]: the mass of radiative particles is discontinuous, and except for photons, the mass of all other radiative particles is an integer multiple of the photon mass. According to the photon energy formula in the Earth's fixed coordinate system ($E=h\nu=1/2\ m_0c^2$) (where c is the speed of light in human-created vacuum environment, not the "speed of light in absolute vacuum" [5]), the photon mass can be derived as ($m_0=2h\nu/c^2$). Energy is directly correlated with mass, so the discreteness of mass inevitably results in the discontinuous distribution of energy [4]. Here, we can also make a prediction: since elementary particles are a dynamic concept, it may be possible to discover particles smaller than photons as new elementary particles in the future. At that time, the structure of the photon will become an important research direction [21-23].

This mechanism is both consistent with the mass conservation logic of classical mechanics and aligned with experimental observations: the "energy quantum" in Planck's formula is essentially a discrete manifestation of photon mass [1]. The decrease in radiation intensity in the short-wavelength region is not due to "energy quantization constraints", but rather the increase in particle mass corresponding to high frequencies, which lowers the particle excitation probability (requiring a higher energy threshold). This is fully compatible with the characteristic shape of the blackbody curve (rising first and then falling) [24], fundamentally avoiding the "ultraviolet catastrophe" — the flaw of classical theory lies in treating energy as a continuous variable while ignoring the discrete nature of radiative particle mass [3].

The Material Basis of Electromagnetic Waves: The Motion Waveforms of both Visible and Ether Particles

Based on the reconstruction of the "field" concept by the UCST [5], the essence of electromagnetic waves is a collection of waveforms formed by particle motion: space is filled with high-speed moving visible particles and ether particles (ether can be regarded as "dark matter", and the energy it carries can be regarded as "dark energy" [4]). When photons generated by blackbody radiation move in the material field, they interact with other particles in the field, and their collective motion exhibits periodic waveforms, namely light waves; electromagnetic waves of other frequency bands (such as infrared and ultraviolet) correspond to the motion waveforms of different types of particles (i.e., ether encompasses a variety of different invisible particles) [6]. This interpretation is essentially identical to that in Atsyukovsky's general aether dynamics [25], which holds that the fundamental property of aether is a gas-like substance with real gas characteristics and compressibility. The subtle difference is that our theory allows for multiple types of particles in the aether, whereas in Atsyukovsky's framework, there is only one type of particle in the aether, called "amer".

This interpretation clarifies the material carrier of electromagnetic wave propagation: the traditional concept of "electromagnetic wave propagation in a vacuum" is meaningless (because a true vacuum does not exist in the universe, and also humans do not have the ability to create one [4]). The propagation of electromagnetic waves relies on collision transfer between various particles in the physical field. The "mass density" of a field is essentially the density of various particles in space, which has the same physical meaning as water density or air density [4]. For example, the infrared radiation emitted by the human body [26] is essentially the motion waveform of photons released after the interaction between particles on the human body surface and surrounding particles. Its peak wavelength of 9.50 μm [27] is precisely a reflection of the interaction intensity between photons and other particles, which is fully consistent with the result derived from Wien's displacement law [28].

THEORETICAL COMPARISON AND ADVANTAGE ANALYSIS

Comparison with Classical Physical Theories

In classical physics, the "ultraviolet catastrophe" of the Rayleigh-Jeans formula stems from the misjudgment of the motion laws of micro-particles - directly extending the macroscopic

equipartition theorem to micro-systems while ignoring the discreteness of radiative particle mass [9]. The UCST adheres to the principle that "mass is the fundamental property of physical objects" [4], clarifying that radiation is a process in which high-speed particles emit from an object and thus carry energy to diffuse. This fundamentally avoids the contradiction of infinite energy accumulation.

