Physical Character of Planck's Quanta: Deterministic Reconstruction of Foundational Physics

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Abstract

It is well recognized that there are unanswered questions in the foundations of physics that currently prevent the inner workings of nature from being understood at a deeper level. These quandaries are manifested most evidently in quantum mechanics, particle physics, and gravitation and cosmology. Against that background, presented here is *photodynamics*, a purely deterministic theoretical framework within which the many unanswered questions in foundational physics can be resolved comprehensively. Photodynamics is conceptualized via four core postulates: (i) all of space and matter is composed fundamentally of *photinos*, indivisible primordial particles that are the source of inertial mass and energy, with a unit photino defined by the elementary quantum of action given by Planck's constant h ; (ii) photinos are distributed spatially in the form of *cells*, contiguous photino packets that are autonomous, elastic, and mobile; (iii) the universe evolves synchronously in discrete time steps; (iv) all dynamic activity in nature arises from the behaviors of physical systems induced by the innate elasticity of their cellular elements. These postulates are formulated into a systematic and coherent mathematical framework that is then applied to the full spectrum of physics from subatomic to cosmological, yielding remarkable results. Notably, Coulomb's law of electrostatics, Bohr's formula for the hydrogen spectrum, the Schrödinger equation, Newton's law of gravity, Maxwell's electrodynamics, and nuclear forces all emerge naturally as consequences of photodynamics, which also settles the measurement problem in quantum mechanics and offers insights into the dynamics of cosmic structures and the origins of dark matter and dark energy.

Keywords Planck's constant • cellular automata • measurement problem • Coulomb's law • gravitation • dark matter

1 Introduction

In the four centuries since the scientific revolution, the scope of physical theories has grown to encompass every notable facet of nature, from the smallest scale of subatomic particles to the large-scale structure of the universe. However, notwithstanding the great advances made possible by these developments, key aspects of foundational physics remain encumbered with unanswered questions that demand resolution if a deeper understanding of the workings of nature is counted among the objectives of science. The domains of physics in which the unresolved questions pose the greatest challenge include quantum mechanics, gravitation and cosmology, and particle physics, as well as aspects of electromagnetism. The purpose of this paper is to demonstrate rigorously that there exists a purely deterministic theoretical framework within which the many unanswered questions in foundational physics can be resolved comprehensively.

The range of challenges in contemporary physical theories is best illustrated with some select examples, as follows. In quantum mechanics, the well-known *measurement problem* points to an apparent contradiction in the formalism describing two integral features associated with the time evolution of the wave function of an atomic system that are ordinarily considered mutually incompatible. At a more conceptual level, the very nature of the quantum state of a system appears to defy any interpretation that can be described as an objective representation of physical reality [1].

In cosmology, the standard cosmological model furnishes no definitive account of the observed deviation of the gravitational behavior of large-scale systems from that predicted by Newton's and Einstein's models of gravity. Nevertheless, this deviation implies the existence of a pervasive *dark matter*, of as-yet unknown origin and form, whose total mass is estimated to be more than five times that of the observable matter present in the universe [2]. The standard cosmological model also offers no definitive account of the acceleration that observations indicate is presently occurring in the expansion of the universe. Rather, it is hypothesized that this is caused by an unfamiliar *dark energy* of unknown origin that permeates space and generates a negative pressure that counteracts the gravitational self-attraction of matter to produce the accelerating expansion of the universe [3].

The gravitational model described by the general theory of relativity is rendered incompatible with the quantum-theoretical standard model of particle physics because of the contradictory implications of the two theories for forces at the microscopic scale. Alternative models that would incorporate the principles of both general relativity and quantum theory within a unified framework, namely quantum gravity, are at present not sufficiently well developed to be tested empirically [4].

These examples underline the diversity in the varieties of unresolved problems that lie embedded in contemporary physical theories. More importantly, they suggest the possibility that the fundamental problem lies not within any given theory *per se* but at a deeper level that transcends the very principles upon which the theories are based. If this is

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so, then there exists the possibility that a new foundation can be built based on a set of universal principles that differ fundamentally from those on which the prevailing theories are based. In that case, there also exists the possibility that a theoretical model can be constructed upon this new foundation such that it incorporates within a self-consistent unifying framework each of the various domains of foundational physics.

Needless to say, such a model would have to meet a number of stringent tests, foremost among which is that the mathematical formulae that it yields must be consistent with those of the experimentally well-tested theories that it replaces. The model must also resolve the various problems that encumber contemporary theories such as those in the examples cited above, and its predictions must agree with scientific observations. In addition, such a model would be expected ideally to offer testable predictions that go beyond those that the prevailing theories are able to furnish.

It is this reasoning that constitutes the basis on which the core hypothesis underlying the theoretical model presented in this paper is formulated. In this model, referred to herein as *photodynamics*, the core hypothesis consists of four postulates. The first postulate relates to the physical character of the elementary quantum of action given by *Planck's constant* [5] and its cardinal place in the workings of nature, far exceeding in importance the central place that it already occupies in atomic physics. The other three postulates relate, respectively, to the composition of space, the nature of time, and the source of mechanical energy. Together, these four factors are shown to give rise to the dynamics from which the numerous spatiotemporal effects at every scale ultimately emerge.

The structure of this paper corresponds to the logical development of the model herein presented and is arranged accordingly in ten sections including the current introductory section. Section 2 describes the core hypothesis of photodynamics, the five physical constants of nature required in its construction, and the principal quantities and concepts that define the base upon which the logic of the model rests. Section 3 defines the overall framework within which the model is constructed, including the fundamental principle from classical theory that gives rise to dynamical effects and equilibrium states in physical systems, and the emergence of a characteristic spatial order at every scale. Section 4 describes the mechanics of three central features of the model, namely the wave function of elementary particles, energy transmission, and phase transition. Section 5 describes the altered perspective on thermodynamics, optics, and the Compton effect in the context of photodynamics. Section 6 gives an account of electromagnetism, including the derivation of a universal electrostatic force function of which Coulomb's law represents a limiting case, the electric and magnetic moments and intrinsic spin of charged particles, as well as the physical character of

electric and magnetic fields and the causal processes underlying the equations of Maxwell's electrodynamics. Section 7 describes the formation of subatomic particles and atoms, attractive and repulsive nuclear forces, nuclear stability, and neutron decay. Section 8 shows the derivation of Bohr's formula for the hydrogen spectrum and a well-defined generalization of it that describes the line spectra of multielectron atoms, as well as the derivation of the Schrödinger equation in the deterministic frame of photodynamics and its interpretation as a precise description of atomic geometry corresponding directly to the quantum states of electrons in an atom. Section 9 gives the derivation of a universal gravitational function of which Newton's law represents a limiting case, and its implications for cosmology such as the dynamics of cosmic structures and the origins of dark matter and dark energy. Section 10 presents a concluding summary.

2 Primary Definitions

2.1 Core Hypothesis

As noted, the core hypothesis of photodynamics consists of four postulates. The first postulate is that there exist indivisible primordial particles, hereinafter called *photinos*, of which all of space and matter is ultimately composed. Described as the very source of inertial mass and energy, a unit photino is defined by the *elementary quantum of action* given by Planck's constant h . (Note that a photino in the present context is unrelated to the particle bearing the same name in supersymmetry theory—commonly known as SUSY—where a photino is described as the lightest SUSY particle and a counterpart to the photon [6, 7].)

The second postulate is that photinos are distributed spatially in the form of contiguous photino packets, hereinafter called *cells*, where each cell is autonomous, elastic, and potentially mobile. Space is thus modeled as a tessellated lattice of contiguous autonomous elastic cells of variable volume and photino content (see Fig. 1).

The third postulate is that, as a system, the universe evolves synchronously in discrete *time steps*. Its evolution is governed by a set of mathematical relationships that describe the states of its constituent cells and their interactions with neighboring cells and the photinos contained therein. The universe thus emulates a system of cellular automata [8] in which all physical activity results from the deterministic application of a fixed set of rules at the elemental level of the cell, rendering the universe spatially discrete and temporally recursive.

Based on the pioneering works by Ulam [9], von Neumann [10], Minsky [11], and Conway [12], the mathematical concept of cellular automata has gained interest in recent years for its behavioral similarities with physical systems. Explorations of these similarities by Wolfram [13] and 't Hooft [14], among others, suggest a deep connection between cellular automata and physical

Fig. 1 Cross-sectional view of contiguous cells in a segment of the spatial lattice. The center of mass of each cell is shown as a white dot.

processes in nature. However, being mainly exploratory, these works do not represent fully formulated theoretical models that describe with exactitude the spatiotemporal behavior of physical systems.

The fourth postulate is that the propensities induced in physical systems by the innate elasticity of their cellular elements constitute the source of all dynamic activity in nature. As with every elastic body, a cell seeks to attain a state of elastic equilibrium such that its extant volume is equal to its equilibrium volume, while any displacement from equilibrium induces elastic potential energy that the cell then seeks to minimize. Because every physical system, regardless of scale, consists elementally of contiguous cells, every system tends inexorably toward a state of lowest potential energy, which, in turn, compels the emergence of dynamic activity in nature at every scale.

2.2 Fundamental Constants and Spatiotemporal Features

Five fundamental constants of nature are required in the construction of the model described in this paper [15]. These are *Planck's constant* $h \approx 6.626 \times 10^{-34} \text{ J s}$, the *fine-structure constant* $\alpha \approx 7.297 \times 10^{-3}$, the *elementary charge* $e \approx 1.602 \times 10^{-19} \text{ C}$, the *gravitational constant* $G \approx 6.674 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$, and lastly the *instant* $\tau \approx 7.372 \times 10^{-51} \text{ s}$.

Whereas the first four are well-known constants of conventional physical theory, the instant τ is defined herein as the elementary unit of time, denoting the period separating two consecutive time steps in the temporal evolution of the universe (see Sec. 2.3 for the rationale behind the numerical value of τ). The inverse of τ is the rate at which the universe evolves, defined as the *terminal frequency* $\nu_\tau \triangleq 1/\tau \approx 1.356 \times 10^{50} \text{ Hz}$.

No other constant that appears in the equations of photodynamics is a fundamental quantity. Some, such as Boltzmann's constant k_B , are proportionality coefficients that harmonize artefactual physical quantities with natural quantities. Others are either system-specific constants or, as in the case of the speed of light c , they are quantities that emerge logically from the fundamental constants.

Fig. 2 Change of state in time step separating two consecutive instants τ_1 and τ_2 .

Direction of time. As a natural system of cellular automata, the temporal evolution of the universe occurs synchronously in discrete, sequential time steps, punctuated by τ . It follows that the progression of time is unidirectional, and that this direction is irreversible.

Unit-action limit. An *action* is defined herein as any event that transforms the extant state of a cell into a different state, with each action executed during a time step (see Fig. 2). Consequently, no two consecutive events may occur within a time period shorter than an instant, whereby τ defines the instantaneous state of the universe.

Furthermore, a cell may execute no more than a single action in a single time step. This prohibition against multiple simultaneous actions restricts each cell to a binary choice such that, in any given time step, a cell may execute either a single action or none. This constraint is hereinafter referred to as the *unit-action limit*.

Spatiotemporal features of photinos. Given that a cell is composed solely of photinos, by definition cells devoid of photinos cannot exist. Moreover, because space consists entirely of contiguous cells, a photino can reside only within the body of a host cell. Whereas a cell may, in principle, contain an unlimited number of photinos, in a physical system the number of photinos resident in any given cell is strictly restricted by the dissipation of its resident photinos through a well-defined entropic process that induces energy transmission (see Sec. 4.3).

In addition, while the transmission of photinos from point to point in space constitutes radiation in the conventional sense, the prohibition against light-speed motion by mass-bearing bodies across spatial distances is upheld nevertheless. This is because light propagates not by individual mass-bearing photinos traveling physically across spatial distances in a void, but rather by the conduction of a chain of successive photinos from cell to neighboring cell within the cellular medium of space. No photino is physically transported any farther than across a single boundary separating two neighboring cells.

2.3 Mass, Energy, and Photino Content

The energy equivalence of mass is defined herein as the (hypothetical) dissipation of the total photino content of a body via photino emission at terminal frequency ν_τ . The

total energy E_0 carried by a sequence of photinos emitted consecutively at terminal frequency in unit time t_0 thus constitutes the energy equivalent of a unit mass m_0 , where (in SI units) $t_0 = 1$ s and $m_0 = 1$ kg. Consequently, E_0 is given by the Planck–Einstein relation [16] for the special case of terminal frequency as

$$E_0 = h\nu_\tau \approx 8.988 \times 10^{16} \text{ J.} \quad (1)$$

Dividing both sides of this equation by m_0 yields

$$\frac{E_0}{m_0} = \frac{h\nu_\tau}{m_0} = c^2, \quad (2)$$

where $c \approx 2.998 \times 10^8 \text{ m s}^{-1}$ defines the *terminal speed of light*. The energy E_h transmitted in unit time t_0 at frequency $\nu_0 (= 1/t_0)$ then constitutes the energy equivalent of a single photino, stated as

$$E_h = h\nu_0 \approx 6.626 \times 10^{-34} \text{ J.} \quad (3)$$

Noting that c^2 is set to a constant value by the relation given in Eq. (2), the universal proportionality between mass and energy established by the special theory of relativity [17, 18] yields $E_0/m_0 = E_h/m_h = c^2$, where m_h is the mass of a photino. Replacing E_h in this equation with $h\nu_0$ from Eq. (3) gives the rest mass of a photino as

$$m_h = \frac{h\nu_0}{c^2} \approx 7.372 \times 10^{-51} \text{ kg.} \quad (4)$$

If a body is composed of n photinos, then its mass m is $m = nm_h$ and the equivalent energy is $E = nE_h$. Because $E_h/m_h = c^2$, it follows that $nE_h/nm_h = E/m = c^2$. Replacing E_h in this relationship with $h\nu_0$ from Eq. (3) and nm_h with m , and then multiplying each term in the chain of equalities by m , we obtain

$$nh\nu_0 = E = mc^2. \quad (5)$$

This equation asserts that the equivalence of mass and energy established by Einstein's special theory of relativity extends further to a three-way equivalence between energy E , mass $m (= E/c^2)$, and photino content $nh (= E/\nu_0 = mc^2/\nu_0)$. Furthermore, in light of the first postulate of the core hypothesis of photodynamics, Eq. (5) implies that it is the (material) photino content nh that constitutes the source of mass as well as of energy.

Note on the numerical value of the instant τ . Based on the definition of the energy equivalence of mass noted above, Eq. (2) gives the relation $h\nu_\tau = m_0c^2$. Hence, given that $\nu_\tau = 1/\tau$, we obtain $\tau = h/m_0c^2 \approx 7.372 \times 10^{-51} \text{ s}$.

Photino transmission frequency and wavelength. The frequency of any propagating wave can be described as the number of successive wavefronts passing through an imaginary fixed surface per unit time. In photodynamics, the frequency of light ν is given by the number n of successive photinos transmitted per unit time t across a surface (e.g., the common interface separating two

neighboring cells), as $\nu = n/t$. The wavelength of light λ then describes the spatial separation between two successive photinos transmitted to the surface from the same direction at frequency ν , while $k = 2\pi/\lambda$ is the associated wave number. Meanwhile, because $n/t = \nu$, it follows that the number of photinos transmitted across a surface at frequency ν in a unit time interval t_0 is given as

$$n = \nu t_0 = \frac{\nu}{\nu_0}. \quad (6)$$

Limiting wavelength and cell radius. Based on the classical relation for the speed u of a propagating wave $u = \lambda\nu$, the *limiting wavelength* λ_τ of a photino conduction wave propagating at terminal frequency can be derived as

$$\lambda_\tau = \frac{c}{\nu_\tau} \approx 2.211 \times 10^{-42} \text{ m.} \quad (7)$$

It is important to note that the conduction of photinos at ν_τ is a purely imaginary limiting case, where successive photinos are (theoretically) conducted from one cell to the next in each consecutive time step. In a physical system, photino transmission occurs through a conditional entropic mechanism, whereby photino conduction waves propagate at frequencies far lower than ν_τ (see Sec. 4.3). Consequently, the shortest wavelengths found in nature are some 30 orders of magnitude longer than λ_τ .

As a measure of physical distance, λ_τ represents the length of a chord connecting the two points of maximum separation located on opposite sides of a conducting cell. In an idealized case where cells are approximated as spherical in shape, the maximal chord of a cell is its diameter. (Note that the spatial contiguity of cells dictates that every cell must be roughly polyhedral in shape. However, given that cells may differ greatly in shape from one another, while any given macroscopic region of space typically consists of a very large number of cells, an average cell can be treated logically as being approximately spherical.)

Consequently, λ_τ represents the maximum average cell diameter that a photino conduction wave would traverse in a single instant if it were to (hypothetically) propagate at frequency ν_τ . This relationship implies that $\lambda_\tau = 2r_\tau$, where $r_\tau \approx 1.106 \times 10^{-42} \text{ m}$ is the *limiting cell radius*. In essence, λ_τ and r_τ represent, respectively, the shortest wavelength of light and the smallest cell radius that nature permits, in principle.

Photino content of subatomic particles. The empirically measured rest mass of an electron m_e is estimated to be $m_e \approx 9.109 \times 10^{-31} \text{ kg}$, equivalent to an energy content $E_e \approx 8.187 \times 10^{-14} \text{ J}$. The average number of photinos n_e contained in an electron is therefore determined as

$$n_e = \frac{E_e}{E_h} \approx 1.236 \times 10^{20}. \quad (8)$$

Similarly, the average number of photinos contained in a proton (n_p) and a neutron (n_n) can be calculated to be $n_p \approx 2.269 \times 10^{23}$ and $n_n \approx 2.272 \times 10^{23}$.

2.4 Quantitative Individuality

An essential component of the logic of photodynamics is the *quantitative individuality* of cells within any finite system, which derives from the truism that the physical volume of a body may take any positive numerical value in the real number domain. It follows that the same holds true for the density of a body, which, by definition, is the ratio of the mass (or equivalently the energy or photino content) of a body to its volume. Pursuant to the well-known theorem by Cantor on the cardinality of infinite sets [19], which establishes that $|\mathbb{R}| > |\mathbb{N}|$, it can be deduced that $\forall a, b \in \mathbb{R}, a < b : |(\mathbb{R} \setminus \mathbb{Q})_{(a,b)}| \gg |\mathbb{Q}_{(a,b)}|$. It therefore follows that $\forall i, j, i \neq j, \exists \delta_{i,j} \in \mathbb{R}, \delta_{i,j} > 0 : P\{|\rho_i - \rho_j| = \delta_{i,j}\} \gg P\{|\rho_i - \rho_j| = 0\}$, where ρ_i and ρ_j are the densities of any two bodies i and j within a system and $P\{A\} \in [0,1]$ is the probability of event A .

In effect, this probability relationship all but forbids absolute numerical parity between the densities of any two physical bodies in a system. Each cell in a finite system is thus rendered distinct, with asymptotic probability one, from every other cell with respect to its density.

Quantitative individuality represents a vital factor in instilling structure and order in the spatial distribution of cells and higher-order bodies at every level, and in the emergence of key physical phenomena such as atomic and gravitational forces, electromagnetism, and optics.

2.5 Density Spectrum

In everyday life, we distinguish objects from one another based on differences that our senses allow us to discern, such as the differences in their shapes, sizes, colors, and scents. However, methodical analysis is necessary when the distinction to be made is between two substances irrespective of their forms. One method, known since antiquity, is to compare their densities. In photodynamics, density represents the defining characteristic of material bodies. It is the density of a body that distinguishes it absolutely from all of the other bodies in a system.

Given the second postulate of the core hypothesis of the present model that the universe consists entirely of contiguous cells, an absolute vacuum in any region of space is precluded by definition. This postulate further asserts that both matter and space must be composed of cells as their common elemental constituents. The model therefore draws no fundamental distinction between matter and space. Matter is made ponderable and distinct from seemingly empty space solely because the density of its cellular elements is much higher than that of the cells that constitute regions of seemingly empty space. The densities

of matter and space thus represent two parts of a continuous spectrum of cell densities.

The density spectrum is closely related to the electromagnetic spectrum. Each describes all possible degrees of photino concentration, in a different mode. Whereas the density spectrum describes the spatial concentration of photinos per unit volume, the electromagnetic spectrum describes the temporal concentration of photinos transmitted per unit time. If V is the volume of a cell, then its *photino density* ρ is given as

$$\rho \triangleq \frac{nh}{V}. \quad (9)$$

Correspondingly, if n photinos are transmitted to a cell in time t , then the radiation energy received by the cell is given as $E = nh/t$. Thus, photino density ρ and radiation energy E describe the photino content nh concentrated per unit volume and per unit time, respectively.

Density spectrum segmentation. For modeling purposes, the density spectrum can be partitioned into three principal segments—in much the same sense that the electromagnetic spectrum is partitioned, by convention, into several broad segments (e.g., radio waves, visible light, X-rays, etc.)—as follows.

The uppermost segment of the density spectrum is defined as the subspectrum of the highest cell densities. The cells whose densities lie within this subspectrum form the constituents of multi-cell clusters representing high-density nuclear particles, where the density of a proton defines the lower end of this subspectrum. These cells are referred to herein as *high-density tangible* (HDT) cells.

The lowermost segment of the density spectrum is defined as the subspectrum of the lowest cell densities. The cells whose densities lie in this subspectrum constitute the (single-cell) elements of an intangible medium, namely of seemingly empty space. These cells are referred to herein as *low-density intangible* (LDI) cells.

The intermediate segment of the density spectrum is defined as the subspectrum of cell densities that are lower than those of HDT cells and higher than those of LDI cells. The cells whose densities lie in the range spanned by this subspectrum constitute (relatively) low-density single-cell subatomic particles, namely electrons. These cells are referred to herein as *low-density tangible* (LDT) cells.

Tangible vs. intangible cells. Just as our perception of visible light is restricted to a narrow band of frequencies within the electromagnetic spectrum, the present model stipulates that our perception of tangible matter is restricted to the HDT and LDT segments of the density spectrum. An object whose density lies in the LDI segment is thus imperceptible without the aid of scientific instruments; we register it only as the absence of tangible matter. It can be argued that evolutionary processes have calibrated our sensory apparatus with these limitations for optimal utility.

The survival of our species within its native environment evidently does not require the direct perception of intangible space, much as it does not require the direct visibility of gamma rays or radio waves.

Segment boundaries. As with the boundaries separating any two neighboring segments in the electromagnetic spectrum (e.g., X-rays and gamma rays), the boundaries separating two neighboring segments in the continuum of the density spectrum cannot be defined precisely. Thus, the density of a cell may be classified as a part of either subspectrum if its density lies in a range that broadly defines the boundary between two neighboring subspectra. Moreover, given that the density spectrum spans the full range of all possible densities, every common and exotic species of particles can be classified as part of one of the three subspectra defined above.

2.6 Photino Content and Energy Imbalance

Actual photino content. The *actual photino content* H_A of a cell is defined as the extant value of its photino content, where $H_A \triangleq n_A h$, and n_A is the *actual photino count* of the cell such that $n_A \in \mathbb{N}^+$.

Rudimental photino content. The *rudimental photino content* H_R of a cell is a fundamental quantity defined as the photino content that a cell must minimally possess, where $H_R \triangleq n_R h$ and n_R is the *rudimental photino count* of the cell, while $n_R \in \mathbb{R}$ and $n_R \geq 1$. The numerical value of n_R (and hence H_R) is set for a cell only during its *phase transition* under extreme conditions (as defined below), and remains constant thereafter under all nonextreme conditions. Note that n_R and H_R lie in the real number domain as a result of the physical mechanism by which their values are set during phase transition (see Sec. 4.4). Moreover, because H_R is the photino content that a cell must minimally possess, it follows that $H_R \leq H_A$.

Ground-state photino content. Whereas the H_R value of a cell is set during phase transition under extreme conditions, given that photinos come in discrete quanta defined by Planck's constant, the physically minimum photino content of a cell in nonextreme conditions can be equal to H_R if and only if n_R is an integer. However, because $n_R \in \mathbb{R}$, the probability of n_R being an integer is vanishingly small. The physically minimum photino content of a cell H_G is therefore defined as its *ground-state photino content* given as $H_G \triangleq n_G h$, where n_G is the *ground-state photino count* of the cell such that $n_G \in \mathbb{N}^+$ and

$$n_G = \begin{cases} \lfloor n_R \rfloor & \text{if } |n_R - \lfloor n_R \rfloor| < |n_R - \lceil n_R \rceil| \\ \lceil n_R \rceil & \text{if } |n_R - \lfloor n_R \rfloor| \geq |n_R - \lceil n_R \rceil| \end{cases} \quad (10)$$

Energy imbalance η . An additional quantity η is defined herein as the difference between the rudimental photino count of a cell and its ground-state photino count, given as

$$\eta \triangleq (n_R - n_G), \quad (11)$$

where, pursuant to Eq. (10), $0 \leq |\eta| \leq 0.5$. A cell is described as being *energy neutral* if its n_R value is such that $\eta = 0$. Meanwhile, a cell is *energy deficient* (denoted as η^+) if its n_R value is such that $0 < \eta < +0.5$, and *energy abundant* (denoted as η^-) if $0 > \eta \geq -0.5$. Any deviation from energy neutrality in a cell is described as a state of *energy imbalance* and has fundamental implications for electromagnetism (see Sec. 6.1).

2.7 Cell Volume, Elastic Limits of Cells, and Extreme Conditions

Actual volume. The *actual volume* V_A of a cell is defined as the extant physical volume of the space that it occupies.

Rudimental volume and lower elastic limit. The *rudimental volume* V_R of a cell is defined as the volume that the cell would occupy if its extant photino content were equal to its rudimental photino content H_R , and is hence the minimum volume that the cell must occupy. As the minimum allowable cell volume, V_R defines the *lower elastic limit* of a cell. A breach of the lower elastic limit of a cell occurs only in conditions of extreme compression, triggering a phase transition and thus resetting its V_R value, which then remains constant in all nonextreme conditions.

Par volume and upper elastic limit. The *par volume* V_P of a cell is defined as the volume that the cell occupies when it is in a state of elastic equilibrium. Par volume represents the maximum allowable cell volume and hence defines the *upper elastic limit* of a cell. A breach of the upper elastic limit of a cell occurs only in conditions of extreme decompression, triggering a (reverse) phase transition and thus resetting its V_P value, which then remains constant in all nonextreme conditions.

Extreme and nonextreme conditions. *Extreme conditions* are defined as those special conditions where the compression or decompression of a cell imposed by its ambient system is sufficient to cause the lower or upper elastic limit of the cell to be breached. *Nonextreme conditions* are normal conditions in which neither the compression nor the decompression is sufficient to cause either elastic limit of a cell to be breached.

Actual, rudimental, and ground-state density. The *actual density* ρ_A of a cell is its extant density stated as $\rho_A = H_A/V_A$. Meanwhile, the *rudimental density* ρ_R of a cell is given as $\rho_R = H_R/V_R$, whereas the *ground-state density* ρ_G of a cell is given as $\rho_G = H_G/V_A$.

2.8 Volume Expansivity and Potential Energy

Cell volume expansivity. A central proposition in the logic of photodynamics is that (in nonextreme conditions) the par volume V_P of a cell is given by the function

$$V_P = V_R + \frac{\alpha}{2} \left(\frac{H_A - H_R}{\rho_R} \right) = V_R \left(1 + \frac{\alpha}{2} \left(\frac{H_A}{H_R} - 1 \right) \right) \\ = V_R \left(1 + \frac{\alpha}{2} \left(\frac{H_A}{(H_G + \eta h)} - 1 \right) \right), \quad (12)$$

where $\alpha/2$ denotes the *fundamental coefficient of volume expansivity* and $\alpha \approx 1/137$ is the *fine-structure constant*.

Mechanically, the V_P value of a cell is updated during each phase transition, when it is set equal to the extant volume V_A of the cell. The quantities V_R , H_R , and H_G are then reset for the cell in accordance with Eq. (12), based on its updated V_P value (see Sec. 4.4).

Elastic potential energy and cell compression. If the actual volume of a cell is V_A , then the divergence of the cell from its equilibrium volume is $V_P - V_A$. In accordance with the law of elasticity, any divergence from its equilibrium volume induces *elastic potential energy* U_V in a cell such that $U_V \propto (V_P - V_A)^2/2$. This relation can be stated as $U_V = (k_V/2)(V_P - V_A)^2$, where a second proposition of the present logic is that the proportionality coefficient k_V is given as $k_V = v_0(\rho_A/V_A)$. The elastic potential energy of a cell is thus stated as

$$U_V = \frac{v_0}{2} \left(\frac{\rho_A}{V_A} \right) (V_P - V_A)^2 = \frac{H_A v_0}{2} \left(\frac{V_P}{V_A} - 1 \right)^2, \quad (13)$$

where the quantity $\kappa = (V_P/V_A - 1)$ defines the *compression* of the cell.

3 Framework

3.1 Autonomic Principle

The *autonomic principle* can be described as the universal propensity of bodies to minimize their stored potential energy. In its broadest sense, the potential energy of a body may appear in any of its various forms, such as that of a stretched spring, the gravitational potential energy of a pendulum at full swing, or the elastic potential energy of a compressed tennis ball or cell.

Stored potential energy. In the context of photodynamics, the potential energy of a body in each of its various forms is described as an extension of the energy generated according to the laws of elasticity. Potential energy thus represents the mechanical energy induced in a body by the displacement of any associated physical quantity $\mathfrak{R}$ from its par value $\mathfrak{R}_{\text{par}}$, if there exists a value $\mathfrak{R}_{\text{par}}$ that the body seeks to attain. Consequently, irrespective of the scale and nature of the body and the nature of $\mathfrak{R}$, the stored potential energy $U_{\mathfrak{R}}$ of the body is defined by the universal relation $U_{\mathfrak{R}} \propto (\mathfrak{R} - \mathfrak{R}_{\text{par}})^2/2$, expressed as an identity by the fundamental function

$$U_{\mathfrak{R}} \triangleq \frac{1}{2} k_{\mathfrak{R}} (\mathfrak{R} - \mathfrak{R}_{\text{par}})^2, \quad (14)$$

where $k_{\mathfrak{R}}$ is a coefficient of proportionality that describes the degree of resistance to the displacement of $\mathfrak{R}$ from its par value $\mathfrak{R}_{\text{par}}$. The autonomic principle can then be stated symbolically as

$$U_{\mathfrak{R}} \rightrightarrows 0, \quad (15)$$

where the notation $x \rightrightarrows \mathfrak{X}$ connotes *maximal change per time step* in the numerical value of a quantity x toward a terminal value $\mathfrak{X}$. This propensity further implies that the autonomic principle enforces a physical resistance to any increase in the value of $U_{\mathfrak{R}}$.

Basic forms of stored potential energy. Three distinct basic forms of stored potential energy may exist simultaneously in a (cell or composite) body, namely (i) U_V due to volumetric nonequilibrium, (ii) U_{η} due to energy imbalance η (see Sec. 6.2), and (iii) U_g due to spatial dislocation from equilibrium (see Sec. 9.2). The total potential energy U of a body is therefore given as

$$U = U_V + U_{\eta} + U_g, \quad (16)$$

where the autonomic principle dictates that $U \rightrightarrows 0$.

Restoring force. In accordance with classical laws governing the behavior of elastic bodies and systems, for which the fundamental principle is defined by Hooke's law of elasticity, under nonextreme conditions, potential energy $U_{\mathfrak{R}}$ produces a *restoring force* $\vec{F}$ such that

$$\vec{F} = -k_{\mathfrak{R}} \vec{\mathfrak{D}}, \quad (17)$$

where $\mathfrak{D} = \mathfrak{R} - \mathfrak{R}_{\text{par}}$. (Note that the phase transition of cells corresponds directly to the *plastic deformation* of macroscopic elastic bodies under extreme conditions.)

