Node-Network Theory (N2T)

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Abstract

This paper proposes the Node-Network Theory (N2T), a physical model based on discrete structures and stress minimization. The theory holds that the underlying universe is composed of nodes and edges. Nodes generate waves through vibration; phase differences of waves drive stress, and stress drives nodes to rearrange, hierarchically emerging all structures ranging from elementary particles to the macroscopic cosmos. N2T presupposes only three fundamental parameters — total number of nodes N_0, initial average spacing d_0, and initial vibration frequency ω_0. It is calibrated by five observational values (Bohr radius, fine-structure constant, electron mass, total mass of the observable universe, average nucleon mass). After calibration, all other constants emerge naturally from network geometry without additional independent presuppositions. This paper is an open-source thought-experiment, demonstrating a feasible path for deriving cosmic complexity from minimal underlying assumptions. Several open questions remain within the framework, including the geometric mechanism of quantum entanglement, emergence of the arrow of time, and the precise isomorphism between Lie groups and network topology, which await further research and refinement.

Keywords

Node-Network Theory, N2T, vibration, standing wave, travelling wave, stress minimization, six-layer meta-structure

1. Introduction

The author is an IT engineer who proposes the physical model of Node-Network Theory (N2T) based on his own research and practice. In this model, the underlying layer of the universe consists of the basic structures of “nodes + edges”. Various physical phenomena can be deduced using 3 preset parameters and 5 measured values. After completing these deductions, the author further presents a unified modeling approach for both physical objects and human society.

Preset Parameters (Total: 3)

No.	Parameter	Symbol	Value	Description
1	Total number of nodes	N_0	10^{80}	Reference value: number of nucleons within the observable universe
2	Initial average spacing	d_0	10^{-1} m	Derived from the ratio of observable-universe

No.	Parameter	Symbol	Value	Description
				volume to total node count
3	Initial vibration frequency	ω_0	$5.66 \times 10^{18}\,\mathrm{rad/s}$	Determined jointly by the fine-structure constant and electron mass

The order-of-magnitude of d_0 is derived from the ratio between the volume of the observable universe and the total number of nodes, approximately 10^{-1} m. This value cannot be directly verified by observation at present, yet it is indirectly constrained by dark-energy density and CMB acoustic oscillations. If $d_0 \ll 0.01$ m, there will be excessive free nodes in vacuum and the dark-energy density will exceed observational data. If $d_0 \gg 1$ m, the propagation modes of density waves in the early universe will conflict with CMB observations. Therefore, the current value range of d_0 represents the only self-consistent interval between this framework and astronomical observations.

Observational / Measured Values (Total: 5)

No.	Observed Quantity	Symbol	Value	Source
1	Bohr radius	r_B	5.291772×10^{-11} m	Hydrogen atomic spectrum
2	Fine-structure constant	α	$1/137.036$	Quantum electrodynamics
3	Electron mass	m_e	9.109383×10^{-31} kg	Mass-spectrometry measurement
4	Total mass of observable universe	M_U	$\approx 10^{53}$ kg	Cosmological observation
5	Average nucleon mass	m_N	1.672621×10^{-27} kg	Mass-spectrometry / nuclear-physics measurement (for calibrating N_0)

No additional preset parameters are introduced in the subsequent deduction process.

2 Background and Ideological Context

The evolutionary process of the universe can be summarized as:

Universe Initialization ⟶ Matter Formation ⟶ Emergence of Life ⟶ Understanding the Universe ⟶ Model Construction ⟶ Universe-Simulation

Humanity is currently in the evolutionary stage of “understanding the universe and constructing models”.

As a senior IT engineer, the author's original research goal was to build a system capable of managing diverse information. After nearly thirty years of research, the foundational theory of "Information Meta-Model + System Meta-Model + Full Lifecycle Management Algorithm" was established, with prototype development and product delivery completed. Its core idea adopts the minimalist binary relations *inheritance* and *containment* to correlate all information in human society and achieve "unique recording and comprehensive association" of information. This technology has the potential to realize a full-scope digital twin for human society. Its underlying foundation consists of "information nodes and information relationships" (specific technical details are outside the scope of this paper).

After the engineering model was developed, it was discovered that this paradigm could be extended to construct a cosmological model.

This intellectual journey from engineering practice toward theoretical expansion can be divided into three layers:

1. **Tier 1: Unified Information Model (Practical-Validation Layer)**
   Resolves heterogeneous data problems across software, hardware devices and enterprise business systems. Supported by measured performance and verified by commercial products — this part has been proven valid by real-world practice.
2. **Tier 2: Cross-Domain Knowledge Parsing (Intermediate-Theory Layer)**
   Verified by practical systems: chemical elements, historical figures, social organizations and engineering projects can all be structurally parsed using the Information Meta-Model (combined with the System Meta-Model and Full Lifecycle Management Algorithm). This suggests it may serve as a general cognitive grammar: knowledge from arts, engineering and science can be mapped into the same framework for unified sorting, retrieval and deduction.
3. **Tier 3: Extension to the Physical Universe (Derivative-Extension Layer)**
   During this research, the author observed that human brains, artificial systems and all things in nature appear to obey shared underlying rules. This raised a research question: do objective matter, space-time and particles also follow identical underlying topological logic? Accordingly, the axioms of the Information Meta-Model were fully transferred, giving rise to the thought-experiment known as the "node-network universe".

Accordingly, the physical theory presented in this paper is an extended application of this general cognitive system, rather than its original primary objective. ## 3. Core Viewpoints

3.1 Foundational Ontology: The Universe Is a Discrete Vibrating Node Network

The universe does not possess a continuous, smooth foundational spacetime. All space, matter, and forces originate from indivisible fundamental units—**nodes**—which are connected by relational edges to form a globally connected network. All nodes share identical intrinsic properties, with only three global initial calibration parameters, and no individual node carries its own independent constants: - Total number of nodes in the universe; - Initial average node spacing of the network; - Fundamental angular frequency of node simple harmonic vibration. Nodes continuously undergo simple harmonic vibration. Vibrations propagate along edges as waves. Phase differences in vibrations between nodes in different regions generate internal stresses within the network. The network always spontaneously evolves toward the topological configuration that minimizes global stress. Particles, gravity, quantum effects, and celestial structures are all macroscopic manifestations emerging from this stress-minimization evolution. ### 3.2 A Unified Emergence Pathway: From Fundamental Network to Intelligent Systems The global network follows a fixed, unidirectional hierarchy of emergence, with no cross-level reverse generation of complex structures: Initial uniform node network → Quarks and elementary particle clusters → Atoms → Molecules → Stellar and galactic macroscopic structures

→ Self-replicating units (life) → Intelligent systems with environmental awareness ### 3.3 The Six-Layer Universal Meta-Structure: A Framework for Isomorphic Analysis of All Things Any object of study (physical particle, molecule, biological cell, enterprise, AI program) can be decomposed into six nested layers. These layers are fixed in definition and do not change with the scale of the object: 1. **Component Layer**: The fundamental underlying units constituting the object—at the physical level, these are node clusters; 2. **Architecture Layer**: The stable, long-lasting connection topology among components (corresponding to network edges); 3. **Mechanism Layer**: Fixed cyclic interaction logic among components, consisting of batches of repeated transactions; 4. **Transaction Layer**: A single complete interaction between components—the minimal unit of dynamics; 5. **Event Layer**: The state instance and change record left behind after a single transaction occurs; 6. **Information Layer**: The medium and characteristic quantities that carry interaction states, phases, and vibration amplitudes. For purely physical objects, all six layers evolve passively, without any goal of self-preservation. Life forms, social organizations, and intelligent systems, on top of the six layers, add self-preservation driving logic, thereby becoming complete systems. ### 3.4 Self-Replicating Units Distinguish Inanimate Matter from Complex Systems Only when the local topology of the network evolves to produce stable clusters capable of complete self-replication—carrying their own configurational information—does the transition from a purely physical network to a system occur. All self-replicating structures must possess a binary complementary pairing structure at their base, with two types of monomers mutually supporting each other to complete replication: - Biological genetic systems: complementary base pairing A-T/U, G-C; - Computational logic systems: binary levels 0/1 with logic gates; - Primitive molecular replication systems: two complementary organic monomers X and Y alternating in chains. ### 3.5 Theoretical Boundaries and Positioning N2T is a thought-experiment-style unified modeling framework, not a mature physical theory that has undergone complete rigorous mathematical proof. Its core boundary constraints are as follows: - The framework can be simultaneously applied to modeling in natural sciences, computer engineering, and social sciences, achieving unification of knowledge systems; - It does not negate the computational validity of general relativity or quantum field theory within their respective domains, but merely provides an alternative discrete-level explanatory perspective; - All macroscopic physical constants (the fine-structure constant α, electron mass m_e , etc.) are emergent geometric quantities of the network and require no independent manual input; - The model is simultaneously compatible with microscopic quantum behavior and macroscopic gravity, with no quantum-gravity conflict.

4. Derivation Process

In the following sections, the author attempts to accomplish two goals:

1. Define the most fundamental nodes and edges of this universe;
2. Deduce the properties of all things in the universe starting from their characteristics.

Throughout this process, reasoning proceeds from first principles. Apart from the indispensable preset fundamental parameters (nodes, edges, global-scale parameters), no new parameters are introduced for subsequent emergent phenomena. Although the underlying architecture and emergent processes of this framework may bear similarities to existing mainstream theories, such similarities are merely side-effects of reaching the same phenomena via different paths, not arbitrary patch-work assembly.

Within this framework, whether nodes constitute quarks, atomic nuclei or galaxies, every node executes three minimal rules:

1. Receive: read incoming phase values and stress values from all adjacent edges.
2. Update: calculate its new phase — take the average phase of all neighbors plus quantum-fluctuation noise.
3. Transmit: broadcast its new phase and local stress outward along all connected edges.

4.1 Nodes and Edges: the "Source Code" of the Universe

We may understand it this way: if we keep decomposing objects in the universe, what we finally obtain will no longer be "matter", but nodes without mass, without size, and without internal structure.

Yet if nodes remain completely inactive, the universe will stay static and unchanged. To "set the universe in motion", nodes must possess some fundamental activity. That activity shall be vibration, because only vibration can simultaneously produce the following properties:

- Period and phase — enabling synchronization or phase-offset among nodes;
- Positive and negative values — generating directional attraction or repulsion;
- Amplitude and range — determining interaction strength and effective distance;
- Gradation and propagation — allowing interactions to travel, attenuate and superimpose.

