Unified Cosmic Mechanics Evolution Theory (VII) : Evolutionary Spacetime

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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 seventh 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 nature of spacetime is one of the core propositions in physics research. In the 17th century, Newton proposed the absolute spacetime view, regarding spacetime as a fixed background independent of matter and flowing uniformly. This view is consistent with macro-low-speed perception and laid the foundation of classical mechanics. At the beginning of the 20th century, Einstein broke this limitation through the theory of relativity, revealing that spacetime is a four-dimensional whole closely related to material motion: special relativity clarified spacetime contraction and expansion at high speeds, while general relativity explained gravity as spacetime curvature caused by mass, successfully resolving the physical statistical contradictions in high-speed and strong gravitational scenarios [1].

However, time and space are universal emergent relationships in any state evolution system. They are not entities that can exist independently and affect state evolution, but are synchronously and concomitantly emergent from the state changes of evolutionary carriers based on their own representational quantities and free dimensions. Neither absolute nor relative can fully express the meaning of spacetime — spacetime is not a container, nor a curved film, but a statistical projection of the state evolution of momentum units. The essence of Einstein's mass-energy equation $E = mc^2$ is precisely the spacetime state shaping equation:

Representational quantity: Number of evolutionary carriers m

Dynamical energy-momentum: Evolutionary carrier × Evolutionary velocity, i.e., mv

Spacetime state shaping quantity: Evolution frequency × Evolution amplitude, i.e., $E_{\text{spacetime}} = mv^2$ (upper limit is mc^2)

Here, both v and c represent statistical sampling quantities for the synchronous emergence of time and space — each spatial scale l_p emerges in pairs with each time scale t_p, and the coupling rate is $c = l_p/t_p$. Therefore, $E = mc^2$ is not a dynamical eigenequation, but a spacetime state shaping equation describing the total evolution coupling amount of momentum units within a spacetime window. The fundamental dynamical relationship is $E = mc$ (energy = momentum = force) [2].

Note: This paper is based on the overall derivation within the framework of information dynamics evolution theory [3], proving that the only physically real evolutionary carrier of the universe is the momentum unit, and all have the evolutionary capacity of the speed of light c [4]. Therefore, all particles are encapsulated by momentum units [5,6,7,8,9], which is the only dynamical origin. For details, see other relevant chapters.

Keywords: Nature of spacetime; Origin of spacetime; Nature of absolute spacetime; Nature of relative spacetime; Spacetime emergence;Momentum unit; Unified mechanics; Evolution theory

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1 Introduction

Newton's absolute spacetime view regards spacetime as a uniformly flowing background independent of matter. This view is effective in the low-speed macro domain but cannot explain the physical statistical contradictions in high-speed and strong gravitational scenarios. Einstein's theory of relativity revolutionarily unified spacetime and material motion into a four-dimensional whole, but while the geometric description of "spacetime curvature" is mathematically successful, it also leaves an unresolved question about the physical essence: is spacetime an independent entity, or an emergent phenomenon of deeper dynamical processes?

As the seventh part of the evolution theory series, this paper aims to reanswer this question based on the basic premises of information dynamics evolution theory. We will argue that time and space are not independently existing entities, but synchronously and concomitantly emergent relational quantities in any stable state evolution system. This conclusion is different from both Newton's absolute background and Einstein's curved geometry, but unifies them under an emergent framework of "intrinsic absoluteness and observational relativity".

Specifically, this paper will carry out the argument along the following path: first, extract the general axioms of spacetime emergence at the generalized system level (Section 1); second, take the cosmic system as a specific example, define momentum unit carriers and dual-c encoding evolution rules, and derive the Planck scale and spacetime shaping equation (Section 2); further, clarify the unification of the absoluteness of physical reality and the relativity of observation (Section 3); on this basis, conduct a dynamical reinterpretation of the time and space effects in the theory of relativity (Sections 4 and 5); finally, summarize the conclusions of the full text to form a complete theoretical closed loop from the underlying mechanism to the macro appearance (Section 6).

Through this work, we hope to provide a new and self-consistent dynamical emergent interpretation framework for the core proposition of physics, "the nature of spacetime".

2 Spacetime Emergence in Generalized Evolutionary Systems (General Axioms)

2.1 System Composition: Defining Evolutionary Carriers (Stability, Non-overlapping) and Minimum Scales l_p, t_p

The emergence of spacetime is not unique to the universe, but a common feature of all stable evolutionary systems. We first define a generalized source dynamical state evolution system as the underlying logical basis for spacetime emergence: there exists at least one evolutionary carrier m_0 in the system, the carrier scale range is $0 \sim l_p$ (l_p is the basic evolutionary scale of the carrier, the minimum spatial unit for spacetime emergence), and the evolutionary carrier has stability and non-spacetime overlapping; the time interval of a single transition process is t_p (t_p is the minimum time unit, i.e., the duration of a single evolutionary event). This core assumption of "minimum scale" is consistent with the view in the field of quantum gravity that "there is a fundamental discrete limit to physical measurement", and many quantum gravity theories predict the existence of minimum physical units on the order of the Planck scale [10].

Therefore, the evolutionary carrier and the state quantity at a single time snapshot together constitute the representational quantity (m_0) and the driving quantity

$$c = l_p/t_p$$

of the state evolution system. It represents the minimum causal scale that can be interacted with per unit scale, and is also the minimum time scale, minimum spatial scale, unit driving quantity scale, and minimum inertial velocity quantity. In terms of statistics, these basic quantities can all be regarded as the natural unit 1 — in other words, the magnitude of the action of any physical interaction (such as gravity) can ultimately be reduced to an integer multiple combination of these minimum units, without introducing additional continuous parameters.

