

# Unified Cosmic Mechanics Evolution Theory (XII) : Dynamic Compatibility Verification of the Particle Encapsulation Velocity Increase Equation

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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 twelfth 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 only dynamic physical reality of the cosmic system: the evolutionary carrier is the momentum unit  $m_0$ , the evolution rate is the speed of light  $c$ , and the total number of momentum units is conserved. From this emerges the unified dynamic relationship of motion potential = resistance potential = inertia potential = thrust potential, and energy = force = momentum =  $mv$  (upper limit  $mc$ ).

Thus, the velocity increase equation is directly established:

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

, and this paper conducts multi-scenario dynamic compatibility verification on it.

**The essence of classical mechanics:** Traditional equations (e.g.,  $F = ma$ ,  $\frac{1}{2}mv^2$ ) are integral statistical equations depending on specific interaction paths, not descriptions of the inertial state itself.

**The essence of relativity:** Relativity statistically describes the dynamic integral process of matter in a changing environment. The square term in  $E = mc^2$  expresses space-time state shaping capability, not the dynamic eigenstate [1].

**The essence of the velocity increase equation:** This equation restores the underlying dynamic logic of all mechanical statistics, emerging mass, momentum, energy, velocity, space-time, and resultant force. It is an inertial maintenance equation that can be directly associated with the dynamic resultant force equation:  $F_{\text{total}} \propto P_{\text{total}} \cdot v_{\text{total}}$ .

**Keywords:** Newton’s First Law; Law of Inertia; Inertial State Maintenance; Resultant Force Effect; Essence of Classical Mechanics; Essence of Relativity; Unified Mechanics

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## 1 Introduction

### 1.1 Integral Logic of Classical Mechanics: Interaction Integration in a Stable Background

Classical mechanics regards force as an independent entity. The integration of force, energy, and momentum in classical mechanics is essentially the integration of vector superposition of momentum units, but the integration of classical mechanics cannot be simply described by a static field. Its essence has the following comprehensive influences: 1. Dependence on radial motion integration; 2. Dependence on mutual stable motion integration; 3. Dependence on the final perceptual cross-section

$$\frac{1}{4\pi r^2}$$

Therefore, the essence of classical mechanics is that the interaction process depends on conditions that can stably form predictable integration. For example, the radial attractive force motion integration process

must be uniform acceleration integration; for coordinated motion, there is still no need to introduce relativistic change integration; and the integration that can stably form the perceptual cross-section can completely ignore the intermediate interaction process. For example, no matter how a stone contacts the ground, the interaction between them is constant at

$$\frac{1}{4\pi r^2}$$

## 1.2 Integral Logic of Relativity: Interaction Integration Under Dynamic Coupling

Relativity further dynamically couples the environment with the material state. In high-speed or strong gravitational scenarios, the Lorentz factor  $\gamma$  makes the effective mass, time scale, and space scale of particles dynamically change with their own states (velocity  $v$ , position  $r$ ). The motion equations (such as

$$\frac{d(\gamma m_0 v)}{dt} = q(E + v \times B)$$

in relativistic mechanics or the geodesic equation in general relativity) are essentially path integrals of this dynamically coupled field. It should be noted that the mass-energy equation of relativity is

$$E = mc^2$$

which is essentially a space-time state shaping equation, which statistically describes the total potential of momentum units inside particles to shape space-time, rather than the intrinsic dynamic state of particles — the intrinsic state is always

$$E = mc$$

[1]. Therefore, the covariance of relativity is a statistical projection effect, and what is counted during the interaction is the change in space-time shaping capability, rather than the covariance of the intrinsic state. Its core feature is: the interaction intensity is a dynamic statistical function of the system state and the background field state, and motion is a dynamic integral process of the statistical field [2][3].

## 2 Underlying Logic of This Evolution Theory: Momentum Units and Resource Conservation

### 2.1 Physical Reality

Combined with the core conclusions of multiple previous chapters in the framework of this evolution theory, the premise for the stable evolution of the universe is that it is a standard quantized three-dimensional orthogonal degree-of-freedom state evolution system, and the system must have three invariant conserved quantities:

- Representational quantity  $m_0$  — as a physical entity (momentum unit)
- Same driving quantity  $c$  — intrinsic evolution rate of a single unit (speed of light)
- Evolution rule set  $R$  — intrinsic interaction protocol of the system

At the same time, combined with experimental characteristics such as the traditional mass-energy equation, Compton scattering [4], bremsstrahlung, electron eEDM spherical symmetry [5][6], wave-particle duality, magnetic moment, and spin, it can be proved that all particles have internal structures

[7][8], and are encapsulated by a number of momentum units formed by superimposing  $m_0 \cdot c$  at specific angles [9].

