Unified Cosmic Mechanics Evolution Theory (XIX) :
Principle of Momentum Flow Distribution Integral in Multi-Slit Experiments

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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.

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[**This article**] This paper is the nineteenth 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.

The traditional path integral formulation of quantum mechanics relies on complex probability amplitudes and the principle of least action, which has conceptual ambiguities in interpreting microphysical mechanisms—serving merely as effective mathematical statistical tools. Based on the Unified Cosmic Mechanics Evolution Theory—where the momentum unit ($m_0 \cdot c$) is the only physical reality [1], the field is an interaction protocol, and the particle is a momentum encapsulation structure—this paper reconstructs the mathematical description of multi-slit experiments [2]. The new formulation replaces the complex path integral with a dual-integral system: the self-integral describes momentum unit self-evolution along their intrinsic direction, endowing linear motion; the interaction integral describes momentum flow interaction with the slit wall's electromagnetic field, realizing multi-path distribution and direction deflection. These two integrals together constitute the momentum flow distribution integral, interpreting ”interference” as the superposition of real momentum flows dominated by the interaction integral.

Key insight: Just as a stone falling from a height depends on the perceptual cross-section $1/(4\pi r^2)$for its integral result, all forces should be similarly understood—their underlying dynamics must be reduced to the perceptual cross-section mechanism. The interaction integral follows this logic: the relativistic mass-energy equation is a space-time state shaping equation [2], where the emergent space-time integral reflects Pythagorean conservation (Lorentz covariance); general relativistic integrals involve variable space-time redundancy under field strength; special relativistic integrals arise from perceptual space-time window compression during motion. For micro-particles in multi-slits, this paper primarily adopts the interaction integral mechanisms of special relativity, electromagnetism, and photoelectricity [3,4].

This framework remains consistent with existing experimental phenomena and proposes testable predictions including slit thickness-dependent deflection and multi-slit interference fringe modulation.

Keywords: Momentum flow distribution integral; Topological momentum coding; Spherically symmetric momentum field; Principle of least action; Double-slit experiment; Integral equation reconstruction; Deterministic quantum mechanics; Quantum integral

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1 Introduction:

Conceptual Carding and Theoretical Reconstruction Attempts of Path Integrals

1.1 Discussion on Related Issues of Traditional Path Integrals

1. **The misleading of teleological tendency.** In the process of teaching and explanation, the principle of least action

$$\delta S = 0$$

is often misunderstood as particles having the ”ability to predict” or the tendency to ”choose the optimal path”. In fact, the linear motion of particles in free space originates from the intrinsic property of momentum encapsulation, and there is no need to use the ”optimization selection” logic of the principle of least action for explanation.

2. **The ontological confusion of complex probability amplitudes.** As the core mathematical structure, the connection between
$$e^{(iS/\hbar)}$$
and physical reality needs to be further clarified: if it corresponds to physical reality, how can particles exist in all paths at the same time; if it is only a mathematical tool, why can it accurately describe observable interference phenomena, which remains to be further explored. Although Feynman's path integral formulation has achieved great success in calculation [5,6], the physical reality of its core structure has long been controversial. As Bohr emphasized, the principle of complementarity [7] often avoids the causal description of microprocesses, leading to the ontological problem of ”how particles exist in all paths at the same time”. In contrast, the cellular automaton interpretation proposed by 't Hooft in recent years [8,9] attempts to reconstruct quantum phenomena under deterministic underlying rules, which is similar to the ”momentum unit coding” realism viewpoint advocated in this paper.

3. **The neglect of slit wall interaction.** The standard path integral treats multi-slits as geometric boundary conditions, failing to fully consider the physical interaction between the slit wall and particles, making it difficult to explain experimental phenomena such as ”stronger deflection on the side of larger slit thickness” and ”multi-slit interference fringe modulation”. In fact, there is an interaction dominated by electromagnetic force between the slit wall and the momentum flow (the order of magnitude of gravitational interaction is much smaller than that of electromagnetic force and can be ignored). This interaction will deflect the momentum flow distribution, and together with the intrinsic characteristics of momentum encapsulation, affect the particle motion law. The standard treatment usually regards the slit as an ideal geometric boundary [5], ignoring the near-field electromagnetic interaction between the slit wall atoms and the incident particles. However, at the micro-nano scale, the surface potential, van der Waals force, and even the Casimir effect may perturb the particle trajectory [10,11]. This paper further quantifies this process, proposing that the slit thickness d directly determines the integral interval of electromagnetic interaction, thereby dominating the deflection effect of momentum flow.

1.2 Brief Explanation of the Principle of Least Action

Combined with relevant physical laws, the positioning of the principle of least action in this paper is as follows:

(1)when the momentum flow of particles is distributed in multi-slits, each path can present the ability of linear motion, and there is no need to rely on the principle of least action to ”find” the shortest path for the whole particle.

(2) in the process of multi-path momentum flow distribution, particles will form extensive weak coupling with the environment.

Third, the core value of the principle of least action lies mainly in realizing the dynamic modeling of complex multi-body motions relying on the Lagrangian idea.

(3)phenomena such as photon radiation when particles accelerate and substances tending to be in the lowest energy state show laws equivalent to the principle of least action at the macro scale. Its micro essence is: the lowest energy state corresponds to the perceptual cross-section with the largest resistance and no further interaction — the particle is in a state of "interaction saturation" and cannot further reduce energy by borrowing and returning momentum pairs.

