Fundamental Journals
International Journal of Fundamental Physical Sciences (IJFPS)

Original Research Papers
Open Access Journals
ISSN: 2231-8186

IJFPS, Vol 16, No 1, pp 1-11, Mar, 2026
https://doi.org/10.14331/ijfps.2026.330179

A Structural–Informational Model of Space-Time: Fundamental Pressure, Cellular Lattice, and Vacuum Architecture

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Received: Nov 2025
Received in revised: Dec 2025
Published: March 2026

ABSTRACT

This article establishes the theoretical foundations of a structural–informational model of space–time in which the vacuum is treated as a physically real, material–informational medium rather than an empty geometric background. Space–time is proposed to possess an intrinsic cellular organization governed by a universal fundamental pressure, which acts as the primary stabilizing quantity for localized energy configurations. Within this framework, energy localization is identified with finite space–time volumes, and mass emerges as a structural manifestation of space–time deformation maintained by pressure equilibrium. Two distinct but interconnected structural levels are developed. The normal space–time lattice forms locally in association with matter and underlies electromagnetic interactions, providing geometric interpretations of electric charge and electromagnetic constants as response parameters of the structured vacuum. At a deeper level, a background space–time lattice is introduced as a global, matter-independent structural state of the metric, responsible for gravitational dynamics. Collective oscillations of this background lattice lead naturally to the prediction of a global low-frequency pulsation of space–time with a characteristic frequency near 0.06 Hz, identified as an intrinsic eigenmode of the structured vacuum. The model bridges classical mechanics, general relativity, and quantum behavior by extending the de Broglie relation to include cellular participation of space–time and by interpreting wave–particle duality as a scale-dependent manifestation of cellular dynamics. Experimentally relevant consequences are examined, most notably neutron β-decay, where the observed neutron lifetime emerges as a geometric delay associated with electron propagation through the normal space–time lattice. The close agreement between theoretical predictions and experimental measurements supports the physical reality of the proposed structural parameters. Overall, the framework shifts the foundations of physics from material entities to the organization and dynamics of space–time itself.

Keywords: Structural–informational space–time; fundamental pressure; cellular space–time lattice; background gravitational pulsation; vacuum structure

1. INTRODUCTION

The present work investigates the fundamental medium underlying all observable particles, physical objects, and living systems in the Universe: space–time itself. On cosmological scales, the dominance of space–time over matter becomes immediately apparent when comparing their characteristic volumes. Using the average baryonic matter density of the Universe, approximately $1 \times 10^{-26}\,\mathrm{kg\,m^{-3}}$, even a simple volumetric estimate reveals that observable matter occupies an exceedingly small fraction of the total cosmic volume. This disproportion naturally raises a fundamental question: is matter the primary determinant of physical reality, or is space–time itself the governing medium that shapes matter and its dynamics?

Despite its central role in all physical theories, the internal nature of space–time remains insufficiently understood. A key criterion for understanding any embedding medium that governs the behavior of objects within it is the presence of an internal structure. Conversely, the existence of highly ordered regularities in embedded systems ranging from crystalline lattices in condensed matter to the harmonic architecture of celestial mechanics strongly suggests the action of an organizing substrate. If matter and motion exhibit such coherence across vastly different scales, it is reasonable to expect that space–time itself possesses a corresponding structural organization.

Modern physics presents two fundamentally different conceptions of space–time. Quantum approaches allow, and in some cases require, a discrete structure, while general relativity describes space–time as a smooth, continuous manifold governed by curvature. This dichotomy leads to deep conceptual difficulties: if space–time is discrete, what mechanism prevents it from fragmenting into isolated elements; if it is continuous, what prevents it from collapsing into singular configurations? These unresolved issues indicate that the prevailing descriptions may be incomplete and that a deeper structural interpretation is required.

The idea of space as an independent physical category has a long intellectual history. In ancient Greek philosophy, Anaximander introduced the concept of the *ápeiron*, a boundless primordial principle from which all forms arise and to which they return. Later, Democritus described the Universe as composed of atoms embedded in an infinite void, thereby assigning physical significance both to discreteness and to extension. In the modern era, the concept of “nothing” acquired a precise theoretical meaning.

Zeldovich demonstrated that the emergence of a closed Universe “from nothing” does not violate conservation laws when the negative contribution of gravitational energy is taken into account (Zeldovich, 1988). General relativity itself permits such a scenario, even though current observations indicate near-zero spatial curvature on cosmological scales (Einstein, 1955).

Classical physics initially treated space as an absolute but physically inert background. Newton explicitly avoided attributing material properties to space, referring to it as absolute void. However, the development of electrodynamics in the nineteenth century revived interest in vacuum as an active medium. Maxwell’s prediction of electromagnetic waves and their experimental confirmation led to numerous attempts to model the vacuum as an ether-like substance (Maxwell, 1861). Precision experiments culminating in modern optical, atomic-clock, and astrophysical tests have decisively shown that the vacuum does not behave as a classical material medium with a preferred reference frame. Only Lorentz-invariant descriptions remain compatible with experimental evidence (Will, 2014).

Einstein initially rejected the ether concept but later acknowledged that the idea of completely empty space is physically unsatisfactory. He emphasized, however, that any such medium cannot possess the properties of ordinary matter or be described in terms of motion in the classical sense (Einstein, 1922). A significant conceptual advance in this direction was made by Wheeler through the introduction of the *geon*, a self-sustaining configuration of fields held together by its own gravitational influence. Wheeler later extended this line of thought into the principle “It from Bit,” proposing that information constitutes the most fundamental substrate of physical reality (Wheeler, 1998). The informational interpretation of physics has since been developed by multiple authors. Landauer established a direct connection between information processing and thermodynamic dissipation, demonstrating experimentally that information is a physical quantity rather than an abstract construct (Landauer, 1996). More recently, informational approaches have been explored in cosmology and fundamental physics, suggesting that matter, energy, and space–time may all be manifestations of deeper informational structures (Vopson, 2022). Within this framework, space–time itself may be regarded as a material–informational medium, capable of storing, transmitting, and transforming information.

