Recursive Instability Collapse (RIC): A Dynamic Framework for Quantum Measurement, Decision-Making, and Cosmology

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August 20, 2025

Abstract. We propose *Recursive Instability Collapse (RIC)* as an adaptive monitoring principle for open quantum systems. A global instability functional $\mathcal{C}$ shapes trajectory-level measurement schedules via the classical measurement record, while the unconditional evolution remains a linear, completely positive and trace-preserving (CPTP) map. In the open-loop/record-averaged special case, the time-local generator is of GKLS form. RIC preserves Born-consistent outcome histograms but *shapes the temporal hazards.* We outline testable predictions in quantum trajectories (S-shaped hazards near threshold), an algorithmic outlook for decision neuroscience (Theta $\rightarrow$ CPP/LRP), and a speculative cosmological analogy (an effectively homogeneous, $w \approx -1$ component). Proof sketches and simulation pseudocode are provided in the appendix.

Keywords: quantum measurement; GKLS/Lindblad; stochastic Schrödinger equation; adaptive monitoring; measurement feedback; Born rule; no-signaling; emergence; EEG; decision-making; dark energy; cosmology

Transparency. This manuscript used AI assistance (Claude 4.1 Opus; Gemini 2.5 Pro; GPT-5 Thinking[2]); concept and philosophical framing by the author; mathematical formalization and drafting largely AI-generated and curated by the author.

Pseudonym. The author publishes under a pseudonym; the asterisk marks this.

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Foreword

The Cost of Hesitation: A Theory of a Deciding Universe

At the heart of modern physics, neuroscience, and cosmology lies a common puzzle: How does bare possibility become an actual, settled fact? These transitions from undecided to definite are usually treated as separate mysteries. The theory proposed here, *Recursive Instability Collapse (RIC)*, offers a unifying working hypothesis: *reality emerges because indecision carries physical costs.* We sketch an adaptive-monitoring mechanism that is falsifiable and remains compatible with the core constraints of quantum theory (Born/no-signaling) in its unconditional description.

1 Contribution & Claims (Overview)

1. **RIC mechanism (adaptive monitoring):** A global instability functional $\mathcal{C}$ schedules measurement rates at the *trajectory level* based on the classical measurement record, with a threshold $C^{\star}$.
2. **Unconditional linear CPTP map:** Averaging over records yields a linear, completely positive and trace-preserving (CPTP) evolution. A GKLS time-local generator holds in the *open-loop/record-averaged* special case.
3. **Born compatibility (hazard shaping):** Outcome weights remain Born-consistent; RIC shapes *hazards in time* without altering histogram weights.
4. **No-signaling:** Local RIC maps on A do not change A-marginals depending on measurement bases on B.
5. **Testability:** (i) SSE/trajectory experiments, (ii) EEG predictions (Theta $\to$ CPP/LRP) at the algorithmic level, (iii) a speculative cosmological analogy ($w \approx -1$, no clustering).
6. **Reproducibility:** Pseudocode (master equation, jumps, no-signaling check), analysis plan, and guardrails for linearity/feedback.

2 Notation

For quick orientation we summarize the main symbols.

Symbol	**Type/unit**	**Meaning / comment**
$\rho(t)$	density operator	state of the open system at time t
$H(t)$	Hamiltonian	(effective) Hamiltonian, possibly time-dependent
L_k	operator	Lindblad/jump/measurement operator (channel k)
$\mathcal{D}[L_k]\,\rho$	superoperator	$L_k \rho L_k^{\dagger} - \frac{1}{2}\{L_k^{\dagger} L_k, \rho\}$
$\gamma_k(t;\xi)$	rate	trajectory-level adaptive monitoring strength (record-only)
$\mathcal{C}[\rho]$	scalar	instability functional; e.g., variance-sum $\sum_k \mathrm{Var}_\rho(L_k)$
$C^{\star}$	scalar	threshold for adapting γ_k
$H_{\mathrm{fb}}(t;\xi)$	Hamiltonian	optional feedback Hamiltonian (Wiseman–Milburn)
	operator	identity

Symbol	Type/unit	Meaning / comment
$\mathrm{Tr}[\cdot]$	scalar	trace; expectations $\langle O\rangle = \mathrm{Tr}[O\rho]$
$\Lambda_{A,t}$	CPTP map	local GKLS dynamics on subsystem A at time t
ρ_{AB}, ρ_A	density operators	joint state AB, and marginal on A

3 Main Text

3.1 Introduction

The idea behind *RIC* is to let open quantum systems be characterized not by fixed external measurement rates, but by *state-dependent adaptive monitoring* at the *trajectory* level. A global instability functional $\mathcal{C}$ acts as an order parameter: when the filtered state's $C_t(\xi)$ is high, monitoring intensifies; when it is low, it weakens. The unconditional ensemble evolution remains linear and CPTP (convex mixture over classical records).

