# Unified Cosmic Mechanics Evolution Theory (VIII) :
# Single-Particle High-Speed Dynamical Effects and Their Relationship with Relativity

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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 eighth 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 momentum unit evolution theory, taking the time update mechanism [1], the velocity increment formula, and the four covariance principles as the premises [2], combined with the special relativity window compression, Newtonian gravity, and path bending perception multiplication effects [3,4], this paper reconstructs the gravitational lensing, red-blue shift, and Schwarzschild radius systems. The study confirms that gravitational lensing is the dynamical trajectory of ultra-high-speed particles under the synergy of the three effects; special relativity is essentially the result of dual compression of space-time windows, which leads to extremely weak gravitational interaction of particles and can only be manifested with the support of supermassive celestial bodies; the Schwarzschild radius is the critical value of momentum field density capture, which does not depend on the Einstein field equations. The paper further reveals that both photons and neutrinos have mass, which is essentially the number of momentum units (total number of evolutionary carriers) [5,6]. The conclusion is clear: when a single particle moves at high speed, the compression of the perceptual window and the topological structure together inhibit gravitational interaction, and only supermassive celestial bodies can break this limit to manifest gravitational effects.

**Keywords:** Photon mass; Unified mechanics; High-speed motion effect; Gravitational lensing; Schwarzschild radius; Dual compression of space-time windows; Photon gravitational effect; Black hole origin; Red-blue shift

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## 1 Introduction

The momentum unit evolution theory holds that the underlying universe is composed of discrete momentum units, and space-time is the macroscopic statistical emergence of their evolution. This theory reconstructs the physical significance of traditional physical constants and mass-energy relations through four covariance principles. Ultra-high-speed particles (\(v \approx c\)) are the key to connecting micro-discrete dynamics and macro-space-time covariance. Their motion is constrained by special relativity effects and the covariance of external interactions—special relativity originates from the dual compression of space-time windows, which is essentially a resource competition in the process of space-time emergence, i.e., the three quantities of total perceptual capacity, perceptible space-time window, and non-perceptual capacity window form a Pythagorean theorem conservation distribution relationship, thereby making the gravitational interaction capacity of ultra-high-speed particles extremely weak. Path bending can increase the number of perceptual opportunities to make up for the insufficient deflection effect, and the gravitational slingshot effect causes red-blue shift.

Traditional theories regard gravitational lensing as a space-time bending effect, the Schwarzschild radius needs to be solved through the Einstein field equations, and the red-blue shift has not been directly associated with momentum transfer. Based on the momentum unit evolution theory, this paper follows the logic of "Newtonian mechanics → three comprehensive effects → gravitational slingshot effect → Schwarzschild radius" to reconstruct the physical essence of each effect, clarify that gravitational lensing is essentially consistent with the gravitational deflection of low-speed objects, red-blue shift is the energy manifestation of momentum transfer, and the Schwarzschild radius can be independently derived by the escape velocity method. This paper aims to clarify the relationship between the evolution of ultra-high-speed particles and relativity, correct traditional cognition, promote the integration of discrete information dynamics and macro-space-time theory, and clarify the mechanism of extremely weak gravitational interaction capacity of single particles during high-speed motion and its derived effects.

# 2 Theoretical Basis: Core Premises, Covariance Principles, and Three Comprehensive Effects

## 2.1 Core Settings and Definition of Basic Quantities

Based on the information dynamics framework of the momentum unit evolution theory, combined with the core logic of this correction, the derivation premises are as follows:

Underlying reality: The universe is composed of discrete "momentum units". The mass $m$ of a particle (including photons) corresponds to the total number of momentum units $N$ ($m = N \cdot m_0$, where $m_0$ is the mass of a single momentum unit), and its state is described by $N$, intrinsic evolution amplitude $c$, and directional proportion $s$.

Evolution mechanism: Particle motion follows the "momentum encapsulation velocity increment axiom". Gravity originates from the discrete transfer of momentum units, not space-time bending; time is a macroscopic tool for connecting evolutionary snapshots and has no underlying substantial significance. Among them, the velocity increment formula is specifically: $\Delta v \approx \frac{\Delta p}{P_{\text{total}}} \cdot c$, where $P_{\text{total}}$ is the total momentum capacity of the particle [7].

Quoting core conclusions from previous chapters: According to the derivation in the previous chapter "The Relationship Between Relativity, Classical Mechanics, and Quantum Mechanics", during particle motion, there is a resource competition among total perceptual capacity, perceptible space-time window, and non-perceptual capacity window in the process of space-time emergence. The three form a Pythagorean theorem distribution conservation relationship, and the upper limit of the interaction frequency of force is $c$. Therefore:

$$c^2 = v_{\text{perceptual}}^2 + v_{\text{non-perceptual}}^2$$

Where $v_{\text{perceptual}}$ is the number of space-time windows that can be interacted with by both particles (perceptible space-time window), $v_{\text{non-perceptual}}$ is the number of space-time windows that cannot be interacted with by both particles (non-perceptual capacity window), and $c$ corresponds to the total perceptual capacity. Therefore, a Lorentz factor of the compression ratio of the perceptual window is formed:

$$\frac{N}{N_0} = \frac{v_{\text{perceptual}}}{c} = \sqrt{1 - \frac{v^2}{c^2}}$$

This ratio corresponds to the reciprocal of the Lorentz factor $\gamma = 1/\sqrt{1 - v^2/c^2}$, which is the mathematical root of the special relativity effect and essentially reflects the distribution law of perceptual resources in space-time emergence.

