Coherence-Selection Interface Theory: A Dual-Domain Framework for Quantum Branching, Emergent Time, and Recent Experimental Trends

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Abstract

We propose Coherence-Selection Interface Theory (CSIT), an interpretational framework in which the universal quantum state defines a potential domain of structured possibilities, while the experienced classical world arises from a global branch-selection interface that produces an actual domain of events. Time is not fundamental but emerges as the ordered index of selection events. We connect CSIT to recent developments in physics, including new results on quantum correlations beyond classical causal structures, large-scale demonstrations of macroscopic quantum coherence and tunneling (recognized by the 2025 Nobel Prize in Physics), advances in quantum hardware and quantum advantage, and renewed emphasis on the need for a better understanding of time in quantum gravity. We also relate CSIT to recent work showing that the universe cannot be fully simulated by any algorithmic process, pointing to a non-algorithmic underlying structure consistent with an ontic potential domain. While these results do not uniquely single out CSIT, they reinforce its core assumptions: that (i) the quantum state encodes real, non-classical structure beyond classical correlations, (ii) macroscopic quantum coherence is physically manipulable, and (iii) a revised conception of time may be required at the interface of quantum theory and gravity. We argue that CSIT offers a unifying interpretational framework for these trends.

1. Introduction

Quantum mechanics has transformed technology and our understanding of nature, yet its interpretation remains unsettled. A 2025 survey of more than 1,000 physicists found deep disagreement about what quantum mechanics says about reality, with no single interpretation commanding a majority [1] [2]. At the same time, experimental and theoretical progress is rapidly clarifying what quantum theory can do and where it departs from classical expectations.

Notable recent developments include:

- A closure of the gap between classical and quantum correlations in complex causal networks of up to six nodes, solidifying the non-classical nature of quantum correlations in structured scenarios [3].
- New work showing that the universe cannot be a complete computer simulation, using Gödel-type arguments to show that reality requires non-algorithmic structure beyond any computable model [4] [5].
- A high-profile call in *Nature* stating that unifying gravity and quantum theory requires a better conceptual understanding of time, emphasizing that existing textbook formulations are inadequate [6] [7].
- Recognition of macroscopic quantum effects with the 2025 Nobel Prize in Physics for experiments in superconducting circuits demonstrating quantum tunneling and quantized energy levels in systems "big enough to be held in the hand," underpinning modern qubits [8] [9].
- Rapid progress in large-scale quantum hardware, including record-breaking neutral-atom systems with thousands of qubits and long coherence times at room temperature, and beyond-classical quantum advantage in molecular calculations [10] [11].

Collectively, these developments point to a world where:

1. Quantum structure is ontically rich and non-classical.
2. Coherence can be engineered at increasingly macroscopic scales.
3. Time itself may require reinterpretation.
4. Our standard computational and simulation pictures of reality may be insufficient.

Coherence-Selection Interface Theory (CSIT) is designed precisely for this landscape. It:

- treats the quantum state as a real potential domain (not merely epistemic),
- introduces a global selection interface that produces experienced actuality,
- defines time as emergent from selection order, and
- yields clear resolutions to multi-observer paradoxes such as Wigner’s friend and Frauchiger–Renner.

In this paper, we (i) review the core structure of CSIT, (ii) show how recent physics results sit naturally within CSIT’s ontology, and (iii) argue that these developments lend indirect support to CSIT’s central claims.

2. Core Structure of CSIT

2.1 Dual-Domain Ontology

CSIT posits two complementary domains:

Potential Domain

- Represented by the universal quantum state $|\Psi(t)\rangle$.
- Structured by decoherence into quasi-classical branches $\{|\Phi_\alpha(t)\rangle\}$.
- Encodes modal structure: what *could* happen and with what weight.

Actual Domain

- The domain of determinate events: measurement outcomes, macroscopic configurations, historical records.
- Represented as an ordered set of events $E = \{e_1, e_2, \ldots, e_k, \ldots\}$.
- This is the experienced classical world.

The universal state evolves unitarily: $|\Psi(t)\rangle = U(t, t_0)|\Psi(t_0)\rangle withdecoherencedynamicallyproducingabranchdecomposition: |\Psi(t)\rangle \approx \sum_\alpha c_\alpha |\Phi_\alpha(t)\rangle, \quad \langle \Phi_\alpha | \Phi_\beta \rangle \approx 0 \text{ for } \alpha \neq \beta$ This is standard decoherence theory [3] [12]. CSIT’s distinctive move is ontological: branches are real potentials, but only one is actualized at each step.

2.2 Global Selection Interface

CSIT introduces a global selection map: $\mathcal{C}_{\text{global}}(t_k) : |\Psi(t_k)\rangle \longrightarrow |\Phi_{\alpha_k}(t_k)\rangle Anactualeventisthen: e_k = F(|\Phi_{\alpha_k}(t_k)\rangle) where F$ is a coarse-graining into classical records (pointer states, measurement outcomes, macroscopic configurations).

Crucially, selection is global: all observers are embedded in the same selected branch. This enforces consistency and avoids the contradictions in extended Wigner’s friend and Frauchiger–Renner experiments, which rely on observer-relative collapse [12].

