The ACT Event Law: A Candidate Formulation

One Postulate, Four Theorems

A Working Note

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Abstract

Every reviewer of ACT, internal and external, has converged on one missing object: an explicit event law—a hazard $\lambda_k(t|\rho, E)$ for the occurrence of event k and a map $\rho \to \mathcal{J}_k[\rho]$ stating what an event physically does. This note supplies a candidate formulation. ACT's event dynamics is proposed as a piecewise-deterministic process (PDP): between events, the ACT-modified Schrödinger evolution of the Mathematical Supplement; events occur in the interaction-selected pointer basis at hazard $\lambda_k(t) = \Lambda(t)\, p_k(t)$, where p_k is the pointer-basis population and $\Lambda(t) = d\Phi/dt$ is the rate of irreversible record formation already defined by the anchoring functional; the event map is the projective update $\mathcal{J}_k[\rho] = P_k \rho P_k / p_k$. The formulation's value is what becomes *provable* once it is written down. Four theorems, each verified numerically to machine precision: (1) **Born uniqueness**—within this event class, the linear hazard $\lambda_k \propto p_k$ is the *only* choice whose unconditioned dynamics is linear; any nonlinear hazard enables superluminal signalling through entangled pairs. The Born weights are therefore not assumed but forced by no-signalling. (2) **No-signalling**—local event maps leave spacelike-separated marginals exactly invariant. (3) **Order-invariance**—commuting spacelike event maps yield joint outcome statistics independent of event ordering, so observed probabilities are frame-independent even though the model's event sequence is not. (4) **Ensemble consistency**—averaging the PDP reproduces the Joos–Zeh dephasing master equation exactly, so the law cannot conflict with any ensemble-level quantum prediction. Energy accounting is stated honestly: conserved in expectation up to a calculable per-event coherence-energy offset drawn against the bath. A structural bonus emerges from the law itself: since $\Lambda = d\Phi/dt$, the survival probability of the pre-event state is $S(t) = e^{-\Phi(t)}$—so Φ *is* the cumulative event hazard, $\Phi \sim 1$ is the e-folding scale rather than a boundary, and the long-criticized "arbitrary threshold" dissolves: no threshold is postulated at all. The note closes with the ledger: what this formulation postulates, what it derives, and what remains open—a fully covariant field-theoretic version chief among them.

1 What Was Missing

The Mathematical Supplement derives record formation: the anchoring functional $\Phi_{\mathcal{O}}$ grows, off-diagonal coherences decay, and pointer components stabilize. It then attaches single-outcome realization to threshold crossing by an explicitly labeled bridge postulate. Five rounds of review identified the same gap: the postulate names *that* one outcome is realized but supplies no law for *which*, *when*, with *what probability*, or with *what physical consequence*. The required object is a stochastic event law:

$$\lambda_k(t \,|\, \rho, E) \qquad \text{and} \qquad \rho \longrightarrow \mathcal{J}_k[\rho]. \tag{1}$$

This note proposes one, in the most conservative mathematical class available—piecewise-deterministic processes, the same class that underlies quantum-jump trajectory theory (Breuer–Petruccione) and GRW hits—and then proves what the proposal buys.

2 The Event Law

Postulate 1 (ACT Event Law)**.** *Let $\{P_k\}$ be the interaction-selected pointer projectors (einselection) for a system whose anchoring functional $\Phi(t)$ is accumulating through coupling to environment E, and let $p_k(t) = \mathrm{Tr}[P_k \rho_S(t)]$. The physical history of the system is a piecewise-deterministic process:*

1. ***Flow:*** *between events, ρ_S evolves by the ACT-modified dynamics of the Supplement (Schwinger–Keldysh reduced evolution; ordinary Schrödinger flow in the decoupled limit).*

2. ***Hazard:*** *event k occurs at instantaneous rate*

$$\lambda_k(t) \;=\; \Lambda(t)\, p_k(t), \qquad \Lambda(t) \;\equiv\; \left.\frac{d\Phi}{dt}\right|_{irr}, \tag{2}$$

   where Λ is the rate of irreversible *record formation: only environmental entanglement that has itself crossed the anchoring criterion contributes (reversible which-path correlations, as in quantum-eraser configurations, contribute zero hazard).*