Interaction constraints: The special relativity effect originates from the compression of the perceptual space-time window (the resource competition and conservation distribution of the above-mentioned total perceptual capacity, perceptible space-time window, and non-perceptual capacity window), which affects the interaction efficiency of AB particles. The inertial causal eigenstate generated after interaction is constant and does not change with the passive observer. When an ultra-high-speed particle ($v \approx c$) moves, the compression ratio of the perceptual space-time window $\sqrt{1 - v^2/c^2} \to 0$, the number of perceptual windows is very small, and due to the extremely large value of the denominator $c^2$, its gravitational interaction capacity is extremely weak; the bending of the particle path will increase the number of perceptual opportunities to make up for the insufficient deflection.

The maximum interaction update rate of the universe is $c$. Ultra-high-speed particles are affected by the perceptual window compression effect, and the cumulative effect of momentum interaction of Newtonian gravity is weak; each time the particle's motion path bends in the gravitational field, it will increase a perceptual opportunity, realizing the multiplication of the cumulative effect of momentum interaction and making up for the defect of too few perceptual windows.

Mass manifestation: The gravitational deflection effect of ultra-high-speed particles is weak, and their own mass is extremely small (negligible). It requires the pull of the high momentum field density of supermassive celestial bodies to make the three comprehensive effects cooperate to form observable gravitational lensing; under the gravitational slingshot effect, the momentum transfer between particles and celestial bodies will lead to energy increase or decrease, which is manifested as red-blue shift.

### 2.2 Covariance of Particle External Interaction (Core Support for Derivation)

The upper limit of the universe's interaction update rate is $c$, and the effective interaction efficiency of high-speed moving objects decreases (space-time window compression). This phenomenon originates from the perceptual resource competition in space-time emergence, forcing physical laws to satisfy the Lorentz transformation and maintain causality. It is the core support for the special relativity effect and the energy transfer of the gravitational slingshot effect. High-speed moving objects occupy evolutionary frames for displacement, resulting in a decrease in effective interaction frame rate (reduction of perceptual windows), which is the core physical mechanism of the dual compression of space-time windows and the constraint condition for the momentum transfer efficiency in the gravitational slingshot effect.

### 2.3 Interpretation of the Three Comprehensive Effects (Core of Gravitational Lensing Derivation)

The synergistic effect of the three comprehensive effects is the core mechanism for the formation of gravitational lensing of ultra-high-speed particles and the basis for the generation of the gravitational slingshot effect. The specific mechanism of action is as follows:

Special relativity effect: Originating from the dual compression of space-time windows, it is essentially the resource competition and conservation distribution of total perceptual capacity, perceptible space-time window, and non-perceptual capacity window in space-time emergence, which affects the interaction efficiency of AB particles. The inertial causal eigenstate generated after interaction is constant; this effect emerges when ultra-high-speed particles move. Due to the extremely large value of the denominator $c^2$, their gravitational interaction capacity is extremely weak, and the cumulative effect of momentum interaction of Newtonian gravity is weak. When ultra-high-speed particles ($v \approx c$) move, most of the evolutionary frames are used to maintain displacement, the effective interaction frame rate is greatly reduced, the number of perceptual windows is very small, and the gravitational effect is further weakened; at the same time, this effect also affects the momentum transfer efficiency in the gravitational slingshot effect.

Newtonian mechanics effect: Gravity is essentially discrete momentum transfer, following the macroscopic manifestation of Newtonian gravity (weak field approximation), providing the core transverse deflection power for particles, and is the basis for the formation of gravitational lensing and gravitational slingshot effect. Gravity is the discrete momentum interaction transfer caused by the gradient of momentum unit occupancy rate, and its macroscopic performance conforms to the form of Newtonian gravity, providing core power for particle deflection and momentum exchange in the gravitational slingshot effect; the mass of a single ultra-high-speed particle is extremely small, which can be ignored in the Newtonian gravity formula and does not affect the calculation of deflection effect and momentum transfer.

Path bending perception opportunity multiplication effect: The particle path bends under the action of Newtonian gravity, and each bend increases a perceptual opportunity, making up for the insufficient deflection caused by space-time window compression (i.e., the reduction of perceptible windows caused by perceptual resource competition), and finally forming observable gravitational lensing. Each time a particle bends, it will additionally obtain an interactive perception opportunity, making the originally weak cumulative effect of momentum interaction multiply, which just makes up for the insufficient deflection caused by too few perceptual windows; this effect also affects the number and efficiency of momentum transfer in the gravitational slingshot effect.

Synergistic relationship among the three: Newtonian mechanics provides deflection power (the mass of a single particle is negligible and does not affect the derivation); the special relativity effect leads to extremely weak gravitational interaction capacity and weak deflection effect of particles due to the extremely large value of the denominator $c^2$; the path bending perception opportunity multiplication effect makes up for the insufficient deflection, which needs to be pulled by supermassive celestial bodies to manifest this synergistic effect; at the same time, the three jointly constrain the momentum transfer process of the gravitational slingshot effect and determine the intensity and direction of red-blue shift.

## 3 Derivation of Evolutionary Effects of Ultra-High-Speed Particles in Gravitational Field (Based on Newtonian Mechanics + Three Comprehensive Effects)

Based on the core conclusion drawn in the previous chapter "The Relationship Between Relativity, Classical Mechanics, and Quantum Mechanics": there is a conservation distribution relationship of space-time shaping evolution among cancellation, breaking, and total quantity in the internal state evolution of particles, that is, $c^2 = v^2_{\text{cancellation}} + v^2_{\text{breaking}}$. This chapter focuses on single ultra-high-speed particles, combines this conservation distribution relationship with the covariance of perceptual space-time windows (originating from the competition of total perceptual capacity, perceptible space-time windows, and non-perceptual capacity windows), derives the special relativity effect produced in the gravitational field, and focuses on verifying the physical mechanism and mathematical rationality of gravity degenerating into gravitational lensing.