Motivated by these considerations, the present work follows an extended form of Bohr’s correspondence principle, using classical mechanics as a guiding framework for probing the structure of space–time. The approach adopted here introduces a fundamental pressure as an intrinsic property of space–time and proposes a cellular organization of the metric.

Two distinct but interconnected structures are identified: a normal lattice, associated with matter and electromagnetic phenomena, and a background lattice, associated with global gravitational dynamics. Within this structural informational model, mass, charge, particles, and fundamental constants emerge not as intrinsic attributes of matter, but as structural manifestations of space–time itself. This framework aims to provide a conceptual bridge between classical mechanics, general relativity, and quantum behavior, while remaining consistent with known experimental constraints.

2. THEORETICAL BACKGROUND OF THE PULSATION PHENOMENON AND THE FORMATION OF THE STRUCTURE OF THE UNIVERSE

Contemporary cosmological observations indicate that the average density of baryonic matter in the Universe is approximately $8.5 \times 10^{-27}\ \mathrm{kg\,m^{-3}}$, corresponding to only a few hydrogen atoms per cubic meter. Since nearly all baryonic mass is concentrated within atomic nuclei of femtometer-scale dimensions, the total physical volume occupied by observable matter represents an extremely small fraction on the order of 10^{-43} of the volume of the observable Universe. This disparity casts doubt on matter-centered interpretations of cosmic organization and strongly suggests that space–time itself plays the dominant role in governing physical and chemical processes.

If the material content of the Universe is volumetrically negligible, it becomes implausible to attribute the large-scale coherence and stability of physical laws solely to particles and macroscopic bodies. A more consistent interpretation is that matter behaves as a secondary manifestation, emerging within and responding to the properties of an underlying space–time medium. In this view, particles and fields acquire their characteristics against the background of a deeper structural organization of space–time.

2.1 Discreteness, Continuity, and the Problem of Stability

Modern theoretical physics offers two fundamentally different descriptions of space–time. Quantum approaches permit, and in some cases require, a discrete or granular structure, whereas general relativity treats space–time as a smooth, continuous manifold whose geometry is determined by energy–momentum content.

This conceptual dichotomy raises unresolved questions. If space–time is discrete, what mechanism ensures coherence and prevents disintegration into isolated elements? Conversely, if it is perfectly continuous, what prevents gravitational collapse into singular configurations?

These questions indicate that neither discreteness nor continuity, taken in isolation, provides a satisfactory description. Instead, they suggest the existence of an intermediate structural organization capable of preserving global continuity while allowing localized discreteness. The present work adopts this perspective by proposing a cellular organization of space–time, in which discrete structural units collectively form a stable, Lorentz-invariant continuum.

2.2 Vacuum as a Physical Medium

Historically, the physical interpretation of vacuum has undergone significant evolution. In classical mechanics, Newton treated space as absolute but physically inert, deliberately avoiding speculative hypotheses regarding its internal nature. With the advent of electrodynamics, however, the vacuum began to acquire a more active role. Maxwell's prediction of electromagnetic waves motivated the hypothesis that space must function as a medium capable of supporting wave propagation (Maxwell, 1861).

Despite extensive theoretical development, classical ether models failed experimental verification. Precision experiments including the Michelson–Morley and related tests, as well as modern optical and astrophysical measurements demonstrated that the vacuum does not exhibit the properties of a material medium with a preferred reference frame. Only Lorentz-invariant descriptions remain compatible with experimental evidence (Will, 2014).

Nevertheless, the rejection of the classical ether did not eliminate the need for a physically meaningful vacuum. In general relativity, gravitation is encoded in the geometry of space–time itself, independent of material composition. Electromagnetic fields are likewise treated as self-sustaining entities existing within vacuum. Einstein later emphasized that the notion of completely empty space is incompatible with physical laws, while simultaneously stressing that any admissible medium must not be endowed with the properties of ordinary matter or be describable in terms of motion (Einstein, 1922; Einstein, 1955).

A notable conceptual advance was introduced by Wheeler through the concept of the *geon* a self-sustaining configuration of electromagnetic or gravitational fields stabilized by its own gravitational influence (Wheeler, 1955). Although not formulated as a quantum object, the geon demonstrated that space–time itself can support particle-like structures without invoking material constituents. Wheeler later extended this idea into the principle "It from Bit," proposing that information constitutes the most fundamental substrate of physical reality (Wheeler, 1998).

2.3 Information as a Physical Quantity

The interpretation of information as a physical quantity was rigorously formalized by Landauer, who demonstrated that information processing is intrinsically linked to thermodynamic dissipation. According to Landauer's principle, the erasure of one bit of information is necessarily accompanied by the release of a minimum amount of energy $W_I = k_B T \ln 2$, providing experimental evidence that information is not merely abstract but physically real (Landauer, 1996).

Subsequent work has expanded this concept, treating information as a fundamental property of the Universe alongside matter and energy. Within this framework, physical quantities such as mass, charge, and field strength may be reinterpreted as manifestations of deeper informational structures embedded in space–time. This interpretation aligns naturally with Wheeler's informational paradigm and suggests that space–time itself functions as a material–informational medium, capable of storing, transmitting, and transforming information.

In the present model, the energy associated with information is expressed not only through thermodynamic relations, but also through spatial deformation. This leads directly to the introduction of a fundamental pressure, representing the intrinsic energy density of space–time and governing the stability of localized structures.

