Unified Cosmic Mechanics Evolution Theory (XV) : Corresponding Relationship of Causal Interaction State Evolution between Photons and Electrons

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Abstract

[**Series Information**] This paper is one of 23 installments in the Unified Cosmic Mechanics Evolution Theory. This framework is built upon the monumental achievements of the great scientists who preceded us. Its mission is to provide a foundational explanation of physical reality through the integration of Logic, Mathematics, and Empirical Observation. By introducing the Generalized Dynamical State Evolution Logic, this framework provides a compatibility reconciliation for classical mechanics, relativity, and quantum mechanics. Driven by natural and necessary evolutionary constraints,this framework resolves long-standing systemic conflicts, addressing core issues such as ultraviolet divergence, quantum uncertainty, the dark matter problem, wave-particle duality, the nature of mass-energy conversion, and conservation anomalies. Its scope extends from microscopic particles to macroscopic matter, and into the emergence of life and intelligence. We wish to state our position clearly: this framework does not negate the brilliant work of our predecessors. On the contrary, we believe the foundational observations and laws established by them are fundamentally correct. Our work is an effort to find a unified path of interpretation that honors their exceptional contributions while advancing our collective understanding. We express our deepest gratitude for the centuries of effort and wisdom that have paved the way for this synthesis.

[**This article**] This paper is the fifteenth in the 22-paper series of the "Unified Cosmic Mechanics Evolution Theory" framework. Grounded in fundamental dynamical evolutionary principles, the framework develops a unified physical description that is consistent across mathematical formalism, logical structure, and empirical phenomena, and provides a coherent reconstruction of classical mechanics, relativity, and quantum mechanics within a single relational evolution system.

Based on the framework of information dynamics evolution theory, this paper proposes that all evolutionary resources in the universe are momentum units, and clarifies the core settings: photons adopt "formation coding" (goose formation coding), while fermions (taking electrons as a typical example) adopt spherical symmetric cancellation encapsulation. Electrons generate momentum deviation only during interaction, and all momentum units encode a constant evolutionary speed c, with the evolutionary direction being the causal inertia direction after interaction. The research shows that no matter how many momentum units a photon obtains transversely, its overall evolutionary speed always remains constant c, and the change is only reflected in the coordinated regulation of wavelength (momentum unit density) and evolutionary cycle frequency. By analyzing the intrinsic correlation between electron radius, momentum deviation and photon wavelength, a complete evolutionary correspondence system of photon-electron causal interaction states is established, revealing the information dynamics essence behind angular momentum conservation, energy conservation and momentum conservation. At the same time, the basic physical connotations of Planck constant $\hbar$ and fine-structure constant are disassembled, providing theoretical support for the information dynamics mechanism unifying electromagnetic interaction and gravitational interaction. On this basis, this paper proposes and derives the law of conservation of total topological state number in photoelectric interaction, further improving the information dynamics evolution framework and revealing the underlying conservation principle of micro-particle interaction.

Keywords: Information dynamics evolution theory; Unified mechanics; Photon formation coding; Electron structure; Causal interaction; Momentum deviation; Photoelectric effect; Conservation of state number

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1 Introduction

The core view of information dynamics evolution theory is that the essence of the universe is the evolution and interaction of momentum units, and all physical phenomena can be reduced to the processes of coding, transmission and transformation of momentum units [1]. As the two most basic particles in the microcosm, the interaction between photons and electrons is the core mechanism supporting electromagnetic interaction and energy transmission, and also the key link connecting micro quantum characteristics and macro physical laws.

In traditional physical theories, there are still many unsolved essential puzzles regarding the relationship between photon wavelength and frequency, the spin and momentum characteristics of electrons, and the separation of gravity and electromagnetic force — such as the "redundancy" of Planck constant $\hbar$ in gravitational formulas, the inverse correlation between electron radius and momentum, and the coordination between the constancy of photon speed and momentum change. Based on the framework of information dynamics evolution theory, taking momentum units as the core evolutionary resource,

this paper clarifies the specific mechanisms of photon formation coding and electron spherical symmetric cancellation encapsulation, systematically sorts out the state correspondence in the photon-electron causal interaction process, disassembles the electromagnetic geometric essence of $\hbar$ and the core unit of gravitational interaction, establishes a unified evolutionary logic system, proposes and derives the law of conservation of total topological state number in photoelectric interaction, and provides a new theoretical perspective for the information dynamics explanation of micro-particle interaction.

2 Core Theoretical Settings

2.1 Evolutionary Resources and Coding Rules

All evolutionary resources in the universe are momentum units, whose core characteristics are as follows: (1) Each momentum unit has an intrinsic constant evolutionary speed c, and the evolutionary direction can be adjusted through the interaction process; (3) A single momentum unit has intrinsic energy m_0 and intrinsic momentum

$$p_0 = m_0 c$$

[2]; (3) The coding method of momentum units determines the particle type, forming two basic encapsulation modes: formation coding of photons and spherical symmetric cancellation encapsulation of fermions [3][4].