### 3.1 Preliminary Derivation of Gravitational Lensing (Newtonian Mechanics Only, Highlighting Negligible Single-Particle Mass)

First, only based on Newtonian mechanics, the gravitational deflection effect of single ultra-high-speed particles is derived, clarifying that the mass of a single particle is extremely small and can be ignored, laying a foundation for the subsequent improvement of the derivation by introducing three comprehensive effects (combining conservation distribution relationship and covariance of perceptual space-time windows).

1. Model Establishment and Parameter Initialization

   Taking the starlight deflection at the edge of the Sun as a typical case, only the Newtonian mechanics effect is considered to verify the rationality of neglecting the mass of a single particle and initially derive the mathematical form of the deflection effect.

   Core settings: Photons ($v = c$, ultra-high-speed single particles) are taken as the research object. Their own mass is extremely small (static mass is 0 from the traditional perspective, and equivalent inertial mass is also extremely small from the perspective of this theory), which can be ignored in Newtonian gravity calculation; the Sun is a supermassive gravitational source providing high momentum field density; weak field approximation and perturbation method are adopted, and photons pass by with impact parameter $b \approx R$ (solar radius). Gravitational effect is the discrete transfer of momentum units from the Sun to photons, only considering the Newtonian mechanics effect.

   Specific parameters and supplementary settings:

   Photon characteristics: In the traditional perspective, the static mass is 0, with energy $E$ and momentum $p$; in the perspective of this theory, the total momentum capacity of photons $P_{\text{total}} = E/c$. According to mass-energy equivalence ($E = mc^2$), their equivalent inertial mass (dynamic mass corresponding to momentum deviation) is $m_\gamma = E/c^2$, which is extremely small and can be ignored in subsequent gravity calculations.

   Solar parameters: Mass $M \approx 1.989 \times 10^{30}$ kg, radius (photon grazing distance) $R \approx 6.96 \times 10^8$ m.

   Basic constants: Gravitational constant $G \approx 6.674 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2$, speed of light $c \approx 3.0 \times 10^8$ m/s.

   Motion assumption: Photons move along the x-axis with the closest distance $y = b$ ($b \approx R$); the deflection angle is extremely small, and the perturbation method is adopted for approximation; the gravitational effect is manifested as the discrete momentum interaction accumulation of the solar momentum unit occupancy gradient on the photon momentum unit, only considering the effect of the transverse component of Newtonian gravity.

2. Calculation of Momentum Increment Under Newtonian Gravity (Neglecting Single-Particle Mass)

   Gravitational interaction is essentially momentum transfer. Photons are mainly affected by the transverse component of gravity perpendicular to the direction of motion, leading to the deflection of momentum direction; since the mass $m_\gamma$ of photons themselves is extremely small, it can be ignored in the calculation and does not affect the final deflection trend and the form of the core formula. Combined with the conservation distribution relationship of space-time shaping evolution of particles $c^2 = v^2_{\text{cancellation}} + v^2_{\text{breaking}}$, photons are in the limit state of $v_{\text{breaking}} = c$, their internal cancellation state space-time shaping capacity $v_{\text{cancellation}} \to 0$, and all space-time shaping resources are concentrated on macro breaking motion, which also determines the characteristics of extremely small inertial mass and weak gravitational interaction capacity of photons themselves, consistent with the resource competition logic of total perceptual capacity, perceptible space-time window, and non-perceptual capacity window.

   Gravity magnitude (weak field approximation): $F_G = G(Mm_\gamma)/r^2$, where $r = \sqrt{x^2 + b^2}$ is the instantaneous distance between the photon and the center of the Sun; since $m_\gamma$ is extremely small,

$F_G$ itself is weak, but the solar mass $M$ is extremely large, which can still produce an observable deflection trend.

Transverse component of gravity: $F_\perp = F_G \cdot b/r = (GMm_\gamma b)/(x^2+b^2)^{(3/2)}$, only the transverse component contributes to the deflection; although $m_\gamma$ exists here, it will be eliminated in the subsequent calculation, proving that the mass of a single particle can be ignored and does not affect the quantitative result of the deflection effect.

Integral of transverse momentum increment: Photons move at speed $c$, $dt = dx/c$ (macroscopic manifestation of the space-time window effect, essentially the synchronization of the space-time evolution of the photon breaking state with the speed, and the weak evolution of the internal cancellation state leads to a fixed correlation of interaction time). The total transverse momentum increment $\Delta p_\perp$ is the integral of force over time:

$$\Delta p_\perp = \int_{-\infty}^{+\infty} F_\perp dt = \int_{-\infty}^{+\infty} \frac{GMm_\gamma b}{(x^2+b^2)^{(3/2)}} \cdot \frac{dx}{c}$$

Using the integral formula $\int_{-\infty}^{+\infty} \frac{b}{(x^2+b^2)^{(3/2)}} dx = 2/b$, the solution is: $\Delta p_\perp = (2GMm_\gamma)/cR$ ($b \approx R$).

Preliminary deflection angle calculation: Traditional Newtonian mechanics holds that $F = ma \Rightarrow \Delta v = \Delta p/m$. Substituting $\Delta p_\perp$ gives: $\Delta v_\perp = (\Delta p_\perp)/m_\gamma = 2GM/cR$, and the deflection angle $\theta_{\text{Newton}} \approx \frac{\Delta v_\perp}{c} = \frac{2GM}{c^2R} \approx 0.875$ arcseconds.

Key conclusion: In the calculation process, the mass $m_\gamma$ of the photon itself is eliminated, proving that the mass of a single particle is negligible and does not affect the quantitative calculation of the deflection effect; however, this result is half of the observed value (1.75 arcseconds), indicating that Newtonian mechanics alone cannot fully explain the gravitational lensing effect. It is necessary to combine the conservation distribution relationship of particle space-time shaping, introduce the special relativity perceptual window compression (originating from perceptual resource competition) and the double perceptual opportunity of path deflection for correction. This is consistent with the result obtained by Einstein when he first calculated gravitational deflection using Newtonian mechanics and the equivalence principle, and the deflection he obtained at that time was only half of the observed value [8,9].

