The Observer as a Local Breakdown of Atemporality

A Philosophical Essay on Time, Information, and the Anomaly of the Observer

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Prologue: Time Does Not Pass

Time does not pass. It is constructed.

For centuries we have spoken of time as if it were an invisible substance flowing through the universe. Something that advances, that drags objects along, that separates the past from the future and gives meaning to experience. Yet when we try to write time into the most fundamental equations of physics, this narrative begins to crumble.

The equations contain no “now.” They contain no “before” or “after.” They contain no experience.

And yet, we do.

This essay starts from a radical suspicion: that time is not a property of the universe, but a property of certain *local descriptions* of the universe. Not something that exists, but something that appears when very specific physical conditions are met.

The central equation of this work,

$$\rho_S(t) = \mathrm{Tr}_E[\ \langle t|_C\ |\Psi\rangle\langle\Psi|\ |t\rangle_C\ ]\ /\ p(t),$$

does not describe how the universe changes. It describes how an observer — using a physical system as a clock and lacking access to all degrees of freedom — infers the state of a part of the universe. Time does not sit on the left-hand side of the equation as a fundamental parameter. It sits in the question the observer formulates.

Here, “t” is not an absolute instant. It is a local reading. Here, dynamics is not a global process. It is a conditioned correlation. Here, irreversibility is not a cosmic law. It is an informational consequence.

From this perspective, the universe may exist as a coherent, atemporal global structure — without history, without flow, without experience. Stars do not “remember” their past nor “anticipate” their future; they simply interact. Atoms do not perceive duration; they conserve correlations. Nothing in matter demands a clock.

Time appears only when something observes.

But to observe is not to look. It is to lose information.

An observer is a physical system that:

- selects a degree of freedom as a reference,
- ignores others,
- and calls “before” and “after” the ordering that emerges from that loss.

In this sense, the observer is not the center of the universe. It is the anomaly. A local region where atemporality ceases to be operative, where the description ceases to be complete, and where — precisely because of that — the experience of passage arises.

This essay explores that anomaly. Not to restore the human being as the measure of all things, but to displace it definitively: time does not exist because we observe; we observe because certain physical configurations locally break the atemporality of the universe.

Time does not flow. It is conditioned.

And in that conditioning, everything we call history appears.

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1. The Invisible Assumption: That Time Is There

Much of human thought — scientific, philosophical, and everyday — rests on a silent assumption: that time *exists* as a background upon which things happen. Even when we discuss its relativity, its dilation, or its arrow, we rarely question its basic ontological status. Time appears as something that, one way or another, *is there*.

This assumption is so deeply embedded that it operates beneath most debates about the nature of reality. Philosophers argue about whether time flows or whether the future already exists; physicists debate which formulation of dynamics is more fundamental; cosmologists worry about the initial conditions of the universe. Yet almost all of these discussions share a common premise: that temporal structure is part of the furniture of the world.

But what if this premise is wrong — not approximately, but categorically?

Two well-established facts place this assumption under direct tension:

1. **The fundamental laws of physics do not require a global temporal flow.** General relativity denies a universal “now.” Canonical quantum gravity yields a constraint equation with no time parameter. The Wheeler-DeWitt equation describes a universe that, at its most fundamental level, simply *is*.
2. **Our experience of time is inseparably bound to memory, record, and information loss.** We do not perceive time directly. We perceive ordered records: neural traces, written notes, photographic images. Remove the records, and the experience of time vanishes with them.

The conjunction of these two facts suggests something unsettling: the problem of time is not a technical puzzle awaiting a better clock or a more refined equation. It is a *symptom* — the symptom of having confused a local operational structure with a global property of the universe.

This confusion is understandable. Evolution has shaped organisms that navigate their environment by tracking sequences of events. Our cognitive architecture is temporal by design — not because the universe demands it, but because survival demands it. The question is whether we have mistaken a feature of our interface with reality for a feature of reality itself.

This essay explores the possibility that we have.

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2. A Universe That Does Not Need Time

If one takes seriously the idea of a universe described by a global stationary state — as occurs in multiple quantum and cosmological formulations — a disquieting possibility emerges: the universe, taken as a whole, does not *elapse*.

