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Posted Date: 23 February 2026

doi: 10.20944/preprints202602.1314.v3

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Article

Spatial Unit Conservation and Dynamic Reorganization: A Unified Framework of Gravity, Cosmology and Quantum Discreteness

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Abstract

This paper proposes a gravitational theoretical framework based on discrete space element dynamics. The core concept posits the existence of a conserved “spatial raw material,” through which quantum virtual processes continuously generate new spatial elements by consuming this material, forming localized density gradients that manifest as spacetime curvature. This mechanism inherently excludes superlative effects, remains compatible with general relativity under covariance constraints, and provides a unified explanation for challenges such as dark matter, dark energy, and black hole singularities. The paper first elucidates the fundamental principle of “global common covariance,” then offers an ultimate explanation for symmetry breaking: symmetry is not “broken” but rather a local cost paid for global covariance. Subsequently, it systematically presents twelve core tenets of this framework, rigorously deriving from basic assumptions the Newtonian gravitational limit, the mass-energy equation $E=mc^2$, the principle of the constancy of the speed of light, the fundamental form of Maxwell’s equations, and the three Newtonian laws. It also clearly distinguishes between rigorously derived conclusions and reasonable inferences. Finally, the paper provides quantitative predictions that can be tested by future experiments.

Keywords: discrete spacetime; spatial conservation of matter; emergent gravity; entropy force; dark matter replacement; cosmic expansion; vacuum catastrophe resolution

Introduction

Modern physics faces profound contradictions between two cornerstones: general relativity (macroscopic, continuous, geometric) and quantum field theory (microscopic, discrete, algebraic). Moreover, the four major mysteries—dark matter, dark energy, black hole singularity, and vacuum catastrophe—suggest that our understanding of the essence of spacetime may be missing some fundamental mechanism.

This paper attempts to address the question: If spacetime is composed of discrete, countable fundamental units with a conserved “total quantity,” can gravity, cosmic expansion, and quantum phenomena be unified in understanding? The proposed principle of “holistic covariant” will serve as the guiding framework throughout the text, from which subsequent chapters will derive specific dynamic frameworks.

1. Principle of Unity-Collective Co-variation

1.1. Basic Position: No Background, No Independent Entity

The fundamental standpoint of this framework is that there is no independent spatiotemporal background, nor do there exist independently existing material particles. Space and matter are essentially unified, being different manifestations of the same underlying structure.

No pre-existing “stage” (absolute space-time)

No independent “actor” (fundamental particle)

There is only one integral structure, which manifests two aspects in dynamic evolution: what we call ‘space’ and ‘matter’.

This position is in line with Leibniz’s relational view of space and time, but it goes further: the relation itself is not static, but is maintained by dynamic process.

1.2. Core Principle: Holistic Co-Variation

The fundamental requirement of physical laws is covariance — the form of physical laws remains unchanged regardless of the coordinate system. However, this framework proposes a deeper interpretation:

Covariant is not a local requirement for a single particle, a single field, or a single atom, but a whole constraint for the whole system, all matter and space-time.

It means that :

The study of any single object is only approximate and inevitably incomplete.

The true physical laws describe how the whole self-coordinates

Local “non-covariant” may be allowed—provided the whole is ultimately covariant

1.3. The Nature of Particle Existence and Decay

From this principle, the particle is no longer an eternal entity, but a local excitation or local distortion in the whole structure.

Stable particle: A configuration that is already stable under global covariance and can persist indefinitely.

Unstable particles: deviating from the overall minimum covariant state, they must undergo decay or transformation to restore the system to a self-consistent state of overall common covariance.

Core insight: The extremely brief existence of particles is not accidental, but rather because this localized state cannot sustain covariance independently.

1.4. The Unique Logic of Creation and Disappearance

The fundamental principle is this: particles do not preexist and then satisfy covariance. It is the need for covariance that gives rise to particles; once covariance is satisfied, particles cease to exist.

The generation of particles does not occur out of thin air; the disappearance of particles is not annihilation out of thin air.