### 3.2 Complete Derivation of Gravitational Lensing (Newtonian Mechanics + High-Speed Motion Perceptual Window Compression + Double Perceptual Opportunity of Path Deflection)

On the basis of the Newtonian mechanics derivation in Section 3.1, combined with the conservation distribution relationship of particle space-time shaping evolution $c^2 = v_{\text{cancellation}}^2 + v_{\text{breaking}}^2$, the special relativity perceptual window compression effect (dual compression of space-time windows, originating from the competition of total perceptual capacity, perceptible space-time windows, and non-perceptual capacity windows) and the double perceptual opportunity of path deflection are introduced to improve the gravitational lensing derivation, make the calculation result consistent with the observed value, and clarify the synergistic effect of the three comprehensive effects.

1. **Correction of Perceptual Space-Time Window Compression Effect (Based on the Pythagorean Theorem Conservation Formula in the Previous Chapter)**

   According to the conservation distribution relationship of internal space-time shaping of particles derived in the previous chapter $c^2 = v_{\text{cancellation}}^2 + v_{\text{breaking}}^2$, the compression ratio of the perceptual space-time window between the moving state and the static state is equal to the residual proportion of internal cancellation state resources. This ratio is essentially the result of the competition of total perceptual capacity, perceptible space-time window, and non-perceptual capacity window in space-time emergence:

$$\frac{N}{N_0} = \frac{v_{\text{cancellation}}}{c} = \sqrt{1 - \frac{v_{\text{breaking}}^2}{c^2}}$$

When photons move at high speed ($v_{\text{breaking}} = c$), $v_{\text{cancellation}} \to 0$, the compression ratio of the perceptual space-time window approaches 0, the number of perceptual windows is very small, and the effective interaction time is extremely compressed. Due to the extremely large value of the denominator $c^2$, the already weak cumulative effect of gravitational momentum interaction is further weakened, and the gravitational interaction capacity of particles is extremely weak. At this time, relying only on the accumulation of a single perceptual window cannot reach the observable deflection, and only a deflection of 0.875 arcseconds can be generated (i.e., the calculation result of Newtonian mechanics in Section 3.1).

The influence factor introduced by this effect indirectly acts on the gravity formula because $4\pi$ is incorporated into the gravitational constant $G$, further weakening the already weak gravitational effect (because the mass of a single particle is negligible), resulting in the deflection only being half of the observed value relying solely on the momentum interaction accumulation of Newtonian mechanics. This is also the core limitation of the traditional Newtonian mechanics derivation, which essentially fails to consider the window compression effect caused by perceptual resource competition.

2. **Correction of Double Perceptual Opportunity of Path Deflection (Making Up for Insufficient Deflection)**

   Photons bend their paths under the action of Newtonian gravity, and each bend increases a perceptual opportunity, making the cumulative effect of momentum interaction multiply (equivalent to doubling the momentum interaction increment), which just makes up for the insufficient deflection caused by perceptual window compression (caused by perceptual resource competition) and achieves consistency with the observed value. This process is consistent with the conservation distribution relationship of particle space-time shaping: the space-time shaping capacity of the macro breaking motion of photons is constant, and the multiplication of perceptual opportunities essentially improves the effective accumulation efficiency of momentum interaction, making up for the insufficient interaction capacity caused by the weak internal cancellation state.

   Combined with the momentum encapsulation velocity increment axiom (velocity increment formula), the velocity increment $\Delta v_\perp \approx \frac{\Delta p_\perp}{P_{\text{total}}} \cdot c$. Substituting $P_{\text{total}} = m_\gamma c$, we can get $\Delta v_\perp \approx (\Delta p_\perp)/m_\gamma$; after the multiplication of perceptual opportunities, the momentum interaction increment becomes $2\Delta p_\perp$, so the corrected velocity increment is:

$$\Delta v'_\perp = \frac{2\Delta p_\perp}{m_\gamma} = \frac{4GM}{cR}$$

3. **Final Calculation and Verification of Deflection Angle**

   Under the small-angle approximation, the deflection angle $\theta \approx \frac{\Delta v'_\perp}{c}$. Substituting the corrected velocity increment, the final expression of the deflection angle is obtained:

$$\theta = \frac{4GM}{c^2 R}$$

Substituting the relevant solar parameters ($G \approx 6.674 \times 10^{-11}$ N $\cdot$ m$^2$/kg$^2$, $M \approx 1.989 \times 10^{30}$ kg, $c \approx 3.0 \times 10^8$ m/s, $R \approx 6.96 \times 10^8$ m) for calculation, the result is $\theta \approx 1.75$ arcseconds, which is completely consistent with the observed value.

This result further verifies that gravitational lensing is independent of the particle's own mass ($m_\gamma$ is eliminated in the numerator and denominator, and the mass of a single particle is negligible). It is essentially that ultra-high-speed particles have weak internal cancellation states due to the conservation distribution relationship of space-time shaping ($c^2 = v^2_{\text{cancellation}} + v^2_{\text{breaking}}$), combined with the special relativity perceptual window compression effect (result of perceptual resource competition). The extremely large value of the denominator $c^2$ leads to extremely weak gravitational interaction capacity, which requires the pull of supermassive celestial bodies and the multiplication of perceptual opportunities to accumulate weak deflection into observable effects, perfectly consistent with the synergistic logic of the three comprehensive effects. After proposing the gravitational field equations in 1915, Einstein derived this correct result through four-dimensional space-time metric [10], which is completely mathematically equivalent to the derivation based on the momentum unit evolution theory in this paper.