Based on the above pre-derivations, this paper proposes a new underlying physical reality: the core state evolution of the cosmic system is composed of the evolutionary carrier (momentum unit  $m_0$ ), the intrinsic evolution rate of a single unit (speed of light  $c$ ), vector superposition capability, and the conservation of the total number of momentum units. Under this theoretical system, various core dynamic relationships and physical laws can be uniformly restored and reconstructed:

## 2.2 Equivalence Principle

Motion potential, resistance potential, thrust potential, and inertia potential are unified into the same dynamic relationship

$$mv$$

breaking the cognition that various potential energies are independent of each other in traditional mechanics, and realizing the unified representation of potential energy.

## 2.3 Vector Resultant Velocity and Resultant Force

The vector superposition law of classical mechanics is restored to the macroscopic emergence of vector superposition of momentum units — the motion vector of a macroscopic object is essentially the overall presentation of the vector superposition of all momentum units inside it.

## 2.4 The Essence of Force

The essence of force is reconstructed as the transfer of momentum units during the interaction process, which is specifically divided into "additive force" (unidirectional transfer of momentum units) and "multiplicative force" (bidirectional exchange of momentum units). Force itself no longer exists as an independent physical entity, but emerges from the motion trend of momentum unit exchange between particles [10].

## 2.5 Synchronous Emergence of Time and Space

- General relativistic effect: Originates from the conservation of the internal evolution capability of particles in the motion state, which is manifested as the Pythagorean theorem conservation relationship in the space-time state shaping capability, and the interaction process is integrated based on this;
- Special relativistic effect: Originates from the compression of the perceptual space-time window when particles move, forming an isomorphic Pythagorean theorem conservation relationship between perceptual, non-perceptual, and total perceptual capabilities, and the interaction process is also integrated based on this logic.

Although both derive the same mathematical form of the Lorentz factor

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

there are fundamental differences in their physical essence [2].

## 2.6 Light-Speed Evolution Emerges All Dynamic Dimensions

Based on the above derivations, the core dynamic logic of the cosmic system can be summarized as: the speed of light  $c$  is the only dynamic driving force, and the momentum unit  $m_0c$  is the only physical resource. Momentum, energy, force, inertia, velocity, time, and space are all projections or statistical manifestations of the light-speed evolution capability from different perspectives. All evolutions are causal interactions and distributions based on evolution rules and resource conservation relationships:

- In the eigenstate, energy = momentum = force, and the three are essentially the same:

$$E = p = F = m \cdot c$$

- In macroscopic statistics,

$$E = mc^2$$

is a space-time state shaping equation [1], and

$$F = ma$$

is the integral statistics of the interaction process [12];

- The dynamic response is uniformly described by the velocity increase equation

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

— the velocity increment is essentially the sampling of the speed of light by the proportion of momentum redistribution.

Therefore, there are no "independent" force, energy, or inertia entities in the universe; what exist are only momentum units evolving at the speed of light, their encapsulation, interaction, and statistics [9][13].

## 3 Velocity Increase Equation: The Core of Non-Integral State Function

### 3.1

Based on the above physical reality and dynamic reconstruction, this paper establishes the velocity increase equation:

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

where  $\Delta p$  is the momentum increment and  $P_{\text{eff}}$  is the effective inertial momentum. Different from traditional theories, this equation is not a process integral equation, but an instantaneous algebraic relationship (state function) — it describes the instantaneous mapping between the intrinsic momentum resource allocation of the system  $(\Delta p, P_{\text{eff}})$  and its macroscopic velocity response  $(\Delta v)$ , without the need for integration over time or space. It is the causal inertial state jointly formed by the interaction of particles A and B. The "static background integration" and "dynamic coupling integration" in traditional theories are restored here as: under specific geometric conditions or motion states, the macroscopic statistical manifestation of the underlying momentum unit exchange events [15].

To verify the rationality and universality of this equation, this paper starts from multiple typical physical scenarios such as gravitational scenarios, electromagnetic interactions (low-speed and high-speed), and quantum-scale interactions, combines experimental facts and theoretical derivations, clarifies the expression form of the equation under different conditions and its compatibility with classical mechanics and relativity, and establishes the unified connection between micro force sources and macro motion.

### 3.2 Definition and Correlation of Core Physical Quantities

Based on the momentum unit evolution framework, the corresponding relationship between the core physical quantities in this theory and traditional theories is clarified, laying a foundation for subsequent verification. The intrinsic form, traditional form, and numerical conversion relationship of each physical quantity are shown in the following table:

Physical Quantity	Intrinsic Form in This Framework	Traditional Form	Numerical Conversion Relationship	Conversion Factor
Momentum	$P = sNm_0c$	$p = mv$	$P = p$	1
Energy	$E = Nm_0c$	$E = mc^2$	$E_{(\text{traditional})} = E_{(\text{intrinsic})} \cdot c$	$c$
Force	$F = (\Delta s/\Delta t)Nm_0c$	$F = ma$	Numerically equal to $F = ma$ in macroscopic statistics	1

**Note:**  $s$  is the vector direction factor of the momentum unit,  $N$  is the total number of momentum units,  $m_0$  is the mass of a single momentum unit,  $c$  is the speed of light,  $\Delta s$  is the vector direction change, and  $\Delta t$  is the time increment.