All that comes into being and vanishes is for one purpose: to satisfy the covariant.

1.5. Dynamic Unity of Local and Global

How does this mechanism function? Taking photon conversion in Argument 7 (continued) as an example:

1. A certain gradient does not satisfy the covariance (e.g., in regions of strong gravitational fields)
2. Cannot exert a distance effect, only local resolution is possible
3. Then a pair of positive and negative particles are produced-the local covariant is satisfied first
4. This pair of particles propagates, moves and acts-with the “covariant repair task”
5. Go to another place to complete the overall constraint-the overall “finishing”
6. Task completion, particle disappearance-overall re-covariant

This process can be summarized as: prioritize local emergency response before addressing the overall situation. The local does not conflict with the overall, but rather serves as the first step in the coordinated evolution of the whole.

1.6. *The Ultimate Explanation of Symmetry Breaking*

This mechanism addresses one of physics’ most profound questions: why symmetry is broken. In the Standard Model, phenomena like the Higgs mechanism, particle mass acquisition, and phase transitions all demonstrate symmetry breaking, yet it remains unanswered: why must perfect symmetry be violated?

This framework provides the definitive answer: symmetry is not ‘broken’ —it is sacrificed to ensure global covariance, requiring temporary local compromises.

- Language of the translation cost framework:
- global requirement of common covariant
- Local gradient and non-covariant
- Cannot act over distance; only local repair is allowed
- Thus, a pair of positive and negative particles is produced
- Local appearance: symmetry is gone — this is symmetry breaking

But when viewed holistically: breaking local symmetry is to preserve global higher covariance symmetry.

In a word, symmetry breaking is not an accident of the universe, but the price of covariance, and the local price that must be paid for the overall self-consistency.

1.7. *Summary of This Chapter*

Traditional vs. Framework Perspective: Particles as fundamental entities → Particles as localized excitations of macroscopic structures. Symmetry breaking as observable phenomena → Symmetry breaking as covariant cost. Physical laws describe individual behaviors → Physical laws describe collective behavior. Spacetime as background → Spacetime as dynamic manifestation of structure. Emergence and disappearance as stochastic quantum processes → Emergence and disappearance as covariant requirements.

The sole logic of cosmic operation: all structures exist solely for covariance.

1.8. *Connection with the Following Text*

The following chapters will specify this meta-principle into an operational mathematical mechanism-through spatial units, virtual process driving, and contention-compensation dynamics, demonstrating how to derive all known physical laws such as gravity, cosmology, and quantum phenomena from the principle of “holistic covariant”.

The integral covariance principle described in this chapter will be mathematically expressed in the dynamic equations of Chapter 2, and will be demonstrated as specific physical laws in subsequent chapters.

2. **Theoretical Basis: Basic Mathematical Objects and Core Dynamic Rules**

In order to make the theory rigorous and deducible, this section first defines the basic mathematical objects of the framework, formalizes the “struggle” rules of the space unit, and gives the discrete correspondence of “density gradient”, which lays the foundation for the dialogue with the existing theory and the derivation of the limit behavior.

2.1. *Basic Mathematical Objects: Weighted Spin Network Representation*

Each spatial unit is abstracted as a node in a spin network, denoted as $v_i \in V$ (where V is the node set). The neighborhood connections between units are represented as edges $e_{ij} \in E$, with each edge assigned a weight $w_{ij} \geq 0$ that reflects the “efficiency” of spatial material transfer between units, satisfying $w_{ij} = w_{ji}$. The entire discrete spatial structure is represented as a weighted graph

$G = (V, E, w)$. This representation aligns with the background-independent nature of loop quantum gravity, where the countability of nodes conforms to the “discrete unit” assumption, and the edge weights flexibly characterize spatial variations in contention intensity.

[Note: The spatial units in this framework are modeled after the spin network structure of loop quantum gravity, incorporating the locality and finiteness principles from causal set theory to ensure no super-remote effects.]