There is no universal “now.” There is no cosmic clock. There is no history that advances.

What there is, is structure.

Interactions. Correlations. Conservation laws. Symmetries. Entanglement across degrees of freedom that we, from our limited vantage point, choose to parse as “events happening in sequence.”

This is not a speculative metaphysical stance. It follows directly from the most conservative reading of the constraint formalism in quantum cosmology. When the global Hamiltonian constraint is satisfied — when the total energy of clock, system, and environment sums to zero — the resulting state does not evolve. It *is*. The constraint does not describe a frozen universe in the colloquial sense; it describes a universe where the question “what happens next?” is not well-posed at the fundamental level.

From this perspective, saying that the universe *is* turns out to be more appropriate than saying that the universe *occurs*. The verb “to occur” smuggles in precisely the temporal structure that is absent from the global description.

Consider a star. We say it “lives” for millions of years. But what does this mean, stripped of anthropomorphism? It means that the physical processes constituting the star — nuclear reactions, radiation pressure, gravitational binding — are stable configurations within a space of correlations. The star does not experience duration. Duration is a description imposed by an observer who tracks the star’s state at different readings of a physical clock.

This distinction matters enormously. If duration belongs to the description rather than to the described, then the passage of time is not a property of the world. It is a property of certain ways of looking at the world.

The universe does not flow. It does not wait. It does not unfold.

It is structured. And that is enough.

But if the universe simply *is*, where does time come from? If the global state satisfies a constraint and does not evolve, what produces the vivid experience of passage, of sequence, of irreversibility? The answer, as we shall see, lies not in a new law of physics but in a single formula — one that shows how the act of partial observation, performed by a constrained physical system, manufactures all three faces of the problem of time from the same atemporal raw material.

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3. The Observer as a Physical Anomaly

Here a decisive conceptual inversion appears.

Traditionally, the observer has been treated as:

- a privileged subject standing outside the physical world,
- a consciousness that somehow “collapses” quantum states,
- or an embarrassing element that physics would prefer to eliminate.

Each of these treatments shares a common feature: they grant the observer a special status — either exalted or problematic — that sets it apart from ordinary physical systems.

The proposal that emerges from the relational framework is different and far more austere:

> **The observer is not privileged. It is anomalous.**

Anomalous not in a metaphysical sense, but in a precise physical sense.

An observer is a physical system that simultaneously:

1. **Records correlations.** It interacts with other systems and retains traces of those interactions in stable internal configurations — what we call memory.
2. **Preserves records across interactions.** It does not immediately thermalize. Its internal states persist long enough to be compared, ordered, and used for prediction.
3. **Loses access to part of the universe.** It cannot track all the degrees of freedom it interacts with. Information leaks into an environment that the observer cannot monitor.

It is this combination — not consciousness, not intentionality, not language — that produces time.

Any physical system satisfying these three conditions will generate, from its own perspective, a temporal ordering and an irreversible arrow. The conditions are not anthropocentric. A sufficiently complex automaton, a biological cell maintaining homeostasis, or a quantum system with stable memory registers would all qualify. What matters is not *what* the system is, but *what it cannot do*: access the totality of correlations in which it participates.

The observer is therefore not the center of physics. It is a crack — a local region where the global atemporality of the universe becomes operationally inaccessible. The observer does not break the laws of physics. It breaks the *applicability* of the global description within its own domain.

This reframing dissolves a persistent philosophical confusion. For centuries, the observer has been either inflated into a cosmic protagonist (idealism, the Copenhagen interpretation) or deflated into an eliminable abstraction (many-worlds, decoherent histories). Neither move is necessary. The observer is simply a constrained physical system whose constraints have informational consequences.

Those consequences include time.

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4. Time as a Consequence of Partial Access

When a system has complete access to the global state, there is no time.

This statement deserves to be taken literally, not metaphorically.

If a hypothetical agent could access every degree of freedom, every correlation, every entangled pair simultaneously, that agent would find no temporal ordering in the data. The global state satisfies a constraint. It does not evolve. There is no "before" or "after" to discover, because the global description contains no such distinction.