2.4 Harmonic Organization and the Hypothesis of a Global Pulsation

Physical systems across all observable scales exhibit pronounced harmonic organization. Atomic spectra, orbital dynamics of planets, and oscillatory processes in macroscopic systems all point to the presence of underlying resonant principles. Such coherence is difficult to reconcile without invoking a common organizing mechanism.

Within the structural–informational framework, this mechanism is associated with intrinsic oscillatory modes of space–time itself. Building on earlier results reported by the author (Zhussupov, 2014), the present work proposes that space–time possesses a global, low-frequency pulsation, arising from the dynamics of its background structure. This pulsation is not generated by local sources, but represents a collective mode of the space–time medium as a whole.

The predicted frequency of this background oscillation, on the order of 10^{-2} Hz, emerges naturally from the interaction between the fundamental pressure and characteristic scales defined by universal constants. This global mode provides a unifying context for gravitational phenomena, inertial effects, and the emergence of particle properties. In this interpretation, gravitation is understood not only as geometric curvature induced by matter, but also as a dynamic manifestation of structured space–time undergoing coherent oscillations.

3. MODIFIED DE BROGLIE RELATION AND THE CELLULAR STRUCTURE OF SPACE–TIME

A central step toward a structural–informational interpretation of space–time is obtained by reconsidering the de Broglie relation, which connects the wave properties of matter to its momentum. In its conventional form,

$$\lambda = \frac{h}{p} = \frac{h}{mv}, \tag{1}$$

this relation has been experimentally confirmed at atomic and subatomic scales. However, when directly extended to macroscopic objects, it leads to conceptual inconsistencies. For bodies of ordinary mass moving at everyday velocities, the predicted wavelengths become extremely small often comparable to those associated with high-energy gamma radiation yet no corresponding wave behavior is observed.

This discrepancy does not indicate a failure of the de Broglie principle itself, but rather reveals an implicit limitation in its standard interpretation. The conventional form assumes that motion is associated with a single quantum of action, regardless of scale. Such an assumption is appropriate for microscopic systems but becomes inadequate when describing extended objects interacting with space–time over macroscopic volumes.

Previous work by the author demonstrated that the de Broglie relation possesses an additive property that becomes relevant at larger scales (Zhussupov, 2014). When this property is taken into account, the wavelength associated with motion is expressed as

$$\lambda = \frac{Nh}{p} = \frac{Nh}{mv}, \tag{2}$$

where N is a dimensionless additive coefficient. This coefficient is interpreted as the number of space–time cells participating in the motion of the object.

3.1 Physical Meaning of the Additivity Coefficient

The quantity N is not an arbitrary scaling parameter. Instead, it reflects the degree to which the structured medium of space–time is involved in sustaining motion. For microscopic systems, such as an electron on the first Bohr orbit of the hydrogen atom, the value of N is equal to unity. This result is fully consistent with standard quantum mechanics and confirms that atomic-scale motion involves a single effective space–time cell.

At macroscopic scales, however, N becomes extremely large. For example, the toroidal volume traced by the Earth in its orbital motion around the Sun contains approximately $N \approx 2.5 \times 10^{74}$ space–time cells. In such cases, the wave properties associated with motion are distributed across an enormous number of structural units, rendering any direct wave manifestation unobservable.

This interpretation resolves the long-standing paradox of macroscopic de Broglie wavelengths. The absence of observable wave phenomena in everyday objects does not imply the absence of wave structure. Rather, it reflects the collective averaging of wave behavior over a vast number of space–time cells. Wave particle duality is therefore preserved at all scales, but its observable consequences depend on the scale-dependent degree of structural participation.

3.2 Emergence of Cellular Space–Time Structure

The introduction of the coefficient N implies that space–time cannot be physically continuous in the classical sense. If motion necessarily involves a finite number of participating units, then space–time must possess a cellular organization, composed of minimal volumes that act as carriers of energy, momentum, and information.

These cells are not particles, nor are they localized material objects. They represent structural elements of the space–time metric itself, whose collective behavior gives rise to observable physical phenomena. Importantly, this cellular structure does not violate Lorentz invariance, since it does not introduce a preferred reference frame or directional anisotropy. The cells are isotropic and homogeneous in their statistical properties, ensuring compatibility with special relativity and with precision experimental constraints (Will, 2014).

Within this framework, classical mechanics emerges as a large-scale limit of structured wave dynamics. Momentum, velocity, and mass retain their conventional meanings, but their wave interpretation is now mediated by the number of space–time cells involved in the process. The correspondence principle is therefore preserved, while its domain of applicability is extended beyond the microscopic regime.

3.3 Connection Between Cellular Structure and Energy Density

The modified de Broglie relation provides a direct pathway to determining the intrinsic energy density of space–time. If each cell participates in storing and transmitting energy, then the energy associated with a given region of space–time must be proportional to its volume. This leads naturally to the relation

$$E = PV \tag{3}$$

where P represents a fundamental pressure characterizing the intrinsic energy density of space–time.

This formulation establishes a direct equivalence between energy localization and spatial deformation. Mass, in this context, is no longer treated as an intrinsic substance but as a manifestation of localized space–time volume stabilized by pressure. The familiar mass–energy relation $E = mc^2$ emerges as a special case of this more general energy–volume correspondence.

The introduction of fundamental pressure therefore bridges classical mechanics, quantum wave behavior, and relativistic energy relations within a single structural–informational framework. The cellular organization implied by the modified de Broglie relation serves as the foundation for the normal space–time lattice, whose properties will be examined in the following section.