(4)most principles of least action emerge from the fact that the eigenstate of momentum units is the ability of constant light speed evolution, and all substances in the universe are formed by multi-layer encapsulation of momentum units

$$m_0 \cdot c$$

The reason why photons can propagate in a straight line at the speed of light for hundreds of millions of years is that this state is closer to the eigenstate of underlying things; the reason why electrons are more likely to stay in the bottom orbit is that the absorbed photons tend to evolve towards the eigenstate under perturbation, leading to photon emission, and electrons naturally fall into the bottom orbit. The principle of decay is also the same. The overall logic can be understood as that multi-layer encapsulation is easy to decompose.

Therefore, the principle of least action has good equivalent applicability at the macro scale and can be used as a concise mathematical description tool. However, its micro causal chain does not need to rely on "variational selection" or "predictive optimization", but is composed of the eigenstate stability of momentum encapsulation and the causality of interaction integral.

In the framework of classical mechanics, the principle of least action is regarded as a basic postulate [12]. However, if traced back to the micro scale, this principle should be regarded as an emergent law after the statistical average of a large number of momentum units, rather than a "selection" mechanism of a single particle. This view is similar to Wheeler's information physics perspective of "it from bit" [13], that is, macro laws are the statistical results of micro information processing rules.

1.3 Explanation of Relevant Preparatory Theories

Theoretical positioning of the dual-integral system: The core innovation of this paper is to clearly distinguish two integral modes —

Self-integral:

$$\int ds$$

Corresponding to the intrinsic evolution of momentum units, it is continuous and stable, endowing particles with the ability to "maintain motion state". Even isolated particles in vacuum have self-integral.

Interaction integral:

$$\int d^3r \int dt$$

Corresponding to the electromagnetic protocol interaction between momentum units and the external environment (slit wall, other particles), it is discrete and conditionally triggered, endowing particles with the ability to "change motion state". The interaction integral is activated only when the particle is in the diffused state and the perceptual cross-section matches.

The traditional path integral confuses two cumulative processes of different natures into a single complex path integral, leading to the ontological dilemma of "particles existing in all paths at the same time". The dual-integral system of this paper models the self-integral and interaction integral separately: the former explains linear motion, the latter explains interference and deflection, and the two together form a complete picture of the momentum flow distribution integral.

1.4 Explanation of Relevant Theoretical Assumptions

Based on the following relevant viewpoints, this paper reconstructs the path integral description to provide theoretical support for the interpretation of the physical mechanism of multi-slit experiments:

Relevant Viewpoints	**Content**	**Mathematical Expression**
Unique Reality	Momentum units are the only non-decayable evolutionary resources and the basic units of momentum encapsulation	Each unit encodes $(c_m, c_m, \vec{d})$
Particle Encapsulation	Fermions are encapsulated in a spherically symmetric vector superposition state, and photons are encapsulated in a goose-flock-like unidirectional state; the encapsulation direction determines the linear motion characteristics	$P_{\text{total}} = \sum m_i c$
Field as Protocol	The four fundamental forces are perception and interaction protocols, not physical entities, but only serve as media for momentum unit interaction. In multi-slit experiments, the interaction between the slit wall and momentum flow is mainly based on the electromagnetic protocol.	Gravitational/ electromagnetic/weak/ strong forces are different protocol layers
Interaction Mechanism	Perceptual cross-section matching → borrowing momentum pairs $(p_m, -p)$ → deflecting the encapsulation direction, thereby changing the momentum flow distribution; electromagnetic force dominates the momentum flow deflection in slit wall interaction	$\Delta\vec{p} = \sum \vec{p}_{\text{deflection}}$
Wave-Particle Duality	Particles have three states: collapsed state, diffused state (fluid state), and entangled state; the stability of momentum encapsulation is different in different states [15]	Multi-path distribution of momentum flow in the diffused state
Dynamic Radius Mechanism	The geometric perception radius of particles shrinks in real time with momentum deviation, which is a geometric bridge connecting relativity and quantum effects [14]	$R(p) = \lambda_C \cdot \Gamma_P(v) = \lambda_C/\sqrt{1 + (p/m_0 c)^2}$
Three-State Phase Transition	Particles adaptively switch between collapsed, diffused, and fluid states according to environmental complexity ξ and dynamic radius R	$\text{State} = f(\xi, R, \text{Obs})$

2 Physical Mechanism of Linear Motion: Intrinsically of Momentum Encapsulation

2.1 Conceptual Carding of Traditional Explanations

In traditional theories, the explanation chain of ”why particles move in a straight line” has logical confusion, and the core problem is equating mathematical tools with physical mechanisms:

The linear motion ability of particles originates from the intrinsic constant driving ability of the evolution carrier in the state evolution system. At each t_p moment in the free dimension, state transition occurs based on its own scale l_p, naturally emerging the linear motion ability. It does not need additional assumptions of space-time background, geodesic properties, integral prediction, and then reconstructing the least action ability. Therefore, the evolution carrier m_0 and the driving ability light speed c in the cosmic system together vectorially superimpose to emerge Newton's first law of motion (inertia law).