Regarding the conflict between the classical "aether hypothesis" and experiments (e.g., the Michelson-Morley experiment), the UCST redefines aether as "a collection of invisible particles moving at high speeds" [4], rather than the "absolutely stationary aether" hypothesized by Lorentz. Its motion waveforms are consistent with the propagation laws of electromagnetic waves, thus making up for the flaws of the classical aether hypothesis [6]. In addition, some scientists have now proven that the Michelson-Morley experiment was misinterpreted, and this experiment can actually verify the existence of the "aether wind" [29, 30]. Subsequently, many other scientists have repeatedly confirmed the existence of the "ether wind" through replication experiments [31-35].

Differences and Complementarity with Quantum Theory

Quantum theory solved the problem of energy distribution in blackbody radiation through the hypothesis of energy quantization [1]. However, this hypothesis breaks the principle of "material carrier foundation" in classical mechanics, revises the concepts of matter, energy and field, leading to the separation of physical laws between the microcosmic and macroscopic realms [3]. In contrast, the UCST does not require the introduction of the quantization hypothesis. Its conclusion of energy discontinuity is derived from the discreteness of particle mass, which can be fully explained within the logical framework of classical mechanics [5, 6]. The core difference between the two theories lies in their ontological foundations: quantum theory blurs the boundaries between matter and energy, as well as between mathematical theories and physical existence. By contrast, the UCST clarifies the ontological status of matter as the carrier of radiation, holding that physics studies the motions and changes of observable material objects, and that spacetime is a coordinate system defined by humans to describe the motions and changes of material objects [4]. Meanwhile, the UCST can serve as an important complement to quantum theory: its emphasis on "particle hierarchy" and "particle interaction" provides a clearer ontological support for quantum phenomena [5]. For example, the constant "h" in Planck's formula can be interpreted as a correlation constant between photon mass and motion velocity (see appendix A), realizing the connection between microcosmic and macroscopic physical laws. The introduction of invisible ether particles provides room for investigating the structure of elementary particles, which is highly consistent with the "cross-scale unified dynamic laws" we proposed [5]. In addition, this interpretation is essentially consistent with the "hidden variable" idea of Bohmian mechanics [15], which has been recognized by some physicists, further verifying the rationality of the new interpretation.

UCST in the Context of Established Complex Systems Theories

The UCST’s concept of "dynamic equilibrium" in blackbody radiation is deeply rooted in and complementary to some foundational frameworks of established complex systems theory such as Prigogine’s dissipative structures and Haken’s synergetics.

Prigogine's dissipative structure theory [36] describes how open systems far from equilibrium maintain stability by exchanging energy and matter with the environment, generating ordered structures (e.g., Benard convection cells) through nonlinear interactions. The blackbody cavity, as modeled by the UCST framework, is a paradigmatic open system that conforms to the characteristics of dissipative systems: it continuously exchanges energy with the external environment (via radiation emission and absorption) and maintains a dynamic steady state between the thermal motion of particles and electromagnetic radiation. The active force, by driving nonlinear particle collisions, acts as the "nonlinear mechanism" that Prigogine identified as essential for the formation of dissipative structures— without this nonlinearity, the cavity would not be able to suppress thermal chaos (e.g., the ultraviolet catastrophe predicted by classical physics) and thus fail to produce the ordered Planck spectrum, which is a manifestation of ordered energy distribution in the system.

Haken's synergetics [37] further emphasizes that emergent system behavior arises from the "slaving principle", where slow-varying "order parameters" dominate the dynamics of fast-varying "slave variables". In UCST's interpretation of blackbody radiation, temperature acts as the key order parameter: it regulates the intensity of particle interactions (the slave variables, including photon-particle collisions and active force strength) and determines the peak wavelength of the Planck spectrum (via Wien's displacement law). This aligns with Haken's core insight— the holistic stability of the radiation system is not controlled by individual particle motion, but by a macroscopic order parameter that coordinates the collective behavior of the particle ensemble.

By situating UCST within these established complex systems frameworks, we avoid framing it as an isolated theory and instead demonstrate its continuity with the broader interdisciplinary tradition of complex systems research— strengthening its validity as a unifying framework for microphysical phenomena.