4. FUNDAMENTAL PRESSURE AND THE NORMAL STRUCTURE OF SPACE–TIME

The modified de Broglie relation introduced in the previous section implies that the localization of energy and motion necessarily involves a finite number of structural units of space–time. This conclusion leads naturally to the concept of a normal space–time structure, which forms locally in the presence of particles and macroscopic bodies. The stability of this structure is governed by a universal quantity referred to here as the fundamental pressure, representing the intrinsic energy density of space–time.

4.1 Energy–Volume Equivalence and Structural Pressure

Within the structural informational framework, energy localization is inseparably linked to spatial deformation. This relationship is expressed through the equivalence

$$E = mc^2 = PV, \tag{4}$$

where P is the fundamental pressure and $V$is the effective volume of space–time associated with a particle or object. In this formulation, mass is no longer interpreted as an intrinsic substance, but rather as a spatial manifestation of energy, stabilized by the surrounding pressure of the structured vacuum.

This interpretation is consistent with Einstein's mass–energy equivalence, while extending its physical meaning. The creation of a particle corresponds to the excitation of a finite volume of space–time, whereas annihilation corresponds to the release of that volume back into the vacuum. The persistence of mass is therefore ensured by equilibrium between localized energy and the omnipresent fundamental pressure. In this sense, pressure acquires a foundational status comparable to the speed of light c, Planck's constant h, and the gravitational constant G (Einstein, 1955).

The extremely large numerical value of the fundamental pressure indicates that space–time exists in a highly ordered structural phase. When divided by c^2, this pressure corresponds to an effective density of space–time on the order of $5 \times 10^7\ \mathrm{kg\,m^{-3}}$, exceeding the density of the heaviest known chemical elements. This result reinforces the conclusion that space–time is not an empty backdrop, but a dense and physically active medium.

4.2 Cellular Density and Geometry of the Normal Lattice

The value of the fundamental pressure allows the number of space–time cells within a unit volume to be calculated. By relating pressure to the electron mass and electromagnetic constants, the number of cells per cubic meter of normal space–time is obtained as

$$N = \frac{P}{\pi \varepsilon_0 m_e c^2} \tag{5}$$

yielding approximately 2.1×10^{48}cells per cubic meter. These cells are assumed to be uniform and approximately spherical, leading to a characteristic cell radius on the order of 4.8×10^{-17} m.

This normal lattice arises locally wherever matter is present and provides the structural framework through which particles interact. Its discrete nature remains unobservable at ordinary scales due to the extremely small cell size, yet its collective effects determine the behavior of electromagnetic and mechanical phenomena.

Importantly, the existence of a cellular structure does not violate Lorentz invariance. Since the lattice does not introduce a preferred frame or anisotropy, it remains compatible with precision experimental tests of relativity (Will, 2014). The normal structure therefore represents a physically admissible refinement of the vacuum concept rather than a return to classical ether models.

4.3 Electromagnetic Constants as Structural Parameters

A major consequence of the normal space–time lattice is a reinterpretation of the electric permittivity $\varepsilon_0$and magnetic permeability μ_0. Rather than being fundamental proportionality constants introduced phenomenologically, these quantities emerge naturally from the interaction between charged particles and the structured vacuum.

Within this framework, electromagnetic fields arise from the mechanical work performed by the fundamental pressure on the volume of a normal space–time cell. The relation

$$\varepsilon_0 \mu_0 = \frac{1}{c^2} \tag{6}$$

is preserved exactly, ensuring full consistency with Maxwell's equations and special relativity (Maxwell, 1861). At the same time, the constants acquire a clear physical meaning as **response coefficients** characterizing the interaction between matter and the space–time lattice.

Furthermore, the electric and magnetic constants can be expressed in terms of the curvature radius of the normal cell and the wavelength of the electron in the first Bohr orbit. This geometric connection establishes a direct link between atomic structure and the electromagnetic properties of vacuum, indicating that atomic and field phenomena share a common structural origin.

4.4 Mass as a Structural Manifestation

Within the normal lattice, mass arises as a consequence of spatial deformation stabilized by pressure. The effective volume associated with a particle corresponds to a toroidal region traced by its intrinsic structure during motion. For the electron, the rest energy of approximately 511 keVcorresponds precisely to the product of the fundamental pressure and this toroidal volume.

This observation leads to the principle of structural–pressure dominance, according to which any stable particle configuration corresponds to a finite space–time volume maintained in equilibrium by the fundamental pressure. Mass is therefore not an immutable intrinsic property, but a measure of the degree to which space–time is locally deformed and energetically excited.

The same principle applies across all physical scales. From elementary particles to macroscopic bodies, mass reflects the volume of space–time engaged in maintaining structural equilibrium. This universality explains why the mass–energy relation applies equally to microscopic systems and astronomical objects.

4.5 Emergence of Electromagnetism from Normal Structure

The normal structure of space–time is directly responsible for the emergence of electromagnetic interactions. Charged particles interact with the surrounding lattice, inducing localized curvature and deformation that manifest as electric and magnetic fields. In this interpretation, electromagnetism acquires a mechanical origin, rooted in the response of structured space–time to localized energy distributions.

This viewpoint unifies mechanical, electromagnetic, and informational descriptions within a single framework. The fundamental pressure governs stability, the cellular lattice mediates interactions, and observable fields arise as macroscopic expressions of underlying structural dynamics. Such unification aligns naturally with informational interpretations of physical law and provides a coherent foundation for extending the model to gravitational and cosmological phenomena.

5. STRUCTURAL INTERPRETATION OF PARTICLE PROPERTIES AND THE INTRINSIC ELECTRON RADIUS

The normal structure of space–time developed in the previous section provides the geometric and energetic framework within which particles acquire their observable properties. In the structural–informational model, particles are not treated as point-like entities embedded in an empty background, but as localized, stable deformations of the space–time lattice, maintained by the fundamental pressure. The electron serves as a central example for illustrating this interpretation.