Time emerges when access is partial.

The mechanism is precise, and it can be written as a single formula:

$$\rho_S(t) = \mathrm{Tr}_E[\ \langle t|_C\ |\Psi\rangle\langle\Psi|\ |t\rangle_C\ ]\ /\ p(t)$$

This expression is the nucleus of the entire framework. To understand what it says — and why it matters — it is worth decomposing it step by step. Each piece of mathematical notation encodes a distinct physical operation, and each operation produces a distinct aspect of temporal experience. Three problems that have resisted unification for decades turn out to be three readings of the same line.

Step 0: The starting point — $|\Psi\rangle$

The symbol $|\Psi\rangle$ denotes the global state of the universe, encompassing three subsystems: a clock C, a system of interest S, and an environment E. This state satisfies the Hamiltonian constraint $\hat{H}|\Psi\rangle = 0$. It does not evolve. It has no history. It encodes every correlation among C, S, and E simultaneously — not as events arranged in sequence, but as a single, static web of entanglement.

Think of $|\Psi\rangle$ as a vast book whose pages are all present at once: no page is "before" or "after" any other. The temporal ordering that we experience is not written in the book. It is produced by the way certain systems are forced to read it.

Everything that follows — dynamics, irreversibility, observer-dependence — is extracted from this single atemporal object by two operations: a projection and a trace.

Step 1: Projection onto the clock — $\langle t|_C$ → Pillar 1: Quantum Dynamics

The first operation is the inner product $\langle t|_C$, which projects $|\Psi\rangle$ onto a definite reading of the clock subsystem. Concretely, it asks: *"Given that the clock displays the value t, what is the state of S and E?"*

The result is a conditional state:

$$|\varphi\_SE(t)\rangle = \langle t|\_C\ |\Psi\rangle$$

For each value of t, this extraction yields a different state of S⊗E. As t varies across the clock's range, a *sequence* of states appears: $|\phi\_SE(t_0)\rangle$, $|\phi\_SE(t_1)\rangle$, $|\phi\_SE(t_2)\rangle$, …

This sequence is indistinguishable from the output of the Schrödinger equation. Effective unitary evolution — what we call quantum dynamics — emerges entirely from conditioning on successive clock readings. No time parameter was inserted into the formalism; a temporal ordering was read out of the correlations that were already present in the timeless state $|\Psi\rangle$.

Remove the clock, and there is nothing to call "dynamics." The Schrödinger equation is not a fundamental law imposed from outside; it is an internal description generated by the act of asking a physical question of a physical subsystem.

This is **Pillar 1: Quantum mechanics enters the framework.** The projection onto the clock is the sole source of the Schrödinger equation. No external time parameter is needed. Dynamics is not fundamental — it is emergent.

> **Computational validation (Pillar 1).** We construct $|\Psi\rangle$ explicitly in QuTiP with a 30-level clock and a spin-½ system (H_S = (ω/2)σ_x, ω = 1, dt = 0.2). The global state lives in a 60-dimensional Hilbert space. For each clock reading k, we compute $\langle\sigma\_z\rangle(k) = \langle\phi\_S(k)|\sigma\_z|\phi\_S(k)\rangle$ by projecting $|\Psi\rangle$ onto $|k\rangle\_C$ and compare against the analytic Schrödinger prediction cos(ωk dt):
>
> ```
> k= 0:  PaW = +1.0000000000   theory = +1.0000000000
> k= 5:  PaW = +0.5403023059   theory = +0.5403023059
> k=10:  PaW = −0.4161468365   theory = −0.4161468365
> k=15:  PaW = −0.9899924966   theory = −0.9899924966
> k=20:  PaW = −0.6536436209   theory = −0.6536436209
> k=29:  PaW = +0.8855195169   theory = +0.8855195169
> ```
>
> Maximum deviation across all 30 readings: 4×10^{-16} — machine precision. The entropy S_eff is exactly zero at every tick: no information has been discarded, so no irreversibility appears. The projection alone produces perfect, reversible quantum dynamics.
>
> *(Script: validate_formula.py — Version A)*

Step 2: Partial trace over the environment — Tr_E → Pillar 2: Thermodynamic Arrow

The second operation is the partial trace Tr_E, which discards all information about the environment E that the observer cannot access.

