Unified Cosmic Mechanics Evolution Theory (XIV) : Particle Velocity Saturation Dynamical Effect

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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 fourteenth 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.

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.

Based on the core framework of the Unified Cosmic Mechanics Evolution Theory, this paper redefines the essential unity of force, energy, and momentum, clarifies the non-substantive emergent characteristics of space-time and fields, systematically elaborates on the velocity saturation dynamical effects during the ultra-high-speed motion of particles. Combined with the momentum topological coding theory, it explains the underlying mechanisms of typical physical phenomena such as special relativistic effects, particle interaction weakening, and dark energy-driven space expansion. The paper supplements the interaction cross-section correction formula based on the covariance factor (v) and the derivation of the momentum flux density threshold under the Compton wavelength, establishes the intrinsic correlation between particle velocity saturation, momentum encapsulation, and field protocol interaction, and improves the theoretical system of the Unified Cosmic Mechanics Evolution Theory in the field of high-speed particle dynamics.

Keywords: Cosmic Information Dynamics; Particle Velocity Saturation; Upper Limit of Force; Field Protocol; Special Relativistic Effect; Space-Time Expansion; Dark Energy

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1 Introduction

The theoretical divergence between classical mechanics, relativity, and quantum mechanics stems from the insufficient understanding of the essence of force, energy, and momentum, as well as the misunderstanding of the physical properties of space-time and fields [1]. The Unified Cosmic Mechanics Evolution Theory proposes that the universe is essentially an evolutionary system of relational states of evolutionary carriers (momentum units) based on rule protocols. Force, energy, and momentum are essentially unified in mv (or mc) [2]. The differences among the three in classical mechanics originate from the time-integration processing of force under low-speed macro approximation, which to a certain extent conceals the intrinsic isomorphism between evolutionary carriers, evolutionary capabilities, and force. Space-time is not an independent physical entity, but an emergent result of the self-state evolution and interaction of evolutionary carriers; the field is a regularized protocol for interaction between evolutionary carriers, rather than an independent physical entity.

Based on the above core cognition, there is a natural upper limit (speed of light c) for the motion velocity of particles. When the particle motion velocity approaches or tends to the speed of light, a series of velocity saturation dynamical effects will occur due to changes in momentum distribution and perceptual interaction capabilities [3]. This paper will systematically sort out the manifestations and underlying

mechanisms of such effects, supplement mathematical derivations combined with momentum topological coding and field protocol theory, provide a consistent explanation for related physical phenomena, and offer a new theoretical perspective for high-speed particle dynamics research.

2 Theoretical Basis: Core Premises of Cosmic Information Dynamics

The preliminary derivations within the framework of this evolution theory are introduced here, see the chapters of Fields and Particles [3], The Essence of Force [4], and Reconstruction of Dynamical Relationships of Basic Physical Dimensions [2], etc.

2.1 Particle Encapsulation and Perceptual Mechanism

All evolutionary carriers in the cosmic system are momentum units. All particles are encapsulated by m momentum units with light-speed evolutionary capabilities: fermions are encapsulated by spherical symmetric cancellation states, and photons are formed by geese formation coding. The interaction between particles occurs through the common perceptual cross-section. In the repulsion protocol, particles jointly toggle outward the same number of momentum units; in the attraction protocol, they jointly toggle inward the same number of momentum units. Due to the superposition of state vectors of momentum flow evolution inside the particles, a cooperative evolutionary capability of 0-c is generated between particles [5].

2.2 Dimensional Reset and Essential Unity of Physical Quantities

Force, energy, and momentum are essentially the same physical quantity, which can all be expressed as mv or mc. The differences among the three in classical mechanics originate from the time-integration processing of force under low-speed macro approximation, which to a certain extent conceals the intrinsic isomorphism between evolutionary carriers, evolutionary capabilities, and force. The Unified Cosmic Mechanics Evolution Theory proposes a dimensional reset scheme, clarifying that all evolutionary carriers can contribute light-speed evolutionary capabilities. Therefore, the upper limit of the influence of any force will not exceed mc (m is the mass of the evolutionary carrier, c is the speed of light), and its core derivation is as follows:

Let the total momentum of the evolutionary carrier be P_{total}, which is composed of N momentum units. Each momentum unit encodes the evolutionary amplitude c, so the total momentum satisfies $P_{\text{total}} = N \cdot p_0$, where p_0 is the momentum of a single momentum unit, and $p_0 = m_0 c$ (m_0 is the mass of a single momentum unit). The essence of force is the mutual motion tendency between evolutionary carriers, and its influence is determined by the interaction capability of momentum units. The upper limit of the influence of force is the total momentum of a single evolutionary carrier, that is, $F \cdot \Delta t \leq P_{\text{total}} = mc$ (Δt is the characteristic interaction time). If the characteristic interaction time $\Delta t = L/c$ (L is the interaction distance), it can be derived that $F \leq mc^2/L$, which confirms that the intensity of force is directly related to mc. See the dimensional reset chapter of this evolution theory for detailed derivation.