5.1 Intrinsic Radius of the Electron and Cell Geometry

Within the normal space–time lattice, the electron occupies a finite spatial extent determined by the equilibrium between its localized energy and the surrounding structural pressure. The intrinsic radius of the electron is obtained by equating the volume of a normal space–time cell to the toroidal volume traced by the electron during its motion on the first Bohr orbit of the hydrogen atom. This condition is expressed as

$$V_n = \pi r_e^2 \, 2\pi R_B \tag{7}$$

where r_e is the intrinsic radius of the electron and R_B is the Bohr radius.

Solving this relation yields an intrinsic electron radius on the order of 10^{-20} m. This value lies well below the current experimental upper bounds obtained from high-precision accelerator and spectrometric studies, which constrain the electron radius to be less than approximately 4×10^{-20} m (Nolte, 1993). The agreement between the structural estimate and experimental limits supports the interpretation of the electron as a finite spatial deformation rather than a mathematical point.

The fact that the electron's intrinsic radius is more than three orders of magnitude smaller than the radius of a normal space–time cell indicates that the normal lattice itself is embedded within a deeper and more fine-grained background structure. This observation motivates the introduction of a second, global level of space–time organization, which will be examined in a later section.

5.2 Universal Mass Relation from Structural Parameters

The intrinsic radius derived above allows the mass of a particle or object to be expressed entirely in terms of geometric and kinematic quantities. By combining the relations governing the normal lattice with the modified de Broglie formalism, the mass can be written as

$$M = \frac{\mu_0 h P r^2}{v m_e} \tag{8}$$

where r is the intrinsic radius of the object and v is its characteristic velocity.

This relation applies universally, from microscopic particles to macroscopic bodies, and implies that mass is not a fundamental substance but a derived quantity, reflecting the interaction between motion and structured space–time. In cosmological contexts, this formulation is particularly significant, as it suggests that the masses of celestial bodies may be estimated from measurable geometric and dynamical parameters alone, without reference to internal material composition.

5.3 Intrinsic Oscillation Frequency of the Normal Lattice

The mass of a normal space–time cell can be calculated directly from its volume using the energy–volume equivalence $E = PV$. The resulting mass is extremely small, on the order of 10^{-41} kg. If such a cell participates in a disturbance propagating at the speed of light, the corresponding de Broglie wavelength and frequency can be determined.

This procedure yields an intrinsic oscillation frequency of approximately 3.4 GHz. While this frequency is not yet recognized as a fundamental constant, it appears repeatedly in empirical technological contexts. Performance benchmarking of modern computer processors consistently shows optimal efficiency near this frequency range, with higher frequencies leading to disproportionately increased thermal dissipation (Colfax Research, 2017). Similarly, the 3.4–3.5 GHz band has been identified as optimal for fifth-generation (5G) wireless communication due to its balance between bandwidth capacity and propagation characteristics (Ericsson Research, 2019).

These converging observations suggest that the normal space–time lattice possesses a **natural resonance frequency**, providing favorable conditions for electromagnetic wave propagation. Within the structural informational model, efficient signal transmission corresponds to resonant energy–information matching between electromagnetic waves and the intrinsic oscillations of space–time cells.

5.4 Structural Origin of Electric Charge

The intrinsic radius of the electron and the geometry of the normal lattice also provide a structural interpretation of electric charge. During its motion through space–time such as during neutron β-decay the electron traces a finite volume determined by its cross-sectional area and path length. Dividing this volume by the volume of a normal space–time cell yields a quantity numerically equal to the number of elementary charges contained in one coulomb.

This result indicates that electric charge emerges as a geometric and structural quantity, rather than as an irreducible intrinsic property of particles. Charge reflects the degree of interaction between a particle's intrinsic deformation and the cellular structure of space–time. From this perspective, the Coulomb unit represents a counting measure of space–time cells involved in electromagnetic interaction.

5.5 Toward Experimental Verification: Prelude to Neutron β-Decay Analysis

The structural parameters derived in this section particularly the intrinsic electron radius and the normal lattice geometry are not introduced as purely theoretical constructs. They lead directly to experimentally testable predictions. One such test arises in the β-decay of the neutron, where the electron must propagate through a structured space–time medium before becoming bound to a proton. The finite lifetime of the neutron, and the discrepancy between different measurement methods, provide a sensitive probe of the interaction between particles and the structured vacuum. In the following section, neutron β-decay is analyzed quantitatively, and it is shown that the structural resistance of space–time naturally accounts for the observed decay times.

6. NEUTRON Β-DECAY AS AN EXPERIMENTAL TEST OF THE STRUCTURAL–INFORMATIONAL MODEL

The structural parameters derived for the normal space–time lattice particularly the intrinsic radius of the electron and the existence of a fundamental pressure led to direct, testable consequences. One of the most sensitive probes of these consequences is neutron β-decay, a process in which an electron is created and subsequently captured into a bound atomic state. The finite lifetime of the neutron provides an opportunity to examine how particles interact dynamically with a structured space–time medium.

6.1 Electron Birth and Structural Resistance of Space–Time

In neutron β-decay, a neutron transforms into a proton, an electron, and an antineutrino. While the proton remains localized, the newly created electron must traverse space–time before it can be captured into the first Bohr orbit of a hydrogen atom. In the structural–informational model, this motion does not occur through an inert vacuum, but through a structured space–time lattice that resists rapid spatial deformation.

As the electron propagates outward from its point of creation, it experiences resistance arising from the fundamental pressure acting on its intrinsic cross-section. This resistance manifests as a gradual, spiral-like trajectory rather than an instantaneous transition. The electron continuously interacts with the normal lattice, and its motion is constrained by the requirement that the space–time volume swept during propagation remains compatible with the equilibrium condition imposed by the fundamental pressure.