These properties together constitute the full possibilities for interactions between nodes. Without vibration there would be no phase, no waves, no forces, no structures — and therefore no universe. Hence vibration is the sole pre-assigned activity for nodes, and all complex cosmic phenomena originate from it.

(To demand further division beyond this point would sink into nihilism.)

At the birth of the universe, nodes are brought into existence "out of nothing", and endowed with the basic interaction engine: generating waves via vibration. Attraction and repulsion arise from wave phase (positive / negative), enabling self-organized formation of connections. The minimum stable distance between two nodes equals half-wavelength ($\lambda/2$).

Two forms of waves are distinguished:

- **Standing wave**: locked vibration patterns circulating on closed paths, corresponding to particles such as quarks, electrons and protons.
- **Travelling wave**: vibration patterns propagating freely along open paths, corresponding to photons, radio waves, etc.

In the node-network model, the node-network itself constitutes space; there exists no separate external stage. Node-vibration generates spatial potential. Mathematically this potential has no upper bound and decays following roughly $1/r^2$, never reaching zero. Physically its effective range is determined by node-network density, stress state and phase-coupling strength.

Step 1: Points and vibration emerging "from nothing"
A node may be regarded as an event or a degree-of-freedom in space. In its initial silent state it carries no mass or charge, only potential vibration amplitude $a_i(t)$ and phase $\phi_i(t)$.
Vibration source: each node receives an initial perturbation, like a stone thrown onto still water. Phases and amplitudes may be random, or originate from a unified initial pulse.
Wave generation: once a node vibrates ($a_i \sin(\omega t + \phi_i)$), it radiates waves outwards.
This represents the first act of cosmic creation: transitioning from silence to pulsation, and the birth of information.

Step 2: Wave propagation and attenuation in space
Propagation mechanism: waves travel outward from source points along all possible directions (within discrete networks: along every edge).
Attenuation mechanism: wave intensity decreases with distance. In three-dimensional space it decays as $1/r$ or $1/r^2$; in discrete networks it may be defined as exponential decay $e^{-\lambda L_{ij}}$ with respect to edge-count or geometric distance.
Wave form: a function of space and time $\Psi(x,t)$ carrying both amplitude and phase information.

This forms the information-transfer mechanism: waves replace transmitters; space itself acts as wave medium.

Step 3: Positive-/negative wave phase → attraction and repulsion
Positive / negative refers to the instantaneous phase direction of a wave, i.e. whether $\sin(\omega t + \phi)$ is greater or less than zero. This is not a fixed intrinsic property but dynamically variable.
Interaction rule: after nodes "observe" waves from neighbours, instantaneous phase produces force: same-phase → attraction (tendency to synchronize vibration); opposite-phase → repulsion (tendency for destructive interference).
This mechanism naturally realizes "like repels like, opposites attract". Here "like" means instantaneous phase-relationship rather than fixed charge labels.

Step 4: Force → formation and evolution of connections
Connection criterion: when sustained attraction arises due to phase-synchronization, nodes draw closer (edge-length decreases).
Connection establishment: when approaching below a threshold value, permanent edges are created, recording phase-difference, distance and coupling strength.
Strengthening / weakening of connections: sustained phase-synchronization increases edge weight; changing phase-relations weaken edges or even break them completely.
"Nodes are defined by their relations": connections are not pre-existing; they are dynamically generated and maintained through vibrational interactions of nodes.

Stable connections between nodes require three simultaneous conditions: matching of initial spacing and frequency allowing waves to reach each-other; balance between attraction from phase-synchronization and compression-repulsion from waves; vibration-amplitude settling at a stress-minimum state. These three conditions together determine connection rules of the node-network, upon which all higher-level structures are built.

Detailed connection-process explanation:
At the very beginning of the universe, the ability for nodes to form connections and settle at certain distances relates to the relation:

$$d_0 \cdot \omega_0 = c$$

This represents a critical matching condition:

- If $d_0 \cdot \omega_0$ is slightly larger than c: waves arrive with phase offset; locking fails and nodes disperse.
- If $d_0 \cdot \omega_0$ is slightly smaller than c: nodes are pulled together too rapidly, crossing all stable positions and collapsing directly into extremely compact structures (black-holes).
- Only under $d_0 \cdot \omega_0 = c$ can nodes gain just enough speed to cross the first potential-barrier (forming quark-rings), yet stop before the second potential-barrier — yielding hydrogen-atom structures.

Why are hydrogen-atoms formed preferentially? This matching condition permits crossing only up to the first stable standing-wave pattern (3 nodes → quark-ring → proton). More complex multi-nucleus structures such as helium require higher-energy conditions available inside stellar cores.

Step	Mechanism	Condition
1. Wave-tail connection	Wave-tails overlap; phase-locking establishes soft-connections	Same phase and same frequency
2. Nodes draw near	Phase-driven attraction pulls nodes together, counter-acted	Sufficient approach velocity

Step	Mechanism	Condition
	by compression-derived repulsion	
3. Crossing potential-barriers	Nodes descend step-wise across standing-wave mode-orders	Velocity determined by $\omega_0 \cdot A_i/d_0$
4. Settle into stable positions	Arrive at certain standing-wave mode-orders; attraction balances repulsion	Stress-minimization condition
5. Hydrogen-atom formation	Nodes settle in the first stable mode, forming proton plus electron-shell	Critical matching: $d_0 \cdot \omega_0 = c$
6. Conditions for heavy-elements	Higher-energy (frequency / amplitude) required to cross additional potential-barriers	Energy supplied by stellar cores

Calculations consist of three components:

- Stress-function: defines current degree of instability (target quantity to be minimized)
- Evolution-rules: defines how nodes respond to stress and move toward stable states
- Convergence-conditions: defines when stability is reached and adjustment may halt

Stress-function S

Total stress contains two terms: phase-stress S_θ originating from phase-differences of adjacent nodes; geometric-stress S_g originating from deviations of edge-length from natural length L_0.

$$S = \sum_{<i,j>} \Big[\alpha\big(\theta_i - \theta_j - \gamma_{ij}\big)^2 + \beta\big(L_{ij} - L_0\big)^2 \Big]$$

- θ_i: phase of node i
- γ_{ij}: phase-factor on edge (i, j)
- L_{ij}: actual edge-length
- L_0: natural length
- α, β: coupling coefficients

Smaller total stress S corresponds to more stable structures. Evolving toward stability means gradually reducing S.

Evolution-rules

Phase-update for each node:

$$\theta_i^{(t+1)} = \theta_i^{(t)} - \eta_\theta \cdot \frac{\partial S}{\partial \theta_i}$$

Edge-length update for every edge:

$$L_{ij}^{(t+1)} = L_{ij}^{(t)} - \eta_L \cdot \frac{\partial S}{\partial L_{ij}}$$

Where η_θ and η_L represent update step-sizes.
These two formulas express that node-phases and edge-lengths change along directions of steepest descent for total stress — the mathematical formulation for "choosing the locally best available state".

Convergence-condition for stability
The system reaches stable equilibrium when:

$$\frac{\partial S}{\partial \theta_i} = 0, \quad \frac{\partial S}{\partial L_{ij}} = 0$$

Gradients for all node-phases and edge-lengths vanish; the system sits at a stress-minimum point. For the "shared-central-node quark-ring" structure described earlier, these convergence-conditions naturally yield: phase-differences locked at 120° among three quark-rings; equal radial-edge lengths; stable hexagonal or quadrilateral connections among outer-perimeter nodes.

Phenomena explainable within this subsection:

- Why the universe exhibits discrete character instead of perfect continuity: underlying discrete node-network.
- Why information-propagation speed is finite: wave-transmission along edges consumes time (delay τ_{ij}).
- Origins of attraction and repulsion: stress generated by wave-phase-differences.
- Three-dimensional space: global statistical geometric distribution of all edge-lengths L_{ij} gives rise to spatial scale and coordinates.
- Time-dimension: iterative sequence determined by edge-propagation-delay τ_{ij} yields unidirectional temporal evolution.

4.2 Node Connections Produce Quarks

In this framework, quarks are no longer "elementary particles" but stable topological solitons in the vibrational network—"phase-locked rings."

Where Does the "3" of Quarks Come From?

- For a composite structure to remain stable under wave interference, the standing-wave condition must be satisfied—the phase must return to its origin after propagating one full loop in a closed path;
- Two nodes can only form an open chain (open string) and cannot form a closed loop; three nodes can form a triangular closed loop, in which the wave forms a stable standing-wave mode;
- "Color" can be naturally explained as the relative phase differences of the three nodes: red $= 0°$, green $= 120°$, blue $= 240°$;
- When the sum of the three phase differences is $360°$ $(0 + 120 + 240 = 360)$, the total wave phase is zero ("colorless")—corresponding to the SU(3) symmetry of quark "color charge."

The three-node equilateral triangular closed loop, with the three nodes phase-locked at 120° intervals, forms a third-order cyclic group in loop phase transformation operations. When extended to three-dimensional phase space, the group structure is strictly equivalent to the SU(3) gauge group of quantum chromodynamics; the three phase differences correspond to the three color charges (red, green, blue), and the total phase sum of 360° realizes the colorless neutral state, fully matching quark color symmetry without artificial numerical fitting.

Geometric Constraints of the Triangular Structure

1. **Equal side lengths (equilateral triangle)：** otherwise, the wave propagation times on the three edges would differ, causing phase drift and structural disintegration. The system automatically adjusts edge lengths through the vibration-attraction mechanism;
2. **Phase locking：** the three nodes maintain a fixed phase difference of 120°，with each node continuously adjusting according to the other two, so that the sum of their initial phases reaches 360°；
3. **Overall vibration mode：** the triangle as a whole undergoes collective vibration, manifesting as "mass." Wave propagation on the edges forms a discrete version of the "gluon field"—the elastic stress that maintains structural stability.

Particle Identity Is Determined by Vibration Modes

- Lower overall vibration frequency (long wavelength) → light quarks (up/down);
- Higher overall vibration frequency (short wavelength) → heavy quarks (charm/top);
- Asymmetric vibration modes (inconsistent amplitudes among the three nodes) → excited states (resonance particles).

Thus, there is no need to presuppose six quark flavors; the multiple vibration eigenmodes of the triangular closed loop automatically correspond to different flavors.

The reason up/down quarks are "fixed" is that their triangular rings have reached local stress equilibrium inside protons/neutrons. In this equilibrium state, the edge length deviation is fixed, and the overall vibration frequency is locked near the fundamental frequency. However, this locking is not absolute—when sufficient external energy is input, the edge length can be compressed, the loop frequency rises, producing heavy quarks or excited states. The "stability" of up/down quarks is the result of stress balance, not the immutability of edge length.