2.3 The Essence of Force

Force is not an independent physical entity, but emerges from the mutual motion tendencies and interaction processes between evolutionary carriers in the system —— as a relational state evolution sys-

tem, there is no direct subordinate relationship between evolutionary carriers in the universe; interaction originates from the perceptual mechanism, and mutual influence originates from the motion tendency deviation generated after interaction. Conversely, the force between two particles emerges from the binding tendency generated by the motion tendency. Therefore, the influence of the interaction force between any particles will not exceed the product of their own mass and the speed of light (mc). The reason why Einstein's equivalence principle is effective is that all forces emerge from the motion tendencies of evolutionary carriers (momentum units) [6].

The field is a regularized protocol for interaction between evolutionary carriers, including encapsulation protocol, perception protocol, resolution protocol, entanglement correlation protocol, etc. Its core function is to constrain the interaction mode of evolutionary carriers, rather than being a physical entity that exerts force. The non-substantiveness of the field can be verified by interaction efficiency: if the field is a physical entity, it needs to switch its size, position, and state in real time with the particles, and its interaction efficiency is much lower than the collinear interaction efficiency of "perceptual cross-section $1/4\ r^2$", and it cannot explain the cancellation, penetration, and action-at-a-distance characteristics of force (such as quantum entanglement and the global coverage of the Earth's magnetic field).

2.4 The Essence of Space-Time

Space-time is also not a physical entity, and its emergence depends on the evolutionary behavior of evolutionary carriers: there is no time without evolution, and space emerges when evolutionary resources evolve based on free dimensions. For example, the RGB color state evolution system constructed by humans can emerge a three-dimensional color state space even without relying on orthogonal three-dimensional space, which confirms that space is an emergent property of evolution, rather than a preset physical framework. The emergent nature of space-time determines that it cannot directly shape the motion of evolutionary carriers, but can only serve as a macro representation of evolutionary behavior. See the dimensional reset and evolutionary space-time chapters of this evolution theory for detailed derivation [7].

2.5 Momentum Topological Coding and Core Formulas of Particle Evolution

The only physically real evolutionary resource in the cosmic system is the momentum unit. All momentum units are encoded with dual c attributes (evolutionary amplitude c, evolutionary frequency c) and evolvable directions. Particles are multi-layer encapsulations of momentum units: fermions adopt spherical symmetric momentum encapsulation, with momentum interaction perception units distributed on the spherical surface, and a causal connection and force resolution anchor at the center. The macro inertial motion velocity of particles is determined by the ratio of momentum deviation to total momentum, and the core formula is:

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

where $\vec{\Delta}p$ is the momentum deviation (the cancellation amount of spherical symmetric momentum pairs), and P_{total} is the total particle momentum. The particle acceleration originates from the continuous change of momentum deviation, that is:

$$a = \frac{d|\vec{\Delta}p|}{dt \cdot P_{\text{total}}}$$

Bosons (such as photons) adopt geese formation single-direction momentum flow encapsulation, with fixed motion direction and no rest mass, which is essentially the one-way cooperative evolution of momentum units. The interaction resolution between particles is carried out based on the perceptual cross-section, and the macro interaction result is jointly affected by the relativistic perceptual time window and the perceptual cross-section. The covariance factor $\eta(v) = \sqrt{1 - v^2/c^2}$ (special relativistic perception factor) is introduced, and the interaction resolution formula is:

$$F_{\text{int}} = f \cdot \frac{\eta(v_1)\eta(v_2)}{4\pi r^2} \cdot P_{\text{total1}} \cdot P_{\text{total2}}$$

where f is the perception and interaction influence factor under the encapsulation protocol, 4 r^2 is the spherical perceptual cross-section of particles, and $\eta(v_1)$ and $\eta(v_2)$ are the covariance factors of the two interacting particles. Note: This formula mainly describes the active scattering between particles and the process of force connection establishment; for radiation dissipation caused by forced deflection, the structural rigidity factor needs to be introduced for correction, see Section 4.3.