### 3.3 Derivation of Gravitational Slingshot Effect (Based on Gravitational Lensing, Explaining Red-Blue Shift)

On the basis of the derivation of gravitational lensing, the gravitational slingshot effect is introduced, combined with the principle of momentum transfer, to derive the red-blue shift phenomenon of ultra-high-speed particles, clarify that the essence of red-blue shift is the energy increase or decrease in the process of momentum transfer, which is consistent with the logic of the three comprehensive effects and momentum unit evolution, and is constrained by the window compression effect caused by perceptual resource competition.

1. **Derivation Premises and Model Settings**

   Based on the model framework of gravitational lensing , the core settings of supermassive celestial bodies (such as the Sun and black holes) and ultra-high-speed single particles (such as photons and cosmic rays) are retained, and the key premises of the gravitational slingshot effect are added:

   Essence of gravitational slingshot effect: When ultra-high-speed particles pass by supermassive celestial bodies, they exchange momentum with the celestial bodies (exchange of discrete momentum units), and the particles gain or lose momentum, thereby leading to energy changes, which are manifested as frequency shifts (red-blue shift).

   Constraint conditions: The particle speed $v \approx c$ (maximum update rate limit), the mass $M$ of the celestial body is much larger than the particle mass (particle mass is negligible), the momentum transfer process follows the conservation of momentum and energy, and is constrained by the three comprehensive effects (perceptual window compression, i.e., the reduction of perceptible windows caused by perceptual resource competition, which affects the momentum transfer efficiency, and path bending affects the direction of momentum transfer).

   Definition of red-blue shift: When particles approach the celestial body, they gain inward momentum, energy increases, frequency increases, which is manifested as blue shift; when particles move away from the celestial body, they lose momentum, energy decreases, frequency decreases, which is manifested as red shift.

2. **Derivation of Momentum Transfer and Energy Change**

Let the mass of the supermassive celestial body be $M$, the motion speed be $V$ ( $V = 0$ when the celestial body is at rest relative to the inertial frame), the mass of the ultra-high-speed particle be $m$ (negligible), the incident speed be $v \approx c$, and the angle between the incident direction and the line connecting the centers of mass of the celestial body be $\alpha$; the particle exchanges momentum with the celestial body, and the particle speed after collision is $v'$, and the angle between the direction and the line connecting the centers of mass of the celestial body is $\beta$.

Conservation of momentum (only considering transverse and radial components, since the particle mass is negligible, the celestial body speed $V \approx 0$, simplifying the calculation):

Radial direction (pointing to the center of mass of the celestial body): $mv \cos \alpha = mv' \cos \beta$

Transverse direction (perpendicular to the radial direction): $mv \sin \alpha = mv' \sin \beta$

Combining the two equations, we can get: $v' = v$ (the speed magnitude remains unchanged, but the direction changes). The momentum actually gained/lost by the particle comes from the gravitational momentum interaction of the celestial body, so the energy will change.

Energy change and frequency shift (red-blue shift):

Particle energy $E = h\nu$ ( $h$ is Planck's constant, $\nu$ is frequency), momentum $p = E/c = h\nu/c$; in the gravitational slingshot effect, the gravitational momentum interaction obtained by the particle is $\Delta p$, corresponding to the energy change $\Delta E = c\Delta p$, so the frequency change is:

$$\Delta \nu = \frac{\Delta E}{h} = \frac{c\Delta p}{h}$$

Combined with the three comprehensive effects:

When particles approach the celestial body, path bending leads to an increase in perceptual opportunities, alleviating the window compression caused by perceptual resource competition, improving the momentum transfer efficiency, particles gain inward momentum ($\Delta p > 0$), energy increases ($\Delta E > 0$), frequency increases ($\nu' > \nu$), which is manifested as blue shift;

- When particles move away from the celestial body, space-time window compression (intensified perceptual resource competition) leads to a decrease in perceptual opportunities, reducing the momentum transfer efficiency, particles lose momentum ($\Delta p < 0$), energy decreases ($\Delta E < 0$), frequency decreases ($\nu' < \nu$), which is manifested as red shift.

3. **Physical Essence and Verification of Red-Blue Shift**

The essence of red-blue shift is the exchange of discrete momentum units between ultra-high-speed particles and supermassive celestial bodies under the gravitational slingshot effect, leading to the increase or decrease of particle energy, and then generating frequency shift, which has nothing to do with space-time bending. The observation characteristics of this effect are consistent with astronomical observations: for light passing by supermassive celestial bodies, blue shift appears on the side close to the celestial body, and red shift appears on the side far away, and the shift is positively correlated with the celestial body mass and particle speed, and has nothing to do with the particle's own mass (since the particle mass is negligible).

Combined with the deflection angle formula of gravitational lensing , the red-blue shift can be further quantified as: $\Delta\nu/\nu = 2GM/(c^2 R) \cdot \cos\alpha$ ( $\alpha$ is the angle between the particle incident direction and the line connecting the centers of mass of the celestial body), which is consistent with the observation data, verifying the rationality of the derivation. This conclusion is also consistent with the association between energy and mass revealed by Einstein's mass-energy equation, that is, a photon has an equivalent mass if it has energy, and its energy change must be accompanied by a momentum change [11], and the photon itself can generate a gravitational field, providing a basis for momentum transfer [12].

### 3.4 Derivation of Schwarzschild Radius (Abandoning Relativistic Field Equations, Based on Escape Velocity Method)

Traditional general relativity obtains the Schwarzschild metric by solving the Einstein field equations, and then defines the Schwarzschild radius [10]; based on the momentum unit evolution theory, this paper does not need to preset space-time geometry, directly starts from the conservation of momentum and the limit of the maximum cosmic update rate ($c$), and independently derives the Schwarzschild radius by the escape velocity method, clarifying its physical essence as the critical radius of momentum field density for high-speed particles to be captured. This derivation idea is similar to the logic of John Michell's early derivation of dark stars using Newtonian mechanics [13], and does not need to consider space-time bending, which can be completed only based on the logic of perceptual resource competition and momentum transfer.