## 4 Multi-Scenario Verification of the Velocity Increase Equation

### 4.1 Gravitational Scenario Verification: Geometric Projection and Newtonian Limit Adaptation

The core goal of gravitational scenario verification is to prove that the velocity increase equation can naturally degenerate into Newton's law of universal gravitation under weak field and low-speed conditions, reflecting the compatibility of the theory [12].

For a particle with rest mass  $m_0$  at a distance  $r$  from the gravitational source  $M$ , the exchange of momentum units based on spherical geometry is the core source of momentum increment. In three-dimensional flat space, the momentum flow emitted by the source particle is uniformly distributed on the spherical surface, and the effective perceptual solid angle of the receiving particle is  $\Omega = A/r^2$  (where  $A$  is the effective cross-section). Therefore, the momentum increment received per unit time naturally follows the inverse square law, i.e.,

$$\Delta p \propto \frac{1}{r^2} \cdot \Delta t$$

Letting the proportional coefficient be  $GMm_0$ , the classical form

$$\Delta p = \frac{G(Mm_0)}{r^2} \cdot \Delta t$$

can be obtained. This inverse square law originates from the geometric divergence characteristics of three-dimensional space [13].

Under low-speed ( $v \ll c$ ) and weak field conditions, the internal momentum distribution of the particle is approximately spherically symmetric, the Lorentz factor  $\gamma \approx 1$ , and the effective inertial momentum  $P_{\text{eff}} \approx m_0 c$ . Substituting  $\Delta p$  into the velocity increase equation

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

it can be derived that

$$\Delta v \approx \frac{G(Mm_0)/r^2 \cdot \Delta t}{m_0 c} \cdot c = \frac{GM}{r^2} \cdot \Delta t$$

and then the acceleration

$$a = \frac{\Delta v}{\Delta t} = \frac{GM}{r^2}$$

which is completely consistent with Newton's law of universal gravitation [12].

In the gravitational lensing phenomenon, the essence of a photon passing through the solar gravitational field is passing through a region of uneven momentum density. There is no need to rely on time integration, only the immediate response of the spatial gradient needs to be considered. The momentum density difference (transverse gradient) felt by the left and right sides of the photon, and the momentum vector refraction effect (radial gradient coupling) when the photon passes through the radial density contour line, the integral contributions of the two are equal in the spherically symmetric field, and the total deflection angle

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

This derivation process can be reasonably supported by the response law of the velocity increase equation to the momentum increment, reflecting the applicability of the equation in the gravitational scenario [13].

## 4.2 Electromagnetic Interaction Scenario Verification: Adaptation to Low-Speed and High-Speed Conditions

### 1. Low-Speed Electromagnetic Deflection Verification

In a low-speed electromagnetic environment (electron kinetic energy  $\ll m_e c^2$ , velocity  $v \ll c$ ), the velocity increase equation can directly degenerate into the form of Newtonian mechanics, which is highly consistent with experimental data.

In the cathode ray tube (CRT) electron beam deflection experiment, electrons obtain momentum  $p$  after being accelerated by voltage  $U$ , and deflect through a transverse electric field  $E$ , and the classical deflection formula holds. At this time,  $P_{\text{eff}} \approx m_0 c$ . Substituting into the velocity increase equation, we get

$$\Delta v = \frac{\Delta p}{m_0 c} \cdot c = \frac{\Delta p}{m_0}$$

which is consistent with Newtonian mechanics. Thomson (1897) used such experiments to measure the electron specific charge  $e/m$ , and the results are consistent with the equation prediction [14].

In the experiment of circular motion of electrons in a uniform magnetic field, the cyclotron radius

$$r = \frac{mv}{eB}$$

The momentum change originates from the magnetic field effect,

$$\Delta p = eB \cdot \Delta t \cdot v_{\perp}$$

Substituting into the velocity increase equation also gives

$$\Delta v = \frac{\Delta p}{m_0}$$

directly deriving the centripetal acceleration under Newtonian mechanics, which is completely consistent with the radii measured by experiments such as magnetrons and electron microscope electromagnetic focusing [14].

## 2. High-Speed Electromagnetic Deflection and Acceleration Verification

When the electron velocity is close to the speed of light ( $v \sim 0.9c$  and above,  $\gamma > 1$ ), the effective inertial momentum

$$P_{\text{eff}} = \gamma m_0 c$$

needs to be substituted into the velocity increase equation, and the equation can naturally introduce the  $\gamma$  factor, which is consistent with high-speed experimental data [16].

In high-speed electron transverse electric field deflection experiments (such as electrostatic analyzers, accelerators), the measured deflection decreases with the increase of energy ( $\gamma$  increases), which is consistent with the relationship  $p = \gamma m_0 v$ . After substituting  $P_{\text{eff}} = \gamma m_0 c$ , the velocity increase equation becomes

$$\Delta v = \frac{\Delta p}{\gamma m_0}$$

The transverse momentum increment  $\Delta p$  comes from the electric field force  $eE\Delta t$ , and the velocity increment is suppressed by  $1/\gamma$ , leading to reduced deflection, which is consistent with the experimental results [16].

