# Axiom 0 for Bit-Collapse Theory (BCT) and a Retention-Threshold Falsification Program

A non-elastic observer-definiteness rule with preregistered defeat conditions

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**Abstract**

Decoherence-based accounts (including Quantum Darwinism and Spectrum Broadcast Structures) explain how robust classical-looking records can emerge via environmental redundancy, but they do not by themselves fix (i) what counts as the same observer across microscopic variation or (ii) when an outcome qualifies as an event for that observer without interpretive elasticity. Bit-Collapse Theory (BCT) addresses these points by tying observer-continuity and experienced definiteness to physically accessible stable records rather than to micro-branch bookkeeping. We state a single operational axiom (Axiom 0): for an agent $A$, the experienced state at time $t$ is the label of an equivalence class $[\Psi(t)]_A$ of global states that are indistinguishable to $A$ with respect to (a) observables physically accessible within a finite integration window $\tau$ and (b) the values of all record variables that are stable-for-$A$ over the same window. In this framework, "collapse" is a discrete class-label update triggered by stable accessible record formation, while global Schrodinger dynamics may remain unitary. We then introduce a preregistered falsification program targeting BCT's retention-based bridge between verified which-way information and event-like definiteness. Across platforms, the test prediction is a reproducible retention-organized transition in interference visibility indexed by a stability proxy $s = R\tau_{\text{loss}}$, with explicit confound controls and model comparison against smooth decoherence alternatives. We also state defeat conditions in advance, so that negative results force refinement or rejection rather than parameter rescue.

**Keywords:** measurement problem; decoherence; Quantum Darwinism; Spectrum Broadcast Structures; which-way information; falsifiability; observer definiteness; records; information

## 1 Scope and target

This paper does *not* introduce new microdynamics. The global quantum state $\Psi(t)$ (pure or mixed) may evolve unitarily on a total Hilbert space $\mathcal{H}$ including system, apparatus, and environment. The paper is operational: it specifies a non-elastic rule for observer-definiteness and a killable empirical wedge.

Two deliverables are the target:

- **Axiom 0:** an observer-definiteness rule stated as an equivalence relation on global states, producing an agent-relative experienced label $[\Psi]_A$.
- **A falsification program:** a preregistered test wedge for the retention-based bridge between verified which-way information and event-like definiteness, with explicit defeat conditions.

The emphasis is discipline. The proposal must be able to die cleanly.

## 2 Operational regime: access, records, and frozen parameters

We work at the level of physically bounded agents/controllers and finite information-integration windows.

### 2.1 Agent and accessible algebra

**Definition 1** (Accessible algebra with integration window)**.** *Fix an agent (or controller) $A$ and an integration window $\tau > 0$. Let $\mathcal{A}_A(\tau)$ denote the set (algebra) of observables physically accessible to $A$ within time $\tau$, including constraints from locality, bandwidth, coupling, and readout.*

**Remark 1.** *$\mathcal{A}_A(\tau)$ is not "what $A$ could access in principle with unlimited time." It is the actual operational interface at timescale $\tau$.*

### 2.2 Record variables and stability proxies

**Definition 2** (Record variable)**.** *A record variable $R$ is a finite-valued observable (or finite jointly readable set of observables) whose value encodes a physical correlation that $A$ can read within $\tau$ through $\mathcal{A}_A(\tau)$.*

To avoid elasticity, stability is defined using measurable proxies motivated by the objectivity literature.

**Definition 3** (Redundancy proxy)**.** *Given an approximate decomposition of the relevant memory/environment into disjoint fragments $\{F_i\}$, a redundancy proxy $r(R)$ counts how many fragments encode the same classical information about $R$ above a fixed information threshold.*

**Definition 4** (Robustness proxy)**.** *Fix $\eta \in (0, 1)$. A record variable $R$ is $\eta$-robust over $\tau$ if typical local perturbations over time $\tau$ flip the readout with probability at most $\eta$.*

