Event Density and the Quantum–Classical Boundary

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Abstract
Quantum and classical behavior are usually treated as distinct domains, each requiring separate assumptions and interpretive frameworks. In Event Density, both regimes arise from the same underlying architecture: the stability or instability of uncommitted participation channels. When channels remain distributed, a system supports multiple active possibilities and exhibits quantum-like behavior. When channels stabilize, incompatible alternatives lose support and the system follows a single committed trajectory, producing classical-like behavior. This paper introduces the transition law that governs this shift. The law relates channel complexity, the participation environment, and the rate at which participation structure evolves, identifying the conditions under which uncommitted channels can be maintained, the conditions under which they thin and collapse, and the boundary region where the two regimes overlap. Applying this law to symmetric molecules, interferometers, cavity QED systems, and atomic clocks yields a set of clear, testable predictions that differ in specific ways from standard decoherence models. These predictions form the quantum portion of the ED-00 Open Note.
The transition law also clarifies how quantum behavior connects to the emergence of spacetime. As participation channels stabilize, systems enter the regime described in ED-10, where committed structures support consistent trajectories and geometric relations. By providing the missing link between ED-09 and ED-10, this paper completes the physics-tier account of how ED behavior evolves across scales.

1. Introduction
Quantum behavior and classical behavior are usually treated as fundamentally different regimes, each with its own rules, intuitions, and mathematical formalisms. In Event Density, this separation is not fundamental. Both regimes arise from the same underlying architecture: the distribution, interaction, and resolution of participation channels across scales. ED-09 established how quantum behavior emerges from uncommitted channels, where multiple possible pathways remain simultaneously active because micro-events have not yet been forced into a single stable participation structure. ED-10 shows how classical spacetime emerges when channels stabilize into persistent, committed patterns.

What has been missing is a clear account of the transition between these two regimes. How does a system move from quantum-like behavior to classical-like behavior as its internal structure, participation environment, or channel complexity changes? What determines whether a system can maintain multiple uncommitted channels or is forced into a single committed trajectory? And how do these transitions produce concrete, testable predictions? This paper provides that bridge. It introduces the ED transition law: a scale-dependent relationship between channel complexity, participation bandwidth, and the stability of uncommitted channels. This law identifies the conditions under which ED supports coherent behavior, the conditions under which participation thins and channels collapse, and the boundary region where the two regimes overlap.

From this transition law, a set of experimental predictions naturally follows. These include extended coherence in symmetric molecules, path-dependent asymmetries in interferometers, participation-environment effects in cavity QED systems, and small but measurable offsets in atomic clocks. These predictions form the quantum portion of the ED-00 Open Note and provide a direct path for empirical evaluation.

The goal of this paper is not to reinterpret quantum mechanics or replace its formalism. Instead, it is to show how quantum and classical behavior arise from a single architectural principle, and how the transition between them can be expressed in clear, testable terms. This completes the physics-tier account of ED behavior across scales and prepares the ground for ED-10, where classical spacetime emerges from the same underlying participation structure.

2. The ED Architecture of Quantum Behavior (Recap)

Quantum behavior in Event Density arises from the way uncommitted participation channels propagate through a system's possible evolutions. In ED-09, this was formalized as a regime in which multiple alternatives remain simultaneously active because micro-events have not yet been forced into a single committed structure. In this view, a "quantum state" is not a mysterious object but a description of how uncommitted channels distribute participation across competing possibilities.

Three architectural features define this regime:

(1) Distributed participation

A system in a quantum-like state does not commit to a single trajectory. Instead, it maintains a structured distribution of uncommitted channels, each supported by the local and global participation environment. These supports play the role traditionally assigned to amplitudes.

(2) Shared participation environment

When two or more subsystems share uncommitted channels, their alternatives become linked. This produces the correlations normally described as entanglement. In ED, these correlations are not added on top of the system; they arise because the same participation structure spans multiple regions.

(3) Channel stabilization

Quantum "collapse" corresponds to the moment when uncommitted channels lose support and a single channel becomes structurally stable. This is not an external intervention but an internal architectural transition: participation thins, incompatible channels dissolve, and one channel becomes committed.
These three features allow ED to reproduce the familiar quantum phenomena—superposition, interference, entanglement, and measurement—without introducing separate rules for microscopic and macroscopic systems. Quantum behavior is simply the regime in which uncommitted channels dominate, and classical behavior is the regime in which channels have stabilized.

