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The Elastic Space Paradigm: A Wave-Based Reconstruction of Physics Foundations, Predictions, and Testable Consequences

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Abstract

This work synthesizes a complete paradigm developed across multiple interconnected publications, and we propose a paradigm where space itself is the fundamental, elastic medium. This framework rehabilitates an absolute reference frame while fully preserving the mathematical formalism of Special Relativity as an effective observational theory. The model replaces the postulate of a featureless vacuum with three physical principles: space elasticity, wave-matter identity, and energy-conserving In/Out wave circulation. From these we derive a self-consistent field theory where particles emerge as localized standing waves and photons as self-propelled dipoles. The paradigm provides mechanistic explanations for core principles: velocity and kinetic energy are geometric deformation states of matter waves, and the equivalence of inertial and gravitational mass follows from their common origin in total deformation energy. Crucially, it yields testable predictions that distinguish it from standard physics, including an asymmetric outcome for the symmetric Twin Paradox scenario and measurable asymmetries in high-energy ion collisions. This work offers a realist, wave-based foundation for reconciling quantum non-locality, relativistic effects, and gravitational interaction.

Keywords: elastic spacetime; In/Out waves; non-local particles; emergent gravity; absolute reference frame; geometric deformation; inertial mass; equivalence principle; photon structure; wave dipole; emergent gravity; foundational physics; asymmetric collision test

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1. Introduction: Beyond the Postulate of Emptiness. Space as the Fundamental Medium

The 20th-century consensus that abandoned the ether was based on a specific interpretation of the Michelson-Morley null result and Einstein's postulate that no privileged reference frame exists. However, this historical interpretation is not experimentally compelled, but stems from a specific ontological choice. As demonstrated in our companion analysis [6], the Michelson-Morley experiment does not prove the absence of a medium; it merely constrains the relationship between longitudinal and transverse deformations that moving matter undergoes relative to such a medium. Einstein's postulate, while operationally brilliant for developing a theory of relative measurements, is ontologically gratuitous and has had the detrimental effect of obscuring the fundamental reality underlying physical phenomena.

We propose a paradigm shift: **Space itself is the fundamental, elastic medium.** This paradigm, developed in a series of foundational papers [1–3,5,7], does not reintroduce a separate 'ether' but identifies the physical fabric of the universe as the sole fundamental entity from which all phenomena emerge.

1.1. Context of this Synthesis

This article synthesizes a complete research program developed across sixteen interconnected publications. All mathematical foundations, mechanistic explanations, and quantitative predictions are provided in these companion papers. Specifically for the foundations presented here:

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- The **derivation of relativistic kinematics** from wave geometry (time dilation, length contraction, $E = \gamma mc^2$) is fully developed in [1,8]
- The **solution to the radiation damping problem** via the IN/OUT wave mechanism is presented in [5]
- The **quantitative prediction** for the decisive asymmetric ion collision test [4]
- The **reconciliation with Michelson-Morley null results** through generalized contraction is demonstrated in [6]
- The **demonstration of mass equivalence** $m_i = m_g$ from wave energy principles is proven in [3]

This paradigm is presented not as mere interpretation, but as a *complete, empirically testable reconstruction* of physics from a single physical postulate: space as a vibratory medium.

This framework rehabilitates a mechanistic understanding of physics while fully retaining the mathematical and observational successes of Special Relativity (SR). Crucially, SR is not contradicted but reinterpreted: it emerges as the indispensable *observational theory* to describe the relations between observers in motion, all of whom are themselves deformed wave patterns in the absolute medium and therefore cannot directly measure their absolute velocity [1]. The postulates of a featureless vacuum and the relativity of simultaneity are replaced by a single, simpler physical postulate: **Space exists as a vibratory entity.** From this, all relativistic phenomena—time dilation, length contraction, $E = mc^2$—emerge as real, physical deformations of wave structures moving through the medium [1,2].

This paradigm resolves the deep paradoxes that plague the standard interpretation (e.g., the Twin Paradox, the attribution of kinetic energy in collisions) while opening new avenues for experimental investigation, such as the asymmetric collision test [4] that could reveal the medium's existence.

How this Paradigm Differs Fundamentally Our approach differs fundamentally from historical ether theories in three key aspects:

1. **Self-consistency**: The medium's state determines wave propagation, while waves modify the medium's properties—creating a closed feedback loop.
2. **Non-locality via In/Out waves**: Localized structures are maintained by incoming/outgoing wave pairs forming evanescent standing waves [5], preventing radiative decay.
3. **Geometric emergence**: Particles and their properties (mass, inertia, velocity) emerge as real, physical deformations of wave structures moving through the medium, as derived in subsequent sections and companion papers [1,2].

1.2. The In/Out Wave Mechanism: Preventing Radiation Loss

A crucial innovation is the **In/Out wave mechanism** that solves the historical problem of radiation damping. Every outgoing wave (Ψ_{out}) is partially reflected back as an incoming wave (Ψ_{in}), creating a self-sustaining circulation [5]. A particle is not a localized source but a **non-local circulation pattern** where energy continuously flows in and out, maintaining stability. This explains why elementary particles do not radiate away their energy: they are not sources but **standing wave nodes** in a global network.

1.3. Non-Locality and Field-Particle Unity

In this paradigm, the separation between "particle" and "field" is artificial. The particle *is* the localized maximum of the field pattern, and the extended field is part of the particle's structure. This naturally explains quantum non-locality and entanglement: separated particles share components of the same underlying wave pattern. Spatial superposition arises naturally when multiple interference maxima coexist.

