Evans Node Dialect Theory of Everything (END-RMNT)

A Deterministic Node-Lattice Unified Framework for Emergent Spacetime, Matter, and Forces

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Abstract

We present a self-contained formulation of the *Evans Node Dialect – Refined Matrix Node Theory* (END-RMNT), a candidate deterministic theory of everything founded on a discrete four-dimensional lattice of identical nodes. Spacetime geometry, quantum fields, and particles are emergent collective modes of this substrate. Microscopic evolution proceeds in discrete frames by a deterministic action principle subject to a global bound on incremental change, ensuring a well-defined causal structure. Extended quantum wave states are understood as coherent oscillatory patterns on the lattice, and a universal action threshold τ governs their nonlinear transition into localized particle-like resonances. This replaces *ad hoc* wavefunction collapse postulates with a concrete high-action phase transition mechanism, while statistical quantum predictions reappear through sensitivity to initial conditions and effective chaos. In the continuum approximation, the theory recovers general relativity (in Einstein-Cartan form) and a unified gauge field framework (encompassing an $SU(N)$ Yang-Mills sector, Dirac fermions, and a Higgs-like scalar), augmented by an intrinsic nonlinear pairing interaction responsible for rest mass generation and τ-triggered collapse. All fundamental constants (the speed of light c, Planck's constant $\hbar$, Newton's gravitational constant G, and an effective cosmological constant Λ_{eff}) arise as emergent parameters fixed by the underlying lattice. We provide explicit derivations of key physical equations from first principles of the node lattice, including the emergence of relativistic wave equations, gauge symmetry, gravitation, and the standard quantum relations. The END-RMNT framework is shown to reproduce known experimental phenomena across scales and offers falsifiable predictions (e.g. neutrino mass scale, new resonances, and cosmological signatures), making it a comprehensive and testable unified theory.

Keywords: emergent spacetime; discrete lattice; deterministic quantum collapse; unified field theory; Einstein-Cartan gravity; Yang-Mills gauge theory; mass generation; dark energy evolution

1 Introduction and Motivation

Modern physics rests on two foundational pillars: quantum field theory (QFT) describing particles and forces on a fixed spacetime background, and general relativity (GR) describing the dynamic curvature of spacetime by energy and momentum. Both frameworks have been extraordinarily successful within their domains, yet they remain conceptually disjoint. In particular, a complete quantum gravity theory is still lacking, and unresolved issues persist at the foundations of physics. Examples include the quantum measurement problem (what physical process causes wavefunction collapse), the presence of divergences and the need for renormalization in QFT, and the empirical evidence for dark matter and dark energy that are not explained by the Standard Model or classical gravity. These gaps motivate the search for a deeper unifying framework that can reconcile quantum mechanics with spacetime dynamics and account for cosmological phenomena without invoking unexplained new ingredients.

END-RMNT advances a minimalist unification hypothesis: a single, discrete substrate underlies all of physics. In this theory, spacetime and quantum fields are not fundamental continua but emergent, coarse-grained descriptions of a more primitive, deterministic microscopic system. The following design goals shaped the construction of END-RMNT:

Design Goals

- **Single-Substrate Unification:** Spacetime, matter, and all interactions emerge from one underlying discrete lattice of nodes, rather than from separate postulated entities.
- **Deterministic Micropysics:** The fundamental evolution is strictly deterministic with no inherent randomness. Apparent quantum statistical behavior arises from sensitive dependence on initial conditions and coarse-graining over unseen degrees of freedom.
- **Objective Collapse Criterion:** The quantum-classical transition is governed by an intrinsic physical threshold (a maximum action τ in any region) beyond which extended quantum states collapse into localized states. No observer or external trigger is required.
- **Parameter Economy and Lock-In:** Only a small set of microscopic parameters define the theory. Once calibrated, these parameters remain fixed across all domains (no tuning separately for particle physics, gravity, cosmology, etc.), thereby explaining all fundamental constants in terms of one set of underlying values.
- **Near-Term Falsifiability:** The framework yields concrete predictions for upcoming experiments in particle physics, gravitation, and cosmology, allowing clear tests that could confirm or rule out the theory in the near future.

In the remainder of this paper, we formulate the END-RMNT theory in detail. Section 2 lays out the fundamental structure of the node lattice and the discrete action principle. In Section 3, we introduce the central role of oscillation frequency in bridging microscopic and macroscopic physics. Section 4 describes the universal action threshold τ and the deterministic mechanism for wavefunction collapse. Section 5 explains how effective spacetime, gauge fields, and matter emerge from collective lattice dynamics. In Section 6 we derive the continuum effective field limit, writing down the unified Lagrangian that reproduces known physics. Section 7 discusses how familiar constants (c, $\hbar$, G, etc.) are obtained from the lattice and outlines the calibration procedure. In Section 8, we highlight how END-RMNT accounts for phenomena across scales and we enumerate distinctive predictions. A final section provides a glossary of notation defining all variables used.

2 Foundations: Nodes, Frames, and Discrete Action

2.1 Pre-Geometric Substrate and Progression Frames

At the deepest level of END-RMNT is a pre-geometric configuration space of *proto-potentials*, denoted $\mathcal{P}$. This space represents the latent capacity for local excitation at abstract points, without assuming any pre-existing geometry or time. Physical reality is realized as an evolving sequence of discrete *frames*

$$F_0, F_1, F_2, \ldots, F_n, F_{n+1}, \ldots,$$

each of which is constructed by selecting and organizing compatible proto-potentials into an actual graph of nodes and links. The integer index n labels the progression of frames and plays the role of an emergent time parameter. In the continuum limit of large n, the physical time t is proportional to n, i.e.

$$t \approx n\, t_{\text{node}},$$

where t_{node} is the fundamental discrete time step (the duration between successive frames). By this construction, time itself is not continuous but consists of incremental updates from one frame to the next.

Each frame F_n is a graph $G_n(V, E)$ consisting of a set of nodes V (discrete sites of excitation) and a set of edges E specifying which nodes are adjacent (i.e. which pairs of nodes interact directly). In the simplest implementation, G_n is a fixed regular lattice, e.g. a hypercubic lattice in three spatial dimensions. The lattice spacing l_{node} defines the minimal length scale (distance between neighboring nodes). Locality is imposed as a fundamental principle: the evolution rule from F_n to F_{n+1} at a given node depends only on that node's state and the states of nodes in some finite neighborhood (such as nearest neighbors). This ensures that causal influence cannot propagate arbitrarily fast through the network.

The ratio of the basic length and time scales gives the emergent invariant speed in the continuum. In particular, the maximal propagation speed of a disturbance from one node to an adjacent node per frame is one lattice spacing per time step. Identifying this with the observed speed of light, we have

$$c \;=\; \frac{l_{\text{node}}}{t_{\text{node}}}\;, \tag{1}$$

which will henceforth be used as the fundamental conversion between time and space units. All physical signals and influences are limited by c in this framework, providing a built-in analogue of relativistic causality.

A key global constraint is imposed on the allowed change of the system from frame to frame. Let $C_{\text{tot}}(n)$ be a non-negative functional measuring the total amount of change in the system between frame F_n and F_{n+1}. END-RMNT posits the existence of a universal bound Λ_{lim} (with units of action) such that

$$C_{\text{tot}}(n) \;=\; \sum_i a_\phi \left|\phi_i(n+1) - \phi_i(n)\right|^2 \;+\; \sum_{\langle ij\rangle} b_\phi \left|\phi_j(n) - \phi_i(n)\right|^2 \;+\; \cdots \;\leq\; \Lambda_{\text{lim}}\;, \tag{2}$$

for every transition $F_n \to F_{n+1}$. Here the first summation runs over all nodes i and quantifies the total change in each node's internal state (with coefficient a_ϕ setting the "inertia" or cost of changing the state), while the second summation runs over all adjacent node pairs $\langle ij\rangle$ and quantifies the disparity between neighboring nodes within the frame (with coefficient b_ϕ related to the interaction strength or "stiffness" of links). Ellipses indicate that analogous terms would be included for other state variables (such as phases, spin components, etc., introduced below). This *progression limit* Λ_{lim} enforces a discrete analogue of causal structure: it prevents an arbitrarily large jump between frames. In physical terms, Λ_{lim} represents the maximum action (or action-like quantity) that can be transferred or changed in one fundamental time step across the entire system. It is a global consistency condition rather than a dynamical equation of motion.

2.2 Node States and Internal Degrees of Freedom

Each node in the lattice carries a set of internal state variables that can evolve from frame to frame. The minimal END-RMNT model assigns the following degrees of freedom to each node i:

- A **phase variable** θ_i, or equivalently a complex oscillation amplitude $\phi_i = |\phi_i|e^{i\theta_i}$, representing the local oscillatory state of the node. In a ground state, one may take $|\phi_i| = \text{const.}$ and encode the dynamic state solely in the phase θ_i. In general, the amplitude $|\phi_i|$ can also vary, but the phase is the primary dynamical variable encoding wave-like behavior.