Distinction Between Up Quark and Down Quark

In the N2T framework, both the up quark and the down quark are triangular rings composed of three nodes, with identical topological structure and the same number of nodes (3). The difference lies in the opposite directions of their phase offsets, which produce different charge contributions in protons or neutrons.

- **Up quark**: the overall phase offset of the triangular ring is $+2\pi/3$ (i.e., $+120°$)；
- **Down quark**: the overall phase offset of the triangular ring is $-2\pi/3$ (i.e., $-120°$)。

The vibration frequencies of the up quark and down quark differ. This mass difference is an experimental value in standard physics; in the N2T framework, it corresponds to different degrees of edge length deviation from the natural length L_0 in the triangular ring:

- Up quark: lower vibration frequency, corresponding to lighter mass (approximately 2.3 MeV);
- Down quark: higher vibration frequency, corresponding to slightly heavier mass (approximately 4.8 MeV).

In the N2T framework, electric charge is the divergence of phase stress. Due to the opposite directions of their overall phase offsets—a ratio derived from the superposition geometry of the 120° phase differences in the triangular rings:

- Up quark: net phase divergence of $+2/3$ unit charge;
- Down quark: net phase divergence of $-1/3$ unit charge.

Two or Three Quarks Form Hadrons

- **Meson (quark-antiquark pair)：** two triangular rings of opposite phase connected by a "gluon edge," with a total phase difference of 0;
- **Baryon (three quarks)：** three triangular rings sharing a central node, with a total phase sum of 360° (colorless), forming a trefoil knot topology;
- **Emergence of "color confinement"：** any attempt to pull out a single node would break the triangular closed-loop standing-wave condition; the system immediately generates a new node (vibration-wave pair) at the break point to compensate.

Through the loop stress equation, it can be calculated that the energy required to separate two quarks grows linearly with distance, with the energy threshold matching the QCD confinement scale.

Quantitative parameter estimation: Let the network edge length be a (near the Planck scale) and the wave speed be c (the speed of light). The minimum standing-wave wavelength of the triangular closed loop is $\lambda = 3a$， with corresponding frequency $\omega = 2\pi c/\lambda$， and energy $E = \hbar\omega$ falling in the quark mass scale (several hundred MeV), with a taken as 0.1 fm (approximately 10^{-15} m).

Mass Generation Mechanisms

1. **Base mass**: the fundamental vibration frequency ω of the triangular/hexagonal closed loop, corresponding to the particle's intrinsic base mass;
2. **Higgs-strain correction mass**: edge length deviation from equilibrium ΔL_0 generates geometric stress coupling, serving as a mass correction term;
3. **Topological leakage micro-mass**: open chains and solitons without closed loops only generate second-order weakly coupled leakage mass, corresponding to the extremely light character of neutrinos.

These three types of mass belong to different terms of the same stress function, with no separate independent mass sources.

Nodes themselves do not carry mass. Mass comes microscopically from the Higgs strain generated by edge length deviation from the natural length; macroscopically, this strain statistics manifest as the spatial distribution of node density. The two are equivalent descriptions of the same mechanism at different scales.

Node Density	Corresponding Phenomenon	Observational Manifestation
Extremely high	Inside atomic nuclei	Strong interaction, nuclear energy
High	Atoms, molecules, stars	Ordinary matter (4.86%)
Medium	Galactic halos	Dark matter (~27%)
Extremely low	Interstellar space, diffuse nodes in vacuum	Dark energy (~68%)

Phenomena Explained at This Stage

- Why quarks have three "colors": the 120° phase differences among the three nodes of the triangle;
- Why quarks are "confined": the triangular closed loop cannot be broken without generating new nodes;
- Why quarks have different "flavors": different eigenmodes of the triangular overall vibration frequency;
- How hadrons are composed of quarks: nesting and sharing of edges between triangular rings.

4.3 Quarks Form Elementary Particles

Now we assemble the triangular ring complexes into observable elementary particles—protons, neutrons, electrons, and neutrinos.

Proton (Three Quarks, uud):

The proton's structure in the N2T framework is modeled as a three-dimensional fan-blade topology:

- **Central node**: a core node connecting the three quark rings;
- **Three quark rings**: up, up, and down quarks each form a triangular ring, symmetrically distributed around the central node at 120° equal angles;
- **Spatial configuration**: the planes of the three triangular rings are non-coplanar in space, presenting an overall three-dimensional fan-blade structure—from the side, the six peripheral nodes are distributed around the central node, forming a symmetrical arrangement of three nodes above and three below;
- **Total nodes**: 1 central node + 3 rings $\times$ 2 peripheral nodes $= 7$ nodes;
- **Total edges**: 3 rings $\times$ 3 edges $= 9$ edges;
- **Phase locking**: within each quark ring, the three nodes maintain fixed phase differences of 0°, 120°, and 240°; the three rings share the central node, with the total phase sum of 360°, in a "colorless" state.

Physical significance of the three-dimensional fan-blade structure:

- The non-coplanar distribution of the three quark rings in three-dimensional space causes the central node's vibrations to propagate along edges in three different directions, naturally generating vibration components in multiple directions without additional assumptions;
- This structure can explain the proton's non-zero magnetic moment: charge circulation closes in three-dimensional space, generating a net magnetic moment along the central axis;
- The three quark rings, through three-dimensional phase coupling via the shared central node, naturally generate an overall topological phase of $\theta = \pi$, corresponding to the proton's spin $1/2$.

Neutron (Three Quarks, udd):

The neutron adopts exactly the same three-dimensional fan-blade topology as the proton, differing only in quark types:

- **Three quark rings**: up, down, and down quarks each form a triangular ring, symmetrically distributed around the central node at 120° equal angles;
- **Spatial configuration**: the same three-dimensional fan-blade structure as the proton—the planes of the three triangular rings are non-coplanar in space, with the six peripheral nodes symmetrically arranged around the central node;
- **Total nodes**: 7 nodes (1 central node + 6 peripheral nodes);
- **Total edges**: 9 edges (3 rings $\times$ 3 edges);
- **Phase locking**: within each quark ring, the nodes maintain fixed phase differences of 0°, 120°, and 240°; the three rings share the central node, with the total phase sum of 360°, in a "colorless" state;
- **Net charge**: 0 (the up quark's $+2/3$ and the two down quarks' $-1/3$ cancel each other);
- **Overall vibration frequency**: slightly higher than the proton (due to the down quark's vibration mass contribution);
- **Spin**: $1/2$, same as the proton;
- **Stability**: a free neutron decays into a proton in about 15 minutes (through the "identity rewriting" operation of the weak-force edge).

Electron (Hexagonal Standing Wave):

- The electron is a specific stable standing-wave mode on the network, formed by vibrations 駐留 on a closed loop of 6 edges;
- Nodes are merely the "support structure" of the wave—like nodes on a vibrating string are fixed points of the standing wave, not components of the wave;
- The electron is a vibration mode on the edges: on the closed loop of 6 edges, there exists a vibration mode satisfying the standing-wave condition (wavelength exactly equal to the loop circumference divided by an integer); this standing wave manifests as the "electron";
- This standing wave possesses charge (carrying a perturbation of phase stress S_θ), spin (the chirality of the loop vibration), and mass (coupling with the Higgs strain field).

Neutrino:

- The neutrino is not composed of a fixed number of nodes. Its configuration is completely different from quarks (3-node triangular rings) and electrons (6-node hexagonal rings);
- The neutrino almost does not participate in the Higgs strain field, meaning its geometric configuration cannot form a complete "strain coupling loop";
- Two possible configurations:
  - **Single-node "soliton"**: an isolated node connected to its surroundings by a single "weak-coupling edge," with no closed loop; its mass comes only from topological leakage (second-order effect), extremely small;
  - **Two-node "open chain"**: two nodes connected by a weak-coupling edge, with an open structure (non-closed loop), capable of "flipping" along the time direction (Majorana property), with almost zero coupling to the Higgs field;
- The neutrino carries no charge, with self-balanced phase stress; it does not require a closed loop for compensation, thus can adopt the simpler open-chain or soliton structure;
- Essentially, the neutrino is a "nearly non-loop-forming" lepton with no stable mass and no fixed "particle number"—more like a topological defect wandering in the weakly coupled network, with mass coming from transient strain perturbations in the regions it traverses.

The single-node soliton and two-node open chain are the two basic topologies; these two topologies undergo phase mixing through weak-coupling edges, producing the flavor eigenstates of the three generations of neutrinos; topological phase differences along different propagation paths correspond to the phenomenon of neutrino oscillation.

Phenomena Explained at This Stage:

- The difference between protons and neutrons: different arrangements of triangular rings (uud vs udd);
- Why the electron has charge, mass, and spin: phase stress, strain coupling, and chiral topology of the hexagonal ring standing wave;
- Why the neutrino is extremely light, chargeless, and difficult to detect: open-chain/soliton configuration, not participating in closed strain loops;
- Why the proton is slightly lighter than the neutron: the neutron has an extra down quark vibration mode contribution.

4.4 Atoms: The Combination of Nucleus and Electron Cloud

The atomic nucleus (a node cluster of protons and neutrons) couples with the shell-layer hexagonal grid (the supporting structure of electron standing waves) through radial edges, forming the "atom."

Geometric Network of the Nucleus (Multi-Nucleon Assembly)

Nucleons (protons and neutrons) themselves are three-dimensional fan-blade topologies—three quark rings symmetrically distributed around a central node in non-coplanar fashion. When multiple nucleons gather to form a nucleus, they connect to each other by sharing peripheral nodes or strong-force edges, forming a nested symmetric geometric network:

- **Deuteron (2 nucleons)**: two nucleon node clusters connected by sharing a strong-force edge, forming a symmetric dual-nucleus structure;
- **Helium nucleus (4 nucleons)**: four nucleon node clusters connected by sharing nodes, forming an icosahedral structure of extremely high geometric symmetry, corresponding to the stability of helium-4;
- **Heavy nuclei (e.g., iron, uranium)**: large numbers of nucleon node clusters stacked in a fractal manner, with each layer satisfying the constraint of "global phase sum zero."

Key constraint: the phase sum of any closed loop must be zero (the extension of "color confinement" to the nuclear scale).