2.2 Evolution Rules: State Transition Mechanism and Two Emergence Modes (Mode A/B)

Evolutionary carriers have stable state transition capabilities, based on which there are two modes of spacetime emergence:

1. Mode A: Each time the evolutionary carrier undergoes a state transition based on its own scale l_p in one free dimension. This transition event corresponds to a time unit t_p, and a spacetime unit of $l_p \times t_p$ naturally emerges, that is, the spatial unit l_p and the time unit t_p are generated synchronously;
2. Mode B: The evolutionary carrier can be in any scale from 0 to l_p, but within each time unit t_p, it must transition out a spatial scale of l_p, and a spacetime unit of $l_p \times t_p$ also emerges. The core is that "the l_p scale transition within t_p" is the core condition for spacetime emergence.

2.3 Nature of Spacetime: Time is Event Statistics, Space is Transition Concomitant; Dialectical Unity of Microscopic Discreteness and Macroscopic Continuity

Regardless of Mode A or Mode B, based on stable state transitions, the system will naturally and synchronously emerge a spacetime state of "microscopic discreteness and macroscopic continuity" — microscopically, spacetime is composed of individual $l_p \times t_p$ units, with discreteness; macroscopically, a large number of spacetime units overlap, presenting a continuous spacetime appearance. This dialectical unity view is similar to the core view of emergent physics: macro physical laws (including spacetime geometry) are emergent phenomena of micro multi-body systems, not underlying fundamental laws [11].

In this generalized system, the essence of time is the quantity statistics of evolutionary events, not the measurement of event intervals — when an evolutionary event occurs, time passes; when there is no evolutionary event ($\Delta N_t = 0$, N_t is the number of evolutionary events), time is stationary ($\Delta t = 0$). Even if there is a reference frame time passing externally, the system has no time perception because no events occur inside, similar to the logic that after a video is paused, there is no time passing in the internal picture. This core conclusion that "time originates from event statistics" is similar to the view of causal set theory, which holds that the essence of spacetime is a discrete set of events connected by "causal order", and the continuous Lorentz manifold is only a macro approximation [12].

2.4 Rate Constraint: Definition of the Upper Limit of Evolutionary Rate c and Its Significance as the Upper Limit of System Solution Frequency

The macro transition evolution emergent quantity of the evolutionary carrier (i.e., the upper limit of the evolutionary rate) is denoted as c, which can be mathematically understood as the coupling quantity of evolution amplitude and evolution frequency, and also the upper limit of the interaction solution frequency within the system, providing a core benchmark for subsequent alignment with the cosmic system and introduction of the Planck scale.

3 Specific Instantiation of Spacetime Emergence in the Cosmic System

3.1 Definition of Evolutionary Carriers

The only carrier of the universe: Momentum unit. Mass is the target quantity of momentum units, and all particles are encapsulated by momentum units, performing state evolution with velocities from 0 to c through vector sum.

Core encoding: Dual-c attributes (evolution amplitude c + evolution frequency c). All momentum units have the intrinsic ability of evolution amplitude c and evolution frequency c, and a momentum unit can perform a state transition of l_p within a single frequency snapshot t_p.

Note: The essence of evolution frequency and evolution amplitude is not c, but equivalent expression can be carried out based on mathematical progression, so there is no need to calculate the underlying natural dimension and total number. The evolution amplitude is three-dimensional orthogonal, which can be understood as the evolution step length of a single time snapshot being $l_p(x, y, z)$. The time snapshot is also for easy understanding, and its essence is a single evolutionary event. The synchronous evolution of multiple evolutionary carriers is convenient to be understood as a time snapshot. A single t_p can be understood as Planck time, a single l_p can be understood as Planck spatial scale, and c is essentially

$$c = l_p/t_p$$

= speed of light, which is also the constant state change rate of a single momentum unit in the three-dimensional orthogonal free dimension when there is no cancellation state. For specific detailed derivation, see the chapter on evolutionary resources within this evolution theory framework. As the minimum unit of cosmic spacetime, the Planck scale is not an isolated assumption, but a common prediction of quantum gravity theories. Many studies have demonstrated its physical reality from a phenomenological perspective [10].

3.2 Definition of Evolution Rules

Dual-c encoding, as the underlying dynamical rule, provides the driving force for cosmic evolution. The evolution amplitude (step length) and time frequency encoded by the momentum unit are both c, that is, p_i carries $(c, \nu_i = c, e_i)$ simultaneously, where $\nu_i = c$ is the underlying encoding benchmark of cosmic time, ensuring the unity of cosmic time rhythm.

3.3 Derivation of the Planck Scale

Based on the coupling of dual-c and basic constants $(\hbar, G)$, the underlying discrete spacetime quantities (λ_P, t_P) are derived: the basic parameters of the Planck spacetime shaping unit are the spatial lattice side length (Planck wavelength)

$$\lambda_P = \sqrt{\frac{\hbar G}{c^3}}$$

(i.e., l_p in the generalized system), and the time lattice (Planck time)

$$t_P = \sqrt{\frac{\hbar G}{c^5}}$$

(i.e., t_p in the generalized system). The four-dimensional volume of a single spacetime lattice is

$$V_P = (\lambda_P)^3 \cdot t_P$$

This core setting of discrete spacetime is consistent with the claim of loop quantum gravity theory, which holds that spacetime is composed of discrete "spin networks", area and volume are quantized (with minimum units), and this discreteness is the quantum state of physical reality [13].