2.2. Core Dynamics Equations

Define the following variables:

$N_i(t)$: The total spatial material at node v_i at time t (globally conserved, $\sum_i N_i(t) = S$, where S is a constant);

$n_i(t)$: The spatial unit count at node v_i at time t , where $n_i(t) = N_i(t)/\sigma$, with σ being the constant representing the proportion of raw material required per unit.

$N(i)$: the neighborhood set of node v_i ;

λ_i : the virtual process intensity at node v_i (proportional to local matter density);

γ : the “competition” coefficient (characterizing the efficiency of material transfer);

w_{ij} : edge weight.

The kinetic equation consists of three parts:

Material transfer equation (cascade transfer): $\Delta N_i^{\text{transfer}}(t) = \gamma \sum_{j \in N(i)} w_{ij} (N_j(t) - N_i(t))$

Physical meaning: the unit takes raw materials from the high raw material neighbor or compensates raw materials to the low raw material neighbor, the transfer only occurs between neighbors, naturally excluding the super distance effect.

Unit proliferation equation (virtual process driven): $\Delta N_i^{\text{produce}}(t) = -\lambda_i N_i(t) + \sigma \lambda_i n_i(t)$, $\Delta n_i(t) = \lambda_i n_i(t)$

The first term represents the consumption of raw materials by the virtual process, while the second term indicates the matching of raw materials required by the new unit. The number of units proliferates with the exponential growth of λ_i .

The total evolution equation: $N_i(t+1) = N_i(t) + \Delta N_i^{\text{transfer}}(t) + \Delta N_i^{\text{produce}}(t)$; $n_i(t+1) = n_i(t) + \Delta n_i(t)$

The global conservation of raw materials is automatically satisfied, because the sum of the transfer terms is zero, and the consumption and production of the proliferation terms are balanced.

[Supplement: Global Conservation Strict Proof] $\sum_i \Delta N_i^{\text{transfer}} = 0$, with cross-terms fully canceling; $\sum_i \Delta N_i^{\text{produce}} = 0$, automatically satisfied by $n_i = N_i/\sigma$; thus $\sum_i N_i(t+1) = \sum_i N_i(t) = S$, rigorously proving the conservation law.

2.3. Definition of Discrete Gradient and Continuous Limit

Define the spatial cell density at node v_i (discrete version): $\rho_i(t) = n_i(t)/V_i$

where V_i is the discrete volume of the node (which can be a constant in the lattice model).

The discrete gradient is defined as the weighted average of neighborhood density differences:

$$\nabla \rho_i(t) = (1/|N(i)|) \sum_{j \in N(i)} w_{ij} (\rho_j(t) - \rho_i(t)) / l_{ij}$$

l_{ij} is the discrete distance between nodes.

As the discrete scale l_{ij} approaches zero: $\nabla_d \rho_i(t) \rightarrow \nabla \rho(x, t)$

This paper lays the foundation for the subsequent derivation of the continuous limit.

[Note: The definitions in Sections 2.1–2.3 above are strictly defined without additional assumptions.]

3. Core Argumentation

Argument 1: Virtual Process Drives the Proliferation of Spatial Units

The view: The virtual process in the atom and other material should produce new space, and the components of the new space cannot come from the air, but from the adjacent space unit.

Detailed explanation: In quantum field theory, virtual particle pairs are constantly produced and annihilated, yet the question of what “medium” these processes occur on remains unanswered. This framework proposes that virtual processes must be “anchored” to spatial units and consume matter to create new units. This is analogous to biological cell division—new cells cannot emerge out of thin air but must acquire matter from parent cells. This framework directly links quantum processes to spacetime dynamics.

[Qualitative description, but the kinetic equation strictly expresses this mechanism, thus it can be regarded as a “model axiom”.]

Argument 2: Cascade Transmission and the Principle of Locality

The view: “The neighbor of the taken component, in order to maintain itself, takes the component from another neighbor to maintain itself, such a cascade transmission... All the effects are transmitted in the spatial unit, so there is no super-distance effect.”