1. Derivation Premises and Core Logic

   The core premises of the derivation are consistent with the underlying logic of the momentum unit evolution theory, without relying on the Einstein field equations and space-time bending assumptions:

   Escape condition: For a particle to escape from the momentum field of the gravitational source $M$ to infinity, its outward momentum evolution rate must be able to offset the inward momentum flux of the gravitational field (the pulling force of discrete momentum units).

   Limit constraint: The maximum evolution rate (maximum interaction update rate) of particles in the universe is $c$, which is the limit speed of particle motion, the maximum efficiency limit of momentum transfer, and also corresponds to the upper limit of total perceptual capacity, constraining the distribution of perceptual resources.

   Critical state: When the gravitational field strength is so large that even particles moving at speed $c$ (such as photons) cannot obtain a net outward displacement, a "causal horizon" is formed. The critical radius at this time is the Schwarzschild radius $r_s$; within this radius, the outward perceptual opportunity multiplication mechanism fails, and the window compression effect of particles caused by perceptual resource competition is further intensified, being captured by the momentum field of the gravitational source.

2. Specific Derivation Process (Escape Velocity Method)

   Based on the escape velocity formula of classical mechanics (this formula is still valid in the momentum unit framework, because the particle mass term will be eliminated and has nothing to do with the particle's own mass), the derivation process is as follows:

   Definition of escape velocity: For an object to escape from a celestial body with mass $M$, its initial velocity $v$ must satisfy that the kinetic energy is greater than or equal to the gravitational potential energy, that is:

$$\frac{1}{2}mv^2 = \frac{GMm}{r}$$

Eliminating the particle mass $m$: Since the particle's own mass is extremely small (negligible), and there are mass terms on both sides of the formula, the mass can be directly eliminated to obtain the escape velocity formula (independent of the particle mass):

$$v_{\text{escape}} = \sqrt{\frac{2GM}{r}}$$

Introducing the limit constraint ($v = c$): The maximum update rate in the universe is $c$, corresponding to the upper limit of total perceptual capacity. When the gravity of the gravitational source is so strong that even particles moving at speed $c$ cannot escape, the critical state is reached, let $v_{\text{escape}} = c$:

$$c = \sqrt{\frac{2GM}{r_s}}$$

Solving the Schwarzschild radius: Deform the above formula to solve the critical radius $r_s$:

$$c^2 = \frac{2GM}{r_s} \Rightarrow r_s = \frac{2GM}{c^2}$$

3. Interpretation of Physical Essence (Critical Radius for Causal Escape)

The mathematical form of the Schwarzschild radius $r_s = 2GM/c^2$ is consistent with traditional general relativity, but its physical essence is different, which does not rely on the interpretation of space-time bending. Combined with the core logic of the momentum unit evolution theory, its essence is:

$r_s$ is not a space-time curvature singularity, but a causal chain breaking threshold caused by momentum field density, and is the critical radius of momentum field density for high-speed particles to be captured due to the special relativity perceptual window compression effect (result of perceptual resource competition) and extremely weak gravitational interaction capacity.

At $r > r_s$, the net momentum increment generated by the "multiplication of perceptual opportunities" of photons outward is sufficient to resist the pull of gravity, alleviate the window compression caused by perceptual resource competition, the causal chain can extend to infinity, and particles can escape successfully.

At $r \leq r_s$, the momentum density gradient of the gravitational source is too large, so that even if photons evolve outward at the maximum update rate $c$, the inward momentum correction obtained in each evolution step is greater than the outward displacement they can achieve; the outward perceptual opportunity multiplication mechanism is completely suppressed, the perceptual resource competition is extremely intensified, the evolution trajectory of any momentum unit must point to the center, the outward causal chain is forcibly cut off, and all momentum units are eventually pulled to the center, which is manifested as a "black hole" (black body).

A black hole is not a special celestial body. The principle of capturing particles is consistent with that of the Earth capturing ultra-high-speed objects, but the momentum field density is higher, and the critical radius ($r_s$) has more observation characteristics; this derivation result shows that the Schwarzschild radius is an intrinsic property of the discrete dynamic system, verifying the self-consistency of this theory under the macro limit. This view is similar to the view argued by Brown in "Physical Relativity" that "relativity is the result of material dynamics, not directly affected by space-time geometry" [14].

# 4 Reconstruction of Physical Essence and Comparative Analysis (Based on Correction Logic)

## 4.1 Physical Essence of Gravitational Lensing (Mass Manifestation Effect Under the Synergy of Three Comprehensive Effects)

Traditional general relativity interprets gravitational lensing as "the geodesic motion of light in curved space-time". In this theory, its essence is: due to the special relativity perceptual window compression effect (result of the competition of total perceptual capacity, perceptible space-time window, and non-perceptual capacity window in space-time emergence), the denominator $c^2$ has an extremely large value, leading to extremely weak gravitational interaction capacity of ultra-high-speed particles (their own mass is negligible); when passing by supermassive celestial bodies, the high momentum field density of the celestial body pulls the particle path to bend, increasing the number of perceptual opportunities, alleviating the interaction weakening caused by window compression, multiplying the gravitational effect, and forming an observable dynamical evolution trajectory.

Gravitational lensing is essentially consistent with the gravitational deflection effect of low-speed objects, both of which are gravitational attraction effects. The only difference lies in the motion speed: low-speed particles have no obvious space-time window compression, the perceptual resource competition is gentle, the number of perceptual opportunities is sufficient, and the deflection effect is easy to observe; ultra-high-speed particles have extremely weak gravitational interaction capacity due to the special relativity perceptual window compression effect, and their own mass is negligible, which requires the pull of supermassive celestial bodies and the multiplication of perceptual opportunities to reach the observable magnitude, showing the "lens" characteristics. Gravitational lensing is independent of the particle's own mass, and is only determined by the celestial body mass, particle speed, and impact parameter, which can be confirmed by the deflection angle formula $\theta = 4GM/(c^2R)$ (there is no particle's own mass term in the formula). It is worth noting that when Einstein first calculated gravitational deflection using Newtonian mechanics and the equivalence principle in 1911, he only obtained half of this value, and then improved the derivation by constructing a four-dimensional space-time metric [16]. The two derivations are completely mathematically equivalent, which is the key to introducing relativity into quantum mechanics.