3. ***Event:*** *when event k fires,*

$$\rho_S \;\longrightarrow\; \mathcal{J}_k[\rho_S] = \frac{P_k\, \rho_S\, P_k}{p_k}, \tag{3}$$

   applied to the system-plus-local-record degrees of freedom. The realized component enters the causal order (temporal existence); the unrealized components become causally inert*: they enter no future hazard, source no future coupling, and constitute unrealized spectral possibility in the sense already used by the manuscript.*

Three remarks before the theorems. First, this is one postulate, not three: the PDP class, the pointer basis, and the projective form travel together as the statement "events are pointer-resolved jumps riding on irreversible record formation." Second, nothing stochastic is added to nature beyond what the bath already supplies: Λ is not a new noise field (contrast GRW/CSL) but the already-derived record-formation rate; the event law assigns ontological weight to monitoring that is physically occurring. Third, the law contains *no* freedom in the probability assignment—that is Theorem 1. Fourth, the law retroactively sharpens the anchoring functional itself: the no-event survival probability is

$$S(t) = \exp\Big[-\int_0^t \Lambda\, ds\Big] = e^{-\Phi(t)}, \qquad P_{\text{event}}(t) = 1 - e^{-\Phi(t)}, \tag{4}$$

so Φ is the cumulative event hazard and the off-diagonal suppression $e^{-\Phi}$ *is* the survival probability—one object, two readings. $\Phi = 1$ is the e-folding scale (63.2% cumulative event probability), not a boundary; the historical threshold language is shorthand, and the threshold-arbitrariness objection is dissolved rather than answered. The Born statistics follow in one line: with populations conserved by the dephasing flow, $P(k) = \int_0^\infty \lambda_k S\, dt = p_k \int_0^\infty \Lambda e^{-\Phi} dt = p_k\,(1 - e^{-\Phi(\infty)})$, so $P(k\,|\,\text{event}) = p_k$ for any monitoring profile. This formulation supersedes the first-to-threshold race language wherever the two differ.

Stated in standard quantum-trajectory language, the law is an *unraveling*: jump operators $L_k = \sqrt{\Lambda}\, P_k$, no-jump effective Hamiltonian $H_{\text{eff}} = H - \frac{i\hbar\Lambda}{2}\nVdash$, jumps $|\psi\rangle \to P_k|\psi\rangle/\|P_k|\psi\rangle\|$. Averaging the trajectories yields exactly one master equation—the dephasing dynamics already present—so anchoring is not a second process layered on decoherence; nothing is double-counted. Three conventions complete the specification. (a) *Repeated jumps:* after a jump into P_k, $p_k = 1$ and further same-channel jumps are identity maps—continuing environmental confirmation, not new events; only state-changing jumps are events. (b) *No event before its record:* Λ counts only irreversible record increments, so an event at any time is accompanied, by construction, by the record formed up to that time; an early event (small Φ) is an event with a small but already-irreversible record. (c) *Scope:* the closed-form Born result holds where the pointer populations are conserved by the flow; in general $P(k) = \int_0^\infty \Lambda\, p_k(t)\, e^{-\Phi} dt$, and the extension to POVM-smeared continuous outcomes (finite-resolution Kraus operators $M_x \propto e^{-(\hat{x}-x)^2/4\sigma^2}$ replacing exact projectors, avoiding unbounded momentum injection) is listed open.

3 Four Theorems

Theorem 1 (Born uniqueness from no-signalling)**.** *Assume: (A) standard Hilbert-space kinematics; (B) hazards local in the pointer projectors, $\lambda_k = \Lambda\, f(p_k)$ with a single universal nonnegative f; (C) mutually exclusive, normalized pointer outcomes; (D) ensemble equivalence—proper and improper mixtures with the same ρ receive the same hazards; (E) local instruments. Then the unconditioned (event-unobserved) evolution of ρ_S is affine in ρ_S if and only if $f(p) \propto p$. For any nonlinear f, an entangled partner's marginal statistics change when local events fire unobserved—superluminal signalling. Hence within (A)–(E) the linear hazard, and with it the Born weighting, is the unique no-signalling choice. The claim is explicitly* not *that no-signalling alone generates Hilbert-space probability theory; the kinematics are assumed, the probability rule is derived.*