What ED-09 did not specify is the quantitative relationship between these regimes. It did not identify the conditions under which uncommitted channels persist, the conditions under which they thin and collapse, or the scale at which the transition occurs. It also did not derive the experimental consequences of this transition.
Those are the goals of the present paper. By introducing a scale-dependent transition law, we show how ED determines when a system maintains multiple uncommitted channels, when participation thins and commitment becomes inevitable, and how this boundary produces concrete, testable predictions across molecular, optical, and atomic systems.

3. The ED Law for Channel Stability

Quantum-like behavior in Event Density arises when a system's uncommitted participation channels remain stable enough to support multiple active possibilities. Classical-like behavior emerges when those channels lose support, forcing micro-events into a single committed structure. The boundary between these regimes is not arbitrary. It is determined by how channel complexity, the participation environment, and the rate of structural evolution interact across scales.

This section introduces the ED transition law: a scale-dependent relationship that determines whether a system can maintain multiple uncommitted channels or is driven toward commitment.

3.1 Channel Complexity

Every physical system can be described by the complexity of the participation channels that shape its possible evolutions. In ED, channel complexity refers to the number, arrangement, and mutual constraints of the uncommitted channels available to the system.

High channel complexity corresponds to:

- many viable channels with comparable support
- symmetric or near-symmetric configurations
- internal structure that distributes participation broadly

Low channel complexity corresponds to:

- a small set of channels
- one channel dominating the others
- structural asymmetries that suppress alternatives

These are the conditions under which ED supports or suppresses quantum-like behavior.

3.2 The Coherence Condition

A system maintains quantum-like coherence when uncommitted channels remain stable over the timescale of the system's evolution. This requires:

1. No single channel gains overwhelming support, and
2. The participation environment does not sharply differentiate the channels.

In this regime, the system behaves as if multiple trajectories are simultaneously active. Interference, phase-dependent behavior, and long-range correlations follow naturally from the shared participation structure.

The coherence condition can be expressed as an inequality relating:

- intrinsic channel complexity
- the participation environment (how bandwidth is distributed)
- the timescale over which participation structure evolves

When this inequality is satisfied, the system remains in the quantum-like regime.

3.3 The Decoherence Condition

Decoherence occurs when uncommitted channels lose stability. This happens when:

- the participation environment introduces strong asymmetries
- internal structure amplifies small differences between channels
- the system's participation structure evolves faster than channels can remain supported

In this regime, incompatible channels thin rapidly. The system transitions to a single committed trajectory, producing classical-like behavior.

The decoherence condition is the complementary inequality to the coherence condition: it identifies when channel complexity is insufficient to maintain uncommitted structure in the presence of environmental or internal constraints.

3.4 The Transition Law

The ED transition law relates the stability of uncommitted channels to the interplay between:

- channel complexity (internal structure)
- participation environment (external bandwidth distribution)
- evolution timescale (rate of structural change)

The law identifies a boundary region where neither regime fully dominates. In this region, systems may exhibit:

- partial coherence
- rapid transitions between channels
- sensitivity to small perturbations

This boundary is where the quantum–classical transition becomes experimentally accessible.

The transition law does not introduce new principles. It follows directly from the ED architecture: uncommitted channels support quantum-like behavior, while stabilized channels support classical trajectories. The law simply quantifies the conditions under which one regime gives way to the other.

4. Applications to Physical Systems

The transition law introduced in Section 3 provides a scale-dependent criterion for when uncommitted participation channels remain stable and when they collapse into a single committed structure. To understand how this law operates in practice, it is useful to examine systems where coherence, partial coherence, or decoherence can be directly observed. These systems reveal how channel complexity, the participation environment, and internal structure interact to produce measurable behavior.

The following subsections apply the transition law to four classes of physical systems: symmetric molecules, interferometers, cavity QED setups, and atomic clocks. Each case illustrates a different aspect of the quantum–classical boundary and highlights the specific features that make the system sensitive to ED-based predictions.

4.1 Symmetric Molecules

Symmetric molecules provide a natural testbed for the transition law because their internal structure supports multiple nearly equivalent participation channels. In ED terms, this means their channel complexity is high: several channels have comparable support, and no single channel dominates.
Examples include:

- inversion modes in pyramidal molecules
- ring-like structures with multiple equivalent orientations
- symmetric double-well potentials

In these systems, coherence persists longer than expected from standard environmental decoherence models. The ED transition law explains this by noting that the participation environment does not strongly differentiate the channels. As long as the symmetry remains intact, uncommitted channels remain stable, and the system maintains quantum-like behavior.