**Definition 5** (Stable-for-$A$ record)**.** *Fix thresholds $r_{\min} \in \mathbb{N}$, $\eta \in (0, 1)$, and readout tolerance $\delta > 0$. A record variable $R$ is* stable-for-$A$ over $\tau$ *at time $t$ if:*

*(1) $R \in \mathcal{A}_A(\tau)$ (accessibility),*

*(2) $r(R) \geq r_{\min}$ (redundancy),*

*(3) $R$ is $\eta$-robust over $\tau$ (robustness).*

### 2.3 Frozen operational regime

For a given test campaign, BCT requires a frozen operational tuple

$$\mathcal{F}_A := (\tau, \delta, r_{\min}, \eta; I_c, \epsilon),$$

where $(I_c, \epsilon)$ specify the information threshold and tolerances used in the falsification program. The tuple is fixed before the scan and may not be retuned point-by-point to rescue conclusions.

## 3 Axiom 0: experienced state as an equivalence-class label

**Definition 6** (Indistinguishability for $A$ over $\tau$)**.** *Let $\Psi$ and $\Phi$ be global states at the same time $t$. Write $\Psi \approx_{A,\tau} \Phi$ if:*

*(1)* ***Accessible statistics:*** *for every* $O \in \mathcal{A}_A(\tau)$,

$$|\mathrm{Tr}(\rho_\Psi O) - \mathrm{Tr}(\rho_\Phi O)| \le \delta;$$

*(2)* ***Stable-record values:*** *for every record variable* $R$ *that is stable-for-*$A$ *over* $\tau$ *at time* $t$*, the record value agrees (within the same readout tolerance).*

**Axiom 0** (Observer-definiteness / experienced label)**.** *Fix an agent* $A$ *and window* $\tau$*. Define a relation* $\sim_A$ *on global states by*

$$\Psi \sim_A \Phi \quad \Longleftrightarrow \quad \Psi \approx_{A,\tau} \Phi.$$

*The experienced state of* $A$ *at time* $t$ *is the label of the equivalence class*

$$[\Psi(t)]_A := \{\Phi \,:\, \Phi \sim_A \Psi(t)\}.$$

*A bit-collapse event for* $A$ *occurs when, between* $t$ *and* $t + \Delta t$*, the class label changes because the set or values of stable-for-*$A$ *record variables changes.*

**Remark 2.** *Global unitary dynamics may remain intact. "Collapse" is not a discontinuity of* $\Psi(t)$ *itself; it is a discrete update of the agent-relative equivalence-class label induced by stable accessible record updates.*

**Proposition 1** (Operational no-semantic-access corollary)**.** *Under Axiom 0, the experienced label* $[\Psi]_A$ *depends only on accessible statistics and stable-for-*$A$ *record values. Features of the global state that are not encoded in* $\mathcal{A}_A(\tau)$ *or in stable-for-*$A$ *records are, by construction, not part of the agent's experienced definiteness.*

**Remark 3.** *This blocks post-hoc semantic moves. If an alleged distinction has no representation in the operational interface, it cannot be inserted into* $[\Psi]_A$ *by interpretation alone.*

## 4 From Axiom 0 to a test wedge

Axiom 0 makes definiteness depend on stable record formation, not on bare microscopic correlation. This immediately creates a falsifiable wedge: once which-way information exists at the one-bit level, event-like definiteness should still depend on whether the record persists long enough to satisfy stability-for-$A$.

### 4.1 Retention variables and bridge statement

We use the following measurable quantities in the test sector:

- $I_{\mathrm{WW}}$: verified which-way information (in bits), certified at each operating point;
- $V$: interference visibility (primary dependent variable);
- $R$: record-writing (or effective refresh) rate for the downstream record channel;
- $\tau_{\mathrm{loss}}$: characteristic loss time for the downstream record channel;
- $\tau_p$: empirical persistence time of the record above the stability criterion;
- $s := R\tau_{\mathrm{loss}}$: stability proxy.

