Mapping interpretation of topological graph elements

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Rule: $\{\{x, y\}, \{y, z\}\} -> \{\{x, z\}, \{x, w\}, \{w, z\}\}$

This document presents a **computational isomorphism** rather than a rigorous physical derivation. It explores how standard physical phenomena (Gravity, Quantum Non-locality) can be interpreted as emergent properties of a minimal graph-rewriting system.

Explanation of the source of the rules:

Abstract & Theoretical Foundation

The evolution rule of this model is synthesized from an abstraction of linear dynamical systems, probabilistic frameworks, and dynamic programming (DP) optimization. It represents a conceptual exploration of how complex causal structures might emerge from minimal computational instructions.

The transition from **bi-directional interactions** (active processing) to **mono-directional causal links** (historical record) serves as a discrete analog for the dynamical phase transition from **Space-like intervals** to **Time-like intervals**. This mechanism effectively enforces a **"Causal Rigidity,"** preserving the immutability of historical states while allowing for local topological fluctuations.

Notation and Formal Definitions

1. x - y (Active Interaction / Space-like)

This denotes a reciprocal relationship where nodes x and y exert mutual influence. In our computational simulation, the precise sequence of interaction is treated as stochastic, representing underlying quantum-like fluctuations before causal fixation.

2. x -> y (Causal Fixation / Time-like)

This denotes a determined causal trajectory. Once a relationship transitions to this state, the path is **"frozen"** or rendered inert. This means it no longer participates in further topological rewriting or evolutionary steps, effectively becoming part of the immutable causal history.

$$The\ mapping\ of\ physical\ phenomena\ and\ formulas\ onto\ topological\ diagrams:$$

Chapter 1: $Newtonian\ mechanics$:

The Computational Foundation of Classical Mechanics

1.1 Formal Definition of State and Existence

In the Computational Universe Model, spacetime is not a continuous background but a discrete directed graph evolved by the fundamental rewriting rule:

$$hat\{R\}: \{\{x, y\}, \{y, z\}\}\ to\ \{\{x, z\}, \{x, w\}, \{w, z\}\}$$

- **Existence (Persistence)**: Defined as the topological consistency of a local node cluster $V\_\{local\}$ across successive computational steps tau. An object "exists" because the Rule performs constant **"In-place Refreshes,"** maintaining the logical structure against the entropy of background graph expansion.
- **Mass (m): The Total Causal Connectivity**
In the Computational Universe Model, the mass m of a local topological defect (particle) is defined not merely by its static density, but by its **Total Topological Degree**. This is the sum of its capacity for future interaction and its accumulated causal history.

1.2 Strict Definitions of Force and Computation

- **Computational Power (*Omega*)**: The system-wide rate of Rule execution. It is the raw "clock speed" of the universe, determining the maximum rate of causal information propagation.
- **Force (*F*)**: Defined as a **non-symmetric bias** injected into the Rule's rewriting direction.

Axiom: Force is the additional computational increment required to forcibly deflect a local causal path from its default geodesic.

1.3 Derivation of Newton's Laws via Graph Theory

[1.3.1] The First Law: Continuity of Causal Paths

Derivation: In the absence of external computational bias, the evolution of a node cluster follows the **Principle of Minimum Computational Effort**.

- Once a cluster establishes a specific rewriting pattern (representing a velocity vector), the system preserves this pattern to maintain **Causal Invariance**. Altering this pattern would require a reallocation of Rule applications.
- **Essence**: Uniform linear motion is the self-perpetuating extension of a **geodesic**

path on the graph.

[1.3.2] The Second Law: $F=ma$ (The Resource Allocation Identity)

Derivation:

1. Changing the direction of evolution requires a logical redirection of every node within the cluster.
2. Higher node density (m) implies a greater number of logical units requiring redirection.
3. A higher rate of change (acceleration a) requires more frequent redirection operations per unit of system time τ.

- **Conclusion**:

$$F\ (Injected\ Computation)\ =\ m\ (Code\ Complexity) \cdot a\ (Path\ Deflection\ Rate)$$

[1.3.3] The Third Law: Symmetry of State Merging

Derivation:

1. Interaction between cluster A and cluster B is fundamentally a **State Merging** event between two sets of rewriting paths.
2. Connections in the causal graph are reciprocal. Any modification A imposes on the topology of B necessitates a simultaneous feedback on the path of A to preserve global causal consistency.

- **Essence**: This is not merely a cancellation of forces, but a mathematical necessity for maintaining **Topological Conservation** within the graph.

Summary

Under this framework, Classical Mechanics is the **macro-statistical manifestation of graph-rewriting rules in low-density, low-velocity regimes.**

Chapter2: *Special Relativity*

The Conservation of Computational Capacity (The Zero-Sum Game)

In this framework, Special Relativity is interpreted not as a geometric property of light, but as a budgeting constraint of computational steps within the system.

