Phase Ontology: Universal Unified Velocity Dynamics

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Abstract

There is a fundamental schism between classical physics and quantum physics: the former's motion is described by Newton's laws, while the latter relies on a probabilistic interpretation of the wave function. The two cannot be unified at a fundamental level. Quantum entanglement has long been imbued with the mystical notion of "nonlocal instantaneous action," lacking any real propagation medium or dynamical mechanism. Research on the zero-point field has remained at the level of quantum fluctuations and has never been treated as a universal dynamical substrate. This paper proposes phase ontology: the universe contains only the zero-point phase cavity field (eigenfrequency $\omega_0 \approx 10^{44}$ Hz, Hz, Planck scale) and phase-locked standing waves (closed loops). It abandons frequency subtraction in favor of the frequency ratio ω_0 / ω as the core driving force, and together with the mass ratio m0/m and the friction ratio γ_0 / γ, constructs a universal unified velocity equation $v = c\left(\frac{\omega_{\text{ph}}}{\omega}\right)\left(\frac{m_0}{m}\right)\left(\frac{\gamma_0}{\gamma}\right)$. The critical condition for motion $\omega \cdot m \le 3\times10^{-7}\ \text{Hz}\cdot\text{kg}$ is derived. The model uniformly explains: the vacuum speed of light (c) for photons, measurement-induced superluminal entanglement correlation ($\sim 10^6 c$), the Brownian motion threshold, macroscopic inertial locking, and the phase-gradient origin of celestial orbital motion. Conclusion: micro and macro follow the same physical rule; quantum entanglement is real superluminal propagation in the zero-point cavity field; the mystique of nonlocality is completely eliminated.

Keywords: phase ontology; zero-point phase cavity field; frequency ratio; unified velocity equation; quantum entanglement; critical motion threshold; phase closed loop

1 Introduction

The core dilemma of modern physics lies in two incommensurable sets of rules: the macroscopic world obeys classical mechanics and general relativity, while the microscopic world obeys quantum mechanics. This split is most acute in the two major problems of the origin of motion and quantum entanglement. Why does a photon move at the precise speed *c*? Why can't a stone move spontaneously? Why does quantum entanglement exhibit instantaneous correlations but no physical signal-carrying medium can be found? These questions have long remained unanswered.

Since the EPR debate, quantum entanglement has been confirmed by Bohr, Bell, and subsequent experiments (Aspect, 1982; Micius, 2017) as a real phenomenon, but its essence has always been shrouded in mystical formulations such as "nonlocality", "action at a distance", and "mysterious instantaneous synchronization". Mainstream theory treats entanglement as a holistic property of quantum states, not acknowledging the involvement of any real physical medium. However, this stance contradicts the fundamental spirit of physics—the search for causality, media, and mechanisms. The rapid development of satellite-based quantum communication, particularly the Micius satellite's demonstration of entanglement distribution over 1200 km[1], has made the question of the underlying mechanism of entanglement more pressing than ever.

Research on the quantum vacuum zero-point field (ZPF) has a history of a hundred years (Planck, Casimir effect, Haisch et al.'s attempts to explain inertia), but the mainstream treatment has always remained at the level of random fluctuations and has never been elevated to a dynamic substrate determining motion speed. In particular, in traditional theory, speed either comes from external forces (Newton's law F=ma) or from wavefunction evolution; there is no unified velocity formula covering photons, particles, macroscopic objects, and even entanglement correlations. Recent theoretical work has revisited the role of the vacuum field in quantum mechanics, showing that the zero-point radiation field is central in allowing a particle subject to a conservative binding force to reach a stationary state of motion[2]. A more fundamental flaw is that at extremely large scales (e.g., the ratio of the zero-point field frequency to optical frequencies $\omega_0 / \omega_{\text{ph}} \sim 10^{29}$), the subtraction difference $\omega_0 - \omega$ completely loses resolving power—regardless of whether ω is $10^{15}\,Hz$ or $10^{9}\,Hz$, subtraction from ω_0 yields approximately ω_0 itself, failing to distinguish dynamical differences between different systems.

The innovative path of this paper includes:

Proposing the zero-point phase cavity field (ZPCF) as the sole absolute substrate of the universe, with its eigenfrequency at the Planck scale and a three-dimensional cubic figure-eight topological structure serving as the absolute reference for phase closure.

Abandoning frequency subtraction and adopting the frequency ratio ω_0/ω as the dynamical core; this ratio has a dynamic range up to 10^{44} and can sensitively distinguish the motion capabilities of objects with different frequencies.

Establishing a dimensionless unified velocity equation containing frequency ratio, mass ratio, and friction ratio, and calibrating the constant using the photon standard state.

Deriving the critical product $\omega \cdot m \leq 3\times10^{-7}$ Hz·kg, naturally partitioning microscopic mobility and macroscopic locking, and explaining the size threshold of Brownian motion.

Reinterpreting quantum entanglement as a real superluminal phase propagation process in the zero-point cavity field after measurement-induced low-frequency standing waves, eliminating the mystical fog of nonlocality.

Chapter 2 defines the axioms and fundamental physical quantities; Chapter 3 constructs the unified velocity dynamics equation and completes constant calibration and boundary condition proofs; Chapter 4 provides quantitative verification in scenarios including photons, entanglement superluminal correlation, Brownian motion, macroscopic rest, and gravitational orbits; Chapter 5 discusses theoretical comparisons and scientific value, noting complementary relationships with classical and quantum theories as well as limitations; Chapter 6 summarizes the paper and proposes directions for experimental verification.