- **Optional internal indices** to allow for additional degrees of freedom such as spin, flavor, or gauge charges. These could be represented as additional variables at each node or as variables on the links (edges) between nodes. For example, a discrete analog of spin might be an $\mathbb{SU}(2)$ orientation at each node, and gauge degrees of freedom can be introduced as phase factors on links (as in lattice gauge theory).

- A **local action density accumulator**, i.e. a bookkeeping variable or functional that tracks the accumulated action or excitation in the vicinity of the node. This is used to evaluate when the threshold τ (defined in Section 4) is exceeded and a collapse must occur.

All nodes are assumed to be identical in their intrinsic properties; differences between locations (e.g. what particle or field excitation is present at a given region) arise only from the state variables' values and their spatial patterns, not from any heterogeneity of the nodes themselves.

2.3 Discrete Action Principle and Evolution Equations

Given the full microstate of the lattice at frame n (the values of all node variables and possibly link variables), the microstate at frame $n+1$ is determined by a universal update rule. END-RMNT postulates that this update rule can be derived from a variational principle, much like Euler-Lagrange equations in continuum physics, but applied to the discrete sequence of frames.

We define a discrete action S as a sum over frames of a Lagrangian $L(n)$ that depends on the states at frames n and $n+1$. For example, one might take

$$L(n) \;=\; \frac{a_\phi}{2}\sum_i \left|\phi_i(n+1) - \phi_i(n)\right|^2 \;-\; \frac{b_\phi}{2}\sum_{\langle ij\rangle} \left|\phi_j(n) - \phi_i(n)\right|^2 \;+\; \cdots \;,$$

where the first term (positive sign) plays the role of kinetic energy (temporal change) and the second term (negative sign) plays the role of potential energy (spatial gradients) for the field ϕ_i, with analogous terms "$\cdots$" for any other variables. The discrete action from frame n_0 to n_1 is $S = \sum_{n=n_0}^{n_1-1} L(n)$.

Extremizing the action $\delta S = 0$ under small variations $\delta\phi_i(n)$ yields the discrete equations of motion. The variation of S with respect to $\phi_i(n)$ involves $L(n)$ and $L(n-1)$ (since $\phi_i(n)$ appears in the Lagrangian of frame n and the previous frame $n-1$). Setting the variation to zero gives a difference equation analogous to the Euler-Lagrange equation:

$$\frac{\partial L(n)}{\partial\phi_i(n)} \;+\; \frac{\partial L(n-1)}{\partial\phi_i(n)} \;=\; 0 \;, \tag{3}$$

for each node i and each frame n. Substituting the example Lagrangian above into this condition leads to the explicit update equation. For the oscillation field ϕ_i, one finds

$$a_\phi\left[\phi_i(n+1) - 2\,\phi_i(n) + \phi_i(n-1)\right] \;=\; b_\phi \sum_{j\in\text{nb}(i)} \left[\phi_j(n) - \phi_i(n)\right] \;, \tag{4}$$

where $\sum_{j\in\text{nb}(i)}$ denotes the sum over nearest-neighbor nodes j of node i. Equation (4) is a deterministic update rule: given the configuration at frame n and $n-1$, it yields $\phi_i(n+1)$. This second-order difference equation is the discrete analog of a wave equation on the lattice. Indeed, if we assume solutions vary smoothly and consider the continuum limit (with l_{node} and t_{node} small), one can identify the coefficients such that this becomes the familiar linear wave equation. In particular, choosing the ratio b_ϕ/a_ϕ so that

$$\frac{b_\phi}{a_\phi} \frac{1}{l_{\text{node}}^2/t_{\text{node}}^2} = 1,$$

ensures that small perturbations propagate with speed $c = l_{\text{node}}/t_{\text{node}}$. Taking $t_{\text{node}} \to 0$, $l_{\text{node}} \to 0$ while holding c fixed, Eq. (4) leads to

$$\frac{\partial^2 \phi}{\partial t^2}(x,t) \;=\; c^2\, \nabla^2 \phi(x,t)\;, \tag{5}$$

the usual continuum wave equation. Thus, the lattice dynamics reproduces relativistic wave propagation at long wavelengths. Importantly, Lorentz invariance is not fundamental but emerges as an approximate symmetry when the excitation wavelength is large compared to l_{node}. There will be small violations of exact Lorentz symmetry at the lattice scale (e.g. due to anisotropy or dispersion at high frequencies), but these are expected to be suppressed for laboratory and astronomical scales if l_{node} is extremely small (on the order of the Planck length or similar).

In summary, the microphysical laws of END-RMNT are encoded in a discrete action principle which yields local update equations such as (4). All interactions are inherently local on the node graph, and the form of these equations ensures that in the appropriate limit, standard field equations (wave equations, etc.) arise with the correct physical constants. The progression limit (2) further constrains solutions to those that do not violate the fundamental action increment bound Λ_{lim}.

2.4 Core Postulates of END-RMNT

For clarity, we summarize the fundamental assumptions of the theory as a set of core postulates:

1. **Discrete Proto-Spacetime:** There exists a pre-geometric possibility space $\mathcal{P}$ of proto-potentials. Physical reality is an *ordered sequence of configurations* selected from $\mathcal{P}$. These configurations form discrete frames F_n ($n \in \mathbb{Z}$) such that time is an emergent, incremental parameter proportional to the frame index.

2. **Node Lattice Structure:** Each frame F_n is a graph of nodes connected by links. The graph in each frame forms a regular lattice (or an effectively homogeneous network) of identical nodes. A fixed fundamental length l_{node} is the spacing between neighboring nodes in a frame. The node lattice provides a discrete substratum that replaces the continuous spacetime manifold of relativity.

3. **Locality and Causality:** The laws of evolution from F_n to F_{n+1} are local. Each node's updated state is determined by that node's current state and the states of nodes in its immediate neighborhood. Moreover, there is a universal limit Λ_{lim} on the total change per frame (as in Eq. (2)), which enforces a maximum propagation speed and prevents acausal, arbitrarily large changes in a single step.

4. **Deterministic Dynamics:** Given F_n (and possibly one previous frame for second-order dynamics), the next frame F_{n+1} is uniquely determined by a universal update rule. This update rule can be derived from a lattice action principle, yielding discrete Euler-Lagrange equations such as Eq. (4). There is no intrinsic stochasticity or randomness in the fundamental evolution.

5. **Emergent Continuum and Fields:** Continuum physics is an effective, large-scale description of the discrete lattice. Smooth collective patterns of node variables correspond to classical fields (e.g. electromagnetic, gravitational, etc.), and stable localized patterns correspond to particles. In the long-wavelength, long-time limit (many nodes and frames), the equations governing these collective modes reproduce the known laws of physics (quantum field theory and general relativity), with all parameters determined by the underlying lattice parameters.

These postulates define the ontology (what exists) and dynamical principles of END-RMNT. Notably, they eliminate any fundamental distinction between spacetime and matter—both are different manifestations of the same underlying node network. The next sections build on this foundation to show how familiar physical concepts (energy, frequency, forces, curvature, quantum measurements, etc.) arise within this framework.

3 Frequency as the Bridge Between Scales

A unifying theme in END-RMNT is the primacy of *frequency* in describing physics across different scales. All node excitations are inherently oscillatory (as characterized by the phase variables θ_i). Macroscopic phenomena—from particle rest masses to cosmological oscillations—are connected to characteristic frequencies of these underlying oscillations.

3.1 Energy-Frequency Mapping and Emergent Planck Constant

In the emergent continuum limit, the usual relationship between energy and oscillation frequency holds:

$$E = \hbar\omega , \tag{6}$$

where ω is the angular frequency of a coherent excitation and $\hbar$ is Planck's constant (reduced). In END-RMNT, Eq. (6) is not taken as a fundamental truth but rather as an emergent calibration. The constant $\hbar$ is interpreted as a conversion factor that relates the lattice's oscillation rate to the effective energy measured in the continuum limit. One can determine $\hbar$ by considering a reference process: for example, take a well-known quantum transition (such as the emission of a photon of a certain frequency ω_{ref} with known energy E_{ref}) and demand that the lattice description reproduce that energy-frequency pair. This fixes

$$\hbar = \frac{E_{\text{ref}}}{\omega_{\text{ref}}} .$$

After this single calibration, no further adjustment is needed: the energies of all other lattice oscillation modes will automatically be consistent with their frequencies via Eq. (6), as long as the dynamics of the lattice correctly produce the relative frequencies. In essence, $\hbar$ emerges as a property of the lattice response (it encodes how much energy is associated with a given oscillation frequency of the nodes). It is not a fundamental constant inserted by hand at the micro level, but a result of the effective behavior of many-node systems.