Equilibrium state. A cell is defined to be in a state of *absolute equilibrium* when $U = 0$. While the autonomic principle dictates that every cell must seek a state of absolute equilibrium, in a physical system under nonextreme conditions, such a state is all but precluded by various physical constraints that are ever-present in any system (e.g., quantitative individuality, among others). A cell is therefore defined to be in its *equilibrium state* when U is functionally minimal, expressed symbolically as

$$U \simeq 0, \quad (18)$$

where the notation $x \simeq \mathfrak{X}$ describes an optimal state such that the extant numerical value of a quantity x is as close as possible to its terminal value $\mathfrak{X}$.

Cell-level nonequilibrium dynamics. By virtue of its innate elasticity, a cell is compelled to seek elastic equilibrium when in a nonequilibrium state, which is given as $V_A \neq V_P$. From Eq. (13), a nonequilibrium state implies that $U_V > 0$. Therefore, in accordance with the autonomic principle, every cell seeks to reduce its elastic potential energy maximally in each time step when its extant volume differs from its par volume, stated as

$$U_V = \frac{H_A v_0}{2} \left(\frac{V_P}{V_A} - 1 \right)^2 \rightrightarrows 0. \quad (19)$$

Moreover, if the constituent cells of a system are in a nonequilibrium state, then so is the system as a whole. Thus, every system is at all times compelled to reduce its total elastic potential energy maximally in each time step, given as $\sum_{i=1}^N U_{V,i} \rightrightarrows 0$, where $U_{V,i}$ is the elastic potential energy of cell i within a system composed of N cells.

Notably, because the V_P of a cell is constant in all but extreme conditions, Eq. (19) implies that in nonextreme conditions $U_V \rightrightarrows 0$ can occur only through one or both of two possible actions, namely $H_A \rightrightarrows H_G$ and $V_A \rightrightarrows V_P$. The latter action induces motion whereby the cells within a system are compelled to self-organize into a characteristic spatial order (as described below), while the former action compels cells to emit photinos as radiation energy, if the prevailing conditions permit (see Sec. 4.3).

3.2 Cell Motion

As Eq. (19) implies, if H_A is held constant then any reduction in the U_V of a cell can occur only if $V_A \rightrightarrows V_P$, which requires the cell to dilate maximally in each time step. Because the cells within a system are spatially contiguous, the dilation of a cell requires its neighboring cells to surrender a portion of the space that they occupy by contracting in volume. However, such forced volume contraction increases the compression κ of the neighboring cells, thus increasing their U_V , which they are compelled to resist in accordance with the autonomic principle. Neighboring cells thus impose spatial constraints that inhibit the ability of a cell to dilate maximally in pursuit of its equilibrium state $U_V \simeq 0$. However, the total elastic potential energy of a system can nevertheless be reduced in each time step if groups of neighboring cells within the system rotate in concert about a common axis such that the volume of each cell within each group is maximized. Such group-wise in-concert rotations define the mechanism of cell motion within a system. This process reduces the total potential energy of the system incrementally, and it terminates when the volumes of all constituent cells in the system are such that $V_A \simeq V_P$, whereby $U_V \simeq 0$ for each cell in the system.

Given the spatial contiguity of cells, when (say) a cell A shifts partly from its extant location to a neighboring location, it must partly displace a cell B occupying that location. In addition, the space partly vacated by cell A must be filled by a cell C from another neighboring location. Cell motion thus entails the simultaneous rotation of a group of neighboring cells, such as a triplet, about a common axis, while the only condition the triplet must satisfy for such motion to occur is $\sum_{i=1}^N U_{V,i} \rightrightarrows 0$.

A two-dimensional plane permits two degrees of freedom, whereby the rotation of a triplet may be either clockwise or counterclockwise. Three-dimensional space

Fig. 3 Step-wise triple cell rotation.

permits multiple degrees of freedom, whereby a group of conjoined neighbors—which might be a pair, triplet, quadruplet, or higher-order grouping—may rotate in any number of ways. However, the logic of triple-cell rotation in a two-dimensional plane applies equally to the rotation of higher-order cell groupings in three-dimensional space, notwithstanding the greater complexity of the latter. Described next is the mechanism of a triple-cell rotation.

Figure 3 shows a triplet $\{A,B,C\}$ rotating counterclockwise in a two-dimensional plane. Given its two degrees of freedom, the triplet may also rotate clockwise. Let $\mathbb{U}_{ABC} = U_V(A) + U_V(B) + U_V(C)$ be the total potential energy of the triplet $\{A,B,C\}$ prior to rotation, $\mathbb{U}'_{ABC} = U'_V(A) + U'_V(B) + U'_V(C)$ be its total potential energy after one counterclockwise turn, and $\mathbb{U}''_{ABC} = U''_V(A) + U''_V(B) + U''_V(C)$ be its total potential energy after one clockwise turn.

Note that a single *turn* in the rotation of a triplet does not imply the movement of an entire cell into space previously occupied by a neighbor. The triplet rotates incrementally, in small step-wise movements. Each turn occurs in a single time step and entails a fractional part of each cell moving into a fractional space vacated by a neighbor. The center of mass of each cell in the triplet thus shifts incrementally, as in Fig. 3, which shows two increments such that the centers of mass of the cells in the triplet, namely c_A , c_B , and c_C , shift fully over two time steps $t+1$ and $t+2$. Moreover, in accordance with the autonomic principle, the rotation of the triplet $\{A,B,C\}$ is possible if and only if $\mathbb{U}_{ABC} > \mathbb{U}'_{ABC}$ for a clockwise turn or $\mathbb{U}_{ABC} > \mathbb{U}''_{ABC}$ for a counterclockwise turn.

Let $\mathcal{A}$ be a set whose elements are a given cell i and all of its neighbors. In each turn, cell i must form an optimal triplet $\mathcal{O}_{ijk}$ with two neighbors j and k selected from all candidate cells in $\mathcal{A}$ such that a single (clockwise or counterclockwise) turn reduces the potential energy of the triplet maximally. Symbolically, this is expressed as

$$\mathcal{O}_{ijk} = \arg \max_{i,j,k \in \mathcal{A}} \left(\frac{\mathbb{U}_{ijk} - \mathbb{U}'_{ijk}}{\mathbb{U}_{ijk} - \mathbb{U}''_{ijk}} \right). \quad (20)$$

If $\mathcal{O}_{ABC}$ now represents an *optimal triplet* $\{A, B, C\}$, then by the unit-action limit, $\mathcal{O}_{ABC}$ is an isolated system for the duration of each turn. By the law of conservation of energy, and as an isolated system during each turn, any reduction in the total potential energy of $\mathcal{O}_{ABC}$ must convert into (rotational) kinetic energy of the triplet. The kinetic energies of the cells A, B, and C are then described as $K_A = m_A |\vec{v}_A|^2/2$, $K_B = m_B |\vec{v}_B|^2/2$, and $K_C = m_C |\vec{v}_C|^2/2$, respectively, where m_A , m_B , and m_C denote the masses of the cells, while $\vec{v}_A$, $\vec{v}_B$, and $\vec{v}_C$ are their linear velocities during the rotation of $\mathcal{O}_{ABC}$. Thus, for the general case in which $\mathbb{U}'_{ABC} > \mathbb{U}''_{ABC}$ and $\mathbb{U}_{ABC} > \mathbb{U}'_{ABC}$, we have

$$\mathbb{U}_{ABC} - \mathbb{U}'_{ABC} = K_A + K_B + K_C. \quad (21)$$

Let t_{ABC} be the time required for one (full) turn in the rotation of $\mathcal{O}_{ABC}$, given as $t_{ABC} \triangleq n_{ABC} \tau$, where n_{ABC} is the number of elapsed instants. Defining $\vec{c}_{AB} = \vec{c}_B - \vec{c}_A$, $\vec{c}_{BC} = \vec{c}_C - \vec{c}_B$, and $\vec{c}_{CA} = \vec{c}_A - \vec{c}_C$, where $\vec{c}_A$, $\vec{c}_B$, and $\vec{c}_C$ are radius vectors of the centers of mass of cells A, B, and C, the velocities of the respective cells can be expressed as $\vec{v}_A = \vec{c}_{AB}/t_{ABC}$, $\vec{v}_B = \vec{c}_{BC}/t_{ABC}$, and $\vec{v}_C = \vec{c}_{CA}/t_{ABC}$. Replacing $\vec{v}_A$, $\vec{v}_B$, and $\vec{v}_C$ in the formulae for K_A , K_B , and K_C with the right-hand sides of these equations, respectively, and then substituting accordingly in Eq. (21), after some algebra we obtain

$$t_{ABC} = \left(\frac{(m_A |\vec{c}_{AB}|^2 + m_B |\vec{c}_{BC}|^2 + m_C |\vec{c}_{CA}|^2)}{2(\mathbb{U}_{ABC} - \mathbb{U}'_{ABC})} \right)^{\frac{1}{2}}. \quad (22)$$

The *rotational speed* ζ_{ABC} of $\mathcal{O}_{ABC}$ can then be described by the relation $\zeta_{ABC} = 1/t_{ABC}$.

Because the lifetime of an optimal triplet $\mathcal{O}_{ABC}$ is a single turn, each cell must form a new optimal triplet upon the completion of each turn. Thus, the point-to-point migration of a cell terminates when it can no longer form a new triplet whose rotation would further reduce the elastic potential energy of the triplet. The overall migration speed of a cell within a system is then determined as a function of the mean rotational speed of the triplets formed by the cell over the course of its migration within the system.

3.3 Nearest-density Order

Suppose that a system $\mathcal{B}$ composed of N cells is restricted by its ambient system to a total volume $V(\mathcal{B})$ such that $V(\mathcal{B}) = (3/4) \sum_{i=1}^N V_{P,i}$, where $i \in \mathcal{B}$. The cells within $\mathcal{B}$ are then compressed in volume such that, on average, $V_{A,i} = (3/4) V_{P,i}$. Now, if the values of $V_{R,i}$, $H_{A,i}$, and $H_{R,i}$ are all known, then $V_{P,i}$ can be determined precisely by Eq. (12). Moreover, because $V_{A,i} \rightrightarrows V_{P,i}$, it follows that $V_{A,i}$ must be maximal for each cell i in $\mathcal{B}$. However, the exact proportion of the total available spatial volume $V(\mathcal{B})$ that is allocated to any given cell i in $\mathcal{B}$ cannot be determined

based on the (known) values of these quantities alone. Rather, the allocation of $V(\mathcal{B})$ to each cell in the system is based on the second postulate of photodynamics, that every cell is essentially a tightly bound cluster of photinos.

Each cell i within $\mathcal{B}$ is thus allocated its share of the total available volume $V(\mathcal{B})$ in proportion to its photino content $H_{A,i}$. Cells of high density, which require proportionately small volumes while possessing high photino contents, are hence allocated space in excess of the volumes they maximally require, and cells of low density may be allocated less space than they require. Somewhat counterintuitively, it is from this very imbalance between spatial allocation and requirement that an optimal order emerges, and it gives rise to a distinct structure in the distribution of cells within a system.

Let $\mathcal{B}$ now represent the hypothetical case of a system whose N cells are initially distributed randomly within an imaginary closed surface of arbitrary extent. In that case, $\sum_{i=1}^N H_{A,i}$ is the total photino content of the system and $\sum_{i=1}^N V_{A,i}$ is its total volume. The extant photino content of a given cell c is then $H_{A,c}$, while its (as-yet undetermined) volume is $V_{A,c}$. The *pro rata* allocation to cell c of its due share of the total volume $V(\mathcal{B})$ of the system is therefore given by $V_{A,c} / \sum_{i=1}^N V_{A,i} = H_{A,c} / \sum_{i=1}^N H_{A,i}$.

Multiplying both sides of this equation by the ratio $(\sum_{i=1}^N H_{A,i}) / V_{A,c}$, we obtain $\rho_c = \rho_B$. This means that in an idealized case where the spatial volume actually occupied by any given cell c is identically equal to its *pro rata* share of $V(\mathcal{B})$, the density distribution within $\mathcal{B}$ must be isotropic everywhere, whereby ρ_B defines the par value of ρ_c . Furthermore, any deviation in the value of ρ_c from this par value, given as $|\rho_c - \rho_B| > 0$, indicates a nonequilibrium state in c and hence also in $\mathcal{B}$ as a whole.

Now suppose that $\rho_{B'}$ is the photino density of a two-cell system $\mathcal{B}'$ composed of any two neighboring cells i and j such that $\mathcal{B}' \in \mathcal{B}$. Based on the previous equation, in the idealized case where its actual share of $V(\mathcal{B}')$ is equal to its *pro rata* spatial allocation, the par value of ρ_i must be such that $\rho_i = \rho_{B'}$, which can be stated in expanded form as $H_{A,i}/V_{A,i} = (H_{A,i} + H_{A,j})/(V_{A,i} + V_{A,j})$. This equation reduces to $\rho_i - \rho_j = 0$, indicating that in the idealized case, the densities of all neighboring cells in a system must be identically equal in numerical value.

However, absolute numerical equality between the densities of any two cells in a system is functionally prohibited by their quantitative individuality, whereby, with asymptotic probability one, $|\rho_i - \rho_j| > 0$ for all cells i and j in the system $\mathcal{B}$. Therefore, there exists a potential energy $U_{B'} > 0$ such that $U_{B'} = (k_{B'}/2)(\rho_i - \rho_j)^2$, where $k_{B'}$ is a system-specific coefficient. Furthermore, given that $U_{B'} \rightrightarrows 0$, a universal propensity is induced that compels every two-cell system $\mathcal{B}'$ within $\mathcal{B}$ toward its equilibrium state $U_{B'} \simeq 0$, whereby $|\rho_i - \rho_j| \rightrightarrows 0$. Consequently, each

cell i within system $\mathcal{B}$ is compelled to form an optimal pair $\mathcal{P}_{ij}$ with a neighbor j such that

$$\mathcal{P}_{ij} = \arg \min_{i,j \in \mathcal{B}} |\rho_i - \rho_j|. \quad (23)$$

Thus, when there exists a set $\mathcal{B}'' = \{\mathcal{P}_{ij}\}$ for all $i, j \in \mathcal{B}$, then $\mathcal{B}$ represents a system in equilibrium, implying that $\forall i, j \in \mathcal{B}, \forall k \neq i, j \in \mathcal{B} : |\rho_i - \rho_j| < |\rho_i - \rho_k|$. It therefore follows that for any given system $\mathcal{B}$ to be in an equilibrium state, all the elements i and j of the system must be arranged in *nearest-density order* such that

$$\rho_i - \rho_j \simeq 0. \quad (24)$$

3.4 Spatial Density Distribution, Density Gradient, and Anisotropy

The order according to nearest density instills a strict sequence in the arrangement of cells relative to one another as a system reaches equilibrium. A one-dimensional case of this arrangement can be described by a string of cells in which the highest-density cell lies at one end and the lowest-density cell lies at the other end, while the densities of the intervening cells decrease sequentially from one end of the string to the other. In a string where the highest-density cell is located at the center, nearest-density order requires that cell densities must decrease sequentially in both directions away from the central cell. This arrangement describes a one-dimensional *Gaussian* (i.e., normal) distribution of cell densities.

Emergent Gaussian density distribution. In three-dimensional physical space, the compulsion of cells to self-organize in nearest-density order dictates that the distribution of cell densities in any given region must follow a corresponding structure, namely a three-dimensional Gaussian density distribution. The highest-density cells thus collectively form the core of a roughly spherically symmetric cell cluster in each region of a system. Cell densities within each cluster then decrease sequentially away from the high-density core radially in each direction (see Fig. 4). This (roughly) concentric symmetry in the spatial density distribution around a high-density core transcends scale and extends to any physical system whose elements are, at least largely, in an equilibrium state. Regardless of the scale of a system, an approximate three-dimensional Gaussian symmetry thus emerges in the density distribution of the elements of the medium surrounding a high-density *primary body* (denoted hereinafter by $\oplus$) that forms the core of the system.

Note on simulation. The emergence of this spatial structure is demonstrated graphically in the computer simulation provided herewith [20]. However, the simulation has its limitations because no computer can reproduce the unlimited precision with which nature measures the density differences between cells, or the

Fig. 4 Two-dimensional schematic of high-density multicell clusters (red) separated by regions of low (blue) and intermediate (yellow and green) density.

frequencies of up to $\nu_\tau \sim 10^{50}$ Hz at which natural processes can occur.

Density gradient. A point on an imaginary spherical surface $\mathcal{S}$ centered on $\oplus$ can be described by its spherical coordinates (r, θ, ϕ) , where the radial coordinate r is measured relative to the center of mass of $\oplus$, while θ and ϕ are measured relative to the polar and azimuthal axes, respectively, of the system enclosed in $\mathcal{S}$ (see Sec. 4.2 for the formation of polar and azimuthal axes in systems). If $\hat{r}$ is a radial unit vector outwardly normal to $\mathcal{S}$, then the *density gradient* at a point (r, θ, ϕ) on $\mathcal{S}$ is given by

$$\vec{\nabla} \rho = \hat{r} \frac{\partial \rho}{\partial r} + \hat{\theta} \frac{1}{r} \frac{\partial \rho}{\partial \theta} + \hat{\phi} \frac{1}{r \sin \theta} \frac{\partial \rho}{\partial \phi}, \quad (25)$$

where $\hat{\theta}$ and $\hat{\phi}$ are the polar and azimuthal unit vectors, respectively. Given the approximate Gaussian symmetry in the density distribution of the elements of a system, in macroscopic systems the variation in the density of the elements located on any given surface $\mathcal{S}$ tends to be negligibly small in the $\hat{\theta}$ and $\hat{\phi}$ directions as compared to radial density variation in the $\hat{r}$ direction. Consequently, the medium surrounding a primary body $\oplus$ tends to have a well-pronounced density gradient only in the radial direction, which implies that $\partial \rho / \partial \theta \approx \partial \rho / \partial \phi \approx 0$, and Eq. (25) reduces to

$$\vec{\nabla} \rho \approx \hat{r} \frac{\partial \rho}{\partial r}. \quad (26)$$

Density distribution patterns. Notably, a sinusoidal order in the sequence of cell densities is consistent with the nearest-density order of cell arrangement because a sinusoidal pattern is simply a sequence in which cell densities alternate cyclically about a mean value while arranged locally in order of nearest density. Therefore, any number of undulating wavelike spatial density patterns that satisfy the requirement of nearest-density order may coexist as substructures within a system. However, the two patterns that predominate in natural systems are (i) three-dimensional Gaussian, where the elements of the system are arranged in roughly concentric radially decreasing density order around a high-density core, and (ii) one-

dimensional sinusoidal, where the system is a *filament* composed of a chain of segments whose elements (which may be cells, atoms, molecules, cosmic structures, particles in motion-induced streamlines, and so on) are all arranged locally in order of sequentially reducing density around the highest-density elements within each segment.

Anisotropy in spatial density distribution. A key consequence of the characteristic Gaussian density distribution inside a system enclosed by $\mathcal{S}$ is that the distribution of spatial density surrounding any given element within $\mathcal{S}$ (e.g., a cell) must be *anisotropic* if the system is in equilibrium. This is because the density of the medium inside $\mathcal{S}$ increases progressively in the direction toward the primary body. Consequently, for any given element within $\mathcal{S}$, the density of its immediate neighbor on the side facing the primary body must be greater than that of its neighbor on the diametrically opposite side facing antiparallel to the direction of the primary body. Meanwhile, the densities of all other immediate neighbors of the element decrease sequentially from the higher-density side (facing the primary body) to the lower-density side diametrically opposite.

3.5 Rank Hierarchy of Nested Clusters

Suppose that a set of N_0 cells constitutes a first-order cluster C_1 , a set of N_1 first-order clusters constitutes a second-order cluster C_2 , a set of N_2 second-order clusters constitutes a third-order cluster C_3 , and so on. If C_0 is the set of all cells in C_1 , then the extant photino density of any cluster C_z is given by

$$\rho(C_z) = \frac{\sum_{i=1}^{N_{z-1}} H_{A,i}(C_{z-1})}{\sum_{i=1}^{N_{z-1}} V_{A,i}(C_{z-1})}, \quad (27)$$

where $z \in \{1, 2, 3, \dots\}$ is defined as the *rank* of a cluster within a multi-level hierarchy of nested clusters.

Proper elements. Moreover, in Eq. (27), each element i represents one of N_{z-1} *proper elements* of the cluster C_z , where a proper element is defined as a unitary cell or cluster of any rank $z - 1$ that is a direct component of C_z . To be clear, this means that the subelements that lie inside the body of a direct component of C_z are not counted as proper elements of C_z . Meanwhile, from the perspective of the system C_z , every proper element in it is a distinct unitary body at par with every other proper element. Hence, no proper element of C_z has a preferred status—irrespective of its magnitude—relative to any of the other proper elements of the system, except in respect to its density relative to that of the other proper elements.

Equilibrium state. If $\bar{\rho}_{\odot,i}$ is the average density of the *ambient medium* (denoted by $\odot$) surrounding a proper element i within a system C_z , then based on Eq. (24) all proper elements of C_z are in equilibrium within the host

system if and only if $\rho_i - \bar{\rho}_{\odot,i} \simeq 0$ for all i . Furthermore, given that C_z is itself a proper element within a higher-order system C_{z+1} , it follows that C_z is in equilibrium within C_{z+1} if and only if its density $\rho(C_z)$ is as close as possible to the average density of its ambient medium $\bar{\rho}_{\odot}(C_z)$, expressed as

$$\rho(C_z) - \bar{\rho}_{\odot}(C_z) \simeq 0. \quad (28)$$

Cluster rank hierarchy. Given the autonomic propensity of cells to self-organize in Gaussian order of cell densities, at the smallest scale, HDT cells cluster in characteristic order to form multi-cell C_1 clusters as nucleons, namely protons and neutrons, as well as other less stable high-density particles (see Sec. 7.1).

In turn, nucleons cluster in roughly concentric Gaussian density order to form C_2 clusters as atomic nuclei. LDT cells (i.e., electrons) then cluster in approximately Gaussian density order around atomic nuclei to form C_3 clusters as complete atoms. The atoms then cluster in nearest-density order to form C_4 clusters as molecules, while any gaps that separate individual atoms within a molecule are occupied by LDI cells, arranged always in nearest-density order.

Molecules of like density then cluster locally to form distinct substances at the macroscopic scale. Moreover, any gap separating two nearby molecules must be occupied by LDI cells arranged in nearest-density order, whereby the density of the intervening LDI cells decreases with radial distance away from each molecule until a point of lowest density is reached. The physical boundary between two C_4 systems is thus defined by the region composed of the lowest-density LDI cells located in the gap separating the two molecules if such a gap exists.

In the framework of the present model, ten rank classifications are sufficient to describe the complete hierarchy of nested clusters, ranging from the subatomic scale to the universe as a whole, such that $z \in [1, 10]$. As noted, individual cells C_0 and clusters C_1 to C_4 all describe microscopic particles. Clusters of higher rank (i.e., C_5 to C_{10}) describe celestial bodies and higher-order systems and are discussed later as part of the broader subjects of gravitation and cosmology in Sec. 9.

Behavioral self-similarity. Because every cluster—regardless of rank—is composed ultimately of individual cells, the behavior of a cluster reflects the collective behavior of its constituent cells, whereby there exists a self-similarity in the autonomic behavior of clusters that transcends scale. Therefore, clusters of every rank substantially mimic the primitive autonomic behavior of individual cells, albeit at speeds that diminish with rank because the number of active elements, and hence the number of autonomic processes entailed, is much greater in clusters of higher rank than in clusters of lower rank.

4 Wave Function, Energy Transmission, and Phase Transition

4.1 Wave-function Mechanics

Whereas photino density ρ_A describes the extant photino content H_A of a cell per unit volume V_A , the distribution of photino density inside a cell is made distinctly anisotropic (synthetically) by the ever-present anisotropy of the density distribution in its ambient system, as follows. Let $\mathcal{s}$ be an imaginary *subspace* of fixed volume $\mathcal{V}_s$ within a cell such that for a cell composed of $\mathcal{N}$ contiguous subspaces, we have $V_A = \sum_{s=1}^{\mathcal{N}} \mathcal{V}_s$. The *internal density* $\tilde{\rho}$ of a subspace $\mathcal{s}$ can then be defined as $\tilde{\rho}_s = n_s h / \mathcal{V}_s$, where n_s is the photino count inside $\mathcal{s}$.

Given that cells possess elasticity and are composed entirely and only of photinos, it follows that elasticity must be an innate property of the photinos of which the cells are composed as well, implying that photinos are themselves governed by the laws of elasticity and hence seek a state of elastic equilibrium within a host cell. Therefore, the logic of nearest-density order in respect to the distribution of cells within a host system extends also to the distribution of photinos inside a host cell.

From the perspective of a given cell i , any neighboring cell j is a unitary proper element of the host system. Therefore, the internal structure of cell j is opaque to cell i and has no direct influence on the distribution of the photinos that lie inside i . Consequently, the photinos inside i cluster such that the $\tilde{\rho}_s$ values of the subspaces in cell i that are located at its boundary with a neighbor j are set proportional to the density ρ_j of cell j as a single composite object. (Likewise, the $\tilde{\rho}_s$ values of those subspaces inside cell j that are located at its boundary with cell i are set proportional to ρ_i .)

Internal anisotropy. As described earlier in Sec. 3.4, the spatial density distribution of the medium surrounding (any) cell i must be anisotropic because of the characteristic Gaussian density distribution of the proper elements of the host system. It follows that the density distribution of the subspaces at the surface of cell i must mirror the ever-present anisotropy in the density distribution of the neighboring cells in the medium surrounding cell i .

In addition, Eq. (28) implies that the density of each subspace in the region separating the surface of cell i from its center of mass c_m must be as close as possible to the average density of its neighboring subspaces, expressed symbolically as $\nabla^2 \tilde{\rho}_s \approx 0$. This internal density distribution further implies that photino density must progressively decrease inward from all points on the surface of a cell, reaching the lowest density at its center of mass c_m . Thus, the anisotropic density distribution of the subspaces at the surface of a cell mirroring that of its ambient medium is also projected to the interior of the cell.

Fig. 5 Cell polarity and internal photino density. The colors denote the grades of photino density of the subspaces within each cell. Red: highest density. Yellow: high-to-intermediate density. Green: intermediate-to-low density. Blue: lowest density. (Center of mass of each cell is shown as a white dot.)

Cell polarity and azimuthal orientation. This induced anisotropy in the internal photino density distribution of a cell inevitably produces an intrinsic *polarity*, which is defined by the axis of symmetry of all $\tilde{\rho}_s$ values that together describe the density distribution inside the cell (see Fig. 5). The *polar chord* of a cell thus passes through its center of mass, with the direction pointing to the higher-density end of the polar chord defined (arbitrarily) as the southward direction of polarity.

An *equatorial plane* of a cell can be defined as a plane that passes through the center of mass of the cell and lies perpendicular to its polar chord. The anisotropic density distribution of the medium surrounding a cell implies that there exists an *azimuth* of a cell, defined herein by the highest-density point on the rim of the equatorial plane, while the *anti-azimuth* of the cell is defined by the (lowest-density) point on the rim diagonally opposite to the azimuth. The *azimuthal orientation* of the cell is hence defined (arbitrarily) as running along its *azimuthal axis* from the anti-azimuth to the azimuth.

Photino flux density. The *photino flux density* at a point x on the polar chord of a cell is defined herein as the photino density of an imaginary cylindrical slice of the cell, where the cross section of the cylinder lies on a plane parallel to the equatorial plane of the cell (i.e., orthogonal to the polar chord). The height of the cylinder is dx and its cross-sectional area is $Z = \pi R^2$, where R is the radius of the cross section (see Fig. 6). Because the density distribution inside a cell reflects the ever-present variations in the densities of the neighboring cells, the photino flux density varies from point to point along the polar chord of the cell. It is greatest at the boundary of a cell with its highest-density neighbor and decreases progressively along the polar chord until reaching the center of mass of the cell, where the photino flux density is minimal. It then increases along the polar chord until reaching the boundary separating the cell from its lowest-density neighbor.

Stationary photino wave and the wave function $\psi(x)$.

The density distribution pattern inside a cell thus approximates a stationary cosine waveform, similar to the distribution of air density in a standing sound wave that forms in a pipe when both ends of the pipe are open to the atmosphere. The standing sound wave has a stationary antinode of maximum amplitude at each of the open ends of the pipe. The fundamental harmonic mode of the wave is then defined by a single stationary node of minimum amplitude, located halfway between the two antinodes. If the length of the pipe is L , then the wavelength of the standing sound wave in its fundamental mode is given by $\lambda_1 = 2L$. The next standing wave pattern that satisfies the conditions at the two open ends occurs when $\lambda_2 = L$, whereby there is one more node and one more antinode within L than in the fundamental mode. In general, the wavelength of a standing sound wave in an open-ended pipe of length L is given as $\lambda_n = \lambda_1/n = 2L/n$, where $n \in \{1, 2, 3, \dots\}$ denotes the harmonic *mode* of the wave.

In the corresponding case of a *stationary photino wave* within a cell, the photino flux density at any given point x on the polar axis of the cell defines the *amplitude* $\mathbb{A}$ of the stationary photino wave as $\mathbb{A} = (n_z h / Z dx)$, where n_z is the number of photinos concentrated in the cylindrical slice of volume $Z dx$. By analogy to a standing sound wave in its fundamental mode, the two antinodes of maximum amplitude correspond to the two ends of the polar chord of the cell, while a single node of minimum amplitude corresponds to the center of mass of the cell. Hence, a stationary photino wave (theoretically) describes the approximate photino density distribution inside a cell. The axis of symmetry of the stationary photino wave thus represents the polar axis of the cell, where the *polarity* of the cell—denoted by a unit vector $\hat{\mathbf{p}}$ —points southward toward the higher-density end of its polar chord.

The general form of a cosine wave is given by $\Psi(x, t) = \mathbb{A} \cos(kx - \omega t)$, where k is the wave number, ω is the angular frequency, and the function varies with time t . However, because the stationary photino wave of a cell is static everywhere, it has no time dependence, whereby its wave function reduces to that in the stationary case $\Psi(x, t = 0) = \psi(x)$. Therefore, given that $\psi(x)$ is an approximate representation of the wave function of a stationary photino wave, the (time-independent) wave function in mode n can be expressed as

$$\psi_n(x) \approx \mathbb{A} \cos(\tilde{k}_n x), \quad (29)$$

where $\tilde{k}_n$ is the wave number of the stationary photino wave of a cell in mode n . If L is the length of the polar chord of a cell in its ground state, then x represents a point on the polar axis such that $x \in [0, L]$, where $x = 0$ denotes the lower-density (northern) end of the polar chord of the cell and $x = L$ denotes its higher-density (southern) end. The wavelength of a stationary photino wave in its

Fig. 6 Amplitude of stationary photino wave at point x on polar chord of cell.

fundamental mode λ_1 (corresponding to the ground state of the cell) is therefore stated as $\lambda_1 = 2L$, while that of a stationary photino wave in mode n is given as

$$\lambda_n = \frac{\lambda_1}{n} = \frac{2L}{n}. \quad (30)$$

Therefore, the wave number of the stationary photino wave in mode n can be written as

$$\tilde{k}_n = \frac{2\pi}{\lambda_n} = \frac{2\pi n}{\lambda_1}. \quad (31)$$

4.2 Universal Polarity

In the context of photodynamics, polarity is a universal feature that exists in cells as well as in all multi-cell and higher-order clusters. The polar axis of a rank-1 cluster, such as a nucleon, is the line described by the axis of symmetry of all the ρ values of the cells distributed within the cluster. Autonomic compulsions enforce the same pattern in the density distribution of their constituent elements, so nuclear clusters, complete atoms, and higher-order clusters exhibit similar intrinsic polarity.

While their concentric spatial distribution requires the densities of the elements of a cluster to decrease radially in each direction from its core, quantitative individuality imposes an additional substructure. A cluster whose elements are largely in equilibrium possesses not only a north–south polarity but also an east–west azimuthal orientation. Surface elements thus increase in density from the northern pole of a cluster to its southern pole and decrease in density from the azimuth of any plane parallel to the equatorial plane of the cluster (analogously, the *prime meridian*) to its anti-azimuth (analogously, the *antimeridian* at 180° longitude).