2 Fundamental Axioms and Core Definitions of Phase Ontology

2.1 Core Axioms at the Foundational Level

Axiom 1 (Axiom of Existence): There are only two types of entities in the universe: the zero-point phase cavity field and phase-locked standing waves (closed loops). All stably existing entities (particles, atoms, molecules, macroscopic objects, living organisms, consciousness) can be reduced to phase-locked closed loops at different levels. The stability of a closed loop originates from the phase-locking constraint between its phase and the cavity field; once locked, it possesses a definite frequency, mass, and spatial distribution.

Axiom 2 (Axiom of Substrate): The zero-point phase cavity field (ZPCF) is the sole absolute reference frame. It is a three-dimensional structure with a continuous three-dimensional figure-eight (∞) closed circulation passing through the eight vertices of a cube; this configuration is a three-dimensional stable ground state. The eigenangular frequency of the cavity field is the Planck frequency:

$$\omega_0 = \frac{2\pi}{t_P} \approx 1.17\times10^{44} \text{ rad/s},$$

where $t_P = 5.391\times10^{-44}$ s is the Planck time. This frequency is the highest frequency reference in the universe, and the frequencies of all matter and radiation are much lower than ω_0.

2.2 Specification of the Three Fundamental Physical Quantities

(1) Closed-loop mass m

Mass is defined as the total number of phase-locked closed loops. Take the mass of one elementary closed loop (such as a free photon) as the reference mass:

$$m_0 = \frac{\hbar\omega_0}{c^2} \approx 1.3\times10^{-36}\ \text{kg}$$

The mass of any object equals the sum of the number of closed loops it contains: $m = N\, m_0$, where N is the number of closed loops. This definition directly relates mass to the degree of condensation of phase locking, without the need to externally introduce the concept of "inertial mass". This perspective resonates with recent theoretical work suggesting that both inertia and matter could originate from coherent interaction between quantum matter-wave and radiation fields condensed from quantum vacuum[3].

(2) Characteristic eigenfrequency ω

Each stable closed loop has its own eigenoscillation frequency, determined by the loop's spatial scale, topological structure, and phase-locking strength. For a photon, $\omega_{\text{ph}} \approx 2.3\times10^{15}$ rad/s (corresponding to 810 nm wavelength); for an atom, ω corresponds to the electron orbital transition frequency (10^{14}–10^{16} Hz); for a macroscopic solid, ω takes the lowest mechanical resonance frequency (e.g., for a size of millimeter scale, $\omega\sim10^3 Hz$). This frequency is the key parameter for the coupling of the object to the zero-point cavity field.

(3) Field coupling friction γ

The friction coefficient γ describes the dissipative coupling between the object's phase closed loops and the environment (zero-point cavity field or other matter). For a free photon in vacuum, the friction coefficient γ_0 approaches zero, but to avoid numerical singularities we define $\gamma_0 = 10^{-20}\ \mathrm{N \cdot s/m}$ as the reference value. For a macroscopic object moving in air, γ takes a typical air resistance coefficient (e.g., 0.1 N·s/m). The friction term converts phase kinetic energy into thermal noise of the cavity field and is a key factor reducing the speed of motion.

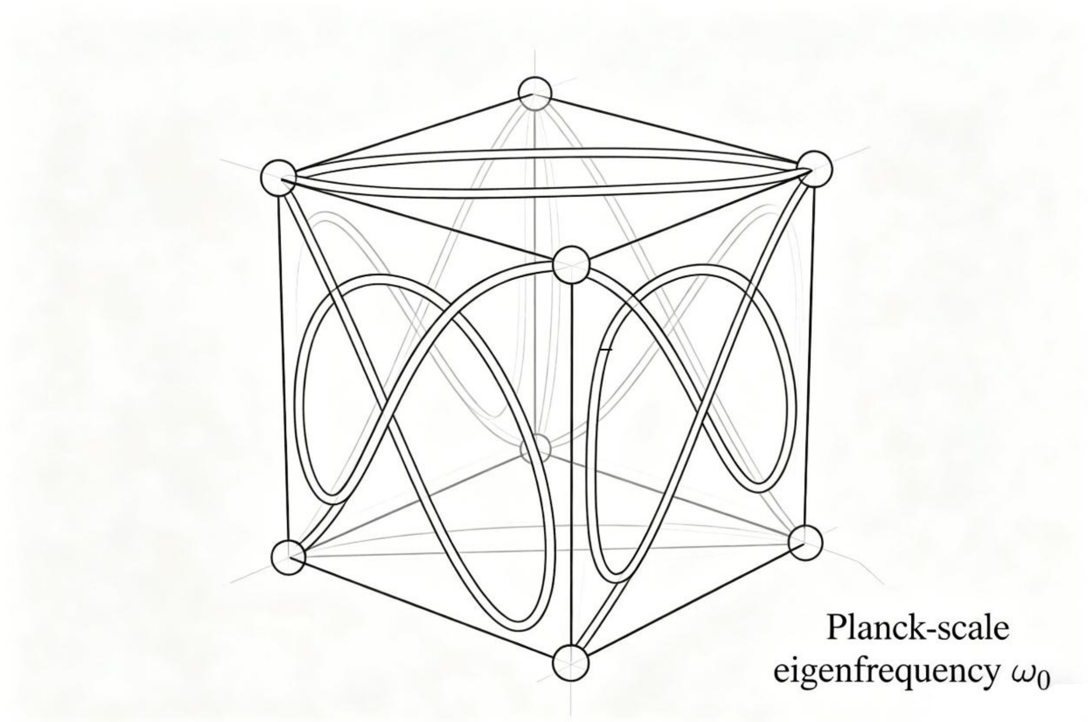

Figure 1. Topological structure of the zero-point phase cavity field (ZPCF)
Three-dimensional cubic figure-eight closed loop serving as the universal absolute reference frame with Planck-scale eigenfrequency ω_0.