The framework culminates in a unified understanding of mechanics where inertia, mass, and forces find wave-mechanical explanations, resolving longstanding puzzles like the equality of inertial and gravitational mass [3]. **It leads to a falsifiable experimental prediction—asymmetry in high-energy ion collisions** [4]—that distinguishes it from standard relativity.

 doi:10.20944/preprints202512.1645.v1

1.4. The Complete Research Program: From Quantum Scale to Cosmic Cycles

This article presents the foundational framework of elastic space. However, this framework enables a **complete reconstruction of physics across all scales**, developed in a series of companion papers:

- **Microphysics and Particle Masses:**
  - A photon-based vector model predicts the proton-to-electron mass ratio m_p/m_e with **seven significant figures accuracy** (1836.152...) and explains quark observations as transient collision artifacts rather than fundamental constituents [9,10].
  - The three fermion generations emerge naturally from spatial anisotropy, with each generation corresponding to a different vibrational mode in the anisotropic elastic medium [10,13].
- **Astrophysics without Dark Components:**
  - Supernova energy amplification through exotic-matter formation provides a mechanistic explanation for the "missing energy" problem in supernova rebound [15].
  - The exotic matter proposed is not an ad hoc construct but emerges naturally from **extending the proton model** using the same $\sqrt{2}$ layer progression that predicts m_p/m_e with 7-figure accuracy. Energy calculations for ordinary-to-exotic matter conversion provide indirect verification.
  - Galactic dynamics and cosmic expansion are explained by energy density diffusion, providing a physical basis for Modified Newtonian Dynamics (MOND) and eliminating the need for dark matter and dark energy [11,12,14].
  - Black holes are described without singularities, as structures of this exotic matter with well-defined physical properties [15].
  - **Prediction:** Ultra-high-energy gamma rays (UHEGRs, > 100 TeV) from exotic matter decay during supernova explosions or black hole formation—providing a natural explanation for extreme-energy astrophysical events that challenge standard models.
- **Cosmology of an Eternal, Cyclic Universe:**
  - The Big Bang singularity is replaced by a Big Bounce in a cyclical universe model, with each cycle beginning from a highly compressed but non-singular state [12,14].
  - The observed expansion of the universe emerges naturally from the dynamics of the elastic medium without cosmological constant or dark energy [11,12].
  - The multiverse emerges as juxtaposed bounce regions with anisotropic properties that naturally explain early galaxy formation observed by JWST [13].
  - Calculations [14] show the cumulative neutrino mass-energy ("missing mass") equals the universe's gravitational potential energy, confirming that $\nabla\rho_E$ redistribution by neutrinos physically structures spacetime curvature.
- **Unification of All Scales:**
  - From the Planck scale to cosmic horizons, all phenomena derive from a single principle: **space as a self-consistent, elastic, vibratory medium**.
  - Dark matter, dark energy, the hierarchy problem, quantum gravity, cosmological singularities, and the nature of quantum measurement all find mechanistic explanations within this unified framework.
  - The paradigm provides testable predictions at every scale. Microscopically: asymmetric ion collisions. Macroscopically: stellar mass ranges for supernova and black hole formation that align with observations, and the prediction of ultra-high-energy gamma rays from exotic matter decay during supernova explosions or black hole formation—energies far exceeding ordinary matter processes.

This elastic space paradigm thus represents not merely an alternative interpretation, but a **complete, testable reconstruction of physics** from quantum scales to cosmic cycles. The present article

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establishes its foundational principles; the companion papers develop its specific applications and quantitative predictions across all domains of physics.

1.5. Further Implications and Resolved Paradoxes

The paradigm naturally resolves foundational quantum mysteries through its mechanistic wave framework:

- **Wave-Particle Unity:** The apparent duality vanishes—the "particle" is the energy center of the standing wave pattern, while the "wave" is the extended IN/OUT structure that is intrinsically part of the particle. Both aspects coexist as features of the same non-local wave entity with localized energy concentration.
- **Measurement Problem:** The problem vanishes upon distinguishing non-local wave extension from localized energy trajectory. While IN/OUT waves extend non-locally (explaining interference), the particle's energy center follows a unique, deterministic path continuously shaped by environmental wave interactions. No collapse occurs—the energy center remains on its determined trajectory throughout.
- **Double-Slit Experiment:** Particles pass through single slits but are guided by IN/OUT wave interference patterns with the environment.
- **Field-Particle Cohesion:** Fields move as rigid blocks with particles, explaining why gravitational attraction points to a body's current position despite finite light speed.
- **Deterministic Foundation:** The universe is fully deterministic; quantum probabilities emerge from incomplete knowledge of detailed wave configurations.
- **Nuclear Binding Mechanism:** The strong nuclear force may be explained by electromagnetic interactions in modified geometries, with calculations predicting correct deuterium binding [16].

These resolutions emerge naturally from wave mechanics in elastic space without additional postulates or interpretations.