2.2 Intrinsic Directionality of Momentum Encapsulation

In the framework proposed in this paper, particles are encapsulated by N momentum units, and the stability of their motion direction originates from the intrinsic characteristics of the encapsulation structure, which is the core physical mechanism of linear motion:

Spherically symmetric encapsulation:

$$\sum_{i=1}^{N} \vec{p}_i = 0$$

→ the particle is in a static state, and the encapsulation direction has no net deviation;

Symmetry breaking:

$$\sum_{i=1}^{N} \vec{p}_i = \Delta\vec{p}(\neq 0)$$

→ the particle is in a moving state, and the net deviation momentum determines the motion direction.

The physical mechanism of linear motion can be further explained as: each momentum unit is encoded with a fixed evolution direction $\vec{d}_i$ ($|\vec{d}_i| = c$), which is the intrinsic property of the momentum unit; when the encapsulation structure is stable, the evolution direction of each momentum unit is relatively fixed without irregular deviation; the direction of the net deviation momentum $\Delta\vec{p}$ is determined by the encapsulation topological structure, forming the overall motion direction of the particle; without external force deflection, the encapsulation topological structure remains unchanged → the direction of $\Delta\vec{p}$ is always stable → the particle presents linear motion.

The velocity emergence relationship is:

$$\vec{v} = \frac{\Delta\vec{p}}{P_{\text{total}}} \cdot c$$

This formula shows that particle velocity is an emergent characteristic of the momentum encapsulation structure, and its magnitude and direction are determined by the intrinsic state of momentum encapsulation, further confirming the connection between linear motion and the intrinsic nature of momentum encapsulation. Combined with the velocity increase axiom $\Delta v = \frac{\Delta p}{P_{\text{total}}} c$, the acceleration of particles (rate of velocity change) originates from the accumulation of momentum deviation, which is similar to the viewpoint of the intrinsic evolution logic of momentum encapsulation in this paper.

2.3 Historical Causality of Direction ”Selection”

The particle motion direction (direction of$\Delta\vec{p}$) is determined by the historical causal chain, rather than any form of ”optimization selection”: it is the causal legacy of the particle's previous interactions (such as the recoil momentum when the particle is emitted from the source), and is a natural result of the previous dynamic process; as a causal evolution system, the motion state of particles is jointly determined by initial conditions and evolution rules. There is no need to rely on the ”variational selection” of the principle of least action. The continuous action of the intrinsic characteristics of momentum encapsulation ensures the stability and causal continuity of the motion direction. This causal interpretation is similar to the core idea of ”deterministic underlying rules” in 't Hooft's cellular automaton interpretation [8,9].

2.4 Macro Equivalence of the Principle of Least Action

Under the limit of a large number of particle statistics or strong coupling, the appearance of the principle of least action can be derived from causal dynamics, which reflects its macro equivalence, but does not change its nature as a mathematical tool, nor can it replace the physical mechanism status of the intrinsic nature of momentum encapsulation: in the classical limit, the average behavior of a large number of momentum units satisfies the Euler-Lagrange equation, and the principle of least action becomes a concise mathematical description of macro motion; in the path integral, the stationary phase approximation leads to the dominant contribution of the path with$\delta S = 0$, which is a mathematical statistical result, not a micro physical causality.

3 Physical Mechanism of Multi-Slit Experiments: Diffused State and Momentum Flow Distribution

3.1 Three-State Switching of Particles

The three-state switching of particles is essentially a change in the state of the momentum encapsulation structure. The distribution mode of momentum flow is different in different states, which is an important premise for multi-slit interference:

State	Description	Role in Multi-Slit Experiments
Collapsed State	Momentum flow converges to a single causal path, the momentum encapsulation structure is stable, and the intrinsic direction is clear	Initial state after emission from the particle source, switching before entering multi-slits, showing linear motion at this time
Diffused State (Fluid State)	Momentum flow is distributed to multi-paths through the internal entanglement protocol, and the momentum encapsulation structure is temporarily in a weakly stable state	Core state when passing through multi-slits, providing conditions for multi-path distribution and interference of momentum flow; at this time, it is easy to be deflected by the electromagnetic interaction of the slit wall
Entangled State	Internal perception protocol between multiple particles, the interaction range of the momentum encapsulation structure extends to multiple particles	Appears in multi-particle interference, and the momentum flow distribution presents multi-particle cooperative characteristics

The core function of the diffused state is to increase the perceptual cross-section with the environment (slit wall) to achieve more weak coupling interactions. This interaction will deflect the distribution direction of momentum flow, and the interaction process is dominated by electromagnetic force, which will not change the intrinsic characteristics of momentum encapsulation; when the particle leaves the multi-slit area, the momentum encapsulation structure returns to stability and presents linear motion again. The essence of electromagnetic interaction can be described by the electromagnetic quantum mechanics equation,

$$F = \alpha \hbar c / r^2$$

and its action mechanism is similar to the viewpoint of "instantaneous borrowing and returning of momentum pairs driven by perceptual cross-section" in this paper.

3.2 Adaptive Three-State Switching Criterion

Particles are not always waves or particles; their state is jointly determined by the dynamic radius $R(p)$ and the environmental topological complexity ξ. Define the state criterion function Λ:

$$\Lambda = \frac{\xi_{\text{topo}} \cdot R(p)}{\lambda_{\text{interaction}}}$$

where ξ_{topo} characterizes the complexity of the slit structure (such as the number of slits and spacing), and $\lambda_{\text{interaction}}$ is the interaction characteristic length.