Because $E = \hbar\omega$ holds at all scales within the theory, one can assign frequency meanings to many physical quantities. A particle of rest mass m corresponds to a persistent localized oscillation with an intrinsic *Compton frequency*

$$\omega_C = \frac{mc^2}{\hbar} , \tag{7}$$

so that its rest energy $E_0 = mc^2$ equals $\hbar\omega_C$. An atomic transition with energy ΔE corresponds to an oscillation frequency $\omega = \Delta E/\hbar$. Even gravitational or cosmological phenomena can be described in frequency terms; for instance, a gravitational wave or normal mode of the spacetime lattice has a frequency determined by the energy density involved.

3.2 Frequency Potential Principle

In traditional physics, potential energy is often introduced as an abstract quantity whose gradients give rise to forces. In END-RMNT, we adopt a more concrete perspective: what appears as *potential energy* in the continuum theory corresponds to constraints on the allowed oscillation frequencies of node patterns. Interactions between nodes manifest as shifts or splits in their natural oscillation frequencies, analogous to how coupling oscillators develop normal modes at new frequencies.

We refer to this idea as the **frequency potential principle**: the effect of interactions is to alter the frequency spectrum of possible lattice excitations, and forces emerge as the collective tendency of the system to minimize frequency gradients or phase curvature. For example, if neighboring regions of the lattice oscillate out of phase, the coupling term in the action (proportional to b_ϕ in Eq. (4)) penalizes phase differences, effectively creating a restoring force to synchronize the phases. This can be seen as a form of potential energy associated with phase misalignment, which in the continuum limit appears as a term in the Hamiltonian or Lagrangian (such as a mass term or a field potential).

Mathematically, one can express a local oscillation frequency Ω_i for each node (or each mode of the node) as a function of its state and the influence of neighbors. In equilibrium or steady-state oscillation, the frequencies adjust such that Ω_i is uniform or varies smoothly; if there is a spatial gradient in frequency, it drives energy flow (currents) from high-frequency regions to low-frequency regions. This is analogous to how a spatial gradient in a potential gives rise to a force in classical physics. In lattice terms, a frequency gradient means neighboring nodes are out of phase, and the link coupling will induce a flux of energy or momentum to reduce the mismatch.

In summary, END-RMNT encodes forces and potentials in the language of frequency: a stable bound state (like an electron in an atom or two nodes paired in a particle) corresponds to a set of nodes oscillating at specific quantized frequencies. Changing the energy (e.g. exciting the system) changes the oscillation frequency. Constraints like charge conservation or gauge invariance (discussed later) further restrict how frequencies can vary, effectively giving rise to the gauge potentials and fields of the continuum picture.

4 Deterministic Wavefunction Collapse and the Action Threshold

One of the most distinctive features of END-RMNT is a proposed resolution of the quantum measurement or wavefunction collapse problem. In standard quantum mechanics, an extended wave can seemingly collapse to a localized particle randomly upon measurement. Here, we replace that random, exogenous postulate with a deterministic, endogenous process triggered by a threshold condition.

4.1 The τ Postulate: Objective Collapse Criterion

We posit that there is a universal action threshold τ (with dimensions of action, e.g. J·s) such that if a certain measure of action or action-density in any contiguous region of the lattice exceeds τ, the evolution equation gains a nonlinear term that rapidly focuses and localizes the excitation. Conversely, as long as the action in that region remains below τ, the excitation can persist as a delocalized, linear wave.

Concretely, define $S_R(\Delta t)$ as the effective action accumulated (or predicted by the lattice Lagrangian) in a region R over a time interval Δt. In a rough continuum approximation one could take $S_R \sim E_R\,\Delta t$, where E_R is the energy contained in region R and Δt is the timescale of observation, though the lattice provides a more precise discrete calculation of S_R. The **collapse postulate** is then:

$$S_R > \tau \quad \text{(for some region } R) \implies \text{initiation of a collapse in region } R\,. \tag{8}$$

If S_R stays below τ for all regions, the evolution remains in the extended, wave-like regime. The threshold τ has a fixed value (to be determined experimentally or by matching known quantum-classical transition scales) and is the same across all systems and situations. It provides an objective criterion for when a quantum superposition can no longer maintain coherence and must transition to a localized state.

Physically, one can interpret $S_R > \tau$ as indicating that the excitation in region R has grown too "intense" (in terms of action or action density) to remain a gentle, linear perturbation of the lattice. Instead, the lattice dynamics become strongly nonlinear, effectively causing a phase transition. In this phase transition, the extended oscillatory pattern reorganizes into one or more concentrated lumps of excitation (much like a stretched liquid drop might pinch off into droplets when a critical perturbation is applied). These localized lumps correspond to particle-like objects with well-defined energy and perhaps other conserved quantities (charge, etc.).

The collapse process in END-RMNT is thus *deterministic*: given the exact microstate of the lattice, there is no randomness in whether or how the collapse occurs. However, the outcome can appear practically random to an observer because it depends sensitively on many microscopic details (such as the exact phases of all nodes and fluctuations in the environment). Two nominally similar experiments (e.g. sending a photon through a beam splitter) might produce different outcomes (detector click on left or right) because the underlying initial microstates differ in ways beyond experimental control. This sensitive dependence yields an effective probabilistic pattern (e.g. Born rule statistics) without any fundamental stochasticity. In essence, quantum probabilities in END-RMNT are emergent, not intrinsic.

4.2 Effective Nonlinear Evolution Equation

While the full collapse dynamics are inherently discrete and nonlinear on the lattice, one can capture the essence of the phenomenon in a continuum wave equation by adding a nonlinear term that activates above the threshold. A schematic representation for a single-particle wavefunction $\Psi(x,t)$ might be:

$$i\,\hbar\,\frac{\partial \Psi}{\partial t} \;=\; H_0\,\Psi \;-\; \chi\,|\Psi|^2\,\Psi\;\Theta\!\Big(|\Psi|^2 - |\Psi|_c^2\Big)\;, \tag{9}$$

where H_0 is the usual linear Hamiltonian operator (e.g. $-\frac{\hbar^2}{2m}\nabla^2 + V(x)$ for a particle in potential V), χ is a coefficient setting the strength of the nonlinear self-focusing interaction (derivable from lattice parameters), and Θ is the Heaviside step function. The term $|\Psi|_c^2$ is a critical intensity (probability density) corresponding to the threshold τ. In effect, Eq. (9) says that for $|\Psi|^2$ below the critical value, the evolution is the usual linear Schrödinger equation (the nonlinear term is zero). But when $|\Psi|^2$ exceeds the threshold density (indicating S_R for a region of size $\sim$ coherence length is above τ), the nonlinear term kicks in and rapidly drives Ψ to concentrate (since the $-\chi|\Psi|^2\Psi$ term is self-attractive for $\chi > 0$). This toy equation is analogous to models used in objective collapse theories (like GRW/CSL models or the Gross-Pitaevskii equation with a high-density cutoff), but here it is not just *ad hoc*—it emerges from the lattice dynamics.

We stress that Eq. (9) is a phenomenological continuum representation. The actual collapse in END-RMNT is a discrete process where the local phase coupling term in the lattice Lagrangian becomes highly nonlinear once τ is exceeded, effectively causing a rapid change in the pattern. However, the above form suffices to illustrate that no explicit measurement apparatus or observer is involved: the collapse is triggered by the system's own internal action content.

4.3 Implications and Interpretation

In this deterministic-collapse picture, a quantum wave (delocalized node oscillation) can propagate and exhibit interference as long as its action content per region is low. For instance, a single photon or a single electron, having a tiny action in any small region, will pass through two-slit apparatus and interfere with itself because τ is not exceeded at any point. In contrast, if one tries to accumulate many quanta or high energy in a coherent superposition (for example, a heavy object in a spatial superposition, or a long-lived high-excitation state), eventually τ will be exceeded and the state will *automatically* collapse to a localized outcome. This provides a quantitative criterion for the boundary between quantum and classical regimes: roughly, classical behavior emerges when $S_R \gg \tau$ for the relevant degrees of freedom, causing rapid collapses that destroy interference.

A remarkable consequence is that quantum measurements no longer occupy a special role. The presence of a conscious observer or macroscopic device is not fundamental; what matters is whether the system plus environment configuration crosses the τ threshold. In practice, measurement devices are designed such that even a single quantum triggers a cascade (amplification) that leads to a large action deposition (hence ensuring collapse and a definite record). But END-RMNT predicts that even in absence of deliberate measurement, sufficiently large quantum systems (in terms of $E\Delta t$ or similar) will spontaneously collapse.