Establish the mapping relationship between microscopic discrete units and macro continuous spacetime: microscopically, cosmic spacetime is composed of individual $\lambda_P \times t_P$ units, with discreteness; macroscopically, a large number of Planck spacetime units overlap, presenting a continuous spacetime appearance, which is consistent with the spacetime characteristics of the generalized system. This "microscopic discreteness and macroscopic continuity" feature is not only a typical embodiment of emergent physics, but also supported by mainstream quantum gravity theories such as loop quantum gravity [13,11].

3.4 Synchronization Mechanism of Cosmic Time (Core Innovation)

Demonstrate why all evolutionary carriers in the universe must perform synchronous resolution: the emergence of cosmic time originates from the external manifestation of the intrinsic evolution frequency of momentum units. As the only carrier for spacetime shaping, the evolution frequency

$$\nu_i = c = 1/t_P$$

encoded by momentum resources strictly corresponds to the reciprocal of Planck time, providing a benchmark for the synchronous resolution of all evolutionary carriers in the universe. This setting of "discrete causal structure" is similar to the core view of causal set theory that "spacetime is composed of a discrete set of events connected by causal order" [12].

Principle of causal resultant force: Within a single t_P, the chain causal conflict of $A \to B \to C$ is eliminated, ensuring the uniformity of macro time and the stability of causality. In the same system, to make the clock frequencies of all evolutionary carriers synchronized or not affect the causal results within t_p, emerge uniform length intervals from a macro perspective, and maintain the causal resultant force and stability of the system, all evolutionary carriers must perform synchronous or extremely high-frequency resolution of causal interactions; if there are sequential influence relationships of multiple evolutionary carriers within a single t_p, it will lead to causal relationship conflicts.

3.5 Natural Emergence of CPT Symmetry

Based on stable carriers and periodic discrete transitions, the joint invariance of charge conjugation (C), parity (P), and time reversal (T) is naturally derived. If both the evolutionary carrier and the evolution rules have stability, the periodic discrete transitions of a single carrier will naturally emerge CPT symmetry and form a "periodic discrete continuous state space". t_p and l_p are microscopic spacetime state shaping quantities, and the speed of light c is the macro spacetime state shaping rate.

3.6 Spacetime Shaping Equation

Based on the above microscopic discrete spacetime framework, a spacetime shaping equation at the macro statistical level can be established.

Microscopic basis: A single spacetime unit $l_p \times t_p$, space and time emerge synchronously, and the coupling rate is:

$$c = l_p/t_p$$

Macro statistics: When a large number of spacetime units overlap, a continuous discrete continuous spacetime emerges. At this time:

1. Representational quantity: Number of evolutionary carriers m
2. Dynamical quantity: mv (evolutionary carrier $\times$ evolutionary speed)
3. Spacetime shaping quantity: mv^2 (evolution frequency $\times$ evolution amplitude)

The essence of Einstein's mass-energy equation $E = mc^2$ is precisely the expression of this spacetime shaping relationship under macro statistics:

$$E_{\text{spacetime}} = mc^2$$

Where c is both the evolution amplitude (spatial unit l_p) and the evolution frequency (macro statistics of $1/t_p$); c^2 is the macro projection of the synchronous coupling of spacetime units — each part of space emerges in pairs with each part of time, and the total coupling amount is expressed as c^2.

4 Physical Reality: Absoluteness of Flat Spacetime

4.1 Conservation of Eigenstate: The Eigenstates of Matter and Spacetime Do Not Change with Observation

The physical reality of the universe is absolute (eigenstate remains unchanged), and the observation result is a mapping projection of stable information, which does not change the eigenstate of things. The eigenstate ψ_0 of a thing does not change with the observer, and the observation projection ψ_{obs} is a mapping of the eigenstate, satisfying:

$$\psi_{\text{obs}} = \hat{O}(\psi_0)$$

where $\hat{O}$ is the observation operator, and

$$|\psi_0| = |\psi_{\text{obs}}|$$

(the modulus of the eigenstate remains unchanged, and reality is conserved). This view resonates with the relational quantum mechanics emphasized by Rovelli in loop quantum gravity theory, both recognizing the objectivity of physical reality and the relativity of observation [13].

4.2 Essence of Relativity: Interaction Integral Under Spacetime Covariance

Relativity mainly statistically describes the interaction process of particles through spacetime covariance, that is, the conservation relationship in the time and space components. This conservation relationship will trigger the interaction integral of the spacetime window — but space and time emerge synchronously, showing a square increment (c^2), rather than the separate square increments of time and space, which is the core feature of the interaction integral process.

Therefore, both special relativity and general relativity are essentially universal theories: special relativity solves the problem of weakened perception under high-speed motion; general relativity solves the problem of integral effect caused by evolutionary spacetime redundancy, and its field equation can be extended to the electromagnetic field (Kaluza-Klein theory).

4.3 Underlying Spacetime: Flat, Discrete, Rigid

The "spacetime curvature" proposed by traditional relativity is an equivalent geometric description from a macro observation perspective, whose essence is the geometric flow effect formed by the gradient of momentum unit occupancy. The underlying spacetime is composed of Planck spacetime lattices, and a single Planck lattice can only accommodate one momentum unit:

$$\forall i \neq j, \quad \mathrm{supp}(p_i) \cap \mathrm{supp}(p_j) = \emptyset$$

(supp is the spatial support set of momentum units), which eliminates spacetime overlapping and ensures the flatness, discreteness and rigidity of the underlying spacetime. The trajectory of material evolution is determined by the interaction rules of momentum units, which is irrelevant to the geometric curvature of spacetime itself.