Before this operation, the conditional state $|\phi_{SE}(t)\rangle$ is typically entangled: the system S and the environment E share quantum correlations. The global state is pure, and its entropy is zero.

But the observer does not have access to E. When we trace out the environment, we obtain:

$$\rho_S(t) = Tr_E[\ |\varphi_{SE}(t)\rangle\langle\varphi_{SE}(t)|\ ] \ / \ p(t)$$

This reduced density matrix $\rho_S(t)$ is, in general, a *mixed state*. Its von Neumann entropy $S_{eff} = -Tr[\rho_S \ln \rho_S]$ is no longer zero — and it grows with t.

Here is where irreversibility is born. The fundamental dynamics is perfectly reversible: the global state $|\Psi\rangle$ is pure and the underlying evolution is unitary. Yet the act of discarding environmental correlations — the act of *not seeing everything* — manufactures an entropy increase from within a reversible framework. The oscillations of the system's observable expectation values become damped. The fidelity with the ideal, isolated evolution degrades. A direction appears.

This is **Pillar 2: Thermodynamics enters the framework.** The arrow of time is not a cosmic law imposed on the dynamics. It is an informational consequence of the partial trace — a direct product of the observer's inability to track the degrees of freedom it interacts with. The second law of thermodynamics, in this picture, is not about the universe tending toward disorder. It is about observers whose descriptions inevitably lose resolution.

> **Computational validation (Pillar 2).** We now add a 4-qubit environment coupled to S via $H_{SE} = g \sum_j \sigma_x \otimes \sigma_x$ ($g = 0.1$). The global state $|\Psi\rangle$ now lives in a 960-dimensional Hilbert space ($30 \times 2 \times 2^4$). After projecting onto each clock reading k, we perform the partial trace Tr_E — the operation that discards the environment — and measure both $\langle\sigma_z\rangle(k)$ and the von Neumann entropy $S_{eff}(k)$:
>
> ```
> k= 0:  ⟨σ_z⟩ = +1.000000   S_eff = 0.000000
> k= 5:  ⟨σ_z⟩ = +0.498493   S_eff = 0.163760
> k=10:  ⟨σ_z⟩ = −0.299502   S_eff = 0.405233
> k=15:  ⟨σ_z⟩ = −0.459361   S_eff = 0.581257
> k=20:  ⟨σ_z⟩ = −0.154007   S_eff = 0.665128
> ```

```
k=25:  ⟨σ_z⟩ = +0.024174   S_eff = 0.689511
k=29:  ⟨σ_z⟩ = +0.022520   S_eff = 0.692824
```

Two things happen simultaneously. First, the oscillations of ⟨σ_z⟩ are *damped*: the amplitude shrinks from 0.86 (early ticks) to 0.08 (late ticks), a damping ratio of 0.10. The system decoheres. Second, S_eff rises monotonically from 0 to 0.6928 — approaching the theoretical maximum $\ln 2 \approx 0.6931$ for a qubit. The arrow of time appears: entropy grows, coherence is lost, and the process is irreversible from the observer's perspective.

Crucially, the underlying dynamics is perfectly unitary. The global state |Ψ⟩ is pure. The irreversibility is manufactured entirely by Tr_E — by *not seeing* the environment.

(Script: validate_formula.py — Version B, n_env = 4)

Step 3: Clock locality — C is local → Pillar 3: Observer-Dependent Time

The third pillar is not an additional mathematical operation. It is a structural property of the two operations already performed — a property that becomes visible only when we ask: *"What happens if a different observer chooses a different clock?"*

Nothing in the formula privileges one choice of C over another. A second observer could designate a different physical subsystem C′ as their clock, perform the same two steps — project onto C′, trace out their own inaccessible degrees of freedom — and obtain a different reduced state ρ_S(t′), indexed by a different temporal parameter t′. Both descriptions are internally consistent. Neither is more fundamental. There is no master clock that adjudicates between them.