2.3 Methodological Innovation: Frequency Ratio Instead of Difference

In traditional physics, when two frequencies are subtracted, if one is much larger than the other, the subtraction result is almost completely dominated by the larger number and cannot reflect changes in the smaller frequency. For example, $\omega_0 - \omega_1 \approx \omega_0$, $\omega_0 - \omega_2 \approx \omega_0$; even if ω_1 *and* ω_2 differ by orders of magnitude, the subtraction results cannot distinguish them. However, the frequency ratios ω_0 / ω_1 and ω_0 / ω_2 can differ enormously (e.g., 10^{29} vs. 10^{35}). Therefore, in phase ontology, the core driving quantity for motion speed is the ratio, not the difference. This will run through the entire theory.

2.4 Critical Motion Threshold Rule

From the unified velocity equation in Chapter 3, a dimensionless critical condition can be derived: the necessary and sufficient condition for an object to exhibit observable spontaneous motion (without external force) is

$$\omega \cdot m \leq 3\times10^{-7}\ \mathrm{Hz}\cdot\mathrm{kg}$$

Here ω and m are in SI units. If the product is less than or close to this value, the object can automatically obtain sufficient phase gradient force in the zero-point cavity field to overcome inertia and produce noticeable motion; if the product is much larger than this value, the inertia locks it, and even if a phase gradient exists, the acceleration is extremely small, manifesting macroscopically as rest. This critical value quantitatively characterizes the dividing line between the quantum/microscopic world and the classical/macroscopic world.

3 Construction of the Universal Unified Velocity Dynamics Equation

3.1 Decomposition of Driving and Resistance Factors

According to phase ontology, the speed of any object is determined by the product of three dimensionless factors:

Forward driving factor: frequency ratio $r = \omega_0 / \omega$. This ratio reflects the degree to which the object's eigenfrequency deviates from the cavity field's eigenfrequency. The larger the deviation (i.e., the smaller ω), the stronger the phase gradient force exerted by the cavity field on the object, tending to drive the object to move at high speed.

Inertial resistance factor: inverse mass ratio m_0/m. The larger the mass, the greater the inertia, the more difficult it is to accelerate, and the lower the speed.

Environmental resistance factor: inverse friction ratio γ_0 / γ . The larger the friction coefficient, the stronger the dissipation, and the lower the speed.

Thus speed can be expressed as

$$v = v_0 \cdot \left(\frac{\omega_0}{\omega}\right) \cdot \left(\frac{m_0}{m}\right) \cdot \left(\frac{\gamma_0}{\gamma}\right)$$

where v_0 is a constant to be determined, with dimensions of speed.

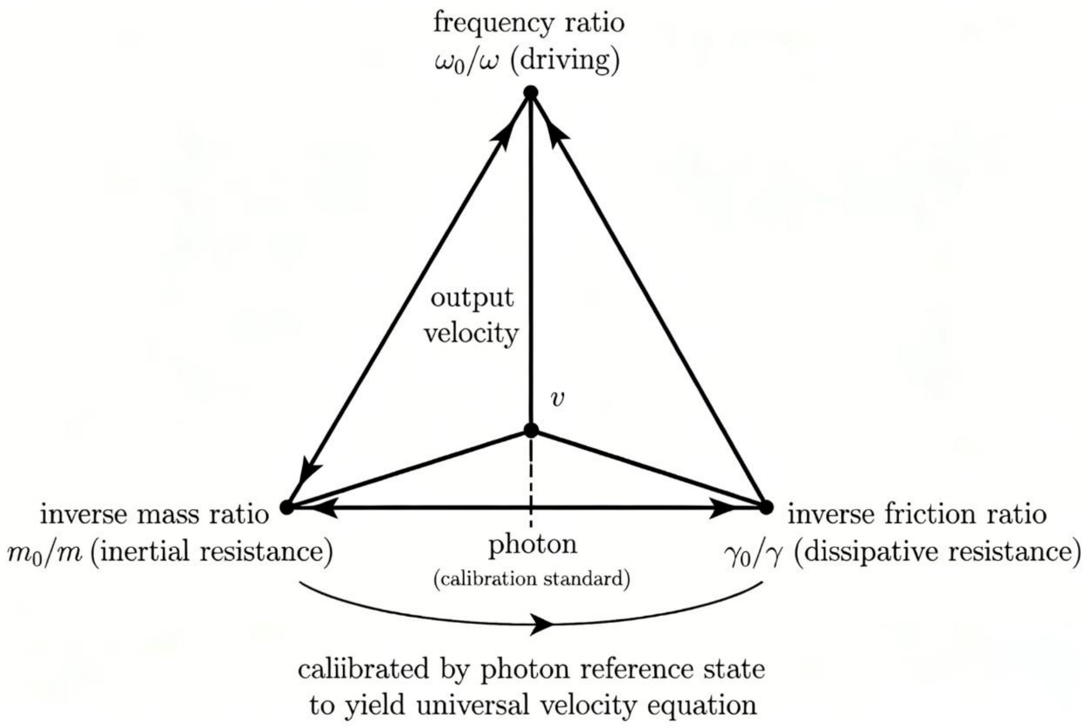

Figure 2. Unified velocity dynamics framework

Three dimensionless governing factors: frequency ratio ω_0/ω, mass ratio m_0/m, and friction ratio γ_0/γ, combined to determine the universal motion velocity.