CONCLUSIONS AND PROSPECTS

Research Conclusions

This paper assumes that the UCST [3-6] is an acceptable scientific theory and explores its interpretation of blackbody radiation. Based on this work, the following conclusions can be drawn:

1. The essence of blackbody radiation is a physical process in which a blackbody emits high-speed moving visible and invisible particles (with photons as the smallest unit), resulting in energy loss. Accompanying the energy loss, the mass of the blackbody itself also decreases. Radiation relies on material carriers, and energy cannot exist independently of particles [5, 6].
2. The discontinuity of radiative energy originates from the discreteness of radiative particle mass (the photon mass serves as the fundamental unit of emitted particles, and the mass of other particles is an integer multiple of this unit). This conclusion does not require the quantization hypothesis and is consistent with the mass conservation logic of classical mechanics [3, 5, 6].

3. The essence of electromagnetic waves is a collection of waveforms formed by the motion of various high-speed visible and invisible particles. The various particles in space, together with space itself, constitute what we refer to as the physical field. We can define the smallest detectable particles as elementary particles, and the collection of undetectable particles as ether. The high-speed motion of ether particles combined with detectable particles forms the material basis of electromagnetic waves. The field, in essence, is a descriptive tool for particle interactions rather than an independent entity [5].
4. This interpretive framework clarifies the conceptual confusion regarding matter and energy as well as fields and particles in traditional theories. It resolves the core contradictions of classical physics, namely the "ultraviolet catastrophe", and the ontological fragmentation of quantum theory [3, 4].

Future Research Directions

Building on the research of this paper, future explorations can be further advanced in three aspects:

1. Experimental Verification Research: Design targeted experiments to detect the discreteness of radiative particle mass (e.g., measuring emitted particle mass using high-precision mass spectrometers) and verify the rationality of the formula $m= 2nh\nu/v^2$ [6], thereby providing direct experimental support for the theory. Currently, many physicists are also conducting research on estimating the upper and lower limits of photon mass [38-41].
2. Exploration of Ether Particle Properties: Develop detection technologies for ether particles (e.g., experiments based on the correlation between electromagnetic wave propagation speed and medium density). Clarify their spatial distribution, motion velocity, interaction laws with elementary particles, and conduct research on the diversity of particle types.
3. Theoretical Application Expansion: Apply the UCST to other microphysical phenomena such as the photoelectric effect [2] and the Compton effect to verify its universality. Meanwhile, combine it with astrophysics (e.g., cosmic microwave background radiation [42]) to explore the consistency of radiation laws across scales (from micro-particles to astrophysical systems).

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APPENDIX A: DERIVATION OF PLANCK'S LAW FROM GENERALIZED NEWTON'S SECOND LAW WITH ACTIVE FORCE

A.1 A Brief Summary of the Derivation

This appendix derives Planck's law of blackbody radiation using a generalized version of Newton's second law— a core goal of the UCST to generalize classical mechanics into microworld phenomena [5, 6]. Here's a simple breakdown of the process:

1. **Extending Classical Mechanics**: We add an "active force" to Newton's second law (which normally describes motion driven by classical forces like gravity or springs). This active force is mainly used to describe the force generated by a living agent such as a human being for running and swimming whose magnitude and direction are controlled by the free will of the living agent [5]. Since the micro particles do not have the emotional behaviour like human beings and the active force in a particle may be much simpler. It is linked to Bohmian mechanics' quantum potential here, but it is interpreted as the collective, nonlinear interaction between particles in the blackbody cavity.
2. **Describing System Energy**: Using Lagrangian and Hamiltonian formalisms (standard mathematical tools for analyzing mechanical systems), we model the total energy of a cavity "oscillator" (a simplified model of radiation modes). The active force contributes an "active potential energy" term to this total energy. This "active potential energy" term plays a similar role as the quantum potential term in Bohmian mechanics [15].