2.2 Formation Coding Mechanism of Photons

Photons adopt formation-style encapsulation, and all momentum units composing photons maintain the same direction and a constant speed of$c$, similar to a group of geese flying at the same speed and direction. Any three-dimensional structure can be encoded through the density modulation of momentum units. Its core characteristics are: (1) Wavelength λ corresponds to the spatial period of momentum unit density modulation, i.e., the macro-occupied scale of photons or the transition scale of a single macro-time window; (2) Frequency f corresponds to the macro-transition cycle frequency, i.e., the number of wavelength packets passing through a certain spatial point per unit time; (3) No matter how the wavelength and frequency are distributed, their product is always c

$$f\lambda = c$$

which originates from the intrinsic evolutionary speed of all momentum units being constant c and is an inherent constraint of formation coding; (4) Each wavelength λ contains a fixed number of momentum units N_λ (a constant determined by the fine-structure constant 1/137 and geometric factors), and the total number of momentum units N of photons is proportional to the frequency$f$. The relevant settings of the fine-structure constant refer to the quantization conditions and fine-structure constant theory proposed by Sommerfeld [5].

[Dynamical Essence of the Constancy of Light Speed]

The formation coding of photons determines that all momentum units composing photons must maintain co-directional and coordinated evolution. Therefore, no matter how the emitting source moves, the additional momentum deviation obtained by photons can only be reflected in density modulation (wavelength/frequency), and cannot change the resultant speed — the resultant speed is always the statistical average of the speeds of each unit, i.e., c.

Taking the train experiment as an example:

Forward emission: Photons obtain positive momentum deviation (from $+v$) $\rightarrow$ frequency increases (blue shift), and the formation-constrained speed remains c.

Backward emission: Photons obtain negative momentum deviation (from $-v$) $\rightarrow$ frequency decreases (red shift), and the formation-constrained speed remains c.

This mechanism reveals the underlying reason for the "constancy of light speed": it is not an assumption of space-time geometry, but an inevitable result of the intrinsic light speed of momentum units and the coordinated evolution of formation coding.

2.3 Spherical Symmetric Cancellation Encapsulation Mechanism of Electrons

As a typical fermion, electrons adopt a spherical symmetric cancellation encapsulation mode, whose core characteristics are: (1) Electrons are composed of N_e momentum units. In the static state, the directions of each momentum unit are isotropically distributed, and the sum of momentum vectors is 0, achieving encapsulation balance, at which time the electron radius is the largest (ground state radius r_{e0}); (2) Electrons have net directional deviation of internal momentum units (defined as momentum deviation Δp) only when interacting with other particles (such as photons), leading to the breaking of spherical symmetry, the "compression" of the encapsulation structure, and the decrease of electron radius with the increase of momentum deviation; (3) The spin characteristic of electrons originates from the spiral precession motion of internal momentum units. A 360° rotation of the spherical surface corresponds to a 180° rotation of the spin axis. This geometric characteristic determines that the electron spin magnitude is 1/2, and there is a clear inheritance relationship between the spin direction and the circular polarization direction of the subsequently excited photons [6]. The core theoretical basis of electron spin refers to the electron quantum theory proposed by Dirac [7], and the relevant physical background of electron radius refers to the high-precision electron radius measurement research by Dehmelt [8] and the extended charge model theory by Barut [9].

2.4 Evolutionary Direction Rule of Momentum Units

All momentum units encode a constant evolutionary speed c, and their evolutionary direction is not fixed, but determined by the causal inertia direction after interaction. This rule leads to: no matter how many momentum units a photon obtains transversely, the newly added momentum units will coordinately adjust their directions with the original units to form a new causal inertia direction. The overall evolutionary speed of the photon always remains c, and only the density of momentum units (reflected as wavelength λ) and the evolutionary cycle frequency (reflected as frequency f) change, that is, the constant total evolutionary speed of momentum units is maintained through the coordinated regulation of wavelength and frequency.

After a photon is emitted, the momentum deviation Δp_{photon} it carries is uniquely determined by the causal inertia state of the emitting source, and propagates at speed c along this causal inertia direction. No matter where the receiver is on the propagation path (how far from the emission point), as long as it receives along this causal inertia direction, the photon momentum deviation received is equal to Δp_{photon} at the time of emission — it is independent of the spatial position of the receiver, only related to the direction, and only related to the own motion state of the receiver. This property is an inevitable result of causal inertia direction coding.

3 Corresponding Relationship of Photon-Electron Causal Interaction States

3.1 Interaction State Correspondence Table

The essence of photon-electron causal interaction is the transmission and coding transformation of momentum units. The state correspondence between the two can be summarized as follows, covering core physical quantities such as spin, energy level, momentum and radius, and clarifying the mapping relationship, conservation law and geometric essence:

Electron State	**Photon State**	**Mapping Relationship**	**Conservation Law**	**Geometric Essence**
Spin direction $\uparrow/\downarrow$	Circular polarization direction Left/Right	Spiral topology inheritance	Angular momentum conservation	Spherical rotation direction $\rightarrow$ Spiral direction
Spin magnitude 1/2	Spin magnitude 1	Period correspondence	Angular momentum quantization	360° spherical rotation $\rightarrow$ 180° axis rotation, weaving two wavelengths
Orbital energy level n	Number of momentum units N in a single wavelength	$N \propto \Delta E$	Energy conservation	Spatial standing wave mode $\rightarrow$ Unit counting
Momentum deviation Δp	Wavelength λ	$\lambda \propto 1/\Delta p$	Momentum conservation	Compression effect $\rightarrow$ Density modulation
Electron radius r_e	Spiral radius r_0	$r_0 = \beta \cdot r_e$ (β is a proportional constant)	Geometric conservation	Encapsulation scale $\rightarrow$ Spiral amplitude
de Broglie wavelength λ_e	Photon wavelength λ_γ	$\lambda_e/\lambda_\gamma = v/c$ (v is electron speed)	Wave-particle correspondence conservation	Correspondence of unit spatial distribution period
Phase ϕ_e	Phase ϕ_γ	$\phi_\gamma = \phi_e + \phi_0$ (ϕ_0 is initial phase difference)	Phase coherence conservation	Inheritance of spiral initial angle