3 Particle Velocity Saturation Dynamical Effects and Mechanisms

When the particle motion velocity approaches the speed of light (v→c), the distribution of momentum units inside the particle tends to be unidirectional, leading to significant changes in perceptual interaction capability and momentum coupling efficiency, forming a series of velocity saturation effects. All effects originate from the saturation of momentum distribution and the weakening of field protocol interaction, rather than space-time curvature or energy conservation breaking.

3.1 Perceptual Capability Weakening Under Ultra-High-Speed Motion: The Essence of Special Relativistic Effects

When the particle motion velocity approaches the speed of light, its perceptual capability with the outside world is significantly weakened. The core reason is that almost all momentum units inside the particle are toggled to the same motion direction to maintain inertial motion, leading to the dual compression of the perceptual space-time window with the outside world —— the time frequency of internal state evolution remains unchanged, while the effective interaction cross-section shrinks, and the macro performance is special relativistic effects (time dilation, length contraction).

This effect can be quantitatively described by the covariance factor $\eta(v) = \sqrt{1 - v^2/c^2}$: when v→c, $\eta(v) \to 0$, which means that the effective time window for external interaction tends to be extremely small, and the perceptual efficiency of particles to the outside world is greatly reduced. For example, two trains passing each other at high speed have their mutually perceived space-time windows compressed compared with the static state, leading to the observation of "time dilation and length contraction" of each other. This is not the curvature of space-time itself, but the perceptual capability saturation effect caused by high-speed motion.

It should be clarified that the intrinsic state evolution of particles (such as spin and the intrinsic frequency of momentum units) is not affected by external velocity, only the perceptual results of external interaction are distorted, which is consistent with the core view of "intrinsic states are non-covariant, and covariance originates from collective interaction effects" in cosmic information dynamics [1].

3.2 Weakening of Force Connection in Non-Inertial Directions Under Ultra-High-Speed Motion

There are only two ways to achieve particle velocity close to the speed of light: one is through the resultant velocity superposition with other particles, and the other is that all momentum units inside the particle are toggled to the same direction (momentum deviation $\vec{\Delta}p \approx P_{\text{total}}$). In either case, the interaction capability of the particle will be saturated, and it will be unable to establish an effective force connection with the outside world. The specific mechanism is as follows:

The essence of the force formed between particles is the cooperative evolutionary capability of particles for external interaction. Therefore, the premise of establishing a force connection with the outside world is that the particle must retain evolvable degrees of freedom inside. When the particle velocity approaches the speed of light, all its evolvable degrees of freedom are "locked" to maintain unidirectional inertial motion, and the lateral response margin is zero. Due to the lack of necessary degrees of freedom to carry non-collinear disturbances, particles cannot establish effective coupling with external fields, leading to the natural failure of lateral force connection [8].

4 Explanation of Physical Phenomena Based on Velocity Saturation Effects

The particle velocity saturation dynamical effect can uniformly explain a variety of high-speed physical phenomena that are difficult to be compatible in classical theories. Its core logic is "velocity saturation $\rightarrow$ unidirectional momentum distribution $\rightarrow$ weakening of perception/interaction capability $\rightarrow$ emergence of macro phenomena". Combined with momentum topological coding and field protocol theory, the specific explanations are as follows:

4.1 The Paradox of Unbounded Space Expansion Speed Caused by Dark Energy

Traditional theories hold that dark energy drives the expansion of cosmic space-time, but they cannot explain the problem of the upper limit of expansion speed, nor can they explain the problem that particles move away from each other faster than the speed of light and cannot perceive and form interaction coupling, thus forming a paradox with the universe being a relational state evolution system. Based on the preliminary logic of this evolution theory:

1. Since space-time is essentially emergent from evolutionary carriers, space-time cannot affect evolutionary carriers.

2. The essence of cosmic expansion is similar to inflating a balloon. The essence of balloon expansion is that the momentum deviation of the internal air is transmitted to the balloon surface, forming a spherical diffusion motion tendency, which has a strict correspondence in the micro mechanism of quantum mechanics, that is, air molecules diffuse outward and collide with the inner wall of the balloon. Therefore, both the problem of balloon expansion and dark energy expansion are not the expansion of space-time itself.

3. Force, energy, and momentum all emerge from the motion tendency of evolutionary carriers, so the three are completely equivalent in the underlying physical mechanism, and their upper limits are all mc.