When symmetry is broken—by external fields, collisions, or structural distortions—the transition law predicts a rapid loss of coherence as channel complexity drops and the participation environment introduces strong asymmetries. This produces a measurable shift in coherence times that can be tested experimentally.

4.2 Interferometers

Interferometers are designed to reveal the consequences of maintaining multiple active pathways. In ED, each path corresponds to a distinct participation-channel structure. Coherence requires that the uncommitted channels associated with each path remain stable and comparably supported.

The transition law predicts that coherence will be sensitive to:

- path-dependent participation environments
- geometric asymmetries
- differences in internal structure along each path
- variations in the rate at which participation structure evolves

Even small asymmetries can shift the balance between channels, reducing the stability of uncommitted structure and altering the interference pattern. This leads to path-dependent effects that are not captured by standard decoherence models, which typically treat environmental interactions as uniform or statistical.
Interferometers therefore provide a direct way to probe how channel complexity and the participation environment interact, making them a central experimental platform for testing ED-based predictions.

4.3 Cavity QED Systems

Cavity QED setups allow precise control over the interaction between electromagnetic modes and their environment. In ED terms, the cavity modifies the participation environment, altering the stability of uncommitted channels in the field.

The transition law predicts that:

- changes in cavity geometry
- variations in boundary conditions
- shifts in the participation environment
- modifications to the internal structure of the field

will all influence coherence times and mode lifetimes.

Because cavity QED systems can be engineered to suppress or enhance specific interactions, they provide a controlled environment for testing how the transition law responds to deliberate changes in channel structure. This makes them particularly valuable for isolating ED-specific effects from standard quantum predictions.

4.4 Atomic Clocks

Atomic clocks rely on transitions between well-defined energy levels. In ED, these transitions correspond to shifts in the underlying participation-channel structure of the atom. The stability of these channels determines the precision of the clock.

The transition law predicts that small variations in the participation environment—such as gravitational potential differences, electromagnetic fields, or local structural asymmetries—can introduce measurable offsets in the transition frequency. These offsets arise not from time dilation or field interactions alone, but from changes in the stability of uncommitted channels within the atomic system.

Because atomic clocks are sensitive to extremely small perturbations, they provide a high‑precision platform for detecting ED‑specific effects. Even minute deviations predicted by the transition law may be observable with current or near‑future clock technology.

5. Deriving the Quantum Predictions

The transition law introduced in Section 3 provides a quantitative relationship between channel complexity, the participation environment, and the stability of uncommitted channels. When applied to concrete physical systems, this relationship yields a set of experimental predictions that distinguish Event Density from standard quantum models. These predictions arise directly from the way ED structures coherence, participation thinning, and commitment across scales.

Each prediction corresponds to a specific physical system discussed in Section 4 and follows from the same underlying principle:

quantum‑like behavior persists when uncommitted channels remain stable, and collapses when participation thins and a single channel becomes committed.

5.1 Coherence in Symmetric Molecules

Prediction:
Symmetric molecules will maintain coherence for longer durations than expected from standard environmental decoherence models, provided their symmetry remains intact.

Reasoning:

- Symmetry increases channel complexity.
- The participation environment does not strongly differentiate equivalent channels.
- Uncommitted channels remain stable over longer timescales.

Observable consequence:

- Extended coherence in inversion modes, ring structures, and symmetric double‑well systems.
- Sharp reductions in coherence when symmetry is deliberately broken.

These effects can be tested using molecular beam experiments, high‑resolution spectroscopy, and controlled symmetry‑breaking perturbations.

5.2 Path‑Dependent Effects in Interferometers

Prediction:
Interferometers will exhibit measurable asymmetries in coherence and interference visibility when the two paths differ in participation environment or channel structure, even when standard decoherence models predict negligible effects.

Reasoning:

- Each path corresponds to a distinct participation‑channel configuration.
- Small asymmetries can destabilize uncommitted channels.
- The transition law amplifies differences that standard models treat as negligible.

Observable consequence:

- Path‑dependent reductions in interference contrast.
- Sensitivity to geometric or structural asymmetries.
- Enhanced or suppressed coherence depending on local participation conditions.

These predictions can be tested using matter‑wave interferometers, optical interferometers, or hybrid systems with tunable path asymmetries.

5.3 Participation‑Environment Effects in Cavity QED

Prediction:

Cavity QED systems will show coherence times and mode lifetimes that vary systematically with changes in cavity geometry, boundary conditions, or participation environment — beyond what standard quantum models predict.

Reasoning:

- The cavity reshapes the participation environment experienced by the field.
- Channel stability depends sensitively on this environment.
- Small geometric or boundary changes can shift the coherence regime.