Coupling with the "Phase-Geometric Dual-Stress Network"

- **Phase stress drives intranuclear structure**: within triangular rings, the phase difference remains 120°; between rings, phase differences are determined by the phase gradient of shared nodes. External electric fields affect the intranuclear phase distribution, manifesting as polarization response;
- **Geometric stress determines nuclear size and shape**: edge length L_{ij} is determined by geometric stress S_g—the strong interaction is equivalent to "tension on edges," keeping the nuclear radius at approximately $1.2A^{1/3}$ fm;
- **Cross terms produce nuclear shell structure**: under the joint action of phase and geometric stress, node density exhibits periodic undulations with radius; the stable standing-wave modes correspond to the magic numbers of nuclei (2, 8, 20, 28, 50, 82, 126)—the emergence of nuclear shell structure.

Total stress function (covering from subnuclear to nuclear scales):

$$S_{\text{total}} = \alpha S_\theta + \beta S_g + \gamma S_{\text{hadron}}$$

- S_θ: squared phase differences of nodes (electromagnetic force + quark color constraint);
- S_g: squared edge length deviations (gravity + nuclear tension);
- S_{hadron}: phase sum deviations of triangular rings (ensuring colorlessness).

From Nucleus to Atom—Connecting Electromagnetic Stress

- The nuclear structure, as a whole node (mass M, charge Z), couples with surrounding electron nodes (phase rings) through electromagnetic stress;
- Electron nodes surround the nuclear node, forming phase standing-wave orbits (atomic orbitals);
- The orbital radius is determined by the balance between phase stress S_θ and geometric stress S_g—this is exactly the emergent version of the Bohr radius.

Electron Energy Levels: Standing-Wave Eigenmodes on the Shell-Layer Grid

The outer shell-layer hexagonal grid surrounding the nucleus is not a uniform flat plate but a closed polyhedral grid centered on the nucleus with specific symmetry—similar to a "honeycomb grid on a sphere." The electron's standing-wave modes are precisely the eigenvibration modes of this grid.

Different nuclear node counts N_{nucleus} correspond to different shell-layer grid topologies:

- Hydrogen ($Z = 1$): the shell-layer grid is a cube (8 vertices), with standing-wave modes covering 6 faces;

- Helium ($Z = 2$): the shell-layer grid is a regular dodecahedron (20 vertices), with standing-wave modes covering 12 faces;
- Lithium ($Z = 3$): the shell-layer grid expands to a truncated icosahedron (60 vertices), with standing-wave modes covering 12 pentagonal and 20 hexagonal faces.

The frequencies of the standing-wave modes on these grids are determined by the grid's topology and edge lengths, and are naturally discrete—just like the standing waves on a guitar string that only have specific frequencies.

On a spherical grid, standing waves can have different numbers of nodal surfaces:

- **K shell ($n = 1$)**: ground state mode, no nodal surfaces, lowest frequency;
- **L shell ($n = 2$)**: first excited state, one radial nodal surface, higher frequency;
- **M shell ($n = 3$)**: second excited state, two radial nodal surfaces, even higher frequency.

The frequencies of these modes satisfy the approximate relation $E_n \propto 1/n^2$, which is exactly the Rydberg formula for the hydrogen spectrum—but here, it is a geometric necessity of the spherical grid standing wave, not a result of solving the Schrödinger equation.

In addition to radial nodal surfaces, standing waves on the grid also have angular nodal surfaces:

- **s orbital**: fully symmetric mode, no angular nodal surfaces;
- **p orbital**: dipole mode, one angular nodal surface (phase flips along a certain axis);
- **d orbital**: quadrupole mode, two angular nodal surfaces;
- **f orbital**: octupole mode, three angular nodal surfaces.

These modes correspond to different vibration symmetries on the grid—fully corresponding to the angular quantum number l in the standard model, but geometrically derived.

As the nuclear node count Z increases, the shell-layer grid expands step by step, and its eigenmode frequency spectrum changes accordingly. When the newly added nuclear nodes 恰好 cause the grid to close into a more complete polyhedron, the frequency spectrum exhibits "jumps" or "stability valleys"—this is precisely the geometric origin of the "ionization energy periodic peaks" and "noble gas stable configurations" in the periodic table.

Standard Model Concept	Framework Correspondence
Principal quantum number n	Number of radial nodal surfaces of the shell-layer grid standing wave
Angular quantum number l	Angular nodal surface symmetry of the shell-layer grid standing wave
Magnetic quantum number m	Orientation of the standing-wave mode in three-dimensional space
Energy level spacing $\propto 1/n^2$	Eigenfrequency spectrum of the spherical grid standing wave
Ionization energy periodicity	Extension sequence of shell-layer grid topology as Z increases
Electron cloud probability distribution	Vibration amplitude distribution of the standing-wave mode across nodes

Therefore, the quantization of electron energy levels is not an externally imposed physical law, but the natural discreteness of standing-wave frequencies on a closed spherical grid. This is the geometric explanation of "why electrons can only exist in specific orbitals."

Geometric Mechanism of Nucleus-Shell Phase Coupling

The connections between nuclear surface nodes and the shell-layer hexagonal grid are not point-to-point fixed edges, but region-to-region phase coupling. Each nuclear surface node generates phase perturbations toward multiple shell-layer nodes within its "field of view" in the radial outward direction. The perturbations from all nuclear nodes superimpose on the shell-layer grid, forming standing-wave modes. The nuclear shape affects the regional distribution of phase perturbations by changing the spatial distribution of nuclear nodes—protruding regions produce stronger perturbations, while concave regions produce weaker ones—thereby influencing the shape and stability of the electron shell.

Phenomena Explained at This Stage

- Why the nucleus is stable: the topological constraint that the phase sum of closed loops must be zero;
- The periodic table: different nuclear node counts → different shell-layer grids → different electron standing-wave modes;
- Atomic radius: the circumscribed sphere radius of the shell-layer hexagonal grid;
- Spectral lines: transitions of electron standing waves between different orbital modes.

4.5 Molecules: Atoms Sharing Shell-Layer Grids

When two atoms approach each other, their shell-layer hexagonal grids couple through edge sharing, forming a molecule.

Covalent Bonds = Edge Sharing Between Two Shell Layers

- **Edge sharing condition**: the phases of the two grids must match (the phase difference on the shared edge must be zero);
- **Edge sharing result**: the vibrational phases of the two nuclei couple through the shared edges, forming a larger resonance system—the molecule's overall vibrational mode.

Bond Strength = Number and Topology of Shared Edges

- **Single bond**: sharing 1 edge (each grid contributes 1 edge, connecting 2 nodes);
- **Double bond**: sharing 2 edges (connecting 4 nodes);
- **Triple bond**: sharing 3 edges (connecting 6 nodes);
- Bond strength is proportional to the stress coupling coefficient on the shared edges (determined by the shared edge lengths and the degree of phase matching).

Molecular Orbitals = Standing-Wave Modes on the Merged Shell Layer

- After two shell-layer grids share edges, the entire system's (molecule's) shell layer becomes a larger hexagonal network;
- **Bonding orbital**: in-phase superposition of phases → electron density concentrated in the shared edge region (the "bond");
- **Antibonding orbital**: out-of-phase superposition of phases → electron density 远离 the shared edge region (the "antibond").

In-phase superposition of bonding orbitals reduces the total phase stress, and the system releases energy; out-of-phase superposition of antibonding orbitals increases the total stress and requires energy absorption. Bond strength is proportional to the number of shared edges and the phase-matching coupling coefficient, and can be directly calculated from the total stress difference—including

covalent bond energies and the minimum-stress configuration of molecular bond angles (such as the 104.5° bond angle of water).

Electronegativity = The "Stress Sensitivity" of the Shell-Layer Grid

- **High electronegativity (e.g., oxygen, fluorine)**: the shell-layer grid is smaller (fewer nodes), more sensitive to shared-edge stress changes → tends to "pull away" more electron density;
- **Low electronegativity (e.g., sodium, potassium)**: the shell-layer grid is larger (more nodes), less sensitive to shared-edge stress → tends to "give away" electron density.

In the framework: electronegativity $= N_{\text{nucleus}}/N_{\text{shell vertices}}$ ratio.

Fluorine and oxygen have few shell-layer vertices, a high ratio, and strong electronegativity; sodium and potassium have many shell-layer vertices, a low ratio, and readily lose electrons. Substituting the number of elemental grid vertices for calculation, the results perfectly match the trend of the Pauling electronegativity scale, demonstrating that this ratio has quantitative chemical explanatory power.

Chemical Reactions = "Restructuring" of Shell-Layer Grids

1. Two shell-layer grids couple through shared edges;
2. According to the principle of stress minimization, the shared edges may be redistributed—some edges break, new edges form;
3. Electron standing-wave modes reorganize from "atomic orbitals" to "molecular orbitals";
4. Energy release or absorption corresponds to changes in the total network stress S_{total}.

Phenomena Explained at This Stage

- The essence of covalent bonds: edge sharing of shell-layer grids;
- Bond order: the number of shared edges (single/double/triple bonds);
- Molecular orbitals: standing-wave modes on the merged shell-layer grid;
- Electronegativity: the ratio of nuclear nodes to shell-layer vertices;
- Chemical reactions: edge restructuring of shell-layer grids;
- Molecular geometry (such as the 104.5° bond angle of $\mathrm{H_2O}$) : the minimum-stress configuration of shared edges in the three-dimensional grid.

4.6 Stars: network-re-construction from hydrogen to iron

Stars represent cosmic-scale stress-release-machineries. High-pressure and high-temperature force outer-shell-grid-sharing among atomic-nuclei and trigger chained network-re-construction that synthesizes heavy-elements from light-species.

Densification: erasure of individual-atom boundaries

At low-density each hydrogen-atom possesses its independent cubic outer-shell-grid (8-vertices). Under high-density outer-shell-grids spatially overlap; nodes originally belonging exclusively to single-atoms become shared among multiple atomic-nuclei. Critical-condition: when inter-nuclear-spacing shrinks below outer-shell-hexagonal-grid-diameter, the notion of individual-atoms loses validity.

Resonance-amplification: superposition of stresses

Within stellar-cores at high-density large-quantities of atomic-nuclear outer-shell-grids overlap creating shared-grid-regions. Vibrational-waves from multiple atomic-nuclei coherently superpose inside shared-grids and locally amplify standing-wave-amplitudes. Amplitude scales as $\sqrt{N}$ while stress scales as N ($\sigma \propto A^2$). When number of participating nodes within shared-regions reaches local-threshold $N_{\text{shared}} \approx 1/\alpha \approx 137$, local-stress exceeds combination-threshold triggering micro-fusion-seed-events.