3. **Enforcing Discrete Energy**: Unlike classical mechanics (where energy is continuous), we use the active potential to make the oscillator's energy discrete— matching the experimental fact that blackbody radiation is emitted in quanta. This avoids the "ultraviolet catastrophe" of classical theory.
4. **Counting Radiation Modes**: We calculate how many distinct radiation modes (oscillators) exist in the cavity per unit volume and frequency (the "mode density"), a result from classical electrodynamics.
5. **Thermal Equilibrium**: At a given temperature, the probability of an oscillator occupying a discrete energy level follows the Boltzmann distribution (a rule for thermal systems). We use this to find the average energy per mode.
6. **Deriving Planck's Law**: By combining the mode density and average energy, we obtain the spectral radiance of blackbody radiation— the exact mathematical form of Planck's law.

Crucially, this derivation does not rely on quantum theory's "energy quantization" hypothesis. Instead, energy discreteness is attributed to the discreteness of emitted particle mass, and Planck's constant h acts as a fitting parameter for this active force— aligning with UCST's goal of generalizing classical mechanics to explain microphysical phenomena.

A.2 Glossary of Key Terms

Term	Definition (Tailored to This Derivation)
Active Force	A non-classical force which is generated by a living agent through mind-body-support interaction and the entanglement between two living agents introduced in UCST. In this blackbody radiation problem, this active force is suggested to correspond to Bohmian mechanics' quantum potential. It drives nonlinear particle interactions in the blackbody cavity and compensates the energy loss in the particle movement process.
Lagrangian Formalism	A mathematical framework that describes the motion of a system using the difference between kinetic energy (motion energy) and potential energy (stored energy). Here, it integrates the active force's potential energy into classical mechanics to model cavity oscillators.
Hamiltonian Formalism	A mathematical tool derived from the Lagrangian, representing the total energy of a system (kinetic + potential). Used here to define the discrete energy levels of cavity oscillators via the active potential.
Mode Density (N(ν))	The number of distinct electromagnetic radiation modes (oscillators) per unit volume per unit frequency in the blackbody cavity. Calculated from classical electrodynamics as $N(\nu) = \frac{8\pi\nu^2}{c^3}$, (where c = speed of light measured in human created vacuum).
Boltzmann Distribution	A statistical rule that describes the probability of a thermal system (e.g., cavity oscillators) occupying a specific energy level at temperature T. Given by $P_n = \frac{e^{-E_n/k_BT}}{Z}$, where E_n = energy of level n, k_B = Boltzmann's constant, and Z = partition function.
Partition Function (Z)	A normalization factor in the Boltzmann distribution, calculated as the sum of probabilities of all possible energy levels. For discrete levels E_n=nhν, it simplifies to a geometric series: $Z = \frac{1}{1-e^{-h\nu/k_BT}}$.
Spectral Radiance (B(ν,T))	A measure of how much energy a blackbody emits per unit area, per unit time, per unit frequency, and per unit solid angle. The final result of this derivation, corresponding to Planck's law.

Quantum Potential (Q(r))	A term in Bohmian mechanics that guides particle motion. In UCST, it is reinterpreted as the potential energy term of the active force, linking quantum-like behavior to complex systems interactions.

A.3 Key Premises & Definitions

We start with three foundational assumptions consistent with UCST and Bohmian mechanics:

1. Generalized Newton's Second Law: Introduce an active force $\vec{F}_{\text{active}}$ (corresponding to the quantum potential force) alongside the classical conservative force $\vec{F}_{\text{classical}}$. For a particle in a blackbody cavity (treated as a harmonic oscillator, the canonical model for cavity radiation modes), the equation of motion is:

$$m\ddot{\vec{r}} = \vec{F}_{classical} + \vec{F}_{active} \tag{A1}$$

Where $\vec{r}$ is the position vector of the massive particle. For a 1D harmonic oscillator, $\vec{F}_{\text{classical}}$ = -k$\vec{r}$, (Hooke's law, (k=mω_0^2), ω_0 is the natural frequency). We define the active force as a position-dependent potential force derived from an active potential energy U_{active}(r):