4.3 Energy Transmission Process

In the framework of photodynamics, radiation energy represents the conduction of photinos from an emitting cell to a receiving neighbor induced by the autonomic

compulsion $U_V \rightrightarrows 0$. Moreover, a cell is defined as being *energized* if its extant photino count n_A exceeds its ground-state photino count n_G , while $n_A - n_G$ gives the number of *unbound photinos* resident in the cell.

Suppose that a cell initially in its ground state becomes energized, thus increasing its H_A . If the spatial constraints imposed by its ambient system prevent an increase in the V_A of the cell commensurate with that in its V_P as determined by Eq. (12), then its $V_P > V_A$, whereby it has potential energy $U_V > 0$ in accordance with Eq. (13). Therefore, as $U_V \rightrightarrows 0$, any decrease in the U_V of the cell can occur if and only if its H_A (and hence its n_A) decreases through the emission of unbound photinos.

In addition, given the spatial contiguity of cells in a system, a photino emitted by a cell must be absorbed by a neighboring cell. Meanwhile, the unit-action limit restricts the cell to emitting no more than one photino per time step.

Entropic condition. The process of cell-to-cell photino transmission can then be described within the general framework of a chain of three cells i, j , and k in which cell i is energized and cells j and k are initially in their ground states. If cell j receives successive photinos emitted by its neighbor i at frequency ν_{in} , then the wavelength of the *incident photino wave* is $\lambda_{in} = c/\nu_{in}$, and the corresponding wave number is $k_{in} = 2\pi/\lambda_{in}$.

Moreover, the autonomic principle dictates that the onward transmission of photinos from cell j to cell k must reduce the total elastic potential energy of the cell pair $\{j, k\}$, connoting an *entropic condition* defined as

$$\frac{(U_{V,j} - U'_{V,j})}{(U'_{V,k} - U_{V,k})} > 1, \quad (32)$$

where $U_{V,j}$ and $U_{V,k}$ are the elastic potential energies of cells j and k , respectively, before the transmission of photinos, and $U'_{V,j}$ and $U'_{V,k}$ are the respective values after the transmission.

Resonance. In the context of photodynamics, *resonance* between an incident photino wave and a receiving cell j occurs when k_{in} is equal to the first harmonic wave number $\tilde{k}_{1,j}$ of the stationary photino wave of cell j . (Note that because the numerical value of ν_{in} , and hence k_{in} , is completely determined by the time interval separating any two successive photinos, it follows that two incident photinos received successively by cell j are sufficient to establish resonance, namely $k_{in} = \tilde{k}_{1,j}$.)

Contingent mechanism. According to the present model, the onward transmission of photinos (i.e., from cell j to k) is a contingent process that is governed by two factors, namely the entropic condition and resonance. Whereas the entropic condition must be satisfied for the transmission of photinos to occur in all cases, resonance creates special

conditions in which photinos are transmitted as ensembles in the form of photons.

Photinos may therefore be transmitted via one of three primary mechanisms, which can be characterized as *simple conduction*, *photonic transmission*, and *thermal conduction*. In addition, *convection* serves as a secondary mechanism for the bulk transmission of photinos. The primary mechanism in any given case is then determined by the status with respect to (a) resonance and (b) the entropic condition, as follows.

Simple conduction. Suppose that cell j receives successive photinos from cell i at incident frequency ν_{in} , and the incident photino waves do not resonate with cell j such that $k_{in} \neq \tilde{k}_{1,j}$. In that case, if the entropic condition given by Eq. (32) is satisfied, then cell j transmits its unbound photinos to cell k at the same frequency (i.e., ν_{in}) as that of the incident photino wave.

Simple conduction is the principal process by which photinos are conducted from cell to neighboring cell in a medium, and hence it constitutes the primary mechanism through which light propagates across spatial distances.

Photonic transmission. Suppose that incident photino waves arriving from cell i resonate with cell j such that $k_{in} = \tilde{k}_{1,j}$. The effect of the resonance is to conditionally inhibit the autonomic compulsion of cell j to emit its unbound photinos to cell k even if the entropic condition given by Eq. (32) is satisfied. Successive photinos received via resonant photino waves are thus retained in cell j and accumulate as unbound photinos until j is in a higher harmonic state such that the mode n of its stationary photino wave is increased by an integer value. Now suppose that cell j has reached a harmonic state $n > 1$ and the entropic condition is satisfied. In that case, cell j must emit unbound photinos to cell k at its *resonant frequency* ν_{res} and descend to a lower harmonic state, where

$$\nu_{res} = \frac{c}{2\pi} \tilde{k}_{1,j}. \quad (33)$$

This mechanism further implies that if cell j is in a harmonic state $n > 1$ and the entropic condition is not satisfied while $k_{in} = \tilde{k}_{1,j}$, then cell j must continue to retain the photinos received from cell i via successive photino waves until j has reached the next higher harmonic state. Now suppose that cell j continues to absorb photinos received via successive resonant photino waves such that the mode of its stationary photino wave has increased from $n = 1$ initially to (say) $n = 5$. If at this stage the entropic condition is satisfied, then cell j must emit photinos at ν_{res} to reduce its potential energy as per Eq. (19) and descend to a lower harmonic state.

However, given that the mode of the stationary photino wave of cell j is now $n = 5$, the value of n can potentially decrease by one level to $n = 4$, or by two levels to $n = 3$, or by three levels to $n = 2$, or by four levels to $n = 1$. The

number of levels by which the value of n decreases in any given case is then determined as follows. Let $\mathcal{C}$ be a set containing all possible levels q by which n may decrease in value. The autonomic principle dictates that n must decrease by an optimal value Q such that the transmission of photinos from cell j to cell k produces the largest reduction in the total elastic potential energy of the cell pair $\{j, k\}$, expressed symbolically as

$$Q = \arg \max_{q \in \mathcal{C}} \left(\frac{U_{V,j}(q) - U'_{V,j}(q)}{U'_{V,k}(q) - U_{V,k}(q)} \right). \quad (34)$$

Photonic transmission thus entails ensembles of photinos being absorbed and emitted by cells at resonant frequencies ν_{res} . In the context of photodynamics, such an ensemble of photinos when absorbed or emitted by a cell (e.g., by an electron) defines a *photon*.

Photonic transmission is central to the mechanism underlying the Compton effect (see Sec. 5.3) and the line spectra of the chemical elements (see Sec. 8.1).

Thermal conduction. Suppose that incident photino waves arriving from cell i do not resonate with cell j such that $\tilde{k}_{in} \neq \tilde{k}_{1,j}$. In that case, if the entropic condition for their onward transmission to cell k is also not satisfied, then the incident photinos must be retained by cell j and accumulate therein as unbound photinos. (Note that the accumulation of unbound photinos in a cell simply raises its temperature; see Sec. 5.1).

Suppose further that the entropic condition remains unmet as the accumulation of the received photinos continues, reaching a level where the photino count of cell j exceeds that needed for the mode of its stationary photino to increase from $n = 1$ initially to (say) $n = 3$. If at this stage the entropic condition is satisfied, then cell j must emit the accumulated unbound photinos to cell k at its *thermal frequency* ν_{thm} , given as

$$\nu_{thm} = \frac{c}{2\pi} \tilde{k}_{n,j}, \quad (35)$$

where $\tilde{k}_{n,j}$ is the wave number of the stationary photino wave of j in its nearest extant harmonic mode (i.e., $n = 3$ in the current example). Photino emissions by cell j then occur at frequency ν_{thm} until either cell j is in its ground state or the entropic condition is no longer satisfied. Importantly, because the mode of the stationary photino wave of cell j decreases in this process (e.g., from $n = 3$ to $n = 2$ to $n = 1$), the numerical value of $\tilde{k}_{n,j}$, and hence the thermal frequency ν_{thm} , decreases with each reduction in n as cell j emits its unbound photinos to cell k .

Thermal conduction represents the mechanism that produces the observed thermal emission spectra associated with *blackbody radiation* [21].

Convection. In a fluid medium with a temperature gradient, convection serves as a secondary mechanism for

the bulk transport of photinos, with the process of convection described well by the classical theory of convective heat transfer. However, the central point of note in the context of photodynamics is that convection is also governed fundamentally by the autonomic principle. Highly energized carrier particles (e.g., molecules) in the medium are set in motion in one (say, upward) direction by the conversion of their U_V to kinetic energy as $U_V \rightarrow 0$. Meanwhile, the motion of less-energized particles in the opposite (downward) direction occurs by the absorption of photinos conducted from their (upward-migrating) highly energized neighbors, which raises the U_V of the (less-energized) particles that then converts to kinetic energy as $U_V \rightarrow 0$. The ensuing bulk transport of unbound photinos by the carrier particles thus churns the fluid continually if fresh photinos continue to be received from a source to energize the carrier particles, thereby inducing a tendency in the medium toward thermal equilibrium (see Sec. 5.1).

4.4 Phase Transition

As noted, extreme compression imposed by the ambient system causes the lower elastic limit V_R of a cell to be breached, while extreme decompression causes the upper elastic limit V_P of a cell to be breached. Either breach triggers a phase transition, which produces a spontaneous change in the state of the cell to one of absolute equilibrium such that $U_V = 0$.

The phase transition of a cell entails two primary actions, namely the resetting of its V_P and ρ_R values. Moreover, the equality given by Eq. (12) dictates that a change in V_P must be balanced by commensurate changes in its arguments V_R, H_A , and H_R . However, because H_A changes dynamically in nonextreme conditions, only V_R and H_R change because of a phase transition, where the latter may further trigger a change in H_G . Consequently, in addition to the two primary actions of resetting the V_P and ρ_R values of a cell, a phase transition further entails the resetting of the three quantities V_R, H_R , and H_G to restore the identity demanded by Eq. (12). The following five-step process describes the mechanism of a phase transition.

Step 1. Reset the par value of the cell to an updated value V'_P such that $V'_P = V_A$.

Step 2. Reset the rudimental volume of the cell to an updated value V'_R such that

$$V'_R = V_A \left(\frac{V_R}{V_P} \right). \quad (36)$$

Rationale. Updating V_P to V'_P and V_R to V'_R in Eq. (12) and then replacing V'_P with V_A (as per step 1) yields the relation $V_A = V'_R [1 + (\alpha/2)((H_A/H_R) - 1)]$. Because Eq. (12) can also be stated as $V_P/V_R = [1 + (\alpha/2)((H_A/H_R) - 1)]$, the previous equation can be written as $V_A = V'_R(V_P/V_R)$, of which Eq. (36) is an alternative expression.

Step 3. Reset the rudimental density of the cell to an updated value ρ'_R such that $\rho'_R = \rho_A$.

Step 4. Reset the rudimental photino content of the cell to an updated value H'_R such that

$$H'_R = H_A \left(\frac{V'_R}{V_A} \right). \quad (37)$$

Rationale. The identity $\rho'_R = \rho_A$ (as per step 3) can be written in expanded form as $H'_R/V'_R = H_A/V_A$, of which Eq. (37) is an alternative expression. In addition, because H'_R is the updated value of the rudimental photino content of the cell, the updated value of the rudimental photino count n'_R is given as $n'_R = H'_R/h$, where $n'_R \in \mathbb{R}$.

Step 5. Reset the ground-state photino content of the cell to an updated value $H'_G = n'_G h$ by resetting the ground-state photino count of the cell to an updated value n'_G such that

$$n'_G = \begin{cases} \lfloor n'_R \rfloor & \text{if } |n'_R - \lfloor n'_R \rfloor| < |n'_R - \lceil n'_R \rceil| \\ \lceil n'_R \rceil & \text{if } |n'_R - \lfloor n'_R \rfloor| \geq |n'_R - \lceil n'_R \rceil|. \end{cases} \quad (38)$$

Rationale. A state of energy neutrality (i.e., $\eta = 0$) in a cell as given by Eq. (11) is functionally prohibited with asymptotic probability one because of the fundamentally divergent mathematical properties of the two associated quantities, namely $n'_R \in \mathbb{R}$ and $n'_G \in \mathbb{N}^+$. Equation (38) is therefore an expression of the physical limitation that the (discrete) ground-state photino count of a cell can equal only the integer part of the (continuous) rudimental photino count of the cell, while the fractional part defines its η value as $\eta = n'_R - n'_G$.

Cell transformation and reverse phase transition. Given the dominant role of density in determining the physical behavior of a cell, any change in its rudimental density is transformational. It alters fundamentally the physical character of the cell as a particle, and this altered character then remains a permanent feature of the cell in all nonextreme conditions.

Note that the mechanism of phase transition described above is the same whether it is the lower or upper elastic limit of a cell that is breached. However, the physical effect in either case is the converse of the other. A phase transition due to breaching the lower elastic limit transforms a cell into a heavier particle by increasing its rudimental density, while a *reverse phase transition* due to breaching the upper elastic limit transforms the cell into a lighter particle by reducing its rudimental density.

5 Thermodynamics, Optics, and the Compton Effect

5.1 Thermodynamics

Based on the statistical mechanics conventionally associated with molecular motion [22, 23], the pressure P exerted by a (monatomic) gas is defined by the

thermodynamic equation $P = (2/3)(N/V)\bar{K}$, which can be restated as $PV = (2/3)N\bar{K}$, where $\bar{K}$ is the average kinetic energy of the N gas molecules contained within a volume V . Moreover, the empirical equation of state for gases is described by the relation $PV = Nk_B T$, where T denotes the temperature and $k_B \approx 1.381 \times 10^{-23} \text{ J K}^{-1}$ is *Boltzmann's constant*. Equating the two relationships yields the thermodynamic equation for temperature, given as $T = (2/3)(\bar{K}/k_B)$. Conventional theory thus describes temperature as a measure of the average kinetic energy of molecules in a system, where translational motion within an otherwise empty volume of space is deemed an intrinsic state of the molecules in the system.

The logic of the present model implies a fundamental departure from the paradigm of statistical mechanics. Firstly, the molecules in a system are separated not by a void of empty space but rather by a physical medium composed of contiguous LDI cells (disregarding, for present purposes, the various other atomic-scale particles that may also be present in the medium). Secondly, while molecular motion tends to be ever present in a system, motion is neither an intrinsic state of molecules nor the fundamental source of the mechanical energy of a system.

Rather, the core hypothesis of photodynamics asserts that the source of the mechanical energy of a system is the elastic potential energy of its constituent elements (i.e., the LDI cells and molecules) induced by their compression $\kappa = (V_P/V_A - 1)$, as described by Eq. (13). Meanwhile, the compression of the elements of a system arises from the compression of the system as a whole, which is determined by the extant conditions prevailing in the immediate environment surrounding the volume of space in which the system is contained. Molecular motion is thus a derivative effect produced by the kinetic energy gained as the cellular constituents of the molecules are compelled—pursuant to the autonomic principle—to reduce their potential energy maximally such that $U_V \rightrightarrows 0$.

Temperature and pressure are thus described as variant functions of the elastic potential energy stored in a system, as follows.

Temperature. The temperature of a system represents a measure of the average elastic potential energy $\bar{U}_V$ of the cellular elements of the system. Substituting $\bar{U}_V$ for $\bar{K}$ in the thermodynamic equation for T yields

$$T = \frac{2}{3} \frac{\bar{U}_V}{k_B}, \quad (39)$$

where the average elastic potential energy of a system composed of $\tilde{N}$ cells is given according to Eq. (13) as

$$\bar{U}_V = \frac{v_0}{2\tilde{N}} \sum_{i=1}^{\tilde{N}} H_{A,i} \left(\left(\frac{V_{P,i}}{V_{A,i}} \right) - 1 \right)^2. \quad (40)$$

The elastic potential energy U_V of a single cell can then be described by the case where the system consists of only one cell, whereby $\tilde{N} = 1$. Replacing $\bar{U}_V$ in Eq. (39) with the right-hand side of Eq. (40) while letting $\tilde{N} = 1$, the temperature of a single cell is given by

$$T = \frac{2}{3} \frac{U_V}{k_B} = \frac{H_A v_0}{3k_B} \left(\frac{V_P}{V_A} - 1 \right)^2. \quad (41)$$

Pressure. Substituting $\bar{U}_V$ for $\bar{K}$ and $\tilde{N}$ for N in the thermodynamic equation for P then yields the relationship $P = (2/3)(\tilde{N}/V)\bar{U}_V$. Replacing $\bar{U}_V$ in this equation with the right-hand side of Eq. (40) while letting $\tilde{N} = 1$, the internal pressure of a single cell can be stated as

$$P = \frac{2}{3} \frac{U_V}{V_A} = \frac{\rho_A v_0}{3} \left(\frac{V_P}{V_A} - 1 \right)^2. \quad (42)$$

Thermal equilibrium and the entropic condition. Given the autonomic compulsion $U_V \Rightarrow 0$, Eq. (41) implies that $T \Rightarrow 0$. If the extant conditions prevailing in its immediate neighborhood do not permit the V_A of a cell to change in value, then it follows that its compression κ remains constant. Hence, if κ is held constant, then Eq. (41) implies that $T \Rightarrow 0$ can occur if and only if $H_A \Rightarrow 0$. Consequently, the temperature of a cell can decrease only by the emission of its unbound photinos. However, the emission of photinos by a cell requires its neighboring cells to absorb the emitted photinos, which can only occur if the entropic condition described by Eq. (32) is satisfied.

Therefore, for the case (say) of simple conduction, the cells in a system must continue to emit their unbound photinos if the entropic condition is satisfied for each photino emission. A system thus reaches *thermal equilibrium* when the photino emissions terminate either because (i) the entropic condition cannot be satisfied for any further photino emissions by the cells in the system or because (ii) the cells in the system have reached their respective ground states and hence possess no unbound photinos that can be emitted.

Temperature and pressure of a system. Whereas Eqs. (41) and (42) describe the case of a single cell, they apply equally to any complete system contained in a contiguous volume of space. In the latter case, the quantities H_A , V_P , V_A , and ρ_A then represent, respectively, the total photino content, total par volume, total actual volume, and the actual photino density of the complete system.

5.2 Refraction and Diffraction of Light

Photinos subsist in high concentrations within the HDT and LDT cells that make up material bodies and in lower concentrations within the predominantly LDI cells that collectively make up the medium of space. Given that no cell can be devoid of photinos, it follows that the total photino count in the universe must far exceed its total cell

count. Every cell therefore typically hosts a great number of photinos, as exemplified by the photino count $n_e \sim 10^{20}$ of an average electron derived in Eq. (8). Positing that the n_G value of an average LDI cell is many orders of magnitude smaller than n_e , the number of photinos hosted by an average LDI cell can nevertheless be expected to be very large (say, $\sim 10^{10}$).

The LDI cells in a medium are in their optimal state when $n_A \simeq n_G$ and $V_A \simeq V_P$ for all cells i and j in the medium. Moreover, according to Eq. (24), the medium is in an equilibrium state when $\rho_i - \rho_j \simeq 0$. For illustrative purposes, consider the (hypothetical) case where the n_G and V_R values of two neighboring LDI cells in a medium happen to be equal. A unit difference in the actual photino counts of the neighboring cells Δn_A , relative to their n_G values, is then of the order of $\Delta n_A/n_G = 1/n_G \sim 10^{-10}$. By comparison, as per Eq. (12), a unit difference in the photino counts of the neighboring cells implies a vastly greater corresponding volumetric difference $\Delta V_P/V_R$ between the two cells, which is of the order of $\alpha/2 \sim 1/274$. It follows that the relative densities of neighboring cells in a medium are determined primarily not by the (minuscule) differences in their respective photino contents but rather by the (vastly greater) differences in their physical volumes.

Refractive index n_m and wavelength of light λ_m . Light is seen to refract when it enters, say, a slab of glass from air if the angle of incidence of the light deviates from the normal to the surface of the glass. This effect is well described by Snell's law as $\sin \theta_2 = (n_1/n_2) \sin \theta_1$, where the light transmitted initially in a medium of refractive index n_1 enters a medium of refractive index n_2 , and θ_1 and θ_2 are the angles of incidence and refraction of the light, respectively. At the macroscopic level, refraction can thus be described simply as the geometric alteration in the trajectory of light by a change in the refractive index of the medium. However, at the microscopic level, the mechanism that causes the wavelength of light and its speed to be altered by the refractive index of the medium requires a more precise description.

In the context of photodynamics, the spatial composition of a medium in which light is transmitted is cellular at an elemental level, where, as described above, the relative densities of the cells are determined primarily by their volumetric differences. Consequently, given that $\bar{\rho}_A = \bar{n}_A h / \bar{V}_A$, the density $\bar{\rho}_A$ of a medium tends to vary inversely with the average volume $\bar{V}_A$, and hence the average diameter, of the cells that make up the medium. Light propagates more slowly in a dense medium than in a rare medium because the average diameter of cells is smaller in a dense medium, whereby the photinos conducted from cell to neighboring cell in a dense medium traverse a shorter distance per unit time than those that are conducted at the same frequency in a rare medium.

By convention, the refractive index n_m of a medium m is defined as the ratio of the (terminal) speed of light c to the speed c_m of its propagation in the medium, stated as $n_m = c/c_m$. Conventional theory attributes this inverse relationship between c_m and n_m to the dynamics of electric fields and associated feedback effects induced by oscillating charges present in a medium [24, 25]. Contrary to the conventional view, photodynamics ascribes the inverse relationship between n_m and c_m to the spatial geometry of the medium, as follows.

Let $\bar{r}_m$ be the average radius of the cells through which light is conducted in a given medium m . If $\mathcal{G}_m$ is the number of cell diameters per unit distance traversed by the light along its path through the medium, then it follows that $\mathcal{G}_m = 1/2\bar{r}_m$. If λ_m is the wavelength of the light, then we have $k_m = 2\pi/\lambda_m$, where the wave number k_m denotes the number of radians per unit distance. Thus, if z_m is the number of cell diameters per radian traversed by the light, then $z_m = \mathcal{G}_m/k_m = \lambda_m/(2\pi(2\bar{r}_m))$, which can be written alternatively as

$$2\bar{r}_m z_m = \frac{\lambda_m}{2\pi}. \quad (43)$$

Multiplying both sides of this equation by the angular frequency ω_m of the light, where $\omega_m = 2\pi\nu_m$ and ν_m is the linear frequency of the light, we obtain

$$(2\bar{r}_m z_m)\omega_m = \lambda_m \nu_m = c_m. \quad (44)$$

As described in Sec. 2.3, the limiting wavelength λ_τ of light entails the (hypothetical) conduction of successive photinos from one cell to the next in each consecutive time step, whereby $\lambda_\tau = 2r_\tau$, where r_τ is the limiting cell radius. Multiplying both sides of this equation by ν_τ gives

$$2r_\tau \nu_\tau = \lambda_\tau \nu_\tau = c. \quad (45)$$

Dividing Eq. (45) by Eq. (44) then gives the refractive index of the medium as

$$\frac{c}{c_m} = n_m = \frac{r_\tau \nu_\tau}{(\bar{r}_m z_m)\omega_m}. \quad (46)$$

Given that $r_\tau = \lambda_\tau/2$ and from Eq. (43) we have $\bar{r}_m z_m = \lambda_m/4\pi$, Eq. (46) can be written alternatively as $n_m = (2\pi\lambda_\tau \nu_\tau)/(\lambda_m \omega_m)$. This equation can be stated as $n_m = 2\pi c/\lambda_m \omega_m$ or equivalently as $\lambda_m = 2\pi c/n_m \omega_m$. Because the frequency of light is determined solely by the light-emitting source, ω_m does not depend on the medium in which the light is transmitted. Therefore, for the general case in which light is transmitted at angular frequency ω , the last equation can be written as

$$\lambda_m = \frac{2\pi c}{n_m \omega}. \quad (47)$$

This experimentally verified equation is well established in conventional theory as an accurate description of the dependence of the wavelength of light on the refractive index of the medium in which the light is transmitted [24].

From the viewpoint of photodynamics, refraction represents the principal phenomenon in optics, from which most other optical effects follow.

Diffraction. The present model describes the diffraction of light passing through a narrow aperture as a characteristic feature produced by the spatial geometry of the medium spanning the aperture. The autonomic principle dictates that each cell in the medium must migrate to its nearest-density location. Hence, because of the high-density material composition of the screen in which the aperture must be located, the highest-density cells in the medium are compelled to migrate to points around the rim of the aperture, while all the other cells in the medium are compelled to relocate to their respective nearest-density locations within the aperture.

Cells within the medium therefore decrease progressively in density from the rim toward the center of the aperture. This arrangement produces a spatial geometry in which the cell volumes (and hence $\bar{r}_m$) increase progressively from the rim toward the center of the aperture. As shown by Eq. (46), n_m varies as the inverse of $\bar{r}_m$, whereby the refractive index of the medium is the highest around the rim of the aperture, and decreases progressively toward its center. Now, according to Eq. (47), λ_m varies as the inverse of n_m . As a plane wavefront of light enters the aperture, this effective “lensing” of the medium shortens the wavelength of the light the most around the rim of the aperture and progressively less so toward its center. Consequently, the distance traversed per unit time by photinos conducted through the (lowest-density) cells at and around the center of the aperture exceeds the distance traversed in the same time period by photinos conducted through the (higher-density) cells around the rim. Thus, an arced wavefront, characteristic of diffraction, forms as the light emerges from the aperture.

5.3 Compton Effect

Photodynamics describes the Compton effect [26] as a feature induced by the autonomic principle. When an incident (resonant) photon transmits photinos that are absorbed by a cell, the V_p of the cell increases in accordance with Eq. (12). If spatial constraints imposed by the ambient system inhibit a corresponding increase in its V_A , then $V_p > V_A$ and the cell acquires potential energy $U_V > 0$ according to Eq. (13). With its V_A constrained by the ambient system, the autonomic compulsion $U_V \Rightarrow 0$ dictates that the cell must minimize its U_V either by the onward transmission of its unbound photinos to a neighbor or by the conversion of U_V into kinetic energy K . The former produces photon emission, whereas the latter produces motion in the cell; both photon emission and cell motion may ensue if the local conditions allow.

As described in Sec. 4.1, the stationary photino wave is a representation of the internal photino density distribution of a cell relative to points along its polar chord. Stating Eq. (30) as $n\lambda_n = \lambda_1$ and multiplying both sides of this equation by $1/c$, we obtain $v_n = nv_1$. Multiplying both sides of this equation by $1/v_0$ therefore gives $v_n/v_0 = n(v_1/v_0)$, which, based on Eq. (6), reduces to

$$n_n = nn_1, \quad (48)$$

where n_1 is the photino count in respect to the first harmonic state of the stationary photino wave of the cell in its ground state, whereby $n_1 = n_G$. The photino count n_2 then relates to the second harmonic state when the cell has absorbed an additional n_v photinos transmitted to it by a resonant incident photon at frequency ν , thereby giving $n_2 = n_G + n_v$. From Eq. (48), we have $n_2 = 2n_G$. Replacing the left-hand side of this equation with the right-hand side of the previous equation thus yields $n_v = n_G$.

Let λ be the wavelength of a resonant photon incident upon a cell, and let λ' be the wavelength of a photon emitted by the cell subsequent to its absorption of the photinos received via the incident photon. The difference between the wavelengths of the emitted and incident photons can then be stated as $\Delta\lambda = \lambda' - \lambda$. Multiplying the right-hand side of this equation by h/h yields the relationship $\Delta\lambda = (h\lambda'/h - h\lambda/h) = (hc/h\nu' - hc/h\nu)$, which, pursuant to Eq. (6), can be written as

$$\Delta\lambda = \left(\frac{hc}{n_{v'}h\nu_0} - \frac{hc}{n_vh\nu_0} \right), \quad (49)$$

where $n_{v'}$ is the number of photinos transmitted from the cell via the photon emitted by it at frequency ν' . As noted, if $n = 2$, the photino count of the cell is $n_2 = n_G + n_v$ before it has emitted a photon at frequency ν' . This implies that the number of photinos transmitted from the cell via the photon emitted by it cannot exceed n_v , expressed as $0 \leq n_{v'} \leq n_v$. Because $n_v = n_G$ for the case of $n = 2$, this relation can be stated as $n_{v'} = \varpi n_G$, where $\varpi = n_{v'}/n_v$ and $0 \leq \varpi \leq 1$. Substituting accordingly in Eq. (49) gives $\Delta\lambda = (hc/\varpi n_G h\nu_0) - (hc/n_G h\nu_0)$, which, based on Eq. (5), reduces to $(\lambda' - \lambda) = (hc/E_G)((1/\varpi) - 1)$, where E_G is the ground-state energy content of the cell.

Multiplying both sides of this equation by $1/hc$, we obtain $(\lambda'/hc) - (\lambda/hc) = (1/E_G)((1/\varpi) - 1)$, which can be stated as $(1/E') - (1/E) = (1/E_G)((1/\varpi) - 1)$, where $E = hc/\lambda$ is the energy of the incident photon and $E' = hc/\lambda'$ is the energy of the emitted photon. Multiplying the term $1/\varpi$ by $h\nu_0/h\nu_0$, we obtain the relation $1/\varpi = (n_v h\nu_0/n_{v'} h\nu_0) = (E/E')$, reducing the last equation to $(1/E') - (1/E) = (1/E_G)((E/E') - 1)$, which can be expressed equivalently as

$$\frac{1}{E'} - \frac{1}{E} = \left(\frac{1}{E_G} \right) \left(\frac{K^*}{E'} \right), \quad (50)$$

where $K^* = E - E' = \varphi + K$, while φ is the *photoelectric work function* [16] representing the (ionization) energy needed to dislodge the electron from its host atom, and K is the kinetic energy of the electron in the event that it is ejected from the host atom if $K^* > \varphi$.

Compton scattering and Compton shift. Let θ be the scattering angle formed by the trajectory of the emitted photon relative to the trajectory of the incident photon. For the range $0 \leq \theta \leq \pi$, the angle θ then varies such that $\cos \theta = (1 - K^*/E')$, whereby K^*/E' in Eq. (50) can be replaced with $(1 - \cos \theta)$ to give the well-established formula of atomic theory for *Compton scattering* as

$$\frac{1}{E'} - \frac{1}{E} = \frac{1}{E_G}(1 - \cos \theta), \quad (51)$$

relating the energy of a scattered photon E' to the energy of the incident photon E and the scattering angle θ .

Equation (51) can be written for the general case of any cell as $(\lambda'/hc) - (\lambda/hc) = (1/m_G c^2)(1 - \cos \theta)$, where m_G is the ground-state rest mass of the cell. Multiplying both sides of this equation by hc yields the *Compton shift* formula

$$\Delta\lambda = \left(\frac{h}{m_G c} \right) (1 - \cos \theta). \quad (52)$$

Compton wavelength λ_C and fundamental harmonic wavelength λ_1 . The quantity $h/m_G c$ in Eq. (52) is conventionally described as the *Compton wavelength* λ_C of a subatomic particle.

Notably, the fundamental harmonic wavelength λ_1 of the stationary photino wave of a cell in its ground state can be expressed variously by the chain of equalities

$$\lambda_1 = \frac{c}{\nu_1} \left(\frac{h}{h} \right) = \frac{hc}{E_G} = \frac{hc}{m_G c^2} = \frac{h}{m_G c} = \lambda_C, \quad (53)$$

establishing explicitly that the Compton wavelength λ_C represents the fundamental harmonic wavelength λ_1 of the stationary photino wave of a cell.