A schematic and numerical representation of this process illustrates the gradual retreat of the electron from the proton under the influence of structural resistance, until it reaches the radius corresponding to the first Bohr orbit. The total distance traveled during this process is extremely large on microscopic scales, of the order of 10^9m, despite the atomic dimensions of the final bound state.

6.2 Electron Velocity and Energy Constraint

The velocity of the electron during neutron decay is constrained by energetic considerations. For a hydrogen atom to form, the kinetic energy of the electron must not exceed the hydrogen binding energy of 13.6 eV; otherwise, the electron would escape capture. Taking relativistic mass–energy increase into account, the electron velocity can be expressed as

$$v_c = c\sqrt{1 - \frac{m_e^2}{m_R^2}} \tag{9}$$

where $m_R = (m_e c^2 + E_k)/c^2$is the relativistic mass corresponding to the electron's kinetic energy. Evaluating this expression under the binding-energy constraint yields a velocity of approximately 2.19×10^6 m s^{-1}, which coincides with the classical speed of the electron in the first Bohr orbit of hydrogen. This result suggests that the electron propagates through space–time at essentially this cruising velocity throughout the decay process.

At this speed, an electron traveling for approximately 890 seconds—the experimentally observed neutron lifetime—covers a distance of roughly 2×10^9m. This distance is of the same order as the wavelength later associated with the background space–time structure, indicating a deep connection between neutron decay dynamics and global space–time properties.

6.3 Volume Swept by the Electron and Charge Quantization

During its propagation, the electron sweeps out a finite volume of space–time determined by its intrinsic radius and the distance traveled. This volume can be calculated either geometrically, as the product of cross-sectional area and path length,

$$V = \pi r^2 l \tag{10}$$

or equivalently by integrating over the relevant spatial interval between the proton Compton wavelength and the Bohr radius,

$$V(x) = \int 18\pi x^2\, dx \tag{11}$$

Both approaches yield essentially the same numerical value for the swept volume, on the order of 2.8×10^{-30} m^3. Dividing this volume by the volume of a normal space–time cell produces a dimensionless quantity of approximately 6.2×10^{18}, which coincides with the number of elementary charges contained in one coulomb.

This correspondence provides strong evidence that electric charge arises from the geometry of space–time interaction, rather than being an intrinsic attribute of particles. Charge quantization emerges naturally as a consequence of discrete cell counting within the structured vacuum.

6.4 Neutron Lifetime and Structural Delay

The neutron lifetime corresponds to the time required for the electron to traverse the structurally permitted volume of space–time before orbital capture. Using the structural parameters derived earlier and the relation between swept volume, fundamental pressure, and electron velocity, the total travel time can be expressed as

$$l = \frac{\mu_0 h P \Delta V}{\pi v m_e^2} \tag{12}$$

where $\Delta V$is the change in swept volume during propagation. Dividing this path length by the electron velocity yields a decay time of approximately 890.8 seconds, in remarkable agreement with experimental measurements.

Two high-precision experimental techniques are currently used to measure the neutron lifetime: the beam method and the storage method. These approaches yield slightly different values, typically near 890 s and 880 s, respectively. The origin of this discrepancy remains an open problem in nuclear physics (Wietfeldt, 2018). Within the structural–informational model, this difference may be interpreted as arising from environmental and thermodynamic effects that alter the effective interaction between the electron and the structured space–time lattice. The beam method, which maintains a more stable dynamic equilibrium, is therefore more naturally aligned with the theoretical prediction.

6.5 Structural Interpretation of Neutron Decay

The agreement between the calculated decay time and experimental neutron lifetimes provides strong support for the existence of a structured space–time medium governed by a fundamental pressure. In this interpretation, neutron β-decay is not merely a weak-interaction process occurring in an inert background, but a dynamic interaction between particles and the cellular structure of space–time.

The neutron lifetime thus acquires a geometric meaning: it represents the time required for space–time to accommodate the emergence and stabilization of an electron within its normal lattice. This interpretation unifies particle decay dynamics, charge quantization, and space–time structure within a single coherent framework.

7. PROBABILISTIC VACUUM WAVES AND THE STRUCTURAL ROLE OF PHOTONS

The results obtained from neutron β-decay analysis indicate that the interaction between particles and space–time is governed not only by localized structural deformation, but also by probabilistic wave phenomena intrinsic to the vacuum itself. Within the structural–informational model, these phenomena arise from the fine internal organization of space–time under the action of the fundamental pressure.

7.1 Vacuum Potential and Probabilistic Wave Structure

In the vicinity of an atom, the fundamental pressure acting on the characteristic atomic volume defines a vacuum potential of the form

$$U = PV_B \tag{13}$$

where $V_B$is the effective volume of the hydrogen atom corresponding to the first Bohr orbit. This potential has a magnitude on the order of 10^{13} eV(tens of tera–electronvolts), exceeding by several orders of magnitude the binding energies associated with atomic and nuclear processes. Such a high potential cannot be directly accessed through particle excitation, but instead reflects the latent structural energy of space–time itself.

The existence of this potential suggests that space–time accommodates atoms through a finely tuned probabilistic organization. This organization may be expressed in terms of vacuum waves whose wavelength is determined by the ratio of Planck's constant to the product of the fundamental pressure and atomic volume,

$$\lambda = \frac{hc}{PV_B} \tag{14}$$

The corresponding wavelength is on the order of 10^{-20} m, with an associated amplitude approximately half the intrinsic radius of the electron. These waves do not represent propagating electromagnetic radiation in the conventional sense, but instead describe probabilistic oscillations of space–time structure that stabilize atomic configurations.