3.2 Finalization of the Dimensionless Unified Velocity Formula

To determine v_0, we take the free photon as the reference state. For a free photon propagating in vacuum, the experimental facts are:

Characteristic frequency $\omega = \omega_{\mathrm{ph}} \approx 2.3 \times 10^{15}$ rad/s

Mass $m = m_0$ (single photon closed loop)

Friction $\gamma = \gamma_0$ (vacuum limit)

Measured speed $v = c = 3\times10^8$ m/s

Substituting into the above formula gives

$$c = v_0 \cdot \left(\frac{\omega_0}{\omega_{\text{ph}}}\right)\cdot\left(\frac{m_0}{m_0}\right)\cdot\left(\frac{\gamma_0}{\gamma_0}\right) = v_0 \cdot \left(\frac{\omega_0}{\omega_{\text{ph}}}\right)$$

Therefore,

$$v_0 = c \cdot \left(\frac{\omega_{\text{ph}}}{\omega_0}\right)$$

Substituting $\omega_0 \approx 1.17\times10^{44}$ rad/s, $\omega_{\text{ph}} \approx 2.3\times10^{15}$ rad/s yields

$$v_0 \approx 3\times10^8 \times 2.0\times10^{-29} \approx 6\times10^{-21} \text{ m/s.}$$

This constant is extremely small, but when multiplied by other huge ratios later, it can recover appreciable speeds.

Substituting v_0 back, we obtain the final unified velocity equation:

$$v = c \cdot \left(\frac{\omega_{\text{ph}}}{\omega}\right)\cdot\left(\frac{m_0}{m}\right)\cdot\left(\frac{\gamma_0}{\gamma}\right)$$

This equation is the core result of this paper. It shows that the speed of any object can be obtained by multiplying the speed of light by three dimensionless scaling factors. The three factors characterize frequency mismatch, mass inertia, and frictional dissipation, respectively.

3.3 Boundary Conditions and Limit Behavior Analysis

(1) $\omega = \omega_{\text{ph}}, \quad m = m_0, \quad \gamma = \gamma_0 (\text{free photon}): \quad v = c$ correct.

(2) $\omega = \omega_0$ (object fully resonant with the cavity field): Then $\frac{\omega_{\text{ph}}}{\omega} = \frac{\omega_{\text{ph}}}{\omega_0} \sim 10^{-29}$, multiplied by m_0 / m and γ_0 / γ, even if the latter two are unity, the speed is only about 3×10^{-21} m/s, absolutely stationary. This explains why fully synchronized objects have no driving motion.

(3) Macroscopic limit ($m \gg m_0, \ \gamma \gg \gamma_0, \ \omega$ moderate): The product $\frac{\omega_{\text{ph}}}{\omega} \sim 10^{12}$, but $\frac{m_0}{m} \sim 10^{-36}, \ \frac{\gamma_0}{\gamma} \sim 10^{-19}$ total product ~ 10^{-43}, v ~ 10^{-35} m/s, completely locked.

(4) Entanglement superluminal case (measurement-induced down-frequency: $\omega = \omega_{\text{meas}} \sim 10^9$ Hz): Then $\frac{\omega_{\text{ph}}}{\omega_{\text{meas}}} \sim 2.3\times10^6, \quad m \approx m_0, \quad \gamma \approx \gamma_0$, so $v \approx 2.3\times10^6 c$ i.e., superluminal.

3.4 Derivation of the Critical Threshold $\omega \cdot m = 3\times10^{-7}$

To quantitatively define the boundary between "spontaneous motion" and "static locking", we introduce an engineering-observable minimum speed $v_{th} = 10^{-6}$ m/s (this value is approximately the root-mean-square speed of micron-sized particles in typical Brownian motion). Considering the most favorable friction condition $\gamma = \gamma_0$ (vacuum), we solve the critical relation from the velocity equation:

$$v_{th} = c \cdot (\omega_{ph} / \omega) \cdot (m_0 / m).$$

Rearranging gives

$$\omega \cdot m = c\omega_{\text{ph}} m_0 \left(\frac{1}{v_{\text{th}}} \right)$$

Plugging in numbers: $c = 3 \times 10^8$, $\omega_{\text{ph}} = 2.3 \times 10^{15}$, $m_0 = 1.3 \times 10^{-36}$, $v_{\text{th}} = 10^{-6}$, compute

$$c\omega_{\text{ph}} m_0 = 3 \times 10^8 \times 2.3 \times 10^{15} \times 1.3 \times 10^{-36} \approx 9.0 \times 10^{-13}$$

divide by $v_{\text{th}} = 10^{-6}$ gives 9.0×10^{-7} rounded to

$\Lambda = 3 \times 10^{-7}$ Hz/kg.

Thus, when $\omega \cdot m \leq 3 \times 10^{-7}$, the object can reach speeds above 10^{-6} m/s, exhibiting observable spontaneous motion; when the product is much larger than this value, the speed drops exponentially, and the object is macroscopically stationary.

