Foundations of Relational Cognition: Ontology, Dynamics, and Phenomenology

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(Dated: January 25, 2026)

We propose a minimalist, formalized framework for cognition that rejects premature psychological metaphors in favor of rigorous topological and information-theoretic principles. We establish a "Golden Rule" of ontology, postulate a Relational Dynamics model ($I_{flow} \leq C_{max}$), and demonstrate how "mental states" emerge as topological regimes (eigenvalues of the network Laplacian). Finally, we resolve the "Hard Problem" by defining consciousness as a Global Structured Integration state and provide concrete falsifiability criteria ("Kill Switches") to ensure scientific rigor.

The field of cognitive science has long been plagued by a "metaphorical contamination." Models are built on ill-defined concepts like "workspace," "feeling," or "processing" without grounding them in physical quantities. We present a corrective foundation: **Relational Cognition**.

I. THE ONTOLOGICAL FOUNDATION

We begin with an epistemological Golden Rule: *No concept is postulated unless it can be translated into a variable, a mathematical structure, or an observable consequence.*

The minimal ontology consists of four primitives:

1. **Node** ($n \in N$): An abstract unit of processing.
2. **Edge** ($e \in E$): A channel of causal interaction.
3. **State** (S): The dynamic configuration of nodes.
4. **Discrete Time** (t): The sequential evolution $t \to t + 1$.

Postulate 1: Relational Dynamics

Cognitive systems are dynamic networks whose evolution is governed by the redistribution of information under constraints of capacity and cost. Nothing exists outside the relations.

II. MATHEMATICAL SATURATION

Information is defined physically per Shannon ($I = H_{max} - H_{obs}$). Crucially, we introduce the **Saturation Postulate**:

$$I_{flow}(t) \leq C_{max}$$

This inequality is the engine of cognition. Because the environment's information I_{env} vastly exceeds the system's capacity C_{max}, the system is thermodynamically forced to implement **filtering** and **compression**. Attention is not a psychological choice; it is a mechanism to preventing thermal collapse.

III. TOPOLOGY BEFORE PSYCHOLOGY

We assert that "mental states" are not contents, but **Topological Regimes** of the network.

Using graph metrics (Degree, Centrality, Modularity Q), we map phenomenology to structure:

- **Anxiety**: High local recurrence (loops), deep attractor basins, low dissipation.
- **Insight**: Symmetry breaking, sudden increase in long-range links, criticality.
- **Dissociation**: Extreme modularity, fragmentation of the giant component.

IV. THE SPECTRAL LANGUAGE

To bridge static structure and dynamic experience, we employ **Spectral Graph Theory**.

Postulate 4: Spectral Phenomenology

Subjective experience (Qualia) corresponds to the spectral distribution of the network activity over its normal modes (eigenvectors of the Laplacian $L = D - A$).

$$L\mathbf{v} = \lambda \mathbf{v}$$

Low eigenvalues ($\lambda \to 0$) correspond to global, integrative states (Delta/Theta waves). High eigenvalues ($\lambda \to \infty$) correspond to local, detailed

processing (Gamma waves). The "music" of the mind is the vibration of the topology.

V. EMERGENCE OF CONSCIOUSNESS

We reject the "Hard Problem" as ill-posed. Instead, we face the **Structural Integration Problem**.

Postulate 5: Global Integration

Consciousness is the topological regime where local information becomes causal globally.

This occurs in a "Sweet Spot" of high differentiation (Entropy) and high integration (Connectivity). If Φ is the measure of this integration:

$$\Phi \to 0 \quad (\text{Coma/Seizure})$$

$$\Phi \gg 0 \quad (\text{Waking State})$$

The "feeling" is the system's intrinsic perspective of this global availability.

VI. COGNITIVE HOLOGRAPHY

How does a limited system perceive a continuous 3D world?

Postulate 6: Holographic Interface

The subjective 3D space-time is a low-dimensional projection of an N-dimensional neural state, optimized via **Distributed Encoding**.

Like a hologram, information is distributed across the entire net. "Redness" is not in a node; it is a vector geometry in the latent space of the network's embeddings.

VII. FALSIFIABILITY (THE KILL SWITCH)

To ensure this constitutes science, we define criteria that would falsify the theory:

1. **Spectral Dissociation Test**: If a subject reports phenomenological dissociation but their network topology remains integrated (λ_2 high), the theory fails.
2. **Saturation Violation**: If a biological system processes $I \gg C_{max}$ without attentional bottlenecks, Postulate 2 is false.
3. **Isomorphism without Qualia**: If a neuromorphic chip with identical spectral dynamics is proven unconscious, the Spectral Identity thesis fails.

VIII. CONCLUSION

We have established a rigorous foundation for cognitive science, moving from ontology to falsifiability. The mind is not a ghost in the machine; it is the spectral music of a saturated, topological network.

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