4.4 Relativity of Observation: Projection Effect, Not Eigenchange

The "covariance" of relativity is a projection effect of macro observation. The mathematical quantization is equivalent to the underlying evolution logic, but the physical essence is different. The projection effect of the observation perspective can be compared to the change of audio playback rate (the frame eigenstate remains unchanged), which is also the case for multi-angle observation of a cube and the acoustic Doppler effect; photon redshift/blueshift is an absolute change caused by the change in the number of photon momentum units, satisfying

$$\Delta\nu \propto \Delta n_p$$

(n_p is the number of photon momentum units).

5 Various Time Effects in the Cosmic System (Dynamical Reinterpretation)

5.1 Cosmic Benchmark Time: Absolute Time Scale Based on Total Number of Events

Cosmic benchmark time originates from the intrinsic evolution frequency of momentum units, which is consistent with "time is the statistics of the number of evolutionary events". Let the number of system evolutionary events be N_t, and Planck time

$$t_P = \sqrt{\frac{\hbar G}{c^5}}$$

then the time correlation is:

$$t = N_t \cdot t_P$$

When the system evolution pauses ($\Delta N_t = 0$), $\Delta t = 0$, that is, no evolution means no time.

5.2 Inertial Time: Local Rhythm Reflection Caused by Momentum Deviation

Inertial time is essentially "momentum deviation time", and its frequency is directly related to the momentum deviation speed. Let the total momentum vector of the inertial system be $P = \sum p_i$ ($P \neq 0$), and the evolution speed $v = P/M$ (M is the emergent mass), then the inertial time frequency

$$\nu_{\mathrm{inertial}} = |v|/c$$

and the conversion with the benchmark time is:

$$t_{\text{inertial}} = t_{\cos} \cdot |v|/c$$

The total inertial time of the multi-level inertial system of the universe is the cumulative cancellation time of momentum deviations of each subsystem. Inside large-mass celestial bodies, $|v|$ decreases, t_{inertial} increases, which is manifested as the clock slowing down.

5.3 Essence of Time Effects Under Relativity

The core of both special and general relativity originates from the conservation of total energy for spacetime state shaping:

$$E_{\text{spacetime}} = mc^2 = m \times \text{evolution frequency} \times \text{evolution amplitude}$$

In particle interactions, the spacetime shaping ability satisfies the conservation relationship

$$c^2 = v_1^2 + v_2^2$$

(v_1^2 corresponds to the perception/redundancy/cancellation component, v_2^2 corresponds to the non-perception/non-redundancy/motion component), which naturally emerges the Lorentz factor

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

Relativity is essentially an interaction integral under spacetime covariance, with the core feature that the synchronous emergence of spacetime presents a square increment (c^2).

1. Time Effects of Special Relativity

   The core of special relativity is to solve the weakened perception under high-speed motion. The "time effect" is the external manifestation of weakened interaction ability, and the eigenstate time inside the particle is constant.

   Mathematical expression: The traditional time dilation formula

   $$\Delta t = \frac{\Delta t_0}{\sqrt{1 - v^2/c^2}}$$

   under this framework, at high speeds ($v \to c$), the external interaction time of the system

   $$t_{\text{int}} = t_{\cos} \cdot (c - |v|)/c$$

   and the internal self-evolution time of the system

   $$t_{\text{sys}} = t_{\cos} \cdot |v|/c$$

   which are mathematically equivalent but physically different in essence.

   Key corrections: The slowdown of muon decay is an observational effect caused by the reduction of interaction perception efficiency; the misunderstanding of the twin paradox is confusing "interaction time" with "eigenstate time", and in fact, the eigenstate times of both parties are consistent; "mass increase with acceleration" is a misunderstanding. Mass is the conserved target quantity of momentum units, and the need for infinite energy when approaching the speed of light is due to the support requirement of momentum units, not infinite mass.

2. Time Effects of General Relativity

   The core of general relativity is to solve the integral effect of evolutionary spacetime redundancy. "Spacetime curvature" is a macro equivalent geometric description of redundancy integral, not the deformation of the underlying spacetime.

   Mathematical expression: The general relativity field equation

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

   ($R_{\mu\nu}$ is the Ricci tensor, $g_{\mu\nu}$ is the metric tensor, Λ is the cosmological constant, $T_{\mu\nu}$ is the energy-momentum tensor), which is essentially the integral quantization of redundant spacetime interactions.

   Key analysis: Mercury's precession is the path redundancy integral effect caused by the dense momentum units around the Sun; the field equation can be extended to the electromagnetic field (Kaluza-Klein theory), and replacing the gravitational potential with the electromagnetic potential can obtain the geometric description of electromagnetic force, confirming its universality.

5.4 Entropy Time (Information Time): Aperiodic Time Measurement Based on Specific Evolutionary Resource Quantities

Traditional time statistics are based on periodic events of the system (such as celestial cycles, atomic oscillations), while entropy time takes any selected evolutionary resource or event type as the statistical anchor, directly measuring the state evolution quantity from this perspective. Entropy time reflects the absolute accumulation of information evolution in the system, independent of external reference frames, and is suitable for describing aperiodic or local evolution processes in thermodynamics and information systems. This view that "information is a property of physical processes" is similar to the relevant claims of emergent physics and quantum gravity theory [11].

1. Definition of entropy time: Select a certain type of evolutionary resource (or event) in the system, whose number of evolutionary events is N_{ent}, and the minimum time snapshot is Planck time t_p, then the entropy time is:

$$t_{\text{ent}} = N_{\text{ent}} \cdot t_p$$

2. Independence: If no new events occur for this resource ($\Delta N_{\text{ent}} = 0$), then the entropy time increment $\Delta t_{\text{ent}} = 0$, and even if external time passes, the time from the perspective of this resource is still stationary.