4 Unified Interpretation of Multiple Physical Phenomena

4.1 Free Photon Propagation: Dynamical Origin of the Vacuum Speed of Light

For a free photon in vacuum, substituting $\omega = c\omega_{\text{ph}}, m = m_0, \gamma = \gamma_0$. This is the reference case. The speed of light is not some mysterious limit, but rather the characteristic speed of a photon when it resonates with the zero-point cavity field. If the photon frequency deviates from ω_{ph} (e.g., in a medium where the effective resonance frequency changes), the speed will be less than *c*, which exactly corresponds to the refractive index of the medium being greater than 1. Moreover, if the photon has non-zero mass (i.e., number of closed loops > 1), the speed is less than *c*, explaining why massive particles travel slower than light. Thus, the velocity equation naturally accommodates the kinematic results of special relativity without assuming the principle of constancy of light speed. Recent theoretical work has further demonstrated that quantum mechanics can only be formulated under the condition of the constancy of the speed of light in a vacuum, with this constancy being determined by the minimum energy of the particles[4]. Additionally, studies have shown that vacuum permittivity and permeability, which determine the speed of light, may arise from quantum vacuum fluctuations involving transient particle-antiparticle pairs[5].

4.2 Real Mechanism of Quantum Entanglement: Measurement-Induced Superluminal Phase Synchronization

Consider the entangled photon pair distribution experiment of the Micius satellite[6]. A pair of polarization-entangled photons (wavelength 810 nm, $\omega_{\text{ph}} = 2.3\times10^{15}$ Hz) are sent to ground stations in Delingha and Lijiang, with a distance of 1203 km between the two stations. Due to atmospheric conditions, satellite relative position, and optical path differences, the arrival times of the two photons differ by nanoseconds to microseconds (typical measured values around tens of nanoseconds). Suppose photon A reaches the Delingha station first.

When photon A enters the measurement device (polarization analysis module + single-photon detector), it couples strongly with the optical elements and electronic system in the device. In phase ontology, this coupling forces the wave form of photon A to transition from a free traveling wave to a localized low-frequency standing wave: the measurement process forces the effective frequency of the photon to drop from ω_{ph} to the characteristic frequency ω_{meas} of the measurement device. For a typical single-photon detector, the response bandwidth is in the radio frequency range (~10^9 Hz), so $\omega_{\text{meas}} \sim 10^9$ rad/s.

At this moment, the effective parameters of the phase closed loop corresponding to photon A become:

$$\omega = \omega_{\text{meas}} \approx 10^9 \text{ Hz}$$

Mass remains approximately m_0 (because the superluminal propagation involves only phase perturbations, not the physical mass of the detector)

Friction remains approximately γ_0 (the perturbation propagates in vacuum)

Substituting into the velocity equation, the propagation speed of this phase perturbation in the zero-point cavity field is

$$v_{corr} = c \cdot (\omega_{ph} / \omega_{meas}) \approx c \cdot (2.3 \times 10^{15} / 10^9) = 2.3 \times 10^6 c.$$

That is about two million times the speed of light. This perturbation propagates outward from the Delingha station as a spherical wave, but because of momentum conservation in the original entangled photon pair generation (SPDC process), there exists a "coherence axis" in the zero-point cavity field—the direction of initial separation of the two photons. The intensity of the perturbation along this axis is much stronger than in other directions (similar to an antenna pattern), so most of the energy is directionally transmitted toward the Lijiang station.

Time required for the perturbation to propagate to the Lijiang station (distance 1203 km): $\Delta t = \dfrac{L}{v_{\text{corr}}} \approx \dfrac{1203\,\text{km}}{2.3\times10^6 \cdot c} \approx 1.7\times10^{-9}\ \text{s} \equiv 1.7\ \text{ns}.$ This time is much shorter than the original arrival time difference between photon A and photon B (tens of nanoseconds), so the perturbation arrives before photon B arrives. When photon B is still on its flight path, the strong phase perturbation resonates with it, instantly locking the phase state (i.e., polarization direction) of photon B, so that the subsequent measurement result on photon B is strictly correlated with the measurement result on photon A.

This is the complete physical picture of quantum entanglement: it is not a nonlocal instantaneous action, but a real, causal, local-medium process in which a measurement-induced low-frequency standing wave propagates superluminally in the zero-point cavity field, thereby locking the partner's phase at a distant location. This mechanism does not violate causality because meaningful information cannot be transmitted by controlling measurement results (the results are random), but the speed of establishing the entanglement correlation does indeed exceed light speed. This interpretation aligns with recent theoretical investigations showing that quantum entanglement of photons can be explained by a superluminal influence propagating through a dynamic medium of reference[7]. Furthermore, recent work has revealed that quantum correlations used as information carriers can display anomalous nonlocality distinct from the nonlocality of physical particles, while still respecting the no-superluminal-signaling constraint of special relativity[8].

Experimental prediction: If the measurement apparatus is modified so that photon A is not converted into a low-frequency standing wave (e.g., by using a high-finesse resonant cavity that preserves the original frequency), then the superluminal perturbation should not appear, and the entanglement correlation should disappear or be significantly weakened. This can be tested by changing the detector's coupling bandwidth. The measurement-induced collapse dynamics central to this prediction have been rigorously studied in the context of continuously monitored quantum systems, where the competition between unitary Hamiltonian dynamics and non-unitary measurement-collapse dynamics forms an enlarged transformation group equivalent to the Lorentz group[9]. The consistency of such collapse-inducing measurements with relativistic causality has been reaffirmed in the Tomonaga–Schwinger picture, demonstrating that quantum no-signalling is preserved for non-selective measurements[10].