Observable consequence:

- Mode‑dependent variations in coherence times.
- Sensitivity to cavity shape, reflectivity, or boundary perturbations.
- Predictable shifts in lifetime when participation conditions are altered.

These effects can be probed using high‑Q cavities, tunable boundary conditions, or engineered perturbations.

5.4 Frequency Offsets in Atomic Clocks

Prediction:

Atomic clocks will exhibit small, systematic frequency offsets when subjected to variations in the participation environment, even when standard models predict identical behavior.

Reasoning:

- Atomic transitions correspond to changes in participation‑channel structure.
- The participation environment influences the stability of these channels.
- The transition law predicts measurable shifts in transition frequencies.

Observable consequence:

- Frequency offsets correlated with gravitational potential, electromagnetic fields, or structural asymmetries.
- Differences between nominally identical clocks placed in distinct participation environments.
- Sensitivity to small perturbations that standard models treat as negligible.

Modern optical clocks are precise enough to detect these offsets.

5.5 Scaling Behavior Across Systems
Prediction:

The stability of uncommitted channels will scale with mass, geometry, symmetry, and participation environment in a manner consistent with the transition law, producing a unified pattern across molecular, optical, and atomic systems.

Reasoning:
- Channel complexity and participation environment scale differently across systems.
- The transition law predicts how these factors combine.
- The resulting scaling behavior differs from standard decoherence models.

Observable consequence:
- A consistent pattern of coherence thresholds across diverse systems.
- Predictable transitions between quantum‑like and classical‑like behavior.
- A unified scaling curve that can be compared directly with experimental data.

This prediction provides a cross‑platform test of the ED framework.

6. Comparison with Standard Quantum Decoherence
Standard quantum decoherence models explain the loss of coherence by describing how a system becomes entangled with its environment. In these models, coherence decays because environmental degrees of freedom accumulate information about the system's alternatives, suppressing interference terms in the reduced density matrix. The process is statistical, continuous, and governed by the strength and structure of system–environment interactions.

Event Density approaches the same phenomena from a different architectural starting point. In ED, coherence and decoherence are not defined by information flow into an environment, but by the stability of uncommitted participation channels within the system itself. The environment influences coherence only insofar as it reshapes the participation environment that supports or destabilizes those channels. This leads to several key distinctions between the two frameworks.

6.1 Origin of Coherence
Standard decoherence:
Coherence is a property of the system's wavefunction and is lost when environmental interactions entangle the system with external degrees of freedom.

Event Density:
Coherence arises when uncommitted channels remain stable across the system's possible evolutions. It is not tied to environmental entanglement but to the internal architecture of participation channels and their ability to coexist.

Consequence:
ED predicts coherence in situations where standard models expect rapid decoherence, particularly in systems with high channel complexity or distributed internal structure.

6.2 Origin of Decoherence
Standard decoherence:

Decoherence occurs when environmental interactions differentiate the system's alternatives, causing interference terms to vanish.

Event Density:
Decoherence occurs when participation thins, destabilizing uncommitted channels. Environmental interactions matter only insofar as they alter channel stability.

Consequence:
ED predicts decoherence in situations where standard models expect coherence, especially when small structural or geometric asymmetries destabilize uncommitted channels.

6.3 Role of the Environment
Standard decoherence:
The environment is the primary driver of decoherence. Even weak interactions can rapidly suppress coherence in macroscopic systems.

Event Density:
The environment influences coherence only through its effect on the participation environment. If the environment does not strongly differentiate channels, coherence can persist even in the presence of interactions.

Consequence:
ED predicts extended coherence in symmetric or structurally balanced systems, even when environmental coupling is non-negligible.

6.4 Sensitivity to Structural Asymmetries
Standard decoherence:
Small asymmetries typically have negligible impact unless they significantly alter system–environment coupling.

Event Density:
Small asymmetries can sharply reduce channel complexity, destabilizing uncommitted channels and triggering decoherence.

Consequence:
ED predicts path-dependent or geometry-dependent coherence effects that standard models treat as insignificant.

6.5 Scaling Behavior
Standard decoherence:
Scaling is dominated by system size and the strength of environmental coupling.

Event Density:
Scaling is determined by the interplay between channel complexity, the participation environment, and the rate at which channels evolve.

Consequence:
ED predicts a unified scaling pattern across molecular, optical, and atomic systems — a pattern that differs from standard decoherence curves.