2.3 Time as Emergent

In CSIT, time is not fundamental. Instead: **Time is the ordering relation on the sequence of global selection events $\{e_k\}$.**

This mirrors approaches to emergent time in quantum gravity and relational quantum mechanics, which emphasize correlations and ordering rather than an absolute time parameter [6] [7]. The recent call for a better understanding of time in efforts to unify gravity and quantum theory directly supports the need for frameworks like CSIT where time is derived, not postulated.

3. Connection to Recent Results in Quantum Correlations

A 2025 study on causal structures with up to six nodes has shown that even in complex networks, there are quantum correlations which cannot be reproduced by any classical model, fully closing a previously open gap [3]. This strengthens the view that:

1. The quantum state encodes non-classical correlations that are not merely epistemic.
2. These correlations are best thought of as a real structure in a potential domain.

In CSIT language:

- The potential domain $|\Psi\rangle$ is not just bookkeeping; it is a structured field of possibilities that constrain actualization.
- Classical causal models are embedded in, not equal to, this richer quantum structure.

These results align with earlier demonstrations of non-local realism violations and Bell inequalities, but the new work’s network-structured, multi-node context is especially relevant for CSIT’s focus on global branch structure rather than isolated subsystems [12]. CSIT treats such correlations as features of the potential domain that the global selection interface must respect. This strengthens the claim that the potential domain is ontically meaningful, not just a calculational device.

4. Macroscopic Quantum Coherence and the Reality of the Potential Domain

The 2025 Nobel Prize in Physics recognized experiments demonstrating quantum tunneling and quantized energy levels in macroscopic superconducting circuits—systems literally “large enough to be held in the hand” [8] [9]. At the same time, neutral-atom platforms have reached 6,000+ qubits with coherence times >10 seconds at room temperature, and Google and others have demonstrated verifiable beyond-classical computations using engineered quantum chips [10] [11].

This has two direct implications for CSIT:

1. **Coherence is a manipulable physical resource at increasingly macroscopic scales.** It is meaningful to speak of coherence landscapes and branch structures in systems far beyond single atoms. This supports CSIT’s assumption that the potential domain is physically structured and engineerable.
2. **Macroscopic quantum systems blur the classical/quantum boundary.** CSIT naturally accommodates this by removing any rigid classical/quantum cut. Instead, it locates the classical world in the actual domain (selection outcomes), not in a specific scale or subsystem type.

The fact that we can now engineer macroscopic superpositions reinforces the CSIT view that the potential domain is real and extends to macroscopic scales until selection occurs.

5. Non-Algorithmic Reality and the Limits of Simulation

Recent theoretical work using Gödel-type arguments has shown that the universe cannot be fully simulated by any algorithmic process [4] [5]. This suggests that physical reality has a non-computable core.

CSIT resonates with this finding in two ways:

1. **The Selection Interface as Non-Algorithmic:** The selection of a specific branch from the potential domain is inherently probabilistic (Born rule) and may be the source of non-algorithmic behavior. If selection were purely algorithmic, the universe would be a deterministic computation.
2. **The Potential Domain as a Continuum:** The Hilbert space of the potential domain is a continuous structure, which generally resists full discrete simulation.

This "no-simulation" result supports interpretational frameworks that, like CSIT, posit an underlying reality (the potential domain and selection interface) that is richer than a mere classical computation.

6. Conclusion

Coherence-Selection Interface Theory offers a unified framework that synthesizes the dual nature of quantum reality: the structured potentiality of the wavefunction and the definite actuality of observed events. By treating the potential domain as ontologically real and introducing a global selection interface, CSIT resolves longstanding paradoxes and provides a natural mechanism for the emergence of time.

Recent developments in physics—from the closure of causal gaps in quantum correlations to the manipulation of macroscopic quantum states and the recognition of non-algorithmic limits—create a fertile context for CSIT. These trends suggest that the future of quantum foundations lies in taking the structure of the quantum state seriously while rethinking the nature of time and actualization. CSIT provides a promising roadmap for this journey.

References

1. Scientific American. (2025). “Survey Reveals Deep Disagreement on Quantum Reality”.
2. Phys.org. (2025). “Physicists Still Divided on Quantum Interpretation”.
3. Quantum Zeitgeist. (2025). “Quantum Correlations in 6-Node Networks Defy Classical Models”.
4. ScienceDaily. (2025). “Universe Cannot Be a Simulation, New Study Shows”.
5. Mind Matters. (2025). “Gödelian Arguments Against Simulation Theory”.
6. Nature. (2025). “To Unify Gravity and Quantum, We Must Rethink Time”.
7. PubMed. (2025). “Time in Quantum Gravity: A Review”.
8. NobelPrize.org. (2025). “The Nobel Prize in Physics 2025”.
9. Le Monde.fr. (2025). “Macroscopic Quantum Effects Win Nobel”.
10. Live Science. (2025). “Neutral Atom Computer Breaks 6000 Qubit Barrier”.
11. The Guardian. (2025). “Quantum Advantage Demonstrated in Molecular Simulation”.
12. Scientific American. (2025). “Resolving the Frauchiger-Renner Paradox”.