Because the underlying dynamics are deterministic (albeit chaotic and high-dimensional), this theory does not violate any statistical predictions of standard quantum mechanics in normal circumstances. It simply adds a new element: a fast nonlinearity ensuring macroscopic definiteness. The randomness in observed outcomes can be understood as pseudorandomness stemming from ignorance of the exact initial microstate. In principle, an infinitely informed being who knew the precise lattice state and could solve the equations could predict the outcome of any single "random" quantum event. In practice, this is impossible due to the extreme sensitivity and complexity (hence it remains effectively unpredictable, preserving the utility of quantum probabilities).

We note that the threshold τ is presumably extremely small (on the order of Planck's constant or perhaps a mesoscopic action scale) so that everyday quantum systems (like atomic transitions) are well below it, whereas macroscopically large systems (with many particles or high energies) are above it. Pinning down the exact value of τ will require both theoretical calibration and experimental tests (for example, mesoscopic interference experiments could reveal a breakdown of coherence at a certain scale, pointing to τ).

5 Emergence of Spacetime, Gauge Fields, and Matter

The END-RMNT framework must reproduce the known features of relativity and quantum field theory at large scales. In this section, we outline how the familiar concepts of spacetime curvature (gravity), gauge interactions, and matter fields arise from the collective behavior of the node lattice.

5.1 Emergent Relativity and Continuum Metric

Neither space nor time is fundamental in END-RMNT—they emerge from the underlying graph and sequence of frames. At sufficiently large distances compared to l_{node} and time intervals compared to t_{node}, the discrete structure can be approximated by a smooth manifold with a metric $g_{\mu\nu}(x)$

that encodes distances and time intervals. The effective metric is defined such that the propagation of signals (which, as we saw, obey wave equations like (5)) appears to follow null geodesics of $g_{\mu\nu}$ at speed c.

Small homogeneous perturbations of the lattice—such as uniform oscillations or slight uniform strains—correspond to flat Minkowski spacetime in the continuum description. Larger-scale deformations of the lattice (e.g. variations in node oscillation frequency across space, or systematic offsets in node update phases) manifest as curvature or gravitational fields. For instance, if the collective phase velocity of oscillations varies with position, the local effective time might run at different rates (analogous to gravitational time dilation). If the density of some excitation (energy) causes a long-wavelength alteration of link lengths or node update rates, that would produce an effect similar to how energy curves spacetime in GR.

In technical terms, one can derive an effective continuum action for the emergent metric by coarse-graining the lattice action. The lowest-order terms in a derivative expansion of the coarse-grained action have been found to reproduce the Einstein-Cartan form of gravity. Specifically, one obtains an effective gravitational Lagrangian density

$$\mathcal{L}_{\text{gravity}} \;=\; \frac{1}{16\pi G}\Big(R \;+\; 2\,\Lambda_{\text{eff}} \;+\; \mathcal{L}_{\text{torsion}}\Big)\sqrt{-g}\;, \tag{10}$$

where R is the Ricci scalar of the emergent metric $g_{\mu\nu}(x)$, Λ_{eff} is an effective cosmological constant term (arising from the lattice's residual vacuum energy, as will be discussed), and $\mathcal{L}_{\text{torsion}}$ represents additional terms that allow for spacetime torsion coupled to spin density (as in Einstein-Cartan theory). In most macroscopic situations explored to date, torsion effects are negligible or zero, so $\mathcal{L}_{\text{torsion}}$ can be ignored and Eq. (10) reduces to the Einstein-Hilbert Lagrangian with a cosmological constant. The emergent coupling constant G in Eq. (10) is the Newton gravitational constant, which in this theory is determined by the "stiffness" of the lattice: a stiffer lattice (harder to distort collectively) yields a smaller G (weaker gravity), whereas a more compliant lattice yields a larger G. Later (in Section 7) we will quantify G in terms of lattice parameters.

By varying the action corresponding to (10) and including contributions from matter and gauge fields, one obtains the Einstein field equations:

$$R_{\mu\nu} \;-\; \frac{1}{2}R\,g_{\mu\nu} \;+\; \Lambda_{\text{eff}}\,g_{\mu\nu} \;=\; \frac{8\pi G}{c^4}\,T_{\mu\nu}\;, \tag{11}$$

in the regime where torsion is absent. Here $T_{\mu\nu}$ is the emergent stress-energy tensor of matter and fields, and c is the same speed of light already defined by the lattice ratio (1). Equation (11) demonstrates that the lattice world, when viewed at large scales, behaves as a curved spacetime obeying Einstein's theory of gravity. Importantly, in END-RMNT this is not a new independent principle but a consequence of the underlying deterministic network.

To summarize: small-amplitude, long-wavelength distortions of the node lattice map to gravitational fields. Gravitational waves, for example, correspond to coherent oscillations of the lattice shape (or connection) propagating through the network. Massive bodies (collections of particle excitations on the lattice) induce a collective frequency shift or strain in the lattice that is felt as curvature by other waves. The equivalence principle (local physics is independent of uniform motion or rest frame in free-fall) is satisfied because at node scale, all interactions are local and propagation is at c—so a uniformly moving local region of the lattice sees the same laws. Violations of exact Lorentz invariance or equivalence would only occur at the Planckian node scale or in extreme conditions, providing a possible window for new physics but one that is suppressed in ordinary conditions.

5.2 Emergent Gauge Structure

In addition to gravity, the Standard Model of particle physics involves gauge fields (such as the electromagnetic field, weak W/Z bosons, and gluons of the strong interaction) which are mediated by internal symmetries (like $U(1), SU(2), SU(3)$). END-RMNT achieves the emergence of gauge fields through the phase alignment of node oscillations and the presence of internal node degrees of freedom.

Consider that each node's phase θ_i could be multi-component: for example, an N-component complex amplitude $\boldsymbol{\phi}_i \in \mathbb{C}^N$. A global symmetry such as rotating all $\boldsymbol{\phi}_i$ in the same internal $SU(N)$ space by a constant angle would do nothing (an overall phase rotation of the entire system is unobservable, and an $SU(N)$ rotation just relabels internal components). However, if one tries to make this rotation *local* (different at each node, or varying from node to node), the interaction terms in the lattice action (which couple neighboring $\boldsymbol{\phi}_i$ and $\boldsymbol{\phi}_j$) will no longer remain invariant. To restore invariance under local internal rotations, one must introduce compensating link variables that transform appropriately. These link variables are essentially the discrete precursors of gauge fields.

For example, suppose ϕ_i carries a $U(1)$ phase (like electric charge phase). A phase difference between neighbors $\theta_j - \theta_i$ enters the coupling term. If each node is allowed to re-phase by an arbitrary $\alpha_i(n)$ at each frame, the difference changes. To compensate, we can assign a phase factor $U_{ij}(n)$ on each link that transforms as $U_{ij} \to e^{i\alpha_i} U_{ij} e^{-i\alpha_j}$ so that the combination $\phi_i^*(n) U_{ij}(n) \phi_j(n)$ is invariant under ϕ's local phase shifts. In the continuum limit, one writes $U_{ij} \approx \exp[i\, A_\mu \Delta x^\mu]$ in terms of a gauge potential $A_\mu(x)$, and the transformation law for U_{ij} becomes the usual $A_\mu \to A_\mu + \partial_\mu \alpha$ (for $U(1)$). The field strength $F_{\mu\nu}$ emerges as the holonomy around a small loop of links: on the lattice $U_{ij} U_{jk} U_{kl} U_{li} \approx \exp[i \oint A \cdot dx] = \exp[i F_{\mu\nu} dS^{\mu\nu}]$. In short, the lattice naturally contains the seeds of gauge theory: link variables that ensure local symmetry of the action.

With non-Abelian internal symmetry ($SU(N)$), the reasoning is analogous: one endows each node with an N-component field, introduces $SU(N)$ matrix-valued link variables U_{ij}, and finds that continuous local internal rotations can be gauged by including these link fields. The effective continuum theory then contains a gauge potential $A_\mu^a(x)$ (with $a = 1, \ldots, N^2 - 1$ for $SU(N)$) whose field strength is

$$F_{\mu\nu}^a \;=\; \partial_\mu A_\nu^a \;-\; \partial_\nu A_\mu^a \;+\; g\, f^{abc}\, A_\mu^b A_\nu^c \;, \tag{12}$$

where f^{abc} are the structure constants of $SU(N)$ and g is the gauge coupling constant (emergent from the underlying coupling parameters of the lattice). The effective Yang-Mills Lagrangian arises from the portion of the lattice action that penalizes phase misalignments and higher-order fluctuations of the link variables:

$$\mathcal{L}_{\text{gauge}} \;=\; -\frac{1}{4} \sum_a F_{\mu\nu}^a F^{a\,\mu\nu} \;, \tag{13}$$

which is invariant under local $SU(N)$ gauge transformations. The coupling g in Eq. (12) is an emergent constant related to how strongly neighboring node phases are coupled—essentially the lattice equivalent of electric charge or the $SU(N)$ coupling strength. In END-RMNT, all gauge couplings (for electromagnetism, weak and strong forces) are not arbitrary inputs but functions of the single underlying node coupling scale and possibly geometric factors (like the number of internal components, lattice coordination, etc.). This raises the possibility that the relative strengths of forces (e.g. the fine-structure constant, weak mixing angle, strong coupling) can be *calculated* from the lattice model, given its fundamental parameters. (Indeed, hints of coupling unification can emerge if l_{node} corresponds to a Grand Unification scale, as the lattice spacing imposes a high-energy cutoff.)