Terminology. We use established terms from measurement and control: *adaptive measurement scheduling*, *measurement-based feedback* (record-only), and the *unitary–dissipative tension.* Earlier humanistic labels motivated the framework but are not used as technical terms here.

4 Formal specification

We use the GKLS form (Lindblad, 1976; Gorini–Kossakowski–Sudarshan, 1976):

$$\dot\rho(t) \;=\; -\,i\,[H(t),\rho(t)] \;+\; \sum_k \gamma_k(t)\,\mathcal{D}[L_k]\,\rho(t), \qquad \mathcal{D}[L]\,\rho := L\rho L^\dagger - \tfrac{1}{2}\{L^\dagger L,\rho\}. \tag{4.1}$$

Let $\mathcal{C}[\rho]$ be an *instability functional* (see Section 4.1). On the *trajectory level*, with classical measurement record $\xi_{[0,t)}$ and filtered state $\rho_c(t;\xi)$, define

$$C_t(\xi) \;:=\; \mathcal{C}\big[\rho_c(t;\xi)\big]. \tag{4.2}$$

The adaptive schedule acts on each trajectory via

$$\gamma_k(t;\xi) \;=\; \gamma_k^{\min} \;+\; \big(\gamma_k^{\max}-\gamma_k^{\min}\big)\, s\!\left(\frac{C_t(\xi)-C^\star}{\Delta}\right), \qquad s(x) := \frac{1}{1+e^{-x}}, \tag{4.3}$$

with threshold $C^\star$ and width $\Delta > 0$. The *unconditional* state is the convex mixture over records, $\rho(t) = \mathbb{E}_\xi[\rho_c(t;\xi)]$, hence the overall evolution is *linear CPTP*. A time-local *GKLS* generator holds in the special case that $\gamma_k(t)$ are open-loop (time-only) or record-averaged to deterministic functions of time.

4.1 Admissible instability functionals and channels

We require for $\mathcal{C}$: (i) nonnegativity; (ii) invariance under admissible GKLS gauge transformations (unitary mixing and shift freedom); (iii) Lipschitz continuity in ρ (well-posed filtering); (iv) stability under coarse-graining.

Why this instability functional $\mathcal{C}$? We additionally seek (v) operational meaning and (vi) identifiability from weak records. We therefore evaluate $\mathcal{C}$ in the canonical traceless GKLS representation (diagonal Kossakowski form), defining $\mathcal{C}[\rho] = \sum_j \mathrm{Var}_\rho(\tilde{L}_j)$. This choice is invariant (unitary mixing and admissible shifts removed) and tied to dissipation: for Hermitian channels one has $-\frac{d}{dt}\operatorname{Tr}\rho^2 = 2\sum_j \gamma_j \mathrm{Var}_\rho(\tilde{L}_j)$, while for general channels $\mathcal{C}$ upper-bounds purity decay up to channel-dependent constants. Empirically, $\mathcal{C}$ admits weak-measurement proxies (variance/Fisher-information surrogates), allowing calibration of the policy. We cross-check robustness with the purity-decay proxy $\mathcal{C}_{\mathrm{pur}}$.

- **Variance sum:** $\mathcal{C}[\rho] = \sum_k \mathrm{Var}_\rho(L_k)$.
- **Information proxy:** a quantum Fisher-information surrogate for the monitored observables.
- **Dissipation proxy:** purity-decay or entropy-production rate under the monitored channels.