As a single-cell particle, the Compton wavelength of an electron $\lambda_{C(e)}$ is determined by replacing m_G in the formula $\lambda_C = h/m_G c$ with the rest mass m_e of an average electron, which gives $\lambda_{C(e)} \approx 2.426 \times 10^{-12}$ m. Because a proton is a multi-cell cluster, strictly speaking, the absorption and emission of a photon by a proton occurs only in one of its constituent cells, which can be referred to as the *interacting cell*. However, because the interacting cell remains bound to its host cluster (i.e., the proton), any kinetic energy induced in the interacting cell by the absorption of photinos received via a resonant incident photon must set the complete cluster, namely the proton as a whole, in motion. Therefore, the rest mass associated with the Compton wavelength of a proton is not that of the interacting cell alone but rather the mass of the proton as a whole. Consequently, a proton can be treated, in effect, as a

single-cell particle with a Compton wavelength $\lambda_{C(p)}$ of ca. 1.321×10^{-15} m, as determined by replacing m_G in the formula for λ_C with the average proton mass m_p .

Similarly, λ_C can be determined for any atomic-scale particle by replacing m_G in the formula for λ_C with the rest mass of that particle. Experimental evidence indicates that an electron that remains bound to its host atom does not produce an appreciable Compton shift. In agreement with the conventional view, this is because the effective mass of a bound electron is not the mass of the electron alone but rather the (far greater) rest mass of the host atom to which the electron is bound.

6 Electromagnetism

6.1 Electric Charge

A *charged particle* is defined herein as any unitary cell or rank-1 particle whose (net) $|\eta|$ value is greater than zero. Given the process by which the n_R of a cell is set during phase transition, the probability that n_R happens to be set to an integer is vanishingly small. Thus, Eq. (11) implies that with asymptotic probability one, any given cell in a system has an energy imbalance such that $|\eta| > 0$.

Cusp of η . The mechanism defined by Eqs. (38) and (11) for setting the η value of a cell further implies that η must be a function that describes a closed circle with unit circumference (i.e., a circle with radius $1/2\pi$ units), on which $\eta = 0$ is the point of energy neutrality. The values of η then increase along the circumference from the energy-neutral point $\eta = 0$ in one (say, clockwise) direction and decrease in the other (counterclockwise) direction. The range of all possible η^+ values is thus defined by increasing positive values of η such that $0 < \eta^+ \leq +0.5$, while the range of all possible η^- values is defined by decreasing negative values of η such that $0 > \eta^- \geq -0.5$. (Note that at $\eta = \pm 0.5$, the sign of η may be taken as either positive or negative because $\eta = 0.5$ is the precise point on the circle described by the η function where the positive-valued η range meets the negative-valued η range, the only other such point being $\eta = 0$.)

The *cusp* of η is defined herein as the point $\eta = 0.5$, connoting the maximum energy imbalance that a cell can have. As with the improbability of a zero η value, the probability that the η of a cell happens to be set equal to precisely 0.5 during a phase transition is vanishingly small. Therefore, with asymptotic probability one, the greatest $|\eta|$ value of a cell in a physical system is very nearly, but not precisely, 0.5.

Cusp range limit δ_η . A *cusp range* can be defined as a range of minor deviations (relative to the cusp) in the numerical values of η , within which the η of a cell can be treated for all practical purposes as being functionally equal to 0.5. Let $\delta_\eta \ll 0.5$ be the *cusp range limit*, representing

Fig. 7 The η function (schematic).

the maximum deviation—on either side of the cusp—in the numerical value of η up to which the η of a cell is deemed functionally equal to 0.5. Taking all values of η on the circle described by the η function in the clockwise direction starting at the point $0.5 - \delta_\eta$ and terminating at the point $0.5 + \delta_\eta$, the cusp range is given by the set of η values that lie in the interval $[(0.5 - \delta_\eta), (0.5 + \delta_\eta)]$. Thus, as shown in Fig. 7, all η^+ values within the cusp range lie in the interval $[(0.5 - \delta_\eta), 0.5]$ and all η^- values within the cusp range lie in the interval $[0.5, (0.5 + \delta_\eta)]$.

Unit charge and fractional charge. A cell whose η value lies in the cusp range is defined herein as possessing a *unit (electric) charge*. Because electrons and protons carry unit charges of opposite sign, their respective (net) η values must lie within the cusp range but on opposite sides of the cusp. In nature, no inherent bias toward any preferred η setting can be presumed to exist during the phase transition of a cell. Therefore, the distribution of those η values that lie within the cusp range must ordinarily be uniform, whereby the statistically expected (mean) η value of a cell carrying a (negative or positive) unit charge in a physical system is given by

$$\eta = 0.5 \pm \frac{\delta_\eta}{2}. \quad (54)$$

Given that the energy imbalance of a cell is (very nearly) maximal when its $|\eta|$ is within the cusp range and decreases as $|\eta|$ approaches zero, the electric charge carried by a cell must decrease correspondingly as $|\eta|$ approaches zero. A cell thus carries a *fractional charge* when its $|\eta|$ value lies outside the cusp range.

Composition of particle charges. As an energy-abundant (η^-) single-cell particle, an electron carries a negative unit charge. Unlike an electron, a proton is an energy-deficient (η^+) rank-1 multi-cell cluster whose positive unit charge arises from a net η^+ difference between the total η of its η^+ cells and the total η of its η^- cells. Given that an electron is a unitary cell, and taking the constituent cells inside a

nucleon to have an average n_G value equal to n_e , the number of cells in an average proton can be calculated, based on Eq. (8), as $[n_p/n_e] = 1836$, and the number of cells in an average neutron as $[n_n/n_e] = 1838$.

Because a neutron is electrically neutral, it can be deduced that the total η of its η^+ cells must offset the total η of its η^- cells, which further suggests that an average neutron contains an equal number of η^+ and η^- cells, namely 919 η^+ cells and 919 η^- cells. Moreover, because a proton carries a net positive charge and contains two cells fewer than an average neutron, it can be deduced that a proton is rendered electrically positive by a deficit of exactly two η^- cells, whereby an average proton consists of 919 η^+ cells and 917 η^- cells.

Intrinsic permanence of η . If a cell is as close as possible to its ground state (i.e., $H_A \simeq H_G$), then as per Eq. (19), its U_V cannot decrease further by the emission of unbound photinos to its neighboring cells. In addition, if the V_A of the cell is constrained by the ambient system from increasing in value, then its U_V can decrease to satisfy the autonomic compulsion $U_V \rightrightarrows 0$ if and only if its argument V_p decreases in value. According to Eq. (12), if $H_A \simeq H_G$, then the V_p of a cell can decrease if and only if its $|\eta|$ value increases, which requires an η^- cell to relinquish and an η^+ cell to acquire a fractional photino ηh . However, because photinos are quantized, the relinquishment or acquisition of a fractional photino by a cell is a physical impossibility, rendering η and the potential energy arising from it permanent features of the cell whose values cannot change under any nonextreme conditions.

Virtual mass m_η . The η of a cell further implies an equivalent fractional photino mass m_η , which as per Eq. (5) is given by the relationship $m_\eta = \eta h \nu_0 / c^2$. However, m_η describes not the mass of an ordinary physical object but rather the fractional deviation of the ground-state photino mass of a cell from its energy-neutral (i.e., rudimental) photino mass, characterized herein as the *virtual mass* associated with the η of a cell. Because η can be either positive or negative in value, so can m_η . A negative m_η connotes a fractional excess of mass that the cell seeks to relinquish in pursuit of energy neutrality, while a positive m_η connotes a fractional deficiency of mass that the cell seeks to acquire to attain energy neutrality. Because cells can neither relinquish nor acquire fractional photinos, m_η remains an intrinsic feature of every cell under nonextreme conditions.

Center-of-mass displacement $\vec{R}_\eta$. Let $\vec{c}_{m|\eta=0}$ be the radius vector of the center of mass of a cell in the theoretical case in which the cell is energy neutral such that $n_R = n_G$ and thus $\eta = m_\eta = 0$. Given that with asymptotic probability one, every cell in a physical system has an energy imbalance, it follows that the center of mass of a

cell (say, in its ground state) is almost surely displaced from the center of mass that it would have had if its η was zero. If $\vec{R}_\eta$ is the displacement of the center of mass of a cell from the energy-neutral point on its polar chord (i.e., from $c_{m|\eta=0}$) caused purely by its virtual mass m_η , then

$$\vec{R}_\eta \triangleq \vec{c}_{m|\eta} - \vec{c}_{m|\eta=0}, \quad (55)$$

where $\vec{c}_{m|\eta}$ is the radius vector of the displaced center of mass on the polar chord of the cell.

Mean geometric location of m_η . The polar chord of a cell can be considered an imaginary rod over which the entire photino content of the cell (and equivalently its mass) is distributed. The photino concentration at any point x on the polar chord is then described by the amplitude A of the stationary photino wave of the cell, where Eq. (29) gives the associated wave function $\psi_n(x)$. Given that $\psi_n(x)$ mirrors the distribution of neighboring cell densities, the photino distribution inside a cell, including the fractional photino ηh (and hence m_η), reflects this geometry.

Because it represents the virtual mass arising from the η of a cell, m_η cannot be described as an object located at a definite geometric coordinate inside the cell. Rather, the location of m_η may be described as a floating coordinate. Induced by the autonomic compulsion of a cell to seek to relinquish or acquire a fractional photino from some (ultimately unreachable) location in the cell, m_η is deemed to be in a virtual state of perpetual circular motion at a constant radius around the polar chord of the cell on a plane perpendicular to its polar axis. Therefore, the *mean geometric location* of m_η is described by the point at which its orbital plane intersects the polar chord of the cell.

Direction of $\vec{R}_\eta$. As the excess fractional photino mass in an energy-abundant cell, the mean geometric location of a negative-valued m_η must be on the (higher-density) southern side of the point $c_{m|\eta=0}$ on the polar chord of the cell. Meanwhile, as the implied deficiency of a fractional photino mass in an energy-deficient cell, the mean geometric location of a positive-valued m_η must be on the northern side of $c_{m|\eta=0}$ on the polar chord of the cell. Thus, given that $\vec{R}_\eta$ is coaxial with the polar chord, the orientation of $\vec{R}_\eta$ in an η^- cell is in the direction of its polarity ($+\hat{p}$), and antiparallel to it ($-\hat{p}$) in an η^+ cell.

6.2 Potential Energy due to η

Let $\vec{d}$ be a normalized measure of the displacement due to m_η of the center of mass of a cell or rank-1 particle (hereinafter referred to as a *cell/particle*) such that

$$\vec{d} \triangleq \frac{\vec{R}_\eta}{R} = \left(\frac{R_\eta}{R} \right) \hat{p}. \quad (56)$$

The quantity $\mathfrak{r}$ is defined herein as the reduced-form first harmonic wavelength of the stationary photino wave (i.e., $\lambda_1/2\pi$) of a cell/particle in the (hypothetical) case where the η value of the cell/particle is exactly maximal, and thus lies at the cusp of the η function. By convention, the *reduced Compton wavelength* is defined as $\tilde{\lambda}_C \triangleq \lambda_C/2\pi$. Hence, based on Eq. (53), we obtain $\lambda_1/2\pi = \tilde{\lambda}_C$, whereby the $\mathfrak{r}$ value of any cell/particle in a system can be stated as

$$\mathfrak{r} \triangleq \tilde{\lambda}_{C|\eta=0.5}, \quad (57)$$

where $\tilde{\lambda}_{C|\eta=0.5}$ is the reduced Compton wavelength of that cell/particle in the theoretical case where its $\eta = 0.5$. The quantity $\mathfrak{r}$ thus represents a standard meter against which the R_η of any cell/particle in a system can be calibrated to give its relative magnitude via the ratio $\mathfrak{d} = R_\eta/\mathfrak{r}$.

In conventional atomic theory the quantity $r_e = \alpha\tilde{\lambda}_C$ is described as the *classical electron radius* with a numerical value of $\sim 2.818 \times 10^{-15}$ m. In the present model, it is a central proposition of electromagnetism that the relation

$$R_\eta = \alpha\tilde{\lambda}_C \quad (58)$$

describes the precise displacement of the center of mass $c_{m|\eta}$ of any cell/particle (due to m_η) from $c_{m|\eta=0}$, where $\tilde{\lambda}_C$ relates uniquely to that cell/particle.

Based on Eq. (28), a normalized measure of the deviation of a cell from equilibrium within its ambient medium $\odot$ can be described by a quantity $\mathcal{D}_\eta$ such that

$$\mathcal{D}_\eta \triangleq \left(\frac{\rho_\odot - \bar{\rho}_\odot}{\rho_\odot} \right) = \left(1 - \frac{\bar{\rho}_\odot}{\rho_\odot} \right), \quad (59)$$

where the placeholder $\odot$ hereinafter denotes any cell/particle that is the object of the discussion underway.

Let U_η be the potential energy induced in a cell/particle $\odot$ by the displacement of its center of mass from the energy-neutral point $c_{m|\eta=0}$. A normalized quantity $\mathcal{U}_\eta$ can then be defined as the stored potential energy U_η per unit deviation of $\odot$ from equilibrium by the relationship $\mathcal{U}_\eta \triangleq U_\eta/\mathcal{D}_\eta$. Based on Eq. (14), the $\mathcal{U}_\eta$ of $\odot$ can be stated as a function of the ground-state energy $H_G\nu_0$ of $\odot$ and the normalized displacement $\vec{\mathfrak{d}}$ of its center of mass by the relationship $\mathcal{U}_\eta = U_\eta/\mathcal{D}_\eta = (H_G\nu_0/2)(\vec{\mathfrak{d}})^2$, written equivalently as

$$U_\eta = \frac{1}{2} n_G h\nu_0 \mathcal{D}_\eta (\vec{\mathfrak{d}})^2. \quad (60)$$

This equation gives an internal measure of U_η from the perspective of $\odot$. Pursuant to Eq. (14), an external measure of the potential energy stored in $\odot$ —from the perspective of the host system—is given by

$$U_\eta = \frac{1}{2} k_\eta (\vec{r})^2, \quad (61)$$

where k_η is a case-specific proportionality coefficient and $\vec{r} \triangleq \vec{c}_{m|\eta} - \vec{c}_0$, while $\vec{c}_0$ is the radius vector of the collective center of mass c_0 of all elements within the system enclosed by an imaginary spherical surface $\mathcal{S}$ of radius r . By definition, therefore, the center of mass of $\odot$ lies on $\mathcal{S}$ at a distance r from c_0 . Equating the right-hand sides of Eq. (60) and Eq. (61), we obtain

$$k_\eta = \frac{n_G h\nu_0}{(\vec{r})^2} \mathcal{D}_\eta (\vec{\mathfrak{d}})^2. \quad (62)$$

If a unit vector $\hat{\mathbf{r}}$ is defined as $\hat{\mathbf{r}} \triangleq \vec{r}/r$ and ϑ is the angle subtended by the axes of $\vec{\mathfrak{d}}$ and $\hat{\mathbf{r}}$ so that $0 \leq \vartheta \leq \pi$, then $(\vec{\mathfrak{d}})^2 = (\vec{\mathfrak{d}} \cos \vartheta)^2 + (\vec{\mathfrak{d}} \sin \vartheta)^2$, and the internal measure of U_η given by Eq. (60) can be stated as

$$U_\eta = \frac{1}{2} n_G h\nu_0 \mathcal{D}_\eta \left((\vec{\mathfrak{d}} \cos \vartheta)^2 + (\vec{\mathfrak{d}} \sin \vartheta)^2 \right). \quad (63)$$

Separating this relationship into its two components gives

$U'_\eta = n_G h\nu_0 \mathcal{D}_\eta (\vec{\mathfrak{d}} \cos \vartheta)^2/2$ describing the potential energy associated with the $\vec{\mathfrak{d}}$ component coaxial with $\hat{\mathbf{r}}$, and $U''_\eta = n_G h\nu_0 \mathcal{D}_\eta (\vec{\mathfrak{d}} \sin \vartheta)^2/2$ describing the potential energy associated with the $\vec{\mathfrak{d}}$ component orthogonal to $\hat{\mathbf{r}}$.

6.3 Force due to η

If $n_\odot$ is the ground-state photino count of a cell/particle $\odot$, then from Eq. (6) we have $n_\odot \nu_0 = \nu_{1(\odot)}$, where $\nu_{1(\odot)}$ is the fundamental harmonic frequency of the stationary photino wave of $\odot$; and because $\nu_{1(\odot)} = c/\lambda_{1(\odot)}$, it follows that $n_\odot h\nu_0 = hc/\lambda_{1(\odot)}$. Thus, pursuant to Eq. (62), the coaxial and orthogonal components of the k_η for $\odot$ are expressed, respectively, as $k'_\eta = (hc/\lambda_{1(\odot)} r^2) \mathcal{D}_\eta (\vec{\mathfrak{d}} \cos \vartheta)^2$ and $k''_\eta = (hc/\lambda_{1(\odot)} r^2) \mathcal{D}_\eta (\vec{\mathfrak{d}} \sin \vartheta)^2$.

From Eq. (17), U_η produces a restoring force $\vec{\mathcal{F}}_\eta$ such that $\vec{\mathcal{F}}_\eta = -k_\eta \vec{R}_\eta$. Therefore, it can be deduced that $\vec{\mathcal{F}}'_\eta$, the coaxial component of $\vec{\mathcal{F}}_\eta$, is given as

$$\vec{\mathcal{F}}'_\eta = -\frac{hc}{\lambda_{1(\odot)} r^2} \mathcal{D}_\eta (\vec{\mathfrak{d}} \cos \vartheta)^2 \vec{R}_\eta \cos \vartheta, \quad (64)$$

while $\vec{\mathcal{F}}''_\eta$, the orthogonal component of $\vec{\mathcal{F}}_\eta$, is given as

$$\vec{\mathcal{F}}''_\eta = -\frac{hc}{\lambda_{1(\odot)} r^2} \mathcal{D}_\eta (\vec{\mathfrak{d}} \sin \vartheta)^2 \vec{R}_\eta \sin \vartheta. \quad (65)$$

Axial coalignment. The autonomic principle dictates that $U_\eta \rightrightarrows 0$ and, according to Eq. (63), ϑ and $\mathcal{D}_\eta$ are the only arguments of U_η whose values are variable under nonextreme conditions. Hence, $U_\eta \rightrightarrows 0$ implies that $\sin \vartheta \rightrightarrows 0$ and $\mathcal{D}_\eta \rightrightarrows 0$. If r and $\mathcal{D}_\eta$ are held constant and $\sin \vartheta \neq 0$, then from Eq. (65) it follows that $\vec{\mathcal{F}}''_\eta \rightrightarrows 0$ as $\sin \vartheta \rightrightarrows 0$, whereby there exists a *torque* $\vec{\tau}$ that impels $\vec{R}_\eta$

$$\vec{F}_\eta = -\mathbb{K}_e \frac{q_0 q_0}{r^2} \mathcal{D}_\eta \left(\frac{\pm \vec{R}_{\eta(\mathcal{O})}}{r_{\mathcal{O}}} \right)^2 \left(\frac{\pm R_{\eta(\mathcal{O})}}{\alpha \lambda_{\mathcal{C}(\mathcal{O})}} \right) \hat{\mathbf{f}}. \quad (73)$$

Universal electrostatic force function $\vec{F}_\eta$. Suppose that a dominant charged particle, which can be called a *primary charge*, lies at the center of mass c_0 of a system inside a closed surface $\mathcal{S}$ of radius r . If $\pm\mathbb{d}_\oplus$ denotes the term $\pm R_{\eta(\odot)}/\alpha\lambda_{c(\odot)}$ in Eq. (73), and given that Eq. (56) implies that $(\pm\vec{R}_{\eta(\odot)}/r_\odot)^2 = (\pm\mathbb{d}_\odot)^2$, Eq. (73) can be written as

$$\vec{F}_\eta = -\mathbb{k}_e \frac{q_0 q_0}{r^2} \mathcal{D}_\eta (\pm\mathbb{d}_\odot)^2 (\partial_\oplus)(\pm\hat{\mathbf{r}}). \quad (74)$$

The term $(\pm\mathbb{d}_\odot)^2$ in this equation can be separated into its two factors such that one factor $\pm\mathbb{d}_1$ is associated with the primary charge located at c_0 , and the second factor $\pm\mathbb{d}_2$ is associated with a charged particle centered on the surface $\mathcal{S}$, which can be called a *test charge*. Noting that Eq. (58) gives $R_\eta = \alpha\lambda_c$, the two factors are stated as $\pm\mathbb{d}_1 = (\pm R_{\eta(1)}/r_1) = (\pm\alpha\lambda_{c(1)})/(\lambda_{c(1)}|_{\eta=0.5})$ and $\pm\mathbb{d}_2 = (\pm R_{\eta(2)}/r_2) = (\pm\alpha\lambda_{c(2)})/(\lambda_{c(2)}|_{\eta=0.5})$.

Meanwhile, the term $\partial_\oplus$ in Eq. (74) is associated with a reference particle that (theoretically) carries the mean η of all the possible values of η that lie within the cusp range on either side of the cusp. This is an axially coaligned *ideal cell* $\oplus$ located in the medium within $\mathcal{S}$ such that $\eta_\oplus = 0.5$. Because $\eta_\oplus$ is (exactly) maximal, from Eq. (58) we have $R_{\eta(\oplus)} = \alpha\lambda_{c(\oplus)}$, whereby $\partial_\oplus = \alpha\lambda_{c(\oplus)}/\alpha\lambda_{c(\oplus)} = 1$. Moreover, because the density of a particle that constitutes a primary charge within a system exceeds that of its ambient medium, the elements of the medium inside $\mathcal{S}$ must be arranged around the primary charge in order of inwardly increasing density. Therefore, because $\oplus$ is an element of the medium within $\mathcal{S}$, the polarity of $\oplus$ must point in the direction $-\hat{\mathbf{r}}$, whereby $(\partial_\oplus)(\pm\hat{\mathbf{r}}) = (1)(-\hat{\mathbf{r}})$.

Thus, replacing the term $(\pm\mathbb{d}_\odot)^2$ with $(\pm\mathbb{d}_1)(\pm\mathbb{d}_2)$ and the term $(\partial_\oplus)(\pm\hat{\mathbf{r}})$ with $-\hat{\mathbf{r}}$, Eq. (74) can be restated as

$$\vec{F}_\eta = \mathbb{k}_e \left(\frac{(\pm\mathbb{d}_1 q_0)(\pm\mathbb{d}_2 q_0)}{r^2} \right) \mathcal{D}_\eta \hat{\mathbf{r}}. \quad (75)$$

Notably, the quantities $\mathbb{d}_1$ and $\mathbb{d}_2$ in this relationship act as scaling factors on q_0 , independent of the distance r . Consequently, for any given distance r between the primary and secondary charges, the magnitude of F_η decreases from its largest value when both the charges consist of cells/particles with unit charge to lesser values when either or both the charges consist of cells/particles with fractional charge.

Equation (75) describes the case where the electrostatic force is between a single-particle primary charge $\pm\mathbb{d}_1 q_0$ and a single-particle test charge $\pm\mathbb{d}_2 q_0$, in isolation from the medium that surrounds the primary charge. However, the medium of space surrounding the primary charge consists of contiguous elements that may individually be unitary cells or rank-1 particles, which, in turn, may be components of composite bodies of matter. Therefore, because each element of the system almost

surely possesses a (net) $|\eta| > 0$, the complete system inside $\mathcal{S}$ possesses a total charge Q such that

$$Q = q_0 \sum_{i=1}^{N_1} \pm\mathbb{d}_i, \quad (76)$$

where N_1 is the total number of elements i in the system, including the primary charge and the elements of its ambient medium inside $\mathcal{S}$. Meanwhile, a test charge may be a single charged particle or a multi-particle cluster composed of elements that may individually be unitary cells or rank-1 particles. If N_2 is the number of elements j in the test charge, then its total charge q is given by

$$q = q_0 \sum_{j=1}^{N_2} \pm\mathbb{d}_j. \quad (77)$$

Because the complete system inside $\mathcal{S}$ consists of all the N_1 elements contained therein, $\pm\mathbb{d}_1 q_0$ must be replaced with Q in Eq. (75) to account for the total charge inside the surface $\mathcal{S}$. Likewise, in the case of the test charge, $\pm\mathbb{d}_2 q_0$ must be replaced with q , whereby Eq. (75) can be restated as the *universal electrostatic force function* given by the relation $\vec{F}_\eta = \mathbb{k}_e (Qq/r^2) \mathcal{D}_\eta \hat{\mathbf{r}}$, expressed equivalently as

$$\vec{F}_\eta = \mathbb{k}_e \frac{Qq}{r^2} \left(1 - \frac{\bar{\rho}_\odot}{\rho_q} \right) \hat{\mathbf{r}}, \quad (78)$$

where ρ_q is the density of the test charge q and $\bar{\rho}_\odot$ is the average density of the medium surrounding q .

Coulomb's law. If the medium of space surrounding $\mathcal{S}$ is treated as an empty void (i.e., $\bar{\rho}_\odot = 0$ and hence $\mathcal{D}_\eta = 1$), then Eq. (78) becomes identical in form to the classical *Coulomb's law of electrostatic force*, given as

$$\vec{F}_C = \mathbb{k}_e \frac{Qq}{r^2} \hat{\mathbf{r}}, \quad (79)$$

where $\vec{F}_C$ denotes the *Coulomb force* and Q now denotes the (fixed) magnitude of the primary charge located a distance r from the test charge q .

Therefore, Coulomb's law can be described as a limiting case of the universal electrostatic force function given by Eq. (78), where the former differs from the latter fundamentally in two respects. Firstly, in Coulomb's law the medium of space is considered devoid of any material content, whereby $\mathcal{D}_\eta = 1$. By contrast, in the framework of photodynamics the medium of space everywhere consists of contiguous cells with strictly nonzero photino densities such that $\bar{\rho}_\odot > 0$, which renders $\mathcal{D}_\eta = 1$ a prohibited state for a physical system. Secondly, Eq. (78) describes Q as the sum of the charges of all the elements of the system inside $\mathcal{S}$ including the primary charge and all fractional and unit charges present in the medium therein. By contrast, Coulomb's law describes Q as the (fixed) magnitude of the primary charge, in isolation from the medium inside $\mathcal{S}$.

Thus, whereas Coulomb's law implies that the magnitude of Q is independent of the distance r from the primary charge, Eq. (78) asserts that the magnitude of Q itself varies with the distance r .

Inversion of $\vec{F}_\eta$ and nuclear forces. If $\bar{\rho}_\odot < \rho_q$, then Eq. (59) implies that $\mathcal{D}_\eta > 0$. Noting that $+\hat{\mathbf{f}}$ is outwardly normal to $\mathcal{S}$, pursuant to Eq. (78), a positive-valued $\mathcal{D}_\eta$ implies that $\vec{F}_\eta$ acts as an attractive force between particles of opposite charge and as a repulsive force between particles of like charge, in agreement with Coulomb's law.

However, in exceptional conditions where $\bar{\rho}_\odot > \rho_q$ and hence $\mathcal{D}_\eta < 0$, the negative-valued $\mathcal{D}_\eta$ reverses the sign of the unit vector $\hat{\mathbf{f}}$ from $+\hat{\mathbf{f}}$ to $-\hat{\mathbf{f}}$, thereby inverting the direction of the electrostatic force between two nearby charges. Thus, noting that $-\hat{\mathbf{f}}$ is inwardly normal to the surface $\mathcal{S}$, Eq. (78) asserts that if $\mathcal{D}_\eta < 0$, then $\vec{F}_\eta$ acts as a repulsive force between particles of opposite charge and as an attractive force between particles of like charge.

As described later in Sec. 7, it is the prevalence of such exceptional conditions inside atomic nuclei that turns $\vec{F}_\eta$ into an attractive force that binds together positively charged protons alongside chargeless neutrons to form nuclear clusters (corresponding to the strong nuclear force in the standard model of particle physics). Moreover, under a set of well-defined conditions, $\vec{F}_\eta$ reverts to a repulsive force between the protons inside a nucleus, thus producing nuclear decay (corresponding to the weak nuclear force).

6.5 Spatial Charge Distribution

Suppose that the medium inside $\mathcal{S}$ consists entirely of unitary cells that are in equilibrium and thereby arranged in nearest-density order such that $\rho_i - \bar{\rho}_\odot \simeq 0$, and hence $\mathcal{D}_{\eta,i} \simeq 0$, for all cells i . Given that any system that consists of two or more cells has a collective center of mass c_0 toward which the polarities of the cells in the system point in the absence of external influences, it follows that the vector $\vec{\mathbb{d}}$ of a cell in such a system points either toward c_0 or radially away from c_0 . Thus, $\vec{\mathbb{d}}$ can be written as $\pm\mathbb{d}$ with respect to the axis connecting the center of mass of the cell to c_0 . As per Eq. (60), the internal measure of the potential energy due to the η of a cell in the medium within $\mathcal{S}$ can then be stated as $U_\eta = (n_G h \nu_0 \mathcal{D}_\eta / 2)(\pm\mathbb{d})^2$.

By the autonomic principle, $U_\eta \Rightarrow 0$. However, because $\mathcal{D}_\eta \simeq 0$ while no other argument of the U_η function given above can change in value under nonextreme conditions, it follows that $U_\eta \simeq 0$, rendering the U_η of every cell in the medium irreducible. Defining $k_U \triangleq \sqrt{n_G h \nu_0 \mathcal{D}_\eta / 2}$ as a cell-specific constant, the U_η

function can be written as $U_\eta = k_U^2(\pm\mathbb{d})^2$, which can be restated as $\sqrt{U_\eta} = k_U(\pm\mathbb{d})$. If the medium inside $\mathcal{S}$ consists of N_m cells, then $\sum_{i=1}^{N_m} \sqrt{U_{\eta,i}} = \sum_{i=1}^{N_m} k_{U,i}(\pm\mathbb{d}_i)$. Meanwhile the autonomic principle enforces the compulsion $\sum_{i=1}^{N_m} \sqrt{U_{\eta,i}} \Rightarrow 0$. Now, although $k_{U,i}$ cannot be reduced further for any individual cell i , the value of $\sum_{i=1}^{N_m} \sqrt{U_{\eta,i}}$ may decrease nevertheless if $\sum_{i=1}^{N_m} \pm\mathbb{d}_i \simeq 0$, thus inducing the compulsion

$$\sum_{i=1}^{N_m} \pm\mathbb{d}_i \Rightarrow 0, \quad (80)$$

where the optimal state of the system is attained when $\sum_{i=1}^{N_m} \pm\mathbb{d}_i \simeq 0$.

Formation of cell pairs and cell-pair dipoles. The optimality condition $\sum_{i=1}^{N_m} \pm\mathbb{d}_i \simeq 0$ is satisfied if and only if the cells in the medium within $\mathcal{S}$ are arranged such that the sum of the $\pm\mathbb{d}$ values of pairs of neighboring cells is as close as possible to zero. This arrangement requires the numerical $\pm\mathbb{d}$ values of any two *paired cells* (say, j and k) to be as close as possible in magnitude but carry opposite signs (e.g., if $\mathbb{d}_j = -0.3$, then $\mathbb{d}_j + \mathbb{d}_k \simeq 0$ if and only if $\mathbb{d}_k \simeq +0.3$).

Consequently, as the cells in the medium cluster in nearest-density order, an additional substructure is imposed by the autonomic compulsion $\sum_{i=1}^{N_m} \pm\mathbb{d}_i \Rightarrow 0$. The medium inside $\mathcal{S}$ consists predominantly not of cells that are individually autonomous but rather of *cell pairs* that are each composed of two cells, where each cell pair behaves as a unitary particle, while $(\mathbb{d}_j + \mathbb{d}_k) \simeq 0$. Moreover, because $\mathbb{d}_j$ and $\mathbb{d}_k$ carry opposite signs, each cell pair behaves as an electric dipole, hereinafter called the *cell-pair dipole*, which can be defined as the chord connecting the centers of mass of the two paired cells.

Given that the compulsion $\sum_{i=1}^{N_m} \pm\mathbb{d}_i \Rightarrow 0$ has no intrinsic dependence on the presence of a primary charge nearby, it follows that the formation of cell pairs in a medium is a universal feature of space, irrespective of the presence or absence of a primary charge.