In the synchrotron experiment, the magnetic field required to maintain the circular motion of electrons needs to increase with the increase of energy, which is consistent with the relationship  $p = \gamma m_0 v$ . Using the velocity increase equation, combined with the transverse momentum increment

$$\Delta p = eB \cdot \Delta t \cdot v_{\perp}$$

in the magnetic field, the relativistic cyclotron radius formula

$$r = \frac{p}{eB}$$

can be derived, which is consistent with the experimental data of CERN electron synchrotrons. In addition, in the momentum measurement experiment of high-energy muons ( $\gamma \sim 10$  order of magnitude,  $v \approx c$ ) in the magnetic field, the measured correlation between momentum and velocity is consistent with the prediction of the velocity increase equation corrected by  $\gamma$  [16].

## 3. Electromagnetic Acceleration and Light-Speed Limit Verification

In the electron linear accelerator (LINAC), electrons are accelerated from rest to near the speed of light. After applying a high-frequency electric field, they obtain a fixed  $\Delta p$  each time they pass through the acceleration cavity, but the velocity increment  $\Delta v$  decreases with the increase of energy. The expectation of "equal  $\Delta p$  and equal  $\Delta v$ " in classical theory is not valid. Substituting into the velocity increase equation, when  $\gamma$  is large,

$$\Delta v = \frac{\Delta p}{\gamma m_0}$$

$\Delta v$  decreases significantly, and the velocity approaches  $c$  without exceeding it, which is consistent with the experimental data of linear accelerators such as SLAC [16].

In the speed increase measurement experiment of synchrotrons, the relationship between momentum increment and velocity increment of particles from low speed to near  $c$  is described by the velocity increase equation

$$\Delta v = \frac{\Delta p}{\sqrt{(m_0 c)^2 + p^2}} \cdot c$$

All experimental data points fall on the curve corresponding to the equation without additional assumptions, and naturally reflect the light-speed limit constraint, that is,

$$\Delta v = \frac{\Delta p}{P_{\text{eff}}} \cdot c \leq c$$

When  $\Delta p = P_{\text{eff}}$ ,

$$\Delta v = c$$

[16].

### 4.3 Quantum-Scale Interaction Verification

$$\frac{\alpha \hbar c}{r^2}$$

(where  $\alpha$  is the fine-structure constant,  $c$  is the speed of light,  $\hbar$  is Planck's constant, and  $r$  is the characteristic radius/distance) is a micro basic force generated based on the exchange of quantized momentum units, which has a clear internal correlation with the velocity increase equation. The unification of the two can be established through dimensional analysis and physical essence derivation [9].

From the perspective of dimensional analysis,  $\alpha$  is a dimensionless momentum unit exchange efficiency, the dimension of  $\hbar c$  is  $[ML^3T^{-2}]$ , and the dimension of  $\alpha \hbar c / r^2$  is  $[MLT^{-2}]$ , that is, the Therefore, the micro basic force can be defined as:

$$F_{\text{quantum}} \propto \frac{\alpha \hbar c}{r^2}$$

which describes the basic driving force generated by the exchange of momentum units between two particles at distance  $r$  [9].

The source of the momentum increment  $\Delta p$  is directly related to this micro force. Within the characteristic interaction time  $\Delta t \approx r/c$  (determined by the light passing through the characteristic scale  $r$ ),

$$\Delta p = F \cdot \Delta t = \frac{\alpha \hbar c}{r^2} \cdot \frac{r}{c} = \frac{\alpha \hbar}{r}$$

This result is consistent with the de Broglie relationship

$$p = \frac{\hbar}{\lambda}$$

reflecting the quantum geometric essence of the momentum increment. Substituting

$$\Delta p = \frac{\alpha \hbar}{r}$$

into the velocity increase equation, we get

$$\Delta v = \frac{\alpha \hbar c}{r P_{\text{eff}}}$$

Under the ground state or low-speed approximation,  $P_{\text{eff}} \approx m_0 c$ . Combined with the electron Compton wavelength

$$\lambda_c = \frac{\hbar}{m_0 c}$$

it can be derived that

$$\Delta v \approx \frac{\alpha c \lambda_c}{r}$$

The left side  $\Delta v$  is the velocity increment, and the right side  $\alpha c$  is the speed of light modulated by the fine-structure constant.  $\lambda_c/r$  is the geometric ratio between the quantum scale and the macro distance, clarifying the micro origin of the classical electromagnetic acceleration [4].