2. Foundational Principles

Axiom 1 (Elastic Space Medium)**.** *Space is a three-dimensional elastic medium characterized by:*

1. *A displacement field $\vec{u}(\vec{r},t)$ representing local deformation*
2. *An energy density $\rho_E(\vec{r},t) = \frac{1}{2}\kappa(\nabla\cdot\vec{u})^2 + \frac{1}{2}\mu(\nabla\times\vec{u})^2 + \frac{1}{2}\sigma\dot{\vec{u}}^2$*
3. *Local compensation: $\nabla\cdot\vec{u} = 0$ for pure transverse waves, but $\nabla\times\vec{u} \neq 0$ provides restoring forces*

Axiom 2 (Wave-Matter Identity)**.** *All physical entities are wave patterns in the elastic medium:*

- *Photons: traveling wave packets with specific polarization*
- *Particles: localized standing wave patterns*
- *Fields: wave interference patterns across the medium*

Axiom 3 (In/Out Wave Conservation)**.** *Every physical entity maintains energy through balanced incoming and outgoing waves:*

$$\frac{dE}{dt} = \oint_S \vec{S}_{out}\cdot d\vec{A} - \oint_S \vec{S}_{in}\cdot d\vec{A} = 0 \tag{1}$$

where $\vec{S}_{in/out} = \frac{c^2}{4\pi}\Re(\vec{\Psi}^*_{in/out}\times(\nabla\times\vec{\Psi}_{in/out}))$. The partial reflection of outgoing waves by the space lattice ensures this balance [5].

3. Mathematical Formulation: From Elastic Medium to Master Equation

This section establishes the mathematical framework of the Elastic Space-Medium Paradigm. We begin with the foundational description of space as a medium, derive the self-consistent master equation for the total wave field, and arrive at the key phenomenological law of wave deflection by energy density gradients.

 doi:10.20944/preprints202512.1645.v1

3.1. The Elastic Medium and its Lagrangian

We posit that space is a three-dimensional, isotropic elastic continuum. Its state is described by a displacement field $\vec{u}(\vec{r},t)$ from a relaxed background. The dynamics of this medium are governed by a Lagrangian density comprising kinetic, potential, and non-local interaction energy:

$$\mathcal{L}_{\text{medium}} = \underbrace{\frac{1}{2}\rho_0 \dot{\vec{u}}^2}_{\text{Kinetic}} - \underbrace{\left[\frac{\lambda}{2}(\nabla\cdot\vec{u})^2 + \mu(\nabla\vec{u}:\nabla\vec{u})\right]}_{\text{Elastic Potential}} - \mathcal{L}_{\text{nl}}[\vec{u}], \tag{2}$$

where ρ_0 is the intrinsic density of space, and λ and μ are its Lamé elastic constants. The non-local term $\mathcal{L}_{\text{nl}}$ encodes the crucial In/Out feedback mechanism: the displacement at a point $\vec{r}$ is coupled to the displacement at all other points $\vec{r}'$ with a retarded kernel K that ensures causality and finite coherence length α^{-1}.

3.2. The Wave-Matter Field and Its Self-Consistency

All physical entities—photons, particles, and fields—are coherent excitations of this medium. We describe them collectively by a complex vector field $\vec{\Psi}(\vec{r},t)$, which can be related to the physical displacement and its time derivative (momentum) via $\vec{\Psi} \sim \vec{u} + i\dot{\vec{u}}/\omega_0$, where ω_0 is a characteristic frequency of the medium. In terms of $\vec{\Psi}$, the Lagrangian takes a canonical wave form with a non-local potential:

$$\mathcal{L} = \frac{1}{2}\dot{\vec{\Psi}}^*\cdot\dot{\vec{\Psi}} - \frac{c^2}{2}\nabla\vec{\Psi}^* : \nabla\vec{\Psi} - V_{\text{nl}}[\vec{\Psi}], \tag{3}$$

where $c = \sqrt{(\lambda+2\mu)/\rho_0}$ is the characteristic wave speed in the medium (identified with the speed of light). The non-local potential V_{nl} implements the self-consistency condition:

$$V_{\text{nl}}[\vec{\Psi}] = \frac{g}{2}\iint_{\mathbb{R}^3} d^3r\, d^3r'\, K(\vec{r}-\vec{r}')\left[\vec{\Psi}^*(\vec{r})\cdot\vec{\Psi}(\vec{r}')\right]\left[\vec{\Psi}(\vec{r})\cdot\vec{\Psi}^*(\vec{r}')\right]. \tag{4}$$

The kernel $K(\vec{R}) = \sin(k_0 R)e^{-\alpha R}/R$ captures both the oscillatory exchange $(\sin(k_0R))$ and finite-range coherence $(e^{-\alpha R})$ of the medium, with $k_0 = \omega_0/c$.

3.3. The Master Equation

Applying the principle of least action $\delta S = \delta\int \mathcal{L}\, d^4x = 0$ to the Lagrangian (3) yields the integro-differential **master equation** of the paradigm:

$$\boxed{\ddot{\vec{\Psi}} - c^2\nabla^2\vec{\Psi} = -g\int_{\mathbb{R}^3} d^3r'\, K(\vec{r}-\vec{r}')\left[\vec{\Psi}(\vec{r}')\cdot\vec{\Psi}^*(\vec{r})\right]\vec{\Psi}(\vec{r}')}. \tag{5}$$

This equation is the core dynamical law. The left side is the standard wave operator. The right side is the non-linear, non-local source term that embodies the self-consistency: the wave amplitude at $\vec{r}$ is driven by its correlation with the wave amplitude at all other points $\vec{r}'$, weighted by the medium's response kernel. This term is responsible for the formation of stable, localized solutions (particles) and mediates their interactions.