Tautness of space and electrostatic cell-pair bonds. According to Eq. (12), the only variable quantity (under nonextreme conditions) that determines the V_P of a cell is its H_A value. Moreover, for any given value of H_A , Eq. (19) implies that $V_A \Rightarrow V_P$, whereby the V_A of every cell in a medium must at all times be as close as possible to its maximal value V_P . Consequently, the constituent cells of a spatial medium must be dilated maximally, implying that they are at all times maximally stretched and taut.

In addition, the cell pairs formed in a medium by the compulsion $\sum_{i=1}^{N_m} \pm \mathbb{d}_i \Rightarrow 0$ must themselves be coupled with neighboring cell pairs such that $\sum_{j=1}^{N'_m} \pm \mathbb{d}_j \simeq 0$, where N'_m is the number of *cell-pair couplets* j in the medium. Every cell pair in a medium is thus bonded with each of its neighboring cell pairs by electrostatic forces, which are great in strength intrinsically but minuscule in magnitude physically because the net charge of each coupled cell pair must inevitably be as close as possible to zero when the system is in its optimal state.

Therefore, while electrostatic forces create bonds of great intrinsic strength between neighboring cell pairs in a medium, the bonds are typically insufficient in magnitude to prevent them from being severed by the kinetic energy imparted on impact by a particle or object in motion within the medium. This spatial structure further implies that a body in motion relative to the medium must pry apart the interlocked cell-pair couplets that lie its path by imparting, and thereby depleting, its kinetic energy as it moves through the medium until its kinetic energy is exhausted.

According to this model, it is the maximal *tautness* in the medium of space, produced by the maximal dilation of its constituent cells and complemented by the *electrostatic bonds* that lock together the cell pairs in it, that allows a strictly local perturbation in the medium to propagate as a wave across great distances in seemingly empty space.

Neutrality of electric charge in a medium. Given that the medium inside $\mathcal{S}$ is in its optimal state if and only if we have $(\mathbb{d}_j + \mathbb{d}_k) \simeq 0$ for all paired cells j and k , it follows that the (net) charge of each cell pair in the medium must be as close as possible to zero, rendering the medium inside $\mathcal{S}$ very nearly (albeit not precisely) electrically neutral.

3-grid and orientations of cell-pair dipole axes. Let the center of mass of each cell pair in a system represents a node in an imaginary three-dimensional Cartesian grid, hereinafter called the *3-grid* (which may be rectilinear or nonrectilinear). The geometric orientation of a cell-pair dipole is then determined by the physical locations of the centers of mass of the two cells inside the cell pair relative to the 3-grid axes x , y , and z . Meanwhile, the respective locations of the centers of mass of the paired cells are determined by such (independent) factors as the balance in the electrostatic forces acting between the cell pair and its neighbors, and the dynamics of nearest-density order in the system. Because these factors almost surely produce spatial geometries that differ locally from case to case, the dipole axis of any given cell pair may have any possible orientation relative to the 3-grid axes, unless there exists a dominant external factor (e.g., a nearby primary charge).

Therefore, no preferred orientation can be expected to exist, on average, in the cell-pair dipole axes in a medium devoid of a primary charge, rendering them functionally random in their orientations relative to the 3-grid axes.

Fig. 9 Electrically unpolarized cell pair. Polarities of cells in folded state.

Electric polarization of a medium. By definition, no net external force is experienced by the cells inside a cell pair that is in equilibrium within its ambient system, leaving only the forces produced inside the cell pair to act on the polar chords of its two paired cells. Therefore, the (antiparallel) polarities of both cells must be in a *folded state* such that both polarities point toward the center of mass of the cell pair if no primary charge is present nearby (see Fig. 9).

By contrast, the $\vec{R}_\eta$, and hence the polar chord on which it lies, of each cell inside a cell pair located near a primary charge experiences a torque $\vec{\tau}$ as given by Eq. (66). Consequently, the polar chord of each paired cell is compelled to pivot toward the $\hat{r}$ axis connecting its center of mass to the primary charge, thus producing axial coalignment. As they become axially coaligned, oppositely oriented electrostatic forces $\vec{F}_{\eta,i}$ and $\vec{F}_{\eta,j}$ act on the two (oppositely charged) paired cells i and j . Consequently, the force acting on the center of mass of one cell (say, $c_{m|\eta,i}$) points in the direction of the primary charge, while the force acting on the center of mass of the other cell ($c_{m|\eta,j}$) points radially away from the primary charge. The two oppositely directed forces acting on the respective ends of a cell-pair dipole thus produce a torque $\vec{\tau}^*$ such that

$$\vec{\tau}^* = (\vec{d}_i \times \vec{F}_{\eta,i}) + (\vec{d}_j \times \vec{F}_{\eta,j}), \quad (81)$$

where $\vec{d}_i$ and $\vec{d}_j$ are the radius vectors of $c_{m|\eta,i}$ and $c_{m|\eta,j}$, respectively, relative to the center of mass of the cell pair.

In turn, the torque $\vec{\tau}^*$ causes the dipoles of the cell pairs in the medium to rotate about their respective centers of mass if the magnitude of $\vec{\tau}^*$ is sufficient to overcome the bonds locking the cell pairs in their extant orientations relative to the 3-grid axes. Given that the magnitude of $\vec{F}_\eta$ varies as the inverse of the square of the distance from the primary charge, so does the magnitude of $\vec{\tau}^*$. It follows that if τ^* is sufficient in magnitude, then the dipole of any given cell pair $\mathbb{c}$ in the medium must rotate to become coaxial with the vector $\vec{r}_c$ connecting its center of mass to

the primary charge. Moreover, when the dipole of $\mathfrak{c}$ is coaxial with $\vec{r}_c$, the (antiparallel) polarities of its two paired cells must be in an *unfolded state* such that they both point away from the center of mass of $\mathfrak{c}$ (see Fig. 10).

A medium is defined as being *electrically polarized* if the cell-pair dipoles that make up the medium are, on average, coaxial with the axis connecting their respective centers of mass to a primary charge, further implying that the polarities of the paired cells inside the respective cell pairs must be in an unfolded state.

Emergence of Gaussian charge distribution. Suppose that a net η^- primary charge composed of atomic particles is located at the center of mass c_0 of the region inside a surface $\mathcal{S}$ of radius r . Cell pairs that make up the LDI medium within $\mathcal{S}$ must then cluster in order of nearest density around the primary charge, while $\sum_{k=1}^{N_m''} \pm \mathfrak{d}_k \rightrightarrows 0$, where N_m'' is the total number of elements k inside $\mathcal{S}$ including the primary charge and the cell pairs in its ambient medium. The 3-grid is then (roughly) spherical around the primary charge, where each 3-grid node represents the center of mass of a cell pair. The z-axis at any given node is thus defined by the vector $\vec{r}_c$ connecting the center of mass of the cell pair $\mathfrak{c}$ to c_0 .

Because the force $\vec{F}_\eta$ acting on the cell pairs inside $\mathcal{S}$ must be attractive with respect to the η^- primary charge if the cell pairs are bound into a cluster around c_0 , it follows that the clustering cell pairs must have (net) η^+ values. As the cell pairs cluster around the η^- primary charge, their η^+ contributions reduce the total charge Q inside the surface $\mathcal{S}$ with each increment in its radius r . Moreover, as the total charge Q inside $\mathcal{S}$ reduces with r , the (net) η values of the cell pairs located at the surface $\mathcal{S}$ decrease in magnitude asymptotically with each increment in r .

A characteristic Gaussian structure thus emerges in the distribution of electric charge within the medium surrounding a primary charge as the system reaches its optimal state $\sum_{k=1}^{N_m''} \pm \mathfrak{d}_k \simeq 0$.

6.6 Electric Field, Potential, and Current

Gauss's law for electric fields. Within the framework of a Gaussian charge distribution in the medium surrounding a primary charge at c_0 , a normalized measure of the electrostatic force acting on the center of mass of a particle located on $\mathcal{S}$ a radial distance r from c_0 can be defined, based on Eq. (78), as the *electric field* $\vec{\mathbb{E}}$ such that

$$\vec{\mathbb{E}}(r) = \frac{\vec{F}_\eta(r)}{q} = \mathbb{k}_e \frac{Q}{r^2} \mathcal{D}_\eta \hat{\mathbf{r}}. \quad (82)$$

If space is treated as an empty void, then $\mathcal{D}_\eta = 1$ and Eq. (82) becomes an alternative expression of *Gauss's law for electric fields*, given as $\vec{\nabla} \cdot \vec{\mathbb{E}} = \rho_{chg}/\epsilon_0$, where ρ_{chg} is the electric charge density.

Fig. 10 Electrically polarized cell pair. Torque $\vec{t}$ pivots polarities of cells to unfolded state. Torque $\vec{t}^*$ rotates the cell-pair dipole axis toward $\vec{r}_c$.

Electric potential and potential difference. A normalized measure of the electrostatic potential energy U_η can similarly be defined as the *electric potential* $\mathbb{V}$ at a point on the surface $\mathcal{S}$ a radial distance r from c_0 such that

$$\mathbb{V}(r) = \frac{U_\eta(r)}{q}. \quad (83)$$

Based on the classical laws relating work done in the point-to-point displacement of a body, the ensuing changes in its (conserved) mechanical energy, and the net force acting on the body, it is well established that the electrostatic potential energy and force are related as

$$U_\eta = F_\eta r. \quad (84)$$

Replacing U_η in Eq. (83) with the right-hand side of this equation and then F_η with the right-hand side of Eq. (78), the *potential difference* between any two points A and B in an electric field produced by a primary charge can be described by the relationship

$$\mathbb{V}_B - \mathbb{V}_A = \mathbb{k}_e Q \left(\frac{1}{r_B} - \frac{1}{r_A} \right) \mathcal{D}_\eta, \quad (85)$$

where r_A and r_B are the radial distances of A and B, respectively, from the center of mass c_0 of the primary charge. Suppose that A is sufficiently distant from c_0 such that $1/r_A \rightarrow 0$. In that case, the electric potential due to the primary charge at a distance r from its center of mass is given by $\mathbb{V} = \mathbb{k}_e (Q/r) \mathcal{D}_\eta$, where r now further connotes the radial distance to an *equipotential surface* $\mathcal{S}$ from its center of mass c_0 .

Electric current, carrier charges, and drift velocity $\vec{v}_d$.

From the viewpoint of photodynamics, *electric current* represents the bulk transport of photinos in a conducting medium. Disregarding (for simplicity) the case of an electrical resistor, photinos are transported in bulk within a

conducting material primarily through a process corresponding to the transmission of energy via a combination of convection and simple conduction as described in Sec. 4.3. (Note that current in an electrical resistor entails thermal conduction as an additional factor.)

In this model, electrons that are initially attached loosely to atoms (i.e., electrons with near-zero φ values) drift within an electrical conductor as mobile bulk photino carriers, characterized herein as *carrier charges*. In essence, unbound photinos are ferried in bulk from point to point by the carrier charges via a convective process across spaces occupied by the LDI cells in the medium separating the atoms and molecules of the conductor. (As in the transmission of light, the LDI cells in the medium can also be expected to conduct photinos, but not in bulk because of their limited photino absorption capacity caused by the ever-present constraints on their volumetric dilation.)

During this (convective) process, the kinetic energy of the carrier charges is generated by the partial conversion of the potential energy induced in them by the bulk absorption of unbound photinos acquired via simple conduction from the tightly bound outer electrons in those (*donor*) atoms to which the electrons are loosely attached initially. The absorbed photinos are then transported by the carrier charges and emitted, upon contact, to the (also tightly bound) outer electrons of other nearby (*receiving*) atoms, thus transmitting unbound photinos in bulk from atom to atom inside the conductor.

From Eq. (83), the compulsion $U_\eta \Rightarrow 0$ implies that $\mathbb{V} \Rightarrow 0$, which further implies that $(\mathbb{V}_H - \mathbb{V}_L) \Rightarrow 0$, where $\mathbb{V}_H > \mathbb{V}_L$. The direction of photino transmission is thus governed by the autonomic compulsion of the system as a whole to minimize its total potential energy U_η and hence its total electric potential $\mathbb{V}$. Consequently, as carrier charges transport photinos in bulk within a conducting material, their *drift velocity* $\vec{v}_d$ is directed, on average, from atoms with higher potential $\mathbb{V}_H$ to those with lower potential $\mathbb{V}_L$. To be clear, the drift velocity of carrier charges does not imply a secular displacement of electrons in the direction of the drift within the conducting material. Rather, when acting as carrier charges, electrons transport photinos from donor atoms to receiving atoms in all directions, whereby their motion inside the conductor is rendered functionally random. However, on average, the (net) displacement of the carrier charges is in the direction given by the drift velocity vector $\vec{v}_d$, enforced fundamentally by the autonomic compulsion $\mathbb{V} \Rightarrow 0$.

Transported photino content $\mathbb{h}$ and current density $\vec{\mathbb{J}}$. Accordingly, the *average bulk photino content* $\mathbb{h}$ transported by a carrier charge from a donor atom to a receiving atoms in a conductor is given as $\mathbb{h} = n_B h$, where n_B is the average number of photinos thus transported.

Furthermore, *electric current density* $\vec{\mathbb{J}}$ is defined herein as $\vec{\mathbb{J}} = j q_e \vec{v}_d$, where $q_e = q_0 \mathbb{d}_e$ is the charge of an

average electron, and j is the average number of carrier charges per unit volume passing through a surface perpendicular to the direction of their drift at velocity $\vec{v}_d$.

6.7 Permanent Electric Dipole Moment

By definition, for an ideal cell (e.g., an ideal electron) $\mathbb{e}$, we have $\eta_e = 0.5$, whereby as per Eq. (58) it follows that $\vec{R}_{\eta(\mathbb{e})} = \alpha \lambda_{C(\mathbb{e})} \hat{\mathbf{p}}$. However, in the case of a physical electron e , η_e almost surely does not lie at the cusp. Rather, η_e lies on the η^- side of the cusp, within the cusp range. To account fully for the deviation of η_e from the cusp, $\vec{R}_{\eta(e)}$ can be described by the right-hand side of Eq. (69) and then equated with $\alpha \lambda_{C(e)} \hat{\mathbf{p}}$ to yield $(n_e \vec{d}_e / e \eta_e) = \lambda_{C(e)} \hat{\mathbf{p}}$, which gives the electric dipole moment of an electron as

$$\vec{d}_e = \eta_e \left(\frac{e \alpha \lambda_{C(e)}}{n_e} \right) \hat{\mathbf{p}}. \quad (86)$$

Equation (54) gives the mean value of the η of an electron as $\eta_e = 0.5 + (\delta_\eta / 2) = (1 + \delta_\eta) / 2$, whereby Eq. (86) can be restated as $\vec{d}_e = (1 + \delta_\eta) (e \alpha \lambda_{C(e)} / 2 n_e)$. Multiplying the right-hand side of this equation by $(h v_0 / c^2) / (h v_0 / c^2)$ and applying the relationship given in Eq. (5) accordingly, the electric dipole moment of an average electron can be written as

$$\vec{d}_e = (1 + \delta_\eta) \frac{e m_h (\alpha \lambda_{C(e)})}{2 m_e} \hat{\mathbf{p}}. \quad (87)$$

Neglecting (for the present) the cusp range limit $\delta_\eta \ll 0.5$, the approximate magnitude of the permanent electric dipole moment of an electron can be determined as

$$d_e \approx \frac{e m_h (\alpha \lambda_{C(e)})}{2 m_e} \sim 1.827 \times 10^{-54} \text{ C m}. \quad (88)$$

For the case of a proton, replacing $\alpha \lambda_{C(e)}$ in Eq. (87) with $\alpha \lambda_{C(p)}$ and η_e with $\eta_p = 0.5 - (\delta_\eta / 2) = (1 - \delta_\eta) / 2$ thus yields $d_p = e m_h (\alpha \lambda_{C(p)}) (1 - \delta_\eta) / 2 m_p$. Therefore, neglecting the cusp range limit δ_η , the magnitude of the electric dipole moment of a proton can be approximated to be $d_p \approx e m_h (\alpha \lambda_{C(p)}) / 2 m_p \sim 5.419 \times 10^{-61} \text{ C m}$.

The magnitude of the electric dipole moment of a neutron can be estimated by modifying Eq. (86) such that $d_n = \eta_n (e \alpha \lambda_{C(n)} / n_n)$. However, because $\eta_n \approx 0$, it follows that $d_n \approx 0$. (Note that because every cell has a nonzero η with asymptotic probability one, it is improbable that the sum of the η values of the many cells that collectively make up a neutron, and thereby the net d_n of a neutron, happens to be identically equal to zero.)

6.8 Intrinsic Magnetic Moment

Replacing m_h in Eq. (87) with $h v_0 / c^2$ in accordance with Eq. (5), and given that $\hbar \lambda_C = \hbar \lambda_c = \hbar \lambda_1$, Eq. (87) can be written alternatively as

$$\vec{d}_e = (1 + \delta_\eta) \left(\frac{e\hbar}{2m_e} \right) \left(\frac{\alpha\lambda_{1(e)}\nu_0}{c^2} \right) \hat{p}, \quad (89)$$

where the quantity $(e\hbar/2m_e)$ defines the *Bohr magneton* μ_B , with a magnitude as given by this formula of ca. $9.274 \times 10^{-24} \text{ J T}^{-1}$.

Multiplying both sides of Eq. (89) by c and given that $\lambda_1 = c/\nu_1$, Eq. (89) can be written equivalently as $\vec{d}_e(c/\alpha)(\nu_{1(e)}/\nu_0) = (1 + \delta_\eta)\mu_B\hat{p}$. Pursuant to Eq. (6), we have $\nu_{1(e)}/\nu_0 = n_e$. Replacing $\nu_{1(e)}/\nu_0$ in the previous equation with n_e and then multiplying the left-hand side of that equation by $h\nu_0 c^2/h\nu_0 c^2$ yields the relationship $(c/\alpha)(m_e/m_h)\vec{d}_e = (1 + \delta_\eta)\mu_B\hat{p}$. Defining (the magnitude of) the *intrinsic magnetic moment* μ_e of an average electron e as $\mu_e \triangleq (1 + \delta_\eta)\mu_B$, the previous relationship can be stated as

$$\vec{\mu}_e = (1 + \delta_\eta)\mu_B\hat{p} = \left(\frac{c}{\alpha} \right) \left(\frac{m_e}{m_h} \right) \vec{d}_e, \quad (90)$$

indicating that $\delta_\eta = |\mu_e|/\mu_B - 1$ describes the magnitude of the *electron magnetic moment anomaly* (denoted conventionally by a_e) with an empirical value of ca. 1.1597×10^{-3} . According to this relationship, $|\mu_e| = \mu_B$ can be true if and only if the value of δ_η is zero, implying that from the viewpoint of photodynamics, the Bohr magneton μ_B denotes the magnitude of the intrinsic magnetic moment of the imaginary ideal cell $\mathbb{e}$ with a theoretical η value of precisely 0.5. Thus, μ_B represents a standard meter against which the magnetic moment of any particle can be calibrated to give the relative magnetic moment of that particle.

Note on the electron magnetic moment anomaly. The cusp range limit δ_η (equivalently, a_e) marks the point on the η function that separates a unit charge from a fractional charge. While this separation is essential in modeling the physical effects associated with electromagnetism, the distinction between a unit charge and a fractional charge cannot be characterized as an intrinsic feature of nature. Consequently, there exists an element of arbitrariness in the numerical value of the cusp range limit, necessitated by the inherently anthropocentric perspective from which electromagnetic effects have to be modeled mathematically. The value of δ_η (and hence a_e) is therefore indeterminable in principle, implying that no degree of precision in its measurement can produce a value that is true in an objective sense.

Magnetic moments in a spatial medium. Equation (90) can be generalized to describe the intrinsic magnetic moment of any cell or composite particle $\mathcal{O}$ as

$$\vec{\mu}_{\mathcal{O}} = \left(\frac{c}{\alpha} \right) \left(\frac{m_{\mathcal{O}}}{m_h} \right) \vec{d}_{\mathcal{O}}. \quad (91)$$

Given that every cell almost surely possesses a nonzero η and hence a nonzero $\vec{d}$, Eq. (91) asserts that there exists a magnetic moment $\vec{\mu}$ not only in each of the HDT and LDT cells that make up tangible bodies of matter, but also in the LDI cells that make up the medium of seemingly empty space everywhere.

Experimental implication. With a value of $\sim 10^{-54} \text{ C m}$, the electric dipole moment of an electron d_e may arguably be too small in magnitude to be measurable directly with presently available technology. Equation (90) indicates that the numerical value of d_e is magnified in the value of μ_e by a factor of $(c/\alpha)(m_e/m_h) \approx 5.076 \times 10^{30}$. Therefore, d_e can be deduced from the more experimentally accessible μ_e value by dividing the empirical μ_e magnitude of ca. $9.285 \times 10^{-24} \text{ J T}^{-1}$ by the value of the term $(c/\alpha)(m_e/m_h)$. This gives a d_e value of ca. $1.829 \times 10^{-54} \text{ C m}$, which differs from the d_e value derived in Eq. (88) by $\sim 2.123 \times 10^{-57} \text{ C m}$, as can be expected given that δ_η is now taken into account, whereas Eq. (88) neglects δ_η in estimating d_e .

Virtual angular momentum $\vec{L}_\eta$. While Eq. (90) describes the relationship among $\vec{\mu}_e$, μ_B , and $\vec{d}_e$ precisely, to furnish an account of the mechanism that gives rise to magnetic moments, Eq. (90) must be constructed differently.

The electric dipole moment of an electron given by Eq. (87) can be restated as $\vec{d}_e = (e\eta_e m_h (\alpha\lambda_{C(e)})/m_e)\hat{p}$. Replacing $\vec{d}_e$ in Eq. (90) with the right-hand side of this equation yields $\vec{\mu}_e = e\eta_e c\lambda_{C(e)}\hat{p}$. Multiplying the right-hand of this equation by $h\nu_0 c^2/h\nu_0 c^2$ gives the magnetic moment of an electron as

$$\vec{\mu}_e = \left(\frac{e}{m_h} \right) m_\eta c\lambda_{C(e)}\hat{p} = \left(\frac{e}{m_h} \right) L_\eta \hat{p}, \quad (92)$$

where $L_\eta \triangleq m_\eta c\lambda_{C(e)}$ defines the magnitude of the *virtual angular momentum* arising from the circular orbit of the virtual mass m_η around the polar chord of the host electron, while c is the speed and $\lambda_{C(e)}$ is the radius of its orbit (see Sec. 6.1). Given that $m_\eta = \eta_e h\nu_0/c^2$, the previous equation becomes $L_\eta = (\eta_e h\nu_0/c^2)c\lambda_{C(e)}$. Thus, neglecting $\delta_\eta \ll 0.5$, the virtual angular momentum is derived as $L_\eta \approx (h\nu_0/2c)\lambda_{C(e)} \approx 4.268 \times 10^{-55} \text{ J s}$, while the orbital frequency ν_η of m_η around the polar chord is given as $\nu_\eta = c/2\pi\lambda_{C(e)} \approx 1.236 \times 10^{20} \text{ Hz}$.

Let $\vec{c}$ now denote the tangential velocity of m_η along its circular orbital path around the polar chord, and let $\vec{\lambda}_{C(e)}$ be the radius vector of the orbit. The instantaneous linear momentum of m_η is then given as $\vec{p} = m_\eta \vec{c}$, and the virtual angular momentum as

$$\vec{L}_\eta = \vec{\lambda}_{C(e)} \times \vec{p}, \quad (93)$$

whereby Eq. (92) may be stated as $\vec{\mu}_e = (e/m_h)|\vec{L}_\eta|\hat{p}$.

As with $\vec{\mu}$, the vector $\vec{L}_\eta$ is coaxial with the polar chord and can be written as $\vec{L}_\eta = \pm L_\eta \hat{p}$. However, the orientation of $\vec{L}_\eta$ is not determined by the mean geometric location of m_η relative to $c_{m|\eta=0}$ on the polar chord of a particle as in the case of $\vec{R}_\eta$ and $\vec{\mu}$. Rather, the orientation of $\vec{L}_\eta$ is determined by the direction of the (virtual) orbit of m_η around the polar chord of the particle with respect to the axial direction toward $c_{m|\eta=0}$.

Spin angular momentum $\pm \hbar/2$. From Eq. (90), we have $\vec{\mu}_e = (1 + \delta_\eta) \mu_B \hat{p}$, which can be stated alternatively as $\vec{\mu}_e = (1 + \delta_\eta) (\hbar/2) (e/m_e) \hat{p}$. Although $\vec{\mu}_e$ represents an intrinsic feature of an electron, contextual factors have an important bearing on its physical implications. Specifically, the quantity $\hbar/2$ in the last equation acquires an explicit $\pm$ sign in the case where the electron is in a bound state within an atom, whereas it is in all cases implicitly positive-valued if the electron is free. This is because the m_η of an electron located inside an atom not only generates a moment $\vec{M}_\eta$ in the electron with respect to its center of mass $c_{m|\eta=0}$ but also contributes to the moment of the host atom with respect to the center of mass of the atom. By contrast, because a free electron is not an integral part of an atom, its m_η has no corresponding implications with respect to a host system.

As described later in Sec. 8.3, each electron that is located inside a (multielectron) atom has a well-defined geometric location that is specified by a set of spatial coordinates relative to the nucleus and the polar axis of the atom. Let $\hat{a}$ be a unit vector denoting the polarity of an atom, where $+\hat{a}$ points in the southward (i.e., higher-density) direction of the atom, while a z -axis represents the polar axis of the atom with positive values of z increasing in the northward direction. The ensuing geometry dictates that an equatorial plane perpendicular to the z -axis bisects the atom at the nucleus into two hemispheres, where any given electron in a multielectron atom lies in either its northern hemisphere or its southern hemisphere.

Recall from Sec. 6.1 that as an η^- cell, the $\vec{R}_\eta$ of an electron must point in the $+\hat{p}$ direction. Meanwhile, $+\hat{p}$ points in the direction of the (high-density) core that lies at the center of the host system. Thus, if an electron is bound within an atom, then its $\vec{R}_\eta$ points toward the nucleus of the host atom. If θ is the (polar) angle made at the nucleus by the $\vec{R}_\eta$ axis of an electron relative to the z -axis of the atom, then we have $0 \leq \theta \leq \pi$, while the $\pm \hat{a}$ orientation of the z -axis component of $\vec{R}_\eta$ is described by a *spin unit vector* $\hat{s} \triangleq (\vec{R}_\eta \cos \theta) / (R_\eta \cos \theta)$. Thus, if the electron is located in the northern hemisphere of the atom (i.e., if $\theta < \pi/2$), then $\hat{s} = +\hat{a}$; and if the electron is located in the southern hemisphere (i.e., if $\theta > \pi/2$), then $\hat{s} = -\hat{a}$ (see Fig. 11). Therefore, the magnetic moment of an electron that is

Fig. 11 Opposite directions of spin $\hat{s}$ of electrons located in northern and southern hemispheres of host atom. Red circles: electrons. Black circle: atomic nucleus.

located inside an atom can be described by the relation $\vec{\mu}_e = (1 + \delta_\eta) (|\hat{s}| \hbar/2) (e/m_e) \hat{p}$, stated equivalently as

$$\vec{\mu}_e = (1 + \delta_\eta) \left| \pm \frac{\hbar}{2} \hat{a} \right| \left(\frac{e}{m_e} \right) \hat{p}, \quad (94)$$

where the term $\pm \hbar/2$ in this equation is conventionally described by a quantity $S_z = \pm \hbar/2$ denoting the z -axis component of the *spin angular momentum* of the electron, while the polarity $+\hat{a}$ is implicit in the direction $-z$. By contrast, in the case of a free electron, there exists no factor corresponding to atomic polarity $\hat{a}$ in respect to its magnetic moment $\vec{\mu}_e$. Therefore, for a free electron, the factor $|\hat{s}| = |\pm \hat{a}|$ represents simply a placeholder with no physical implications, and it becomes operative as the direction with respect to the z -axis if and only if the electron becomes a component part of a host atom.

Whereas S_z features prominently in quantum theory as the (z -axis component of) spin angular momentum, according to photodynamics it does not describe angular momentum in any true sense, notwithstanding the inference to the contrary in its measurement units (J s). Rather, the term $(1 + \delta_\eta) |S_z|$ in Eq. (94) can be described as an allegorical representation of the reduced-form *fractional photino content* $\eta_e \hbar$ of the virtual mass m_η of an electron e , where, as per Eq. (54), $\eta_e = (1 + \delta_\eta)/2$ is the statistically expected η value of an average electron.

6.9 Electrodynamics

It is well established that a circulating *magnetic field* $\vec{B}$ is induced in the space surrounding an electric charge if the charge is in motion, and by an electric field that changes with time. Moreover, a magnetic field that changes with time induces a circulating electric field $\vec{E}$, generating current flow in a conductor situated within the (changing) magnetic field. These electromagnetic effects are encoded, respectively, in the *Ampere–Maxwell law* expressed as

Fig. 12 Electric polarization of cell pair $\mathfrak{c}$ upon entry of carrier charge at P_{in} .

Fig. 13 Rotation of dipole of cell pair $\mathfrak{c}$ due to carrier charge motion from P_{in} toward P_{out} .

$\vec{\nabla} \times \vec{\mathbb{B}} = \mu_0(\vec{\mathbb{J}} + \epsilon_0 \partial \vec{\mathbb{E}} / \partial t)$ and *Faraday's law* given as $\vec{\nabla} \times \vec{\mathbb{E}} = -\partial \vec{\mathbb{B}} / \partial t$, where $\vec{\mathbb{J}}$ is the electric current density and $\mu_0 = 1/\epsilon_0 c^2$ is the *magnetic constant*. In the context of photodynamics, these effects can be understood by considering the states of the electric field and electric polarization in a spatial medium under various conditions.

Consider first the case where no primary charge is present in the spatial region inside a closed surface $\mathcal{S}$. In that case, no electric field can be present within $\mathcal{S}$, and the medium therein must be electrically unpolarized. Therefore, as described in Sec. 6.5, the dipole axes of the cell pairs centered on the nodes of the 3-grid inside $\mathcal{S}$ must be functionally random in their orientations relative to the 3-grid axes x , y , and z , and the polarities of the two paired cells in each cell pair must be in a folded state.

Consider next the case where a stationary primary charge is present inside $\mathcal{S}$. The medium then contains an electric field $\vec{\mathbb{E}}$ that acts on the centers of mass of the two (oppositely charged) paired cells inside each cell pair within $\mathcal{S}$, producing a torque $\vec{\tau}^*$, as per Eq. (81), on the cell-pair dipoles therein. If $\vec{\tau}^*$ is sufficient in strength to overcome the bonds locking the cell-pair dipoles in their electrically unpolarized orientations, then the medium inside $\mathcal{S}$ becomes electrically polarized. The cell-pair dipoles within $\mathcal{S}$ are then, on average, coaxial with the vectors $\vec{r}$ connecting the respective centers of mass of the cell pairs to the primary charge, and the polarities of the two paired cells in each cell pair are in an unfolded state.

Now consider the case where a small segment of a conducting wire loop lies on the axis of symmetry connecting the two (closed) ends of an imaginary cylindrical surface $\mathcal{Y}$, where the region inside $\mathcal{Y}$ contains no primary charge initially. The wire segment then becomes current-carrying if an electric current runs through the wire loop. In that case, successive carrier charges transport an average bulk photino content $\mathbb{h}$ (of mass $m_{\mathbb{h}}$) from donor atoms to receiving atoms in the wire segment

inside $\mathcal{Y}$, while drifting at a (net) velocity $\vec{v}_d$, as described in Sec. 6.6. The (net) motion of the successive carrier charges inside the wire segment can then be treated, statistically, as the unidirectional motion of a sequence of waves of primary charges transiting at velocity $\vec{v}_d$ that, in turn, produce an electric field $\vec{\mathbb{E}}$ inside $\mathcal{Y}$.