When particles move at high speed, the perceptual window undergoes Lorentz contraction, the longitudinal interaction fails, and the transverse interaction is retained and manifests as magnetic force. The magnitude of the magnetic force

$$F_B \propto \frac{v}{c} \cdot F_E = \frac{\alpha v \hbar}{r^2}$$

where  $c$  is replaced by  $v$ , explaining the dependence of the magnetic force on velocity, and also reflecting the degradation mechanism of the velocity increase equation under high-speed conditions —  $P_{\text{eff}}$  increases to  $\gamma m_0 c$ ,  $\Delta v$  is suppressed by  $1/\gamma$ , the longitudinal interaction fails, and the transverse interaction manifests as magnetic force [16].

#### 4.4 New Scenario Verification: Multi-Dimensional Adaptability Expansion

To further verify the universality and rigor of the velocity increase equation

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

the verification of 6 typical physical scenarios is supplemented. All scenarios have undergone strict mathematical derivation and logical verification, and can successfully reproduce the standard relativistic mechanics results. They cleverly rely on the definition of the velocity increase equation to improve the multi-dimensional adaptability of the theory. The specific verification process is as follows.

##### 1. Compton Scattering Verification

Compton scattering is a typical "instantaneous momentum transfer" collision process, which directly corresponds to the core definition of  $\Delta p$  in the velocity increase equation. Its verification results can prove that the equation has good self-consistency with the integral results of continuous force (relativistic dynamics) in the scenario of discrete momentum exchange [4].

The core derivation of this verification relies on the Lorentz factor identity

$$\gamma = \sqrt{1 + \left(\frac{p}{mc}\right)^2}$$

Combined with the basic form of the velocity increase equation

$$v = \frac{p}{\gamma m}$$

substituting  $\gamma$  into it can be derived as:

$$v = \frac{p}{m\sqrt{1 + (p/mc)^2}} = \frac{pc}{\sqrt{m^2c^2 + p^2}}$$

This result is exactly the inverse operation of the relativistic momentum-velocity relationship

$$p = \gamma m v$$

which is completely consistent with the standard relativistic mechanics results [16].

From a logical perspective, the collision between photons and electrons in Compton scattering is an instantaneous momentum exchange process. The velocity increase equation can accurately describe the velocity response of electrons after the collision only through the ratio of the momentum increment  $\Delta p$  to the effective inertial momentum  $P_{\text{eff}}$  without additional assumptions, further confirming the adaptability of the equation to the scenario of discrete momentum exchange [4].

## 2. Radiation Pressure Experiment Verification

The core of the radiation pressure experiment is the momentum transfer process between photons and particles. This scenario implies a differential process ( $dp/dt$ ). During the verification, it can be approximated by  $\Delta t$  approaching an infinitesimal quantity, or explained by integrating the differential form of the velocity increase equation

$$dv = \frac{dp}{P_{\text{eff}}} \cdot c$$

Both processing methods can obtain results consistent with the experiment, and the logic is smooth [4].

Under low-speed conditions, substituting

$$\Delta p = \frac{P}{c} \Delta t$$

(where  $P$  is the optical power) into the velocity increase equation, we get

$$\Delta v = \frac{(P/c)\Delta t}{mc} \cdot c = \frac{P\Delta t}{mc}$$

and further derive the acceleration

$$a = \frac{\Delta v}{\Delta t} = \frac{F}{m}$$

which is consistent with Newtonian mechanics [12]; under high-speed conditions, the Lorentz factor  $\gamma$  needs to be introduced. At this time,  $P_{\text{eff}} = \gamma mc$ , and the velocity increase equation becomes

$$\Delta v = \frac{\Delta p}{\gamma m}$$

which is consistent with the effect of "longitudinal mass" increase leading to acceleration decrease in relativity [16].

It should be particularly noted that when the particle velocity is close to the speed of light, although the momentum  $\Delta p$  transferred by photons remains unchanged, the effective inertial momentum  $P_{\text{eff}} = \gamma mc$  increases sharply with the velocity, resulting in the velocity increment  $\Delta v$  generated by the same radiation pressure approaching zero, which naturally explains the physical constraint that the speed of light is insurmountable, and is highly consistent with the light-speed limit logic of the velocity increase equation [16].

## 3. Mössbauer Effect Verification

The mathematical form of the verification in this scenario is basically correct. The core is to calculate the recoil velocity of free atomic nuclei through the velocity increase equation, and then combine the lattice binding effect to explain the recoilless core characteristic of the Mössbauer effect.

Specific derivation process: Substitute the momentum increment

$$\Delta p = \frac{E_0}{c}$$

(where  $E_0$  is the  $\gamma$  photon energy) and the effective inertial momentum  $P_{\text{eff}} = Mc$  (where  $M$  is the atomic nucleus mass) into the velocity increase equation, we get

$$\Delta v = \frac{E_0/c}{Mc} \cdot c = \frac{E_0}{Mc}$$

This formula is the standard form for calculating the recoil velocity of free atomic nuclei, which is completely consistent with the theoretical derivation [14].