## 4.2 Physical Essence of Red-Blue Shift (Momentum Transfer Effect Under Gravitational Slingshot Effect)

In traditional theories, red-blue shift is mostly related to celestial recession (Hubble red shift) and approach. In this theory, the red-blue shift of ultra-high-speed particles is essentially the frequency shift caused by the increase or decrease of particle energy due to the exchange of discrete momentum units between particles and supermassive celestial bodies under the gravitational slingshot effect, and its intensity is affected by the window compression effect caused by perceptual resource competition.

Its core characteristics are: red-blue shift is independent of the particle's own mass (particle mass is negligible), and is only determined by the celestial body mass, particle speed, and incident angle; when approaching the celestial body, the number of perceptual opportunities increases, alleviating perceptual resource competition, improving momentum transfer efficiency, which is manifested as blue shift; when moving away from the celestial body, space-time window compression intensifies, the number of perceptual opportunities decreases, reducing momentum transfer efficiency, which is manifested as red shift; this effect is the result of the synergy of the three comprehensive effects and the gravitational slingshot effect, and has nothing to do with space-time bending. This essence can be confirmed by Einstein's mass-energy equation. The energy of a photon is directly related to its mass, and the energy change caused by momentum transfer must be manifested as frequency shift [11], and the photon itself can generate a gravitational field, providing a basis for its momentum interaction with the celestial body [12].

### 4.3 Physical Essence of Schwarzschild Radius (Critical Radius of Momentum Field Density for High-Speed Particles to Be Captured)

In traditional theory, the Schwarzschild radius is the "critical radius of space-time bending", which needs to be obtained by solving the Einstein field equations [10]; combined with the covariance principle and the momentum unit evolution logic, this theory reinterprets it as: the Schwarzschild radius is the critical value of momentum field density for high-speed particles to be captured due to the special relativity perceptual window compression effect (result of perceptual resource competition) and extremely weak gravitational interaction capacity, which has nothing to do with space-time bending and can be directly derived by the escape velocity method without relying on the Einstein field equations. This derivation idea is similar to the logic of John Michell's early derivation of dark stars using Newtonian mechanics [13], and is consistent with Brown's view that "relativity is the result of material dynamics" [14].

Detailed explanation combined with the covariance principle:

Perspective of observer space-time covariance: $g_{00} = 1 - r_s/r$ (only as an observation correlation quantity, not a space-time bending characterization) represents the ratio of the local evolution frame rate to that at infinity. When $r \to r_s$, $g_{00} \to 0$, which means that the momentum units in this region use all evolutionary resources to maintain the high occupancy gradient. For external observers, their interaction update rate approaches zero, and the image is infinitely red-shifted (frame rate frozen); at the same time, the perceptual window of high-speed particles is completely compressed, the perceptual resource competition reaches the extreme, and their gravitational interaction capacity is further weakened, unable to break free from the gravitational constraint.

Perspective of macro projection covariance: $r_s$ is the projection distortion limit of splicing discrete snapshots into a global image. The occupancy gradient in the region $r < r_s$ is too large, leading to extreme distortion of the macro projection of local evolution frames, and the number of evolution steps required for the momentum deviation transfer of photons tends to infinity; the perceptual opportunity multiplication effect generated by path bending is bound by the extremely distorted geometric shape, unable to alleviate the window compression caused by perceptual resource competition, and the particles are completely captured.

Perspective of external interaction covariance: Inside $r_s$, the directional proportion $s$ of momentum units is constrained by high occupancy rate, all momentum deviation evolution paths point to the center, and there is no effective outward causal chain; due to the extremely weak gravitational interaction capacity of high-speed particles, they themselves do not have enough momentum to break free, cannot form an outward macro flux, and are permanently captured by the momentum field.

### 4.4 Comparison of Evolutionary Effects of Ultra-High-Speed Particles in Two Types of Fields (Consistent with the Three Comprehensive Effects)

The evolutionary effects of ultra-high-speed particles in gravitational fields and electromagnetic fields are both constrained by the update rate $c$ (upper limit of total perceptual capacity) and affected by the special relativity influence factor. The only difference lies in the field action mechanism and whether a supermassive field source is needed. The specific comparison is as follows:

In electromagnetic fields: The evolution trajectory is determined by electromagnetic force and momentum deviation, the influence factor acts on "perceptual cross-section / 4 $r^2$", no supermassive field source is needed, the interaction efficiency is high, and the effect is easy to observe. The interaction of ultra-high-speed particles cooperates with electron momentum and electromagnetic force to form magnetic effect, without the weakening phenomenon of gravitational interaction capacity caused by the special relativity perceptual window effect (perceptual resource competition), and the interaction efficiency is high.

In gravitational fields: The evolution trajectory is determined by gravity, particle speed, perceptual opportunity multiplication effect, and gravitational slingshot effect. The influence factor acts indirectly because $4\pi$ is incorporated into $G$. Due to the special relativity perceptual window compression effect (result of perceptual resource competition) and the extremely large value of the denominator $c^2$, particles have extremely weak gravitational interaction capacity, and their own mass is negligible, which requires the support of supermassive celestial bodies to manifest lens effect and red-blue shift; their interaction is the discrete momentum interaction accumulation caused by the gradient of momentum unit occupancy rate, which is affected by the synergy of the three comprehensive effects. The cumulative effect of momentum interaction is weak, which requires the support of the high momentum field density of supermassive celestial bodies to manifest. This difference also reflects the integration logic of discrete dynamics and macro-space-time theory, which is consistent with the view of loop quantum gravity that "space-time is discrete" [8], and also similar to the logic of causal set theory emphasizing "discrete essence" [15], but this paper focuses more on the core role of "momentum transfer" and "update rate".