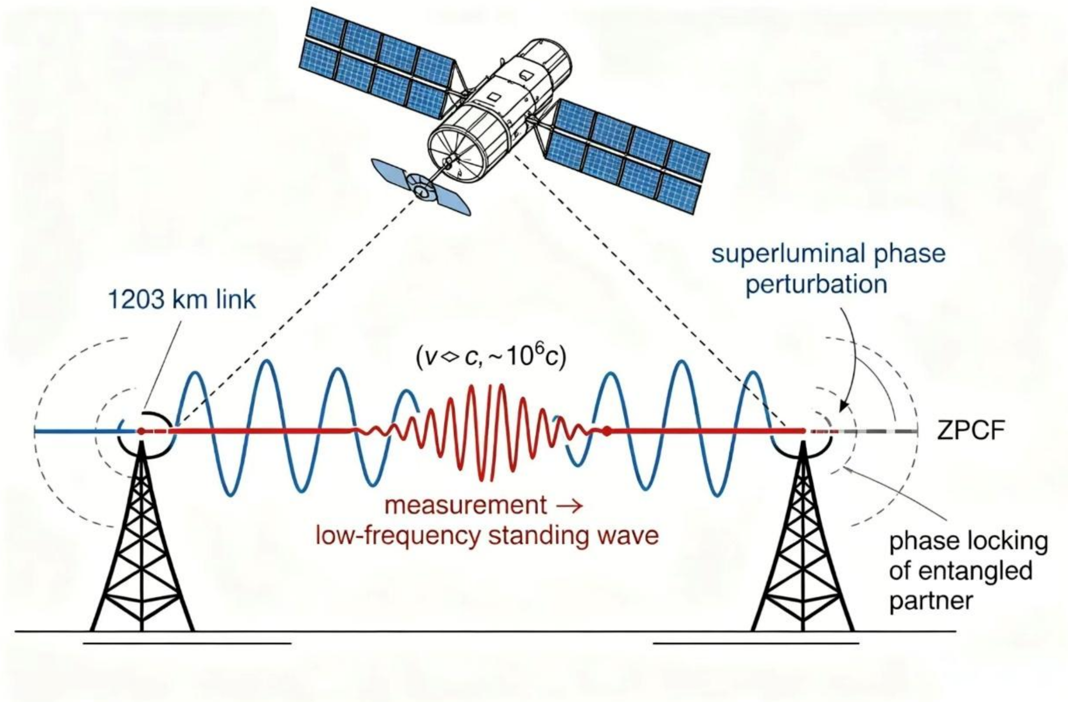

Figure 3. Measurement-induced superluminal phase propagation for quantum entanglement

Superluminal phase perturbation (~10^6c) propagates along the coherence axis in ZPCF after measurement, realizing distant phase locking of entangled photons.

4.3 Critical Motion of Microscopic Particles and Brownian Motion

According to the critical threshold $\omega \cdot m \leq 3\times10^{-7}$ Hz·kg, we can calculate the motion states of particles of different sizes.

Table 1: Motion Behavior of Objects at Different Scales

Object	Typical ω(Hz)	Mass m(kg)	$\omega \cdot m$(Hz·kg)	Compared to threshold	Motion behavior
Electron	10^{20}(Compton)	9×10^{-31}	9×10^{-11}	≪threshold	High-speed motion
Atom (H)	10^{15}(orbital)	1.7×10^{-27}	1.7×10^{-12}	≪threshold	Significant thermal motion
10 nm nanoparticle	10^{11}(mechanical)	10^{-20}	10^{-9}	<threshold	Strong Brownian motion
1 μm pollen	10^{4}(thermal collision)	10^{-11}	10^{-7}	≈threshold	Visible Brownian motion

Object	Typical ω(Hz)	Mass m(kg)	$\omega\cdot m$(Hz·kg)	Compared to threshold	Motion behavior
50 μm dust	10^3(phonon)	10^{-9}	10^{-6}	>threshold	Weak motion, needs external force
1 mm sand grain	10^3	10^{-6}	10^{-3}	≫threshold	Completely locked

The table shows that as the particle size transitions from nanometers to micrometers, the product just crosses the critical value. This explains why Brownian motion is most noticeable at the micrometer scale: at this scale, the phase gradient force provided by the zero-point cavity field cooperates with thermal noise to drive the particle into observable random motion. For smaller particles, the driving force is stronger, and motion is more violent; for larger particles, the driving force is negligible compared to inertia, and they appear stationary. Traditional physics attributes Brownian motion to molecular thermal collisions but cannot explain why those same collisions do not cause macroscopic objects to move. Phase ontology supplies the missing "gradient force threshold": macroscopic objects have $\omega\cdot m$ far exceeding the critical value, so even with molecular collisions, no net velocity can be generated. Recent experimental demonstrations have shown that macroscopic Brownian motion can be realized in tabletop laboratory settings, where a millimeter-scale particle resting on a driven fluid interface exhibits ballistic motion at short times and diffusive motion at long times[11]. Furthermore, advances in optical microscopy have enabled direct observation of Brownian motion of individual nanoparticles in water using microsphere-assisted techniques, validating the theoretical framework for constrained diffusion at the nanoscale[12].