The carrier charges thus successively enter the region enclosed in $\mathcal{Y}$ at one end P_{in} of its axis, then move through the wire segment along the axis of $\mathcal{Y}$ at velocity $\vec{v}_d$, and exit $\mathcal{Y}$ at the other end of the axis P_{out} . For illustrative purposes, let the transit of each carrier charge through $\mathcal{Y}$ be in conformity with an idealized case where prior to its entry at P_{in} and after its exit at P_{out} , there exists no primary charge inside $\mathcal{Y}$. Thus, the medium therein contains an electric field $\vec{\mathbb{E}}$, and is electrically polarized, only while a carrier charge is present inside $\mathcal{Y}$. Within this general framework, there emerges a set of distinct—albeit inherently correlated—features governing the physical effects associated with electrodynamics, as follows.

Angular motion of cell-pair dipoles. The medium inside $\mathcal{Y}$, which is electrically unpolarized initially, becomes electrically polarized upon the entry of a carrier charge at P_{in} because the electric field $\vec{\mathbb{E}}$ thus created acts on the paired cells in each cell pair within $\mathcal{Y}$ to produce a torque $\vec{\tau}^*$ on the cell-pair dipoles therein. Consequently, the dipole of an average cell pair $\mathfrak{c}$ centered on a (fixed) 3-grid node inside $\mathcal{Y}$ becomes coaxial with the vector $\vec{r}_c$ connecting $\mathfrak{c}$ to the carrier charge, while the polarities of the paired cells in $\mathfrak{c}$ transition to an unfolded state (see Fig. 12). Because the vector $\vec{r}_c$ is anchored at its two ends to $\mathfrak{c}$ and the carrier charge, respectively, the orientation of the (coaxial) dipole of $\mathfrak{c}$ changes continuously with the changing inclination of the vector $\vec{r}_c$ relative to $\mathfrak{c}$ as the carrier charge moves from P_{in} toward P_{out} (see Fig. 13). The dipole of $\mathfrak{c}$ thus rotates about its center of mass as it follows the motion of the carrier charge in the wire segment, and then reverts to its

electrically unpolarized (and hence folded) state upon the exit of the carrier charge from $\mathcal{Y}$ at P_{out} .

A key consequence of this mechanism is that the angular direction in which the dipole of $\mathfrak{c}$ rotates during the motion of the carrier charge from P_{in} to P_{out} is dictated uniquely by the direction of current flow in the wire segment along the axis of $\mathcal{Y}$. Meanwhile, the entry and exit of the carrier charge at P_{in} and P_{out} spontaneously reorients the dipole of $\mathfrak{c}$ from an electrically unpolarized state initially to a polarized state on entry at P_{in} , and to an unpolarized state on exit at P_{out} .

This process is repeated as successive waves of carrier charges enter, then transit, and then exit the region within $\mathcal{Y}$. Because the dipole of $\mathfrak{c}$ is in an electrically unpolarized state both before and after the transit of a carrier charge through $\mathcal{Y}$, the dipole is in an electrically polarized state only while the carrier charge is in transit from P_{in} to P_{out} . Consequently, the angular motion of the dipole of $\mathfrak{c}$ is restricted to a single angular direction in each successive carrier charge transit through $\mathcal{Y}$, which is dictated by the direction of current flow in the wire segment. To be clear, this means that the angular motion of the dipole of $\mathfrak{c}$ is not an oscillation such as that of a swinging pendulum. Rather, it is unidirectional, analogous to the view through a small opening onto an otherwise obscured clock face, showing only a part of the full rotation of the second hand of the clock in each cycle.

Magnetic field $\vec{\mathbb{B}}$ due to moving charges. The angular velocity $\vec{\omega}_{\mathfrak{c}}$ of the (rotating) dipole of $\mathfrak{c}$ during the transit of successive carrier charges through the wire segment inside $\mathcal{Y}$ can be determined as $\vec{\omega}_{\mathfrak{c}} \approx (\vec{r}_{\mathfrak{c}} \times \vec{v}_d)/r_{\mathfrak{c}}^2$, where $r_{\mathfrak{c}}$ is the distance from $\mathfrak{c}$ to the carrier charge. In addition, the torque $\vec{\tau}^*$ imposes the constraint that the two ends of the dipole of $\mathfrak{c}$, namely the centers of mass of the two (oppositely charged) cells i and j inside $\mathfrak{c}$, must rotate in the same angular direction relative to the center of mass of $\mathfrak{c}$. Consequently, the total angular momentum $\vec{L}_{\mathfrak{c}}$ of the dipole of $\mathfrak{c}$ is given as

$$\vec{L}_{\mathfrak{c}} = \vec{\omega}_{\mathfrak{c}}(m_i d_i^2 + m_j d_j^2), \quad (95)$$

where m_i and m_j are the masses of the two cells inside $\mathfrak{c}$, and d_i and d_j are the distances to $c_{m|\eta,i}$ and $c_{m|\eta,j}$, respectively, from the center of mass of $\mathfrak{c}$.

Modifying Eq. (92) for the case of cell pairs in a medium, the magnetic moment of the dipole of $\mathfrak{c}$ can be stated as $\vec{\mu}_{\mathfrak{c}} = (e/m_h)\vec{L}_{\mathfrak{c}}$. The *magnetization vector* $\vec{\mathbb{M}}_{\mathfrak{c}}$ associated with $\mathfrak{c}$ is then determined as $\vec{\mathbb{M}}_{\mathfrak{c}} = \vec{\mu}_{\mathfrak{c}}/V_{\mathfrak{c}}$, where $V_{\mathfrak{c}}$ is the spatial volume occupied by the cell pair $\mathfrak{c}$. It follows that the magnetic field $\vec{\mathbb{B}}_{\mathfrak{c}}$ at the 3-grid node on which $\mathfrak{c}$ is centered is given by the relationship

$$\vec{\mathbb{B}}_{\mathfrak{c}} = \mu_0 \vec{\mathbb{M}}_{\mathfrak{c}} = \mu_0 \left(\frac{e}{m_h} \right) \left(\frac{\vec{L}_{\mathfrak{c}}}{V_{\mathfrak{c}}} \right). \quad (96)$$

The direction of $\vec{\mathbb{B}}_{\mathfrak{c}}$ implicit in this relationship is that of $\vec{L}_{\mathfrak{c}}$ and hence also of $\vec{\omega}_{\mathfrak{c}}$, which, by definition, is perpendicular to the axes of both $\vec{r}_{\mathfrak{c}}$ and $\vec{v}_d$. Thus, the direction of $\vec{\mathbb{B}}_{\mathfrak{c}}$ is parallel to a tangent to the curvature of the (cylindrical) surface $\mathcal{Y}$ at the point of intersection of the surface and a line normal to it that passes through $\mathfrak{c}$. Meanwhile, the sense of the direction of $\vec{\mathbb{B}}_{\mathfrak{c}}$ is given by the right-hand rule with respect to the direction of current flow, denoted hereinafter by the unit vector $\hat{u} = \vec{v}_d/v_d$.

Given that each 3-grid node i in a medium denotes the center of mass of a cell pair, it follows that $\vec{\mathbb{B}}$ represents a macroscopic generalization of the magnetic field $\vec{\mathbb{B}}_i$ at all 3-grid nodes i in the medium. Because $\vec{\mathbb{B}}_i$ points in the same angular direction relative to the direction of $\hat{u}$ at all nodes i , the magnetic field around a current-carrying wire is described by its curl as $\vec{\nabla} \times \vec{\mathbb{B}}$. Moreover, because the curl arises ultimately from the current in the wire segment, it follows that $\vec{\nabla} \times \vec{\mathbb{B}} \propto \vec{\mathbb{J}}$, where $\vec{\mathbb{J}}$ is the current density (see Sec. 6.6), while $\mu_0 \triangleq 1/\epsilon_0 c^2$ is posited to be the associated proportionality coefficient, giving $\vec{\nabla} \times \vec{\mathbb{B}} = \mu_0 \vec{\mathbb{J}}$.

Changing electric field $\partial \vec{\mathbb{E}}/\partial t$ and curl $\vec{\nabla} \times \vec{\mathbb{B}}$. The mechanism described above dictates that an electric field must be produced upon the entry of a carrier charge into $\mathcal{Y}$ at P_{in} and extinguished upon its exit at P_{out} . In essence, therefore, an electric field $\vec{\mathbb{E}}_{\mathfrak{c}}$ is switched “on” at the 3-grid node at $\mathfrak{c}$ upon the entry of a carrier charge at P_{in} and is switched “off” upon its exit at P_{out} . Moreover, as the carrier charge moves from P_{in} toward P_{out} , the magnitude and direction of the electric field $\vec{\mathbb{E}}_{\mathfrak{c}}$ acting on the cell pair $\mathfrak{c}$ change in response. This is because, as per Eq. (82), the magnitude of $\vec{\mathbb{E}}_{\mathfrak{c}}$ varies as the inverse of the square of the distance $r_{\mathfrak{c}}$ between the (fixed) 3-grid node at $\mathfrak{c}$ and the (moving) carrier charge, while the angular direction of $\vec{\mathbb{E}}_{\mathfrak{c}}$ varies as the inclination of the vector $\vec{r}_{\mathfrak{c}}$ (relative to $\mathfrak{c}$) varies with the motion of the carrier charge along the axis of $\mathcal{Y}$ toward P_{out} .

The state of the electric field $\vec{\mathbb{E}}_i$ at each 3-grid node i in the medium thus changes cyclically. It changes spontaneously (from off to on) as each successive carrier charge enters $\mathcal{Y}$ at P_{in} , then continuously (while on) as the carrier charge moves toward P_{out} , and then again spontaneously (from on to off) as the carrier charge exits $\mathcal{Y}$ at P_{out} . It is this time-ordered sequence of changes induced in the state of the electric field at each 3-grid node i within $\mathcal{Y}$ that defines a changing electric field $\partial \vec{\mathbb{E}}_i/\partial t$, which in turn enforces the unidirectional angular motion of cell-pair dipoles, and thereby the induction of a magnetic field $\vec{\mathbb{B}}_i$ at each 3-grid node therein. Thus, as an object unto itself, irrespective of its source, $\partial \vec{\mathbb{E}}_i/\partial t$ constitutes a concomitant factor in the induction of a magnetic field $\vec{\mathbb{B}}_i$ at each node i in a medium, and hence, at the macroscopic level, in

producing the curl $\vec{\nabla} \times \vec{\mathbb{B}}$. As in the case described in the preceding discussion, this implies that $\vec{\nabla} \times \vec{\mathbb{B}} \propto \partial \vec{\mathbb{E}} / \partial t$, where the proportionality coefficient in the present case is $1/c^2$, giving $\vec{\nabla} \times \vec{\mathbb{B}} = \epsilon_0 \mu_0 \partial \vec{\mathbb{E}} / \partial t$.

Combining this relationship with the relationship derived above then gives the Ampere–Maxwell law, expressed as $\vec{\nabla} \times \vec{\mathbb{B}} = \mu_0 (\vec{\mathcal{J}} + \epsilon_0 \partial \vec{\mathbb{E}} / \partial t)$.

Energy E_i transported by an electric current. The wave velocity $\vec{v}_d$ of carrier charges can be described in terms of wavelength λ_i , defined as the average spatial separation between two successive carrier charges, and wave frequency ν_i such that $\vec{v}_d = \lambda_i \nu_i \hat{u}$. The wave frequency is then given as $\nu_i = (n_i/t)$, denoting the passage of an average of n_i carrier charges per unit time through a unit area perpendicular to $\hat{u}$ in a current-carrying wire. Thus, given that $\mathbb{h} = n_B h$ is the average bulk photino content transported by a carrier charge (see Sec. 6.6), the energy E_i transported by successive waves of carrier charges (i.e., by an electric current) in unit time t_0 is given as

$$E_i = \mathbb{h} \nu_i = (n_i n_B) h \nu_0. \quad (97)$$

Changing magnetic field $\partial \vec{\mathbb{B}} / \partial t$ and curl $\vec{\nabla} \times \vec{\mathbb{E}}$. Faraday’s law of induction relates a changing magnetic field and the curl of the electric field in a surface area Y enclosed by a boundary path C as $\vec{\nabla} \times \vec{\mathbb{E}} = -\partial \vec{\mathbb{B}} / \partial t$, where, by definition, $\vec{\nabla} \times \vec{\mathbb{E}} \triangleq \lim_{\Delta Y \rightarrow 0} (1/\Delta Y) \oint_C \vec{\mathbb{E}} \cdot d\vec{l}$, where ΔY is a small segment of the surface area Y and $d\vec{l}$ is an incremental segment of the path C . Based on Eqs. (95) and (96), it can be easily shown that $\vec{\mathbb{B}}_c = \mathcal{B}_c \vec{\omega}_c$, where $\mathcal{B}_c$ is a case-specific coefficient that is independent of the angular velocity $\vec{\omega}_c$ of the dipole of an average cell pair $\mathfrak{c}$ situated in Y . Therefore, given that $\vec{\omega}_c = \vec{v}_{\perp,c} / \bar{d}_c$, it follows that $\vec{\mathbb{B}}_c = \mathcal{B}_c \vec{v}_{\perp,c} / \bar{d}_c$, where $\vec{v}_{\perp,c}$ is the *tangential velocity* of the rotating dipole of $\mathfrak{c}$ and $\bar{d}_c$ is the mean distance from the center of mass of $\mathfrak{c}$ to the centers of mass of the two oppositely charged cells therein. This implies that if there exists a (constant) magnetic field $\vec{\mathbb{B}}_c$ at the 3-grid node on which $\mathfrak{c}$ is centered, then there also exists a rotating dipole of $\mathfrak{c}$, and hence a corotating electric field $\vec{\mathbb{E}}_c$, such that a tangent to the (unidirectional) angular motion of $\vec{\mathbb{E}}_c$ points in the direction of $\vec{v}_{\perp,c}$.

Now suppose that the magnetic field $\vec{\mathbb{B}}_c$ is not constant but rather it is changing with time. In that case, we have $\partial \vec{\mathbb{B}}_c / \partial t = \partial (\mathcal{B}_c \vec{v}_{\perp,c} / \bar{d}_c) / \partial t = \vec{a}_{\perp,c} / \bar{d}_c$, where $\vec{a}_{\perp,c}$ is the *tangential acceleration* in the angular motion of the electric field $\vec{\mathbb{E}}_c$ about the center of mass of $\mathfrak{c}$. In the context of photodynamics, it is this tangential acceleration of $\vec{\mathbb{E}}_c$ produced inevitably by a changing magnetic field $\partial \vec{\mathbb{B}}_c / \partial t$ that defines the curl of the electric field $\vec{\nabla} \times \vec{\mathbb{E}}_c$ with respect to the 3-grid node on which $\mathfrak{c}$ is centered. As is the case for

any object rotating about a fixed point, the tangential acceleration $\vec{a}_{\perp,c}$ of $\vec{\mathbb{E}}_c$ (and hence $\vec{\nabla} \times \vec{\mathbb{E}}_c$) points in the $+\vec{v}_{\perp,c}$ direction if $\vec{v}_{\perp,c}$ is increasing and in the $-\vec{v}_{\perp,c}$ direction if $\vec{v}_{\perp,c}$ is decreasing. Consequently, the direction of the curl $\vec{\nabla} \times \vec{\mathbb{E}}_c$ in the case where $\partial \vec{\mathbb{B}}_c / \partial t < 0$ is opposite to that in the case where $\partial \vec{\mathbb{B}}_c / \partial t > 0$.

Given that each 3-grid node i in a medium denotes the center of mass of a cell pair, it follows that $\vec{\mathbb{E}}$ represents a macroscopic generalization of the electric field $\vec{\mathbb{E}}_i$ at all 3-grid nodes i in the medium spanning the surface area Y . Moreover, because the angular acceleration of $\vec{\mathbb{E}}_i$ at all nodes i points in the same angular direction with respect to the center of mass of the cell pair at node i , the circulation of the electric field in any closed boundary path C of the surface Y is described well by its curl as $\vec{\nabla} \times \vec{\mathbb{E}}$. Therefore, neglecting the sign associated with this relationship, we obtain $|\vec{\nabla} \times \vec{\mathbb{E}}| = |\partial \vec{\mathbb{B}}_c / \partial t|$.

Induced current flow and Lenz’s law. Suppose that a conducting wire loop enclosing a surface area Y is situated in a region of space with a constant magnetic field $\vec{\mathbb{B}}$ that is perpendicular to the plane of Y . (Note that if $\vec{\mathbb{B}}$ is not perpendicular to Y , then only the perpendicular component of $\vec{\mathbb{B}}$ contributes to the effects described herein.) In that case, there exists an electric field $\vec{\mathbb{E}}_i$ that is rotating at a constant angular velocity $\vec{\omega}_i$ at each 3-grid node i inside Y , whereby the energy available in the system to do work is consumed as the rotational kinetic energy of the cell-pair dipoles in the medium within Y .

Meanwhile, the carrier charges—while they are still attached loosely to donor atoms inside the wire loop—act as stationary primary charges, producing electrostatic forces that tether the (stationary) carrier charges to the local network of (fixed) 3-grid nodes i on which the cell pairs in the medium within Y lie. Any motion of the carrier charges (i.e., electric current) in the wire loop thus requires this network of electrostatic connections to be first severed and then rearranged dynamically with the motion of the carrier charges. Given that the available internal energy of the closed system is consumed as the rotational kinetic energy of the cell-pair dipoles at nodes i , the additional energy needed to sever and dynamically rearrange the network of electrostatic connections must come from a source external to the system. Moreover, the energy E_i transported by the carrier electrons in the wire loop must also be provided by the external source, where the energy delivered by the source may be in any of several forms. For instance, it may be mechanical energy such as that applied in causing the wire loop to rotate about a diagonal axis, or in changing the enclosed area Y or the motion of a magnet relative to Y , or a change in the (primary) current in a wire segment nearby.

Furthermore, the (induced) motion of carrier charges inside the wire loop itself produces a magnetic field at the

3-grid nodes in the medium within Y , while autonomic compulsions dictate that the system must optimize the consumption of the total available energy delivered to it from without. Thus, the direction of the current induced in the wire loop must be such that the magnetic field it produces is directed so as to minimize, and hence oppose, any changes in the extant network of electrostatic connections within the area Y . By the logic of photodynamics, it is this compulsion to oppose any change in the extant electrostatic network inside Y that enforces the relation described by the minus sign (signifying Lenz's law) in Faraday's law, thus giving $\vec{\nabla} \times \vec{E} = -\partial \vec{B} / \partial t$.

Gauss's law for magnetic fields. By definition, a circulating magnetic field $\vec{\nabla} \times \vec{B}$ implies that the field lines must form closed loops. Therefore, the total magnetic flux passing through a closed surface situated inside a magnetic field must be zero, whereby the divergence of $\vec{B}$ at any 3-grid node therein must obey *Gauss's law for magnetic fields*, given as $\vec{\nabla} \cdot \vec{B} = 0$.

7 Subatomic Particles, Atoms, and Nuclear Forces

7.1 Particle Formation

The logic of photodynamics implies that subatomic particles are forged from the LDI cells of ordinary space through the process of phase transition in conditions of extreme compression. Such conditions exist within the inner strata of an active star, where the compression is sufficiently great to breach the lower elastic limits of LDI cells and trigger phase transitions, thereby raising their rudimental densities to LDT levels and thus creating electrons. Further compression inside the innermost strata of the star triggers further phase transitions, thereby raising the rudimental densities of the LDT cells progressively to HDT levels and thus creating the cells that make up high-density multi-cell nucleons.

Notably, this process is accompanied and aided by convection currents that transport the higher-density cells produced in and around the stellar core to the outer strata of the star where the conditions are nonextreme, and lower-density cells from the outer strata to the extreme environments of its inner strata. The HDT cells convected to the outer strata, together with LDT and LDI cells, then cluster to form multi-cell nucleons.

This model further stipulates that the particles manufactured, altered, upgraded, and reprocessed in this continual cycle are then ejected into the circumstellar medium periodically through stellar flares during the lifetime of the star, and (almost) in their entirety if the star explodes as a supernova at the end of its active life.

Nuclear particles. The autonomic compulsion described by Eq. (80) dictates that the total charge Q of an evolving

multi-cell cluster must decrease with the addition of each cell i such that $Q = e \sum_i \pm \mathbb{d}_i \Rightarrow 0$. A fully evolved nucleon is thus formed when $Q = e \sum_i \pm \mathbb{d}_i \simeq 0$, at which stage no further cells can be added to the cluster without the autonomic principle being violated. The final product of this process is a multi-cell HDT cluster with $Q \simeq 0$, where the fully-evolved HDT particle consists of an optimal combination of constituent (HDT, LDT, and LDI) cells and carries very nearly zero net charge, namely a neutron. This mechanism further suggests that protons with positive unit charges are ordinarily produced indirectly as daughter particles through neutron decay via reverse phase transition (see Sec. 7.5).

Exotic particles. Because the evolution of a multi-cell particle entails no inherent constraints with respect to the combination of its constituent cells, or to the magnitudes and signs of their respective charges, in principle, any cell combination is possible as long as the final product results in $Q \simeq 0$. Therefore, any number of combinations of HDT, LDT, and LDI cells may cluster into multi-cell particles, whereby particles with $Q \simeq 0$ but suboptimal cellular compositions may be created to form exotic particles. However, given that the multi-cell particle with the optimal cellular composition and $Q \simeq 0$, namely a neutron, is itself prone to decay outside an atomic nucleus via reverse phase transition, particles with suboptimal cellular compositions must tend to decay more readily.

7.2 Atoms

As noted in Sec. 6.4, there exist exceptional conditions inside an atomic nucleus that produce an inversion of the electrostatic force $\vec{F}_\eta$, as described further below. For the present discussion, it suffices to note that an atomic nucleus carries a net positive charge, which consists of the positive charges of the N_p protons therein, as well as the minuscule (but almost surely nonzero) net charges of its N_n neutrons. To account for all its protons i and neutrons j , the net charge of a nucleus Q_N^+ is thus given, based on Eq. (76), as $Q_N^+ = e \left(\sum_{i=1}^{N_p} +\mathbb{d}_i + \sum_{j=1}^{N_n} \pm \mathbb{d}_j \right)$.

Pursuant to Eq. (80), negatively charged electrons must then cluster (in nearest-density order) round the atomic nucleus such that the net charge Q_A of the evolving atom decreases with the addition of each electron, stated as $Q_A = (Q_N^+ + Q_E^-) \Rightarrow 0$. The total charge of the electrons k in the atom is then given as $Q_E^- = e \sum_{k=1}^{N_e} -\mathbb{d}_k$, where the maximum number of electrons N_e is reached when

$$Q_A = (Q_N^+ + Q_E^-) \simeq 0, \quad (98)$$

at which stage no further electrons can be added to the atom without the autonomic principle being violated.

Residual charge δ_Q and atomic bonds. Because $\mathbb{d}$ and e are continuous quantities, so are Q_N^+ and Q_E^- , which implies

that with asymptotic probability one, the Q_A value of an atom is not identically equal to zero. Therefore, for any given atom there almost surely exists a *residual charge* δ_Q , the numerical value of which is determined as

$$\delta_Q = \begin{cases} Q_A - [Q_A] & \text{if } |Q_A - [Q_A]| < |Q_A - \lceil Q_A \rceil| \\ Q_A - \lceil Q_A \rceil & \text{if } |Q_A - [Q_A]| \geq |Q_A - \lceil Q_A \rceil| \end{cases}. \quad (99)$$

According to this formula, δ_Q is a fractional charge that may have either a positive or a negative value, denoted by δ_Q^+ and δ_Q^- , respectively. A δ_Q^+ value indicates an insufficiency of the total negative charge contributed by the electrons in the atom to neutralize the total positive charge of the atomic nucleus. Conversely, a δ_Q^- value indicates that the total negative charge contributed by the electrons exceeds the total positive charge of the nucleus.

In the case of the atoms of the noble gases, the deviation from $\delta_Q = 0$ is negligibly small. However, for atoms in general the deviation from $\delta_Q = 0$ is considerable, and it constitutes a central factor in the formation of atomic bonds and thereby in the creation of molecules of the numerous substances found in nature.

7.3 Nuclear Forces

The universal electrostatic force function $\vec{F}_\eta$ given by Eq. (78) differs prominently from Coulomb's law in respect to the term $\mathcal{D}_\eta = (1 - \bar{\rho}_\odot/\rho_q)$, which features in the former function but not in the latter. Most significantly, in the case where $\bar{\rho}_\odot > \rho_q$, the negative value of $\mathcal{D}_\eta$ acts to invert the direction of the electrostatic force such that $\vec{F}_\eta$ becomes attractive between like charges and repulsive between unlike charges. Described below are the special conditions that exist inside atomic nuclei due to which $\vec{F}_\eta$ acts to bind together positively charged protons alongside electrically neutral neutrons to form nuclear clusters.

Density difference between protons and neutrons. As described in Sec. 4.4, a proton can be treated as a single-cell particle with respect to its Compton wavelength, whereby from Eqs. (30) and (53) we have $\lambda_{C(p)} = 2L_p$, where the polar chord L_p represents the diameter of an average proton. If R_p is the radius of the proton, then it follows that $\lambda_{C(p)} = 4R_p$, whereby the mass density ϱ_p of an average proton can be estimated as

$$\varrho_p = \frac{3m_p}{4\pi R_p^3} = \frac{48m_p}{\pi\lambda_{C(p)}^3} \approx 1.108 \times 10^{19} \text{ kg m}^{-3}. \quad (100)$$

(Note that the current experimental estimate based on the standard model of particle physics gives the proton radius as $R_p \approx 0.84 \times 10^{-15} \text{ m}$ [27], whereas the present model gives it as $R_p = \lambda_{C(p)}/4 \approx 0.33 \times 10^{-15} \text{ m}$.)

Similarly, if R_n is the radius of a neutron, then the mass density ϱ_n of an average neutron can be estimated as

$$\varrho_n = \frac{3m_n}{4\pi R_n^3} = \frac{48m_n}{\pi\lambda_{C(n)}^3} \approx 1.114 \times 10^{19} \text{ kg m}^{-3}. \quad (101)$$

Thus, the mass density (and hence the photino density) of an average neutron lies just above that of an average proton in the density spectrum.

Function of neutrons in atomic nuclei. Neutrons are present along with protons in every atomic nucleus with the singular exception of the hydrogen nucleus. Suppose that a single proton constitutes a test charge q , whereby $\rho_q = \rho_p$, and q is located (deep) inside an atomic nucleus composed of multiple nucleons including protons as well as neutrons. The medium $\odot$ surrounding q then consists of both neutrons and protons and has an average density $\bar{\rho}_\odot$. Because $\rho_n > \rho_p$, it follows that $\bar{\rho}_\odot > \rho_q$. Consequently, pursuant to Eq. (78), the electrostatic force $\vec{F}_\eta$ between positively charged protons located inside an atomic nucleus becomes attractive if (and only if) the nucleus consists of a combination that includes neutrons in addition to protons.

Attractive nuclear force. Conventional particle theory stipulates a distinct short-range (attractive) *strong nuclear force* that acts to counter the (repulsive) Coulomb force $\vec{F}_C$ between positively charged protons inside an atomic nucleus. By contrast, the present model asserts that because of the special conditions that exist inside an atomic nucleus wherein $\bar{\rho}_\odot > \rho_q$, it is the (directionally inverted) electrostatic force $\vec{F}_\eta$ acting now as an attractive force that keeps positively charged protons along with electrically neutral neutrons bound together in the nucleus of an atom.

7.4 Nuclear Stability

While every atomic nucleus that consists of more than one nucleon must contain neutrons along with protons for $\vec{F}_\eta$ to become an attractive force, the stability of a nucleus further demands an optimal ratio between the neutrons and protons in the nucleus. In the present context, any proton located inside a nucleus constitutes a test charge q , whose immediate neighbors collectively constitute its ambient medium $\odot$. Moreover, the total number of particles in the set of all immediate neighbors of q is all but fixed irrespective of the composition of $\odot$, if the surface of a proton is taken to be (on average) approximately spherical and constant in size. Meanwhile, neglecting (for the present) the case where q is located at the surface of the nucleus, the medium $\odot$ surrounding q consists of a combination of protons and neutrons. Within this general framework, an optimal *neutron-to-proton ratio* requires a critical balance between two opposing compulsions, namely (i) to maximize the total charge $Q_\odot$ in the medium $\odot$ and (ii) to maximize its average density $\bar{\rho}_\odot$ – as follows.

Optimal neutron-to-proton ratio in nuclei. Suppose that the medium $\odot$ surrounding q consists entirely of protons.

In that case, $\bar{\rho}_{\odot} \approx \rho_q$, implying $\mathcal{D}_{\eta} = (1 - \bar{\rho}_{\odot}/\rho_q) \approx 0$, whereby as per Eq. (78) the magnitude of the force F_{η} between $\odot$ and q is functionally zero, rendering q a free particle and thus causing the (proton) cluster to disintegrate. Now suppose that $\odot$ consists entirely of neutrons. In that case, the total charge in $\odot$ is $Q_{\odot} \approx 0$, implying that the magnitude of F_{η} between $\odot$ and q must again be functionally zero, rendering q a free particle and thus causing the cluster to disintegrate.

In contrast to these two hypothetical cases in which the cluster of nucleons is inherently unstable, consider the case where the nucleus consists of an equal number of protons and neutrons. In that case, because $\bar{\rho}_{\odot} > \rho_q$, it follows that $\mathcal{D}_{\eta} = (1 - \bar{\rho}_{\odot}/\rho_q) < 0$, whereby there exists an attractive force $\vec{F}_{\eta}$ between $\odot$ and q . Furthermore, because the total (positive) charge $Q_{\odot}$ in the medium $\odot$ is (roughly) proportional to the number of protons in $\odot$, the magnitude of the force F_{η} between $\odot$ and q must be greater than zero. Therefore, each proton q in the nucleus is bound electrostatically to its neighbors, thereby producing a stable nuclear cluster, in principle.

However, quantitative individuality dictates that the densities of the nucleons inside a nucleus, as well as their respective charges, must almost surely differ in value (even if infinitesimally) from one another. Hence, the presence of an equal number of protons and neutrons in a nucleus does not necessarily indicate an optimal neutron-to-proton ratio. Rather, optimality requires a critical balance such that the nucleus contains sufficiently many neutrons to maximize the average density $\bar{\rho}_{\odot}$ of the medium $\odot$ around each proton q , while also containing sufficiently many protons to maximize the total charge $Q_{\odot}$ within $\odot$. This implies that a suboptimal balance in its neutron-to-proton ratio renders a nucleus susceptible to disintegration if that balance can be disturbed easily by minor perturbances caused by external factors (e.g., by radiation received from incident photons).

Surface protons vs. inner protons in nuclei. Notably, the medium $\odot$ surrounding protons located at the surface of an atomic nucleus includes not only the neighboring protons and neutrons inside the nucleus but also the (low-density and negatively charged) inner electrons of the atom. This composition of $\odot$ implies that the values of both $\bar{\rho}_{\odot}$ and $Q_{\odot}$ must be lower in those cases where q is located at the surface of a nucleus than in the cases where q is fully inside the nucleus. Therefore, because $\bar{\rho}_{\odot}$ is smaller in value for a surface proton, $\mathcal{D}_{\eta}$ is closer to the value where its sign can change from negative to positive, and hence revert $\vec{F}_{\eta}$ into a repulsive force between positively charged protons. Moreover, because $Q_{\odot}$ is smaller in magnitude, so is the force F_{η} between $\odot$ and q , implying a correspondingly weaker electrostatic bond that holds q in place within the

Fig. 14 Band of nuclear stability. Stable nuclides are shown in black. Unstable nuclides are color-coded to show the types of decay that they tend to entail. Source: https://commons.wikimedia.org/wiki/File:Table_isotopes_en.svg

nucleus. Thus, a proton located at the surface of an atomic nucleus is inherently more susceptible to being dislodged from its location by minor perturbances caused by external stimuli, and hence to disintegration, than is a proton deeper inside the nucleus.