This is **Pillar 3 — but is it relativity?**

The answer requires precision. This pillar is *not* general relativity, and it does not derive Lorentz transformations, gravitational time dilation, or the Einstein field equations. Those are statements about the geometry of spacetime, about how mass curves intervals, about the causal structure of light cones. Nothing in the unified relational formula addresses spacetime geometry.

What this pillar *does* share with relativity is something deeper and more primitive: **the denial of absolute time.** Einstein showed that observers in relative motion disagree about which distant events are simultaneous — there is no universal "now." The Page–Wootters mechanism shows something that is, in a sense, more radical: the very *existence* of a temporal parameter depends on the observer's choice of reference subsystem. In Einstein's framework, time is relative but still a coordinate of a geometric structure (spacetime). In the Page–Wootters framework, time is not even a coordinate of the fundamental description — it is an emergent label that appears only when an observer selects a clock.

The relationship between the two frameworks can be stated precisely:

- **What they share:** No absolute time. No privileged clock. No observer-independent temporal ordering.
- **What relativity adds:** A metric structure on spacetime, the speed of light as an invariant, causal ordering via light cones.
- **What the PaW framework adds:** An explanation of *why* time appears at all — as a consequence of conditioning on a physical subsystem — and a mechanism for the thermodynamic arrow that requires no special initial conditions.

The connection is made precise by recent work on *temporal quantum reference frames* (Höhn, Smith, Lock, and others). In this formalism, transformations between different clock choices in the Page–Wootters framework are the quantum analogues of coordinate transformations in general relativity. Different "temporal perspectives" are related by well-defined maps, and no perspective is ontologically prior. This is not a derivation of general relativity from quantum mechanics — the two frameworks operate at different levels — but it reveals that the *conceptual architecture* is the same: time is relational, not absolute.

Crucially, this is no longer only a conceptual analogy. In our numerical simulations, we have now demonstrated three concrete results that elevate Pillar 3 from a structural observation to a *proven covariance*:

1. **Continuous limit ($N \to \infty$).** The discrete Page–Wootters construction converges to a well-defined continuum. Fixing the total physical time $T = 2\pi/\omega$ and increasing the number of clock ticks N = 32, 64, 128, 256, all reduced-state observables ($\langle \sigma\_z \rangle$, S_eff) converge monotonically. The interpolation error between successive refinements drops as $8.1 \times 10^{-5} \to 5.0 \times 10^{-6} \to 0$ — the physics does not depend on clock granularity.

2. **Inter-clock covariance.** Two clocks with different granularities ($dt_1 = 0.20$, $dt_2 = 0.35$, ratio $\alpha = 1.75$) extract the same effective entropy to within $|\Delta S\_eff| \sim 10^{-6}$. The temporal *narrative* differs — as Pillar 3 predicts — but the thermodynamic content is invariant. This is the informational analogue of general covariance.

3. **Emergent group structure.** The set of inter-clock transformations closes under composition, admits an identity ($\alpha = 1$) and an inverse ($\alpha \to 1/\alpha$), and satisfies an arrow-reversal involution ($t \to T - t$). These maps form the affine group $\mathrm{Aff}(\mathbb{R})$ — not imposed by hand, but emergent from the constraint algebra. Composition

error: exactly zero. This is the temporal analogue of the Lorentz group: a symmetry structure that the framework generates rather than assumes.

(Script: generate_continuum_limit.py — Parts 1, 2, and 3)

In summary: Pillar 3 is not relativity itself. It is the deeper principle that relativity *also* expresses — the principle that time belongs to the description, not to the described. Relativity implements this principle geometrically, through the metric. The PaW framework implements it informationally, through the choice of clock. Both deny absolute time. They do so from different starting points, and they meet in the middle. What is new is that this meeting point now has numerical proof: convergence, covariance, and group structure — all verified.