Therefore, the "dark energy" driving space-time expansion is an essential conceptual error, which is the macro material structure expansion effect caused by the evolution of momentum deviation between

particles, and the speed at which all particles move away from each other will not exceed twice the speed of light. If the expansion exceeds the speed of light, it requires particles to collide with another particle faster than the speed of light.

4.2 Speed Limitation of Lever Rotation and Circular Motion

The paradox of "lever rotation can exceed the speed of light" in the classic thought experiment can be reasonably explained by the velocity saturation effect: the rotation of the lever depends on the force connection between internal particles (mainly electromagnetic force). When the lever rotation speed tends to the speed of light, the momentum units of the particles at the edge of the lever will all be concentrated in the rotation direction, making it impossible to establish electromagnetic force connection with other particles inside the lever — the breakage of the force connection will cause the lever to disintegrate, and all particles enter an independent inertial motion state. Therefore, the speed at both ends of the lever rotation can never exceed the speed of light.

Similarly, the circular motion speed of any particle cannot reach the speed of light. The particle deflection process needs to interact with the outside world (such as field protocols, other particles), and the interaction will increase the number of macro events, resulting in the momentum distribution of particles cannot be completely concentrated in the circular motion direction, and there are always some momentum units used for interaction. Therefore, the circular speed can never reach the speed of light, which has nothing to do with space-time curvature.

4.3 Radiation Dissipation and High-Energy Coupling Effects Under Particle Acceleration Limit

When particles are accelerated to near the speed of light ($v \to c$), their internal momentum units are highly concentrated in the inertial motion direction, entering a "velocity saturation state". At this time, the response mechanism of particles to external disturbances changes fundamentally, which is no longer the conventional momentum deviation adjustment, but shows two typical and logically consistent physical phenomena: radiation dissipation caused by forced deflection of external fields, and encapsulation breakage and new particle generation triggered by collisions of high-speed saturated particles. Both phenomena are based on momentum topological coding and field protocol rules, combined with particle generation mechanism, space-time exclusivity and Compton wavelength related laws, which are completely consistent with the core conclusion of "velocity saturation leading to changes in interaction characteristics" mentioned earlier. Its underlying logic can be systematically sorted out around three core rules: particle stability, momentum input, and space-time exclusivity.

1. Radiation Mechanism: Field Protocol Mismatch, Space-Time Conflict, and Momentum Spillover Under Rigid Saturation State

   Traditional theories hold that radiation originates from charge acceleration, while from the perspective of cosmic information dynamics, the essence of radiation is the momentum unit spillover effect caused by the excessive rigidity of the momentum flow structure when the velocity-saturated particles resist the forced toggle of external fields and alleviate the space-time occupation conflict. This mechanism can perfectly explain the seemingly contradictory phenomenon of "weakened high-speed particle interaction accompanied by strong radiation" — the "weakened interaction" here specifically refers to the ability of particles to actively respond to the outside world, while radiation is an inevitable cost of passively resisting forced disturbances and resolving space-time occupation conflicts.

Mechanism analysis: When particles enter the velocity saturation state, all internal momentum units are locked in the inertial motion direction, and there are no free units available to smoothly buffer the direction disturbance of external fields; at the same time, the representational quantity m_0 of particles has the characteristics of space-time exclusivity and needs to occupy an exclusive space-time evolution space. If an external field (such as a magnetic field, atomic nucleus gravitational field) forcibly toggles the particle momentum units and changes their motion direction through the field protocol, it will destroy the original space-time occupation balance of the particles and trigger space-time conflicts. At this time, the rigid momentum flow structure of the particles is in severe mismatch with the external field protocol, and it can neither adapt to the disturbance through conventional momentum deviation adjustment nor alleviate the conflict through space-time occupation adjustment. To maintain causal continuity, momentum conservation, and space-time exclusivity, some momentum units that are forcibly toggled cannot be recaptured by the topological encapsulation structure of the main particle, and can only be "shaken off" in the form of independent momentum flow (photons), forming radiation (such as synchrotron radiation, bremsstrahlung) [9][10]. This process is essentially a passive response mechanism in which particles actively spill over excess momentum units to resolve space-time conflicts and maintain their own structural stability.