Definitions

C (System Clock / Speed of Light): The maximum number of rewriting operations allowed per node per tick. Normalized to $C = 1\ (1\ Hop\ /\ 1\ Tick)$. This represents the hard limit of the system's refresh rate.

V_{space} (Spatial Velocity): The portion of the budget spent on "Topological Reconfiguration" (breaking old edges and forming new ones to displace the node in the graph).

V_{time} (Temporal Velocity): The portion of the budget spent on "Internal State Updates" (processing local loops, aging, and recording history).

The Fundamental Theorem: Conservation of Action

Since the Rule executes a fixed number of operations per tick, a particle cannot exceed its total computational budget. The allocation is orthogonal:

$$|\vec{V}_{total}|^2 = V_{space}^2 + V_{time}^2 = C^2$$

Deriving Time Dilation (The Lorentz Factor)

Consider an object moving with spatial velocity v ($where\ V_{space} = v$). The remaining computational budget for its internal time (V_{time}) is:

$$V_{time} = \sqrt{C^2 - v^2} = C\sqrt{1 - \frac{v^2}{C^2}}$$

At Rest ($v = 0$): $V_{time} = C$. The object experiences maximum internal processing (aging at the normal rate).

At Max Speed ($v \to C$): $V_{time} \to 0$. All computational resources are diverted to spatial displacement. The object has zero budget left for internal updates. Thus, Time stops.

Conclusion: Time Dilation is mathematically equivalent to computational latency induced by heavy resource allocation to motion.

Mass-Energy Equivalence ($E = mc^2$)

The Dimensional Unfolding Algorithm

The squared term (c^2) in standard physics is often abstract. In Computational Cosmology, it represents a specific $Data\ Type\ Conversion$ from 1D Storage to 2D Interaction.

Geometric Definitions

Mass (m) [$1D$]: The size of the compressed data packet. It represents the number of nodes locked in "Frozen Paths" (closed logical loops). It behaves as linear data (Bitstream).

Energy (E) [$2D$]: The "Action Flux" or "Causal Coverage Area" when that packet is unpacked and interacts with the background graph.

c ($Rate$): The system's propagation bandwidth.

The Decompression Process

When a "$Frozen\ Path$" ($Mass$) is broken, the linear data unfolds into a planar network. This expansion happens along two axes simultaneously:

$Axis\ X$ ($Read\ Rate$): The rate at which nodes are released from the loop.

$$J\_\{out\} = m \backslash cdot\ c$$

$Axis\ Y$ ($Spread\ Rate$): The rate at which the causal wavefront expands into neighbors.

$$R\_\{spread\} = c$$

Total Integration

Energy is the total Computational Area activated by the release of Mass.

$$E = \backslash text\{Read\ Rate\} \backslash times \backslash text\{Spread\ Rate\}$$

$$E = (m \backslash cdot\ c) \backslash cdot\ c$$

$$E = m\,c\text{\^{}}2$$

Conclusion: $E = mc\text{\^{}}2$ is the cost function of the universe's "$Unzip\ \&\ Render$" algorithm. It quantifies the transition from $Linear\ Storage$ (m) to Planar Interaction (E).

General Relativity

Gravitational Lensing via System Lag

We replace the abstract "Curvature of Spacetime" with the concrete concept of "Computational Density & Lag."

The Model: Vacuum vs. Mass

Vacuum: Sparse node distribution. The Rule executes instantly. $v\_\{proc\} \backslash approx\ C$.

Mass (M): Extremely dense node cluster (Frozen Paths). The Rule struggles to process the sheer volume of connections, creating a local $Processing\ Bottleneck$.

The Refractive Index of Spacetime

We model the high-density region as a medium with a high "*Computational Refractive Index*" (n). The effective processing speed v_{eff} at a distance r from Mass M is:

$$v_{eff}(r) = \frac{C}{n(r)}$$

Where the *Congestion Index* $n(r)$ is derived from the node density gradient:

$$n(r) \approx 1 + \frac{G M}{r c^2}$$

Deriving Gravitational Time Dilation

The "Local Clock" $(d\tau)$ ticks slower because the system is lagging:

$$d\tau = \frac{dt_{vacuum}}{n(r)} \approx dt \left(1 - \frac{GM}{rc^2}\right)$$

This derivation aligns perfectly with the weak-field approximation of the Schwarzschild metric.

Deriving Geodesics (Gravity as Optimization)

Why do objects fall?

Standard Physics: They follow *geometric curvature*.

Computational Universe: They follow the *Path of Maximum Reuse*.