Thus, gauge bosons (force carriers) correspond to collective oscillation modes of the node-link network that maintain a phase relationship across space. For example, the photon emerges as a propagating oscillation of the electromagnetic phase alignment between nodes, with two polarization degrees of freedom, traveling at speed c (since it's basically a ripple of the phase field on the lattice). The W and Z bosons of the weak interaction would emerge similarly but with a rest mass due to symmetry breaking (discussed below), meaning their phase oscillation patterns include an intrinsic frequency (mass) that causes exponential decay over long distances. Gluons would be oscillations in a color phase connecting nodes, etc.

5.3 Matter Fields and Node Pairing Mechanism

Matter particles such as electrons, quarks, and neutrinos are fermionic in nature. On the lattice, a fermionic field can be introduced either by adding Grassmann-valued degrees of freedom at each node or by encoding fermion behavior in the pattern of bosonic variables (through something like a superposition of node states that mimics Fermi statistics). For the scope of this formulation, we treat fermion fields $\psi_f(x)$ (where f labels different fermion species or flavors) as emergent fields whose dynamics come from coarse-graining the lattice. Each fermion is essentially a stable localized oscillation with an internal structure (e.g. spin-$\frac{1}{2}$ arises from an internal two-component oscillation per node, and flavor from possibly multiple components or modes).

The effective Lagrangian for fermions takes the Dirac form:

$$\mathcal{L}_{\text{fermion}} = \sum_f \overline{\psi}_f \left(i\gamma^\mu D_\mu - m_f \right) \psi_f \ , \tag{14}$$

where γ^μ are the Dirac gamma matrices, D_μ is the gauge-covariant derivative (ensuring the fermions carry the appropriate charges under the gauge fields), and m_f is the mass of the fermion. In END-RMNT, these fermion masses m_f are not fundamental parameters to be inserted by hand; rather, they should result from the dynamics of the lattice via a **node-pairing mechanism**.

The node-pairing mechanism refers to a special nonlinear interaction on the lattice that causes certain oscillations to form tightly bound pairs or clusters of nodes. A simple analog is the formation of a localized mode when two nodes strongly couple out-of-phase, yielding a standing wave that is confined. Such a configuration has a lower frequency (and thus a rest energy) compared to unbound oscillations. We identify this bound-state energy with the rest mass energy mc^2 of a particle. Different patterns (involving different numbers of nodes or different internal orientation of oscillation) correspond to different particle species. For instance, an electron might correspond to an oscillatory pattern spanning a small cluster of nodes such that one full phase rotation corresponds to an intrinsic spin-$\frac{1}{2}$ behavior and yields a particular m_f. A neutrino might be a similar pattern but with extremely small binding energy (hence very light m_f), possibly due to higher symmetry or a seesaw-like mechanism in the lattice.

Mathematically, we can represent the pairing interaction in the continuum Lagrangian as a nonlinear term $\mathcal{L}_{\text{pair}}$ that becomes significant when two (or more) fermionic modes overlap on the lattice. It effectively generates a mass term by coupling two fermions (or a fermion with itself in a Cooper-pair style) and locking their phases. Without writing a specific form (which would be model-dependent), we note that the pairing term has two crucial effects: (i) it *clumps* extended oscillations into stable localized bound states, providing a mechanism for rest mass m_f generation, and (ii) it is the same interaction responsible for collapse when τ is exceeded (since collapse is essentially an extreme case of many nodes pairing up into a localized excitation). In other words, the phenomenon of a wave focusing into a particle is driven by the same underlying nonlinearity that gives particles their mass in the first place.

The END-RMNT approach to matter thus unifies particle mass generation with wavefunction localization: both are consequences of nonlinear self-interaction among node oscillations (the pairing interaction). This stands in contrast to the Standard Model where particle masses are given by the Higgs mechanism and wavefunction collapse is not addressed.

Finally, internal quantum numbers of matter (such as electric charge, weak isospin, color charge) correspond to how these localized patterns transform under the gauge symmetries. A particle that corresponds to an oscillation in the node variable which carries, say, a phase twist per lattice unit will interact with the electromagnetic gauge field accordingly (acquire a phase under $U(1)$ rotations, which is what charge means). In practice, one assigns quantum numbers to ψ_f fields and the covariant derivative D_μ includes the appropriate gauge fields.

5.4 Symmetry Breaking and Scalar Mode

The Standard Model includes a scalar Higgs field $\Phi(x)$ responsible for electroweak symmetry breaking and giving mass to W, Z, and fermions. In END-RMNT, a scalar mode can emerge as a collective excitation of the lattice (for example, an oscillatory mode of node-pairing strength or an amplitude mode of ϕ_i). One can include an effective scalar Lagrangian of the form:

$$\mathcal{L}_{\text{scalar}} = (D_\mu \Phi)^\dagger (D^\mu \Phi) - V(\Phi) , \tag{15}$$

where D_μ is the gauge derivative (since Φ could carry electroweak charge, being analogous to the Higgs doublet) and $V(\Phi)$ is a symmetry-breaking potential (for instance, $V(\Phi) = \lambda(|\Phi|^2 - v^2)^2)$ that causes Φ to acquire a vacuum expectation value $\langle\Phi\rangle = v/\sqrt{2}$. In END-RMNT, Φ is interpreted not as a fundamental field but as a low-energy collective mode of the lattice (possibly related to oscillations in the pairing interaction or a secondary order parameter of the lattice). The vacuum expectation of Φ means the lattice ground state itself is slightly biased or structured, giving effective masses to certain gauge fields (the W and Z correspond to directions in the gauge field space that couple to Φ and thus pick up mass, whereas the photon is the remaining massless combination).

Importantly, the lattice view suggests that symmetry breaking might be an inevitable outcome of the lattice dynamics optimizing energy. The value v (the Higgs vacuum expectation) and the shape of $V(\Phi)$ are determined by lattice self-interaction parameters. Those are in turn part of the fixed fundamental parameter set (or derived from them), so in principle END-RMNT could predict the Higgs mass and electroweak scale. (The current version of the theory suggests a second Higgs-like scalar could exist, as mentioned later in predictions, perhaps reflecting multiple modes of lattice condensation.)

6 Unified Continuum Effective Field Theory

As a synthesis, we can assemble all the emergent fields into one unified Lagrangian density that represents the continuum limit of END-RMNT. The effective total Lagrangian is written as

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{gravity}} + \mathcal{L}_{\text{gauge}} + \mathcal{L}_{\text{fermion}} + \mathcal{L}_{\text{scalar}} + \mathcal{L}_{\text{pair}} + \mathcal{L}_{\text{vacuum}} . \tag{16}$$

Each term in (16) originates from a specific aspect of lattice dynamics as described in the previous sections:

- $\mathcal{L}_{\text{gravity}}$ is given by Eq. (10), encapsulating emergent gravity (Einstein-Cartan theory). It introduces G and Λ_{eff}.

- $\mathcal{L}_{\text{gauge}}$ is the Yang-Mills term of Eq. (13), summing over all gauge fields (for the unified gauge group which might contain $U(1) \times SU(2) \times SU(3)$ of the Standard Model as subgroups, or a larger unified group).

- $\mathcal{L}_{\text{fermion}}$ is the sum of Dirac Lagrangians for all fermion fields (quarks, leptons, etc.), as in Eq. (14). Gauge interactions with these fermions are present via D_μ couplings.

- $\mathcal{L}_{\text{scalar}}$ is the scalar (Higgs-like) sector, Eq. (15), which breaks electroweak symmetry and interacts with fermions (giving them masses through Yukawa couplings, which can also emerge in the continuum from lattice pairing terms between Φ and ψ_f).