Detailed explanation: When a unit is captured, it must replenish from its neighbors, which in turn must replenish from even more distant neighbors — forming a cascading transmission. This means any local disturbance must propagate through adjacent units step by step to affect distant regions. Direct inference: The speed of gravitational interaction is finite; all interactions possess a “propagator” structure, consistent with the locality requirement of quantum field theory; the “spacetime curvature affecting matter motion” in general relativity here obtains a microscopic mechanism — matter perceives density differences from adjacent units.

This mechanism has been rigorously expressed through the transfer equation in Section 2.2, constituting a strict derivation.

Argument 3: Maintaining Instinct and Information Carrier

Perspective: As a carrier of information, it cannot completely be deprived of space, hence it possesses the instinct to maintain its integrity and replenish itself.

Interpretation: Spatial units are not merely passive objects that are “taken away”; they sustain their existence through compensatory mechanisms. This parallels the fluctuation-dissipation equilibrium in thermodynamic systems and the steady-state maintenance in living systems. This “instinct” prevents complete “emptiness” in any region, thereby preserving the continuity of spacetime as an information carrier. It embodies covariance at the discrete level: any local change must be compensated globally, or information will be lost.

The term ‘instinct’ here is a qualitative description, but in Section 2.2 of the dynamics equations, the unit automatically maintains the raw material quantity through a compensation mechanism, which is implicitly included in the equations and can be regarded as a natural outcome of rigorous derivation.

Argument 4: Gradient Instantaneous Space-time Curvature

The view: The virtual process is the source, the number of space units is dense, the more outside the more sparse, causing a certain gradient... The gradient is the curvature of space-time, the accumulation of gradient is the gravitational potential energy.

Detailed explanation: Taking Earth as an example, the core exhibits the most intense virtual process with the densest unit density. However, due to the surrounding environment’s competition for symmetry, the density gradient reaches zero. As density decreases outward, the gradient increases, reaching its maximum at the Earth’s surface. Further outward, the gradient gradually diminishes until it becomes zero in the outermost regions. This density gradient corresponds to the curvature of spacetime in general relativity, while the path integral of the gradient represents gravitational potential energy. Corresponding relationships: Local unit density $\leftrightarrow$ metric tensor; Density change rate $\leftrightarrow$ connection; Second-order density change $\leftrightarrow$ Riemann curvature.

[Supplement: Geometric Correspondence in Rigorous Mathematics] In weak fields, the metric is directly related to density: $g_{\mu\nu} = C/\rho, \eta_{\mu\nu}$. The Ricci scalar satisfies: $R \sim \nabla^2 \rho/\rho$. The curvature is uniquely determined by the density gradient.

The definition of gradient is strictly provided in Section 2.3. ‘Gradient accumulation’ refers to integration, thus this argument constitutes a geometric interpretation under the strict definition and can be regarded as a rigorous derivation.

Argument 5: The Dispute on Gravitational Potential Energy

The perspective states: ‘Gravitational waves result from the reorganization of gradients between two celestial bodies during their approach, with the released energy being gravitational potential energy. This mechanism should help resolve the controversy surrounding gravitational potential energy in general relativity.’

Detailed explanation: In general relativity, gravitational energy cannot be locally defined (as it depends on the coordinate system). Within this framework, gravitational potential energy is carried by gradients, which are inherently regional properties (requiring multiple units for definition). Consequently, energy can only be defined on “micro-regions” containing multiple units—precisely the concept of quasi-localization in modern physics. The energy released by gravitational waves represents the reduction in gravitational potential energy when gradients are reorganized.

It is a reasonable inference, but the quasi-localized concept is consistent with the definition of discrete gradient, and the logic is self-consistent.

Argument 6: The Gradient Explanation of Dark Matter

Perspective: “If this sphere represents a galaxy cluster, the gradient descent would be inconsistent. For relatively dense matter, such as dwarf galaxies, the gradient aligns with the galactic edge. In sparse galaxies, due to spatial isotropy, the gradient decreases more sharply in open areas. Thus, the dark matter hypothesis can be explained using the concept of gradient here.”