Collapsed State (Particle State): When $v \to c$ leads to $R(p) \to 0$, or there is strong observation interference, $\Lambda \ll 1$. At this time, the momentum flow is highly localized, the diffusion term disappears, and the particle moves in a straight line along a single causal path.

Diffused/Fluid State: When $v \ll c$ ($R \approx \lambda_C$) and in a multi-slit complex topology, $\Lambda > \Lambda_c$. At this time, the momentum encapsulation "softens", the momentum flow splits into multiple sub-flows, and the topological momentum flow distribution integral is activated.

Physical significance: This mechanism explains why high-energy electrons (small R) are more like particles, while low-energy electrons (large R) are more likely to undergo interference. The dynamic radius $R(p)$ is the "valve" controlling this phase transition.

3.3 Dual Attributes of Slits

Different regions of multi-slits have different effects on momentum flow, which essentially deflect the momentum flow distribution through electromagnetic interaction, thereby affecting the interference phenomenon. This effect is physical, rather than the geometric boundary condition in the traditional path integral, and the slit thickness directly affects the electromagnetic interaction intensity:

Region	**Attribute**	**Interaction Protocol**	**Effect**	**Mathematical Expression**
Intra-slit Channel	Weak Potential Barrier Diversion Zone	Weak Electromagnetic Perception	Allows momentum flow to pass through, with little disturbance to the momentum encapsulation structure	$\tau \approx 1$

Slit Wall Material	Strong Potential Barrier Interaction Zone	Strong Electromagnetic Interaction	Deflects momentum flow to adjacent slits, disturbs the momentum flow distribution in the diffused state; the larger the slit thickness, the stronger the electromagnetic interaction and the more significant the deflection effect (can explain the phenomenon that photons deflect to the side of larger slit thickness)	$\kappa \propto d \cdot U_b$

Slit wall interaction coefficient (quantifying the deflection effect of the slit wall on momentum flow, dominated by electromagnetic force):

$$\kappa_{\text{wall}} = \alpha_{\text{EM}} \cdot \frac{d}{a_0} \cdot \frac{Z_{\text{eff}}}{r_{\text{lattice}}^2} \cdot \eta(v)$$

where α_{EM} is the electromagnetic coupling constant, which clearly reflects that the interaction is dominated by electromagnetic force; d is the slit thickness, which directly determines the interaction intensity, consistent with the experimental phenomenon of "photons deflecting to the side of larger slit thickness"; in the multi-slit scenario, the interaction of adjacent slit walls will form a superposition effect, further regulating the momentum flow distribution. Combined with the special relativistic effect, the perceptual window factor

$$\Gamma(v) = \sqrt{1 - v^2/c^2}$$

will compress the interaction space-time window during high-speed motion, leading to the electromagnetic force showing an effect similar to magnetic force, which is similar to the viewpoint of relativistic correction of electromagnetic interaction in this paper.

3.4 Inter-Slit Momentum Flow Transfer Factor

In a multi-slit system, the proportion of momentum flow transferred from slit i to any slit j ($j \neq i$) can reflect the deflection effect of the slit wall electromagnetic interaction on the momentum flow distribution. Its positive correlation with the slit thickness can explain the experimental phenomenon of "stronger deflection on the side of larger slit thickness", and the multi-directional transfer effect in the multi-slit scenario can explain the modulation characteristics of interference fringes:

$$\xi_{ij} = \beta \cdot \frac{d \cdot U_b}{r_{ij}^2} \cdot \eta(v) \quad (\text{when} \vec{r} \in \text{slit wall region}, j = 1, 2, ..., N; j \neq i)$$

where N is the total number of multi-slits, and r_{ij} is the center distance between slit i and slit j. The transfer factor satisfies the following laws, consistent with basic physical laws such as momentum conservation:

$\xi_{ij} = \xi_{ji}$ (symmetry): The momentum flow transfer between slits is bidirectionally symmetric;

$\sum_{j=1,j\neq i}^{N} \xi_{ij} \leq 1$ (total transfer does not exceed the incident flow): Consistent with the law of momentum flow conservation;

$\xi_{ij} \propto d$ (the larger the slit thickness, the more transfer): The larger the slit thickness, the stronger the electromagnetic interaction between the slit wall and the momentum flow, the more obvious the deflection effect on the momentum flow, and the larger the deflection angle; in the multi-slit scenario, the superposition of transfer factors of adjacent multi-slits will lead to secondary modulation of interference fringes, and this mechanism is also applicable to the slit thickness-dependent deflection phenomenon of photons. Existing high-precision electron diffraction experiments have been able to accurately control the slit geometric parameters [16], but few studies have systematically changed the slit thickness and observed the asymmetric shift of fringes. The transfer factor proposed in this paper can provide theoretical support for such experiments.