Mathematical correction: The radiation power is not only related to the external deflection intensity and space-time conflict degree, but also positively correlated with the particle velocity saturation degree. Introduce the Lorentz factor $\gamma = \frac{1}{\eta(v)} = \frac{1}{\sqrt{1-v^2/c^2}}$ (characterizing velocity saturation rigidity) and the structural integrity coefficient $S(v)$ (when $v \to c$, $S(v) \to 0$, that is, the encapsulation structure is easy to break and the space-time exclusivity is easy to be destroyed), the radiation power formula is corrected as:

$$P_{\text{rad}} \propto \gamma^4 \cdot \left|\frac{d\vec{v}}{dt}\right|^2 \cdot \frac{1}{S(v)}$$

Among them, the γ^4 term reflects the radiation enhancement effect of ultra-relativistic particles, $\left|\frac{d\vec{v}}{dt}\right|^2$ characterizes the forced deflection intensity of the external field and the resulting space-time conflict degree, and $\frac{1}{S(v)}$ reflects the structural rigidity and space-time exclusivity sensitivity caused by velocity saturation — the closer the velocity is to the speed of light, the worse the structural integrity, the easier the space-time exclusivity is to be broken, and the more intense the momentum spillover caused by the same deflection force. This is completely consistent with the phenomenon in experiments that "the faster the velocity (the larger γ), the stronger the synchrotron radiation power" [10], and at the same time echoes the previous conclusion of "weakened high-speed particle interaction (decreased active response ability)", solving the original logical contradiction.

2. Coupling Mechanism: Encapsulation Breakage, Momentum Input, and Potential Space Particle Replication and Recombination Under High-Energy Collision

The generation of new particles (such as electron-positron pair generation, multiple particle generation in colliders) is not a spontaneous behavior during single particle acceleration, but the result of violent collisions between two high-speed saturated systems (particle and particle, particle and strong field source). Its core logic is "momentum input → encapsulation breakage → space-time occupation conflict → potential space particle replication → momentum unit recombination", rather than the original "single particle energy accumulation triggering coupling". This mechanism not only conforms to the phenomenon of "particles generated out of thin air" in experiments (essentially, input momentum triggers the parent particle to replicate particles from the potential space), but

also avoids the misunderstanding of violating momentum conservation. At the same time, combined with the resolution characteristics of Compton wavelength, it deepens the theoretical connotation of momentum topological coding and particle stability [11].

Trigger conditions (based on momentum encapsulation, information resolution, space-time exclusivity, and particle generation rules):

(a) **Resolution penetration condition:** The wavelength λ of the incident momentum flow (or colliding particles) must be less than the Compton wavelength of the parent particle $\lambda_C = \frac{h}{mc}$ (h is Planck's constant, m is the mass of the parent particle). The Compton wavelength is essentially the "minimum information resolution" of the momentum topological encapsulation of the parent particle, and also the critical scale for the particle to maintain space-time exclusivity — that is, the "pixel size" of the particle encapsulation structure. When the incident wavelength $\lambda \leq \lambda_C$, it means that the "information granularity" of the incident momentum flow is smaller than the encapsulation granularity of the parent particle, which can not only penetrate the field protocol barrier on the particle surface, directly disturb the internal momentum units, leading to the failure of the encapsulation structure, but also break the space-time exclusivity balance of the parent particle, triggering violent space-time occupation conflicts, providing prerequisites for particle replication and recombination [12]. It should be noted that λ_C is the characteristic scale of the parent particle encapsulation structure (corresponding to the critical state of momentum deviation $\Delta p = mc$), not the minimum possible radius. When the collision energy is much higher than the threshold (such as $\gamma \gg 1$ in high-energy colliders), the particle can be transiently compressed to a scale much smaller than λ_C ($r_e = \lambda_C/\gamma \to 10^{-18}$m or even smaller). At this time, the encapsulation structure is in an extremely unstable "super-critical state", and the efficiency of encapsulation breakage and particle replication is greatly improved, that is:

$$\lambda \leq \lambda_C \implies \text{Momentum topological encapsulation protocol failure+Space-time exclusivity breaking}$$

(b) **Momentum input and particle generation threshold conditions:** The total input momentum of the collision system (including the momentum corresponding to the incident momentum and the momentum of the parent particle itself) must meet two core requirements: first, provide sufficient evolutionary resources to enable the parent particle to have the ability to replicate new particles from the potential space; second, make up for the momentum loss during encapsulation breakage and particle replication. From the energy perspective, the center-of-mass energy of the collision must satisfy $E_{\text{cm}} \geq 2mc^2$ (taking electron-positron pair generation as an example); from the perspective of momentum units, the total number of available momentum units N_{total} of the collision system (including the number of units corresponding to the input momentum and the number of units of the parent particle itself) must be greater than the minimum number of units N_{new} required for new particle construction, and the corresponding relationship is:

$$N_{\text{total}} \geq N_{\text{new}} = \frac{m_{\text{new total}}c}{p_0}$$

($m_{\text{new total}}$ is the total mass of new particles, $p_0 = m_0 c$ is the momentum of a single momentum unit), ensuring that there are sufficient momentum resources for parent particle encapsulation breakage, potential space particle replication, and new particle re-encapsulation [13][14].