The bridge claim is intentionally narrow:

**Retention-threshold bridge (BCT component under test).** Conditioned on verified $I_{\mathrm{WW}} \geq I_c$ (conservative default: $I_c \approx 1$ effective bit), interference visibility is predicted to become *retention-organized*: scanning $\tau_{\mathrm{loss}}$ through a near-threshold region produces a reproducible transition (or knee) in $V$ that aligns with the stability proxy $s = R\tau_{\mathrm{loss}}$, rather than being fully captured by arm-dephasing parameters alone.

This is the component that must survive or fail. It is not a generic claim about all decoherence phenomena.

## 5 Preregistered model competition

To prevent interpretive drift, the central analysis is framed as model competition, not narrative fitting.

### 5.1 Threshold-like family (BCT-style)

A minimal threshold-like family can be written as a logistic in $\log s$:

$$V(s) = V_{\min} + \frac{V_{\max} - V_{\min}}{1 + \exp\big[k(\log s - \log s_0)\big]}, \tag{1}$$

with $k > 0$ and transition scale $s_0$ interpreted within the frozen regime $\mathcal{F}_A$.

Equation (1) is a *preregistered candidate family*, not a universal law. The decisive question is whether the data support a retention-organized transition under controls.

### 5.2 Smooth alternatives (decoherence-style)

Preregistered alternatives should include smooth monotone models (e.g., exponential or power-law dependence on independently measured dephasing parameters, including non-Markovian smooth variants) without a threshold-like knee in the organizing variable $s$.

The test criterion is not "does the BCT family fit at all," but whether it provides robust explanatory gain relative to smooth alternatives under the same preregistered controls and penalties.

## 6 Falsification program and defeat conditions

### 6.1 Experimental wedge

The falsification program is platform-agnostic at the conceptual level but strict at the protocol level.

**Experiment 1: scan $\tau_{\mathrm{loss}}$ with verified $I_{\mathrm{WW}}$.** Configure a platform with certified $I_{\mathrm{WW}} \geq I_c$ at each operating point. Insert a downstream record buffer whose retention time $\tau_{\mathrm{loss}}$ is tunable over a range that crosses the hypothesized threshold region. Monitor:

(1) $I_{\mathrm{WW}}$ (must remain above threshold),

(2) arm-dephasing proxies (must remain within preregistered bounds),

(3) visibility $V$.

Fit the resulting data to the preregistered threshold-like and smooth families.

**Experiment 2: two-dimensional scan in $(R, \tau_{\text{loss}})$ and $s$-collapse.** Repeat Experiment 1 at multiple values of $R$ (or a controllable proxy that changes $R$ without materially changing arm dephasing). Re-plot $V$ against $s = R\tau_{\text{loss}}$ and test for transition alignment/data collapse across the different $R$ settings.

**Experiment 3 (cross-check): accessible vs inaccessible record.** Engineer a condition where a record exists physically but is not accessible to $A$ within $\tau$, and compare against a matched condition where it is accessible. BCT predicts that event-like effects track *accessible stable record* structure, not mere hidden correlation.

### 6.2 Preregistered confound controls

At minimum, preregister:

- bounds/monitoring for arm dephasing and path-length drift,
- engineering tests that limit back-action from buffer tuning to interferometer arms,
- verification of $I_{\text{WW}}$ at each scan point,
- calibration maps from hardware settings to $\tau_{\text{loss}}$ and (if used) $R$.

### 6.3 Defeat conditions (declared in advance)

The program is intentionally killable. The following defeat conditions are sufficient for rejection of this BCT component in their respective domains.

**Defeat 1: no retention dependence under verified one-bit which-way information.** In a near-threshold scan with verified $I_{\text{WW}} \geq I_c$ at every point and independently measured $\tau_{\text{loss}}$, visibility $V$ shows no systematic dependence on retention (within preregistered uncertainties and after confounds are bounded).

**Defeat 2: persistence-with-interference.** In conditions where the record demonstrably retains $I_{\text{WW}} \geq I_c$ for $\tau_p \gg \tau$ (meeting the persistence requirement implied by stability-for-$A$), interference remains high or recoverable in a way incompatible with an event-like class update.