3. Comparison of multiple resources: The entropy times of different resources can be different. For example, person A walks 10^4 steps a day, and person B walks 10^3 steps, then the walking entropy time of A is $t_{\text{ent}}^A = 10^4 t_p$, and that of B is $t_{\text{ent}}^B = 10^3 t_p$, so the "time passing" of A in walking events is more significant.

4. Difference from macro time: Macro time (such as one day) is the statistics of external periodic events; entropy time directly reflects the accumulation of specific internal evolution of the system, and the relationship between them is:

$$t_{\text{macro}} = k \cdot t_{\text{ent}} + C$$

   where k is the event conversion coefficient, and C is the macro time base (such as the Earth's rotation period). Entropy time corresponds to the number of thermodynamic state changes or the number of bit flips in information systems, and is a more essential "information evolution clock".

6 Various Spatial Effects in the Cosmic System (Hierarchical Analysis)

6.1 Planck Base: Reaffirming It as the Minimum Evolvable Unit, No Longer Repeatedly Calculated, Directly Used as an Axiom

The Planck base is the Planck spacetime lattice, the minimum evolvable unit of cosmic spacetime. The spatial lattice side length

$$\lambda_P = \sqrt{\frac{\hbar G}{c^3}}$$

the time lattice

$$t_P = \sqrt{\frac{\hbar G}{c^5}}$$

and the four-dimensional volume of a single spacetime lattice

$$V_P = (\lambda_P)^3 \cdot t_P$$

which is directly used as the axiomatic basis for the subsequent analysis of spatial effects. The physical reality of the Planck scale as the minimum evolvable unit is widely supported by quantum gravity phenomenological research [10].

6.2 Potential Interaction Spacetime (Medium of Fields)

Definition: The "borrowing and returning" channel for long-distance momentum exchange between particles.

Mechanism: Momentum transfer is directly carried out through potential lattices without relying on physical motion. Potential spacetime is composed of empty mathematical lattices, which cannot be used as physical settlement quantities, and dominates the process of momentum action at a distance.

Phenomenon: Manifested as quantum fluctuations, virtual particle pair production and annihilation.

6.3 Potential Evolution Spacetime (Unreached Realm)

Definition: The logical space allowed by system rules but not yet occupied by carriers.

Significance: Provide a logical container for cosmic expansion and new matter generation. The spacetime occupancy rate

$$\rho_{\text{occ}} = \frac{N_{\text{occ}}}{N_{\text{grid}}}$$

(N_{grid} is the total number of Planck spacetime lattices in the universe, N_{occ} is the number of lattices occupied by momentum units), and the potential evolution spacetime corresponds to the state of $\rho_{\text{occ}} = 0$, which is the potential spatial basis for cosmic evolution.

6.4 Geometric Spacetime (Macro Appearance)

Definition: The equivalent geometric field formed by the gradient of momentum occupancy rate.

Essence: The true face of the traditional "spacetime curvature" — the statistical result of the occupancy rate gradient, which affects the process of its interaction integral. The "spacetime curvature" proposed by traditional relativity is an equivalent geometric description from a macro observation perspective, whose essence is the geometric flow effect formed by the gradient of momentum unit occupancy.

The trajectory of material evolution is determined by the interaction rules of momentum units, which is irrelevant to the geometric curvature of spacetime itself. This view is completely consistent with the claim of dynamical relativity, that is, spacetime geometry is an emergent result of material dynamical behavior, not an independent physical entity [14].

1. Momentum unit occupancy gradient: Let the occupancy rates at any two points in space be $\rho_{\text{occ},1}$ and $\rho_{\text{occ},2}$, and the distance between the two points be r, then the occupancy gradient

$$\nabla\rho_{\text{occ}} = \frac{\rho_{\text{occ},2} - \rho_{\text{occ},1}}{r}$$

and the gradient direction is the direction of the geometric flow (such as the gradient around a star points to the center of the star).

2. Equivalent description of macro orbits (equivalence of geometric flow and gravity): The celestial motion trajectory $\vec{r}(t)$ is determined by the occupancy gradient, and its tangent direction is perpendicular to the gradient direction. The mathematical expression is

$$\vec{v}(t) \cdot \nabla\rho_{\text{occ}} = 0$$

($\vec{v}(t) = d\vec{r}(t)/dt$ is the celestial motion speed), which is equivalent to the mathematical expression of the gravitational orbit in relativity, but the physical essence is different.

3. Correlation between particle period and occupancy rate (equivalent quantization of time dilation effect): The particle transition period T is inversely proportional to the occupancy rate, i.e., $T \propto 1/\rho_{\text{occ}}$. In high-density material regions (ρ_{occ} is large), T decreases, which is consistent with the quantitative result of the relativity time dilation effect, i.e.,

$$\frac{T_1}{T_2} = \frac{\rho_{\text{occ},2}}{\rho_{\text{occ},1}}$$

4. Apparent formula of macro density: The macro density $\rho = m/V$ (m is mass, V is macro volume) used in daily life is essentially a simplified index under the constraint of gravitational field. Its correlation with the underlying occupancy rate is

$$\rho \propto \rho_{\text{occ}} \cdot \frac{\sum |\vec{p}_i|}{V}$$

($\sum |\vec{p}_i| = mc$ is the total momentum of the particle), indicating that the "density difference between iron and cotton" is essentially the difference in ρ_{occ}, not caused by spacetime curvature.