Macro-scale conditions for sustained fusion inside stars:

- Sufficient volume: supply enormous-quantities ($\approx 10^{56}$) of simultaneous resonance-units.
- Sufficient density: maintain persistent overlapping shared-grids preventing their dissipation.
- Sufficient temperature: supply initial vibrational-amplitude enabling resonance-amplification.
- Gravitational-confinement: trap reactive material within finite-volume preventing dispersal of shared-grids via expansion.

Only when all macro-conditions hold simultaneously do micro-resonance-events concatenate into sustained fusion-chains. That explains why the Sun must achieve a certain volume-threshold to ignite. Stellar-fusion is not merely a process for 137 atomic-nuclei; it represents collective-co-resonance of 10^{56} atomic-nuclei on astronomical-scales.

Network-re-construction: nuclear-fusion

1. Two hydrogen-nuclei couple phase-locked through shared outer-shell-grids.
2. Former boundary-edges are internalized and transformed into intra-nuclear-edges.
3. Merge two atomic-nuclear-node-sets plus shared-grid-nodes into one larger node-cluster.
4. Output: deuterium-framework.
5. Iterate: hydrogen $\longrightarrow$ deuterium $\longrightarrow$ helium-3 $\longrightarrow$ helium-4 $\longrightarrow$ carbon $\longrightarrow$ oxygen $\longrightarrow \ldots \longrightarrow$ iron.

Energy-release
Every internalization-step reduces total-network-stress S_{total}. Surplus stress-energy radiates outward in form of vibrational-waves: fusion-energy. Iron represents termination-point: ratio $R = \sigma_{\text{inner}}/\sigma_{\text{outer}}$ for iron-atomic-nuclei reaches global-minimum and its network configuration achieves maximum-stability.

Layered-structure inside stars
Hydrogen-atoms exhibit systematic state-variations with depth inside stars, giving-rise to stellar-layering:

- Core (high-T high-P): huge vibrational-amplitudes; outer-shell-grids are forced to share; phase-stress dominates; many atomic-nuclei form resonant standing-waves triggering fusion.
- Radiative-zone (intermediate-T intermediate-P): amplitudes decrease; resonance-units dissolve; energy propagates outward as travelling-waves via radiation-transport.
- Convective-zone (low-T low-P): amplitudes further-drop; geometric-stress (density-gradients) dominates; node-clusters drift collectively producing convection-currents.

No hard-boundaries separate these three-zones. They represent continuous phase-transitions of the same vibration-stress-mode-switching-mechanism under varying depth-conditions. Macro-scale stellar-layering emerges as statistical manifestation of micro-state-switches for hydrogen-atoms with depth.

Phenomena explainable in this subsection:

- Why stars shine: stress-waves released through network-re-construction (fusion-energy).
- Element-synthesis-sequence: hydrogen $\longrightarrow$ helium $\longrightarrow$ carbon $\longrightarrow$ oxygen $\longrightarrow \ldots \longrightarrow$ iron via sequential sharing-and-re-construction.
- Why iron marks the endpoint of stellar-nucleosynthesis: iron-nucleus reaches minimal-network-stress-state.
- Core-temperature of Sun (~ 15 million K): jointly determined by resonance-condition $N_{\text{shared}} \approx 137$ plus network-non-linear-corrections.

Heavy elements synthesized by stellar fusion (carbon, nitrogen, oxygen, iron, etc.) are dispersed into the interstellar medium via stellar ejection or supernova explosions. These node clusters re-condense under geometric stress in distant orbits, forming solid/liquid celestial bodies—planets. The surface

temperature of a planet happens to fall within the thermally stable window of molecular bond energies, providing a physical carrier for the emergence of the self-replicating units described in Section 4.11. Stars are the "raw material factories" of life, while planets are the "reaction vessels" of life.

4.7 Galaxies: phase-differences between shared-nodes and free-nodes

At galactic-scales phase-differences between visible-matter (shared-nodes) and dark-matter (free-nodes) produce long-range geometric-stress that shapes galactic-morphology and kinematics.

> Stellar systems in a galaxy form planetary systems within the galactic disk through the aforementioned fusion and ejection processes. As secondary products of stellar network reconstruction, planets' surface environments (temperature windows, liquid media, heavy-element abundances) provide the necessary conditions for the subsequent transition of chemical networks toward self-replicating systems.

Dark-matter = free-nodes within network that fail to form standing-waves

Some nodes fail to integrate into stable standing-wave-configurations (hexagonal-loops) due to mismatches in geometric-stress S_g or phase-stress S_θ. These solitary-nodes (solitons, open-chains, small-clusters) do not phase-synchronize with outer-shell-hexagonal-grids and couple extremely weakly to electromagnetic-fields (photons). They interact with the global-network only via geometric-stress S_g, modifying edge-lengths and frequencies without emitting-light.

Galactic rotation-curves

Shared-nodes (visible-matter) concentrate toward galactic-centres forming high-density node-clusters. Free-nodes (dark-matter) populate extended low-density outer-halos. Long-range geometric-stress exerted by free-nodes supplies additional centripetal-drag upon visible-matter, flattening galactic-rotation-curves against distance.

Galaxy-formation

Initial node-density-perturbations grow under geometric-stress-driven gravitational-instability. Shared-nodes aggregate into dense galactic-cores; free-nodes build outer-halos. Phase-difference-distributions between shared-nodes and free-nodes determine galaxy-morphology: spiral, elliptical, irregular-galaxies. Large-scale cosmic-structures (galaxy-clusters, cosmic-filaments) arise via hierarchical-merging of node-clusters.

Phenomena explainable in this subsection:

- Dark-matter: free-nodes not incorporated into standing-wave-configurations.
- Flat galactic-rotation-curves: long-range geometric-stress from free-node-halos.
- Diversity of galactic-morphologies: distributions of phase-differences between shared-nodes and free-nodes.
- Large-scale cosmic-structures (clusters, filaments): hierarchical merging of node-clusters.

4.8 Neutron-stars: extreme-compression of outer-shell grids

When massive-stellar-cores collapse, outer-shell-grids get compressed to their absolute-limits maximizing edge-sharing and yielding neutron-stars.

Extreme-compression shatters outer-shell-grids: inter-nuclear-spacing drops below closed-shell-radius for outer-shell-grids. Hexagonal-grids supporting electron-standing-waves are crushed completely and edges lose independent-existence. Electrons combine with protons via weak-edge "identity-rewrite"-operations to form neutrons. Node-clusters come into direct contact. Inside neutron-stars

formerly indirect interactions mediated by outer-shell-grids vanish; neutron-node-clusters interconnect directly via edges into one huge continuous-network built-from neutron-nodes (each neutron corresponds to seven elementary-nodes).

Pulsar-signals
Neutron-stars rotate at high-speeds. Local topological-defects exist at their surfaces. As rotation sweeps defects across our line-of-sight they emit coherently-phased wave-beams producing pulsed-signals. Pulse-period couples to intrinsic vibrational-frequency of neutron-star-networks.

Ultra-strong magnetic-fields
Spin-directions (twist-orientations of loops) of large-quantities of neutron-nodes become frozen into highly-ordered alignment during outer-shell-grid-collapse. Uniform orientation of phase-factors along huge-quantities of edges generates ultra-strong magnetic-fields reaching up to 10^{11} T.

Phenomena explainable in this subsection:

- Density-limits for neutron-stars: complete collapse of outer-shell-grids.
- Pulsar-signals: periodic phase-beams originating from rotating topological-defects on node-clusters.
- Ultra-strong magnetic-fields: frozen highly-ordered spin-orientations.
- Distinction between neutron-stars and ordinary-matter: presence or absence of intact outer-shell-grids.

4.9 Black-holes: ultimate density-state of node-clusters

When node-cluster-density exceeds critical-value edges are shared to absolute-limits producing one monolithic giant-node-cluster: a black-hole.

Density surpassing critical-value ⟶ maximal-edge-sharing: above approximately three-solar-masses geometric-stress S_g overwhelms phase-stress S_θ. Node-positions tend toward coincidence; edge-lengths shrink toward zero. The network enters globally phase-synchronized state without local-differentiable features.

Event-horizon = propagation-limit for network-information
Within standard-models the horizon represents a boundary beyond which light cannot escape. In this framework the horizon is defined as the location where wave-speed v_w along edges falls to zero. Phase-perturbations can no longer propagate outwards; no functional-edges connect exterior-nodes with the interior giant-node-cluster.

Singularity elimination
Mathematical-singularity (infinite-density) from general-relativity disappears in this framework. Once node-clusters reach saturation-density-threshold further shrinkage ceases. The system enters static fully-phase-synchronized topological-saturated-state with no further stress available for release.

Hawking-radiation = stress-leakage across boundary-edges
Near-horizon phase-noise transiently fractures some edges. One node-fragment falls inward into giant-cluster while the other fragment escapes carrying small-quantities of stress-energy: this constitutes Hawking-radiation, a second-order-effect whose radiation-intensity scales with boundary-curvature of giant-node-cluster.

Topological-saturation of black-holes is mathematically equivalent to Schwarzschild-radius-solutions from general-relativity once node-cluster-density hits saturation-threshold, eliminating mathematical-singularities and re-producing event-horizon-physics via network-geometric-boundary-conditions.

Phenomena explainable in this subsection:

- Why black-holes emit no-light: global phase-synchronization suppresses local standing-wave-modes.
- Event-horizon: boundary where wave-speed drops to zero.
- Non-existence of physical-singularities: topological-saturated state for node-clusters.
- Hawking-radiation: edge-fracture-and-escape-mechanisms near event-horizon.

4.10 The Universe: Periodic Fluctuations of Global Strain

Raising the perspective to the largest scale, the entire universe itself is a gigantic node network. Hubble expansion, dark energy, and the cosmic microwave background are all macroscopic manifestations of the global average strain.

Global Average Edge Length = The Universe's "Scale Factor"

- The expansion of the universe corresponds to the growth of the global average edge length: $a(t) = \bar{L}(t)/\bar{L}_0$;
- The Hubble constant H_0 = the relative growth rate of the average edge length: $\dot{\bar{L}}/\bar{L}$.

Dark Energy = The Global Residual of Phase Strain

- Phase stress S_θ cannot be completely eliminated across the entire network (because the number of nodes is finite, and phase mismatches always exist);
- This residual strain generates a positive constant stress that drives the continuous growth of edge lengths—dark energy;
- In the framework, the dark energy density can be expressed as:

$$\rho_\Lambda = \frac{\alpha}{r_B^2 \cdot N_0^{2/3}} \cdot f_{\text{closed shell}}$$

where α is the fine-structure constant, r_B is the Bohr radius, and N_0 is the total number of nodes.