Evolution process (based on field protocol self-organization, space-time exclusivity, and particle replication rules):

When two velocity-saturated particles collide head-on, the huge momentum input by both sides and the rigidly locked momentum flow will first transiently compress each other's encapsulation structures to a scale much smaller than the Compton wavelength ($r_e = \lambda_C/\gamma$), then instantly break each other's momentum topological encapsulation structures, and at the same time seriously damage the space-time exclusivity of the particles, triggering violent space-time occupation conflicts. After the encapsulation is broken, a large number of free momentum units inside the parent particle are released. At the same time, the evolutionary resources provided by the incident momentum trigger the parent particle as a coding template to excite virtual momentum pairs $(p, -p)$ from the potential space (vacuum fluctuation ground state) and pull momentum units, and replicate a new particle according to its own coding rules — this is the essence of the "particles generated out of thin air" in experiments: it is not created out of nothing, but the parent particle combines the input momentum to replicate particles from the potential space and complete materialization.

Subsequently, the self-organization of field protocols and conservation coding rules (charge, lepton number, etc.) are activated. The released free momentum units and the virtual momentum pairs replicated from the potential space quickly cluster according to the principles of momentum conservation, coding matching, and space-time exclusivity, and solidify to form a new stable particle structure. After the new particles are solidified, they occupy new space-time Planck lattices, meet the requirements of space-time exclusivity, and complete the evolution process of "old encapsulation destruction — momentum input — potential space replication — new encapsulation rebirth" [15].

Supplementary explanation: The essence of the originally conjectured "space-time overlap" is that the perceptual cross-sections of two saturated particles completely overlap during the collision, the incident momentum flow directly interacts with the internal momentum units of the parent particle, and the space-time exclusivity of both parties is broken, providing space conditions for encapsulation breakage and potential space particle replication. The "momentum flux density critical value" can be derived from the Compton wavelength — the momentum flux density under the Compton wavelength $\rho_p = \frac{P_{\text{input}}}{\lambda_C^2}$ is exactly equal to the critical penetration density of the parent particle encapsulation structure $\rho_{p0} \propto mc$ (dimension is momentum/area, consistent with momentum flux density), and it is also the minimum momentum flux density that triggers the parent particle to replicate particles from the potential space. Therefore, the Compton wavelength is a natural critical scale for triggering encapsulation breakage and particle replication, rather than a "condition set to fit the result" [12].

Application in the high-energy field.

4.4 Light-Speed Disintegration Effect of Composite Particles

Composite particles (formed by the coupling of multiple basic particles through field protocols) will inevitably disintegrate when subjected to violent deflection or when the relative velocity of internal components tends to the speed of light. The core reason is that the stability of composite particles depends on the force connection between internal particles (such as strong force and electromagnetic force). If a composite particle moves uniformly as a whole, its internal component particles are stationary (or low-speed) relative to the center of mass. At this time, the relative velocity between internal particles is very low, and the internal force connection is not broken; only when the internal components try to move at high speed relative to the whole, or the whole is subjected to violent deflection/collision, the momentum units of the internal particles will be concentrated in their own motion direction, making it impossible

to establish force connection with other particles, leading to the collapse of the coupling structure of the composite particle [11].

It should be noted that the disintegrated particles can still maintain synchronous motion. Since the particles themselves still have a perception mechanism (inline perception protocol, i.e., quantum entanglement), they can re-interact through field protocols under specific conditions, adjust the momentum distribution state, and form a new coupling structure, which provides a theoretical basis for particle recombination and phase transition.

4.5 Underlying Mechanism of Black Hole Force Effects

1. **Dynamical Essence of Black Holes**

   There exists a celestial body with an extremely large perceptual gravitational cross-section per unit area (not volume) in the cosmic system, which enables any other particle to form an interactive capability with the celestial body at a long distance, thereby affecting the particles and the particles inside the black hole that form a common perceptual cross-section to jointly toggle the distribution state of their own momentum units, making the particles have more momentum unit evolution directions pointing to the inside of the black hole. However, particles moving close to the speed of light have dual compression of the perceptual space-time window, leading to special relativistic effects, resulting in extremely weak gravitational perception capability. It is necessary to make the gravitational perception of light-speed moving particles manifest within the Schwarzschild radius range where the black hole has a dense gravitational perception cross-section [6][16].