3.2 Core Evolutionary Logic Chain: Momentum and Scale Correlation between Electrons and Photons

Based on the above settings, the evolutionary causal relationship between photon wavelength, electron radius and momentum deviation can be divided into four core links, forming a complete logical closed loop, reflecting the evolutionary essence of information dynamics:

1. Evolutionary Relationship between Electron Radius and Momentum Deviation

   The momentum deviation Δp of electrons is defined as the vector sum of all internal momentum

units

$$\Delta p = \sum_{1}^{N_e} p_i$$

and its macro performance is the total momentum of electrons

$$p_e = \Delta p$$

The inverse correlation between electron radius r_e and momentum deviation Δp originates from the compression effect of spherical symmetric encapsulation: in the static state ($\Delta p = 0$), the internal momentum units of electrons are isotropically distributed, the encapsulation structure is the loosest, and the radius reaches the maximum value r_{e0}; when electrons interact with particles such as photons, they obtain momentum deviation, the internal momentum units deflect in the same direction, the spherical symmetry is broken, the encapsulation structure is compressed, and the radius decreases with the increase of momentum deviation [10][2].

According to the scale-radius equation, the electron radius can be expressed as:

$$r_{e0} = \frac{\lambda_C}{\alpha \cdot 137} = \lambda_C$$

where $\lambda_C = h/(m_e c)$ is the Compton wavelength (m_e is the electron rest mass, h is the Planck constant) [11], n is the winding number (proportional to the momentum deviation Δp), and 1/137 is the fine-structure constant [5], which is the fixed density ratio of momentum units compressed in the electron radius or photon wavelength, and the more momentum units, the more compact the compression. From this, it can be directly derived that:

$$r_e \propto 1/\Delta p$$

that is, the electron radius is inversely proportional to the momentum deviation. The larger the momentum deviation, the larger the winding number n, and the smaller the electron radius. When the stable radius of the electron reaches the minimum value (the radius corresponding to the Compton wavelength), the excited photon is extreme ultraviolet light, and the energy it carries that can shape the space-time state reaches the maximum value. The correlation between electron radius and Compton wavelength refers to Compton's quantum theory of X-ray scattering [11], and the detection of electron structure is based on Hofstadter's high-energy scattering research [12].

2. Photon Generation Mechanism: Coding Transformation of Electron Spiral Precession

The generation of photons originates from the transition process of electrons from high energy levels to low energy levels, and its essence is the release of internal momentum units of electrons and the transformation of formation coding. The momentum units inside electrons move along spiral trajectories on the spherical surface, and their core geometric characteristics are: a 360° rotation of the spherical surface corresponds to a 180° rotation of the spin axis. This characteristic not only determines that the electron spin magnitude is 1/2 [7], but also is the key mechanism for photon generation — this spiral motion forms periodic disturbances in space. When the disturbances reach the resonance condition, some momentum units break away from the spherical symmetric encapsulation of electrons and form photons in the form of formation coding.

Since the spiral structure of photons is inherited from the spiral precession motion of electrons, there is a clear proportional relationship between the photon wavelength λ and the electron radius r_e, which can be expressed as:

$$\lambda = k \cdot r_e$$

where k is a geometric factor (order of magnitude is about 2π or 4π, determined by the spiral topology). This relationship indicates that the size of the electron radius directly determines the wavelength scale of the excited photon. The smaller the electron radius, the shorter the wavelength of the excited photon. The relevant theoretical background of electron transition and photon generation refers to Bohr's atomic structure model [13].

3. Causal Correlation between Photon Wavelength and Electron Momentum Deviation

   Combining the conclusions of 3.2.1 and 3.2.2, it can be directly derived from $r_e \propto 1/\Delta p$ and $\lambda \propto r_e$ that:

   $$\lambda \propto 1/\Delta p$$

   that is, the photon wavelength is inversely proportional to the electron momentum deviation. The physical significance of this causal correlation is: the larger the electron momentum deviation, the smaller its radius, the shorter the spatial period of the spiral precession motion, and the shorter the wavelength of the excited photon; on the contrary, the smaller the electron momentum deviation, the larger the radius, and the longer the wavelength of the excited photon. This correlation not only satisfies the law of momentum conservation, but also reflects the information coding logic of momentum unit density modulation — the shorter the wavelength, the higher the momentum unit density, and the more the total number of momentum units carried by the photon.

4. Evolutionary Law of Photon Energy and Wavelength

   Based on the formation coding mechanism of photons, each wavelength λ contains a fixed number of momentum unitsN_λ, and the total number of momentum units N of photons is proportional to the frequency f

   $$N = N_\lambda \cdot \text{number of wavelengths} \propto f$$

   Since the energy of a single momentum unit is m_0, the total energy E of the photon can be expressed as:

   $$E = N \cdot m_0 = (N_\lambda \cdot m_0) \cdot f = hf$$

   where $h = N_\lambda \cdot m_0$, that is, the essence of Planck constant h is the product of the number of momentum units in a single wavelength and the energy of a single momentum unit, which is a characteristic constant of photon formation coding; while the essence of Planck constant $\hbar$ is the electromagnetic topological configuration action with the participation of the fine-structure constant.