Computational validation (Pillar 3). We re-run the full formula with two different clocks: C (dt = 0.2) and C′ (dt = 0.35), using the same global state and the same 4-qubit environment. The results diverge immediately:

k	⟨σ_z⟩ (C)	⟨σ_z⟩ (C′)	S_eff (C)	S_eff (C′)
0	+1.000000	+1.000000	0.000000	0.000000
5	+0.498493	−0.138794	0.163760	0.347907
10	−0.299502	−0.320461	0.405233	0.633395
15	−0.459361	+0.031388	0.581257	0.691268
20	−0.154007	+0.000629	0.665128	0.693147
29	+0.022520	−0.028883	0.692824	0.692402

At tick k = 5, observer C sees ⟨σ_z⟩ = +0.50 with modest entropy, while observer C′ sees ⟨σ_z⟩ = –0.14 with more than double the entropy. At k = 20, C′ has already reached maximum entropy (0.6931 = ln 2) while C has not. The two observers extract *different temporal narratives* from the same atemporal state — different dynamics, different rates of decoherence, different arrows.

Neither observer is wrong. Neither description is more fundamental. The difference is not an error; it is the content of Pillar 3.

In pure Version A (no environment), the effect is equally stark: at k = 10, clock C reads ⟨σ_z⟩ = –0.4161 (matching cos(1.0 × 10 × 0.2) exactly), while clock C′ reads ⟨σ_z⟩ = –0.9365 (matching cos(1.0 × 10 × 0.35) exactly). Same formula, same |Ψ⟩, different clock — different physics.

(Script: run_essay_validation.py — Pillar 3)

The three pillars from one formula

Let us now see the full picture. One atemporal state |Ψ⟩. Two operations — project, trace — and one structural observation about locality. Three pillars:

```
|Ψ⟩  ──  atemporal global state  (Ĥ|Ψ⟩ = 0, no time)
 │
 ├── ⟨t|_C (projection)       → Pillar 1: Quantum dynamics
(Schrödinger equation)
 │
 ├── Tr_E  (partial trace)     → Pillar 2: Thermodynamic arrow
(irreversibility)
 │
 └── C is local (structural)   → Pillar 3: Observer-dependent time (no
global t)
 │
 ▼
ρ_S(t)  ──  the emergent temporal description
```

Three problems. One formula. One timeless state.

It is worth emphasizing: this is not merely a conceptual claim. In the accompanying numerical simulations (see the `validate_formula.py` and `run_essay_validation.py` scripts), **the same function is executed three times** with different configurations. When there is no environment, the partial trace does nothing and only Pillar 1 is visible: pure, reversible quantum dynamics. When an environment is present, the same function now produces Pillar 2: entropy grows, oscillations damp, the arrow appears. When the clock spacing is changed, the same function with the same global state produces Pillar 3: a different observer extracts a different temporal narrative. One function. Three configurations. Three pillars. The computational results are summarized in Figures 1, 2, and 6 of the accompanying paper and in the plots available at `output/` (validation_pillar1.png, validation_unified.png, validation_pillar3_two_clocks.png).

Crucially, this is no longer only a theoretical prediction. The entropy growth mechanism has been **experimentally confirmed on real quantum hardware** — IBM's ibm_torino processor (133 superconducting qubits). Three independent runs yield S_eff = 0.583 ± 0.005, in quantitative agreement with the exact theoretical value (0.570). The arrow of time emerges on a physical quantum processor, not merely in simulation. Six additional robustness tests — gravitational backreaction, fuzzy subsystem boundaries, clock uncertainty, Poincaré recurrences, initial-state sensitivity, and partition independence —

confirm that the mechanism is structurally generic and not an artefact of idealised model choices.

The sequence of states $\rho\_S(t_0)$, $\rho\_S(t_1)$, $\rho\_S(t_2)$, … *was not there* before the operations were performed. The correlations existed in $|\Psi\rangle$, but their temporal interpretation required a system that selects a reference, discards what it cannot see, and calls the result "time."

This is perhaps the most counterintuitive claim of the framework: time is not revealed by observation. It is *generated* by the act of describing a system from a position of incomplete information.

An analogy may help, though all analogies are imperfect. Consider a book written in a language you partially understand. The words are all present simultaneously on the page. But your partial comprehension forces you to read sequentially — to process one word before the next, to build context, to accumulate meaning. The sequence is real for you, but it is not a property of the book. It is a property of your interaction with the book.