3.4. Wave Deflection by Energy Density Gradients

A direct phenomenological consequence of the elasticity of the medium is that the propagation of waves is influenced by spatial variations in the medium's own energy density. The total energy density $\rho_E(\vec{r},t)$ of the medium is a functional of the wave field, $\rho_E[\vec{\Psi}]$. For slowly varying gradients compared to the wave's own frequency, the effect on the wave phase and trajectory can be derived from a WKB approximation of the master equation, leading to the **deflection law**:

$$\boxed{\nabla^2\vec{\Psi} - \frac{1}{c^2}\frac{\partial^2\vec{\Psi}}{\partial t^2} = -\frac{1}{c^2}[\nabla\rho_E\otimes\nabla]\vec{\Psi}}. \tag{6}$$

 doi:10.20944/preprints202512.1645.v1

where the operator $[\nabla\rho_E \otimes \nabla]$ acts on $\vec{\Psi}$ as:

$$[\nabla\rho_E \otimes \nabla]\vec{\Psi} = (\nabla\rho_E \cdot \nabla)\vec{\Psi} + \nabla\rho_E \times (\nabla \times \vec{\Psi})$$

This equation is of paramount importance. It shows that the wave equation acquires an effective source term proportional to the projection of the energy density gradient onto the wave's own spatial gradient. This is the mechanistic origin of:

- **Gravity**: A particle (a wave packet) is deflected toward regions of higher ρ_E, which are created by other particles.
- **Photon Guiding**: The coupled dipole centers of a photon (see Section 5) experience a net force from their own asymmetric ρ_E field, enabling self-propulsion.
- **Refractive Index**: In a static, inhomogeneous medium, Eq. (6) reduces to $\nabla^2\vec{\Psi} + (\omega^2/c^2)n^2(\vec{r})\vec{\Psi} = 0$, with $n^2(\vec{r}) \propto 1/\rho_E(\vec{r})$.

Equations (5) and (6) together form the mathematical backbone of the theory. The former describes the global self-consistent genesis of fields and particles; the latter describes how these entities move and interact within the energy density landscape they collectively create.

Theorem 1 (Energy-Momentum Conservation)**.** *The system described by Eqs.* (5) *and* (6) *conserves a total energy-momentum tensor* $T^{\mu\nu}_{total} = T^{\mu\nu}_{wave} + T^{\mu\nu}_{medium}$*, where*

$$T^{00}_{total} = \rho_E, \quad \textit{and} \quad \partial_\mu T^{\mu\nu}_{total} = 0. \tag{7}$$

Proof. The conservation follows from the invariance of the action under spacetime translations (Noether's theorem), which holds despite the non-local term due to its dependence only on coordinate differences $\vec{r} - \vec{r}'$. □

4. Derived Phenomena and Quantitative Predictions

4.1. Photon Structure and the Origin of Spin

Solving the coupled system of Eqs. (5) and (6) for a propagating light-like excitation yields a family of solutions. The most stable corresponds to a double-helix structure: two vibrational centers maintaining a fixed separation of $\lambda/2$ and revolving around a common axis as they advance at speed c. The helical trajectory emerges naturally from the torque induced by the asymmetric energy density gradient between the leading and trailing centers. This structure inherently carries angular momentum. Quantization of the helical wavelength ($\lambda = h/(\gamma mc)$ for massive particles, $\lambda = h/(E/c)$ for photons) directly yields the observed spin $\hbar$ per cycle. The photon's spin-1 is thus not an added quantum number but the topological signature of its helical wave configuration in the medium.

4.2. Emergence of the Inverse-Square Law

A profound success of the wave-based approach is the natural emergence of the inverse-square law for both radiation and gravity. Consider the energy density field $\rho_E(r)$ of a stationary particle, modeled as a spherical standing wave. In three dimensions, the energy density of a standing wave pattern decays as:

$$\rho_E(r) \propto \frac{\sin^2(kr + \delta)}{r^2} \approx \frac{1}{r^2} \quad \text{for } kr \gg 1 \tag{8}$$

The gradient, $\nabla\rho_E \propto 1/r^3$, when inserted into the deflection law (6), produces a central force decaying as $1/r^2$. This provides a unified geometric origin for the Newtonian and Coulomb force laws, traditionally separate postulates.

4.3. The Space Lattice and Partial Reflection as an Emergent Limit

At energy scales approaching the Planck energy, the solution to the field equations suggests a crystallization of the wave medium into a stable, high-energy lattice—a natural ground state. This

 doi:10.20944/preprints202512.1645.v1

lattice, while not a rigid scaffold, provides the impedance mismatch necessary for the partial reflection of lower-energy IN/OUT waves, thereby closing the self-consistency loop that stabilizes particles. The reflection coefficient R can be expressed in terms of the impedance of free space Z_0 and the effective impedance of the particle's wave field Z_p, offering a pathway to quantitative estimates of particle lifetimes and coherence scales.

5. Photon as Coupled Vibrations

5.1. The Photon Ansatz

A photon is not a point particle but two coupled vibrational centers:

$$\vec{\Psi}_\gamma(\vec{r},t) = \vec{A}_1(\vec{r}-\vec{R}_1(t))e^{i\omega t} + \vec{A}_2(\vec{r}-\vec{R}_2(t))e^{i(\omega t+\pi/2)} \tag{9}$$

with constraints:

$$|\vec{R}_1(t) - \vec{R}_2(t)| = \lambda/2 = \pi c/\omega \tag{10}$$

$$\vec{A}_i(\vec{\rho}) = A_t(\rho)\hat{e}_t + A_l(\rho)\hat{e}_l, \quad A_l \ll A_t \tag{11}$$

The $\pi/2$ phase difference creates rotating polarization.

5.2. Mechanism of Propagation

Proposition 1 (Self-Sustained Motion)**.** *The two centers propel each other through the energy density gradient created by their interference pattern.*

Proof sketch: The interference term $\vec{A}_1 \cdot \vec{A}_2^*$ creates an asymmetric energy density ρ_E with gradient along the propagation direction. Equation (6) then provides net force.