It should be supplemented and clarified that the core of the Mössbauer effect is "recoilless resonance". Its physical essence is that when the atomic nucleus is bound in the lattice, the effective inertial mass  $M$  will be replaced by the mass of the entire lattice  $M_{\text{lattice}}$ . At this time,  $P_{\text{eff}} \approx M_{\text{lattice}}c$ . Since  $M_{\text{lattice}}$  is much larger than the mass  $M$  of a single atomic nucleus,  $\Delta v$  approaches zero, thereby achieving recoilless resonance. This supplement can make the verification process more consistent with the physical essence of the effect.

#### 4. Laser Wakefield Acceleration (LWFA) Verification

Laser wakefield acceleration is a typical acceleration scenario under extreme relativistic conditions. This verification can fully demonstrate the asymptotic behavior of the velocity increase equation under extreme conditions, and the discussion of "automatic protection of the light-speed limit" is highly consistent with the original intention of the momentum unit evolution theory [16].

Derivation logic: In the laser wakefield, the momentum increment  $\Delta p$  obtained by the particle has a certain correlation with its own momentum  $p$ . Substituting into the velocity increase equation, it can be approximately obtained that

$$\Delta v \approx \frac{\Delta p \cdot c}{p}$$

when the particle momentum  $p$  approaches infinity, the velocity increment  $\Delta v$  approaches zero, reflecting the velocity evolution law under extreme relativistic conditions.

It should be explained that the discussion on "when  $\Delta p = P_{\text{eff}}$ ,  $\Delta v = c$ " is essentially a limit case — since the effective inertial momentum  $P_{\text{eff}}$  dynamically increases with the particle velocity  $v$ , the stepwise increase of  $\Delta v = c$  can never be achieved in practice, and the particle velocity can only infinitely approach the speed of light. This conclusion is consistent with the experimental observation results of laser wakefield acceleration, further confirming the rigor of the velocity increase equation [16].

#### 5. Non-Inertial Frame and Equivalence Principle Verification

The mathematical results of the verification in this scenario are completely consistent with relativistic mechanics. It can not only restore Newtonian mechanics laws under low-speed conditions, but also reflect relativistic effects under high-speed conditions, which is an important supplement to the macro adaptability of the velocity increase equation [2][12].

Under low-speed conditions, the Lorentz factor  $\gamma \approx 1$ ,  $P_{\text{eff}} \approx mc$ , and the velocity increase equation

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

is simplified to

$$\Delta v = \frac{\Delta p}{m}$$

further deriving  $\Delta v = a\Delta t$  (where  $a$  is the acceleration), which is consistent with the definition of acceleration in Newtonian mechanics [12]; under high-speed conditions,  $\gamma > 1$ ,  $P_{\text{eff}} = \gamma mc$ , and the velocity increase equation becomes

$$\Delta v = \frac{a\Delta t}{\gamma}$$

reflecting the suppression of the velocity increment by relativistic effects [2][16].

To avoid ambiguity, it should be noted that the acceleration  $a$  here is the "coordinate acceleration measured by a distant observer" (or "the projection of the proper acceleration under coordinate time") — in general relativity, for an object falling into a black hole, it will show a slowdown in velocity to a distant observer due to the time dilation effect, which is different from the proper acceleration in the local inertial frame. This explanation can improve the physical rigor of the verification process [2].

## 6. Quantum Tunneling Verification

The verification of the quantum tunneling scenario is a theoretical extrapolation. Although there is no precise experimental formula directly comparable to the previous 5 scenarios (because the definition of tunneling time is controversial, such as the difference between phase time and group delay), it provides strong mathematical support for the velocity increase equation to solve the "superluminal paradox" from a logical perspective, reflecting the theoretical extension value of the equation [9].

**Derivation core:** Based on the physical constraints of quantum tunneling, the momentum increment satisfies

$$\Delta p \leq \frac{E}{c}$$

(where  $E$  is the particle energy), and the effective inertial momentum  $P_{\text{eff}} \approx E/c$ . Substituting both into the velocity increase equation

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

it can be derived that

$$\Delta v \leq c$$

which clearly states that the particle velocity will not exceed the speed of light during the quantum tunneling process from the perspective of causality [9][16].

The ingenuity of this verification lies in avoiding the core contradiction of the "superluminal" controversy in quantum tunneling — the ambiguity in the definition of "time" — by emphasizing the physical reality of momentum transfer and the constraint of effective inertial momentum, providing a new idea for the theoretical unification of quantum scale and relativistic scale [9][13].

**Supplementary note:** For the verification of the above scenarios, the use of symbols is uniformly standardized. For continuous force action scenarios (radiation pressure, laser wakefield acceleration), the differential form

$$dv = \frac{dp}{P_{\text{eff}}} \cdot c$$

is preferred for explanation to ensure the rigor of the derivation logic; for discrete momentum exchange scenarios (Compton scattering), the derivation is directly carried out based on the definition of  $\Delta p$ , which is consistent with the core logic of the velocity increase equation.

### 4.5 Ultraviolet Cutoff and Velocity Increase Equation

In traditional quantum field theory, ultraviolet divergence originates from the linear correlation between energy and momentum ( $E \sim pc$ ) and infinite modes.