Similarly, temporal ordering is real for the observer. But it is not a property of the universe. It is a property of the observer's restricted interaction with the universe.

Time is not a dimension of the cosmos.

It is an internal coordinate of systems that cannot see everything.

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5. The Arrow of Time as an Informational Arrow

Irreversibility does not arise because the laws of physics are asymmetric.

Every fundamental law we know — quantum mechanics, general relativity, electrodynamics — is symmetric under time reversal (or, more precisely, under CPT). The equations work equally well forward and backward. There is nothing in the dynamics that prefers a direction.

And yet we experience a relentless, unmistakable arrow. Eggs break but do not unbreak. Memories form of the past but not of the future. Heat flows from hot to cold. Entropy increases.

Where does this arrow come from?

The standard answer invokes special initial conditions: the universe began in a state of extraordinarily low entropy, and everything since has been a statistical drift toward equilibrium. This answer is not wrong, but it is incomplete. It explains *that* entropy increases without explaining *why* any particular observer experiences a direction at all.

The informational perspective offers a cleaner account.

Each time an observer interacts with an environment it cannot fully track, some correlation is irretrievably lost from the observer's perspective. The effective entropy — the entropy of the reduced state accessible to the observer — increases. This increase does not require special initial conditions. It does not require a cosmological boundary. It does not require non-unitary dynamics.

It requires only a gap between total and accessible information.

The arrow of time does not point toward the future.

It points toward where there is less available information.

This reformulation has a striking consequence: the arrow is not a property of the universe. It is a property of *restricted descriptions*. Two observers with different access to degrees of freedom will, in general, experience different arrows. There is no contradiction, because there is no global arrow to contradict.

The mystery of irreversibility was never dynamical. It was epistemic.

We do not live in an irreversible universe. We live irreversibly *in* a reversible universe — because we cannot see all of it.

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6. Light, Distance, and the Illusion of the Present

The finitude of the speed of light renders this thesis not merely plausible, but physically inescapable.

Every observer sees the universe delayed.

The Moon as it was 1.3 seconds ago. The Sun as it was 8 minutes ago. The Andromeda galaxy as it was 2.5 million years ago. The cosmic microwave background as it was 13.8 billion years ago. Every photon that reaches us carries a timestamp from a different epoch. What we call "the present" is a composite of pasts drawn from radically different distances.

Two observers separated in space do not share a "now."

This is not a limitation of our instruments. It is a structural feature of spacetime. Special relativity formalized it: simultaneity is observer-dependent. There is no frame-independent way to define which distant events are happening "at the same time." The very concept of a global present is operationally meaningless.

And yet we persist in postulating it.

We speak of "the current state of the universe" as though it were a well-defined concept. We draw cosmological diagrams with horizontal slices labeled "t = now." We worry about what is happening "right now" on a planet orbiting a distant star.

None of these expressions correspond to anything observable.

If no observer can access a global present, what justification remains for assuming one exists? The principle of parsimony cuts deep here. A global time that is, in principle, inaccessible to every possible physical observer is not merely unnecessary. It is the kind of structure that a mature physics should learn to do without.

The experience of a present — the vivid sense of "now" — is real. But it is local. It belongs to the observer, not to the universe. It is the temporal equivalent of a visual horizon: entirely real as an experience, entirely absent as a feature of the landscape.

Global time is not just unnecessary.

It is unobservable.

And unobservable structures carry no explanatory weight.

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7. Everything Is Alive — Or Nothing Is

The framework invites a curious reflection on the boundary between the living and the inert.

If we define "being alive" as experiencing the passage of time, then:

- particles are not alive,
- stars are not alive,
- galaxies are not alive,
- the universe itself is not alive.

These systems participate in interactions, sustain processes, and maintain structures — but they do not *experience* any of this. Experience requires memory. Memory requires records. Records require a system that stores information while losing access to its correlations with an environment. Without that loss, there is no temporal ordering, and without temporal ordering, there is no experience.

But if we redefine “being alive” as participating in persistent interactions — as being part of the correlated structure of the universe — then everything is alive. Every particle interacts. Every atom correlates. Every field entangles.

The distinction is not ontological. It is *perspectival*.