5.3. Internal Energy Transfer and the Hidden Longitudinal Balance

The stability and energy conservation of the photon soliton rely on a crucial internal mechanism involving the longitudinal (Z) component (here, we define the Z-axis as the propagation direction of the photon, with X and Y axes forming the transverse plane). The two coupled vibrational centers do not oscillate in phase. Their Z-deformations are **anti-correlated**: when one center undergoes a longitudinal compression ($\nabla \cdot \vec{u} > 0$), the other experiences a simultaneous rarefaction ($\nabla \cdot \vec{u} < 0$), and vice-versa.

This creates a **localized, oscillating standing wave of compression** along the axis between the centers. This standing wave is not a radiative mode; it acts as a dynamic energy reservoir that **transfers energy reversibly between the two transverse vibration centers**. At the instant when both transverse (X/Y) oscillations pass through zero amplitude simultaneously—a moment of potential "energy disappearance" in a purely transverse model—the energy is momentarily stored entirely in this longitudinal compression field. It is then returned in phase to drive the next half-cycle of transverse oscillation.

Thus, the Z-component is not an optional feature but a **necessary condition for energy conservation and stable propagation**. It explains why the photon does not radiate its energy away: the system is a closed, resonant loop where energy continuously cycles between transverse kinetic energy and longitudinal potential (compressional) energy of the medium. The famous transverse character of light ($\vec{E} \perp \vec{B} \perp \vec{k}$) is the observable manifestation of this internal dipole oscillation, while the longitudinal balance (dynamically screened at the scale of far-field interactions) remains a hidden, non-radiative degree of freedom essential for the soliton's integrity.

 doi:10.20944/preprints202512.1645.v1

5.4. Longitudinal Momentum from Transverse Waves

Despite the small amplitude of the longitudinal component ($A_l \ll A_t$), the coupled dipole structure generates net momentum in the propagation direction through interference:

$$\vec{p}_\gamma = \frac{1}{c^2}\int d^3r\,\vec{S} = \frac{\omega}{c}\hat{k}\int d^3r\left[|\vec{A}_1|^2 + |\vec{A}_2|^2 + 2\Re(\vec{A}_1\cdot\vec{A}_2^*)\right] \tag{12}$$

The cross term provides the directional component.

6. Particles as Localized Standing Waves

6.1. Standing Wave Condition

A particle corresponds to a self-sustained standing wave pattern:

$$\vec{\Psi}_p(\vec{r},t) = \vec{f}(r)\left[e^{i\omega t} + \beta e^{-i\omega t}\right], \quad r = |\vec{r}| \tag{13}$$

where the In/Out wave ratio β satisfies $|\beta| = 1$ for perfect standing waves.

6.2. Self-Consistency Equation

Substituting into (5) gives the eigenvalue problem:

$$-\omega^2\vec{f}(r) = c^2\nabla^2\vec{f}(r) - g\int d^3r'\,K(\vec{r}-\vec{r}')\left[\vec{f}(r')\cdot\vec{f}(r)\right]\vec{f}(r') \tag{14}$$

Theorem 2 (Quantized Frequencies)**.** *For a given g, this equation admits solutions only for discrete ω_n, providing natural quantization.*

6.3. Mass-Energy Relation

The particle's effective mass comes from the energy of its standing wave pattern:

$$m = \frac{E}{c^2} = \frac{1}{c^2}\int d^3r\left[\frac{\omega^2}{2}|\vec{f}|^2 + \frac{c^2}{2}|\nabla\vec{f}|^2 + V_{\text{nl}}[\vec{f}]\right] \tag{15}$$

where $V_{\text{nl}}[\vec{f}] = \frac{g}{4}\iint d^3r\,d^3r'\,K(\vec{r}-\vec{r}')|\vec{f}(\vec{r})\cdot\vec{f}^*(\vec{r}')|^2$.

7. Foundational Mechanics Reinterpreted

7.1. Velocity as a Geometric Deformation

A particle's velocity $\vec{v}$ relative to the spatial medium is not an independent variable but a specific, sustained deformation of its internal standing wave structure [1]. This deformation, involving a front-rear asymmetry in the In/Out wave field [2], is the physical reality underlying Lorentz transformations.

7.2. Kinetic Energy as Deformation Energy

The kinetic energy $K = (\gamma - 1)mc^2$ is the real energy stored in the velocity-dependent deformation of the particle's wave structure [2]. This resolves the relativistic paradox of kinetic energy attribution. In a collision, energy released comes unambiguously from the relaxation of these deformation energies. This leads to the testable prediction of the asymmetric ion collision experiment [4].

7.3. Inertia and the Equivalence of Masses

- **Inertial mass (m_i)** quantifies resistance to acceleration—the energy required to *reconfigure* the wave deformation pattern against the elasticity of space [2,7].
- **Gravitational mass (m_g)** quantifies the strength of interaction with energy density gradients—how much the *existing* deformation pattern responds to and creates gradients in ρ_E [3].

 doi:10.20944/preprints202512.1645.v1

Both measure the same underlying quantity: the total deformation energy $E = mc^2$ of the wave structure (Eq. (15)). Their proportionality is therefore necessary, not coincidental [3].

7.4. The Nature of Forces

- **Gravity** is the **deflection** of a particle's constituent waves by the gradient of ambient energy density $\nabla\rho_E$ created by other masses—a geometric effect.
- **Other forces** are **transactions of energy** mediated by quasi-stationary wave channels formed through phase synchronization of particles' In/Out fields.