4 Momentum Flow Distribution Integral Equation

4.1 New Topological Momentum Flow Distribution Integral Equation

The total momentum flow density at position X on the screen essentially needs to use momentum deviation integral, and for the convenience of statistics, the following specific integral method is adopted. This method is no longer a simple area integral, but an integral over the volume inside the slit to reflect the cumulative effect of electromagnetic deflection in the slit thickness direction:

$$\rho_{\text{flow}}(X) = \sum_{k=1}^{N} \left[\int_{V_k} \underbrace{\Gamma_P(v)\,\sigma_{\text{perceptual}}(R)}_{\text{Relativistic \& Geometric Modulation}} \cdot \underbrace{U_{\text{wall}}(\vec{r})}_{\text{Slit Wall Potential Field}} \, d^3r \right]_k \cdot \cos(\Delta\theta_k)$$

where the integral region V_k covers the entire volume (length × width × thickness d) of the k-th slit.

Note: The integral volume element $d^3r = dxdydz$, where the z-axis is along the slit thickness direction. The traditional path integral only integrates over the path length ds, while this equation explicitly accumulates the deflection effect of the slit wall potential field $U_{\text{wall}}(z)$ over the entire thickness through the integral over dz, which is the mathematical root of the 'slit thickness saturation effect'.

Analysis of core innovative terms:

Volume integral $\int d^3r$: The traditional path integral only considers the path length, while this equation explicitly includes the integral in the slit thickness z-direction. This means that the thicker the slit, the stronger the cumulative electromagnetic deflection on the momentum flow, directly leading to the "slit thickness saturation deflection effect".

Dynamic radius modulation $\sigma_{\text{perceptual}}(R(p))$: The perceptual cross-section is no longer fixed, but $\sigma \propto R(p)^2$. When the particle moves at high speed, $R(p)$ shrinks, leading to a sharp decrease in the weight of the integral kernel. This mathematically proves that "slit wall interaction weakens for high-speed particles".

Relativistic factor $\Gamma_P(v)$: Explicitly appears in the integral kernel, indicating the reduction of interaction efficiency caused by the compression of the time window at high speed.

4.2 Definition of Physical Quantities (All Real Dynamic Quantities)

Each physical quantity in the equation corresponds to a clear physical meaning, without abstract mathematical constructs, suitable for multi-slit scenarios:

Symbol	Name	Physical Meaning	Expression
$\vec{r}$	Slit Surface Coordinate	Integral variable, corresponding to the spatial position of the multi-slit region	(x_m, y)
$\eta(v)$	Velocity-Dependent Interaction Coefficient	Modulation of interaction efficiency by particle inertial velocity, related to the intrinsic velocity of momentum encapsulation, affecting electromagnetic interaction response	$\eta(v) = \frac{v}{c} \cdot \frac{P_{\text{total}}}{P_{\text{total}}+\Delta p}$
$\sigma_{\text{perceptual}}(\vec{r})$	Perceptual Cross-Section Matching Factor	Perceptual efficiency between particles and the slit wall electromagnetic potential barrier, determining the electromagnetic interaction intensity between momentum flow and the slit wall; in multi-slit scenarios, the superposition effect of adjacent slit walls needs to be considered	$\frac{A_{\text{perceptual}}}{4\pi r^2} \cdot \chi_{\text{coupling}}$
$T(\vec{r})$	Geometric Transmission Function	Diversion ability of multi-slit geometric structure to momentum flow, reflecting the influence of geometric characteristics such as slit width, slit thickness, and slit spacing on momentum flow	$T_w(\vec{r}_\perp) \cdot T_d(z)$
T_w	Transverse Slit Width Function	Passing probability determined by slit width, only related to the transverse size of the slit	1 inside, 0 outside
T_d	Longitudinal Slit Thickness Function	Longitudinal passing region determined by slit thickness, directly related to the range of slit wall electromagnetic interaction	1 when $z \in [0, d]$
ξ_{ij}	Inter-Slit Transfer Factor	Proportion of momentum flow deflected by the slit wall to adjacent slits, quantifying the deflection effect, directly determining the degree of slit thickness-dependent deflection	See Eq. (4-New)

Among them, the definition of the perceptual cross-section matching factor is similar to the ”perceptual cross-section driven” mechanism of quantum tunneling, that is, force interaction is determined by the perceptual cross-section matching degree, not directly related to distance, and its essence is the process of borrowing and returning momentum pairs.

4.3 Correction of Inter-Slit Transfer Factor

Based on the volume integral derivation, the inter-slit transfer factor ξ_{ij} should be corrected to:

$$\xi_{ij} = \beta \cdot \Gamma_P(v) \cdot \frac{R(p)^2}{r_{ij}^2} \cdot \int_0^d U_b(z)dz$$

This formula clearly shows that the transfer amount is proportional to the integral value of the slit thickness, proportional to the square of the dynamic radius, and proportional to the relativistic factor.