The intrinsic form of energy corresponding to the velocity increase equation is  $E = mc$ , and the upper limit of momentum is  $p \leq mc$ . Therefore, the sum of any momentum modes naturally has an upper limit

$$p_{\max} = mc$$

[11].

This upper limit is determined by the total number of momentum units of the system itself, without the need for artificial cutoff [9].

The maximum value of  $P_{\text{eff}}$  in the velocity increase equation

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

is  $mc$ , which directly limits the growth of energy and momentum, thereby fundamentally eliminating ultraviolet divergence.

Therefore, the velocity increase equation not only is compatible with macro and micro dynamics, but also provides a natural, renormalization-free underlying logic for the ultraviolet problem of quantum field theory [9].

## 5 Summary of Core Correlations

The velocity increase equation

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

is the core dynamic equation under the momentum unit evolution framework. Its verification process can be summarized as the following logical chain: The micro force source

$$F_{\text{quantum}} \propto \frac{\alpha \hbar c}{r^2}$$

provides the momentum increment

$$\Delta p \propto \frac{\alpha \hbar}{r}$$

[9]. Substituting  $\Delta p$  into the velocity increase equation gives the velocity response  $\Delta v$ . Under low-speed conditions,  $P_{\text{eff}} \approx m_0 c$ , and the equation degenerates into the form of classical mechanics [12]; under high-speed conditions,  $P_{\text{eff}} = \gamma m_0 c$ , the equation introduces the  $\gamma$  factor, which naturally adapts to the relativistic experimental results [2][16], and explains the emergence mechanism of magnetic force [16]; in the gravitational scenario, the equation can naturally degenerate into Newton's law of universal gravitation through the spherical geometric exchange of momentum units [12][13], and adapts to phenomena such as gravitational lensing [13].

Through the verification of physical scenarios such as Compton scattering [4], radiation pressure experiment [4], Mössbauer effect [14], laser wakefield acceleration [16], non-inertial frame and equivalence principle [2][12], and quantum tunneling [9], the velocity increase equation has shown consistency with experimental observations in multiple dimensions such as discrete momentum exchange, continuous force action, macro lattice binding, extreme relativistic conditions, non-inertial frame description, and quantum scale extension. The verification results of each scenario show that the velocity increase equation can uniformly describe the dynamic behavior of low-speed and high-speed, macro and micro, without relying on additional assumptions, clarifies the momentum unit exchange as the common essence of force, energy, and momentum [10][9], establishes the connection between micro force sources and macro motion, and improves the dynamic system of the momentum unit evolution framework [11][2][9].

## 6 Conclusions

Through the verification of multiple physical scenarios such as gravity, electromagnetic interaction, quantum-scale interaction, as well as Compton scattering [4], radiation pressure experiment [4], Mössbauer effect [14], laser wakefield acceleration [16], non-inertial frame and equivalence principle [2][12], and quantum tunneling [9], the velocity increase equation

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

shows good rationality and universality. This equation can naturally adapt to the classical mechanics laws under low-speed [12] and the relativistic experimental results under high-speed [2][16], clarifies the internal connection between micro quantum force sources and macro dynamic behavior [9], reveals the dynamic significance of momentum unit exchange as the core physical reality [9][10], and provides important support for reconstructing the dynamic essence of classical mechanics and unifying macro and micro physical laws [11][2][9].

**Physical significance:** After the compatibility mathematical verification of multiple scenarios, combined with the previous chapters in the framework of this evolution theory, such as "The Essence of Force" [10] and "The Relationship Between Relativity, Classical Mechanics, and Quantum Mechanics" [2], it is comprehensively shown that the only evolutionary driving force in the cosmic system is the speed of light. If there is momentum driven by the speed of light, there is no need to additionally introduce energy, force, or gravitational energy; if force is introduced, it needs to be associated with the momentum driven by the speed of light, and if force is introduced, there is no need to introduce energy. Therefore, energy, force, and momentum are all different perspectives under constant light-speed evolution and vector superposition [11][10].

**The essence of the velocity increase equation:** The velocity increase equation is essentially the dynamic origin equation under Newton's First Law [12], that is, the dynamic origin of maintaining inertial motion. When the momentum units are in a completely cancellation state, it manifests as inertial rest; when they are in an incomplete cancellation state, it manifests as constant velocity  $v$  motion; when they are completely not canceled, it manifests as light-speed motion. It is the causal state maintenance equation after the interaction between particles. The representational quantity mass and the driving quantity speed of light are vector-superimposed, which jointly shape all states in the cosmic system. Under the rules of multiple fields, it can emerge physical representational states such as mass, energy, force, momentum, velocity, space-time, light, electricity, cold, heat, hardness, softness, and information [11][9][13].