This distinction bridges Relativity (governing the large-scale ρ_E landscape) and Quantum Mechanics (describing resonant wave transactions within it).

8. Reduction to Established Physics: From Medium Deformation to Classical Laws

In our paradigm, established theories are not fundamental but emerge as effective descriptions of the underlying wave dynamics in the elastic spatial medium. The key is the identification of the **energy density** $\rho_E(\vec{r},t)$ and its **gradient** $\nabla\rho_E$ as the primary physical quantities governing wave propagation and, consequently, particle behavior.

8.1. From Soliton Dynamics to Macroscopic Electrodynamics

Maxwell's vacuum equations ($\Box\vec{A} = 0$) do not describe the *fundamental* degrees of freedom of the spatial medium. They emerge as the **effective, low-energy theory** governing the collective behavior and far-field interactions of photon solitons.

The internal, non-radiative longitudinal standing wave (Section 5.3) is integrated out in this effective description. What remains are the **observable dipole characteristics** of the soliton—the coupled transverse oscillations of its centers. In the macroscopic limit (many photons, weak fields), the average effect of these dipoles propagating at speed $c = \sqrt{\kappa/\rho_0}$ and interacting via their induced energy density gradients $\nabla\rho_E$ is mathematically equivalent to the propagation and interaction of a vector potential $\vec{A}$ satisfying the wave equation.

Therefore, the fields $\vec{E} = -\partial_t\vec{A}$ and $\vec{B} = \nabla\times\vec{A}$ are not primitive waves in an elastic solid but **emergent collective variables**. Their transversality is a direct consequence of the dipolar structure of the underlying soliton, and the absence of a longitudinal radiative mode in Maxwell's theory reflects the internal, balanced nature of the Z-component required for the soliton's stability.

8.2. From Envelope Dynamics to the Schrödinger Equation

A massive particle is a localized, non-linear wave structure (soliton) described by a complex envelope $\psi(\vec{r},t)$ modulating a high-frequency carrier wave tied to the medium's rest energy: $\Psi_p \sim \psi(\vec{r},t)e^{-imc^2t/\hbar}$. When the spatial variation of ψ is slow compared to the Compton wavelength, substituting this ansatz into the master equation (5) and averaging over the fast oscillation leads to an effective non-linear Schrödinger equation:

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi + \frac{\delta V_{\text{nl}}}{\delta|\psi|^2}\psi.$$

Here, m is the soliton's mass (its total deformation energy divided by c^2), and the non-linear term V_{nl} arises from the self-consistent In/Out feedback. In the limit of weak self-interaction or for single-particle states, this reduces to the standard Schrödinger equation. This derivation shows that the quantum wavefunction ψ is fundamentally the **envelope of a physical wave in the medium**, and $\hbar$ emerges as the scale relating the phase of this wave to energy.

8.3. Emergence of Relativistic Kinematics

As rigorously demonstrated in [1], a state of uniform motion with velocity $\vec{v}$ relative to the medium is not a dynamical primitive but a specific *geometric deformation state* of a particle's standing wave

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structure. The Lorentz factor $\gamma = (1 - v^2/c^2)^{-1/2}$ describes this deformation. All mathematical tools of Special Relativity (time dilation, length contraction, $E = \gamma mc^2$) remain operationally valid for relating measurements made by deformed observers, but find a mechanistic explanation: they describe the real, physical deformation of wave patterns in the absolute spatial frame [6].

9. Connection to General Relativity and Gravity

9.1. Gravity as Energy Density Gradient

General Relativity accurately describes gravitational phenomena but leaves the underlying mechanism unexplained. In our framework, gravity emerges from gradients in space's energy density $\rho_E(\vec{r})$, not from curvature of an abstract manifold. The effective metric is:

$$g_{\mu\nu} = \eta_{\mu\nu}\left(1 + \frac{2}{c^2}\Phi(\vec{r})\right), \quad \Phi(\vec{r}) = \int \frac{G\rho_E(\vec{r}')}{|\vec{r} - \vec{r}'|} d^3r' \tag{16}$$

where Φ is the gravitational potential directly linked to ρ_E.

9.2. Other Forces as Synchronized Wave Channels

While gravity operates via energy density gradients, other fundamental forces (electromagnetic, strong, weak) employ direct energy transport along **quasi-stationary wave channels**. These channels form automatically between particles through phase synchronization:

$$\Delta\phi_{ij} = \frac{\omega}{c}|\vec{r}_i - \vec{r}_j| + n\pi \tag{17}$$

When this condition is met, resonant energy exchange occurs with characteristic coupling constants.

10. Testable Predictions

10.1. Photon Substructure and Modified Dispersion

Table 1. Key predictions distinguishing the paradigm from standard physics across all scales.

Phenomenon	Standard	Our Prediction	Test Method
Twin Paradox (symmetrical)	Symmetrical ageing	Asymmetrical ageing	Precision clocks on satellites
Asymmetric ion collision	Symmetrical outcomes	Asymmetrical outcomes	H^+/He^+ collisions
Proton mass prediction	Not predicted from first principles	$m_p/m_e = 1836.152\ldots$ (7 figures)	High-precision mass spectrometry
Galaxy rotation	Requires dark matter	Explained by energy diffusion (MOND)	Detailed galaxy mapping
Supernova energy	Missing energy problem	Exotic-matter amplification	Supernova observations
Deuterium binding	Quantum chromodynamics	Electromagnetic model with exact prediction	Nuclear spectroscopy
Ultra-high-energy gamma rays	Challenging to explain	From exotic matter decay	HAWC, LHAASO, CTA observations
Cosmic energy budget equivalence	Dark energy / Λ as separate component	Gravitational potential energy of baryonic mass $\sim$ "Missing" neutrino mass-energy	Cosmological parameter fits & neutrino astrophysics

10.2. The Asymmetric Ion Collision Test

The most decisive test is an asymmetric collision between relativistic H^+ and He^+ ions [4]. Detailed calculations in [4] predict a measurable asymmetry with full experimental specifications provided. Special Relativity predicts perfect symmetry between the configurations (H^+ fast on He^+ at

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rest vs. He^+ fast on H^+ at rest). Our paradigm, where kinetic energy is an absolute deformation of the wave structure, predicts a measurable asymmetry in reaction cross-sections or product spectra due to velocity-dependent modifications of internal binding energies.