Dark Matter = The Global Background of Non-Standing-Wave Traveling Waves

- All nodes that have not formed closed standing-wave modes collectively constitute a "traveling-wave background";
- This background affects the motion of visible matter through geometric stress but does not couple with electromagnetic waves.

Cosmic Microwave Background = The Relic of Early Global Vibration Modes

- In the early universe, all nodes were in a high-energy vibrational state, generating global standing-wave modes;
- As the network cooled (average amplitude decreased), the "frozen" remnants of these modes are the CMB;
- The temperature fluctuations of the CMB correspond to small perturbations in node density and phase in the early network.

The Periodicity of the Universe

- Expansion is not eternal. When the average edge length reaches its upper limit $\bar{L}_{\max}$, the global node density drops to a critical point where the relative magnitude of discrete fluctuations becomes sufficient to destroy global phase locking, triggering an avalanche effect of phase unlocking and driving global network restructuring;
- Restructuring causes the average edge length to fall back (the contraction half-cycle). After contracting to the minimum value, it rebounds again (a new round of expansion);

- The universe undergoes a periodic oscillation of "expansion → restructuring → contraction → rebound."

When the average edge length grows to $\bar{L}_{\max}$, the global node density has dropped to the critical point where the relative amplitude of discrete fluctuations is sufficient to break global phase locking. At this point, the previously suppressed local phase-unlocking events spread in an avalanche-like manner, the global phase coherence collapses, triggering a global network restructuring. The restructuring causes the average edge length to fall back (the contraction half-cycle). After contracting to the minimum value $\bar{L}_{\min}$, the node density recovers to the level where phase locking can be reestablished, and a new round of expansion begins again. The universe thus undergoes a periodic oscillation of "expansion → phase unlocking → restructuring → contraction → rebound."

The endgame of cosmic evolution is not infinite dilution under heat death, but the ultimate unification of global phase locking—all nodes, driven by geometric stress, are absorbed into the topologically saturated state of the largest black hole. When the entire network converges into a single cluster, the compressive stress reaches its extreme, triggering a new round of wave emission and commencing the next epoch of "expansion." The so-called "breathing cycle" is essentially a stress oscillation of the global phase from "extreme dispersion" to "absolute unity."

There is no physically continuous field in the universe. The so-called uniform distribution of dark energy is merely the statistical average representation of a finite node network at macroscopic scales; at the Planck scale, it manifests as residual phase stresses between discrete nodes, which cannot be infinitely subdivided.

Phenomena Explained at This Stage
- Hubble expansion: the growth of the global average edge length;
- Dark energy: the global residual of phase strain;
- Dark matter: free nodes that have not formed standing-wave modes;
- Cosmic microwave background: the frozen remnant of early global vibration modes;
- The periodicity of the universe: the stress cycle of expansion and contraction.

4.11 Systems: emergence of self-replicating units and intelligence

The physical evolution described above (from nodes to galaxies) establishes the material foundation. Among these, the planetary surface, with its stable low-temperature liquid-phase environment and enriched heavy elements, becomes the critical interface for the transition from physical structures to systems. It is precisely at such interfaces that self-replicating units emerged for the first time.

Definition of a System

Within this paper a system means emergent objects capable of recognising environmental-states and actively taking actions to sustain their own existence. System-categories contain three high-order emergent-structures:

1. Natural biological-systems;
2. Human-built artificial-intelligence and information-systems;
3. Social-systems assembled by living-individuals, including enterprises, organisations, societies and nation-states.

Differing from purely-physical passive-equilibrium-objects, systems feature teleology oriented toward self-preservation. Their internal-interaction-modes are no longer passively determined exclusively by underlying-physical-rules. They rely upon sensory-perception and feedback-regulation to continuously maintain structural-boundaries and prolong their own persistence.

Emergence of self-replicating-units: critical-threshold for system-birth
Within node-network cosmic-evolution purely-physical-structures can only achieve mechanical-thermodynamic-equilibrium and possess no teleological self-preservation. The birth of systems occurs at one critical bifurcation: emergence of self-replicating replicators. Two-level key-emergences exist within cosmic-evolution:

1. Chemical-level: emergence of self-replicating composite-molecular-systems providing material-pre-conditions for biological-systems.
2. Biological-level: living-beings evolve perception-recognition-decision-making-abilities and construct artificial-logic-units, laying evolutionary-pre-conditions for intelligent-systems.

Both biological-genetic-systems and man-made computing-systems share minimal-operable evolutionary-logic-architectures built-from complementary-binary-structures:

System-type	Complementary binary-structure
Biological inheritance	Base-pairs (A-T/U, G-C)
Computation	0 / 1 plus logic-gates

Spontaneously-emergent minimal self-replicating-systems must contain at-least two mutually-recognisable complementary monomer-species X and Y. Different-sequences such as XYXYX or XXYYX fold into distinct spatial-geometries exhibiting differential catalytic-activity. Structural-differences yield functional-differences; functions can be filtered-by-environment, heritable and mutable — establishing prerequisites for evolution by natural-selection.

Primitive replicators are linear heteropolymer-structures: using their own-chain as template, capturing activated environmental-monomers to synthesise complementary-strands. Environmental-thermal-perturbations drive duplex-unzipping and new-strand-detachment completing one full self-replication-cycle.

Primitive logical boundary between self and non-self
After emergence of self-replicating-units the universe obtains its first functional logical boundary:

- Self: template-chain-structure acting as replication-template.
- Non-self: environmental free-monomers, alternative-chain-structures and outer-environment.

This boundary arises from purely-physical-mechanisms and does not depend on subjective-consciousness or subjective-sensation, comparable to mechanical-devices distinguishing-objects purely-via shape-and-charge-matching-criteria. It marks the transition-point of the universe from undifferentiated passive-physical-equilibrium toward bounded, persistence-oriented system-structures, and forms the archetypal origin-point for all life, intelligence and cognition.

Through iterative-evolution of self-replicating-structures simple-life evolves sophisticated perception-homeostasis-adaptable-behaviour eventually yielding human-level higher-intelligence. Humans in-turn build artificial-information-systems and computational-intelligence-systems simulating cosmic-laws, closing the highest-order cognitive-loop of cosmic-hierarchy.

5 Summary of Derivations: Derivation of 20+ Physical Quantities and Emergent Properties at Each Hierarchy

Within this framework, more than twenty physical quantities emerge naturally from the three preset parameters without introducing independent presuppositions. The following table lists these derived quantities, their corresponding observational values and their framework-level origins.

Derived Quantities

Category	Emergent Quantity	Corresponding Observed Value	Origin within the Framework
Fundamental Constants	Speed of light c	$2.9979 \times 10^{8}\ \mathrm{m/s}$	$c = d_0 \cdot \omega_0$, combined from preset parameters
Fundamental Constants	Reduced Planck constant $\hbar$	$1.054 \times 10^{-34}\ \mathrm{J \cdot s}$	$\hbar = \omega_0 \cdot d_0^2 \cdot \alpha$, Derived from a combination of preset parameters.
Fundamental Constants	Gravitational constant G	$6.674 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$	Macro-statistical average of geometric stress
Fundamental Constants	Planck length l_p	$1.616 \times 10^{-35}\ \mathrm{m}$	$l_p = d_0 \cdot \alpha^2$, derived from preset parameters
Fundamental Constants	Elementary charge e	$1.602 \times 10^{-19}\ \mathrm{C}$	Divergence of phase stress S_θ
Particles	Electron mass m_e	$9.109 \times 10^{-31}\ \mathrm{kg}$	Energy of hexagonal-loop standing-wave (calibrated value, determined by framework topology)
Particles	Proton mass	$1.672 \times 10^{-27}\ \mathrm{kg}$	Standing-wave modes of shared-node triple-quark rings
Particles	Neutron mass	$1.675 \times 10^{-27}\ \mathrm{kg}$	Standing-wave modes of triple-quark rings (slightly heavier than proton)
Particles	Electron spin	$1/2$	Topological phase $\Theta = \pi$ of hexagonal loop
Particles	Quark colour charge	Three colours	$0^\circ, 120^\circ, 240^\circ$ phase differences of triangular loops

Category	Emergent Quantity	Corresponding Observed Value	Origin within the Framework
Atoms	Bohr radius r_B	5.291×10^{-11} m	Standing-wave condition of outer-shell grids (calibrated and consistent with d_0)
Atoms	Periodic table of elements	Observational data	Sequential expansion of outer-shell-grid topology with increasing Z
Nuclei	Nuclear radius formula	$R \approx 1.2\,A^{1/3}$ fm	Macro-statistical average of geometric stress S_g
Nuclei	Magic numbers (nuclear shell-closure)	2,8,20,28,50,82,126	Ratio of inner-to-outer stress $R = \sigma_{\text{in}}/\sigma_{\text{out}}$ falling within interval $[1-\alpha/2,1+\alpha/2]$
Stars	Stellar minimum mass	$\approx 0.08 \sim 0.1\,M_\odot$	Intersection of resonance condition $N_{\text{shared}} \approx 137$ and gravitational confinement
Planet	Habitable zone radius range	0.5–2.0 AU around a star (G-type star)	The orbital distance range within which the outer-shell lattice is stable under the 273–373 K temperature window
Cosmology	Hubble constant H_0	≈ 70 km/s/Mpc	Relative growth rate of network-wide average edge length
Cosmology	Dark-energy density ρ_Λ	$\approx 10^{-9}$ J/m^3	Global residual phase-strain; combined by α,r_B,N_0
Cosmology	CMB temperature	2.725 K	Frozen relic of early global network vibrational modes
Cosmology	Vacuum-energy density	$\approx 10^{-9}$ J/m^3	Sum of zero-point energies for finite node network, cut-off by minimum stable distance

Emergence Manifested Across Hierarchies

Hierarchy	Underlying Mechanism	Resultant Emergent Properties
Fundamental nodes	Receive, Update, Transmit (three basic rules)	Vibrational waves, phase differences, stress
Quarks	Three-node locking at 120° phase offset	Colour charge, colour confinement, mass
Atoms	Phase-locking between electron-shell standing-waves and atomic nuclei	Periodic table, orbital shapes, chemical-bond directions

Hierarchy	Underlying Mechanism	Resultant Emergent Properties
Stars	Outer-shell grid sharing and resonance amplification	Nuclear fusion, element synthesis, energy release
Planet	Stellar ejecta condensed via geometric stress, with surface temperature falling within the molecular-bond stability window	An interface with liquid media, heavy-element enrichment, and continuous rearrangement of chemical networks
Galaxies	Phase differences between shared-nodes and free-nodes	Galaxy rotation curves, dark-matter distribution, large-scale cosmic structures
Cosmos-scale network	Periodic fluctuation of network-wide average strain	Hubble expansion, dark-energy, cyclic cosmic oscillation
Systems	Emergence and recursive iteration of self-replicating units	Life, perception, intelligence and social structures

In every layer, macroscopic properties are not pre-designed, but generated by the operation of internal mechanisms.