Gauge-fixed instability functional. We evaluate $\mathcal{C}$ in the *canonical traceless GKLS representation*: we diagonalize the Kossakowski matrix in an orthonormal, traceless operator basis to obtain Lindblad operators $\{\tilde{L}_j\}$ that are unique up to phases and permutation. We then define

$$\mathcal{C}[\rho] = \sum_j \mathrm{Var}_\rho(\tilde{L}_j) = \sum_j \left(\langle \tilde{L}_j^\dagger \tilde{L}_j \rangle_\rho - |\langle \tilde{L}_j \rangle_\rho|^2 \right), \tag{4.4}$$

which is invariant under admissible GKLS gauge transformations (unitary mixing and shifts absorbed by Hamiltonian counterterms). *Robustness proxy:* we also report the dissipator-only purity-decay rate $\mathcal{C}_{\mathrm{pur}}[\rho] := -\frac{d}{dt}\operatorname{Tr}\rho^2\big|_{H=0}$ as an invariant cross-check.

5 Properties (proof sketches in the appendix)

Controller embedding. Adaptive record-driven policies can be represented by coupling S to a classical controller ancilla C with GKLS evolution on $S\otimes C$; tracing out C yields the (possibly non-divisible) CPTP map observed on S.

- **Unconditional linear CPTP map:** Averaging over classical records yields a linear CPTP evolution (convexity of CPTP maps).
- **GKLS special case:** If $\gamma_k(t)$ are open-loop or record-averaged to deterministic functions, the time-local generator attains GKLS form.
- **Born compatibility:** Jump intensities remain proportional to $\operatorname{Tr}\Big(L_k^\dagger L_k\, \rho_c\Big)$; hazards are shaped in time but histogram weights follow Born statistics.
  Guardrail: Any outcome-dependent leakage into γ_k would bias histograms and violate Born; such policies are excluded.
- **No-signaling:** Local, time-dependent GKLS maps on A do not alter A-marginals depending on the basis chosen on B.

5.1 Predictions and empirical paths

(Q) Quantum trajectories. Jump hazards near threshold should show an *S-curve* (cf. Eq. (4.3)). Testable in trapped ions/superconducting platforms via adaptive readout (photon counting, QND).

(N) Neuro (algorithmic outlook). Read RIC as an *algorithmic* principle of adaptive monitoring: transient Theta increase (instability) preceding a steep CPP/LRP phase (commitment). This statement is substrate-agnostic (compatible with classical decision circuitry) and does not require quantum coherence in neural tissue.

RIC-specific dissociation: trial-by-trial a **positive** correlation between estimated hazard $h(t)$ and a neural instability proxy $C_\Theta(t)$ (frontal theta), and a calibration relation

$$\operatorname{logit}\left(\frac{\gamma(t)-\gamma_{\min}}{\gamma_{\max}-\gamma(t)}\right) \approx \frac{C_\Theta(t-\tau)-C^\star}{\Delta}. \tag{5.1}$$

In hierarchical Bayesian analyses, $\gamma(t)$ should explain CPP/LRP slope beyond RT, drift and bound latents; failure favors classical models.

(C) Cosmology (speculative analogy). We speculate that a pervasive collapse stream could stabilize an effective, homogeneous component with $w \approx -1$ without clustering. This is not a derived result; quantitative coupling to Friedmann dynamics and precision-data tests are deferred.

6 Relation to prior work (concise)

RIC differs from standard measurement-based feedback control (Wiseman–Milburn) by (i) using a *global* instability functional to schedule measurement strengths *at the trajectory level via the classical record* and (ii) ensuring that the *unconditional* evolution remains a linear CPTP map (convex mixture over records). In the open-loop/record-averaged special case the time-local generator is GKLS. RIC stays within the Belavkin/continuous-measurement picture but highlights an order parameter $\mathcal{C}$ that guides adaptive monitoring.

7 Limitations and open questions

Choice of $\mathcal{C}$ and L_k may be *identifiability-critical*; naive implementations risk effective nonlinearity if the record/trajectory split is ignored. Open questions: CP-divisibility conditions; controller–ancilla embeddings that yield explicit GKLS on $S \otimes C$; information optimality of $s(\cdot)$; thermodynamic cost of adaptivity; sharper (no-)go results beyond Markovianity.

8 Minimal example & falsifiability

A qubit with $H = \frac{\Omega}{2}\sigma_x$, $L = \sqrt{\kappa}\,\sigma_z$, $\mathcal{C} = \mathrm{Var}_\rho(\sigma_z)$ and Eq. (4.3) already shows the qualitative RIC signature: quiet phases at low monitoring, punctuated by brief high-clarity bursts. Systematic departure from Born histograms near threshold, under record-only scheduling, would falsify RIC.