   Combining the inherent constraint relationship of photons $f\lambda = c$, the relationship between photon energy and wavelength can be further derived:

   $$E = hc/\lambda$$

   that is, the shorter the wavelength, the higher the photon energy. This law is consistent with experimental observations, and its essence is the energy embodiment of momentum unit density — the shorter the wavelength, the higher the momentum unit density, the more energy accumulated in unit space, and the higher the energy of the photon.

3.3 Overall Physical Image of Causal Interaction Evolution

Integrating the above logic chain, the overall physical image of photon-electron causal interaction evolution can be summarized as: electrons obtain momentum deviation Δp through interaction with

other particles → the spherical symmetric encapsulation of electrons is compressed, and the radius r_e decreases → the spatial period of the electron spiral precession motion is shortened, and the wavelength λ of the excited photon is shortened → the photon frequency $f = c/\lambda$ increases, and the momentum unit density increases → the total number of momentum units N of the photon increases, and the energy $E = hf$ increases.

The core key point is: no matter how many momentum units a photon obtains transversely during interaction, since all momentum units encode a constant evolutionary speed c, and the evolutionary direction will be adjusted to the causal inertia direction after interaction, the overall evolutionary speed of the photon always remains c. Only through the coordinated changes of wavelength (momentum unit density) and frequency (evolutionary cycle), the coding of momentum units and the transmission of energy are realized. This process strictly follows the laws of angular momentum conservation, energy conservation and momentum conservation, and its essence is the information coding of momentum units and the dynamic adjustment of evolutionary direction.

[Unified Dynamical Explanation of Redshift Phenomenon]

Both Doppler redshift and gravitational redshift have the underlying mechanism of resultant velocity effect (momentum conservation $m_1v_1 = m_2v_2$), but the triggering conditions are different [14]:

Doppler redshift: When a photon is emitted, the motion state of the emitting source is directly encoded as the momentum deviation of the photon. The intrinsic frequency carried by the photon already contains the motion information of the source.

Gravitational redshift: After a photon establishes gravitational coupling with a celestial body, it inherits the inertial motion speed of the celestial body. Photons have intrinsic mass (composed of momentum units), but due to high-speed motion ($v = c$), the perceived space-time window is compressed ($\eta(v) \to 0$), and the gravitational coupling with ordinary matter is extremely weak; only in a strong gravitational field (massive celestial body), the gravitational effect of photons is manifested, showing frequency change (redshift or blueshift).

The two redshifts can be superimposed (such as GPS considering both Earth's rotation and Earth's gravitational field), and the superposition result satisfies the total momentum conservation. This mechanism reduces the redshift phenomenon from the geometric description of "space-time curvature" or "Doppler effect" to the dynamical process of momentum unit interaction [15].

4 Disassembly of Planck Constant

4.1 Essence of Planck Constant: Electromagnetic Topological Configuration Action with the Participation of Fine-Structure Constant

In traditional physical theories, Planck constant $\hbar$ is often regarded as the core constant of quantum mechanics, but its appearance in gravitational formulas has always had logical redundancy. Based on the information dynamics evolution framework of this paper, the essence of $\hbar$ can be disassembled: the essence of $\hbar$ is not the action of a single momentum unit, but the electromagnetic topological configuration action with the participation of the fine-structure constant. Its specific expression can be written as

$$\hbar = (1/137) \cdot n \cdot (m_e c \cdot r_e)$$

where the physical significance of each parameter is: 1/137 is the fine-structure constant [5], which is the compression factor of the photoelectric interaction of the electron spiral winding structure on the

momentum unit density;n is the count of momentum units (related to the winding number); $(m_e c \cdot r_e)$ is a specific micro-scale parameter of a single electron. The three together constitute the action of the electromagnetic topological configuration, i.e., $\hbar$.

This disassembly shows that $\hbar$ is the core characteristic constant of electromagnetic interaction, which includes the electromagnetic geometric characteristics of electrons (1/137), the count of momentum units (n) and micro-scale information. In photoelectric interaction, photons are wound with the electron radius, and the electromagnetic topological configuration action within the radius is $\hbar$. Therefore, $\hbar$ becomes a basic constant related to electromagnetic interaction and the fine-structure constant; at the same time, it is clear that the action of a single momentum unit is not $\hbar$, but the electromagnetic topological configuration action with the participation of the fine-structure constant is $\hbar$. This conclusion solves the redundancy puzzle of $\hbar$ in gravitational formulas, and provides key theoretical support for the information dynamics mechanism unifying electromagnetic interaction and gravitational interaction. The relevant theoretical background of electromagnetic interaction and topological configuration refers to Feynman's basic physical process theory [16].

4.2 Role Orientation of $1/137$ and n

In the framework of information dynamics evolution, the roles of $1/137$ and n are clearly distinguished. The two jointly participate in the composition of the electromagnetic topological configuration, and then determine the specific value of $\hbar$. The specific orientations are as follows:

Basic momentum unit n $(n_0 = 1)$: It is the "basic brick" composing all things in the universe. It is not only the component unit of material structure in electromagnetic force, but also the only source of gravitational interaction. Its quantity directly determines the strength of gravity.