Proof. The unconditioned generator contributed by events is $\mathcal{L}_{\text{ev}}[\rho] = \Lambda \sum_k f(p_k) \left(\frac{P_k \rho P_k}{p_k} - \rho \right)$. The term $\frac{f(p_k)}{p_k} P_k \rho P_k$ is linear in ρ iff $f(p)/p$ is constant. For nonlinear f, prepare $|\psi\rangle = \sqrt{p}\,|00\rangle + \sqrt{1-p}\,|11\rangle$; Alice's unobserved events leave Bob the marginal $w_0 = f(p)/[f(p) + f(1-p)] \neq p$. Numerically: $f(p) = p^2$, $p = 0.7$ shifts Bob's population from 0.700 to 0.845—an operational signal. For $f(p) = cp$, $w_0 = p$ identically. □

Corollary 1 (Born statistics)**.** *In the measurement regime (monitoring fast relative to system dynamics, so populations are conserved between events—exactly true for pure dephasing), the probability that the first event is k equals $p_k(0)$, for* any *monitoring profile $\Lambda(t)$. Verified semi-analytically: $p_0 = (0.5, 0.3, 0.2)$ yields $P(k) = (0.5, 0.3, 0.2)$ under a strongly time-varying Λ.*

This answers the standing objection directly: the Born-shaped hazard is not inserted—it is the unique member of the event class that does not turn entanglement into a telegraph. The same conclusion follows independently from outcome coarse-graining: requiring that merging two outcomes into one coarse outcome commute with the law ($\lambda_{k_1 \cup k_2} = \lambda_{k_1} + \lambda_{k_2}$ with the same universal f) forces Cauchy additivity $f(x+y) = f(x) + f(y)$, hence linearity. Two independent routes, one answer. This is consonant with the known linearity constraints on collapse models (Gisin); the contribution here is its statement as a uniqueness theorem internal to ACT's event class.

Theorem 2 (No-signalling)**.** *For a bipartite system, Alice's local event maps satisfy $\text{Tr}_A\left[\sum_k P_k^A \rho\, P_k^A\right] = \text{Tr}_A[\rho]$. Bob's reduced state, hence every local expectation value, is invariant under Alice's unobserved anchoring events.*

Theorem 3 (Frame-independent joint statistics for commuting spacelike event instruments)**.** *Let Alice's and Bob's event maps act on commuting algebras, $[P_a^A \otimes \mathbb{1}, \mathbb{1} \otimes P_b^B] = 0$. Then the joint outcome distribution $P(a,b) = \mathrm{Tr}[(P_a^A \otimes P_b^B)\,\rho\,(P_a^A \otimes P_b^B)]$ is identical whether Alice's event precedes Bob's or conversely (verified: difference $= 0$ exactly). Consequently all* observable *statistics are frame-independent. The model's internal event sequence for spacelike pairs is not frame-independent; all* observable *joint statistics are order-independent (Theorem 3), and ACT's working position is that the internal ordering is unobservable bookkeeping—whether it is ontologically gauge awaits the covariant formulation, listed open. Bell-violating correlations are inherited from the shared pre-anchored state, exactly as the manuscript's Bell section states, and the price already acknowledged there (nonfactorizable causal structure) is unchanged by the event law. A fully covariant microdynamic remains open.*

Theorem 4 (Ensemble consistency)**.** *Averaging the PDP over its own stochasticity yields the generator $\mathcal{L}[\rho] = \Lambda\left(\sum_k P_k \rho P_k - \rho\right)$: the Joos–Zeh pointer-basis dephasing master equation with rate Λ. (Linearity verified numerically; mixture error $= 0$.) The event law therefore reproduces every ensemble-level prediction of standard open-system quantum mechanics, and is empirically equivalent to standard quantum-trajectory statistics wherever the environment is genuinely monitored. Its new content is ontological—events occur objectively, observer or no observer—plus whatever rate contribution the mass channel adds to Λ.*

4 Energy Accounting, Stated Plainly

Per event, the expected post-event energy is $\sum_k p_k \langle k|H|k\rangle$, which differs from the pre-event $\langle H\rangle$ by exactly the coherence energy $\Delta E_{\mathrm{coh}} = \sum_{j\neq k} \mathrm{Re}\,\rho_{jk} H_{kj}$ (worked example: offset 0.099 on an $\mathcal{O}(2)$ Hamiltonian; zero for pointer-diagonal states). Under the flow, this same coherence energy is what the FDT-paired bath exchange is already dissipating; in the measurement regime the offset is bounded by the off-diagonal norm that has, by construction, decayed below $e^{-\Phi}$ at event time. The honest summary: **energy is conserved in expectation, with per-event fluctuations bounded by the residual coherence energy at threshold and drawn against the bath**. Exact per-event conservation is not claimed; whether the event map can be refined to conserve energy eventwise (e.g., by augmenting $\mathcal{J}_k$ with a bath-side compensation) is an open problem, listed below.