9 Summary

RIC provides a compact, testable mechanism: *instability steers measurement strengths without sacrificing unconditional linear CPTP evolution.* The appendix contains proof sketches and simulation blueprints enabling replication and falsification.

Author contributions & AI disclosure

Gestan Morgan*: idea, problem statement, recursive/dual conceptual framing (cf. the author's texts), prompt design, curation and final editing. **AI assistants** (Claude 4.1 Opus; Gemini 2.5 Pro;

GPT-5 Thinking[2]): preliminary formal structure, proof sketches, simulation pseudocode; language tightening. Content curated, checked, and integrated by the author. **Responsibility:** remaining errors are the author's.

A Formal foundations and simulation sketches for RIC

A.1 Setting and notation

We consider an open quantum system with density operator $\rho(t)$ and GKLS dynamics (4.1). In RIC, trajectory-level rates $\gamma_k(t;\xi)$ are adapted as functions of the record-derived instability $C_t(\xi)$ with threshold $C^\star$, cf. Eq. (4.3).

A.2 CPTP under adaptive scheduling: conditions and concise proof

Assumption 1 (Record-only feedback)**.** *Scheduling $\gamma_k(t;\xi)$ and any $H_{\mathrm{fb}}(t;\xi)$ are functions of time and the* past classical record $\xi_{[0,t)}$ *along a trajectory; no direct functional dependence on the ensemble state $\rho(t)$.*

Proposition 1 (Unconditional CPTP map)**.** *Averaging over classical records yields a linear CPTP map for $\rho(t) = \mathbb{E}_\xi[\rho_c(t;\xi)]$.*

Concise. Linearity holds by taking expectations. Convex combinations of CPTP maps are CPTP, hence $\Phi_{t,0}$ is CPTP. Predictability (record-only, no peeking into the future) ensures each $\Phi_{t,0}^{(\xi)}$ is a legitimate adapted evolution (e.g., via Belavkin filtering/Hudson–Parthasarathy dilation). □

Lemma 1 (GKLS special case)**.** *If $\gamma_k(t)$ and $H_{\mathrm{fb}}(t)$ are deterministic (open-loop or record-averaged), the time-local generator attains GKLS form with time-dependent coefficients. Otherwise the unconditional map need not be CP-divisible (though CPTP).*

Concise. Deterministic time-dependence yields a time-local GKLS master equation (standard). Record-driven adaptivity introduces classical memory: the end-map remains CPTP (by the previous proposition), but intermediate propagators may fail CP-divisibility. A controller-ancilla dilation on $S\otimes C$ restores GKLS on the joint system; tracing out C yields the observed (possibly non-divisible) CPTP map on S. □

A.3 Born compatibility of trajectories

Proposition 2 (Born compatibility with hazard shaping)**.** *For jump unravelings with conditional state $\rho_c(t;\xi)$ and trajectory-level $\gamma_k(t;\xi)$ that satisfy Assumption 1,*

$$\Pr\{\textit{jump } k \textit{ in } [t,t{+}dt) \,|\, \rho_c(t;\xi)\} \;=\; \gamma_k(t;\xi)\; \mathrm{Tr}\big[L_k^\dagger L_k\, \rho_c(t;\xi)\big]\, dt. \tag{A.1}$$

Outcome weights (histograms) remain Born-consistent; RIC reshapes the temporal hazard profile without altering relative weights.

Concise. The jump intensity is $\gamma_k(t;\xi)\ \mathrm{Tr}\Big(L_k^\dagger L_k\, \rho_c\Big)$; record-only policies modulate only the prefactor, not the Born factor. Thus RIC reshapes timing (hazards) while preserving Born-consistent histograms. □

A.4 No-signaling under local RIC dynamics

Proposition 3 (No communication)**.** *Let ρ_{AB} be an initial (possibly entangled) state. Apply a local, time-dependent GKLS map $\Lambda_{A,t}$ (RIC-compliant) on A, and any local operation on B without back-channel to A. Then $\rho_A(t) = \mathrm{Tr}_B[(\Lambda_{A,t}\otimes\mathcal{I}_B)\rho_{AB}]$ is independent of the measurement basis on B, by linearity and complete positivity. RIC allows no superluminal communication. With finite detection efficiency $\eta \in (0,1]$, splitting each channel as $(\sqrt{\eta}L, \sqrt{1-\eta}\,L)$ and conditioning policies on the local observed record preserves locality and the no-signaling conclusion.*