Geometric factor 1/137: It is the "geometric constraint" formed by electromagnetic force to encapsulate momentum units into fermions such as electrons. Its essence is the filling rate and efficiency of spiral winding, which is the core parameter of electromagnetic interaction, determining electromagnetic characteristics such as electron radius and energy level [5]. It also participates in the composition of electromagnetic topological configuration and is a key component of $\hbar$ as the electromagnetic topological configuration action.

Composite constant$\hbar$: It is the specific embodiment of the electromagnetic topological configuration action with the participation of the fine-structure constant, and is the "topological action characterization" of electromagnetic interaction. Its essence is the electromagnetic topological configuration action determined by the fine-structure constant, the count of momentum units and the micro-scale of electrons. In gravitational formulas, it only serves as the conversion factor between "macro mass unit and basic momentum unit", not the essential parameter of gravity.

As the core role of the electromagnetic geometric factor, the fine-structure constant 1/137 can be understood as the fixed density ratio of momentum units compressed in the electron radius or photon wavelength, and the more momentum units, the more compact the compression; it only participates in the electromagnetic encapsulation of electrons and the composition of electromagnetic topological configuration, and then determines the value of $\hbar$, providing key theoretical support for the information dynamics mechanism unifying electromagnetic force and gravity. The relevant physical significance of the fine-structure constant refers to Sommerfeld's research [5].

5 Derivation and Significance of the Law of Conservation of Total Topological State Number in Photoelectric Interaction

5.1 Core Definition: Physical Measure of Topological Weaving Number and State Number

In the framework of information dynamics evolution, "state" is not an abstract probability amplitude, but the geometric topological configuration of momentum units. To quantify this configuration and establish a conservation relationship, the dimensionless "Topological Weaving Number (W)" is defined, which consists of two parts: spin weaving quantity (S) and orbital/translational weaving quantity (O), corresponding to different topological characteristics of momentum units:

1. Spin weaving quantity (S): Corresponding to the spiral winding density of internal momentum units, closely related to particle spin and fine-structure constant 1/137 [5], reflecting the intrinsic topological configuration of momentum units;
2. Orbital/translational weaving quantity (O): Corresponding to the spatial translation or revolution trend caused by the overall momentum deviation, related to momentum deviation Δp and de Broglie wavelength, reflecting the external motion topology of momentum units.

Based on the above definition, the physical measures of the state numbers of electrons and photons are further clarified, both based on the number of momentum units as the core benchmark, combined with topological characteristics for quantification:

Total state number of electrons (W_e): Mainly determined by the winding number n of its internal momentum units, which can be expressed as

$$W_e \approx n_{\text{total}} = n_{\text{spin}} + n_{\text{orbit}}$$

Among them, n_{spin} is the basic encapsulation number (related to the fine-structure constant 1/137), corresponding to the intrinsic topological characteristics of electron spin [7]; n_{orbit} is the winding number increased by the excited state, corresponding to the orbital topological change caused by the momentum deviation Δp, and n_{orbit} is proportional to Δp. The electron spin magnitude is fixed at 1/2, corresponding to the topological invariant of 360° spherical rotation and 180° axis rotation, which is the core benchmark of the spin weaving quantity.

Total state number of photons (W_γ): Determined by the total number of momentum units N it contains, which can be expressed as

$$W_\gamma = N_{\text{linear}} + S_{\text{spin}}$$

Among them, N_{linear} corresponds to the number of linear momentum units of photon formation coding, which is proportional to the frequency f ($N \propto f$); S_{spin} corresponds to the spin (circular polarization) topological direction of photons, counted as ± 1 unit state, inherited from the spin direction of electrons [7].

5.2 Conservation Axiom and Mathematical Derivation

1. **Proposal of Conservation Axiom**

   Law of Conservation of Total Topological State Number in Photoelectric Interaction: In any isolated photon-electron causal interaction process, the total topological weaving number W_{total} of the

system remains unchanged, that is, the total topological state number of the system before and after interaction is equal, and the expression is:

$$W_{\text{before}} = W_{\text{after}}$$

When expanded, it is:

$$(S_e + O_e)_{(\text{initial})} + (S_\gamma + O_\gamma)_{(\text{initial})} = (S'_e + O'_e)_{(\text{final})} + (S'_\gamma + O'_\gamma)_{(\text{final})}$$

Among them, the subscript "initial" indicates the state before interaction, and "final" indicates the state after interaction;S_e and O_e are the spin weaving quantity and orbital weaving quantity of electrons, respectively, and S_γ and O_γ are the spin weaving quantity and linear weaving quantity of photons, respectively.

2. **Derivation Process Based on the Existing Framework**

   Taking the typical interaction process where an electron transitions from a high energy level (state A) to a low energy level (state B) and releases a photon (state γ) as an example, combined with the formulas and settings established in this paper, the conservation relationship is derived as follows:

   State before interaction: The electron is in a high excited state with large momentum deviation, large winding number n_A and small radius r_A. At this time, only electrons exist in the system, no photons, and the total state number

   $$W_{\text{in}} = W_e(n_A) = n_{\text{spin}} + n_{\text{orbit}_A}$$

   (n_{orbit_A} is the orbital winding number corresponding to the high energy level). The relevant theory of electron energy levels refers to Bohr's atomic structure model [13] and Lamb and Retherford's Lamb shift experiment research [17].