10.3. Predictions Across All Scales

The elastic space paradigm makes testable predictions at every scale of physics:

- **Microscopic Scale:**
  - Precise prediction of the proton-to-electron mass ratio with seven significant figures accuracy [9]
  - Explanation of quark observations as transient collision artifacts rather than fundamental particles
  - Prediction of three and only three fermion generations due to spatial anisotropy [10]
  - Asymmetric outcomes in specific ion collision configurations [4]
  - Exact prediction of deuterium binding from electromagnetic model [16]
- **Astrophysical Scale:**
  - Mechanistic explanation for supernova energy without missing energy [15]
  - Galaxy rotation curves explained without dark matter via energy density diffusion [11]
  - Black holes described as non-singular exotic matter structures
  - Stellar mass ranges for supernova and black hole formation that match observations
  - Ultra-high-energy gamma rays (UHEGRs, EHEGRs) from exotic matter decay as explanation for extreme-energy astrophysical events
- **Cosmological Scale:**
  - Cyclical universe model with Big Bounce replacing Big Bang [12]
  - Explanation for early galaxy formation observed by JWST through anisotropic multiverse regions [13]
  - Elimination of dark energy through natural expansion dynamics of elastic medium
  - Testable predictions for universe geometry and expansion history

These predictions collectively provide multiple independent avenues for experimental verification or falsification of the paradigm.

11. Resolving Quantum and Relativistic Paradoxes

11.1. Wave-Particle Duality

Explanation: The apparent duality resolves into a unified description: what is called the "particle" is the energy center—the localized concentration of the standing wave pattern. The "wave" aspect comprises the extended IN/OUT wave structure that is integral to the particle itself. Both are simultaneously present as different aspects of the same physical entity: a non-local wave structure with a localized energy center.

11.2. Measurement Problem

Solution: The measurement problem dissolves when distinguishing between a particle's non-local wave structure and its localized energy center. While the IN/OUT waves extend non-locally (explaining interference and entanglement), the particle's energy center—its "center of mass"—follows a single, deterministic trajectory. This trajectory is continuously determined by the interference between the particle's own IN/OUT waves and those of the entire environment. Photons, like all particles, do not explore "all paths" simultaneously; they follow unique paths progressively determined by environmental wave interactions. There is no collapse because the energy center was always localized along a specific trajectory.

 doi:10.20944/preprints202512.1645.v1

11.3. Non-Locality and Entanglement

Mechanism: Separated particles share components of the same standing wave pattern via the In/Out mechanism [5]. Measurement at one location instantly reconfigures the entire pattern.

11.4. Quantization

Origin: Discrete energy spectra arise from topological constraints: particle cores are closed-loop standing waves where constituent wavelengths must be exact divisors of loop perimeters. The IN/OUT wave mechanism (each displacement radiating new transverse waves) further restricts to specific frequency sets that maintain self-consistency in the elastic medium.

11.5. Foundational Paradoxes Resolved

Twin Paradox: Proper Time as a Measure of Absolute Motion.

The classic Twin Paradox is not a paradox within our paradigm but a direct consequence of the absolute nature of motion through the spatial medium. Ageing is governed by *proper time* τ, which is not an abstract parameter but the physical count of cycles completed by an entity's internal standing wave structure. As derived geometrically from the wave nature of matter [8], a particle moving at velocity v relative to the medium undergoes a real deformation: to maintain its standing wave coherence while translating, the internal wave paths, which are closed loops in its rest frame, appear to an external observer as helical trajectories of pitch v. The critical effect is that a greater fraction of the wave's propagation period is devoted to translation along the helix, leaving less "time" to complete a full internal cycle. This directly reduces the rate of all internal processes—atomic, chemical, and biological—manifesting as time dilation: $d\tau = dt/\gamma(v)$, where $\gamma(v)$ depends on the particle's speed *relative to the absolute medium*.

This framework resolves the symmetrical variant of the paradox, where each twin departs from Earth in opposite directions at equal speed relative to Earth, and later returns. Standard relativity, relying solely on relative velocity, predicts symmetrical ageing. Our paradigm makes a starkly different prediction: the ageing difference will depend on Earth's own velocity $\vec{V}_\oplus$ through the medium. The twin whose journey direction is more aligned with $-\vec{V}_\oplus$ (thus achieving a higher *absolute* speed) will age less. This measurable asymmetry, null in standard relativity, provides a definitive experimental test to distinguish between a purely relative and an absolute, medium-based description of motion.

Kinetic Energy Attribution in Collisions.