Concise. Local CPTP maps commute with partial trace and do not depend on remote basis choices; hence $\rho_A(t)$ is independent of measurements on B. Detection inefficiency is a local dilation and leaves the argument unchanged. □

A.5 Well-posedness and numerical guardrails

Lemma 2 (Well-posedness)**.** *If g is bounded and Lipschitz and $\mathcal{C}$ is Lipschitz in ρ (Hilbert–Schmidt norm), then the stochastic master/Schrödinger equations with record-only coefficients admit strong existence and uniqueness; standard strong-order schemes converge under step-size ablation.*

Concise. Finite-dimensional Itô SDE theory with predictable, Lipschitz coefficients ensures strong solutions and uniqueness; boundedness controls moments. Convergence follows from standard results for strong-order integrators under step-size refinement. □

Numerically we use strong-order integrators, step-size ablations and bias checks to verify convergence of moments and hazard statistics as $dt \downarrow 0$.

A.6 Simulation sketches (pseudocode)

A. Unconditional master equation with adaptive rates

Listing 1: Unconditional GKLS with adaptive rates (record-only)

```
import numpy as np

def D(L, rho):
    return L @ rho @ L.conj().T - 0.5*(L.conj().T@L@rho + rho@L.conj().T@L)

def rk4_step(rho, H, Ls, gammas, dt):
    def rhs(r):
        dr = -1j*(H@r - r@H)
        for L, g in zip(Ls, gammas):
            dr += g * D(L, r)
        return dr
    k1 = rhs(rho)
    k2 = rhs(rho + 0.5*dt*k1)
    k3 = rhs(rho + 0.5*dt*k2)
    k4 = rhs(rho + dt*k3)
    return rho + (dt/6.0)*(k1 + 2*k2 + 2*k3 + k4)
```

B. Jump trajectories with adaptive rate

Listing 2: Stochastic trajectory (jump unraveling)

```
def jump_trajectory(rho0, H, Ls, gamma_of_t, T, dt, rng):
    rho = rho0.copy()
    traj = []
    for n in range(int(T/dt)):
        t = n*dt
        gammas = gamma_of_t(t) # deterministic (record-averaged) schedule
        Heff = H(t) - 0.5j*sum(g*L.conj().T@L for L, g in zip(Ls, gammas))
        rho_tilde = rk4_step(rho, Heff, [], [], dt)
        p_no = np.real(np.trace(rho_tilde))
        if rng.uniform() < 1 - p_no:
            rates = np.array([g*np.real(np.trace(L@rho@L.conj().T)) for L, g in zip(Ls,
                 gammas)])
            k = rng.choice(len(Ls), p=rates/np.sum(rates))
            rho = Ls[k] @ rho @ Ls[k].conj().T
            rho = rho / np.trace(rho)
            traj.append(("jump", t, k))
        else:
            rho = rho_tilde / p_no
            traj.append(("nojump", t, None))
    return traj
```

C. No-signaling test (entangled pair)

Listing 3: A-marginals invariant under B-basis choice

```
def nosig_experiment(rho_AB, HA, LsA, gammaA, UB_list, T, dt, Nreal=1000, rng=None):
    # UB_list: different local bases/POVMs on B (as unitaries)
    from numpy import kron, trace
    marginals_per_B = []
    for UB in UB_list:
        hist = []
        for r in range(Nreal):
            rho = rho_AB.copy()
            rho = evolve_unconditional(rho, HA, LsA, gammaA, dt, T)
            rho = (kron(np.eye(lenA), UB)) @ rho @ (kron(np.eye(lenA), UB.conj().T))
            rhoA = partial_trace_B(rho)
            hist.append(rhoA)
        marginals_per_B.append(avg(hist))
    return compare_ci(marginals_per_B)
```

A.7 Identifiability considerations

We constrain policies by pre-calibrating $\gamma_{\min/\max}$ and enforcing monotonicity of g with width Δ in a plausible band. Channel-selective designs (QND vs. non-QND) break collinearities between $\mathcal{C}$, g, and $\{L_k\}$. We assess parameter identifiability via profile-likelihoods and Sobol sensitivity; when multiple $(\mathcal{C}, g)$ remain equivalent, we report *equivalence classes* rather than point models.

Selected references

Lindblad (1976); Gorini–Kossakowski–Sudarshan (1976); Wiseman (1994); Belavkin (1992); Carmichael (1993).