3. **State after interaction:** The electron transitions to a low energy level, the momentum deviation decreases, the winding number n_B decreases ($n_B < n_A$), and the radius r_B increases (recovering part of the spherical symmetry); at the same time, a photon is released, carrying the momentum units "overflowed" during the electron transition. At this time, the total state number of the system

   $$W_{\text{out}} = W_e(n_B) + W_\gamma(N) = (n_{\text{spin}} + n_{\text{orbit}_B}) + (N_{\text{linear}} + S_{\text{spin}})$$

   where n_{orbit_B} is the orbital winding number corresponding to the low energy level, and N is the total number of momentum units carried by the photon. The energy change of electron transition refers to Bethe's theory of electromagnetic shift of energy levels [18].

4. **Key connection point:** According to the energy formula$E = hf$ and the energy level difference relationship $E = \Delta E_e$ (energy level difference of electron transition) proposed in this paper, the energy lost by the electron corresponds to the potential energy loss of its internal momentum units, and the energy E is proportional to the number of momentum units N ($E = N \cdot m_0$). Therefore, the reduced winding number of the electron (i.e., the number of units released by the rearrangement of internal momentum units) is exactly equal to the number of momentum units N obtained by the photon.

5. **Derivation conclusion:** The reduced winding number of the electron $\Delta n_e = n_{\text{orbit}_A} - n_{\text{orbit}_B}$, and the number of momentum units N obtained by the photon

   $$N = \Delta n_e$$

Combined with the definition of photon state number $N_{\text{linear}} = N$ and S_{spin} inheriting the electron spin topology (size conservation), it can be obtained:

$$n_{\text{orbit}_A} - n_{\text{orbit}_B} = N_{\text{linear}}$$

Substitute into the total state number expression:

$$W_{\text{in}} = n_{\text{spin}} + n_{\text{orbit}_A}$$

$$W_{\text{out}} = (n_{\text{spin}} + n_{\text{orbit}_B}) + (N_{\text{linear}} + S_{\text{spin}}) = n_{\text{spin}} + n_{\text{orbit}_B} + (n_{\text{orbit}_A} - n_{\text{orbit}_B}) + S_{\text{spin}}$$

Since there is a topological inheritance relationship between the electron spin weaving quantity n_{spin} and the photon spin weaving quantity S_{spin}, the two are complementary in size (the period correspondence between electron spin 1/2 and photon spin1), and the overall topological contribution is conserved. Therefore,

$$W_{\text{in}} = W_{\text{out}}$$

that is, the total topological state number is conserved.

5.3 Topological Transformation Mechanism and Innovative Value

1. **Spin-Linear Topological Transformation Mechanism**

   The essence of photon generation is the transformation of the internal topological structure of electrons: at the moment of photon generation, a part of the spiral spin topology (Self-spin topology) inside the electron is "straightened" and transformed into the linear propagation topology (Linear propagation topology) of the photon, while retaining the spin direction (i.e., the circular polarization direction of the photon), realizing the conserved transformation of the topological structure. The specific transformation relationship is: the reduced number of spiral turns of electrons = the increased number of wavelength segments of photons + the spin topology of photons. This mechanism not only explains the generation principle of photons, but also verifies the conservation of the total topological state number.

   If the electron revolves outside the atomic nucleus, its orbital angular momentum is composed of the directional deviation of momentum units, which belongs to the orbital weaving quantity (O_e); during the interaction process, the orbital weaving quantity can be converted into the linear weaving quantity of photons (O_γ), which also follows the conservation of total topological state number, further expanding the scope of application of the conservation law. The relevant theory of electron orbital angular momentum refers to Bohr's atomic model [13].

2. **Innovative Improvement to the Paper**

   The addition of the law of conservation of total topological state number upgrades the information dynamics evolution framework of this paper from "phenomenon description" to "underlying principle", bringing three core innovative values:

   Revealing the underlying conservation essence: The original manuscript only explains the change laws of physical quantities such as wavelength, radius and energy in the photon-electron interaction process, while the law of conservation of total topological state number reveals the "inevitability of change" — the coordinated changes of all physical quantities are essentially to maintain the

total topological state number from being generated or disappeared out of thin air. This is a more underlying "information/geometric conservation" than energy conservation and momentum conservation, providing a unified constraint principle for micro-particle interaction.

The ultimate key to solving the redundancy problem of $\hbar$: Combined with the conservation law, it can be further argued that the essence of $\hbar$ is the electromagnetic topological configuration action with the participation of the fine-structure constant, which is the "process constant" of topological weaving in electromagnetic interaction — electromagnetic force focuses on the topological configuration of momentum units (how to "weave"), so $\hbar$ becomes the core constant of electromagnetic interaction; while gravity only cares about the number of momentum units (the total amount of "weaving materials") and does not care about the topological configuration, so $\hbar$ is a redundant factor in gravitational formulas and can be completely stripped. This conclusion further improves the disassembly of the essence of $\hbar$, echoing the core view of this paper that "the action of a single momentum unit is not $\hbar$, but the electromagnetic topological configuration action with the participation of the fine-structure constant is $\hbar$". In short, "$\hbar$ is the 'stitch size' of electromagnetic weaving process, while gravity only cares about the 'total length of thread' (total number of units)".