**Defeat 3: retention metrics add no explanatory power (decoherence-only / wrong scaling).** Either:

(a) $V(\tau_{\text{loss}})$ is fully accounted for by independently measured arm-dephasing parameters once controls are enforced (retention variables do not improve model comparison under preregistered criteria), or

(b) an apparent transition fails to organize by $s = R\tau_{\text{loss}}$ when $R$ is varied, and instead tracks unrelated hardware knobs.

## 7 Scope discipline and relation to existing frameworks

### 7.1 What this paper does not claim

This paper does not claim that Axiom 0 derives the Born rule, specifies a unique collapse dynamics, or replaces all of measurement theory. It also does not claim that Quantum Darwinism or Spectrum Broadcast Structures "prove" BCT. Rather, QD/SBS motivate operational proxies for record redundancy and robustness, while Axiom 0 supplies the non-elastic observer-definiteness rule.

### 7.2 Why this is not a primitive cut

No privileged measurement act is introduced. Definiteness is not a primitive postulate; it is tied to stable record formation relative to $(A, \tau)$ and is tested by downstream retention manipulations under verified which-way information.

### 7.3 Why this is not Many-Worlds bookkeeping

The claim is not that all branches are equally experienced. The claim is that distinct experienced labels for a given agent require distinct stable-for-$A$ record structures. Outcomes that never produce such records for $A$ do not correspond to distinct $[\Psi]_A$ labels for that agent.

### 7.4 Companion-paper relation (RTP)

A broader Phase-2 operational spine (measurement wedge, irreversibility, inter-agent reconciliation, and record-support measure constraints) is developed separately in the companion note *The Record Threshold Principle (RTP)*. This FoP paper isolates the flagship core: Axiom 0 plus a killable retention-threshold falsification program.

## 8 Conclusion

The paper contributes one non-elastic rule and one killable wedge. Axiom 0 defines an agent's experienced state as an equivalence-class label fixed by accessible statistics and stable-for-$A$ record values over a finite integration window. The falsification program then asks a narrow but decisive question: conditioned on verified one-bit which-way information, does interference visibility organize by record retention in a reproducible threshold-like way, or not?

The answer can be negative. That is a feature, not a defect. The proposal is structured so that defeat conditions force refinement or rejection rather than parameter rescue.

## Statements and declarations

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remain with the author.

## A Optional: concrete operationalization of $R$ and $\tau_{\text{loss}}$

The proxy $R$ may be implemented as a measured write/refresh rate of a memory channel (e.g., logging frequency, refresh cycles, or effective write events per unit time). The proxy $\tau_{\text{loss}}$ may be implemented by controlled erasure, dephasing, or thermalization of a downstream record buffer, with independent calibration. A valid test campaign should preregister how these proxies map to the stability criteria used in the frozen regime.

## References


[1] W. H. Zurek, Quantum Darwinism, *Nature Physics* **5**(3), 181–188 (2009).

[2] M. Zwolak, H. T. Quan, and W. H. Zurek, Quantum Darwinism in a mixed environment, *Physical Review Letters* **103**, 110402 (2009).

[3] R. Horodecki, J. K. Korbicz, and P. Horodecki, Quantum origins of objectivity, *Physical Review A* **91**, 032122 (2015).

[4] J. K. Korbicz, Roads to objectivity: Quantum Darwinism, spectrum broadcast structures, and strong Quantum Darwinism — a review, *Quantum* **5**, 571 (2021).

[5] F. Batori, *Bit-Collapse Theory (BCT): Temperature, Memory Loss, and a Thermal Route to Falsifiability*, standalone technical note (v1.1), December 6, 2025. (Thermal falsifiability route document.)

[6] F. Batori, *BCT Phase-2 Canon materials (Axiom0 addendum, falsification package, and related notes)*, Zenodo concept DOI: 10.5281/zenodo.18496128.

[7] F. Batori, *The Record Threshold Principle (RTP): A Phase-2 operational spine for Bit-Collapse Theory (BCT)*, companion note, February 2026.

[8] F. Batori, *BCT Glossary (Canonical Terms)*, Phase-2 terminology reference, February 5, 2026.