7.2 Photons as Structural Elements of Space–Time

Within this framework, photons emerge as natural candidates for mediating vacuum waves. Electron–positron annihilation produces two photons with total energy $2\,m_e\,c^2 = 1.022\,MeV$; in the center-of-mass frame each photon carries $m_e\,c^2 = 0.511\,MeV$. This coincidence suggests that photons are not merely carriers of electromagnetic interaction, but structural constituents of space–time itself.

In the structural–informational interpretation, the electron may be regarded as a composite configuration formed from two photons embedded within the normal space–time lattice. The probabilistic vacuum waves described above reflect oscillatory modes of these embedded photon structures. This interpretation aligns with earlier informational approaches that treat particles as stable excitations of an underlying informational substrate (Landauer, 1996; Wheeler, 1998).

The participation of photons in vacuum structure is further supported by the presence of the cosmic microwave background radiation, which demonstrates that photons permeate the Universe and behave statistically as an ideal gas. Their ubiquitous distribution makes them natural candidates for forming a background organizational layer of space–time.

7.3 Electric Charge from Photon–Vacuum Interaction

The probabilistic vibration of photons within the atomic vacuum potential leads to a reinterpretation of electric charge. The elementary charge can be expressed as the square root of the work performed by the vacuum potential on a photon oscillating with amplitude comparable to its intrinsic radius,

$$e = \sqrt{4\pi\varepsilon_0 \alpha r_f P V_B} \tag{15}$$

where r_f is the intrinsic radius of the photon and α is the fine-structure constant.

In this formulation, electric charge is not an independent fundamental quantity, but a **structural response** arising from photon–vacuum interaction. Charge quantization reflects discrete vibrational modes of photons embedded within space–time, stabilized by the fundamental pressure. This interpretation provides a geometric and informational basis for the existence of the fine-structure constant.

7.4 Photon Gas, Statistical Mechanics, and Cellular Vacuum Structure

Further insight into the structural role of photons is obtained by considering their statistical behavior. The standard description of a photon gas treats photons as bosons occupying discrete modes within a finite volume. Schwabl showed that the number of photon modes depends sensitively on boundary conditions and geometry (Schwabl, 2006).

In the present context, photons are considered within a spherical rather than a Cartesian volume, corresponding to the geometry of space–time cells. Accounting for this geometry modifies the density of states and leads to the expression

$$N = \frac{\pi^4 \zeta(3)}{4} V \left(\frac{kT}{\hbar c}\right)^3 \tag{16}$$

where $\zeta(3)$ is Apéry's constant. Evaluating this expression yields a characteristic photon occupation volume whose radius coincides, to within numerical accuracy, with the intrinsic photon radius inferred from structural considerations.

This result provides strong support for the hypothesis that vacuum possesses a cellular structure, with photons occupying and stabilizing discrete spatial domains. Statistical mechanics thus becomes a tool for probing the fine-grained organization of space–time rather than merely describing radiation thermodynamics.

7.5 Toward a Background Space–Time Lattice

The fact that the intrinsic photon radius is comparable to, but smaller than, the electron's intrinsic radius suggests the existence of a more fundamental structural level of space–time. While the normal lattice is associated with matter and electromagnetic interaction, photons appear to belong to a deeper organizational layer that exists even in the absence of matter.

This observation motivates the introduction of a background space–time lattice, composed of finer cells and characterized by greater structural rigidity. The probabilistic vacuum waves discussed in this section represent the dynamical manifestation of this background structure. In the following section, the geometry, energetics, and oscillatory behavior of the background lattice are analyzed in detail, leading to the prediction of a global low-frequency gravitational mode.

8. BACKGROUND SPACE–TIME LATTICE AND GLOBAL GRAVITATIONAL PULSATION

The normal space–time lattice discussed in previous sections arises locally in association with matter and governs electromagnetic interactions. However, the large disparity between the intrinsic radius of the electron and the characteristic size of the normal lattice cell indicates that this structure cannot represent the most fundamental organizational level of space–time. Instead, it points toward the existence of a deeper, globally distributed background space–time lattice, present even in the absence of matter.

8.1 Definition of the Background Space–Time Lattice

The background lattice is introduced as a universal structural state of space–time, underlying and supporting the normal lattice. Unlike the normal structure, which forms locally around particles and macroscopic bodies, the background lattice exists throughout the Universe and defines the metric properties of vacuum itself.

In dynamic form, this background structure manifests through gravitational wave–like oscillations. Within the structural–informational framework, these oscillations can be described using a de Broglie–type relation, where the momentum is defined as the ratio of the cell energy to the speed of light. The energy of a background cell is given by the product of the fundamental pressure P and the background cell volume V_b.

The volume of a background space–time cell may be expressed as

$$V_b = \frac{\lambda h G}{c^3} \tag{17}$$

where λ is the characteristic wavelength associated with the background oscillation, h is Planck's constant, G is the gravitational constant, and c is the speed of light. Solving the de Broglie relation for λ and substituting into the above expression yields a background cell volume that is independent of wavelength,

$$V_b = \frac{h}{c}\sqrt{\frac{G}{P}} \tag{18}$$

This result indicates that the background lattice is defined solely by fundamental constants and the intrinsic pressure of space–time.

8.2 Geometry and Harmonic Ratios of the Background Lattice

Evaluating the background cell volume yields a value on the order of 10^{-59} m^3, corresponding to a characteristic radius of approximately 1.3×10^{-20} m. This scale is smaller than the

normal lattice cell radius and comparable to the intrinsic radius of the electron.
Remarkably, the ratio between characteristic radii of the background lattice and the electron yields, to high numerical accuracy, the golden ratio. This proportionality is not introduced heuristically, but emerges naturally from the structural relations governing space–time organization. The appearance of the golden ratio is interpreted here as a stability coefficient, reflecting an optimal geometric configuration that minimizes local distortion of the background metric.
Such harmonic ratios are well known in variational problems and do not imply numerological significance. Instead, they indicate that matter configurations embedded in structured space–time tend toward geometries that extremize structural stability.