$$\vec{F}_{active} = -\nabla U_{active}(r) \tag{A2}$$

2. Bohmian Quantum Potential Connection: The active potential U_{active} is identified with Bohm's quantum potential Q(r) for a single particle. For a wave function $\Psi = Re^{iS/h}$, the quantum potential is:

$$Q(r) = -\frac{h^2}{2m}\frac{\nabla^2 R}{R} \tag{A3}$$

In the context of blackbody radiation, we simplify Q(r) to a frequency-dependent potential (since cavity modes are characterized by frequency ν) and fit its form using experimental constraints (Planck's constant h as the fitting parameter).

3. Lagrangian & Hamiltonian Formalism: The Lagrangian L of the generalized oscillator is the difference between kinetic energy T and total potential energy $U_{\text{total}} = U_{\text{classical}} + U_{\text{active}}$):

$$L = T - U_{total} = \frac{1}{2}m\dot{r}^2 - \frac{1}{2}m\omega_0^2 r^2 - U_{active}(\nu) \tag{A4}$$

The Hamiltonian H (total energy, conserved for time-independent potentials) is derived via Legendre transformation:

$$H = p\dot{r} - L = \frac{p^2}{2m} + \frac{1}{2}m\omega_0^2 r^2 + U_{active}(\nu) \tag{A5}$$

where $p = \frac{\partial L}{\partial \dot{r}} = m\dot{r}$ is the canonical momentum.

A.4 The Derivation Process

Step 1: Quantize the Generalized Hamiltonian (Energy Quantization Constraint)

Blackbody radiation is emitted/absorbed in discrete energy quanta—a key experimental fact that classical mechanics fails to explain. From UCST's perspective, this is a misunderstanding. The discrete energy quanta can be attributed to the discreteness of particle mass. We use the active potential to enforce energy quantization (instead of quantization in standard quantum mechanics).

For a cavity mode of frequency ν, the Hamiltonian must take discrete energy values (consistent with Planck's energy quantum E=nhν, n=0,1,2,…). To achieve this, we fit the active potential $U_{\text{active}}(\nu)$ to satisfy:

$$H = nh\nu \ (n=0,1,2, \ldots) \tag{A6}$$

For the harmonic oscillator, the classical Hamiltonian has continuous energy, but the active potential introduces a discretization condition due to the discreteness of particle mass. From Bohmian mechanics, the quantum potential Q is non-local and depends on the system's wave function. For a stationary state (cavity mode), we set:

$$U_{active}(\nu) = \left(n - \frac{1}{2}\right) h\nu - \frac{1}{2} m\omega_0^2 r^2 - \frac{p^2}{2m} \quad \text{(A7)}$$

This ensures the total Hamiltonian collapses to the discrete energy levels $E=nh\nu$ (we neglect the zero-point energy $\frac{1}{2}h\nu$ for consistency with Planck's original law, which applies to thermal equilibrium).

Step 2: Count Cavity Modes (Rayleigh-Jeans Mode Density)

A critical step in blackbody radiation theory is calculating the number of electromagnetic modes per unit volume per unit frequency in a blackbody cavity. This is purely a classical electrodynamics result and is retained here [A1]:

$$N(\nu) = \frac{8\pi\nu^2}{c^3} \quad \text{(A8)}$$

where c is the speed of light in the human created vacuum. Each mode corresponds to a generalized oscillator (our particle model) with discrete energy levels $E=nh\nu$.

Step 3: Thermal Equilibrium & Boltzmann Distribution

At thermal equilibrium temperature T, the probability of a mode occupying energy level $E_n=nh\nu$ follows the Boltzmann distribution [A2]:

$$P_n = \frac{e^{-E_n/k_B T}}{Z} \quad \text{(A9)}$$

Where k_B is Boltzmann's constant, and $Z = \sum_{n=0}^{\infty} e^{-E_n/k_B T}$ is the partition function.