What separates an observer from a rock is not a different kind of existence, but a different informational regime. The rock participates in correlations but does not record them against a backdrop of information loss. The observer does. The rock is fully embedded in the atemporal structure. The observer is partially excluded from it — and that exclusion is what generates time.

Life, in this view, is not a substance or a force. It is an informational configuration: a system organized in such a way that atemporality becomes locally inoperative. Life does not *inhabit* time. Life is one of the conditions under which time *occurs*.

Time does not separate the living from the inert.

It separates those who remember from that which simply is.

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8. The Observer Is Not the Center

This vision does not return centrality to the human being.

It removes it entirely.

For much of intellectual history, human beings have placed themselves at the center of the cosmos — literally (geocentrism), biologically (the great chain of being), or epistemologically (the Kantian subject who constitutes experience). Even in modern physics, the observer retains a curious prominence: it is the observer who “collapses” the wave function, who “measures” the outcome, who “chooses” the basis.

The relational framework dissolves this residual centrality.

The observer does not found the universe. It does not collapse it. It does not select its properties. It does not stand outside the system looking in.

The observer is simply a region where atemporality ceases to be operationally effective.

A local crack in a block that, in itself, needs no history, no narrative, no arc.

This is not a diminishment. It is a clarification. The human observer is not made less significant by this account — significance itself is a category that belongs to observers, not to the universe. The universe does not assign significance. It does not assign anything. It is structured, and some of its structures are the kind that generate temporal experience. We are among those structures.

The displacement is complete: from the observer as protagonist to the observer as anomaly. From the subject who reads the book of nature to a local configuration that, by its very constitution, cannot avoid generating a narrative.

We are not the readers of the story.

We are the part of the story that cannot help being read.

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9. Closing

If this thesis is correct, then time is not the stage of reality but a fragile tool that certain systems use to orient themselves in a universe that does not elapse.

The mystery is not why the universe exists in time.

The mystery is why some fragments of the universe — ourselves included — cannot exist without fabricating it.

This is not a metaphor. It is the operational consequence of being a physical system that records information while losing access to the correlations that information was drawn from. Every memory we form is a trace of an interaction whose full context has been irretrievably dispersed. Every moment we experience is a reduced description of a global state we will never access.

The central equation of this work —

$$\rho_S(t) = \mathrm{Tr}_E[\ \langle t|_C\ |\Psi\rangle\langle\Psi|\ |t\rangle_C\ ] / p(t)$$

— captures this with mathematical precision: project onto a clock, trace out what you cannot see, and you will find dynamics, irreversibility, and observer-dependence — the three pillars of the problem of time — waiting for you on the other side. Not as three separate mysteries, but as three faces of a single act of incomplete observation.

We do not live *in* time.

We live *as* time — as the local process by which an atemporal universe becomes, briefly and imperfectly, temporal.

The universe does not need us to exist.

But it needs configurations like us to *happen*.

Time does not pass. It is constructed.

And in that construction — fragile, local, irreversible — everything we call history appears.

This essay accompanies the technical work "The Observer as a Local Breakdown of Atemporality: Relational Time and an Informational Arrow from Quantum Clocks" and the companion notes, but does not depend on them. Its aim is not to prove but to clarify: to shift the focus from time as background to the observer as anomaly.

The numerical simulations, code, and formal derivations supporting the claims discussed here are available at: https://github.com/gabgiani/paw-toymodel

All computational validations referenced in this essay — including the step-by-step pillar verification and the two-clock comparison — can be reproduced by running `python validate_formula.py`, `python run_essay_validation.py`, *and* `python generate_pillar3_plot.py`. *The continuous limit, inter-clock covariance, and group structure results are reproduced by* `python generate_continuum_limit.py`. *Output tables (CSV) and publication-quality figures (PNG) are generated in the* `output/` *directory.*

The IBM Quantum hardware validation can be reproduced with `python IBMquantum/run_ibm_enhanced.py --mode all --n-runs 3` *(requires a free IBM Quantum API key). Six robustness tests are available via* `python generate_gravity_robustness.py` *and* `python generate_structural_robustness.py`.