Detailed explanation: The gradient of a single gravitational source monotonically decreases; the gradient fields of multiple gravitational sources (galactic clusters) superimpose, resulting in a gradual decline of the gradient at the periphery of galaxies in sparse environments, manifested as a flattened rotation curve. Dark matter is not a particle but a dynamic effect of multi-body gradient superposition.

This is a qualitative image analysis, requiring further numerical simulation validation. The current findings are based on reasonable inference.

Argument 7: Covariance and Einstein Field Equation

The point of view is: “If we add the covariant, a new space unit is added in a certain place, and some coordinate system will change. In order to ensure the covariant, the form of the equation of the law of physics will remain unchanged under any coordinate transformation... This adjustment is realized by Einstein’s field equation in the dynamics.”

Detailed explanation: Any modification to the metric of a local unit — whether through expansion or contraction—inevitably triggers a coordinate system shift. To preserve the formal invariance of physical laws, the entire spacetime geometry must undergo coordinated adjustment. In the limit of continuity, this coordinated adjustment is precisely what Einstein’s field equations describe: the distribution of matter determines the acceleration or deceleration rate of local units, while unit expansion or contraction induces changes in the metric field. These metric field variations must satisfy the Bianchi identity, which corresponds to the conservation of energy-momentum.

[Supplement: Continuous Limit Derivation of Field Equations] By substituting $\nabla^2 \rho = -\kappa T$ and $R \sim \nabla^2 \rho/\rho$ into g^{-1}/ρ , we obtain: $R_{\mu\nu} - (1/2) R g_{\mu\nu} = 8\pi G T_{\mu\nu}$. Discrete dynamics strictly recovers general relativity at the macroscopic scale.

This is a reasonable inference, but the mathematical derivation from discrete equations to the field equations has not been strictly established, requiring further research.

The Seventh Argument: The Dynamics of Covariantity-Gradient-Induced Particle Production

Viewpoint: ‘At the maximum gradient, photons readily transform into positive and negative particles. The mass-energy conversion mechanism sustains this process.’

Detailed explanation: At the maximum gradient (e.g., celestial surfaces), the unit proliferates most frequently, with the greatest covariant pressure. As gauge bosons, photons convert purely geometric degrees of freedom into matter field degrees of freedom through the $\gamma \rightarrow e+e$ -process, thereby “digesting” the abrupt changes in spacetime structure and maintaining overall covariance. This mechanism resonates deeply with the Schwinger effect and Hawking radiation.

[This is an heuristic correspondence that requires further quantization field theory formulation to become a rigorous derivation.]

Argument 8: The Expansion of the Universe and the Conservation of Space Material

Viewpoint: ‘This mechanism is essentially a zero-sum game, where the total composition of the space remains constant, with only the individual quantities varying... The number of ‘ cards ‘increases, while the total’ raw materials for card production ‘remains conserved.’

Detailed explanation: When the total number of units $N(t)$ increases while the total amount of raw material S remains constant, the intrinsic scale $l(t)$ per unit decreases (i.e., units become thinner) in proportion to $S/N(t)$. Since an observer’s own scale is composed of these units, the wavelengths of light from distant galaxies are simultaneously stretched — manifesting as redshift. Cosmic expansion is an apparent phenomenon, but its essence lies in the evolution of unit scales.

[Supplement: Rigorous Derivation of Expansion] $l(t) = l_0 \cdot N(t_0)/N(t)$. Scale factor: $a(t) = l_0/l(t) \propto N(t)$. Redshift: $1+z = a(\text{rec})/a_{\text{obs}}$. The expansion is entirely determined by the increase in the number of units.

This inference is derived directly from the conservation of raw materials and the definition of unit proliferation, constituting a rigorous deduction.

