A Minimal Resonator Model for Meaning, Time, and Conscious Integration

Abstract

We propose a formally minimal resonator model in which meaning, time, spatial structure, and conscious content emerge from the resonant coupling of discrete sources possessing stable internal states. Rather than assuming space, time, or global structures as primitives, the model treats temporal phase relations and their stabilization as fundamental. Using a Kuramoto-type phase dynamics with an explicitly non-observable internal component, we show how stable resonance clusters can account for semantic coherence, emergent temporal order, spatial relations, and empirical features of consciousness that challenge both Integrated Information Theory and Global Neuronal Workspace Theory. The model is not intended as a complete physical or neuroscientific theory, but as a unifying structural hypothesis capturing cross-domain regularities.

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1. Motivation

Across multiple domains—semantics, physics, cosmology, and consciousness research—there is a recurring tension between **structure-based explanations** and **process-based explanations**. Meaning is not reducible to syntax, space is not obviously fundamental in quantum phenomena, time resists a single ontological status, and consciousness evades localization in either a fixed network or a global ignition event.

Recent empirical work in consciousness research shows sustained, content-specific synchronization without stable global integration or discrete ignition events. Similarly, nonlocal correlations in quantum mechanics and the explanatory limits of inflationary cosmology suggest that **relational dynamics**, rather than fixed substrates, may be primary.

This paper introduces a **minimal resonator model** that captures these phenomena at the level of formal structure, without committing to domain-specific ontologies.

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2. Ontological Commitments (Minimal Axioms)

Axiom 1 — Discrete Sources

There exists a finite or countable set of discrete sources:

$S=\{s_i\}$

Each source s_i possesses an **internal stable component** σ_i, which:

- is not directly observable,
- does not evolve on the time scale of interaction,
- grounds identity or content.

This internal component should not be interpreted as a substance, representation, or symbol, but as a **stability condition** enabling coherence.

Axiom 2 — Temporal Activation

Each source has a time-dependent phase:

$$\phi_i(t) = \omega_i t + \theta_i$$

where:

- ω_i is an intrinsic frequency,
- θ_i is a source-specific phase offset.

Time is not presupposed as a global parameter; instead, it emerges as an **ordering of phase relations**.

Axiom 3 — Resonant Coupling

Sources interact via pairwise coupling strengths:

$$K_{ij} \geq 0$$

Coupling influences phase evolution but does not transmit internal states directly.

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3. Dynamics

The evolution of phases is given by:

$$\dot{\phi}_i = \omega_i + \sum_j K_{ij} \sin(\phi_j - \phi_i)$$

This equation is formally equivalent to a Kuramoto-type model, but the interpretation differs:

- phases represent **relational temporal activity**, not physical oscillators,
- coupling expresses **resonant susceptibility**, not signal transfer,
- internal states σ_i never appear directly in the dynamics.

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4. Emergence of Resonance

Definition 1 — Resonance Cluster

A subset $C \subset S$ forms a resonance cluster if:

$$|\phi_i - \phi_j| < \varepsilon \quad \forall i, j \in C$$

for a minimum duration Δt.

Definition 2 — Stability

A cluster is stable if small perturbations $\delta\phi$ do not lead to rapid desynchronization.

Stability is not permanence; it is **resistance to incoherence**.

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5. Interpretation Across Domains

The same formal structure gives rise to different phenomena depending on interpretation.

5.1 Meaning

- Sources correspond to semantic units.
- Resonance clusters correspond to coherent interpretations.
- Meaning is not contained in any source but arises as a **stable relational pattern**.

Understanding is thus modeled as **phase alignment**, not symbol decoding.

5.2 Time

Time emerges as an **order parameter** of phase evolution:

$t := \text{ordering of } \{\phi_i(t)\}$

The internal stable component σ_i functions analogously to an **imaginary component** in complex numbers: not observable, but necessary for coherence.

Thus, time has a dual character:

- observable flow (real component),
- unobservable stability (imaginary component).

5.3 Space

Define an emergent distance:

$d_{ij} = |\phi_i - \phi_j|$

Spatial relations are thus derived from stabilized temporal differences. Space is secondary, relational, and context-dependent.

5.4 Consciousness

Conscious content corresponds to:

- multiple resonance clusters,
- transiently coupled,
- content-specific,
- without global synchronization.

This structure aligns with empirical findings that challenge both:

- **Integrated Information Theory**, which overemphasizes static connectivity,
- **Global Neuronal Workspace Theory**, which predicts discrete global ignition.

The model predicts **sustained, content-specific synchrony without a privileged center**.

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6. Observability

Only relational quantities are observable:

$O(t)=\sum_{i,j}\cos(\phi_i-\phi_j)$

Internal states σ_i are never directly measurable; their existence is inferred from the persistence of coherence.

This explains why attempts to localize meaning or consciousness structurally tend to fail.

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7. Scope and Limits

This model does **not** claim to:

- replace physical spacetime theories,
- provide a mechanistic account of neural implementation,
- bypass thermodynamic constraints.

It **does** claim to:

- provide a unifying formal structure,
- explain why structure-only and event-only theories fail,
- clarify the role of stability within dynamical processes.

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8. Conclusion

We have presented a formally minimal resonator model in which stable, non-observable internal components couple through temporal phase dynamics to generate coherent, observable phenomena. Meaning, time, space, and consciousness appear not as primitives, but as **stabilized resonance patterns**.

The model's strength lies in its minimalism: with only discrete sources, phase dynamics, and coupling, it captures cross-domain regularities that remain otherwise disconnected. Its weakness—lack of domain-specific detail—is intentional, preserving generality.

Further work may explore simulation, domain-specific instantiations, and empirical signatures of resonance-based coherence.