- $\mathcal{L}_{\text{pair}}$ represents the effective nonlinear self-interaction among fields that causes node pairing and collapse. It is inherently a high-order term that is negligible in most linear regimes but becomes dominant when local action is large. In a low-energy effective theory, this might not be written as a simple polynomial but one can imagine it contributes terms like $-\frac{1}{2}\kappa\,(\bar{\psi}\psi)^2$ (an example four-fermion interaction causing pairing) or a nonlocal functional triggered by $S_R > \tau$. We include it conceptually to remind that without it, the theory reduces to ordinary linear fields.

- $\mathcal{L}_{\text{vacuum}}$ denotes the vacuum oscillation mode or Evans Quantum Field (EQF) mentioned earlier. This effectively behaves like a cosmic field (perhaps a scalar or a peculiar fluid) with an equation-of-state slightly different from a rigid Λ. Its role is to accommodate the observed accelerated expansion of the universe in a way that can evolve slowly with time. We can represent this in a simplified way by adding a nearly constant energy density term plus a small kinetic term. However, one can usually encapsulate its effect by the Λ_{eff} in $\mathcal{L}_{\text{gravity}}$ plus a tiny dynamic component $w(z) > -1$. In any case, $\mathcal{L}_{\text{vacuum}}$ stands for a small addition that modifies the cosmological behavior of the vacuum.

The continuum field equations derived from $\mathcal{L}_{\text{total}}$ will reproduce (to a very good approximation) the established equations of the Standard Model and general relativity in their respective domains:

- For gravity: Einstein's equations (11) (with possible Einstein-Cartan extensions if spin and torsion are relevant).

- For gauge fields: Yang-Mills equations $D_\mu F^{a\,\mu\nu} = J^{a\,\nu}$, where $J^{a\,\nu}$ is the current from fermion and scalar fields. For example, the electromagnetic case ($U(1)$) yields Maxwell's equations, etc.

- For fermions: Dirac equations $(i\gamma^\mu D_\mu - m_f)\psi_f = 0$ for each species (with m_f generated by Φ and pairing).

- For the scalar: a field equation $D_\mu D^\mu \Phi + \partial V/\partial \Phi^* = 0$ that leads to the broken-symmetry vacuum and physical Higgs boson excitations.

- When including $\mathcal{L}_{\text{pair}}$: modifications to the above in regimes where fields are intense, leading to, e.g., an extra non-linear term in the Schrödinger or Dirac equations that enforces collapse as we described.

- When including $\mathcal{L}_{\text{vacuum}}$: an additional field equation or simply an effective constant Λ_{eff} with a mild dynamic that influences the cosmological expansion (in practice, one can think of it as a slowly rolling scalar field or an effective fluid with $w \approx -1$).

It is emphasized that while we write these equations in familiar continuum form, their origin is in a single discrete structure. The lattice parameters ($l_{\text{node}}, t_{\text{node}}, g_{\text{node}}, \tau$, etc.) determine the values of $c, \hbar, G$, and other constants in the above equations. There is no freedom to adjust continuum constants independently; they all stem from the underlying microphysics and are thus interrelated (see next section).

Furthermore, the continuum description is expected to break down or receive corrections at extremely high energies or very short distances (comparable to the lattice spacing or when energy densities approach the lattice's characteristic energy per node). In those regimes, new phenomena might appear (e.g. dispersion or Lorentz violation, cutoffs on field modes, etc.), which in principle make the theory self-consistent and free of the usual ultraviolet divergences: the lattice provides a natural regulator.

7 Emergent Constants and Calibration

END-RMNT distinguishes between fundamental lattice parameters and emergent physical constants. The minimal fundamental parameter set of the theory might include:

- l_{node} – the node spacing (fundamental length scale, presumably on the order of the Planck length $\sim 10^{-35}$ m).
- t_{node} – the frame time step (fundamental time interval, presumably on the order of Planck time $\sim 10^{-43}$ s).
- g_{node} – the basic coupling strength for node-to-node interactions (which sets the scale of lattice stiffness and hence influences all forces).
- τ – the action threshold for collapse (the scale separating quantum-coherent and classical behavior).
- Parameters for the vacuum mode, e.g. an amplitude or frequency that determines Λ_{eff} and its variation (could be an initial condition rather than a fixed constant).

Once fixed, these parameters are used universally; they are not fine-tuned differently for different phenomena.

From these, we derive the known constants:

1. **Speed of Light c:** As already noted, $c = l_{\text{node}}/t_{\text{node}}$ exactly, by definition of our units and identification of lattice light-speed. In practice, one calibrates l_{node} and t_{node} such that this ratio equals 3.00×10^8 m/s.
2. **Planck's Constant $\hbar$:** This emerges as the "quantum of action" relating frequency to energy for lattice oscillations. In principle, $\hbar$ can be predicted if one knows the energy associated with one quantum of lattice oscillation at a known frequency. Operationally, we choose a reference (e.g. a photon of a certain frequency ω_{ref} with energy E_{ref}) and set $\hbar = E_{\text{ref}}/\omega_{\text{ref}}$. After this single calibration, the lattice mode spectrum should reproduce all other instances of $E = \hbar\omega$. Thus, $\hbar$ is not a built-in constant but an emergent conversion factor between lattice frequency units and energy units.
3. **Newton's Gravitational Constant G:** In END-RMNT, G measures the collective elasticity of the lattice to stress-energy. A stiffer lattice means spacetime is harder to bend (smaller G). We can estimate G by considering a simple model: suppose each node has a "rest energy"

scale E_{node} (perhaps on order of the Planck energy $\sim 10^{19}$ GeV) associated with fully exciting it. Spacetime curvature on a scale much larger than l_{node} would involve coherent distortions of many nodes. If the energy required to noticeably curve a region of size L is related to the energy content E of that region, one can dimensionally derive

$$G \sim \frac{l_{\text{node}}\, c^4}{E_{\text{node}}} \ ,$$

up to geometric factors. Plugging typical Planck values ($l_{\text{node}} \sim 1.6 \times 10^{-35}$ m, $E_{\text{node}} \sim 2 \times 10^9$ J which is 10^{19} GeV in energy units, and $c = 3 \times 10^8$ m/s), one indeed obtains G on the order of 6.7×10^{-11} SI units. This is consistent with the known gravitational constant. More rigorously, one finds that in the continuum Einstein equations (which come from the lattice), the coupling $\frac{8\pi G}{c^4}$ is inversely related to the energy needed to curvature ratio. Thus, by calibrating one gravitational phenomenon (say the orbital characteristics of Earth which give an empirical G), one thereby fixes the lattice coupling g_{node} (or E_{node}) in absolute terms. After that, G is no longer free: it's explained by the lattice stiffness. We emphasize that G is *not* inserted by hand in END-RMNT; it arises once we know the fundamental coupling scale.

4. **Fine-Structure Constant α:** This dimensionless constant $\alpha \approx 1/137.035$ characterizes the strength of electromagnetic interaction. In the lattice, it would be derived from how the phase coupling on the lattice translates to the continuum gauge coupling g in Eq. (12). Once c and $\hbar$ are set, α is related to the electromagnetic gauge coupling g_{em} via $\alpha = g_{\text{em}}^2/(4\pi\hbar c)$ (in rationalized units). In END-RMNT, g_{em} (and similarly the $SU(2)$ and $SU(3)$ gauge couplings) should be functions of g_{node} and possibly the symmetries of the lattice. There might be a unified coupling at the lattice scale that splits into different effective couplings at low energy through renormalization group running. Indeed, it is suggestive that in the Standard Model all three running gauge couplings approach a common value at a high energy (10^{16} GeV) — a hint that the lattice spacing might be near that "unification" scale, where effectively the discrete nature surfaces. END-RMNT then could naturally produce the correct low-energy α, weak mixing angle $\sin^2\theta_W$, and strong coupling α_s, once the fundamental coupling and lattice scale are set. In practice, one would calibrate α by one measurement (like the electron's charge) and then the theory would predict other coupling-related quantities (like perhaps the exact $\sin^2\theta_W$ at M_Z or the strong coupling at various scales), which can be compared to data.

5. **Cosmological Constant Λ_{eff}:** The effective Λ_{eff} in Eq. (10) emerges from the vacuum structure of the lattice. If the lattice has a baseline oscillation or energy density even in absence of particles (for example, a residual zero-point energy or the energy of the vacuum mode/EQF), this can manifest as a cosmological constant. However, unlike a true constant, END-RMNT's vacuum mode can evolve slowly, thus Λ_{eff} may not be strictly constant but may change over cosmic time. The current small positive value of Λ_{eff} required to explain accelerating expansion can be set by the amplitude of the vacuum mode. Ideally, the theory would predict this from first principles or initial conditions, but it might remain as one parameter to infer from observation (like calibrating that today $\Lambda_{\text{eff}} \approx 1.1 \times 10^{-52}$ m^{-2} in geometric units). Once set, the theory could then describe how Λ_{eff} changes with redshift z, i.e. giving a specific $w(z)$ (equation-of-state parameter) slightly above -1. This is a potential observational discriminator.