Realizing the unified expression of fermions and bosons: Based on the conservation law, a unified state number equation can be proposed:

$$\sum N_{\text{unit}} \cdot T_{\text{topology}} = \text{Constant}$$

where N_{unit} is the total number of momentum units, and T_{topology} is the topological factor (spiral topological factor for fermions such as electrons, linear topological factor for bosons such as photons). This equation clarifies that the essential difference between fermions and bosons lies only in the different topological factors, while the total amount of underlying evolutionary resources (momentum units) is always conserved, providing a concise mathematical expression for unifying the micro-particle interaction theory. The relevant theoretical background of particle classification and topological characteristics refers to Wilczek's research on the origin of mass [19].

6 Summary of Core Formulas and Evolutionary Laws

6.1 Core Physical Formulas

Constraint between photon wavelength and frequency:

$$f\lambda = c$$

(originating from the constant intrinsic speed of momentum units, the inherent law of formation coding);

Relationship between electron radius and winding number:

$$\boxed{r_e = \frac{\lambda_C}{\alpha\, n}}$$

(λ_C is the Compton wavelength [11], n is the winding number, proportional to the momentum deviation, $\alpha = 1/137$ is the fine-structure constant [5], which is the fixed density ratio of momentum units compressed in the electron radius or photon wavelength, and the more momentum units, the more compact the compression); n is a variable. When electrons interact with gravitational and electromagnetic environments, the increase or decrease of momentum units will directly affect the macro wavelength of photons, indirectly regulate the macro frequency, and change the electron radius at the same time.

Relationship between electron radius and momentum deviation:

$$r_e \propto 1/\Delta p$$

(direct embodiment of the compression effect of spherical symmetric encapsulation);

Relationship between photon wavelength and electron radius:

$$\lambda = k \cdot r_e$$

(k is the geometric factor, originating from spiral topology inheritance);

Causal correlation between photon wavelength and electron momentum deviation:

$$\lambda \propto 1/\Delta p$$

(core correlation of causal evolution);

Photon energy formula:

$$E = hf = hc/\lambda$$

($h = N_\lambda \cdot m_0$, reflecting the correlation between momentum unit count and energy, and the action of a single momentum unit is not $\hbar$, but the electromagnetic topological configuration action with the participation of the fine-structure constant is $\hbar$);

Speed increase formula:

$$\text{New speed} = \frac{\text{New momentum deviation}}{\text{Total momentum (equivalent total mass number)}} \cdot c$$

(correlating core physical quantities such as energy, mass, momentum and speed, which is the core formula of the framework);

Conservation formula of total topological state number:

$$(S_e + O_e)_{(\text{initial})} + (S_\gamma + O_\gamma)_{(\text{initial})} = (S'_e + O'_e)_{(\text{final})} + (S'_\gamma + O'_\gamma)_{(\text{final})}$$

(always holds in the isolated system photoelectric interaction process).

Ground state radius (static or low speed, $\Delta p \approx m_e c/137$, $n \approx 137$):

$$r_{e0} = \lambda_C/(\alpha \cdot 137) = \lambda_C \approx 2.43 \times 10^{-12}\text{m}$$

(Compton wavelength order of magnitude, corresponding to the characteristic scale of the electron encapsulation structure)

Correspondence to classical radius (medium momentum deviation, $\Delta p \approx m_e c \cdot 137$, $n \approx 137^2$):

$$r_{\text{classical}} = \lambda_C/(\alpha \cdot 137^2) = \lambda_C/137 \approx 2.82 \times 10^{-15}\text{m}$$

(same order of magnitude as the classical electron radius)

Dynamic radius (general case):

$$r_e = \lambda_C/(\alpha \cdot n)$$

the radius decreases inversely with the increase of momentum deviation

Limit compression radius (high-energy collision, $\gamma = 1/\sqrt{1 - v^2/c^2} \gg 1$):

$$r_{\min} = \lambda_C/\gamma$$

corresponding to $n = 137\gamma$, at this time the electron is transiently compressed to an extremely small scale (such as the LHC energy level can reach 10^{-18}m)

6.2 Key Evolutionary Laws

Constant speed law: The evolutionary speed of all momentum units is always c. No matter how many momentum units a photon obtains transversely, its overall evolutionary speed is always c, and only the wavelength and frequency change coordinately;

Inverse correlation law: Electron momentum deviation is inversely correlated with electron radius, electron radius is positively correlated with photon wavelength, photon wavelength is inversely correlated with electron momentum deviation, and photon wavelength is inversely correlated with photon energy;

Coding inheritance law: The spiral direction of photons inherits the spin direction of electrons [7], the phase of photons inherits the phase of electrons (with a fixed initial phase difference), and the spiral radius of photons is positively correlated with the electron radius;

Conservation law: In the photon-electron interaction process, angular momentum, energy, momentum and geometric scale all satisfy conservation, whose essence is the coding transformation and quantity conservation of momentum units; the conservation of total topological state number is the underlying constraint, determining the coordinated change trend of each physical quantity;

Topological transformation law: The spiral spin topology of electrons can be converted into the linear propagation topology of photons, and the total topological weaving number remains unchanged during the transformation, reflecting the conservation of the topological configuration of momentum units;

Essence law of $\hbar$: Planck constant $\hbar$ is not the action of a single momentum unit, but the electromagnetic topological configuration action with the participation of the fine-structure constant [5], which is the core characteristic constant of electromagnetic interaction.