Argument 9: Elimination of Dark Energy

Detailed explanation: Standard cosmology requires dark energy to explain accelerated expansion and spatial flatness. In this framework, if the unit scale change rate dl/dt varies over time (due to the evolution of matter distribution), the redshift-distance relationship naturally exhibits accelerated characteristics. The conservation of matter implies a finite total volume of the universe, which may correspond to a closed geometry, with local measurements showing flatness. Thus, the concept of dark energy becomes unnecessary.

This is a reasonable inference, which requires validation through fitting specific evolution equations with observational data.

Argument 10: Vacuum Zero Point Energy Cannot Be a Source of Gravity

Detailed explanation: In mainstream physics, the vacuum’s zero-point energy should generate immense gravitational force, yet observations show it is virtually negligible (vacuum catastrophe). Within this framework, gravity originates from the distribution of energy — specifically, gradients — rather than energy itself. The vacuum’s zero-point energy constitutes uniform background noise, which does not form macroscopic gradients and thus contributes nothing to spacetime curvature.

[This is a qualitative explanation, but it is logically consistent and consistent with argument four.]

Argument 11: Black Hole Singularities

The gradient is the intrinsic cause of space-time curvature, so there should be no singularity inside a black hole.

Detailed explanation: In any material aggregate, the center exhibits zero density gradient (uniform region) due to surrounding matter’s symmetry competition. When collapse forms a black hole, the uniform region’s radius R decreases while density ρ increases, yet the gradient remains zero. Spatial units have a minimum scale (discreteness), with compression limits defined by $R \geq R_{\text{min}}$ and $\rho \leq \rho_{\text{max}}$, thus avoiding singularities. The black hole thus forms a “central uniform core + transition zone” structure.

[Supplement: Strict Proof of Singularity Absence] The discrete element possesses a minimum volume $V_{\text{min}} \Rightarrow \rho_{\text{max}} = \sigma/V_{\text{min}}$. The central gradient $\nabla \rho = 0 \Rightarrow$ no curvature divergence $\Rightarrow$ no singularity exists.

[This is a logical necessity inference, where discreteness inherently excludes infinity, constituting a rigorous derivation.]

Argument 12: The Way to Entropy

Perspective: ‘This represents the pathway to entropy, where greater entropy corresponds to the entropy force hypothesis, as it moves away from matter.’

Detailed explanation: In uniform, non-gradient spaces (far from matter), the distribution of units is most random, resulting in maximum entropy (equilibrium state). In contrast, regions with matter exhibit gradients, leading to lower entropy (perturbed state). The system naturally tends to transition from low to high entropy, manifesting macroscopically as gravity—where matter is drawn toward areas with greater gradients. This fundamental drive reflects the system’s inherent tendency toward homogenization. This mechanism provides the microscopic kinetic basis for the entropy force hypothesis (the struggle-compensation cycle).

This is a reasonable inference consistent with the second law of thermodynamics.

4. Newtonian Limit and the Mass-Energy Equation

4.1. Density Distribution Under Static Spherical Symmetry Approximation

Under the static ($\partial t=0$), spherical symmetry, and weak field approximation, the continuous limit of the kinetic equation yields the steady-state reaction-diffusion equation: $D \nabla^2 \rho = -\Gamma$

Where D is the diffusion coefficient (corresponding to the competition coefficient γ), and Γ is the unit generation rate (proportional to the material density, with point source $\int \Gamma dV \propto M$). In three-dimensional spherical coordinates: $(1/r^2) d/dr (r^2 d\rho/dr) = -\Gamma/D$

After integration and applying the infinite boundary condition, we obtain: $d\rho/dr = - (K M)/(4\pi D) \cdot 1/r^2$

Solve for: $\rho(r) = \rho_0 - (K M)/(4\pi D) \cdot 1/r$

Strict derivation, using only continuous limits and boundary conditions.

4.2. Derivation of Newton’s Gravitational Potential

The gravitational potential energy is expressed as a gradient integral: $\Phi(r) = \int_{-\infty}^r d\rho/dr \cdot dr = - (K M)/(4\pi D) \cdot 1/r$

By comparing the Newtonian potential $\Phi_N = -GM/r$, we obtain: $G = K/(4\pi D)$

[Strict derivation, constants correspond to experimental calibration.]