2. **Interaction Upper Limit of Black Holes**

   Although a black hole is a dense celestial body, since all attractions are macroscopically oriented to a common inward motion tendency, the force generated by the motion tendency of all particles does not exceed mc. Therefore, even a black hole, the attractive force on any particle does not exceed mc, that is, the interaction saturation effect.

3. **Black Hole Paradox in Traditional Theories**

   Therefore, we cannot simply perform time integration of force and energy inside the black hole according to traditional theories, leading to paradoxes such as infinite contraction, infinite energy emergence, and information loss.

   The conclusion in traditional general relativity that energy and gravity diverge at the black hole singularity (i.e., the predicted "infinity") essentially stems from the non-physical extrapolation of the time integration process under the classical mechanics framework. In the Newtonian paradigm, kinetic energy is defined as the line integral of force in space ($E_k = \int F \cdot dr$), which is equivalent to the accumulation of acceleration over time ($\Delta v = \int a\, dt$). This model implies a key assumption: the velocity v can grow unbounded with the extension of the integration interval.

   However, from the perspective of the Unified Cosmic Mechanics Evolution Theory, there is an absolute upper limit c for velocity, which corresponds to the physical limit of the rearrangement rate of momentum units inside the particle. When particles fall into the strong gravitational field region of a black hole and approach the speed of light, the physical image undergoes a fundamental correction:

   (a) The conclusion in traditional general relativity that energy and gravity diverge at the black hole singularity (i.e., the predicted "infinity") essentially stems from the non-physical extrapolation

of the time integration process under the classical mechanics framework. In the Newtonian paradigm and the subsequent formal extension of special relativity, kinetic energy is often expressed as the line integral of force in space ($E_k = \int F \cdot dr$), which is mathematically equivalent to the accumulation of acceleration over time. The traditional derivation implies a key assumption: the velocity v can grow unbounded with the extension of the integration interval, or after introducing relativistic corrections, mc^2 is incorrectly regarded as an upper limit of an "energy container" that can be completely filled, thus ignoring the truncation mechanism of kinematics itself [13][14].

(b) **Boundedness of time integration:** Since the velocity increment Δv is strictly constrained in the interval $[0, c]$, no matter how deep the gravitational potential well is, the time integral of velocity over acceleration $\int a\,dt$ naturally converges to c. The "infinite time integration" that leads to divergence in traditional theories is naturally terminated in physics due to the velocity saturation mechanism. Here, c is the absolute boundary of kinematics, not a constant that only appears as a conversion factor in traditional formulas; once this boundary is touched, the integral accumulation effect in the time dimension immediately fails and no longer has divergent significance.

(c) **Correction path of energy conservation:** In traditional derivations, it is often mistakenly assumed that the released gravitational potential energy ΔE_p will be converted into kinetic energy numerically equivalent to mc^2. But from the new perspective, when gravity does work to try to push the particle beyond the velocity limit, the excess energy cannot be converted into kinetic energy that violates the velocity upper limit (because v is already locked near c, $\Delta v \to 0$).

At this time, the mc^2 term in the traditional formula only reflects as a conversion factor of energy dimension, not the final destination of physical entities. This part of the excess energy that cannot be converted into macro translational kinetic energy will be directly released to the external environment through radiation dissipation mechanisms (such as high-energy photon emission) and structural dissociation work (overcoming atomic or nucleon binding energy). In short, the energy is not "accumulated" into infinite kinetic energy, but undergoes phase-change dissipation due to the closure of kinematic channels [13][17].

4. **Reconstruction of Force Finiteness**

Given that when $v \to c$, the longitudinal acceleration $a = dv/dt$ asymptotically approaches zero, and the momentum change rate dp/dt is limited by the maximum momentum flux density (on the order of $mc/\tau_{\min}$ determined by the basic time unit $\tau_{\min}$), the effective force acting on the particle must be bounded in physical essence. The gravitational divergence derived in traditional theories due to the assumption that velocity can infinitely approach the singularity is actually ignoring this fundamental limit of velocity saturation on force transmission efficiency [6][16].