7 Conclusions and Prospects

7.1 Conclusions

Based on the framework of information dynamics evolution theory, taking momentum units as the core evolutionary resource, this paper clarifies the core mechanisms of photon goose formation coding and electron spherical symmetric cancellation encapsulation, establishes a complete evolutionary correspondence system of photon-electron causal interaction states, proposes and derives the law of conservation of total topological state number in photoelectric interaction, disassembles the essence of Planck constant *hbar*, and draws the following core conclusions:

1. The essence of photon-electron interaction is the coding transformation and evolutionary direction adjustment of momentum units. All momentum units encode a constant evolutionary speed c, and the evolutionary direction is the causal inertia direction after interaction. The photon speed remains constant at all times, and the change is only reflected in the coordinated regulation of wavelength and frequency;

2. A complete causal logic chain between electron radius, momentum deviation and photon wavelength is established: the increase of electron momentum deviation $\rightarrow$ the decrease of electron radius $\rightarrow$ the shortening of photon wavelength $\rightarrow$ the increase of photon frequency and energy. This process strictly follows various conservation laws, and its underlying constraint is the conservation of total topological state number;

3. The law of conservation of total topological state number in photoelectric interaction is proposed,

which clarifies that the total topological weaving number of photon-electron interaction in an isolated system remains unchanged. It reveals the underlying information/geometric conservation principle of micro-particle interaction and realizes the upgrade from phenomenon description to principle revelation;

4. The essence of Planck constant *hbar* is disassembled, and it is clarified that *hbar* is the electromagnetic topological configuration action with the participation of the fine-structure constant [5], and the action of a single momentum unit is not *hbar*, which solves the redundancy puzzle of *hbar* in gravitational formulas;

5. The core role of the fine-structure constant 1/137 as an electromagnetic geometric factor is clarified [5]. It is the fixed density ratio of momentum units compressed in the electron radius or photon wavelength, and only participates in the electromagnetic encapsulation of electrons and the composition of electromagnetic topological configurations (thereby determining *hbar*), and has nothing to do with gravitational interaction. At the same time, a unified state number equation is established to realize the essential unification of fermions and bosons, providing key theoretical support for the information dynamics mechanism unifying electromagnetic force and gravitational force;

6. The uncertainty principle is solved, and deterministic photoelectric effect and momentum topological coding quantum mechanics are established. Measurement requires inputting momentum deviation, which affects its radius and spin state, but the total evolutionary state number remains conserved;

7. Dynamics of electron radius: The electron radius is not a fixed constant, but changes dynamically with the momentum deviation Δp — the radius is approximately 2.82×10^{-15}m at rest, the Compton wavelength $\lambda_C \approx 2.43 \times 10^{-12}$m is the critical scale for generation, and it can be transiently compressed to below 10^{-18}m in high-energy collisions ($r_e \propto 1/\Delta p$). This explains why electrons exhibit a finite radius at low energy (such as the classical electron radius and Compton wavelength), but behave as point particles in high-energy collisions — the latter is a transient state of extreme compression, not a steady-state structure;

8. Dynamical essence of the observer effect: The observer effect is not a mysterious process of "state collapse caused by measurement", but the causal transmission of the motion deviation of the emitting source. When particles such as photons are emitted, their momentum deviation is uniquely determined by the causal inertia state of the emitting source and encoded in the distribution of the particle's momentum units.
   This coding has invariance in the direction of causal inertia — it is independent of the spatial position of the receiver and only related to the direction: as long as the reception is carried out in the direction of causal inertia, no matter how far the distance is, the received momentum deviation is the same, that is, there is a continuous state evolution between two causes and effects (emerging continuous space-time), and the next receiver inherits this causal momentum deviation; the frequency/energy difference measured by the receiver originates from the relative relationship between its own motion state and the intrinsic momentum of the photon. This mechanism reduces the observer effect to the causal transmission process of emission-reception [20];

9. Unified dynamical explanation of redshift phenomenon: Both Doppler redshift and gravitational redshift originate from the resultant velocity effect ($m_1 v_1 = m_2 v_2$), and the difference lies in the source of momentum deviation: Doppler redshift comes from the motion state of the emitting source (encoded at emission), and gravitational redshift comes from the gravitational interaction between photons and celestial bodies (inherited after interaction). Photons have intrinsic mass, but due to

high-speed motion ($v = c$), the perceived window is compressed, and a massive celestial body is required to manifest its gravitational effect. The two can be superimposed, and the superposition result satisfies the total momentum conservation.

7.2 Prospects

The photon-electron causal interaction evolution system and the law of conservation of total topological state number established in this paper provide a new perspective for the information dynamics explanation of micro-particle interaction, but there are still many directions for further in-depth research:

1. The specific quantitative relationship between the geometric factor k and the fine-structure constant 1/137 needs to be accurately derived combined with experimental data;
2. The specific physical characteristics of the basic momentum unit n_0 and its correlation with the Planck scale;
3. The experimental verification scheme of the law of conservation of total topological state number, how to verify the validity of the conservation law by observing the correlation between the count of momentum units and the topological configuration;
4. Based on the framework of this paper, further expand to the interaction and evolution of other micro-particles (such as protons and neutrons), establish a more comprehensive information dynamics particle interaction theory, and verify the universality of the law of conservation of total topological state number;
5. The accurate quantification method of topological weaving number, combined with quantum mechanics experimental data, improve the mathematical expression of the topological factor T_{topology}.

Relevant experimental verification can refer to Hofstadter's high-energy scattering experiment [12] and Dehmelt's high-precision particle measurement method [8], and theoretical expansion can refer to Feynman's path integral theory [21].

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