4.4 Conservation Law

Total momentum flow is conserved, consistent with the intrinsic properties of momentum encapsulation, suitable for multi-path distribution in multi-slit scenarios:

$$\int_{\text{screen}} \rho_{\text{flow}}(X) d^2X = \rho_{\text{total}} = N \cdot m \cdot c$$

4.5 Formation of Interference Fringes

The interference intensity at position X on the screen originates from the self-superposition of momentum flow in the diffused state, rather than the probability superposition of particles in different paths. Its phase difference is the real phase difference of the geometric path, which can avoid the ontological confusion of complex probability amplitudes; in multi-slit scenarios, the interference fringes are formed by the superposition of momentum flows from all slits, showing modulation characteristics of main maxima, secondary maxima, and dark fringes:

$$I(X) = \sum_{i=1}^{N_{\text{slit}}} \rho_{\text{flow},i}(X) + 2 \sum_{1 \leq i < j \leq N_{\text{slit}}} \sqrt{\rho_{\text{flow},i}(X) \cdot \rho_{\text{flow},j}(X)} \cdot \cos(\Delta\phi_{ij}(X))$$

where N_{slit} is the total number of multi-slits, and $\rho_{\text{flow},i}(X)$ is the momentum flow density at position X on the screen from the i-th slit, reflecting the respective momentum flow contributions of multi-slits and their mutual superposition effects; $\Delta\phi_{ij}(X)$ is the geometric phase difference between the momentum flows of the i-th and j-th slits at position X on the screen, which is a real number, completely abandoning the complex form and ensuring the consistency of the theoretical framework.

Geometric phase difference:

$$\Delta\phi_{ij}(X) = \frac{2\pi}{\lambda_{\text{eff}}} \cdot (L_i(X) - L_j(X)), \lambda_{\text{eff}} = \frac{h}{P_{\text{total}}}$$

The phase here is the real phase difference of the geometric path, originating from the optical path difference, rather than the intrinsic phase of the complex probability amplitude. Combined with the photoelectric relationship $f\lambda = c$, the wavelength λ of photons is their macro occupied scale or the transition scale of a single macro time window, and the frequency f is the macro transition cycle frequency. The product of the two is always the speed of light c, which is similar to the physical image of photon ”goose-flock-like coding” in this paper.

The formation of interference fringes is a natural result of multi-path distribution and superposition of momentum flow, and its physical root is the diffused state characteristics of momentum encapsulation and the electromagnetic interaction of the slit wall. In multi-slit scenarios, the superposition of momentum flow transfer between adjacent slits leads to the modulation of main maxima and secondary maxima of the fringes; the slit thickness affects the momentum flow transfer by changing the electromagnetic interaction intensity, thereby causing the fringes to deflect to the side of larger slit thickness, which is not directly related to the principle of least action.

5 Comparative Analysis with Traditional Path Integrals

To clearly present the differences between the framework of this paper and the traditional path integral, and to facilitate further discussion on the physical mechanism of multi-slit experiments, the core characteristics of the two are compared as follows, focusing on the difference in the role of slit thickness electromagnetic interaction in multi-slit scenarios:

Characteristics	**Standard Path Integral**	**Momentum Flow Distribution Integral (Framework of This Paper)**
Basic Object	Complex probability amplitude ψ (abstract mathematical construct)	Real momentum flow density ρ_{flow} (physical reality)
Integral Object	All possible paths $x(t)$ (prone to teleological interpretation)	Geometric points $\vec{r}$ in the slit region (physical space coordinates, including slit thickness dimension, suitable for multi-slits)
Weight	$e^{(iS/\hbar)}$ (depends on the principle of least action)	$\eta(v) \cdot \sigma_{\text{perceptual}} \cdot \mathcal{T} \cdot (1 + \sum \xi)$ (real dynamic quantity, including electromagnetic coupling term, related to momentum encapsulation, slit wall electromagnetic interaction, and slit thickness, suitable for multi-slit transfer superposition)
Path Concept	Possible history of particles (abstract, prone to implicit ”selection” tendency)	Spatial distribution channel of momentum flow (physical, originating from the diffused state of momentum encapsulation, multi-channel distribution in multi-slit scenarios)
Explanation of Linear Motion	Dominance of the least action path (mathematical description, prone to teleological misleading)	Stability of momentum encapsulation direction (physical mechanism)
Direction ”Selection”	Variational principle is prone to implicit teleology	Determined by historical causal chain (legacy of previous interactions of momentum encapsulation)
Origin of Interference	Superposition of amplitudes from different paths (complex superposition, with ontological confusion)	Self-superposition of momentum flow of the same particle (real superposition, clear physical mechanism, dominated by electromagnetic interaction, multi-channel superposition in multi-slit scenarios)
Role of Slit Wall	Boundary condition (mathematical treatment, no physical interaction, difficult to explain slit thickness deflection and multi-slit fringe modulation)	Electromagnetic interaction deflects momentum flow (physical effect, quantifiable, slit thickness affects interaction intensity, can explain photon slit thickness deflection and multi-slit fringe modulation)
Slit Thickness Dependence	Implicit in higher-order corrections (difficult to clearly explain experimental phenomena)	Explicit $\xi_{ij} \propto d$ (can explain slit thickness deflection phenomenon, dominated by electromagnetic force, superposition modulation fringes in multi-slit scenarios)
Conservation Law	Probability conservation (abstract mathematical conservation)	Momentum flow conservation (physical reality conservation, suitable for multi-channel distribution in multi-slits)

Principle of Least Action	Basic postulate (often mistaken for physical mechanism)	Mathematically equivalent tool (mainly used for dynamic modeling of complex multi-body motions)

Unlike Bohmian mechanics, which introduces a ”quantum potential” to guide particle trajectories [17], the framework of this paper does not need to introduce additional non-local potential fields, but directly explains interference through the ”diffused state - electromagnetic deflection” mechanism of momentum units. This not only retains the causality of realism but also avoids the theoretical difficulty of superluminal correlation, providing a new path based on local electromagnetic interaction for understanding multi-slit experiments, which is similar to the core idea of the ”realism interpretation” of Bohmian mechanics [17].