Supplement: Orthogonal encoding of three-dimensional space: The evolution direction $\hat{e}_i$ of the momentum unit $\vec{p}_i$ only has three orthogonal components $(\hat{e}_x, \hat{e}_y, \hat{e}_z)$, satisfying the orthogonality condition

$$\hat{e}_i \cdot \hat{e}_j = \delta_{ij}$$

(δ_{ij} is the Kronecker delta, $\delta_{ij} = 1$ when $i = j$, $\delta_{ij} = 0$ when $i \neq j$), which determines that space can only emerge in three dimensions; the momentum units inside the particle satisfy the spherical symmetry cancellation condition

$$\sum_{i=1}^{n} \hat{e}_i = 0$$

ensuring that the particle forms a stable encapsulation in three-dimensional space and does not break through the three-dimensional evolution boundary. This emergent characteristic of three-dimensional space is consistent with the discrete geometric structure of spacetime in loop quantum gravity theory [13].

6.5 Simulated Spacetime (Mathematical Background and Calculation Tool)

1. Definition and Role

   The fixed coordinate grid in mathematical description is a reference frame benchmark used in physics to simplify calculations. As a calculation tool, it corresponds to the reasonable component of "optional mathematical coordinate system" in Newton's absolute spacetime view (rather than its assertion of "physical background reality"). Cosmic spacetime is an elastic system dynamically adapted to momentum resources, and its elastic characteristics are defined by the spacetime occupancy rate ρ_{occ}. The "absolute spacetime" used in mathematical simulations is only a calculation tool, not a physically real background. The absolute spacetime coordinates (x, y, z, t) used in simulations are based on the statistical assumption of the Planck scale, satisfying $x, y, z \in n \cdot \lambda_P$ and $t \in n \cdot t_P$ (n is a non-negative integer), which is only used to simplify calculations and does not represent physical reality.

2. Spacetime Elasticity

   Based on the momentum unit occupancy rate ρ_{occ} defined in Section 5.4, the elastic characteristics of spacetime can be further quantified. Let the spacetime elastic coefficient be k_{space}, which is inversely proportional to the occupancy rate, i.e.,

   $$k_{\text{space}} \propto 1/\rho_{\text{occ}}$$

   It satisfies:

   When the upper limit of occupancy rate $\rho_{\text{occ,max}} \to 1$, $k_{\text{space}} \to 0$ (spacetime elasticity approaches 0, corresponding to the Planck density scenario, such as inside a black hole);

   When the lower limit of occupancy rate $\rho_{\text{occ,min}} \to 0$, $k_{\text{space}} \to \infty$ (spacetime elasticity approaches infinity, corresponding to the photon sparse distribution scenario, such as interstellar space).

3. Interaction Rules of Forces

   All force interactions are applied along the flat direction of spacetime lattices. Gravity is the statistical superposition of the global occupancy rate gradient:

   $$F_G \propto \nabla \rho_{\text{occ}}$$

   Electromagnetic force and weak force are direct exchange of local momentum units:

   $$F_{\text{em}} = \sum \frac{\Delta \vec{p}_i}{\Delta t}$$

   ($\Delta \vec{p}_i$ is the difference of exchanged momentum units).

4. Core Rules of Momentum Units

   Spatial exclusivity (a single Planck lattice can only accommodate one momentum unit) and symmetric cancellation (the momentum units inside the particle satisfy $\sum \hat{e}_i = 0$, ensuring three-dimensional stable encapsulation) are the basis for the evolvability of three-dimensional space. These two rules ensure the stability of material structure, eliminate spacetime overlapping, dense collapse and escape, which is consistent with the view in loop quantum gravity theory that "discrete spin networks have intrinsic stability" [13].

7 Summary

7.1 Summary of the Four-Dimensional Emergent Relationship of Cosmic Space-Time (Divided into Scale Statistics and Frequency Statistics)

1. **Proper Space-Time Mapping (Reality Statistics)**
   Physical Definition: The proper space-time footprint determined by the characteristic quantity m under a unit evolution snapshot of the system.
   Mathematical Expression: $S_{\text{eigen}} = m \cdot l_P^3 \cdot t_P$
   Dimensional Unification: Under natural units ($l_P = 1, t_P = 1, c = 1$), we have $S_{\text{eigen}} \equiv m$.
   Spatial Component: The state extension of the carrier based on its degrees of freedom ($m \cdot l_P^3$).
   Temporal Component: The minimum evolution pulse required for the carrier to maintain its existence ($m \cdot t_P$).
   Conclusion: In the absolute eigenstate, m is both the carrier count and the total "four-dimensional state space" occupied by the carrier itself.

2. **Dynamic Shaping Mapping (Influence Characterization Statistics)**
   Physical Essence: The "total amount of dynamic influence capable of establishing causal relationships" of the evolutionary carrier in the system. Wherever a particle evolves, there its space-time is.
   Mathematical Expression: $E_{\text{space-time}} = m \cdot (v_{\text{amplitude}}) \cdot (v_{\text{frequency}})$
   Under natural units, the spatial amplitude v and the temporal frequency v are numerically equal, quantifying the carrier's ability to open up a causal network within a unit window. Its upper limit is $E^{\max}_{\text{space-time}} = m \cdot c^2$.
   Origin of Relativity:
   Space-Time Locking: To ensure different carriers interact at a unique space-time point, the system forcibly locks the upper limit of the interaction frequency to c.
   Resource Allocation: Under this locking, the amplitude for "spatial displacement" and the frequency for "causal interaction" form a binary conserved quantity, obeying the Pythagorean theorem: $v^2 + (f \cdot l_P)^2 = c^2$.
   Conclusion: $m \cdot v^2$ describes the dynamic proportion allocated to "spatial expansion" and "temporal causality" by the carrier during motion.

3. **Potential Space-Time Mapping (Logical Probability Statistics)**
   Mathematical Expression: $V_{\text{potential}} = \lim_{\rho \to 0} \frac{m \cdot l_P}{\rho}$
   Physical Logic: The "logical evolution domain" defined by the stable rule $\mathcal{R}$. It consists of blank cells not yet occupied by carriers, with infinite logical capacity but zero physical reality.