A moving object scans its neighborhood and finds that connecting to the high-density Mass allows it to share existing causal paths (Deduplication), whereas moving into empty space requires generating new paths (High Computational Cost). Following *Dijkstra's Algorithm* (or *Fermat's Principle*), the object's trajectory naturally bends towards the region of highest density.

Conclusion: Gravity is not a force pulling objects; it is the **statistical tendency of causal paths to merge into high-density clusters to optimize storage efficiency.

Chapter3: Electromagnetism

The Dynamics of Topological Chirality

Formal Definition of Charge and Field

In the Computational Universe Model, if Mass is defined as "Frozen Paths" (undirected structural density), then Charge is defined as **"Directed Frozen Paths"** or **"Topological**

Chirality."

- Charge (q) as Chirality:

Charge is formally defined as the topological handedness of a local node cluster during the Rule rewriting process.

  - **Positive Charge (+):** A cluster where the Rule exhibits a **Clockwise Bias** (Right-Handedness) in generating causal loops.
  - **Negative Charge (-):** A cluster where the Rule exhibits a **Counter-Clockwise Bias** (Left-Handedness) in generating causal loops.
  - **Neutral (q=0):** A cluster where topological chirality is symmetric or statistically canceled (e.g., a Neutron).

- Electric Field $(\vec{E})$ as Graph Tension:

The Electric Field is not a physical fluid, but a Tension Gradient across the causal graph. When a Chiral Node attempts to connect with the neutral background mesh, the mismatch in rewriting direction creates a topological stress. The spatial distribution of this "twisting stress" is what we observe as the Electric Field.

- Magnetic Field $(\vec{B})$ as Graph Vorticity:

The Magnetic Field represents the Dynamic Vorticity of the Rule's rewriting flow. When a Chiral Node moves (Current) or when Graph Tension changes, neighboring nodes are forced to undergo rotational rewriting to maintain connectivity. This "rotational flow of rewriting" is the Magnetic Field.

Deriving Maxwell's Equations from Graph Rewriting

We reinterpret Maxwell's Equations not as axiomatic laws, but as conservation and propagation rules governing the topology of the causal graph.

1. Gauss's Law: The Source of Tension

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

- **Graph Interpretation:** A Chiral Node (Source ρ) inevitably forces a "twist" upon the surrounding non-chiral background graph. This topological distortion cannot vanish; it must propagate outwards to infinity.
- **ϵ_0 (Permittivity):** Represents the **"Topological Stiffness"** of the background graph—its resistance to being twisted by a charge.

2. Gauss's Law for Magnetism: The Topological Constraint

$$\nabla \cdot \vec{B} = 0$$

- **Graph Interpretation:** The fundamental Rule {{x, y}, {y, z}} -> {{x, z}, ...} always forms closed triangular circuits. In a directed graph formed by such rules, any "rotational flux" must be a closed loop to maintain causal consistency.
- **Conclusion:** A "magnetic monopole" (a node with only outgoing or incoming rotational flux) is **topologically forbidden** in this rewriting system.

3. Faraday's Law: Dynamic Stress Transfer

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

- **Graph Interpretation:** $\frac{\partial \vec{B}}{\partial t}$ represents a change in the rotational rewriting velocity (Vorticity). To preserve graph connectivity during this acceleration, adjacent regions must generate an opposing "linear tension" (Electric Field). This is the graph's **Elastic Response** to dynamic shear.

4. Ampere-Maxwell Law: The Propagation Mechanism

$$\nabla \times \vec{B} = \mu_0 \left(\vec{J} + \epsilon_0 \frac{\partial \vec{E}}{\partial t} \right)$$

- **Graph Interpretation:** Rotational Flow (Magnetic Field) is generated by two mechanisms:
    1. **$\vec{J}$ (Current):** The physical displacement of Chiral Nodes drags the surrounding mesh into rotation.
    2. **$\frac{\partial \vec{E}}{\partial t}$ (Displacement Current):** A purely local change in Topological Tension triggers a chain reaction of rewriting, creating vorticity even without the motion of matter.
- **Conclusion:** This proves that the Rule can sustain a self-propagating chain of "Twist-Flow" updates in a vacuum—which is Light.

The Speed of Light as System Latency

By combining the Graph Tension (ϵ_0) and Graph Inertia (μ_0), we derive the propagation speed of causal updates:

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

- **Computational Meaning:** Light is not a particle traveling through space; it is the **"Wavefront of Rule Execution"** propagating across the grid.

- **Limit:** Since the Rule can only update neighbor-to-neighbor (1 Hop per Tick), the propagation speed c is necessarily a finite constant, representing the **Maximum System Latency**.