5 What the Law Answers

The six questions every reviewer posed, answered within the model: *What becomes actual?* The pointer component k, with its local record. *What happens to unrealized components?* Causally inert; they enter no future hazard or coupling; unrealized spectral possibility. *Does the global state change?* Yes—Eq. (3), applied jointly for entangled systems; Theorems 2–3 ensure this is operationally local and frame-consistent. *How are spacelike events coordinated?* Observable joint statistics are order-invariant (Theorem 3); the ontological status of the internal ordering awaits the covariant formulation. *Is no-signalling maintained?* Theorem 2, exactly. *Energy?* Conserved in expectation; per-event accounting bounded and stated.

Wigner's friend now has a dynamical answer rather than a bare assertion: once the friend's apparatus crosses threshold, the hazard has fired with probability one at macroscopic Λ, the event map has applied, and Wigner's unitary description fails *because a jump occurred*—a statement internal to the model, falsifiable with it. The quantum-eraser distinction is built in at Eq. (2):

reversible which-path entanglement contributes zero hazard, so erasure experiments proceed exactly as observed.

6 The Ledger

Postulated (one item): events are pointer-resolved projective jumps riding on irreversible record formation—the PDP form of the Postulate, including the einselected basis and the identification of Λ with $d\Phi/dt|_{\mathrm{irr}}$. This is ACT's successor to the bridge postulate: sharper, but still a postulate. The claim that *this* unraveling is physically real is addressed by the companion note *Why This Unraveling?* (June 2026): under the Record Condition—events condition only on redundantly recorded, fragment-accessible environmental data—conjugate-conditioned unravelings of every type are excluded, the einselected and recorded observables coincide, and the pointer basis becomes an output of environmental redundancy; within the piecewise-deterministic class the pointer-jump law is then unique, while record-conditioned continuous localization in the pointer manifold remains admissible. What remains irreducibly postulated: the ontic status of record-conditioned jumps, and the discrete-jump form as against such diffusion.

Derived (four items): Born weighting, uniquely, from no-signalling (Theorem 1, two independent routes); no-signalling itself (Theorem 2); frame-independence of all observable statistics (Theorem 3); exact consistency with ensemble quantum mechanics and standard trajectory theory (Theorem 4).

Resolved by the law itself (one item): the $\Phi = 1$ conventionality. Equation (4) shows no threshold exists to be conventional: Φ is a cumulative hazard and $\Phi \sim 1$ its e-folding scale.
Open (three items): (i) per-event energy conservation, in particular for jump projectors that do not commute with the kinetic energy; (ii) a covariant field-theoretic formulation in which the frame-independence of Theorem 3 is manifest as a property of the ontology rather than verified pairwise for commuting instruments; (iii) the microscopic universal channel and window derivation, unchanged from the Supplement's constraint section. Also open at the level of generality: the jump map for degenerate, nonprojective, or continuous outcome families, and the non-Markovian regime.

7 What This Changes

ACT's structure before this note: record-formation dynamics + bridge postulate. After: record-formation dynamics + *one sharp stochastic law* from which the Born rule, no-signalling, frame-independent statistics, and ensemble consistency are theorems. That is the completeness standard GRW set for collapse models in 1986—an explicit, falsifiable-in-principle stochastic dynamics—reached here without introducing a fundamental noise field, because ACT's events ride on environmental monitoring that is already physically present. The manuscripts should adopt the law as "candidate event law" with this note's ledger verbatim; Lecture 8's open-steps list shortens by one (the Born hazard is no longer assumed) and gains one (the reality-of-this-unraveling clause now carries the postulate's weight). The Scientific Status box gains a row: *Derived, conditional on the event class: Born weights, no-signalling, order-invariance, ensemble consistency.*