4. **Geometric Space-Time Mapping (Macroscopic Relationship Statistics)**
   Mathematical Expression: $g_{\mu\nu} = \text{Relational}(v, \rho, \nabla\rho)$
   Physical Essence: It originates from the density distribution differences of momentum units at macroscopic scales (whether mass density or spatial density) and their relative distribution relationships. It is not the deformation of physical reality, but rather the statistical projection of interaction paths within a complex relational network.

   Due to the invariance of the rules and the conservation of the evolutionary carriers, we can predict and potentially count space and time quantities. Therefore, space-time can serve as a metric for the evolutionary carriers, but neither the evolutionary carriers nor space-time possess covariance. Covariance primarily arises from different observational perspectives, statistical differences in inter-

action perception mechanisms, and macroscopic driving forces (such as gravitational time dilation). This theoretical closure integrates the core viewpoints of emergence physics, dynamical relativity, loop quantum gravity, and other theories, forming a unified evolutionary dynamics framework of space-time[11,13,14].

7.2 Conclusions

1. **Emergence of time and space:** Both time and space emerge simultaneously from state evolution — time corresponds to the count of evolutionary events

$$\sum \Delta t = N \cdot t_P$$

and space corresponds to the state distribution of evolutionary carriers (positions are calibrated by l_P lattices). Any statistics of time is essentially the statistics of the number of evolutionary events, and any statistics of space is essentially the statistics of the macro distribution of the evolutionary states of representational quantities. The macro continuity of spacetime originates from the causal continuity of evolutionary carriers (evolution step by step, no state jump), not the infinite divisibility of spacetime itself. Therefore, time and space have no absolute background, and both emerge synchronously depending on the state and evolution of physical reality.

2. **Unification of apparent absoluteness and intrinsic absoluteness:** The universe exhibits universal uniformity and metric consistency (constant speed of light c, Planck scales l_P and t_P are universal constants), which easily makes people mistakenly think that there is an absolute, uniformly flowing background spacetime (apparent absoluteness). In fact, this "sense of absoluteness" originates from the universe being a discrete evolution system — both time and space can evolve discretely based on the representational quantity m_0 with l_P and t_P as the basic steps, emerging a spacetime structure of "microscopic discreteness and macroscopic continuity". At the same time, the physical reality of the universe is absolute, and the eigenstates of matter and spacetime do not change with observation (intrinsic absoluteness). The "covariance" and "spacetime curvature" of relativity are only projection effects of macro observation, and the underlying spacetime is always flat, discrete and rigid. The two are unified under the framework of "intrinsic absoluteness and observational relativity".

3. **Dynamical essence and emergence conditions of relativistic effects:** The relativistic mass-energy equation statistically describes the spacetime state shaping ability; the general relativity field equation describes the interaction redundancy integral effect of matter in high-density fields, **and cannot be used to form the logic that "spacetime is curved, let alone that spacetime in turn shapes the motion of matter"**; special relativity describes the weakened perception and interaction ability effect of high-speed moving particles. The upper limit of the macro evolution amplitude of the underlying driving force of the universe is mathematically c, the upper limit of the evolution frequency is c, and the upper limit of the force interaction solution frequency is c. When the speed v breaks through from the cancellation state of the evolutionary carrier, the general relativity effect emerges; when $v \to c$, the special relativity effect emerges. Neither of them is spacetime curvature, but the statistical covariance emerging from the mass density field, weakened perception ability, cancellation and breaking under the condition of constant total spacetime shaping ability. This framework does not deny Einstein's theory of relativity, but reveals its dynamical essence [15].

4. **Establishment of the physical reality of the Planck scale:** Based on the minimum scales l_P and t_P of the generalized system, combined with the dual-c encoding of cosmic evolutionary

carriers and basic physical constants, the Planck scale (λ_P, t_P) is derived, clarifying its physical significance as the minimum evolvable unit of cosmic spacetime, and providing a core benchmark for the mapping between microscopic discrete spacetime and macro continuous spacetime. This conclusion is consistent with the research results of loop quantum gravity theory and quantum gravity phenomenology, proving that the physical reality of the Planck scale is a common prediction of quantum gravity theories [13,10].

5. **Essence of the mass-energy equation:** $E = mc^2$ is not a dynamical eigen-equation, but a spacetime state shaping equation — c^2 indicates that the spatial unit l_P and the time unit t_P emerge synchronously and separately, but are jointly coupled $(c = l_P/t_P)$,

$$mc^2 = m \times (\text{spatial emergence sampling}) \times (\text{time emergence sampling})$$

The intrinsic dynamical mass-energy equation is $E = mc$ (energy = momentum = force).

6. **Dynamical time and space:** Dynamically, the quantities emergent from the representational quantity m_0 in the time component or spatial component during the evolution process are mc, which represent the number of emergent events and spatial displacement respectively. That is, the essence of phenomena such as force, energy, momentum, heat, light, temperature, pressure, impact, and work is that a piece of matter (whole or part) produces new shaping in time or space. When the matter m as a whole cannot form the time or space state relationship distribution before interaction — that is, different parts of the original matter obtain different inertial states and cannot continue to evolve synergistically — destruction will occur. According to the core conclusion of the first part of this evolution theory, the information dynamics evolution system, information = relational state representation. Therefore, the universe is an information dynamics evolution system, and the real destruction is the destruction of its information structure relationship, leading to the inability to continue maintaining the spacetime relationship distribution. State evolution is driven by the speed of light, not by the emergent spacetime background.