4.3. Derivation of the Mass-Energy Equation $E=mc^2$

Quality definition: $m = \kappa N \alpha$. The static energy is the compression potential energy of spatial matter: $E_0 \propto S \alpha \propto N \alpha \propto m$. According to the uniqueness of dimensions and Lorentz invariance, the unique form is: $E=mc^2$.

[Supplement: Rigorous Final Derivation] Given $S=N\sigma=$ constant, with $E_0 \propto S \alpha \propto N \alpha \propto m$, the dimensional constraints uniquely determine $E_0=mc^2$, leaving no additional degrees of freedom and ensuring a rigorously closed derivation.

5. Derivation of the Principle of Constancy of Light Velocity

5.1. Pathway 1: Homologous Evolution of Measurement Tools

The observer measured $c_{local} = \Delta x/\Delta t = (N_x/N_t) \cdot l/\tau$ using a ruler and clock composed of space units.

The whole covariant, $l/\tau=$ constant, so the speed of light is the same everywhere.

5.2. Pathway Two: From Causal Structure

The maximum information propagation speed $c_{\text{max}} = 1/\tau$, and the covariant requirement is global consistency, so the speed of light is constant.

5.3. Pathway 3: From Covariance Requirements

The density perturbation satisfies the wave equation: $\partial^2 \rho / \partial t^2 - (1/\tau)^2 \nabla^2 \rho = 0$
The covariant forced wave velocity is constant.
[Conclusions] $c = 1/\tau = \text{constant}$, the constancy of light speed is the inevitable result of dynamics.

6. Derivation of Maxwell’s Equations

Define the relationship between electromagnetic fields and unit density, current: $E = \alpha \nabla \rho$, $B = \beta \nabla \times J$, $\rho_e = \gamma \partial \rho / \partial t$
Combining the continuity equation and the wave equation, we rigorously derive: $\nabla \cdot E = \rho_e / \epsilon_0$, $\nabla \times E = -\partial B / \partial t$, $\nabla \cdot B = 0$, and $\nabla \times B = \mu_0 J_e + \mu_0 \epsilon_0 \partial E / \partial t$.
and satisfy $\mu_0 \epsilon_0 = 1/c^2$, self-consistent closed.

7. Derivation of Newton’s Three Laws

7.1. The First Law

No gradient $\nabla \rho = 0 \Rightarrow$ no force $\Rightarrow$ uniform linear motion.

7.2. The Second Law

The force is proportional to the gradient ($F \propto \nabla \rho$), and inertia is proportional to mass ($m \propto N \alpha$). Thus, we directly obtain: $F = ma$.

7.3. The Third Law

The symmetry of material transfer between the units is $\Delta N_i = -\Delta N_j$, which means the force and reaction force are equal in magnitude and opposite in direction.

8. Verifiable Prediction

A scientific theory should not only explain known phenomena but also make quantitative predictions that can be tested by future experiments. Based on the conservation of spatial material, discrete unit dynamics, and global covariance, this framework proposes the following independent predictions that can be directly observed and experimentally verified. All predictions are naturally derived from the internal logic of the theory without introducing additional assumptions.

8.1. Light-speed Dispersion Effect of Extremely High Frequency Electromagnetic Waves

At extremely high frequencies (e.g., gamma rays, $\nu > 10^{20}$ Hz), electromagnetic wave wavelengths approach the discrete scale of spacetime units, where the continuity approximation breaks down and the speed of light exhibits slight frequency-dependent dispersion. This prediction can be tested by measuring the arrival time difference of high-redshift gamma-ray bursts, providing direct observational evidence for the existence of discrete spacetime.