8.3 Background Cells as Gravitational Oscillators

The mass associated with a background space–time cell is obtained by dividing its energy by c^2,

$$m_b = \frac{PV_b}{c^2} \tag{19}$$

Although extremely small, this mass provides inertia to the background cells. The gravitational interaction between neighboring cells then acts as a restoring force, allowing collective oscillations to propagate through the background lattice. These oscillations are interpreted as gravitational waves intrinsic to space–time itself, rather than disturbances generated by localized astrophysical sources.
The wavelength associated with these oscillations is found to be on the order of 5×10^9 m. Dividing this wavelength by the speed of light yields a characteristic oscillation period corresponding to a frequency of approximately 0.06 Hz.

8.4 Fundamental Frequency of Space–Time Pulsation

The intrinsic oscillation frequency of the background lattice can be expressed in terms of fundamental Planck-scale quantities as

$$\omega = \sqrt{\frac{Pl_P}{m_P}} \tag{20}$$

where l_P and m_P are the Planck length and Planck mass, respectively. Substituting numerical values yields $\omega \approx 0.0596$ Hz. This value coincides with the frequency inferred independently from the structural wavelength of the background lattice. The agreement between these two derivations provides strong evidence that the background oscillation represents a natural eigenmode of space–time, determined solely by its intrinsic structural parameters.
Such low-frequency oscillations may be interpreted as a global gravitational background mode, representing a continuous pulsation of the Universe. Importantly, this pulsation is not generated by any localized source and does not violate Lorentz invariance. Instead, it reflects the collective dynamics of the structured space–time medium.

8.5 Connection to Vacuum Impedance and Electromagnetic Response

The existence of a global background oscillation allows the electromagnetic response of vacuum to be reinterpreted. The electric constant $\varepsilon_0$may be expressed in terms of the background oscillation frequency, electron mass, and fundamental constants, revealing a direct connection between vacuum impedance and space–time dynamics.
The vacuum impedance $Z_0 = \sqrt{\mu_0/\varepsilon_0}$thus acquires a dual interpretation: as a static electromagnetic response parameter and as a dynamic consequence of the oscillatory background structure of space–time. Small deviations between frequencies derived from electromagnetic and gravitational considerations may reflect self-consistent feedback between the static and dynamic properties of the structured vacuum.

8.6 Physical Interpretation and Implications

Within the structural–informational model, the background lattice represents the most fundamental organizational level of space–time. The normal lattice, associated with matter and electromagnetic phenomena, forms as a localized excitation of this background. Mass, charge, inertia, and gravitation emerge as different expressions of how energy deforms and interacts with the underlying space–time structure.
The predicted global pulsation at approximately 0.06 Hzimplies that all matter interacting with space–time may exhibit weak, coherent modulation at this frequency. Such modulation would be extremely subtle but, in principle, detectable through precision mechanical, electromagnetic, or interferometric measurements.

9. CONCLUSION

In this work, a structural–informational model of space–time has been developed to address fundamental limitations in prevailing descriptions of the physical vacuum. Motivated by the extreme volumetric insignificance of matter on cosmological scales and by long-standing conceptual tensions between quantum discreteness and relativistic continuity, space–time has been treated as an active, material–informational medium possessing intrinsic structure.
The model introduces a fundamental pressure as a primary physical quantity governing the stability of localized energy configurations. Within this framework, mass–energy equivalence emerges naturally as an energy–volume relation, and mass itself is reinterpreted as a spatial manifestation of energy stabilized by the structured vacuum. The introduction of a cellular organization of space–time provides a coherent resolution to the discreteness–continuity dichotomy, allowing discrete structural units to coexist within a Lorentz-invariant continuum.
Two distinct but interconnected levels of space–time organization have been identified. The normal space–time lattice forms locally in association with matter and gives rise to electromagnetic interactions through mechanical deformation of the vacuum structure. Fundamental electromagnetic constants acquire a geometric and dynamical interpretation as response coefficients of this lattice. At a deeper level, a background space–time lattice has been

proposed as a globally distributed structural state of the metric, existing independently of matter and responsible for gravitational dynamics.
Within this background lattice, collective oscillatory behavior leads to the prediction of a global low-frequency pulsation of space–time with a characteristic frequency near 0.06 Hz. This mode arises naturally from the interplay between the fundamental pressure and Planck-scale quantities and represents an intrinsic eigenmode of the structured vacuum. The background pulsation provides a unifying context for gravitational phenomena, inertia, and the emergence of particle properties.
The structural informational framework yields experimentally relevant consequences. In particular, neutron β-decay has been shown to provide a sensitive probe of space–time structure, with the observed neutron lifetime emerging as a geometric delay associated with the interaction between the electron and the normal space–time lattice. The agreement between theoretical predictions and experimental lifetimes supports the physical reality of the proposed structural parameters.
More broadly, the model offers a conceptual bridge between classical mechanics, general relativity, and quantum behavior, while remaining consistent with established experimental constraints. By treating particles, fields, and constants as emergent structural manifestations of space–time, the framework shifts the focus of fundamental physics from material entities to the organization and dynamics of the vacuum itself.
Future work will focus on refining the observational and experimental signatures of the predicted background pulsation, exploring its implications for precision metrology and gravitational-wave detection, and extending the structural informational approach to cosmological evolution and dark-sector phenomena. The results presented here suggest that a deeper understanding of space–time structure may provide a unified foundation for diverse physical processes across all scales.

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