Repulsive nuclear force. Conventional particle theory stipulates a distinct short-range (repulsive) *weak nuclear force* that acts to counter the (attractive) strong force between nucleons, inducing nuclear decay. By contrast, the present model asserts that there exists no nuclear force other than the universal electrostatic force $\vec{F}_{\eta}$, which both binds nucleons together and pries them apart, depending on extant conditions. According to this model, it is the critical balance, or absence thereof, between the $\bar{\rho}_{\odot}$ and $Q_{\odot}$ values associated with the protons located in the nuclei of the isotopes of different elements that accounts for the characteristic form and composition of the well-known *band of nuclear stability* (see Fig. 14).

7.5 Neutron Decay

In the context of photodynamics, the decay of a neutron is described as the partial unraveling of its optimally constituted cellular structure, triggered fundamentally by one of two events. One event is a reverse phase transition induced by extreme decompression (see Sec. 4.4), while the other is the absorption of energy imparted by an external source such as a resonant incident photon or the impact of an incident particle. Whereas decay due to reverse phase transition is associated principally with free neutrons, decay due to the absorption of energy from an external source is associated ordinarily with neutrons within atomic nuclei.

Neutron–proton density threshold and reverse phase transition. A reverse phase transition occurs when the upper elastic limit of a cell is breached (i.e., $V_A > V_P$) in an environment where the density of the ambient medium is far lower than that of the cell. As shown by Eqs. (100) and (101), the average density of a neutron lies just above that of a proton in the density spectrum, whereby the midpoint between the densities of the two particles can be taken as the *neutron–proton density threshold*.

The present model stipulates that no physical environment exists in nature where the density of the medium is sufficiently low to cause a breach of the upper elastic limit of cells inside a particle of proton density (or of a lower density). Therefore, a proton cannot decay as a consequence of reverse phase transition in any natural environment. By contrast, a neutron, or any other multi-cell particle whose density exceeds the neutron–proton density threshold, is prone to decay by reverse phase transition when subjected to extreme decompression upon exposure to a medium whose density is far lower than its own.

Photon-induced decay. If a cell that is located at the surface of a neutron receives photinos transmitted to it by an incident photon, then its photino content H_A increases as it absorbs the incident photinos, which increases its V_P value in accordance with Eq. (12). If local spatial constraints prevent a commensurate increase in its V_A , then the cell acquires (reducible) potential energy U_V as per Eq. (13). If φ is the photoelectric work function associated with the extant location of the cell, then as $U_V \rightarrow 0$, the cell gains kinetic energy $K = U_V - \varphi$ if $U_V > \varphi$, and detaches from its host neutron. Consequently, the optimal cellular structure of the neutron unravels partially, thereby producing its decay. The logic of photodynamics suggests that it is mainly this mechanism that causes the spontaneous decay of neutrons inside atomic nuclei.

Impact-induced decay. In the case where neutron decay occurs because of the impact of an incident (moving) particle, the kinetic energy K carried by the incident particle first converts into potential energy U_V in one or more cells within the neutron. Those cells then acquire kinetic energy K (if $U_V > \varphi$) as $U_V \rightarrow 0$ and detach from the host neutron, thereby unravelling the optimal cellular structure of the neutron partially and thus causing its decay. The logic of this model suggests that it is principally this mechanism that causes the decay of neutrons in high-energy particle collisions.

Neutron decay by β^- emission. Irrespective of its cause, the essential outcome of neutron decay is to pare the (unstable) neutron into a (stable) proton, while also releasing other daughter particles as well as high-frequency photons. This process defines the mechanism of β^- neutron decay, as follows.

The difference between the total number of cells in an average neutron and an average proton can be estimated as $(n_n - n_p)/n_e \approx 2.53098726$. However, because the total number of cells in a multi-cell cluster must be an integer, the actual difference between the number of cells in a neutron and a proton must be $\lfloor (n_n - n_p)/n_e \rfloor = 2$. The fractional part of the previous value implies that, in addition to the photino contents of its two more cells, a neutron contains ca. $(n_e \times 0.53098726) \approx 6.561 \times 10^{19}$ more photinos than does a proton, equivalent to roughly 4.347×10^{-14} J of energy.

It is well established experimentally that the decay of a neutron by β^- emission produces three particles, namely a proton, an electron, and an antineutrino ($\bar{\nu}$), in addition to excess energy Ω , expressed by convention as

$${}^1_0n_1 \rightarrow {}^1_1p_0 + {}^0_{-1}e_0 + \bar{\nu} + \Omega. \quad (102)$$

From the viewpoint of photodynamics, this relation describes well the balance that must exist to account fully for the conservation of not only energy and electric charge but also the total number of particles in the system. As indicated in the description above, the decay of a neutron by β^- emission must produce one proton and precisely two single-cell particles, as well as excess energy Ω . Therefore, in addition to a proton with unit positive charge, one of the two single-cell daughter particles is an LDT cell (electron) with unit negative charge, while the other is an LDI cell ($\bar{\nu}$) with fractional charge. If prior to its decay the neutron carried a net zero electric charge, then charge is conserved if and only if cell $\bar{\nu}$ carries a (positive or negative) fractional charge such that its η value is equal to the (minuscule but nonzero) value of the net δ_η of the proton and the electron released in the decay.

The excess energy Ω may be partly transmitted as the energy E_γ carried by emitted photons and partly retained in the form of unbound photinos by the daughter particles, while the latter may generate potential energy U_V . Given that $U_V \rightarrow 0$, motion may be induced in the daughter particles by the (partial or total) conversion of their U_V into kinetic energy K . While the extant conditions specific to any given occurrence of β^- decay must determine the proportion in which each form of excess energy may appear, if Ω is present in each of its various forms, then its components are described by

$$\Omega = E_\gamma + U_V + K + \varphi + n_{ret}h\nu_0, \quad (103)$$

where n_{ret} is the total number of unbound photinos retained by the daughter particles.

Neutrinos and mass. Given that neutrinos and antineutrinos are LDI cells, and because no cell can be devoid of photinos, it follows that every neutrino and antineutrino possesses a nonzero mass whose magnitude is determined by its photino content, as described by Eq. (5).

8 Atomic Spectra, Schrödinger Equation, and Atomic Geometry

8.1 Atomic Line Spectra

As described in Sec. 6, the η of an electron induces electrostatic potential energy U_η , while $\mathcal{U}_\eta = U_\eta/\mathcal{D}_\eta$ describes the normalized electrostatic potential energy of the electron. Based on Eq. (60), the internal measure of the $\mathcal{U}_\eta$ of an electron is given as $\mathcal{U}_\eta = (n_G h\nu_0/2)(\mathbb{d})^2$. From Eqs. (5) and (56), we have $n_G h\nu_0 = m_G c^2$ and $\mathbb{d} = R_\eta/r$, respectively, whereby the previous equation becomes

$$U_\eta = \frac{1}{2} m_e c^2 \left(\frac{R_{\eta(e)}}{r_e} \right)^2, \quad (104)$$

where the average ground-state electron mass m_e replaces the general ground-state mass term m_G .

Hydrogen spectra. Because $\eta_e = 0.5$ by definition, we have $r_e = \lambda_{C(e)|\eta=0.5} = \lambda_{C(e)}$. Moreover, for a stationary photino wave in mode n , based on Eq. (30) we obtain $\lambda_{C(e),n} = n\lambda_{C(e)}$. Hence, for any given electron e , we have $r_{e,n} = n\lambda_{C(e)} = n r_e$. Now, because η_e lies in the cusp range, Eq. (58) implies that $R_{\eta(e)} \approx \alpha\lambda_{C(e)}$. Thus, Eq. (104) can be restated to give the $\mathcal{U}_\eta$ for any value of n as

$$\mathcal{U}_{\eta,n} \approx \frac{1}{2} m_e c^2 \left(\frac{\alpha\lambda_{C(e)}}{n\lambda_{C(e)}} \right)^2. \quad (105)$$

Multiplying the right-hand side of this equation by $(\mathbb{k}_e/\mathbb{k}_e)^2$ yields $\mathcal{U}_{\eta,n} \approx (m_e/2)(\alpha c/\mathbb{k}_e)^2 (\mathbb{k}_e)^2 (1/n)^2$. Because Coulomb's constant may be expressed variously as $\mathbb{k}_e = \alpha(\hbar c/e^2) = 1/4\pi\epsilon_0$, the previous equation can be given as $\mathcal{U}_{\eta,n} \approx (m_e/2)(\alpha c e^2/\alpha\hbar)^2 (1/4\pi\epsilon_0)^2 (1/n)^2$.

Because the absorption of photons by an electron increases its $\mathcal{U}_{\eta,n}$ while the emission of photons decreases its $\mathcal{U}_{\eta,n}$, the (quantized) energy levels E'_n of an electron in an atom are related as $E'_n = -\mathcal{U}_{\eta,n}$. Replacing $\mathcal{U}_{\eta,n}$ in this equation with the right-hand side of the previous equation thus gives the energy levels of emission and absorption spectra for the (single-electron) hydrogen atom as

$$E'_n \approx -\frac{m_e e^4}{32\pi^2 \epsilon_0^2 \hbar^2} \left(\frac{1}{n} \right)^2 \approx -\frac{13.6}{n^2} \text{ eV}, \quad (106)$$

in agreement with empirical evidence, as well as with the energy levels predicted by the *Bohr formula* and by the quantum mechanical model.

Rydberg formula. Suppose that an electron located inside an atom is in an excited state such that $n > 1$ and it possesses potential energy that does not exceed its photoelectric work function. Autonomic compulsions dictate that the electron must then emit a photon to reduce its potential energy if the entropic condition given by Eq. (32) is satisfied, while the optimal number of levels Q by which n must decrease as a consequence of the photon

emission is determined in accordance with Eq. (34). The energy $h\nu$ carried by the emitted photon is then given by the difference between the initial (higher) energy level of the electron E_i and its final (lower) energy level E_f , whereby $h\nu = E_i - E_f$. Replacing $h\nu$ in this equation with hc/λ and replacing E_i and E_f (each) with the middle term in Eq. (106) yields the *Rydberg formula*, stated as

$$\frac{1}{\lambda} \approx \frac{m_e e^4}{64\pi^3 \epsilon_0^2 \hbar^3 c} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right), \quad (107)$$

where the numerical coefficient in this equation gives the *Rydberg constant* $R_\infty \approx 1.097 \times 10^7 \text{ m}^{-1}$.

Absorption vs. emission spectra. Because the autonomic process of energy transmission compels a cell to minimize its unbound photino count, every cell—including every electron inside an atom—tends to be (approximately) in its ground state. Consequently, *absorption spectra*, which entail the transition of an electron from lower to higher energy levels, tend to be associated with cases where the electron is initially in its ground state such that $n = 1$. *Emission spectra*, on the other hand, are not subject to this constraint because they entail transitions from higher to lower energy levels, implying that the electron must initially be in an excited state with any one of all possible n values and may transition to any lower energy level down to $n = 1$, as described previously in Sec. 4.3.

Shortcomings of the hydrogen model. The discussion of R_η thus far has been limited to the displacement of the center of mass $c_{m|\eta}$ of a particle from its energy-neutral point $c_{m|\eta=0}$ due solely to its intrinsic η . Suppose that an electron of negative charge q is subjected to an electrostatic force F_η by a (net) positive charge Q . In that case, in addition to the displacement due to its intrinsic η , the center of mass of the electron must be further displaced because of F_η from the point on the polar chord of the electron where $c_{m|\eta}$ is located in the absence of F_η .

In the present context, the charges Q and q underlying F_η are implicit in the term $(e^2)^2$ in Eq. (106) such that $e^2 = Qq = (e\mathbb{d}_Q)(e\mathbb{d}_q)$ and $|\mathbb{d}_Q| = |\mathbb{d}_q| = 1$. This implies that Q and q each consist of a single particle with opposite unit charge, connoting the special case of the hydrogen atom. However, this relationship neglects the quantity α in the term $\mathbb{d} = R_\eta/r = \alpha(\lambda_C/\lambda_{C|\eta=0.5})$ for each particle in the atom, as well as the deviation that almost surely exists in its λ_C value from $\lambda_{C|\eta=0.5}$. Thus, while for the hydrogen atom the deviation of the implied Q value (i.e., $Q = e$) from its true value may be deemed negligible, for atoms with atomic numbers $Z > 1$, the deviation becomes considerable and grows with Z . Consequently, the E'_n values predicted by Eq. (106) deviate increasingly from the true E'_n values with increasing values of Z . To account for any atom with atomic number $Z \geq 1$, as well as for the

quantity α and the deviation of λ_C from $\lambda_{C|\eta=0.5}$ for each particle in the atom, the true value of Q must incorporate these factors, or good approximations thereof.

Total charge Q_S . Suppose that S is a spherical surface centered on the nucleus of a multi-electron atom and an electron $\odot$ of charge q lies on S . In that case, the total charge Q_S inside S includes the total (positive) nuclear charge Q_N^+ and the total (negative) charge $Q_{E(S)}^-$ of $N_{e(S)}$ electrons k that lie within, and on, the surface S , excluding (expressly) the electron $\odot$, whereby

$$Q_S = Q_N^+ + Q_{E(S)}^-. \quad (108)$$

The total electron charge inside S (excluding that of $\odot$) is then $Q_{E(S)}^- = e \sum_{k=1}^{N_{e(S)}} -\mathbb{d}_k = -e\alpha \sum_{k=1}^{N_{e(S)}} (\lambda_{C,k}/\lambda_{C(e)})$. Given that $\lambda_{C,k}/\lambda_{C(e)} = \eta_k/\eta_e$ where $\eta_e = 0.5$, the previous equation becomes $Q_{E(S)}^- = -2e\alpha \sum_{k=1}^{N_{e(S)}} \eta_k$. From Eq. (54), $\eta = (1 + \delta_\eta)/2$ is the statistically expected η value of an electron inside S . Taking this expected value as the estimated η_k for each electron inside S thus gives the relation $Q_{E(S)}^- \approx -e\alpha \sum_{k=1}^{N_{e(S)}} (1 + \delta_\eta)_k$, which becomes

$$Q_{E(S)}^- \approx -\alpha(1 + \delta_\eta)(eN_{e(S)}). \quad (109)$$

The (minuscule) plus and minus deviations around $\eta = 0$ in the η values of the neutrons in an atomic nucleus can be expected ordinarily to average to a vanishingly small magnitude, especially in atoms with larger atomic mass numbers. Neglecting the (~ 0) average charge of the neutrons, the total charge of an atomic nucleus with N_p protons i (where $N_p = Z$) is therefore given by the relationship $Q_N^+ \approx e \sum_{i=1}^{N_p} +\mathbb{d}_i$. Because $\eta = (1 - \delta_\eta)/2$ is the statistically expected η value of a proton, employing the same logic as that applied to derive Eq. (109), the total charge of an atomic nucleus is approximated as

$$Q_N^+ \approx \alpha(1 - \delta_\eta)(eN_p). \quad (110)$$

Replacing Q_N^+ and $Q_{E(S)}^-$ in Eq. (108) with the right-hand sides of Eqs. (110) and (109), respectively, the net charge in S becomes $Q_S \approx e\alpha \left((1 - \delta_\eta)N_p - (1 + \delta_\eta)N_{e(S)} \right)$, which can be written equivalently as

$$Q_S \approx e\alpha \left((N_p - N_{e(S)}) - \delta_\eta(N_p + N_{e(S)}) \right) \approx e\check{Z}, \quad (111)$$

where $\check{Z} \triangleq (Q_S/e)$ is the *effective particle count* inside the surface S , while $\check{Z} \in \mathbb{R}$, and $\delta_\eta = a_e \approx 1.1597 \times 10^{-3}$ is the electron magnetic moment anomaly.

Electron charge q . Multiplying the middle term in Eq. (92) by $\alpha\hbar v_0 c^2/\alpha\hbar v_0 c^2$ and rearranging the terms, we obtain $\alpha\lambda_{C(e)} = \alpha\mu_e/e\eta_e c$, and hence $R_{\eta(e)} = \alpha\mu_e/e\eta_e c$. Given that $\mu_B = e\hbar/2m_e$, pursuant to Eq. (90) it follows that $\mu_e = (1 + \delta_\eta)(e\hbar/2m_e)$, where $(1 + \delta_\eta)/2 = \eta_e$ and $\delta_\eta/2$ is the statistically expected mean deviation of the η of

an (average) electron e from $\eta_e = 0.5$. However, to describe the true deviation of the (unique) $\eta_\odot^-$ value of a given electron $\odot$ from η_e , the term $\eta_e = (1 + \delta_\eta)/2$ must be replaced with $\eta_\odot^- = (0.5 + \Delta_\eta) = (1 + 2\Delta_\eta)/2$, where $\Delta_\eta = \eta_e - |\eta_\odot^-|$ denotes the true deviation uniquely for the electron $\odot$. Hence, the μ_e function given above must be restated as $\mu_\odot = (1 + 2\Delta_\eta)(e\hbar/2m_\odot)$ to explicitly describe the case of a specific electron $\odot$ in an atom, whereby $R_{\eta(\odot)} = \alpha(1 + 2\Delta_\eta)(e\hbar/2m_\odot)/(e\eta_\odot c)$.

If q is the (negative) charge carried by the electron $\odot$, then $\mathbb{d}_q = -\mathbb{d}_\odot = -R_{\eta(\odot)}/\lambda_{C(e)}$, which can now be stated as $\mathbb{d}_q = -\alpha((1 + 2\Delta_\eta)/2\eta_\odot\lambda_{C(e)})(\hbar/m_\odot c)$. Noting that $\hbar/m_\odot c = \lambda_{C(\odot)}$ and $\lambda_{C(\odot)}/\lambda_{C(e)} = \eta_\odot/\eta_e$, the previous equation simplifies to $\mathbb{d}_q = -\alpha(1 + 2\Delta_\eta)/2\eta_e$, and given that $\eta_e = 0.5$, this equation becomes $\mathbb{d}_q = -\alpha(1 + 2\Delta_\eta)$. The charge $q = e\mathbb{d}_q$ of the electron $\odot$ is thus given as

$$q = -e\alpha(1 + 2\Delta_\eta) = e\check{z}, \quad (112)$$

where $\check{z} \triangleq (q/e)$ and $\check{z} \in \mathbb{R}$.

Line spectra of any atom with $Z \geq 1$. Based on Eqs. (111) and (112), $((e\check{Z})(e\check{z}))^2$ replaces the term e^4 in Eq. (106) to give the energy levels $\check{E}_n$ of emission and absorption spectra for any atom with $Z \geq 1$ as

$$\check{E}_n \approx -\frac{m_e e^4}{32\pi^2 \epsilon_0^2 \hbar^2} \left(\frac{\check{Z}\check{z}}{n} \right)^2. \quad (113)$$

Furthermore, modifying the Rydberg formula given by Eq. (107) similarly yields

$$\frac{1}{\lambda} \approx \frac{m_e e^4}{64\pi^3 \epsilon_0^2 \hbar^3 c} \left(\left(\frac{\check{Z}\check{z}}{n_F} \right)^2 - \left(\frac{\check{Z}\check{z}}{n_1} \right)^2 \right). \quad (114)$$

Fine structure and hyperfine structure of line spectra. Pursuant to the relationships given in Eqs. (111) and (112) for $\check{Z}$ and $\check{z}$, Eq. (113) implies that a difference of a single photino mass m_h between the masses m_e of two photon-emitting electrons must cause the energies of the photons emitted by the respective electrons to differ by a factor of α^4 , all other factors being held constant. Thus, according to the present model, it is the presence of such (minor) differences in the photino contents, and hence the masses, of the corresponding photon-emitting electrons in like atoms that produces the observed *fine structure* splitting of energy levels in atomic spectra [28].

This model further implies that the observed *hyperfine* splitting of energy levels in atomic spectra arises from the intrinsic differences among photon-emitting electrons in respect to their Δ_η values embedded via Eq. (112) in the respective $\check{z}$ values. This is because a unique Δ_η value is set for each electron at its inception during phase transition, implying that the Δ_η values of electrons are unpredictable

in principle, rendering the hyperfine structure of line spectra inherently random.

8.2 Schrödinger Equation

The framework of photodynamics implies a fundamental departure from the paradigm of quantum mechanics, whereby the wave function of an electron entails neither any time dependence nor wave superposition. Rather, as a single-cell LDT particle with a well-defined spatial volume V_A , an electron consists entirely and only of photinos, while the (static) internal distribution of its constituent photinos is described by the wave function $\psi_n(x)$ of its stationary photino wave. Moreover, each electron situated inside an atom occupies a unique geometric location relative to all other constituents therein, which is dictated by the autonomic compulsion of every electron to be in an equilibrium state within the host atom.

As in the case of a thermodynamic system described in Sec. 5.1, the core hypothesis of photodynamics implies that the mechanical energy of an electron in an atom consists fundamentally of its stored potential energy. Motion is therefore not an intrinsic feature of an electron, and is generated only by the conversion of its potential energy into kinetic energy, as exemplified by the Compton effect and the *photoelectric effect* [16].

The total mechanical energy E_n of an electron located inside an atom is hence given as $E_n = \tilde{U}_V + \tilde{U}_\eta$, where $\tilde{U}_V$ is its elastic potential energy and $\tilde{U}_\eta$ is its (normalized) electrostatic potential energy. For any given electron in an atom, $\tilde{U}_V$ denotes the potential energy associated with the absorption and emission of photinos transmitted via thermal conduction, while $\tilde{U}_\eta$ denotes the potential energy associated with the absorption and emission of (resonant) photons via photonic transmission. Multiplying both sides of the previous equation by $\psi_n(x)$ thus yields

$$\tilde{U}_V \psi_n(x) + \tilde{U}_\eta \psi_n(x) = E_n \psi_n(x), \quad (115)$$

where Eq. (29) gives $\psi_n(x) \approx A \cos(\tilde{k}_n x)$ as the wave function of the stationary photino wave of the electron in mode n . Taking the second derivative of $\psi_n(x)$, we obtain $d^2\psi/dx^2 \approx -\tilde{k}_n^2 A \cos(\tilde{k}_n x)$, where $\psi = \psi_n(x)$. Replacing $A \cos(\tilde{k}_n x)$ in this equation with the left-hand side of Eq. (29) gives $-d^2\psi/dx^2 \approx \tilde{k}_n^2 \psi$, which can be restated as $-d^2\psi/dx^2 \approx (2\pi/\lambda_n)^2 \psi$. Given that $2\pi/\lambda_n = 2\pi\nu_n/c = h\nu_n/\hbar c = m_{e,n}c^2/\hbar c$, where $m_{e,n}$ is the mass of the electron with its stationary photino wave in mode n , the previous equation becomes

$$-\left(\frac{\hbar}{m_{e,n}c}\right)^2 \frac{d^2\psi}{dx^2} \approx \psi. \quad (116)$$

Pursuant to Eq. (13), the elastic potential energy of the electron is given as $\tilde{U}_V = (1/2)n_{e,n}h\nu_0\kappa^2$, where $n_{e,n}$ is the photino count of the electron while n is its nearest

extant harmonic mode, and κ is the compression to which it is subjected by the ambient system in its host atom. Based on Eq. (5), the previous equation can be stated as

$$\tilde{U}_V = \frac{1}{2}m_{e,n}c^2\kappa^2. \quad (117)$$

Meanwhile, based on Eq. (113), the normalized electrostatic potential energy $\tilde{U}_\eta$ of the electron with its stationary photino wave in mode n is given by

$$\tilde{U}_\eta = -\tilde{E}_n. \quad (118)$$

Therefore, replacing the first $\psi_n(x)$ term on the left-hand side of Eq. (115) with the left-hand side of Eq. (116) and replacing $\tilde{U}_V$ with the right-hand side of Eq. (117) yields

$$-\frac{\hbar^2}{2m_{e,n}} \frac{d^2\psi}{dx^2} (\kappa^2) + \tilde{U}_\eta \psi \approx E_n \psi. \quad (119)$$

This equation represents a one-dimensional case where the axis of symmetry of a stationary photino wave extends outward in one direction from a point of origin along an arbitrary (x) axis. A three-dimensional analogue of Eq. (119) is then described by the case where the respective axes of symmetry of multiple stationary photino waves extend radially outward from the nucleus of an atom at different orientations into one of the two hemispheres of the atom. Meanwhile, the respective axes of symmetry of those stationary photino waves whose outermost nodes lie on the same surface $\mathcal{S}$ are oriented such that the angle subtended at the nucleus by each pair of nearest axes is constant. This arrangement is expressed by the three-dimensional extension of Eq. (119) as

$$-\frac{\hbar^2}{2m_{e,n}} \nabla^2 \psi (\kappa^2) + \tilde{U}_\eta \psi \approx E_n \psi, \quad (120)$$

where now $\psi = \psi_n(r, \theta, \phi)$ in spherical coordinates. This generalized relation corresponds to the *time-independent Schrödinger equation*, modified by the term κ^2 .

8.3 Atomic Geometry

Using the standard technique of separation of variables, the solutions of Eq. (120) are restricted to those that are separable and factorable as $\psi(r, \theta, \phi) = R(r)\Theta(\theta)\Phi(\phi)$, where $R(r)$, $\Theta(\theta)$, and $\Phi(\phi)$ are all functions of single variables. The separated solutions can then be expressed as $\psi_{n,l,m_l}(r, \theta, \phi) = R_{n,l}(r)\Theta_{l,m_l}(\theta)\Phi_{m_l}(\phi)$, in which the indices (n, l, m_l) take values such that $n = 1, 2, 3, \dots$, while $l = 0, 1, 2, \dots, n-1$ and $m_l = 0, \pm 1, \pm 2, \dots, \pm l$. Noting that these solutions are associated with the Laplacian component $-\nabla^2\psi$ of Eq. (120), the indices (n, l, m_l) represent parameters that translate readily into geometric coordinates of the *local maxima* of ψ in one (of the two) hemispheres of the atom. The geometry of a complete atom therefore entails the further incorporation of a mirror image of the same arrangement in the other hemisphere. This

augmented depiction is then of multiple (common) axes of back-to-back stationary photino waves extending radially in two opposite directions from the atomic nucleus into each of the two hemispheres of the atom (see Fig. 15).

Because the local maxima of ψ describe those points in an atom where photino concentration is (locally) maximal, it follows that the coordinates of the local maxima represent the physical locations of electrons inside the atom. To describe the locations of all local maxima of ψ —and hence of all electrons—in both hemispheres, a fourth index must be defined to identify the hemisphere with which the three indices (n, l, m_l) are associated. In keeping with convention, this fourth index is denoted herein by m_s , where the northern hemisphere of an atom may be described (symbolically) as $m_s = +z$ and the southern hemisphere as $m_s = -z$.

Conversion of the indices (n, l, m_l, m_s) into the spherical coordinates (r, θ, ϕ) of the local maxima of ψ , and hence of the electrons, entails a two-step process. The four indices (n, l, m_l, m_s) are first converted to three *geometric coordinates* $(\mathfrak{m}, \mathfrak{l}, \mathfrak{m})$, which are then converted into spherical coordinates (r, θ, ϕ) . The geometric coordinates in an atom are described in a reference frame that consists of an origin (the atomic nucleus), a z -axis (the polar axis of the atom), and a y - z plane (the azimuthal plane of the atom). Noting that the $+z$ direction points northward while the $+y$ direction points to the atomic azimuth, the indices (n, l, m_l, m_s) are converted to geometric coordinates $(\mathfrak{m}, \mathfrak{l}, \mathfrak{m})$ such that

$$\mathfrak{m} = n, \quad (121)$$

$$\mathfrak{l} = \begin{cases} l & \text{if } m_s = +z \\ (2n - 1) - l & \text{if } m_s = -z \end{cases}, \quad (122)$$

$$\mathfrak{m} = \begin{cases} m_l & \text{if } m_l \geq 0 \\ m_l + (2l + 1) & \text{if } m_l < 0 \end{cases}. \quad (123)$$

These geometric coordinates can then be converted into spherical coordinates (r, θ, ϕ) simply by setting $r = \mathfrak{m}$, $\theta = \pi\mathfrak{l}/(2\mathfrak{m} - 1)$, and $\phi = 2\pi\mathfrak{m}/(\mathfrak{m}_{\max} + 1)$, where

$$\mathfrak{m}_{\max} = \begin{cases} 2\mathfrak{l} & \text{if } \mathfrak{l} < \mathfrak{m} \\ 2((2\mathfrak{m} - 1) - \mathfrak{l}) & \text{if } \mathfrak{l} \geq \mathfrak{m} \end{cases}. \quad (124)$$

Geometric coordinate system. The system of geometric coordinates described herein corresponds to the standard geographic coordinate system commonly used to specify locations on or near the surface of the Earth. The $\mathfrak{m}$ coordinate thus corresponds to the “elevation” above the atomic nucleus and defines the *shell number* of an electron within an atom (see Fig. 16). The $\mathfrak{l}$ coordinate corresponds to the “latitude” measured relative to the north pole of the atom and defines the *subshell number* of an electron within any given shell $\mathfrak{m}$ (see Fig. 17). Lastly, the $\mathfrak{m}$ coordinate corresponds to the “longitude” measured relative to a reference azimuth (i.e., the highest-density electron) in any

Fig. 15 Two-dimensional schematic of axes of symmetry of stationary photino waves in atom. Red line: local maxima of ψ for $n = 1$. Green lines: local maxima of ψ for $n = 2$. Open circles: centers of mass of electrons. Filled-in circle: center of mass of nucleus.

subshell $\mathfrak{l}$ and defines the *longitudinal number* of an electron within the subshell $\mathfrak{l}$ (see Fig. 18).

Configuration of an atom. The spherical coordinates of an electron in an atom are described in a standard x - y - z reference frame, where the radial coordinate r specifies the shell number $\mathfrak{m}$ of the electron, while the polar coordinate θ gives the latitude of its subshell $\mathfrak{l}$ relative to the north pole of the atom. An equatorial x - y plane bisects the atom, dividing each shell into northern and southern halves. Each half-shell is then segmented into $\mathfrak{m}$ subshells, where each subshell lies on a plane parallel to the x - y plane. Subshells $\mathfrak{l} = 0$ and $\mathfrak{l} = 2\mathfrak{m} - 1$ denote the two polar subshells at the northern and southern poles of the shell $\mathfrak{m}$, respectively, where $\mathfrak{l} \in \{0, 1, 2, \dots, 2\mathfrak{m} - 1\}$. Within any given shell, each polar subshell consists of a single electron, while every other subshell consists of multiple electrons, forming a chain of electrons describing a circle centered on the polar (i.e., z) axis of the atom.

Because every electron must be arranged in nearest-density order relative to its neighbors in each direction x , y , and z , the highest-density electron in each subshell of an atom lies on a common y - z (azimuthal) plane, on the $+y$ side of the z -axis of the atom. The azimuthal plane of an atom thus forms the reference plane relative to which the azimuthal coordinate ϕ of an electron in any given subshell $\mathfrak{l}$ is measured. The longitudinal number $\mathfrak{m} = 0$ therefore denotes the highest-density electron in a subshell, located at the intersection of the subshell and the y - z plane, where $\mathfrak{m} \in \{0, 1, 2, \dots, \mathfrak{m}_{\max}\}$ and $\mathfrak{m}$ increases in the direction of increasing ϕ .

Table 1 gives the quantum states of electrons as defined by the indices (n, l, m_l, m_s) for the principal quantum numbers $n = 1, 2, 3$, illustrating the equivalence of the quantum states and the corresponding geometric coordinates of electrons in an atom.