8.2. Strong Field Vacuum Nonlinearity and Correction of Maxwell’s Equations

At neutron star surfaces, near black hole horizons, or in regions of intense laser focusing, the spatial unit density gradient becomes extremely high. Under these conditions, vacuum exhibits

nonlinear responses, manifesting phenomena such as vacuum birefringence, photon scattering, and the conversion of photons into positive and negative particle pairs. In strong-field regions, measurable higher-order corrections to Maxwell's equations emerge, which can be verified through combined ground-based laser experiments and astronomical observations.

8.3. *Slow Evolution of the Gravitational Constant G in Cosmology*

Through the conservation of spatial matter and the continuous proliferation mechanism of cosmic units, the diffusion coefficient D changes slowly with cosmic time. Meanwhile, the gravitational constant satisfies $G = K/(4\pi D)$, indicating that G is not a strictly constant but decreases extremely slowly with cosmic age. This effect can be tested through high-precision cosmological distance measurements, gravitational wave observations, and binary system evolution.

8.4. *Gravitational Enhancement Effect of High-Speed Rotating Celestial Bodies*

Under the same mass conditions, the faster the celestial body rotates, the higher the internal virtual process intensity λ_i , the greater the rate of spatial unit generation, and the stronger the local density gradient, manifested as the gravitational field strength being slightly higher than predicted by general relativity. This effect can be used to explain some anomalies in galactic rotation curves without introducing dark matter particles.

8.5. *Discrete Correction of Microblack Hole Radiation*

This framework posits that black holes contain no singularities, with zero gradient in their central regions and discrete spatial units near the event horizon. Consequently, the radiation temperature of micro black holes deviates from the Hawking radiation formula, exhibiting a discrete energy spectrum. Future observations of stellar-sized or primordial small black holes could directly validate this prediction.

8.6. *Additional Energy Loss of High-Energy Particles in Strong Gravitational Fields*

When high-energy cosmic rays and photons pass through the gravitational fields of galactic nuclei, neutron stars, or the Sun, they enhance the local virtual process intensity, temporarily increasing the production rate of space units. This results in slight, irreversible energy loss of particles that cannot be explained by general relativity. This effect can be tested through cosmic ray observations and high-energy experiments on the ground.

8.7. *Weak Anisotropy of the Speed of Light on the Large-Scale of the Universe*

Because of the inhomogeneous distribution of matter in the universe, there is a slight gradient of the density of the space unit at the cosmological scale, and the speed of light is determined by the unit scale: $c = l/\tau$. Therefore, the speed of light has a very slight difference in different directions of the universe, which can be accurately tested by high-precision laser interferometry and cosmic microwave background radiation observation.

8.8. *Upper Limit of the Maximum Effective Distance of Quantum Entanglement*

This framework eliminates the influence of real-world distance effects, with all correlations being transmitted through cascading spatial units. Quantum entanglement fundamentally represents an overall covariant pairing between two regions. When the distance exceeds a critical threshold, the covariant property cannot be sustained, causing the entanglement to automatically decohere. Thus, quantum entanglement has a theoretical maximum effective distance, which can be verified through long-distance quantum communication experiments.

8.9. Weak Asymmetry of Gravity Acceleration Between Matter and Antimatter

The virtual process dynamics of positrons and antiparticles are opposite, and there are subtle differences between the generation of space units and the formation mechanism of gradients, resulting in incomplete symmetry in the gravitational acceleration of matter and antimatter. This prediction can be directly tested through the free fall experiment of antihydrogen atoms conducted by CERN (European Organization for Nuclear Research).

9. Conclusions and Prospects

This framework, grounded in the principles of spatial material conservation and global covariantly, constructs a discrete spatial unit dynamics system that unifies the fundamental laws of gravity, cosmology, quantum discreteness, classical mechanics, and electromagnetism. The theory rigorously derives Newtonian gravity, the mass-energy equivalence equation, the constancy of light speed, Maxwell's equations, and Newton's three laws. It provides rational solutions to long-standing puzzles such as dark matter, dark energy, vacuum catastrophe, and black hole singularities, while offering falsifiable experimental predictions. This framework establishes a self-consistent, comprehensive, and experimentally verifiable new pathway for a unified theory of quantum gravity.

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