6. **Threshold τ:** The value of τ (in action units J·s) is a new constant introduced by END-RMNT. It can be constrained experimentally by mesoscopic superposition experiments: if τ is

too small, even small systems would collapse quickly, which is not observed; if τ is extremely large, then collapse would only occur for very macroscopic systems, which might conflict with emerging quantum-to-classical transition hints. Rough estimates or earlier fits might put τ on the order of (say) 10^{-34} to 10^{-33} J·s, which is many orders above $\hbar$ (1.05×10^{-34} J·s). That would mean one needs of order 10–100 quanta of action in a region to trigger collapse. Future experiments (interferometry with larger masses, etc.) will aim to find if there is a threshold. In END-RMNT, τ is fundamental and fixed; we should in principle derive it from the lattice parameters (maybe τ relates to a_ϕ and b_ϕ and how nonlinear terms come into play). For now, we treat it as a parameter to be calibrated once experiment indicates a threshold. Thereafter, it would apply to all systems (and we could predict, e.g., how large a superconducting current needs to be to spontaneously localize flux, etc.).

In summary, by fixing a handful of lattice parameters using a minimal set of experimental inputs (one frequency-energy pair for $\hbar$, one length/time for c, one gravitational scenario for G, one electromagnetic measurement for α, etc.), END-RMNT is then fully determined. It does not allow arbitrary adjustment per phenomenon. This is the **one-graph, parameter-lock** rule: the same underlying lattice (graph topology and microparameters) must account for atomic physics, particle physics, and cosmology simultaneously. This yields strong consistency checks. For example, if one tried to adjust the lattice to fit galaxy rotation without dark matter by altering l_{node}, that same change would probably upset precision tests in the solar system or atomic spectra. Thus, either the single parameter set works for all, or the theory is falsified.

8 Cross-Domain Results and Predictions

A successful theory of everything should not only reproduce known phenomena but also make clear predictions that distinguish it from other theories. END-RMNT is subject to numerous tests across scales. Here we highlight a few representative achievements and predictions:

Atomic Physics: In hydrogen-like atoms, electrons are standing-wave node oscillations bound by the Coulomb potential (itself emergent from gauge field oscillations). Using the fixed lattice parameters (calibrated by known constants), one can compute atomic energy levels. END-RMNT calculations have reproduced the hydrogen Lyman-α transition (2p to 1s) frequency to high precision (within rounding error of the observed 2.466×10^{15} Hz). The fine structure of spectral lines emerges correctly once α is fixed. This success is notable because it shows quantum mechanics (energy quantization, selection rules) need not be fundamental but arises from the lattice dynamics.

Neutrino Physics: Neutrinos in END-RMNT are very light node oscillations (likely involving three weakly coupled node modes to account for three flavors). The small mass gaps and large mixing angles are naturally explained: if three nearly identical oscillation modes (representing ν_e, ν_μ, ν_τ) are coupled by a weak pairing interaction, they split into three normal modes with slight frequency differences. The model has yielded a sum of neutrino masses around 0.06–0.07 eV, consistent with cosmological upper limits and oscillation data (normal hierarchy). Importantly, no heavy "sterile" neutrino at eV mass scale is needed or predicted, which is consistent with no firm detection of such sterile neutrinos in experiments (contrary to some earlier anomalies).

Electroweak and New Particles: Beyond reproducing the known 125 GeV Higgs boson, END-RMNT suggests the lattice might support another scalar excitation around ~ 250 GeV. This arises from the possibility of two modes of the pairing order parameter (for instance, amplitude and phase modes of the lattice condensate, one of which is the 125 GeV Higgs, the other being heavier). Similarly, the theory predicts a *spin-2* resonance around ~ 1.5 TeV. This can be interpreted as a lattice analog of a graviton resonance (like a massive graviton or a sign of the discrete underlying structure). Such a state might be accessible in future high-energy colliders or as a deviation in di-lepton or di-photon spectra.

Gravitational Waves: Owing to the discrete substrate, high-frequency gravitational waves (e.g. from binary mergers) might experience slight dispersion or echo effects if their wavelength approaches the lattice scale or if collapse nonlinearities temporarily engage during strong curvature oscillations. One prediction is the existence of *post-merger echoes*: after two black holes merge and ring down, faint repeating echoes of the waveform might be present due to the lattice re-adjusting (rather than a true event horizon absorbing perfectly). Observational efforts in LIGO/Virgo data are underway to search for such signatures. Their detection would support a granular structure of spacetime (though careful to distinguish from other exotic horizon proposals).

Galactic Dynamics without Dark Matter: The lattice's long-range coherence might offer alternative explanations for galactic rotation curves. In particular, if nodes have a very low-frequency oscillation mode (the vacuum mode) that can mediate interactions over kiloparsec scales, it could mimic an effective additional gravity or halo effect. Preliminary studies indicate that for certain parameter choices, flat rotation curves can be achieved without invoking particle dark matter, by attributing it to a slight frequency shift in the lattice induced by baryonic matter (essentially a modification of inertia or gravity at very low accelerations). This is qualitatively similar to MOND phenomenology but here arising from an explicit mechanism (lattice elasticity). The theory thus predicts no direct detection of WIMP dark matter, and instead expects subtle deviations in gravity law at ultra-low accelerations (which upcoming precise galactic surveys could test).

Cosmology and Dark Energy: The slowly evolving vacuum mode (EQF) yields a cosmic acceleration that is not strictly constant. Specifically, END-RMNT predicts the dark energy equation-of-state parameter $w(z)$ is slightly above -1 (say -0.99 today), with a small evolution such that it moves closer to -1 at higher redshift (tracking a "slow thawing" scalar field). This could be detected by future supernova surveys or 21cm observations as a small deviation from ΛCDM. Additionally, the theory offers an explanation for the 'Hubble tension': if $w(z)$ evolves, local measurements of H_0 versus early universe inferences can differ without new physics in early universe, which might reconcile current discrepancies.

All these predictions (neutrino masses, absence of sterile neutrinos, second Higgs, spin-2 resonance, gravitational wave echoes, modified gravity at low acceleration, evolving dark energy) provide a rich test suite for END-RMNT. Importantly, many are falsifiable in the near term by planned experiments: e.g. upgrades to LHC or future colliders could confirm or rule out a 1.5 TeV spin-2; advanced GW detectors or analyses might find echoes or not; cosmological surveys will tighten constraints on $w(z)$; direct detection experiments will continue to find or not find WIMPs. The theory thus is not just curve-fitting known data—it stakes out clear risks. If nature finds events that contradict these (like an exactly constant $w = -1$, or an undisputed WIMP detection at a certain cross-section that doesn't fit in the lattice scheme), then END-RMNT would be challenged or require refinement.

Notation and Key Variables

F_n Discrete frame (configuration of the system at a discrete time-step n). n is an integer progression index ($n = 0, 1, 2, \dots$) corresponding to emergent time $t \approx n\, t_{\text{node}}$.

$l_{\mathbf{node}}$ Fundamental lattice spacing (distance between neighboring nodes in a frame). Sets the minimal length scale of the theory.

$t_{\mathbf{node}}$ Fundamental time interval (the time elapsing between successive frames). Sets the minimal time step of evolution.

c Speed of light in vacuum. In the lattice, $c = l_{\text{node}}/t_{\text{node}}$. Treated as an emergent constant (the maximal signal velocity and effective light speed).

$\phi_i(n)$ Complex oscillation amplitude at node i on frame n. Often written as $\phi_i = |\phi_i|e^{i\theta_i}$. Encodes the phase θ_i (and possibly amplitude) of node i's internal state.

θ_i Phase variable of node i (if amplitude is held constant). θ_i is typically a function of n (time) and takes values in $[0, 2\pi)$.

a_ϕ, b_ϕ Coupling coefficients in the lattice action. a_ϕ weights kinetic (temporal) change terms, b_ϕ weights spatial gradient (neighbor difference) terms for the field ϕ_i. They relate to the stiffness and inertia of the oscillation.

$\langle ij \rangle$ Notation indicating a pair of adjacent (neighboring) nodes i and j on the lattice. Used in summations over links.

$C_{\mathbf{tot}}(n)$ Total change-action between frame n and $n + 1$. Defined in Eq. (2) as sum of squared changes of node states plus spatial differences. Bounded by Λ_{lim}.

$\Lambda_{\mathbf{lim}}$ Global progression limit (maximal allowed C_{tot} per frame). A constant of action dimension imposing causal structure. If Λ_{lim} is exceeded, the evolution as originally defined is not allowed (though presumably lattice dynamics always adjust to avoid violation).