The $\pm$ sign of electron spin S_z . As described in Sec. 6.8, the $|\pm\hbar/2|$ term in Eq. (94) is positive-valued for a free

Fig. 16 Shell number m . Fig. 17 Subshell number l . Fig. 18 Longitudinal number m .

electron. However, if an electron is bound within an atom, then it must be located either in the northern or southern hemisphere of the host atom, while the negative charge of the electron implies that its $\vec{R}_\eta$ points toward the atomic nucleus (see Fig. 11). Consequently, the z -axis component of the spin angular momentum S_z of an electron located in the northern hemisphere of an atom must point southward in the $+\hat{a}$ direction (i.e., along the polarity of the atom),

whereby $S_z = +\hbar/2$. Conversely, if an electron is located in the southern hemisphere of an atom, then its S_z must point northward in the $-\hat{a}$ direction, whereby $S_z = -\hbar/2$. Therefore, this model asserts that the sign of the S_z of an electron that is bound within an atom is determined explicitly by only the hemisphere m_s of the host atom (i.e., $\pm z$) in which the electron is located.

Quantum state					Spherical coordinates			Geometric coordinates		
Principal quantum number n	Orbital quantum number l	Magnetic quantum number m_l	Spin quantum number m_s	Associated spectroscopic notation*	Radial coordinate r	Polar angle θ	Azimuthal angle ϕ	Shell number m	Subshell number l	Ordinal number m
1	0	0	$+1/2$	1s (1)	1	0	0	1	0	0
1	0	0	$-1/2$	1s (2)	1	π	0	1	1	0
2	0	0	$+1/2$	2s (1)	2	0	0	2	0	0
2	0	0	$-1/2$	2s (2)	2	π	0	2	3	0
2	1	0	$+1/2$	2p (1)	2	$\pi/3$	0	2	1	0
2	1	1	$+1/2$	2p (2)	2	$\pi/3$	$2\pi/3$	2	1	1
2	1	-1	$+1/2$	2p (3)	2	$\pi/3$	$4\pi/3$	2	1	2
2	1	0	$-1/2$	2p (4)	2	$2\pi/3$	0	2	2	0
2	1	1	$-1/2$	2p (5)	2	$2\pi/3$	$2\pi/3$	2	2	1
2	1	-1	$-1/2$	2p (6)	2	$2\pi/3$	$4\pi/3$	2	2	2
3	0	0	$+1/2$	3s (1)	3	0	0	3	0	0
3	0	0	$-1/2$	3s (2)	3	π	0	3	5	0
3	1	0	$+1/2$	3p (1)	3	$\pi/5$	0	3	1	0
3	1	1	$+1/2$	3p (2)	3	$\pi/5$	$2\pi/3$	3	1	1
3	1	-1	$+1/2$	3p (3)	3	$\pi/5$	$4\pi/3$	3	1	2
3	1	0	$-1/2$	3p (4)	3	$4\pi/5$	0	3	4	0
3	1	1	$-1/2$	3p (5)	3	$4\pi/5$	$2\pi/3$	3	4	1
3	1	-1	$-1/2$	3p (6)	3	$4\pi/5$	$4\pi/3$	3	4	2
3	2	0	$+1/2$	3d (1)	3	$2\pi/5$	0	3	2	0
3	2	1	$+1/2$	3d (2)	3	$2\pi/5$	$2\pi/5$	3	2	1
3	2	2	$+1/2$	3d (3)	3	$2\pi/5$	$4\pi/5$	3	2	2
3	2	-2	$+1/2$	3d (4)	3	$2\pi/5$	$6\pi/5$	3	2	3
3	2	-1	$+1/2$	3d (5)	3	$2\pi/5$	$8\pi/5$	3	2	4
3	2	0	$-1/2$	3d (6)	3	$3\pi/5$	0	3	3	0
3	2	1	$-1/2$	3d (7)	3	$3\pi/5$	$2\pi/5$	3	3	1
3	2	2	$-1/2$	3d (8)	3	$3\pi/5$	$4\pi/5$	3	3	2
3	2	-2	$-1/2$	3d (9)	3	$3\pi/5$	$6\pi/5$	3	3	3
3	2	-1	$-1/2$	3d (10)	3	$3\pi/5$	$8\pi/5$	3	3	4

*By convention, the notation nL^N describes the number N of electrons for any given value of L (symbolically named $s, p, d, f, \dots$ connoting l values 0, 1, 2, 3, ... respectively) in each n value of an atom. To allow all possible electrons for each n value to be listed individually, the superscript N is replaced in this table by the sequential order (shown in brackets) in which electron orbitals are typically filled for each l value pursuant to Hund's rule.

Table 1 Spherical and geometric coordinates of electrons in shells 1, 2, and 3 according to their quantum states.

8.4 Double-slit Experiment

Photodynamics offers a straightforward explanation for the otherwise mysterious phenomenon observed in the well-known *double-slit experiment* [29], as follows.

The case of atomic-scale particles. In this experiment, atomic-scale particles such as electrons are fired one at a time through two narrow parallel slits in a screen and are detected as they strike a second screen on the opposite side. As the number of particles sent through the two slits increases, a pattern of bright and dark bands is observed to build up on the rear screen. However, such a pattern can only be due to interference caused by the superposition of overlapping waves. Because ordinary physical bodies do not superpose, this phenomenon implies a duality whereby atomic-scale particles appear to behave also as waves.

According to the present model, this effect is caused not by a subliminal wave–particle duality in the character of atomic-scale particles but rather by the dynamics of the LDI medium through which the particles move. A minor compression wave is produced in the medium when an electron gun fires an electron. The compression wavefront then propagates through the medium to the first screen and through the two slits to the rear screen. However, it diffracts as it passes through the slits. The points at which the two diffracted wavefronts overlap form the locus of constructive interference, whereby the density of the medium is maximal at the locus. An electron is of higher density than the LDI cells in the medium, whereby its equilibrium location at any given instant is with those cells in the medium whose densities are the closest to its own. These are the maximally dense cells at the locus of each diffracted wavefront. In effect, the electron “surfs” the shifting locus of constructive interference from the front screen to the rear screen.

The electron therefore illuminates the rear screen at the point at which its carrier locus strikes that screen. This process repeats each time an electron is fired, causing the rear screen to be illuminated at each point at which a locus of constructive interference strikes it. Because the spaces between the loci are left unilluminated, the bright and dark bands characteristic of an interference pattern appear after multiple electrons have been registered on the rear screen.

(Note that because the compression waves propagating in the medium are very minor, the energy they carry is minuscule. Therefore, any instruments placed in the slits to detect the passage of electrons must do so by absorbing much of the energy carried by the compression waves, thus disrupting their diffraction and ensuing interference.)

The case of monochromatic light. The interference pattern produced in the double-slit experiment in which monochromatic light passes through two nearby slits can be explained similarly. However, the wavefront in this case is of photinos concentrated in the LDI cells of the medium through which the light wavefront propagates. The

concentration of photinos is hence maximal at the locus of constructive interference where the diffracted wavefronts emerging from the two slits overlap. As the loci carrying the highest concentration of photinos reach the rear screen, they illuminate it the most, while the lower concentrations of photinos in the spaces between the loci illuminate the screen less, thereby producing a pattern of bright and dark bands characteristic of wave interference.

9 Gravitation and Cosmology

9.1 Hierarchy of Nested Cosmic Clusters

Further to the discussion on the hierarchy of nested clusters in Sec. 3.5, clusters ranked higher than C_4 (i.e., molecules) correspond to celestial bodies and higher-order systems. A C_5 cluster is thus defined as a satellite body (e.g., a planet or a moon or another body of matter) that is located within a system dominated by a local star (e.g., the solar system). A C_5 cluster consists of various substances, where each is composed of numerous C_4 systems arranged (at the strictly local level) in nearest-density order.

Dominion of a core body. For the purposes of the discussion to follow, the intangible region of space (composed principally of an LDI medium) separating the surface of a tangible body of matter that forms the core of a cluster and the outer boundary of the cluster is defined herein as the *dominion* of the core body. In effect, a dominion is the region of intangible space in which the influence of the core body predominates such that all proper elements of the medium inside the dominion are in equilibrium when arranged in order of nearest density around the core body. For instance, the dominion of Earth can be described roughly as the region of space extending from the surface of the Earth to points beyond the outer bounds of the terrestrial magnetosphere.

Note on celestial magnetic fields. In agreement with the *dynamo theory* [30], the present model suggests that the magnetic field, and hence the magnetosphere, of a celestial body very probably arises from the electromagnetic effects induced by circulating convection currents in the molten metallic outer core of the celestial body.

However, the logic of photodynamics implies that regardless of the origin of the magnetosphere surrounding a celestial body, its observable contours describe the variations in the spatial density of the dominion of the core body (see Sec. 9.3). Thus, while a celestial body may or may not possess a measurable magnetic field, every celestial body possesses a dominion whether or not there exists a magnetic field that highlights its density contours.

Cosmic unicluster. A distinction must be made between the term “cluster” in its generic sense and in the sense of a distinct object within its ambient system. A *unicluster* is hence defined herein as a unitary body that includes both components of a well-ordered cluster, namely the core

body of tangible matter that lies at the center of mass of the cluster and the dominion that surrounds the core body. A unicluster is thus a distinct physical object within its ambient medium and represents a single proper element of the higher-order host system in which it resides.

Higher-order cosmic clusters. A C_6 cluster is defined as the complete unicluster of a C_5 core body, where the unicluster resides as a unitary object within the dominion of a primary stellar body. For instance, the terrestrial unicluster consists of the Earth and its dominion and resides as a unitary object within the solar dominion.

A C_7 cluster is defined as the unicluster of a stellar body, which includes the body proper as well as its dominion. For instance, the solar unicluster consists of the Sun at its core and the solar dominion that surrounds it, where the latter occupies the region of space extending from the surface of the Sun to points beyond the outer bounds of the heliosphere. C_7 uniclusters typically reside within galaxies. However, lone C_7 uniclusters and small groups of C_7 uniclusters may also be located in otherwise unpopulated regions of intergalactic space, if they are in an equilibrium state as per Eq. (28).

A C_8 cluster is defined as the complete unicluster of a galaxy. It consists of the galactic core, together with its dominion extending to points beyond the outer bounds of the surrounding dark halo, including the LDI medium and all stellar uniclusters and other bodies of matter therein.

In turn, autonomic compulsions induce C_8 uniclusters to form C_9 groupings as galactic clusters and superclusters. From the perspective of the higher-order (C_{10}) host system, every C_9 grouping in it is just another proper element that, despite its vast scale, is indistinct from any of its other proper elements except in respect to its density.

Universe as a rank-10 unicluster. The universe as a whole is defined as a C_{10} cluster, within which the distribution of matter at all cosmic scales is described by the pattern of nested uniclusters described above. If this pattern also holds true at the C_{10} level, then the complete universe must itself be a unicluster in which the observable universe represents the core, and a grand dominion composed of an LDI medium extends far beyond the outermost reaches of the observable core.

9.2 Gravitational Mechanics

Local displacement from equilibrium $\mathcal{D}_g$. According to Eq. (28), a *satellite body* (denoted by $\ominus$) located in the dominion of a primary body $\oplus$ is in equilibrium with respect to its ambient medium when $(\rho_\ominus - \bar{\rho}_\ominus) \simeq 0$. A normalized measure of the displacement of $\ominus$ from equilibrium, $\mathcal{D}_g$, at the local level can then be defined as

$$\mathcal{D}_g \triangleq \left(\frac{\rho_\ominus - \bar{\rho}_\ominus}{\rho_\ominus} \right) = \left(1 - \frac{\bar{\rho}_\ominus}{\rho_\ominus} \right). \quad (125)$$

Dislocation from equilibrium point $\vec{\mathcal{D}}_r$. As described in Sec. 3.4, the unit vector $\hat{r}$ is outwardly normal to an imaginary spherical surface $\mathcal{S}$ of radius r , where $\mathcal{S}$ is centered on the primary body $\oplus$. Meanwhile, $\mathcal{S}$ lies within the dominion of $\oplus$, and the satellite body $\ominus$ lies on the surface $\mathcal{S}$. As described by Eq. (26), the medium in the dominion of $\oplus$ has an appreciable density gradient only in the radial direction $\hat{r}$, whereby the equilibrium location of $\ominus$ must be at a point that lies on the axis of $\hat{r}$. Let $\vec{r}_0$ be the radius vector of the point on the axis of $\hat{r}$ at which $\ominus$ is in equilibrium with respect to the primary body $\oplus$. If $\vec{r}$ is the radius vector of the extant location of $\ominus$ relative to $\oplus$, then a quantity $\vec{R}_g$ can be defined as the dislocation of $\ominus$ from its equilibrium point on the axis of $\hat{r}$ as

$$\vec{R}_g \triangleq \vec{r} - \vec{r}_0. \quad (126)$$

A quantity $\vec{\mathcal{D}}_r$ is then defined as a normalized measure of the dislocation of $\ominus$ from its equilibrium point r_0 such that

$$\vec{\mathcal{D}}_r = \frac{\vec{R}_g}{r}. \quad (127)$$

Gravitational potential energy U_g . A quantity $\mathbb{D}$ can then be further defined as the (local) displacement of $\ominus$ from equilibrium per unit dislocation of $\ominus$ from its equilibrium point on the axis of $\hat{r}$ as

$$\mathbb{D} \triangleq \frac{\mathcal{D}_g}{\mathcal{D}_r}. \quad (128)$$

Let $\mathcal{U}_g$ be a normalized measure of the potential energy of $\ominus$ such that $\mathcal{U}_g \triangleq U_g/\mathbb{D}$, where, in accordance with Eq. (14), $U_g = (k_g/2)(\vec{R}_g)^2$ is the *gravitational potential energy* induced in $\ominus$ by its dislocation $\vec{R}_g$ from the equilibrium point r_0 . Given that $n_\ominus h\nu_0$ describes the energy content of $\ominus$, while $\vec{\mathcal{D}}_r$ is a normalized measure of $\vec{R}_g$, based on Eq. (14) we obtain $\mathcal{U}_g = (n_\ominus h\nu_0/2)(\vec{\mathcal{D}}_r)^2$. Pursuant to Eqs. (5) and (127), this equation becomes $\mathcal{U}_g = (m_\ominus c^2/2)(\vec{R}_g/r)^2$, where $m_\ominus$ is the mass of $\ominus$. The previous equation can then be written equivalently as

$$U_g = \frac{1}{2} \frac{m_\ominus c^2}{r^2} \mathbb{D} (\vec{R}_g)^2, \quad (129)$$

whereby the coefficient k_g associated with the underlying proportionality relation $U_g \propto R_g^2/2$ is given as

$$k_g = \frac{m_\ominus c^2}{r^2} \left(\frac{\mathcal{D}_g}{\mathcal{D}_r} \right). \quad (130)$$

Universal gravitational function $\vec{F}_g$. Let $m_\mathcal{S}$ be the total mass contained inside the surface $\mathcal{S}$ such that

$$m_\mathcal{S} = m_\oplus + m_\ominus, \quad (131)$$

where $m_\oplus$ is the mass of the primary body $\oplus$, while $m_\boxplus$ is the total mass of all proper elements of the medium inside $\mathcal{S}$ including its constituent LDI cells, particles, and satellite bodies present therein.

From Eq. (17), U_g produces a restoring force $\vec{F}_g$ such that $\vec{F}_g = -k_g \vec{R}_g$, which as per Eq. (130) can be expressed as $\vec{F}_g = -(m_\oplus c^2 / r^2) (\mathcal{D}_g / \mathcal{D}_r) R_g \hat{r}$. Multiplying the right-hand side of this equation by $m_\mathcal{S} r / m_\mathcal{S} r$, after some algebra, we obtain $\vec{F}_g = -(rc^2 / m_\mathcal{S}) (m_\mathcal{S} m_\oplus / r^2) \mathcal{D}_g \hat{r}$. If a quantity G is defined such that

$$G = \frac{rc^2}{m_\mathcal{S}}, \quad (132)$$

then the *universal gravitational function* $\vec{F}_g$ can be stated as $\vec{F}_g = -G(m_\mathcal{S} m_\oplus / r^2) \mathcal{D}_g \hat{r}$, written equivalently as

$$\vec{F}_g = -G \frac{m_\mathcal{S} m_\oplus}{r^2} \left(1 - \frac{\bar{\rho}_\oplus}{\rho_\oplus}\right) \hat{r}. \quad (133)$$

Gravitational constant G . An intuitive understanding of the nature of the *gravitational constant* G can be gained by multiplying the right-hand side of Eq. (132) by $V_\mathcal{S} / V_\mathcal{S}$, which yields

$$\varrho_\mathcal{S} = \left(\frac{3c^2}{G}\right) \frac{1}{A_\mathcal{S}}, \quad (134)$$

where $V_\mathcal{S}$ is the spatial volume of the region enclosed in $\mathcal{S}$, while $\varrho_\mathcal{S}$ is the mass density of the contents of the region inside $\mathcal{S}$, and $A_\mathcal{S}$ is the surface area of $\mathcal{S}$. This equation implies a universal proportionality $\varrho_\mathcal{S} \propto 1/A_\mathcal{S}$, where the gravitational constant $G \approx 6.674 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$ represents a scaling factor on the constant $3c^2$, giving the coefficient of this proportionality as $3c^2/G$. Autonomic compulsions dictate that all proper elements of the system inside $\mathcal{S}$ must self-organize in order of nearest density relative to one another. In essence, therefore, Eq. (134) asserts that this order produces a spatial geometry where the density $\varrho_\mathcal{S}$ of the complete system inside $\mathcal{S}$ varies always as the inverse of the surface area $A_\mathcal{S}$ of the system.

Newton's law of gravity. In both Newton's model of gravity and Einstein's general theory of relativity, the medium of space surrounding a primary body is assumed—tacitly if not explicitly—to be an empty void. In the context of photodynamics, an empty void as the medium of the dominion of a primary body implies $m_\boxplus = 0$ and $\bar{\rho}_\oplus = 0$. It follows that when $m_\boxplus = \bar{\rho}_\oplus = 0$, Eq. (131) becomes $m_\mathcal{S} = m_\oplus$, and $\mathcal{D}_g = \left(1 - (\bar{\rho}_\oplus / \rho_\oplus)\right) = 1$, whereby Eq. (133) reduces to *Newton's law of gravity*

$$\vec{F}_N = -G \frac{m_\oplus m_\oplus}{r^2} \hat{r}, \quad (135)$$

where $\vec{F}_N$ denotes the gravitational force according to Newton's law. Thus, Newton's law of gravity represents a

limiting case of Eq. (135), where the former treats the medium of space as being devoid of any material content.

Buoyancy force. Contrary to conventional theory, Eq. (133) asserts that gravity is not a unidirectional force. If $\bar{\rho}_\oplus < \rho_\oplus$, then $\vec{F}_g$ describes an attractive force, in agreement with the conventional view of gravity. However, if $\bar{\rho}_\oplus > \rho_\oplus$, then $\vec{F}_g$ becomes a repulsive force, which in conventional theory is deemed a distinct phenomenon described as the *buoyancy force* produced by the pressure P exerted on the surface area A of a body by the medium in which it is submerged.

From the perspective of photodynamics, conventional theory presents an inverted view of the direction of causation with respect to the phenomenon of buoyancy. According to the present model, it is not the pressure exerted by the ambient medium that produces a net force in the $+\hat{r}$ direction on a submerged body. Rather, it is the force $\vec{F}_g$ acting in the $+\hat{r}$ direction that produces pressure on the body when $\bar{\rho}_\oplus > \rho_\oplus$. This conclusion follows from the definition of pressure as $P = F/A$, implying that P is a function of F_g . By contrast, as described above, F_g derives from first principles as defined by the theoretical foundations of photodynamics, implying that the direction of causation must be from F_g to P , and not vice versa.

9.3 Satellite uniclusters

According to Eq. (133), the *equilibrium condition* $\mathcal{D}_g \simeq 0$ must be satisfied for any satellite body to maintain a stable orbital distance r relative to the primary body in its host system. However, because the density of every cosmic body far exceeds that of an LDI medium, no satellite body can in itself satisfy $\mathcal{D}_g \simeq 0$, implying that there must exist another factor that enables it. A key proposition of the present model is that this enabling factor is the presence of an ultralow-density medium inside the (proportionately very large) region that makes up the dominion of a cosmic satellite body. The object that maintains a stable orbital distance r from the primary body is therefore not the satellite body proper, but rather its complete unicluster.

To satisfy the condition $\mathcal{D}_g \simeq 0$, the density of the medium in the dominion of a satellite body must be sufficiently lower than the density of the medium ambient to the satellite unicluster to offset the far greater density of the body proper within. However, the medium inside a naturally occurring *intrinsic dominion* decreases in density radially and progressively from the highest level at the surface of the body proper to the lowest level at the boundary of its unicluster with the ambient medium. This structure implies that the density of the intrinsic dominion of a body cannot become lower than that of the medium ambient to its unicluster through a purely natural process. Therefore, the lowering of the density of the dominion of a satellite body occurs synthetically and prior to its unicluster

being gravitationally locked into a stable orbit around the primary body, as follows.

Formation and structure of a satellite unicluster.

Physically, the density of a dominion is lowered by the partial inversion of the (intrinsic) dominion of the cosmic body during its gravity-induced motion toward the primary body in the host system. The structure produced by this partial inversion then resembles that produced by the motion of an aircraft through the atmosphere, in which the air ahead of the aircraft is densified while the air to its rear is rarefied. In the case of a cosmic body in motion through (say) a circumstellar LDI medium, the lowest-density outermost layers on the leading side of the (intrinsic) dominion of the moving body are dislocated to its trailing side, forming an elongated low-density *tail*. In turn, the dislocation of the outermost layers of the intrinsic dominion of the body leaves the comparatively higher-density inner layers of the dominion on the leading side exposed to the ambient medium. Moreover, some of the now exposed higher-density outer layers of the dominion on the leading side also dislocate rearward, forming a (comparatively) higher-density sheath encasing the low-density tail. Meanwhile, the density of the sheath itself decreases progressively rearward from its highest-density points on the leading side of the moving unicluster.

The density distribution inside the dominion of a moving body on the trailing side thus differs markedly from that on the leading side. On the leading side, the dominion decreases progressively in density from the surface of the body proper to the boundary of the unicluster with the ambient medium where its density becomes indistinct from that of the ambient medium. By contrast, on the trailing side the density first decreases progressively from the surface of the body proper to a region in the elongated tail where it is at its lowest level and well below that of the medium ambient to the unicluster. It then increases progressively from the lowest-density region in the tail to the boundary of the unicluster with the ambient medium where its density is indistinct from that of the ambient medium. In this way, the density of the tail is reduced synthetically to an ultralow level that is far below the density of the medium ambient to the moving unicluster. Moreover, with this density structure in place, the medium inside the tail is several orders of magnitude lower in density than the body proper, while the volume of space that the tail occupies is many orders of magnitude greater than that of the body proper.

Attainment of a stable orbit. Because of its ultralow density, a buoyancy force acts on the tail, directed antiparallel to the gravitational force acting on the body proper, which retards the onward motion of the cosmic unicluster toward the primary body of the host system. There then exists a statistically small but physically viable likelihood that there are (special) cases in which the

Fig. 19 Structure of terrestrial magnetosphere showing the large volume of space occupied by the (ultralow density) magnetotail and lobes relative to that of Earth. (Source: NASA). https://www.nasa.gov/sites/default/files/images/517890main_Earth-Magnetosphere.jpg

outward buoyancy force acting on the moving unicluster fully offsets the inward gravitational force acting on it. It follows that in any such case the net gravitational force reduces to $\vec{F}_g \approx 0$, implying that the equilibrium condition $\mathcal{D}_g \approx 0$ is satisfied, whereby the unicluster attains a stable orbit at a radial distance r from the primary body in the system. In all other cases where these conditions are not met, the moving unicluster must either gravitate into the primary body or be carried by its (high) kinetic energy into an unstable elongated orbit around the primary body.

Orbital motion of satellite uniclusters. According to this model, if a satellite unicluster is in a stable orbit at a distance r from the primary body, then its orbit is ordinarily not due to any secular motion of the unicluster relative to its ambient medium. Rather, a satellite unicluster in a stable orbit is typically stationary with respect to its ambient medium, and it is the medium in which it is located that is dragged into circular motion by the rotation of the primary body about its rotational axis. (Note that retrograde motion is an indication that a satellite may be in secular motion relative to its ambient medium.)

Contours of magnetospheres. Notably, the partially inverted density structure of the dominion of a cosmic body corresponds precisely to the structure observed in the magnetospheres of cosmic bodies (e.g., planetary magnetospheres, the heliosphere, etc. [31]). From the viewpoint of photodynamics, this is not coincidental. As stated earlier, whereas the magnetic field of a cosmic body is generated via mechanisms that are described well by the dynamo theory, the contours of its magnetosphere are formed by, and highlight, the spatial density variations in the structure of its dominion. Of particular note are the characteristic *tail lobes* observed in the *magnetotails* of those cosmic bodies that possess detectible magnetic fields (see Fig. 19). In the context of the present model, the tail

lobes describe the ultralow-density region inside the elongated tail of the dominion of a satellite body, which, as noted above, produces its orbital stability.

9.4 Implications for Cosmology

Cosmic expansion. As noted, if the pattern described by the hierarchy of nested cosmic clusters also holds true at the C_{10} level, then the complete universe must itself be a grand unicluster. If this is so, then it further suggests that the unicluster of our universe must be bounded, implying that it lies within a higher-order host system as one amongst numerous similar C_{10} uniclusters. In that case, periodic variations in the conditions prevailing in its external environment should subject the unicluster of our universe to cycles of compression and decompression that, in turn, produce alternating phases of contraction and dilation. Observational evidence indicates that the universe is currently expanding, and at an accelerating rate, which suggests that the present epoch is part of a dilation phase induced by the prevailing conditions and autonomic factors in the environment external to our universe. Notably, this conclusion contradicts the *dark energy* hypothesis [3], which postulates an unknown (internal) source of negative pressure within our universe that counteracts the gravitational self-attraction of matter to produce the accelerating cosmic expansion.

Cosmic microwave background radiation (CMBR). Photodynamics describes the observed CMBR [32] as thermal radiation emanating from the LDI cells that make up the medium of seemingly empty space across the cosmos. Each LDI cell in the medium of space acts as a blackbody that radiates energy through the process of thermal conduction as described in Sec. 4.3. Moreover, the ubiquity of radiation-emitting LDI cells across the universe implies that the distribution of CMBR must be approximately isotropic, as is observed to be the case. Observations further indicate that CMBR is (slightly) more pronounced if it emanates from those regions of the cosmos where matter is more highly concentrated than if it emanates from regions with lower matter concentration. Contrary to the conventional view, the present model implies that this is not because matter was seeded in this way in an early phase of the evolution of the universe. Rather, it is so because the LDI cells that make up the medium of space are compelled to self-organize in order of nearest density around celestial bodies, whereby they cluster more densely in regions where bodies of matter are more highly concentrated.

Trajectory of light near celestial bodies. The deflection observed in the trajectory of light traversing the space near a celestial body is described by the general theory of relativity as a gravitational effect [33]. According to photodynamics, the deflection occurs because of refraction (see Sec. 5.2). This is because the density, and hence the

refractive index, of the LDI medium inside the dominion of a celestial body increases radially inward toward the body proper, thereby causing the light to refract as it traverses the medium inside the dominion of the body.

Dark matter. The medium $\boxplus$ surrounding a primary celestial body $\oplus$ consists predominantly of LDI cells, while the spatial volume contained inside the surface $\mathcal{S}$ varies at a rate proportional to r^3 . Thus, if $\mathcal{S}$ encloses a region within the dominion of $\oplus$ in a comparatively small cosmic system (e.g., the solar system), then the total mass of the medium inside $\mathcal{S}$ is (proportionately) negligible, thus rendering $m_{\boxplus} \ll m_{\oplus}$ and hence $m_{\mathcal{S}} \approx m_{\oplus}$. Therefore, the near-equality $\vec{F}_N \approx \vec{F}_g$ holds at the (relatively) small scale of the solar system, whereby Newton's law of gravity holds true for all practical purposes at this scale.

However, if $\mathcal{S}$ is a closed surface at the periphery of a large-scale cosmic system (e.g., a galaxy or galaxy cluster), then its radius r is vastly greater than the scale of the solar system, and the volume of space contained therein is far greater still. Thus, in a large-scale system, the total mass $m_{\boxplus}$ of the LDI cells in the medium is not negligible relative to $m_{\oplus}$, rendering $m_{\mathcal{S}} > m_{\oplus}$, implying that $\vec{F}_N < \vec{F}_g$. Given that $\vec{F}_g$ takes $m_{\boxplus}$ into account whereas $\vec{F}_N$ implies that $m_{\boxplus} = 0$, if the distance of a celestial object from the primary body in its host system is so large that $m_{\mathcal{S}}$ differs considerably from $m_{\oplus}$, then the gravitational effects predicted by $\vec{F}_N$ become inaccurate.

Consequently, a pronounced deviation is observed in the gravitational behavior (e.g., the orbital periods) of celestial bodies located in the periphery of large-scale cosmic systems from their behavior as predicted by Newton's (as well as Einstein's) model of gravity. The standard cosmological model attributes this deviation to the existence of mass associated with an unseen dark matter that pervades the universe. According to photodynamics, it is the collective mass $m_{\boxplus}$ of the LDI cells that make up the medium of seemingly empty space within every system that constitutes the latent mass of dark matter.

10 Conclusion

In this paper, it has been shown rigorously that the various shortcomings known to exist in foundational physics can be resolved comprehensively through its systematic reconstruction based on a new set of purely deterministic universal principles. For instance, the new theoretical model that emerges settles the measurement problem in quantum mechanics, while in cosmology it makes explicit the hitherto unknown nature and origin of dark matter.

In this model, a modified Schrödinger equation describes the distinct energy levels of atomic spectra for not only the hydrogen atom but also for many-electron atoms, while its solutions describe the geometric coordinates of electrons inside a host atom. The fine

structure and hyperfine splitting of spectral lines have been shown to arise from well-defined structural variations in the internal composition of electrons. While spin angular momentum has been established in this model as an intrinsic feature of every electron, the sign of electron spin is shown to be inherently contextual. Thus, whereas spin is always positive for a free electron, the $\pm$ sign of the spin for a bound electron is determined explicitly by its geometric location within its host atom.

A universal gravitational function has been derived from first principles, of which Newton's law of gravity is shown to be a limiting case. The gravitational constant G has been further shown to represent an invariant scaling factor in the coefficient of an emergent universal proportionality that inversely relates the total mass density inside an arbitrary spherical surface centered on a body of matter to the area of that surface.

As is the case in contemporary physical theory, electromagnetism is of fundamental importance in the model presented in this paper not only in terms of its directly observable effects, but also with respect to atomic theory in particular. A universal electrostatic force function has been derived from first principles, of which Coulomb's law is shown to be a limiting case. Notably, this function not only describes ordinary electrostatic forces that are

attractive between unlike charges and repulsive between like charges, but also nuclear forces. It has been shown that there exist special conditions inside an atomic nucleus whose effect, mathematically, is to invert the sign of the electrostatic force, thus creating an attractive force that binds together positively charged protons along with electrically neutral neutrons into a nuclear cluster. However, the sign of the electrostatic force can readily revert to its ordinary state under certain well-defined conditions, thus restoring the repulsive force between the positively charged protons inside an atomic nucleus and thereby triggering nuclear decay. Meanwhile, the well-known equations of Maxwell's electrodynamics have been shown to describe underlying physical processes that are inherently and entirely mechanical in nature.

It has been shown that the mathematical formulae and predictions of the model presented in this paper are consistent with those of experimentally well-tested contemporary theories. Nevertheless, further experiments aimed specifically at testing those predictions of this model that go beyond the predictions of prevailing theories would be apposite to discover any limitations to which the new theoretical model may be subject.

Supplementary Materials A computer simulation of the model presented in this article and all associated files are available as supplementary materials [20]. These materials consist of four components: (i) a folder named "Simulation_Executable" containing an executable computer simulation (LatticeCellularAutomata.exe) and related .dll files; (ii) a user guide (UserGuide.pdf) that provides instructions for running the computer simulation; (iii) a short video demonstration of the simulation (Video Demonstration.mp4); (iv) a folder named "Simulation_Source Code" containing the source code of the simulation program.

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