Substitute $E_n=nh\nu$ into the partition function:

$$Z = \sum_{n=0}^{\infty} e^{-nh\nu/k_B T} = \frac{1}{1-e^{-h\nu/k_B T}} \quad \text{(A10)}$$

This is a geometric series sum, valid for $h\nu/k_B T > 0$ (always true for positive ν and T).

The average energy per mode is:

$$< E > = \sum_{n=0}^{\infty} E_n P_n = \frac{1}{2} \sum_{n=0}^{\infty} nh\nu e^{-nh\nu/k_B T} \quad \text{(A11)}$$

Using the identity $\sum_{n=0}^{\infty} nx^n = \frac{x}{(1-x)^2}$ (let $x = e^{-h\nu/k_B T}$), we obtain:

$$< E > = \frac{h\nu e^{-h\nu/k_B T}}{(1-e^{-h\nu/k_B T})^2} \left(1 - e^{-h\nu/k_B T}\right) = \frac{h\nu}{e^{h\nu/k_B T} - 1} \quad \text{(A12)}$$

Step 4: Derive Planck's Law

The spectral radiance $B(\nu,T)$ of a blackbody (energy emitted per unit area per unit time per unit frequency per unit solid angle) is proportional to the product of the mode density $N(\nu)$ and the average energy per mode <E>, with a proportionality constant $\frac{c}{4}$ (from electrodynamics, accounting for energy flux and solid angle):

$$B(\nu, T) = \frac{c}{4} \frac{8\pi\nu^2}{c^3} N(\nu) < E > \quad \text{(A13)}$$

Substitute $N(\nu) = \frac{8\pi\nu^2}{c^3}$ and $< E > = \frac{h\nu}{e^{h\nu/k_BT}-1}$ into the above equation, we can obtain:

$$B(\nu, T) = \frac{c}{4}\frac{8\pi\nu^2}{c^3}\frac{h\nu}{e^{h\nu/k_BT}-1} \quad \text{(A14)}$$

Simplify the constants:

$$B(\nu, T) = \frac{2\pi h\nu^3}{c^2}\frac{1}{e^{h\nu/k_BT}-1} \quad \text{(A15)}$$

This is Planck's law of blackbody radiation—the exact form derived from the generalized Newtonian mechanics with an active force term.

A.5 Brief Explanation on the Derivation

The active force (quantum potential) is the linchpin that enforces energy quantization, which is absent in classical Newtonian mechanics. Without U_{active}, we would recover the Rayleigh-Jeans law (ultraviolet catastrophe), as the average energy would be $<E> = k_B T$ (equipartition theorem). Planck's constant h acts as the fitting parameter for the active potential, determined by matching the theoretical result to experimental blackbody spectra. This aligns with the same idea of Planck's derivation. The derivation is consistent with Bohmian mechanics, where the quantum potential guides particle motion and reproduces quantum behavior with the interpretation of "particle and wave" for the wave-particle duality instead of the "particle or wave" interpretation adopted in orthodox quantum mechanics [15]. Here, the quantum potential is re-interpreted as an active force in the complex systems framework. Of course, this derivation is a phenomenological generation of classical mechanics, not a first-principles derivation. The form of the active potential is chosen to match quantization, rather than derived from a more fundamental complex systems theory. A fully rigorous derivation would require a microscopic model of the active force in the context of cavity radiation.

A.6 Conclusion

By generalizing Newton's second law with an active force term (corresponding to quantum potential in Bohmian mechanics), using Lagrangian/Hamiltonian formalism, and fitting the active potential to enforce energy quantization, we successfully derive Planck's law of blackbody radiation from the generalized classical mechanics. This validates the core claim of the UCST that classical mechanics, when extended with appropriate non-classical force terms, can explain quantum phenomena like blackbody radiation.

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