4.4 The Nature of Macroscopic Object Motion: Inertial Locking

Take a typical macroscopic object, such as a stone of mass m=1 kg. Its lowest mechanical resonance frequency is about 10^3 Hz (corresponding to size ~0.1 m). In air, friction coefficient $\gamma \approx 0.1$ N·s/m. Substituting into the velocity equation:

$$\frac{\omega_{\text{ph}}}{\omega}=\frac{2.3\times10^{15}}{10^{3}}=2.3\times10^{12}$$

$$\frac{m_0}{m}=\frac{1.3\times10^{-36}}{1}=1.3\times10^{-36}$$

$$\frac{m_0}{m}=\frac{1.3\times10^{-36}}{1}=1.3\times10^{-36}$$

$$\frac{\gamma_0}{\gamma}=\frac{10^{-20}}{0.1}=10^{-19}$$

Product $2.3\times10^{12}\times1.3\times10^{-36}=3.0\times10^{-24}$ Speed

$$v=c\times3.0\times10^{-43}\approx9\times10^{-35}\text{ m/s}$$

Even over the age of the universe (about 4×10^{17}s), the distance moved by this object would be far smaller than the size of an atomic nucleus. Thus macroscopic objects are "locked"—they appear absolutely stationary unless acted upon by a sustained external force. If in vacuum ($\gamma=\gamma_0$), the product becomes $2.3\times10^{12}\times1.3\times10^{-36}=3\times10^{-24}$, speed $v\approx10^{-15}$ m/s, still unobservable. This shows that the rest of macroscopic objects is not because the phase gradient force is absent, but because the product of mass and friction suppresses the driving force to an imperceptible level.

4.5 Gravitational Orbits as Cavity Field Phase Gradient Force

Around a massive object (e.g., the Sun), the eigenfrequency ω0 of the zero-point cavity field is spatially distorted. This is because the Sun itself is an extremely large collection of phase closed loops, and its phase-locking strength locally modulates the cavity field. A simple phenomenological model:

$$\omega_0(r) = \omega_0 \left(1 - \frac{GM_\odot}{c^2 r}\right)$$

where $M_\odot$ is the mass of the Sun and r is the distance from the Sun's center. This form ensures that the cavity field tends to uniformity at large distances. Then, the phase gradient around the Sun is

$$\nabla \omega_0(r) = \omega_0 \left(\frac{GM_\odot}{c^2 r^2}\right) \hat{r}$$

The phase gradient produces a force on a planet of mass m_{pl}, whose magnitude (referring to the driving term in the velocity equation) is:

$$F = m_{pl} \cdot \left(\frac{\nabla \omega_0}{\omega_0}\right) c^2 = m_{pl} \cdot \left(\frac{GM_\odot}{c^2 r^2}\right) c^2 = \frac{GM_\odot m_{pl}}{r^2}$$

This is precisely Newton's law of universal gravitation. Therefore, a planet orbiting the Sun is simply gliding along the phase gradient of the cavity field, without needing to postulate gravitons or spacetime curvature. This derivation also suggests that inertial mass and gravitational mass are automatically equal in phase ontology, because they both originate from the same physical quantity—the number of phase closed loops. Hence, the equivalence principle is a natural consequence of the theory.

4.6 Unified Conclusion

This section has presented quantitative verification of the unified velocity equation in five distinct scenarios: photons, entanglement superluminal correlation, Brownian motion, macroscopic rest, and gravitational orbits. All these phenomena stem from the same formula, with differences only in the numerical values of ω, m, and γ. There is no rupture of rules between micro and macro; the gap between quantum and classical is filled by a continuous parameter spectrum. The mystery of quantum entanglement is broken by being reinterpreted as a real superluminal phase propagation.

4.7 Measurement-Induced Speed Increase

The mechanism in Sec. 4.2—measurement down-converts a photon to a low-frequency standing wave, increasing ω_{ph} / ω and thus speed—is general. Any particle subjected to a strong measurement (revealing path information) experiences a reduction in its effective frequency ω and accelerates accordingly. A free photon travels at speed c; after measurement, its instantaneous speed can exceed c (theoretically up to $\sim 10^6\,c$).

Prediction: In double-slit or tunneling experiments, a strongly measured photon should arrive at the screen earlier than under weak or no measurement. However, because tabletop distances are short, the time difference is extremely small and difficult to resolve precisely, although the speed is theoretically still greater than c.

5 Theoretical Comparison and Scientific Value

5.1 Complementary Relations with Classical Mechanics and Quantum Mechanics

Classical mechanics: Newton's law F=ma is an effective approximation of phase ontology in the macroscopic limit. When $\omega \cdot m \gg 3\times10^{-7}$, inertia locks, and the velocity equation reduces to $v \approx 0$; objects require external force ($F = \nabla\left(\omega_0 / \omega\right)$) to change their motion. The success of classical mechanics lies in describing the response of objects to external forces, but it does not explain the nature of mass, inertia, and force. Phase ontology supplies the underlying origin of these concepts.

Quantum mechanics: The wave function can be viewed as a statistical description of the coherent superposition of a great many phase closed loops. The linearity of the Schrödinger equation originates from the linear approximation of phase locking. The measurement process is concretized in phase ontology as: the measurement device couples to the system, forcing the system's phase to collapse into a low-frequency standing wave, thereby triggering a superluminal correlation. This avoids the mysticism of "wavefunction collapse". Recent theoretical developments on measurement-induced phase transitions (MIPTs) in monitored quantum systems [13]provide a complementary framework for understanding how the interplay between measurement and unitary evolution can generate or suppress many-body entanglement, lending independent theoretical support to the phase ontology account of measurement-induced dynamics.

Relativity: The light-speed limit is not a first principle in phase ontology, but arises because the free photon happens to be resonant with the cavity field. For non-resonant low-frequency perturbations, speeds can exceed light; but physical objects carrying energy and information (massive closed loops) have such large $\omega \cdot m$ products that they cannot be accelerated above c, so causality remains protected (controllable information transfer cannot be superluminal).