In relativistic collisions, kinetic energy is frame-dependent, creating paradoxes about its "real" location. Our paradigm resolves this: kinetic energy is the real deformation energy stored in each particle's wave structure relative to the medium [2]. In a collision, the total energy released comes unambiguously from the sum of the deformation energies of the colliding particles. The proposed asymmetric H+/He+ collision test [4] is designed to measure precisely this: by comparing configurations where different particles carry the deformation (kinetic) energy, we can determine if the collision products differ, thereby validating that kinetic energy is an absolute property stored in individual particles.

Origin of Motion.

The paradigm provides a mechanistic answer to the profound question: "What is velocity?" Rather than being an unexplained primitive vector, velocity is a sustained geometric deformation state of a particle's standing wave pattern [1]. Motion is the self-consistent, rigid translation of this deformed pattern through the medium, powered and guided by the In/Out wave feedback loop.

Equivalence of Inertial and Gravitational Mass.

The centuries-old mystery of why $m_i = m_g$ finds a natural resolution. Both measure the same underlying physical quantity—the total deformation energy $E = mc^2$ of the particle's wave structure—but in different contexts:

 doi:10.20944/preprints202512.1645.v1

- **Inertial mass (m_i)** quantifies resistance to acceleration, i.e., the energy required to *reconfigure* the wave deformation pattern against the elasticity of space.
- **Gravitational mass (m_g)** quantifies the strength of the particle's interaction with an energy density gradient, i.e., how much its *existing* deformation pattern responds to and creates gradients in ρ_E.

Since both phenomena spring from the same root—the particle's total wave deformation energy—their proportionality is not a coincidence but a necessity [3]. The gravitational constant G then encodes the elasticity of space that couples deformation energy to the creation of and response to energy density gradients.

12. Conclusion

We have presented a complete, self-consistent reconstruction of physics from a single postulate: **space as a three-dimensional elastic, vibratory medium**. This paradigm, developed across sixteen interconnected publications, provides a unified framework spanning from quantum phenomena to cosmic cycles.

12.1. Core Achievements

The paradigm mechanistically derives all fundamental phenomena:

- **Photons** as coupled vibrational dipoles with intrinsic spin from helical wave structure
- **Particles** as self-sustained standing waves maintained by IN/OUT wave circulation
- **Gravity** as deflection by energy density gradients, not abstract curvature
- **Velocity** as geometric deformation of wave patterns
- **Mass equivalence** from common origin in deformation energy
- **Quantum phenomena** from wave interference and non-local IN/OUT structure

12.2. Quantitative Predictions and Testability

The paradigm's value lies in its empirical accessibility:

- **Microscopic:**
  - Proton-to-electron mass ratio predicted to 7 significant figures
  - Asymmetry in H^+/He^+ collisions
  - Exact deuterium binding from electromagnetic model
  - Three fermion generations from spatial anisotropy
- **Astrophysical:**
  - Supernova energy amplification without missing energy
  - Galaxy rotation without dark matter (MOND basis)
  - Black holes as non-singular exotic matter structures
  - Stellar mass ranges matching observations
  - Ultra-high-energy gamma rays from exotic matter decay (UHEGR,EHEGR)
- **Cosmological:**
  - Cyclical Big Bounce replacing Big Bang singularity
  - Cosmic expansion without dark energy
  - Early galaxy formation from anisotropic multiverse regions
  - Order-of-magnitude equivalence between the universe's gravitational binding energy and its apparent missing energy

12.3. Paradigm Shift

This represents more than a new theory—it is a complete worldview shift:

- **Single Substance:** Space as the only fundamental entity
- **Single Mechanism:** Self-consistent wave dynamics in elastic medium

 doi:10.20944/preprints202512.1645.v1

- **Complete Coverage:** All phenomena from Planck scale to cosmic horizons
- **No Ad Hoc Elements:** Elimination of dark matter, dark energy, singularities
- **Deterministic Foundation:** Restoration of mechanistic causality

12.4. Future Directions

Immediate priorities include:

1. Numerical simulations of the master equation (Eq. 5)
2. Experimental realization of the asymmetric ion collision test
3. Further development of astrophysical and cosmological predictions
4. Detailed comparison with precision measurements across all scales

The elastic space paradigm offers not just reinterpretation but **mechanistic explanation** for all major physics phenomena. With multiple testable predictions at every scale, it provides clear pathways for empirical validation or falsification. We invite the scientific community to engage with this comprehensive research program that aims to rebuild physics from a single, physically intuitive foundation.

Acknowledgments

I thank the physics community for maintaining an open discourse on foundational issues.

Companion Publications

This work synthesizes a research program developed across sixteen interconnected publications:

Foundational Framework (this synthesis builds upon):

- **Velocity as Geometric Deformation** [1]
- **Inertia and Kinetic Energy** [2]
- **Unified Mechanism for Inertial/Gravitational Mass** [3]
- **Experimental Test via Asymmetric Collisions** [4]
- **IN/OUT Wave Mechanism** [5]
- **Michelson-Morley in a Medium** [6]
- **The Vibrational Fabric of Spacetime** [7]
- **Deriving Relativistic Kinematics** [8]

Microphysical Applications:

- **Photon-Based Vector Particle Model for Proton/Neutron Masses** [9]
- **Proton Mass and Origin of Fermion Generations** [10]
- **Electromagnetic Model for Proton-Neutron Binding in Deuterium** [16]

Astrophysical and Cosmological Applications:

- **Energy Density Diffusion for MOND and Dark Energy** [11]
- **The Diffusive Universe: Cyclical Model without Dark Components** [12]
- **Multiverse as Source of Anisotropy** [13]
- **Supernova Energy Amplification through Exotic Matter** [15]
- **Exotic Matter Formation as the Trigger of a Cosmological Bounce** [14]

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