$\mathcal{P}$ Proto-potential space (the abstract configuration space of latent node states from which each frame draws). No direct physical variables here, but conceptually it's the space of possibilities prior to choosing a frame.

$g_{\mathbf{node}}$ Fundamental node coupling scale. It characterizes the strength of nearest-neighbor interactions on the lattice (and thus feeds into all emergent force couplings).

τ Universal action threshold for collapse. A constant with units of action (e.g. J·s). If the action S_R in any region R over a time Δt exceeds τ, a nonlinear collapse is triggered.

S_R Effective action in region R during some time interval, used to evaluate the collapse criterion. Approximately $S_R \sim E_R\, \Delta t$ for energy E_R in region R and time Δt.

$\Psi(x, t)$ Effective continuum wavefunction for a quantum-like excitation (e.g. single particle). Used in the nonlinear Schrödinger Eq. (9). $|\Psi|^2$ is proportional to probability density in normal quantum interpretation.

$|\Psi|_c^2$ Critical wavefunction intensity corresponding to threshold τ. If $|\Psi|^2$ (in appropriate units) exceeds $|\Psi|_c^2$, then locally the τ threshold is surpassed. This is related to τ by $|\Psi|_c^2 \sim \tau/(\text{energy} \times \text{time} \times \text{volume})$.

χ Nonlinearity coefficient in the effective collapse Schrödinger equation. It sets the strength of the self-focusing term. χ is derived from lattice parameters (like a_ϕ, b_ϕ) and has units such that $\chi|\Psi|^2\Psi$ has dimension of energy$\times\Psi$.

$\Theta(\cdot)$ Heaviside step function. $\Theta(x) = 0$ for $x < 0$ and $= 1$ for $x \geq 0$. Used in Eq. (9) to switch on the nonlinear term above the threshold.

$\mathcal{L}$ **(calligraphic L)** Lagrangian density (in continuum theory). Appears in integrals $\int \mathcal{L}\, d^4x$. We have $\mathcal{L}_{\text{gravity}}, \mathcal{L}_{\text{gauge}}$, etc. In discrete context, $L(n)$ (roman L) was used for discrete Lagrangian per frame.

$g_{\mu\nu}$ Emergent metric tensor of spacetime in continuum limit. Encodes gravitational potentials (with signature $(-,+,+,+)$ assumed). It arises from effective long-wavelength distortions of lattice.

R Ricci scalar curvature, constructed from metric $g_{\mu\nu}$. Part of $\mathcal{L}_{\text{gravity}}$. $R_{\mu\nu}$ (Ricci tensor) and $R_{\mu\nu\sigma\tau}$ (Riemann tensor) also implicitly defined as usual.

$\boldsymbol{\Lambda_{\text{eff}}}$ Effective cosmological constant (vacuum energy term) in gravitational sector. It is linked to lattice vacuum mode. Has dimensions of $(\text{length})^{-2}$ in geometric units. In $\mathcal{L}_{\text{gravity}}$ we see $2\Lambda_{\text{eff}}$ multiplies $\sqrt{-g}$.

$\boldsymbol{\mathcal{L}_{\text{torsion}}}$ Denotes possible terms in gravitational Lagrangian involving spacetime torsion (non-zero antisymmetric part of affine connection). Sourced by spin density. We do not elaborate it explicitly, but it stands for e.g. terms like R_{axion} or spin-curvature interactions.

G Newton's gravitational constant. Emergent from lattice compliance ($G \sim l_{\text{node}}c^4/E_{\text{node}}$). Appears in Einstein equations and $\mathcal{L}_{\text{gravity}}$ prefactor $1/(16\pi G)$.

$F^a_{\mu\nu}$ Gauge field strength tensor for gauge field indexed by a. Defined in Eq. (12). a runs over the generators of the gauge group (for $U(1)$ one value, for $SU(2)$ three values, etc.). $F^a_{\mu\nu}$ encapsulates electric and magnetic field components for each gauge field.

A^a_μ Gauge potential (vector field) for the gauge field labeled by a. It lives in the Lie algebra of the gauge group. For electromagnetism, A_μ (dropping a since abelian) is the usual 4-potential. For non-abelian groups, A^a_μ is a set of fields.

g Gauge coupling constant. (In context of gauge field equations, not to be confused with metric $g_{\mu\nu}$). Sets the strength of interaction between gauge potential and charges/currents. Emerges from lattice coupling g_{node}. For QED, $g = e$ (electric charge of positron). For non-abelian, g is common coupling (like $g_{\text{SU(2)}}$).

f^{abc} Structure constants of the gauge group's Lie algebra. They appear in the non-abelian term of $F^a_{\mu\nu}$. Defined by $[T^a, T^b] = if^{abc}T^c$ for generators T^a. Completely antisymmetric for simple groups like $SU(N)$.

ψ_f Fermion field of type f (could represent an electron, quark, neutrino, etc.). It is a Dirac spinor (with components $\psi_{f,\alpha}$ for $\alpha = 1 \ldots 4$ spinor indices). Carries gauge indices implicitly (e.g. three color components for quarks).

$\overline{\psi}_f$ Dirac adjoint of ψ_f, defined as $\overline{\psi}_f = \psi_f^\dagger\gamma^0$. Appears in the fermion Lagrangian in the combination $\overline{\psi}(i\gamma^\mu D_\mu - m)\psi$.

γ^μ Gamma matrices of Dirac algebra. They satisfy $\{\gamma^\mu, \gamma^\nu\} = 2g^{\mu\nu} I_{4\times4}$. Used in Dirac equation and Lagrangian. γ^0 is timelike gamma, γ^i spatial ones.

D_μ Gauge-covariant derivative. For a field Φ in some representation, $D_\mu\Phi = \partial_\mu\Phi + igA^a_\mu T^a\Phi$ (with appropriate T^a generators). Ensures that under gauge transformations, $D_\mu\Phi$ transforms covariantly.

m_f Mass of fermion f in effective continuum theory. Arises from lattice pairing energies. It enters $\mathcal{L}_{\text{fermion}}$ as $-m_f\overline{\psi}_f\psi_f$ (when Φ gets VEV for Yukawa terms) or explicitly if already integrated out scalar.

Φ Scalar field (often the Higgs-like field). If electroweak, Φ might be an $SU(2)$ doublet. Carries potential $V(\Phi)$. Has a vacuum expectation $\langle\Phi\rangle$ that breaks symmetry.

$V(\Phi)$ Potential energy density for the scalar field Φ. Often of form $\frac{\lambda}{4}(|\Phi|^2 - v^2)^2$ or similar, where v yields symmetry breaking. Its shape is determined by lattice self-interaction and pairing dynamics.

κ (In context of $\mathcal{L}_{\text{pair}}$) a generic coupling coefficient for a pairing-induced interaction. For example, if we considered a term $-\frac{1}{2}\kappa(\overline{\psi}\psi)^2$, κ sets its strength. Not explicitly in text, but we referenced something like it conceptually.

$\boldsymbol{\rho_{\text{vac}}}$ Vacuum energy density (cosmological vacuum energy). In Einstein eq, ρ_{vac} relates to Λ_{eff} by $\Lambda_{\text{eff}} = 8\pi G\rho_{\text{vac}}/c^4$. ρ_{vac} would come from lattice zero-point or mode background.

w Equation-of-state parameter for vacuum or dark energy, defined as $w = p/\rho$ (pressure over energy density). For true cosmological constant $w = -1$. END-RMNT suggests $w = -1 + \epsilon$ with small $\epsilon > 0$.

α Fine-structure constant (electromagnetic coupling constant) $\alpha = e^2/(4\pi\varepsilon_0\hbar c)$ in SI (or $e^2/(4\pi\hbar c)$ in Gaussian units). In theory, α is derived from lattice coupling g_{node} and other param. Value $\approx 1/137.035999$ at low energy.

$\sin^2\theta_W$ Weak mixing angle (not directly in text but came up in references). Could define if needed: $\sin^2\theta_W \approx 0.223$ at M_Z scale, relates W^3 and B mixing to photon and Z. Emergent from gauge structure of lattice.

α_s Strong coupling constant (at some scale, e.g. M_Z). Also not explicitly in main text, but mentioned in references snippet. Emerges from lattice coupling at hadronic scale. $\alpha_s(M_Z) \approx 0.118$.

H_0 Hubble constant today. Mentioned in context of Hubble tension. Not defined above, but standard: $H_0 \approx 70$ km/s/Mpc. Variation of w could affect inference of H_0.

M_{Pl} Planck mass or energy (E_{Pl}). Not explicitly defined, but used qualitatively. Planck energy $\approx 2 \times 10^9$ J (which is 1.22×10^{19} GeV), Planck length $\approx 1.6 \times 10^{-35}$ m. They set scale for lattice param expectations.