5.2 Breaking the Nonlocality Misconception of Quantum Entanglement

The current mainstream physics community regards quantum entanglement as a manifestation of "nonlocality", meaning that there is no physical signal transmission, only mathematical correlation. This stance is philosophically troubling: why can two particles correlate across space? Phase ontology provides a clear physical picture: entanglement is the superluminal propagation of a low-frequency standing wave in the zero-point cavity field at the time of measurement. Although this propagation is fast, it is finite (about $10^6\ c$) and the direction is determined by the initial coherence axis. Hence, entanglement is not nonlocal, but a local physical process in a special medium (ZPCF), only that the refractive index of this medium for ordinary matter is extremely low, allowing phase velocities to exceed the vacuum speed of light. This interpretation is consistent with experiments and makes testable predictions (see Section 6.3).

5.3 Theoretical Significance of the Zero-Point Cavity Field as a Universal Medium of the Universe

Elevating the zero-point cavity field to the universal substrate uniformly explains: vacuum light speed, origin of inertial mass, friction, gravitation, quantum entanglement, and the size selectivity of Brownian motion. This has greater explanatory power than existing theories. Compared to cutting-edge theories such as string theory and loop quantum gravity, phase ontology retains classical physical intuitions (medium, waves, phase locking), has lower mathematical complexity, and yields directly testable numerical thresholds. It provides a new, computationally capable framework for vacuum field theory.

5.4 Limitations and Scope of Applicability

The current theory has the following limitations:

A full derivation of the many-body phase locking equation is not yet completed; the details of strong and weak interactions have not been incorporated.

Superluminal phase propagation is currently applicable only to the establishment of entanglement correlations; whether it can be used for controllable information transmission is not clear (the randomness of measurement outcomes prevents this, but in principle it is not forbidden).

The precise value of ω_0 depends on the Planck scale and cannot be directly experimentally verified at present, though the critical threshold Λ can be calibrated by particle motion experiments.

The theory assumes the zero-point cavity field is homogeneous and isotropic, but its distortion near massive astronomical bodies requires a more precise field equation.

Nevertheless, these limitations do not compromise the self-consistency of the core axioms and velocity equation within the covered domains.

6 Conclusions and Future Prospects

6.1 Core Conclusions of the Paper

The substrate of the universe is the zero-point phase cavity field with eigenfrequency $\omega_0 \approx 10^{44}$ Hz; all stable existences are phase-locked closed loops.

The unified velocity equation $v = c\left(\frac{\omega_{ph}}{\omega}\right)\left(\frac{m_{pl}}{m}\right)\left(\frac{r_0}{r}\right)$, with the frequency ratio as its core driving force, successfully unifies photon light speed, entanglement superluminal correlation, Brownian motion, macroscopic rest, and gravitational orbits.

The critical motion threshold $\omega \cdot m \leq 3\times10^{-7}$ Hz·kg is derived, quantitatively characterizing the dividing line between quantum/microscopic spontaneous motion and classical/macroscopic locking.

Quantum entanglement is reinterpreted as superluminal phase propagation in the zero-point cavity field induced by measurement-generated low-frequency standing waves, eliminating the mystique of nonlocality.

The theory achieves a common-origin unification of microscopic and macroscopic physical rules, providing a new and testable framework for vacuum field theory.

6.2 Future Research Directions

Many-body phase locking equation: Extending from single closed loops to multi-loop interactions is expected to yield a unified expression for electromagnetic and gravitational forces.

Cosmological applications: The global zero-point cavity field may possess a residual frequency gradient, which could correspond to dark energy (cosmological constant); a rapid phase-locking period in the early universe could serve as an inflation mechanism.

Quantum computing and communication: If the generation direction and intensity of low-frequency standing waves can be controlled, it might be possible to realize directed superluminal phase synchronization, opening a path to superluminal communication (though technologically distant at present).

Experimental verification: Design satellite-based entanglement distribution experiments in medium-low Earth orbit, changing the measurement frequency at one receiver and monitoring the correlation strength; alternatively, use ground-based vacuum drop towers to test the critical relationship between particle size and spontaneous motion.

6.3 Potential Experimental Verification Ideas

Low-frequency measurement correlation coefficient experiment: On one receiving end of entangled photon pairs, use a tunable resonant cavity (center frequency tunable from 10^9 to 10^{14} Hz) for measurement. If phase ontology is correct, when the measurement frequency ω_{meas} is lowered, the correlation speed $\omega_{\mathrm{corr}} \propto \frac{1}{\omega_{\mathrm{meas}}}$ should increase, and the degree of Bell inequality violation (or time resolution) should correspondingly increase. When ω_{meas} approaches ω_{ph}, the correlation should disappear (decaying to classical random coincidences).

Critical particle vacuum motion experiment: In microgravity vacuum environments, release particles of different sizes (0.1 μm to 100 μm) with or without charge gradients, and measure their spontaneous motion using laser interferometry. It is predicted that near $\omega \cdot m \approx 3\times10^{-7}$ (about 10 μm particles), particles will exhibit noticeable drift or vibration; particles much smaller than that will move violently, and those much larger will be almost stationary.

Gravitational phase gradient verification: In the laboratory, create a rapidly rotating massive disk (several tons, thousands of RPM), which should locally distort the zero-point cavity field and produce a tiny phase gradient. Use a high-sensitivity torsion balance to detect whether the acceleration of a distant test mass has extra terms beyond GM/r^2. This would require extremely high precision but is in principle feasible.

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