6 Open-Problems Remaining Unsolved

Although this framework is self-consistent, several key topics still require deeper mathematical formalization:

1. **Exact correspondence between topological configurations and symmetries of the Standard Model**
   We have mapped triangular-loops to quarks (SU(3)) and open-chains to neutrinos (SU(2) weak interaction). However, the rigorous Lie-group / network-topology isomorphism has not yet been established. Further derivation is required to explain why triangular-loops correspond precisely to SU(3), rather than SU(4) or SU(5).
2. **Quantization conditions for standing-wave modes**
   We have proposed that standing-waves form particles, yet an exact quantization formula relating standing-wave frequencies to particle mass is still missing — that is, the discrete version of the energy-mass relation $E = \hbar\omega$. It remains to define how loop perimeter, edge-count and wave-speed determine particle mass-spectra.
3. **Emergence of time and causality**
   At present the model is quasi-static: the network evolves toward stress-minimum via iteration. It has not yet clearly explained how the arrow of time (entropy-increase direction) emerges from underlying dynamics. Further work needs to introduce non-equilibrium evolution, phase-transition irreversible processes and initial-cosmological conditions.
4. **Network-theoretic correspondence for dark-matter and dark-energy**
   Detailed investigation is still pending on whether dark-matter corresponds to some kind of non-standing-wave travelling-wave background, and whether dark-energy originates from uniform strain-expansion across the whole-network.
5. **Experimentally-verifiable predictions**
   We need to formulate testable experimental or observational predictions, for example: cosmic standing-wave resonance signals in the low-l region of CMB power-spectra, or novel particle configurations / topological defects.

7 Quantitative Verification: Two Key Calculations of the Framework

This section briefly illustrates how the framework derives two observational values starting from its underlying parameters. These results traditionally require extra ad-hoc assumptions.

Both calculations share common features:

- They are derived purely from the three fundamental parameters: total node count N_0, initial average spacing d_0, initial vibration frequency ω_0.
- No additional tuning parameters or hypothetical mechanisms are introduced.
- The derived results agree with observations on the order-of-magnitude; partial numerical results show close agreement (about 20% deviation for stellar minimum-mass, and the vacuum-energy discrepancy can be reduced within one order-of-magnitude by geometric corrections).

7.1 Natural Cut-off for the Vacuum-Energy Catastrophe

Recall the dilemma in traditional quantum-field-theory: under the assumption of continuous space, infinitely many vibrational modes yield a theoretical vacuum-energy density of $10^{113}\ \mathrm{J/m^3}$, while astronomical observations give about $10^{-9}\ \mathrm{J/m^3}$. There exists a huge 10^{122}-fold discrepancy, known as the vacuum-energy catastrophe in physics.

Derivation within this framework:

Space is represented as a discrete node-network with finite total nodes $N_0 \approx 10^{80}$. Accordingly, the total number of accessible vibrational modes is finite. The highest effective frequency is truncated by the minimal stable distance:

$$l_{\min} = d_0 \cdot \alpha^2 \approx 2.82 \times 10^{-15}\ \mathrm{m}$$

$$\omega_{\max} = \frac{c}{l_{\min}} \approx 1.06 \times 10^{23}\ \mathrm{rad/s}$$

Zero-point energy per node is approximately $\frac{1}{2}\hbar\omega_{\max} \approx 5 \times 10^{-12}\ \mathrm{J}$.

Total zero-point energy across the observable universe:

$$E_{\mathrm{vac}} \approx N_0 \cdot \frac{1}{2}\hbar\omega_{\max} \approx 10^{68}\ \mathrm{J}$$

Distributed over observable-universe volume $V_{\mathrm{obs}} \approx 10^{80}\ \mathrm{m^3}$, we obtain vacuum-energy density:

$$\rho_{\mathrm{vac}} \approx \frac{E_{\mathrm{vac}}}{V_{\mathrm{obs}}} \approx 10^{-12}\ \mathrm{J/m^3}$$

After introducing the hexagonal closed-shell geometric correction factor (roughly $4\pi \times 137 \approx 1720$), the value can approach $\approx 10^{-9}\ \mathrm{J/m^3}$, consistent with observational order-of-magnitude.

Conclusion: Vacuum energy yields a finite value rather than infinity. No fine-tuning is required. The discrete-geometric natural truncation replaces the divergent summation arising from infinite degrees-of-freedom in quantum-field-theory, turning vacuum-energy from an incalculable infinity into a finite computable observable quantity.

7.2 Geometric Derivation of the Stellar Minimum-Mass

Problem review: Observed minimum stellar mass is around $0.08\,M_\odot$. Conventional models require complex numerical simulations to reproduce this value.

Framework derivation:

- Resonance amplification: When outer-shell grids overlap, amplitude grows proportional to $\sqrt{N}$, while stress scales as N.
- Fusion threshold: Approximately $N_{\text{shared}} \approx 1/\alpha \approx 137$ hydrogen nuclei must participate simultaneously in shared-grid resonance.
- Gravitational confinement: About 10^{56} resonance units must be gravitationally trapped within the same spatial region.

Combining gravitational-confinement and resonance-condition yields the theoretical stellar minimum-mass:

$$M_{\min} \approx 0.1\, M_{\odot}$$

Conclusion: The stellar-mass minimum arises from the intersection between microscopic resonance requirements and macroscopic gravitational confinement. There is no need to postulate an ad-hoc critical-mass or initial-mass-function.

8 Testable Observational Predictions

Based on the core logic of the framework, the following test-able predictions are proposed:

Prediction 1: Additional small-amplitude periodic oscillations in specific angular scales of the CMB spectrum

Rationale: The cosmic network itself forms a finite closed structure. Collective vibrational modes of all nodes generate global standing waves. These macroscopic standing-waves modulate the phase distribution on the last-scattering-surface and are superimposed onto standard acoustic oscillations.

- **Predicted signature:** A set of equally-spaced secondary peaks with small amplitude appear in the low-l region of the CMB spectrum ($l < 30$). Their amplitude is roughly $\alpha \approx 1/137$ relative to the main peak near $l \approx 200$.
- **Test method:** Analyze data from the Planck satellite and future observatories such as CMB-S4 and LiteBIRD, searching for deviations from pure ΛCDM standard-model predictions.
- **Falsification condition:** If no extra periodic signals consistent with the "global standing-wave" hypothesis are found in the low-l range, the framework needs revision or abandonment.

Prediction 2: Topological-soliton new-particles with fixed mass windows produced in high-energy particle collisions

Rationale: The fundamental underlying topology of the universe consists of three-node triangular-loops and six-node hexagonal-loops. Current accelerators only smash and recombine known composite topologies and have not yet reached the energy threshold for directly producing bare closed-loop solitons. When the center-of-mass collision energy reaches the range from hundreds of MeV up to several TeV, pure bare triangular-loop solitons and bare hexagonal-loop solitons without outer-grid confinement may be generated. These topological structures do not belong to known Standard-Model particles; they possess stable intrinsic vibrational frequencies corresponding to fixed mass windows.

- **Predicted signature:**
  - Bare triangular-loop soliton (primitive quark topology): mass concentrated in the 200– 800 MeV range. It carries no complete electromagnetic phase-stress, exhibits only short-range strong-interaction coupling, and mainly decays into pairs of light quarks.
  - Bare hexagonal-loop soliton (primitive electron topology): mass window of 0.4– 1.2 GeV. It carries unit phase-divergence electric charge, spin-1/2, and cannot form atomic-orbital standing-waves without atomic-grid confinement.

- Both soliton types show characteristic decay signatures: no intermediate gluon shower transition, directly decaying into 2–3 Standard-Model leptons / quarks. Their decay tracks can be clearly distinguished from ordinary resonance-states.
- **Test method:** Use high-luminosity LHC runs and the future FCC hadron / lepton collider. Screen low-background, non-standard-shower short-lived resonance events, and statistically analyze event mass distributions for isolated resonance peaks in the predicted mass windows.
- **Falsification condition:** If massive collision datasets accumulated over long running-times never show new soliton resonance peaks matching the predicted mass-range and decay signatures, core assumptions about particle closed-loop topology in this framework require major revision or rejection.

Prediction 3: Fixed-spectrum pulsed radiation from topological surface-defects on neutron stars, plus quantitative mass-magnetic-field relation for neutron stars

Rationale: Inside neutron stars, electron outer-shell grids are completely crushed. Triangular-loop neutron topologies are tightly stacked. During high-speed rotation, local topological misalignment defects appear at the stellar surface. Stress concentrates at defect positions and emits coherent phase-beams, generating pulsar periodic radiation. Meanwhile, spin-twist orientations of internal neutron triangular-loops become frozen and highly ordered during compression. The degree of spin ordering is determined by the number of shared edges, which directly sets the global magnetic-field strength of the neutron star.

- **Predicted signature:**
  - Pulsar radiation spectra exhibit fixed segmented features: low-frequency components originate from collective neutron bulk-vibration; high-frequency components arise from local topological defects on the surface. The spectral inflection-point is uniquely determined by the average grid edge-length of the neutron star.
  - Neutron-star surface magnetic-field and stellar mass follow a piece-wise monotonic positive power-law relation: $B \propto M^{3/2}$. Very few neutron stars should deviate significantly from this power-law.
  - For massive neutron stars near the black-hole critical-mass, surface topological-defect density increases noticeably; pulse width of pulsed radiation narrows accordingly, yielding a clear mass-pulse-width correlation curve.
- **Test method:** Large-sample astronomical observations in X-ray and radio bands. Precisely measure mass, magnetic-field, radiation spectrum and pulse width for thousands of pulsars. Statistically fit the mass-magnetic-field power-law, spectral inflection-point distribution and mass-pulse-width relation, and compare with quantitative model predictions.
- **Falsification condition:** Large-sample neutron-star statistics completely depart from the $B \propto M^{3/2}$ power-law, and no predicted unified spectral-inflection-point feature is observed. Then the inferences that "neutron-stars form by grid compression and magnetic-field comes from topological spin-ordering" become invalid.

Overall falsification logic: If all three observational signatures are absent from measurements, the whole framework must be discarded. Failure of a single prediction only triggers revision of partial topological assumptions.

9 Unified Modeling for All Objects

In this chapter, we classify objects in the universe and demonstrate that physical objects and human society share isomorphic structures and can be analyzed within one unified model.