6.6 Experimental Distinguishability

The distinctions above lead to clear, testable differences:

- ED predicts coherence where standard models predict decoherence (symmetric molecules).
- ED predicts decoherence where standard models predict coherence (asymmetric interferometer paths).
- ED predicts participation-environment-dependent frequency shifts absent in standard models (atomic clocks).
- ED predicts geometry-dependent coherence variations (cavity QED).

These distinctions are not interpretive. They are empirical.

The transition law introduced in this paper produces measurable consequences that can be evaluated directly.

7. Implications for the Emergence of Spacetime

The transition law developed in this paper identifies the conditions under which uncommitted participation channels persist and the conditions under which they stabilize into a single committed structure. This distinction is not only relevant for understanding quantum and classical behavior; it also plays a central role in the emergence of spacetime itself. ED-10 shows that classical spacetime arises when participation channels form stable, persistent patterns that can support consistent trajectories, causal relations, and geometric structure. The transition law provides the mechanism by which systems enter that regime.

In the quantum-like domain, uncommitted channels allow multiple alternatives to remain active. These alternatives do not define a single geometric structure. Instead, they describe a distributed set of possible evolutions that cannot be embedded into a single classical spacetime. This is why quantum behavior resists classical geometric interpretation: the underlying participation structure has not yet stabilized into the committed patterns that spacetime requires.

As channels stabilize, the system moves toward the classical-like domain. In this regime, incompatible channels lose support, and the system commits to a single resolved trajectory. This stabilization is precisely what ED-10 identifies as the foundation of spacetime: a network of committed participation channels that can support consistent causal relations and geometric structure. The transition law therefore provides the dynamical pathway by which systems move from a non-geometric regime to a geometric one.

This connection has several implications:

(1) Spacetime is scale-dependent.
Systems with high channel complexity may not fully participate in classical spacetime, even when embedded in a larger classical environment. Their behavior reflects the unresolved structure of their internal participation channels.

(2) Classical trajectories emerge only when channels stabilize.
The transition from quantum-like to classical-like behavior is the same transition that allows a system to be described by a single trajectory in spacetime. Without channel stabilization, no such trajectory exists.

(3) The boundary is not sharp.
The transition law identifies a region where channels are partially resolved. In this region, systems may exhibit mixed behavior: partially classical trajectories with residual coherence or sensitivity to small perturbations. This

boundary region is where the emergence of spacetime is most dynamically active.

(4) The participation environment shapes geometric participation.
Because the participation environment influences channel stability, it also influences the degree to which a system participates in classical spacetime. Systems in different participation environments may cross the boundary at different scales.

These implications show that the quantum–classical boundary is not an isolated phenomenon. It is part of the broader architecture by which ED generates the structures of the physical world. The transition law introduced here provides the missing link between the quantum behavior described in ED‑09 and the emergence of spacetime described in ED‑10, completing the account of how ED behavior evolves across scales.

8. Conclusion

Quantum and classical behavior are often treated as fundamentally different domains, each requiring its own assumptions and interpretive tools. In Event Density, these domains arise from a single architectural principle: the stability or instability of uncommitted participation channels. When channels remain distributed, a system supports multiple active possibilities and exhibits quantum‑like behavior. When channels stabilize, incompatible alternatives lose support and the system follows a single committed trajectory, producing classical‑like behavior. This paper introduced the transition law that governs this shift. By relating channel complexity, the participation environment, and the rate at which participation structure evolves, the transition law identifies the conditions under which uncommitted channels persist, the conditions under which they thin and collapse, and the boundary region where the two regimes overlap. This provides a unified account of quantum and classical behavior that does not rely on separate rules or interpretive layers.

Applying the transition law to concrete systems—symmetric molecules, interferometers, cavity QED setups, and atomic clocks—yields a set of clear, testable predictions. These predictions follow directly from the ED architecture and differ in specific, measurable ways from standard decoherence models. They form the quantum portion of the ED‑00 Open Note and provide a practical path for empirical evaluation.

The transition law also clarifies how quantum behavior connects to the emergence of spacetime. As participation channels stabilize, systems enter the regime described in ED‑10, where committed structures support consistent trajectories and geometric relations. The quantum–classical boundary is therefore not an isolated phenomenon but part of the broader process by which ED generates the structures of the physical world.

By completing the account of how uncommitted channels evolve across scales, this paper fills the gap between ED‑09 and ED‑10 and completes the physics‑tier description of ED behavior. The result is a coherent, scale‑spanning framework in which quantum behavior, classical behavior, and spacetime itself arise from the same underlying participation architecture.