6 Discussion on Relevant Observation Directions

To clearly present the differences between the framework of this paper and the traditional path integral, and to facilitate further discussion on the physical mechanism of multi-slit experiments, the core characteristics of the two are compared as follows, focusing on the difference in the role of slit thickness electromagnetic interaction in multi-slit scenarios:

6.1 Slit Thickness Saturation and High-Speed Attenuation Effects (Core Prediction)

Slit thickness saturation: It can be seen from Equation (5-New) that when the slit thickness d increases to a certain extent, due to the shielding effect or geometric limitation of the potential field U_{wall}, the integral value will tend to be saturated, and the fringe shift will no longer increase linearly with d.

High-speed attenuation: It can be seen from the $\Gamma_P(v)$ and $R(p)$ terms that when using a high-energy electron beam of $0.9c$ in experiments, the deflection caused by the slit thickness should be significantly lower than that of a low-energy electron beam of $0.1c$. This cannot be explained by traditional wave optics, because traditional theory holds that the shorter the wavelength (higher energy), the weaker the diffraction, but the theory proposed in this paper predicts the relativistic attenuation of the ”interaction coupling intensity” itself.

6.2 Deflection Difference Ratio of Different Particles

The deflection intensities of electrons, photons, and neutrons may be different. This difference originates from the different momentum encapsulation structures of different particles, leading to differences in their perceptual cross-sections for electromagnetic interaction with the slit wall, which can further confirm the intrinsic nature of momentum encapsulation and the role of electromagnetic interaction. In multi-slit scenarios, this difference may be reflected in the details of fringe modulation. It is speculated that the deflection intensity ratio is:

$$\frac{\Delta X_e}{\Delta X_\gamma} = \frac{\sigma_{\text{perceptual},e}}{\sigma_{\text{perceptual},\gamma}} = \frac{\alpha_{\text{EM}}}{\alpha_{\text{polarization}}} \approx 10^2 \sim 10^3$$

Combined with the relationship between the photoelectric effect and the electron radius (the electron radius is inversely proportional to the magnitude of the momentum deviation), the smaller the electron radius, the shorter the wavelength of the excited photon and the larger the momentum deviation. This characteristic will further affect the electromagnetic interaction intensity between the particle and the slit wall, which is similar to the viewpoint of ”momentum encapsulation structure determines interaction characteristics” in this paper.

6.3 Local Momentum Flow Enhancement

It is speculated that a temporarily existing local momentum flow enhancement may be detected near the multi-slit wall. This phenomenon originates from the momentum flow transfer process. In multi-slit scenarios, the momentum flow enhancement effect near adjacent slit walls may form a superposition, which can be used as evidence of physical interaction between the slit wall and the momentum flow. Moreover, this enhancement effect may become more significant with the increase of slit thickness, which is positively correlated with the electromagnetic interaction intensity. This speculation is similar to the mechanism of ”local momentum change caused by borrowing and returning of momentum pairs” in quantum tunneling.

6.4 Modulation Characteristics of Multi-Slit Fringes

It is speculated that the number and intensity of secondary maxima of multi-slit interference fringes may decrease with the increase of slit spacing r_{ij} and increase with the increase of slit thickness d. This modulation characteristic originates from the superposition effect of momentum flow transfer between multi-slits, which can be observed and verified by changing the slit spacing and slit thickness.

7 Discussion on Theoretical Significance

7.1 Causal Regression of Physical Interpretation

The framework of this paper attempts to return the physical interpretation of multi-slit experiments to causal logic and abandon the teleological tendency: the motion mode of particles is determined by their intrinsic structure (momentum encapsulation), and linear motion is a natural result of the stability of the momentum encapsulation direction; during interaction, particles change their encapsulation state through the perceptiontoggle protocol (mainly the electromagnetic protocol in multi-slit experiments), thereby changing the momentum flow distribution. The slit thickness affects the momentum flow transfer by regulating the electromagnetic interaction intensity. In multi-slit scenarios, the superposition of multi-directional transfer forms phenomena such as interference, slit thickness-dependent deflection, and fringe modulation. This process follows a clear causal chain and does not require the logic of ”optimization selection”. This causal regression idea is similar to the realist viewpoints of 't Hooft's cellular automaton interpretation and Bohmian mechanics [8,9,17].

7.2 Attempt at Causal Interpretation of Quantum Phenomena

Based on the framework of this paper, a purely causal interpretation of quantum phenomena such as multi-slit interference can be carried out, attempting to resolve some conceptual ambiguities in traditional interpretations: taking the real momentum flow density as the basic physical reality instead of the abstract complex probability amplitude; taking the multi-path distribution and superposition of momentum flow instead of the probability superposition of particles in different paths; taking the electromagnetic interaction between the slit wall and the momentum flow instead of geometric boundary conditions, clarifying the role of slit thickness in interference phenomena, and providing a new idea for the interpretation of quantum phenomena. This interpretation idea is similar to Wheeler's information physics perspective of ”it from bit” [13], both emphasizing the encodability of physical reality and the laws of causal evolution.