4.6 Explanation of the Weak Interaction Characteristics of Neutrinos

The difficulty of neutrinos in establishing electromagnetic force connection with the outside world is essentially that all their momentum units are used for their own inertial motion, and their interaction capability is in a saturated state, making them unable to participate in the perception and resolution of electromagnetic protocols. However, it should be clarified that the cooperative motion of force is not equal to perception — any particle, regardless of its state, has a perception mechanism (inline and external perception protocols). Neutrinos can achieve weak interaction through the strong perceptual

cross-section of high-density dense matter (such as atomic nuclei), which is related to the spherical symmetric encapsulation coding of neutrinos as fermions [15].

The difference between neutrinos and photons originates from the difference in momentum encapsulation protocols: photons adopt geese formation single-direction momentum flow encapsulation, and their perception protocol is the electromagnetic propagation protocol, so they are prone to electromagnetic interaction; as fermions, neutrinos adopt spherical symmetric encapsulation coding, and the omnidirectional distribution of momentum units tends to be saturated, leading to weakened electromagnetic interaction capability. This conclusion can be verified by experiments: when electrons are accelerated to near the speed of light, their momentum units are gradually concentrated in a single direction, and the electromagnetic interaction will be significantly weakened [18]. It is worth noting that the weakening of interaction capability is mainly reflected in the sharp reduction of elastic scattering cross-section (difficult to be deflected or captured), but under the forced action of a strong external field, this "rigidity" will instead lead to a sharp increase in inelastic radiation energy loss, which is not contradictory [9][10].

5 Discussion and Conclusions

5.1 Theoretical Significance

The proposal of the particle velocity saturation dynamical effect, based on the core framework of the Unified Cosmic Mechanics Evolution Theory, reinterprets a series of physical phenomena of high-speed particles, breaks the substantive assumption of "space-time curvature" in classical relativity, unifies the underlying mechanisms of high-speed physical phenomena into momentum distribution, perceptual interaction, and field protocol rules, and provides a new possibility for the theoretical coordination between quantum mechanics and relativity in the micro high-speed field.

The mathematical derivations supplemented in this paper, including the interaction cross-section correction formula based on the covariance factor (v) and the derivation of the momentum flux density threshold under the Compton wavelength, establish the quantitative relationship between particle velocity, momentum deviation, perception efficiency, and interaction intensity, improve the mathematical system of the Unified Cosmic Mechanics Evolution Theory, and provide theoretical guidance for subsequent high-speed particle dynamics experiments (such as neutrino acceleration, photon coupling experiments).

5.2 Key Conclusions

1. There is a natural upper limit (speed of light c) for particle velocity. The essence of velocity saturation is that all momentum units inside the particle are concentrated in a single motion direction, leading to weakened perception and interaction capabilities;
2. Special relativistic effects are not space-time curvature, but the compression of the perceptual space-time window caused by particle velocity saturation, and the internal intrinsic state evolution of particles is not affected;
3. Unified mechanism of radiation, scattering, and particle generation: Velocity-saturated particles have two core response modes under external disturbances —— (a) Radiation is the momentum spillover of the rigid structure resisting forced deflection and resolving space-time occupation conflicts; (b) New particle generation under high-energy collision is the "old encapsulation destruction — potential space replication — new encapsulation rebirth" process completed by the parent particle as a template, combining input momentum to replicate particles from the potential space

and recombine momentum units. Both follow momentum conservation, space-time exclusivity, and Compton wavelength critical conditions.

4. The relative motion velocity between any particles in a local inertial system does not exceed 2c. Composite particles will inevitably disintegrate when subjected to violent deflection or when the relative velocity of internal components tends to the speed of light, which is an inevitable result of momentum topological coding and velocity saturation effects;

5. The core condition for new particle coupling under the Compton wavelength is that the incident wavelength is less than the Compton wavelength (resolution penetration) and the number of momentum units meets the construction requirements. Its essence is that the collision triggers momentum encapsulation breakage and potential space recombination, rather than "equal mass" or single particle spontaneous coupling [12].

5.3 Outlook

Future research can focus on the experimental verification of the particle velocity saturation effect. By accelerating particles such as electrons and neutrinos, observing the changes in their interaction capabilities and radiation characteristics, and verifying the quantitative formulas proposed in this paper; at the same time, we can further explore the specific mechanism of the momentum encapsulation protocol, improve the intrinsic correlation between field protocols and particle velocity saturation, and promote the in-depth application of the Unified Cosmic Mechanics Evolution Theory in the field of high-energy physics. In addition, we can construct momentum topological coding diagrams and curves of interaction cross-section and radiation power changing with velocity to further enhance the intuitiveness and persuasiveness of the theory.

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