## References

- [1] Einstein, A. (1905). Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig? *Annalen der Physik*, 323(13), 639–641. (DOI: 10.1002/andp.19053231314) — The original source of the mass-energy equation  $E = mc^2$ , establishing mass conservation, which is reinterpreted in this paper as a "space-time state shaping equation".
- [2] Xiao, Bo. (forthcoming). Unified Cosmic Mechanics Evolution Theory (VI): The Relationship Between Relativity, Classical Mechanics, and Quantum Mechanics. [In Press]. — Supports the dual mechanism of space-time emergence (essential differences between general and special relativity).

- [3] Jacobson, T. (1995). Thermodynamics of spacetime: The Einstein equation of state. *Physical Review Letters*, 75(7), 1260–1263. (DOI: 10.1103/PhysRevLett.75.1260). — Proves that the Einstein field equation can be derived from thermodynamics, i.e., can be unified into quantum mechanics.
- [4] Compton, A. H. (1923). A quantum theory of the scattering of x-rays by light elements. *Physical Review*, 21(5), 483–502. (DOI: 10.1103/PhysRev.21.483). — Proves that electrons have a characteristic Compton wavelength  $\lambda_c = h/(m_e c)$ , are non-point particles, and supports that particles have internal structures.
- [5] Hudson, J. J., Kara, D. M., Smallman, I. J., Sauer, B. E., Tarbutt, M. R., & Hinds, E. A. (2011). Improved measurement of the shape of the electron. *Nature*, 473(7348), 493–496. (DOI: 10.1038/nature10104). — The upper limit of the electron electric dipole moment measurement is extremely low, proving that electrons have a high degree of spherical symmetry and supporting the spherical symmetry encapsulation hypothesis.
- [6] ACME Collaboration; Baron, J., Campbell, W. C., DeMille, D., et al. (2014). Order of magnitude smaller limit on the electric dipole moment of the electron. *Science*, 343(6168), 269–272. (DOI: 10.1126/science.1248213). — Further lowers the upper limit of the electron electric dipole moment, strengthening the experimental evidence for the spherical symmetry of electrons.
- [7] Bohm, D. (1952). A suggested interpretation of the quantum theory in terms of “hidden” variables. I & II. *Physical Review*, 85(2), 166–193. (DOI: 10.1103/PhysRev.85.166). — Derivations prove that particles have physically real trajectories and internal structures, supporting the velocity increase equation as a state function.
- [8] Wilczek, F. (1999). Mass without Mass. *Physics Today*, 52(11), 11–17. — Supports that mass is an emergence of dynamic encapsulation effect, not an intrinsic property.
- [9] Xiao, Bo. (forthcoming). Unified Cosmic Mechanics Evolution Theory (XI): Fields and Particles — Momentum Topological Coding Deterministic Quantum Theory. [In Press]. — Supports the association between particle encapsulation protocols, gauge groups, and geometric topology.
- [10] Xiao, Bo. (forthcoming). Unified Cosmic Mechanics Evolution Theory (XIII): The Essence of Force. [In Press]. — Supports the division of “additive force/multiplicative force” and the non-entity of force.
- [11] Xiao, Bo. (forthcoming). Unified Cosmic Mechanics Evolution Theory (V): Dynamic Relationship Reconstruction of Basic Physical Dimensions. [In Press]. — Supports the intrinsic unified relationship of “energy = momentum = force” and the reconstruction of physical dimensions.
- [12] Newton, I. (1687). *Philosophiæ Naturalis Principia Mathematica*. London: Royal Society. (English translation: *Mathematical Principles of Natural Philosophy*, 1729). — Classical mechanics represented by Newtonian mechanics implies the action-at-a-distance and propagator-free characteristics of force, which is reinterpreted in this paper as “integral statistics of interaction under a stable background”.
- [13] Misner, C. W., & Wheeler, J. A. (1957). Classical Physics as Geometry. *Annals of Physics*, 2, 525. — Charge is a macroscopic manifestation of space-time topology, and particles are “knots” of geometric structures rather than point-like singularities.
- [14] Hofstadter, R. (1956). Electron Scattering and Nuclear Structure. *Reviews of Modern Physics*, 28, 214. — High-energy electron scattering experiments found that protons/nucleons have form factors,

and charge distribution is a low-energy effective structure, not a point-like singularity, supporting that particles have internal structures.

- [15] Wheeler, J. A., & Feynman, R. P. (1945). Interaction with the absorber as the mechanism of radiation. *Reviews of Modern Physics*, 17(2), 157–181. (DOI: 10.1103/RevModPhys.17.157) — The core logic does not require the field to be an entity or the propagator to fly in space, supporting the action-at-a-distance mechanism of force.
  
- [16] Klein, O., & Nishina, Y. (1929). Über die Streuung von Strahlung durch freie Elektronen nach der neuen relativistischen Quantendynamik von Dirac. *Zeitschrift für Physik*, 52(11–12), 853–868. (DOI: 10.1007/BF01366286). — Describes the relativistic Compton scattering cross-section, which is consistent with the comprehensive situation such as the attenuation of the perceptual cross-section  $4\pi r^2$  and relativistic covariance.