Chapter 4: Quantum Mechanics

The Diffusion of Causal Potential

3.1 Formal Definition of the Wave Function (ψ)

In standard physics, the wave function is an abstract probability amplitude. In the Computational Universe, it is a concrete measure of **"Rewriting Potential."**

- *The Wave Function* (ψ) *as Causal Potency*:

We define $\psi(x,t)$ not as a particle's state, but as the state of the Graph Location x itself.

$$\psi(x,t) = \sqrt{\rho(x,t)} \cdot e^{i \theta(x,t)}$$

  - **Magnitude ($\rho = |\psi|^2$):** The **Computational Density** or "Attention" of the System. It represents the probability that the Rule will choose node x for the next update operation.
  - **Phase (θ):** The **Cyclic State** of the local rewriting engine. Since *the Rule* $\{\{x,y\},\{y,z\}\} \rightarrow \ldots$ is a multi-step process, θ encodes which step of the algorithmic cycle the node is currently in.
  - **The Imaginary Unit (i):** Represents the **Orthogonal Rotation** between the internal update cycle (Time) and the external topological expansion (Space).

3.2 Deriving the Schrödinger Equation from Graph Random Walks

We derive the Schrödinger Equation by treating the Rule execution as a **Discrete Random Walk** on the causal graph.

1. The Conservation of Rewriting Probability

Total system attention is conserved (Unitary Evolution). The Rule must happen somewhere.

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \vec{J} = 0$$

This continuity equation describes the flow of computational focus across the network.

2. The Kinetic Term: Topological Diffusion

When the Rule executes at node x, it creates new edges connecting x to its neighbors. Statistically, this causes the "Update Potential" to diffuse outward.

On a discrete grid, the rate of change of a value depends on the average of its neighbors minus its current value. This is the Discrete Laplacian:

$$D \cdot (\psi_{neighbors} - \psi_{center}) \approx -\frac{\hbar^2}{2m} \nabla^2 \psi$$

- **Interpretation:** The $-\frac{\hbar^2}{2m} \nabla^2$ term represents the **Cost of Diffusion**. It is the computational effort required to spread the causal structure into the void.
- $\boldsymbol{\hbar}$ **(Planck's Constant):** Represents the **Graph Resolution** or "Pixel Size." It quantifies the minimum discrete action required to define a valid graph update.

3. The Potential Term: Structural Resistance

$$V(x) \psi$$

- **Interpretation:** $V(x)$ represents the **Topological Resistance** of the local environment. If node x is near a massive cluster (High Density) or a strong field (High Tension), the cost to update x increases. The Rule is less likely to execute there unless sufficient energy is supplied.

4. The Master Equation: Resource Allocation Balance

By balancing the "Rate of State Change" (Energy) against "Diffusion" and "Resistance," we obtain:

$$i \hbar \frac{\partial \psi}{\partial t} = \left[-\frac{\hbar^2}{2m} \nabla^2 + V(x) \right] \psi$$

- **LHS (E):** The total computational budget allocated to updating this region.
- **RHS (Hamiltonian $\hat{H}$):** The sum of the cost to diffuse structure ($Kinetic$) and the cost to overcome local density ($Potential$).

3.3 Quantum Tunneling as Graph Hopping

Standard physics views tunneling as "passing through a wall." In Graph Dynamics, it is **"Non-Local Connectivity."**

- Mechanism:

$The\ Rule\ \{\{x, y\}, \{y, z\}\} -> \ \{\{x, z\}, ...\}$ establishes a direct link between $x\ and\ z$, effectively bypassing the intermediate node y.

- Interpretation:

If a potential barrier $V(x)$ (e.g., a wall of high node density) exists, a classical particle must climb over it. However, the Graph Rewriting Rule operates on Topological Adjacency, not geometric distance.

There is a non-zero probability that the Rule generates a "shortcut" edge that connects a node inside the barrier directly to a node outside the barrier.

Conclusion: Tunneling is not magic; it is a Cross-Link Update that skips the "blocked" nodes in the graph.

3.4 Wave Function Collapse as Update Finalization

- **The Measurement Problem:** Why does $\backslash psi$ collapse to a point when observed?
- Computational Answer:

$\backslash psi$ represents the "List of Potential Updates" (a pending queue).

"Measurement" (Interaction) forces the System to Commit to a specific update path to maintain causal consistency with the observer.

Once the Rule executes and the new edges are written to the database, the "potential" (\psi) instantly vanishes and becomes "history" (Classical Reality).

Collapse is simply the transition from RAM (Pending Calculation) to Hard Drive (Written History).

Chapter Summary

Quantum Concept	**Computational Interpretation**
Wave Function (\psi)	**Update Potential** (Queue of pending rewrites).
Schrödinger Eq.	**Diffusion Equation** of computational attention.
Tunneling	**Shortcut Edge Generation** bypassing a dense cluster.

Quantum Concept	**Computational Interpretation**
Collapse	**Commit Operation** (Finalizing the rewrite).