7.3 Clarification of the Positioning of the Principle of Least Action

Combined with the analysis of the framework of this paper, the positioning of the principle of least action is further clarified: its core value lies in serving as a mathematical description tool, realizing the dynamic modeling of complex multi-body motions relying on the Lagrangian idea, showing good equivalence at the macro scale, and being able to concisely describe macro motions and statistical laws. However, it is not a causal mechanism of microphysical processes and cannot explain the interaction details at the micro scale (such as the electromagnetic interaction mechanism of photon slit thickness-dependent deflection and multi-slit fringe modulation); its effectiveness in the classical limit and macro scale originates from the statistical average of momentum encapsulation dynamics, which can be derived from momentum encapsulation dynamics and interaction rules, and does not have a fundamental status beyond physical causality. In the framework of classical mechanics, the principle of least action is regarded as a basic postulate [12]. The positioning in this paper is not contradictory to this classical formulation, but further clarifies its applicable scale and essence, which is similar to the viewpoint in Prigogine's non-equilibrium dynamics that ”macroscopic laws originate from microscopic statistical averages” [18]. The essence of energy dissipation is that the degree of freedom variables in a system have a high degree of freedom, and it has a high ability of self-inertial evolution, difficult to be constrained by potential wells.

8 Conclusion

Based on the relevant viewpoints of the Unified Cosmic Mechanics Evolution Theory, this paper takes the intrinsicality of momentum encapsulation as the core physical mechanism of linear motion, combines the role of slit wall electromagnetic interaction in dominating momentum flow , and introduces special relativistic corrections (Γ_P(v), R(p)) to describe the compression effect of perceptual space-time windows at high speeds, attempting to reconstruct the mathematical description and physical interpretation of multi-slit experiments. At the same time, it briefly explains the principle of least action, clarifying its positioning as a macro-equivalent mathematical tool. The main conclusions are as follows:

1. Attempt at framework reconstruction: Replace the complex path integral with the real momentum flow distribution integral

$$\rho_{\text{flow}}(X) = \sum_{k=1}^{N} \left[\int_{V_k} \Gamma_P(v) \cdot \sigma_{\text{perceptual}}(R(p)) \cdot U_{\text{wall}}(\vec{r}) d^3 r \right]_k \cdot \cos(\Delta\theta_k)$$

, introduce volume integral and dynamic radius terms to adapt to multi-slit multi-directional momentum flow transfer scenarios; clarify that the principle of least action is mainly used for dynamic modeling of complex multi-body motions, showing equivalence at the macro scale, returning to its nature as a mathematical tool. Its causal explanation function at the micro scale has been replaced by the self-integral (describing intrinsic linear motion) and interaction integral (describing electromagnetic , and introducing the special relativistic correction Γ_P(v)) in this paper. This reconstruction idea is similar to the realist viewpoints of 't Hooft's cellular automaton interpretation and Bohmian mechanics [8,9,17], all attempting to get rid of the ontological confusion of complex probability amplitudes.

2. Electromagnetic interpretation of slit thickness effect and multi-slit modulation: Introduce the corrected inter-slit transfer factor

$$\xi_{ij} = \beta \cdot \Gamma_P(v) \cdot \frac{R(p)^2}{r_{ij}^2} \cdot \int_0^d U_b(z)dz$$

to quantify the of momentum flow by slit wall electromagnetic interaction, adapting to the transfer superposition effect between each pair of slits in multi-slit scenarios; clarify that the deflection of photons to the side of larger slit thickness is mainly dominated by electromagnetic force (gravitational contribution 10 times, negligible). In multi-slit scenarios, transfer superposition may lead to modulation characteristics of main maxima and secondary maxima in interference fringes, accompanied by slit thickness saturation and high-speed attenuation effects. Among them, the high-speed attenuation effect originates from the modulation of the interaction integral kernel by the special relativistic correction factor Γ__P(v), reflecting the physical mechanism of "high-speed motion leading to a reduction in perceptual space-time windows". The quantitative description of electromagnetic interaction is based on the electromagnetic quantum mechanics equation

$$F = \alpha\hbar c/r^2$$

, combined with the special relativistic perceptual window factor, which is similar to the viewpoint of "relativistic correction of electromagnetic force" in this paper.

Relevant Observation Directions

Combined with theoretical derivation, the following observation directions are proposed for reference in subsequent experimental verification: slit thickness saturation and high-speed attenuation effects, particle type-dependent deflection ratio ΔX__e/ΔX__ 10^2 10^3, local momentum flow enhancement near the slit wall, and the secondary maxima of multi-slit fringes decreasing with the increase of slit spacing r__ij and increasing with the increase of slit thickness d. Among them, the "high-speed attenuation effect" is the key difference between this theory and traditional wave optics: the latter only attributes it to the shorter wavelength, while this theory predicts the relativistic attenuation of the interaction coupling intensity itself. These observation directions can be verified with existing high-precision diffraction experimental technologies [16], further improving the theoretical framework of this paper.

The framework of this paper attempts to be consistent with multi-slit experimental phenomena, providing a purely causal interaction idea for the interpretation of quantum mechanics, that is, quantum phenomena can be regarded as the dynamic distribution result of momentum units under the encapsulation protocol. As a causal evolution system, the universe follows clear dynamic rules in its microprocesses. This research still has some shortcomings, and the theoretical framework will be further improved, revised and optimized in combination with experimental data.

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