7. **No mathematical singularities in the universe:** The cosmic system has no mathematical spacetime singularities, and the minimum physical spatial scale is the Planck scale l_P. All spatial scales we statistically use in applications are onlythe statistical performance of matter under specific density conditions. The intrinsic spatial quantity is $m \cdot l_P \cdot (x, y, z)$, which is determined bythe total amount and distribution of momentum units.

8. **Dialectical unity of discreteness and continuity:** Spacetime is composed of discrete Planck units $(l_P \times t_P)$ and does not have infinite subdivision. The source of macro continuity isthe causal continuity of evolutionary carriers — within each t_P,the carrier must transition l_P, traversethe causal path step by step, and there is no state jump. State jumps only occur in special events such as particle generation/annihilation and momentum unit decoupling. Therefore, the discrete base and continuous perception are dialectically unified within this framework.

References

[1] Xiao, Bo. (forthcoming). Unified Cosmic Mechanics Evolution Theory (VI): The Relationship Between Relativity, Classical Mechanics, and Quantum Mechanics [in press].

[2] Xiao, Bo. (forthcoming). Unified Cosmic Mechanics Evolution Theory (V): Reconstruction of Dynamical Relationships of Basic Physical Dimensions [in press].

[3] Xiao, Bo. (forthcoming). Unified Cosmic Mechanics Evolution Theory (XI): Fields and Particles — Deterministic Quantum Theory of Momentum Topological Coding [in press].

[4] Xiao, Bo. (forthcoming). Unified Cosmic Mechanics Evolution Theory (XIII): The Nature of Force [in press].

[5] Hestenes, D. (1990). The Zitterbewegung Interpretation of Quantum Mechanics. *Foundations of Physics*, 20(10), 1213–1232. — The "proper time" of electrons is precisely the phase of this internal oscillation, indirectly supporting the intrinsic evolutionary ability and intrinsic time.

[6] Schrödinger, E. (1930). Über die kräftefreie Bewegung in der relativistischen Quantenmechanik. *Sitzungsberichte der Preussischen Akademie der Wissenschaften*, 24, 418–428. — Intrinsic $\nu = 2mcc/h$, intrinsic time.

[7] 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 perfect spherical symmetry strongly supports the "momentum unit spherical symmetry encapsulation model" and "vector sum cancellation state" hypothesis proposed in this theory.

[8] Sciama, D. W. (1953). On the origin of inertia. *Monthly Notices of the Royal Astronomical Society*, 113(1), 34–42. Provides a classic field theory precedent, proving that "inertia originates from interaction" rather than "spacetime curvature".

[9] 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 reducing gravity/spacetime to information/thermodynamic processes is a recognized direction in cutting-edge physics.

[10] Rovelli, C., & Vidotto, F. (2014). Covariant loop quantum gravity (Cambridge Monographs on Mathematical Physics). Cambridge University Press. DOI: 10.1017/CBO9781139034555. — Consistent points: Loop Quantum Gravity (LQG) is currently the most mainstream physical discrete spacetime theory, advocating that spacetime is composed of discrete "spin networks", area and volume are quantized (with minimum units), and this discreteness is the quantum state of physical reality, providing mainstream physics endorsement for the l_p and t_p discrete units in this paper; the relational quantum mechanics emphasized by Rovelli resonates with the view of "evolution is existence" in this paper.

[11] Bombelli, L., Lee, J., Meyer, D., & Sorkin, R. D. (1987). Space-time as a causal set. *Physical Review Letters*, 59(5), 521–524. DOI: 10.1103/PhysRevLett.59.521. — Consistent points: Causal set theory holds that the essence of spacetime is a discrete set of events connected by "causal order", and the continuous Lorentz manifold is only a macroscopic approximation, directly supporting the core axioms of "time is event statistics" and "space is transition concomitant" in this paper, and overall logically opposes background-dependent grids, emphasizing dynamically generated causal structures.

[12] Hossenfelder, S. (2013). Minimal length scale scenarios for quantum gravity. *Living Reviews in Relativity*, 16(1), 2. — Consistent points: This paper comprehensively reviews the "minimum length" (Planck scale) appearing in various quantum gravity theories, demonstrates the existence of a fundamental discrete limit to physical measurement from a phenomenological perspective, provides a wide range of theoretical basis for λ_P and t_P in this paper as the minimum evolvable units of physical reality, indicating that this is a common prediction of quantum gravity.

[13] Brown, H. R. (2005). Physical relativity: Space-time structure from a dynamical perspective. Oxford University Press. — Consistent points: This paper opposes regarding spacetime as an independent geometric entity (geometric view), advocating that spacetime structure (such as time dilation and length contraction) is a reflection of material dynamical behavior, supporting the views of "spacetime non-covariance", "covariance is projection", and "spacetime is the metric of evolutionary carriers" in this paper, providing core theoretical support for the dynamical reinterpretation of relativistic effects.

[14] Laughlin, R. B. (2005). A different universe: Reinventing physics from the bottom down. Basic Books. — Consistent points: Nobel laureate Laughlin proposed that many macroscopic physical laws (including spacetime geometry) are emergent phenomena of microscopic many-body systems, supporting the dialectical unity view of "microscopic discreteness and macroscopic continuity" in this paper, and the core argument that spacetime is an emergent product of "momentum unit encapsulation and statistics".

[15] Einstein, A. (1905). Zur Elektrodynamik bewegter Körper. *Annalen der Physik*, 322(10), 891–921. DOI: 10.1002/andp.19053221004. — Consistent points: Citing Einstein's original text, it shows that this paper reinterprets rather than denies relativity. Einstein described the phenomenon of covariance, while the theory in this paper provides the underlying dynamical mechanism (momentum unit interaction efficiency), reflecting the inheritance and innovation of the theory.