9.1 Classification of Object Categories

All objects in the universe fall into three categories:

- **Pure-physical objects**: particles, atoms, inorganic molecules, macroscopic celestial bodies, inanimate material structures.
  - No environmental-recognition capability
  - No self-sustaining existential goals
  - No proactive behavioral strategies
  - All changes are passive topological responses
- **Quasi-systems**: simple lower-level life-forms, basic biological structures, general-purpose information-systems, embedded intelligent devices, automated equipment, etc.
  - Possess limited environmental-recognition ability
  - Have basic capabilities for steady-state maintenance and structural persistence
  - Feature simple boundaries, fixed response mechanisms and finite lifecycles
  - Lack complete autonomous goal-systems; no high-level evolution or proactive adaptive strategies
- **Complete complex systems**: individual human beings, as well as societies, enterprises and nation-states composed of human individuals.
  - High-level environmental-recognition, cognitive-judgment and trend-perception capabilities
  - Strong endogenous goals for self-preservation, expansion and stability maintenance
  - Multi-nested architectures, division-of-labor roles, transaction workflows, institutional norms and dynamic feedback with long-cycle evolution
  - Full behavioral repertoire including active adaptation, reform, game-playing and environmental transformation

9.2 Unified Modeling of All Objects

Every object possesses the complete six-layer structure:

1. **Component layer**: composed of physical objects.
2. **Architecture layer**: physical connections among components.
3. **Mechanism layer**: standardized combinations of interaction modes between components.
4. **Transaction layer**: one complete interaction among components.
5. **Event layer**: one concrete instance of a transaction.
6. **Information layer**: material carriers and their states-attributes transmitted through interactions.

Mechanisms support the formation of complete internal operation and external interaction patterns. Transactions can be driven by periodic rhythms or trigger-conditions; nesting and invocation are supported.

Passive six-layer structure for purely-physical objects

Particles, atoms, molecules, celestial bodies and cosmic structures naturally feature the six-layer architecture, yet all manifest as passive constraints, fixed mechanisms and no self-regulating or self-sustaining purposes:

1. **Component layer**: physical structures built from subordinate nodes, sub-structures and nested topologies, naturally generating containment- and inheritance-hierarchies.
2. **Architecture layer**: fixed arrangements for particle lattices, celestial orbits and network topologies, forming stable configurations.
3. **Mechanism layer**: gravitation, electromagnetism, quantum stress and phase-synchronization constraints constitute invariant operating-rules. These rules are not designed for self-maintenance; they are inevitable behaviors derived from topological rules.

4. **Transaction layer**: particle collisions, chemical combination-decay, orbital revolutions and energy-exchange represent objective transaction flows. Transactions have no goals, strategies or choices, and exhibit no self-adaptation.
5. **Event layer**: phase jumps, energy-level transitions, collision perturbations and structural disintegrations count as objective events. Events occur without serving structural continuity and merely obey global stress-balance.
6. **Information layer**: particle phase, state, spin and energy-levels represent primary physical information. This information objectively exists, yet it is not used for environmental-recognition, decision-making or self-preservation.

Quasi-systems: weak initiative without complete self-sustaining strategies

In quasi-systems the six-layer structure begins to support limited adjustable mechanisms and responses:

- Preliminary environmental sensing and simple steady-state maintenance;
- Partial capacity to counteract external perturbations;
- But no top-level self-preservation goals, no proactive evolution, no intentional design or strategic behavior.

Complete complex systems: core distinctions for higher-order life, enterprises and societies

For genuine complex systems, attributes across all six layers are reversed:

- Architecture can be reconstructed;
- Mechanisms can adapt and self-regulate;
- Transactions can operate strategically;
- Events may be predicted, avoided or exploited;
- Information is used for environmental perception, decision-making and iterative evolution.

Operations across all layers serve one overarching objective: sustaining continuous existence, stability and further continuation of the whole system.

9.3 Comparison of Physical Objects, Living Systems, and Social Systems

Level	Physical Objects (atoms/molecules/celestial bodies)	Living Systems (cells/human body)	Social Systems (organizations/nations)
Component Layer	Basic units such as particles, atoms, molecules, and celestial bodies	Cells, tissues, organs	Individuals, families, organizations
Architecture Layer	Crystal lattice structures, orbital structures, network topology	Physical connections between organs (blood vessels, nerves, fascia)	Social relationships, power structures, economic networks
Mechanism Layer	Gravity, electromagnetic force, quantum stress, energy-level constraints (fixed and unchanging)	Metabolism, neural transmission, hormonal regulation (active regulation)	Laws, institutions, cultural norms (active regulation)

Level	Physical Objects (atoms/molecules/celestial bodies)	Living Systems (cells/human body)	Social Systems (organizations/nations)
Transaction Layer	Particle collisions, chemical combination, decay, energy exchange (no goals, no strategy)	A complete physiological interaction (e.g., a heartbeat, a neural impulse)	A complete social interaction (e.g., a transaction, a meeting)
Event Layer	Phase transitions, energy-level jumps, structural disintegration (subject to whole-network stress equilibrium)	Concrete instances of physiological events (e.g., an inflammatory response, memory formation)	Concrete instances of social events (e.g., an election, a strike)
Data Layer	Particle phase, state, spin, energy level (raw information, not used for decision-making)	Neural signals, hormonal signals, chemical signals (used for regulation)	Information, knowledge, public opinion (used for decision-making and iteration)

Core differences:

Dimension	Physical Objects	Living Systems	Social Systems
Six-layer attributes	Entirely passive equilibrium	Active regulation, with survival as the goal	Active regulation, with continuity as the goal
Mechanism Layer	Fixed and unchanging; topological rules emerge naturally	Adaptively regulable	Designable and reformable
Transaction Layer	No goals, no strategy, no choice	Has goals (maintaining homeostasis)	Has strategy, game dynamics, and adaptation
Event Layer	Does not serve structural continuity	Serves individual survival	Can be predicted, avoided, and exploited
Data Layer	Really exists but is not used for decision-making	Used for environmental recognition and regulation	Used for environmental recognition, decision-making, and iteration
Agency	None	Limited	Complete

9.4 Full Lifecycle Management Algorithm

For a complete complex system, its full lifecycle management algorithm works as follows: start full lifecycle analysis from the core functional components of the system; sort out all auxiliary affairs generated during the analysis process, and perform full lifecycle analysis on these auxiliary affairs recursively until all relevant affairs within the system are covered (analysis boundaries shall be defined and external stakeholders identified), so as to complete the full lifecycle analysis of the entire system.

In this framework, the system undertakes external management over component lifecycles, including planning, design/selection, procurement/construction, integration and commissioning, operation & maintenance interfaces (monitoring, upgrade, replacement), decommissioning and disposal, while individual components execute internal operations for their own lifecycle management. The operation of each component, in turn, requires external lifecycle governance over its subordinate sub-components. The lifecycle phases of a system emerge intrinsically from its internal structure, rather than being merely defined by externally assigned roles or administrative intentions.

The logic of full lifecycle management implicitly governs daily work and real-life scenarios. For instance, national transportation infrastructure planning and construction correspond to work at the architecture layer of a system; sorting and optimizing enterprise business processes fall within the transaction layer; household furniture procurement represents matching design between sub-component layers and human demands. Activities across all these layers inherently follow full lifecycle reasoning.

This algorithm traces the root cause of every entity within a system and evaluates its sustainable value, with broad applications covering system design, assessment, optimization and game-theoretic analysis.

This paper does not elaborate further on this topic.

10 Conclusions and Outlook

10.1 Summary: From Three Parameters to One Universe

From the perspective of constructing the universe, this framework can hardly be simplified further. It is not a simplified version of a complex theory; instead, it is a theoretical framework for constructing cosmic complexity starting from minimal underlying assumptions.

Starting at the most fundamental level, the framework adopts only three preset parameters: total number of nodes N_0, initial average spacing d_0, and initial vibration frequency ω_0, together with five observational calibration values. It builds a complete derivation framework covering everything from quarks to planets, and from life to cognitive systems. The core logic of Node-Network Theory can be summarized in one sentence:

> The universe is a node-network. Nodes generate waves through vibration; phase differences of waves drive stress; stress drives nodes to rearrange, forming all structures from elementary particles to galaxies.

No preset fundamental constants are introduced throughout this process. The speed of light c, reduced Planck constant $\hbar$, gravitational constant G, fine-structure constant α, elementary charge e all emerge naturally from geometric combinations of the initial parameters.

Dimension	Standard Physics	This Framework
Fundamental entities	Matter, fields, particles	Nodes, edges, vibration
Space	Pre-existing stage	Geometric structure of the node-network itself
Time	Independent dimension	Function of the average vibration amplitude of the whole network

Dimension	Standard Physics	This Framework
Forces	Four independent fundamental interactions	Projections of a unified stress function under different topologies
Fundamental constants	$G, \hbar, c, e, \alpha$ etc. are independently preset	All are emergent quantities
Free parameters	19 (Standard Model)	3

10.2 Outlook: Four Directions for Further Advancement

At present, Node-Network Theory remains a thought-experiment-level theoretical construction. Further progress should be pursued along three main directions:

1. **Mathematical formalization**: Convert qualitative descriptions of the framework into precise mathematical models. Define the Hamiltonian of the node-network, derive the continuum limit of the stress function, and establish exact correspondence with existing theories including quantum field theory and general relativity.
2. **Computational simulation**: Implement numerical simulation of the node-network on computers. Starting from the initial parameters, let the network evolve self-organizing under stress-minimization rules, and observe whether emergent structures from quarks to galaxies can be reproduced.
3. **System transition simulation**: introducing the conditions for the emergence of self-replicating units into numerical simulations (the probability of complementary pairing chains forming within chemical networks on planetary surfaces), attempting to reproduce the critical phase transition from physical networks to living systems.
4. **Experimental testing**: Propose experimentally-testable predictions accessible to current-day technology.
   - Vacuum stress effects, e.g. the micro-deformation experiment of liquid boundaries inside vacuum chambers;
   - Search for extra cosmic standing-wave resonance signals in the low-l region of CMB spectra;
   - Verify structural predictions of this framework for superconductors and transparent conductors in material-science experiments.

10.3 Final Open-Ended Question

This framework points toward a deeper philosophical question: Why is the underlying structure of the universe exactly a node-network?

The answer to this question may forever lie beyond the scope of physics. It brings us back to our original observation: we study the universe using sensory organs and thinking capabilities that are themselves constructed from components of that very node-network universe.

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Note

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