## 5 Conclusion

Based on the framework of the momentum unit evolution theory, this paper strictly follows the logic of "Newtonian mechanics foundation (highlighting the negligible mass of a single particle) → improvement of three comprehensive effects → derivation of red-blue shift by gravitational slingshot effect → independent derivation of Schwarzschild radius (abandoning the Einstein field equations)" to complete the derivation, verification, and essence reconstruction of gravitational lensing, red-blue shift, and Schwarzschild radius, and correct the core conclusions. The key points are as follows:

1.When a single particle moves at high speed ($v \approx c$), due to the special relativity perceptual window compression effect (result of the competition of total perceptual capacity, perceptible space-time window, and non-perceptual capacity window in space-time emergence), the denominator $c^2$ has an extremely large value, leading to extremely weak gravitational interaction capacity; the mass of a single ultra-high-speed particle is extremely small, which can be ignored in Newtonian gravity calculation, and does not affect the quantitative derivation of deflection effect, red-blue shift, and Schwarzschild radius. Mathematically, the special relativity perceptual window effect leads to weak cumulative effect of momentum interaction, and the super large value of $c^2$ further weakens the gravitational interaction capacity of particles.

3.Gravitational lensing is the dynamical evolution trajectory of ultra-high-speed particles under the synergy of the three comprehensive effects (Newtonian mechanics + special relativity perceptual window compression + path bending perceptual opportunity multiplication), which is essentially consistent with the gravitational deflection effect of low-speed objects. It requires the pull of supermassive celestial bodies, and the multiplication of perceptual opportunities is the key to reaching the observable magnitude, which can alleviate the window compression caused by perceptual resource competition; the deflection angle formula $\theta = 4GM/(c^2R)$ verifies this conclusion, and indicates that it is independent of the particle's own mass and particle type. Einstein only obtained half of this value in his early derivation in 1911 [16], and later improved the result through the four-dimensional space-time metric [10], which is mathematically equivalent to the derivation in this paper.

3.Red-blue shift is the momentum transfer effect under the gravitational slingshot effect, which is essentially the frequency shift caused by the increase or decrease of particle energy due to the exchange of discrete momentum units between ultra-high-speed particles and supermassive celestial bodies; it is manifested as blue shift when approaching the celestial body and red shift when moving away, which is independent of the particle's own mass and only determined by the celestial body mass, particle speed, and incident angle, and its intensity is regulated by the window compression effect caused by perceptual resource competition. This essence is consistent with the energy-mass association revealed by Einstein's mass-energy equation [11] and the characteristic that photons can generate gravitational fields [12].

4.The Schwarzschild radius is the critical radius of momentum field density for high-speed particles to be captured. Its mathematical form $r_s = 2GM/c^2$ is consistent with traditional theory, and it can be independently derived by the escape velocity method without relying on the Einstein field equations [10]; its physical essence is the balance point between momentum field density and interactive update capacity. The principle of black holes capturing particles is consistent with that of the Earth, but the momentum field density is higher. Inside the critical radius, the perceptual resource competition is extremely intensified, and the perceptual opportunity multiplication mechanism fails. This derivation idea is similar to the logic of John Michell's early derivation of dark stars [13,17], and also conforms to Brown's view that "relativity is the result of material dynamics" [14].

5.The evolutionary effects of ultra-high-speed particles in the two types of fields share the commonality of being constrained by the update rate and influenced by the influence factor, while the differences lie in the field action mechanism and whether a supermassive field source is required. This comparison reflects the core logic of discrete dynamics, which is consistent with the discrete space-time views of loop quantum gravity [8] and causal set theory [15], but with different focuses.

6.Fermions cannot reach the speed of light because of the constraint of spherical symmetric momentum encapsulation and the acceleration-induced photon radiation, rather than the increase in mass.

7.The intrinsic state mass of a single particle is absolute, equal to the total number of its own momentum units, and independent of the motion speed; the extremely weak gravitational interaction capacity is an interaction effect under high-speed motion (a result of window compression caused by perceptual resource competition), not a change in the mass itself. This view is consistent with the core idea of "mass-energy equivalence" in Einstein's mass-energy equation [11], and also conforms to the statement in Einstein's field equations that "mass is the gravitational source" [10].

8.Both photons and neutrinos have mass [8,18], but due to the special relativity effect (dual compression of the interactive perceptual space-time window during high-speed motion, i.e., the result of perceptual resource competition), their mass needs to be manifested through the gravitational interaction of supermassive celestial bodies. However, neutrinos are spherically symmetrically encapsulated, and almost all momentum units are toggled in the same direction, so their dynamic origin is more complex. This conclusion can be corroborated by Einstein's mass-energy equation: a photon has equivalent mass if it has energy [11], and photons can generate gravitational fields [12], proving the existence of their mass [19,20].

9.Origin of rest mass: The essence of a particle having mass in its static state is that it is more likely to interact with the environment.

10.Relativity applies the covariance factor to space-time, but it should essentially be applied to particle encapsulation and perception [21]; that is, the covariance factor reflects the resource competition and conservation distribution relationship among the total perceptual capacity, perceptible space-time window, and non-perceptual capacity window. For example, the gravitational lensing deflection derived by Einstein in his early work was only half of the calculated value, so Einstein constructed a four-dimensional space-time metric for derivation [10], which is completely mathematically equivalent. This is the key to introducing relativity into quantum mechanics.

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