Pulse Ontology and the Arrow of Time: Reconciling Block Universe with Quantum Becoming

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Abstract

This paper advances a novel ontological framework for the problem of time. Relativity yields a block universe without becoming, while quantum mechanics introduces indeterminacy without clear temporality. Existing accounts—thermodynamic entropy, presentism, or process metaphysics—fail to reconcile these tensions. The proposed pulse ontology interprets time as a sequence of quantum pulses: discrete disclosures of potential into actuality, grounded in field excitations, entanglement entropy, and holographic projection. This framework preserves determinism at the global level, secures becoming through sequential disclosure, and aligns phenomenological continuity with physical discreteness. While conceptually robust, the account requires further mathematical development and experimental confirmation to establish its full legitimacy within physics.

Keywords

Time ontology; arrow of time; block universe; quantum pulses; entanglement entropy; holographic principle; quantum field excitations

1 Introduction

The perception of time arises from our awareness of change. What is commonly experienced as the passage of time may be understood not as a direct apprehension of a physical flow, but as the detection of transformations in the external world. Psychological and phenomenological studies suggest that this apparent continuity is a construction of perception. The phi phenomenon and cinematic motion illustrate how discrete frames, when rapidly sequenced, generate the illusion of smooth flow. In this respect, temporal passage in lived experience is not a primitive feature of reality but a cognitively synthesized impression (VanRullen & Koch, 2003).

This observation raises a fundamental question: if our experience of time is a perceptual artifact, what does it imply for the ontological status of time in physics? Einstein's remark that "the distinction between past, present, and future is only a stubbornly persistent illusion" (Einstein, 1955) highlights this tension. Yet within the framework of relativity, time is not merely illusory; it is treated as a genuine dimension inseparably fused with the three dimensions of space. The challenge is therefore to specify what this temporal dimension measures. Spatial dimensions quantify extension along independent axes: length, width, and height. By analogy, the temporal dimension may be interpreted as quantifying the rate of change of these spatial configurations. Within spacetime, when the geometry of the spatial axes dilates, temporal intervals dilate accordingly, reflecting the increased duration of such transformations.

From this standpoint, time—whether considered phenomenologically or physically—may be understood as a measure of change in spatial states. At both the macroscopic scale of material systems and the microscopic scale of quantum processes, time is inseparable from transformation. This framing provides an entry point into the problem of the arrow of time. In relativity's block universe, past, present, and future coexist within a static manifold, implying that the future is ontologically given. Yet this raises a conceptual difficulty: in what sense can the future exist before it becomes actual? Philosophers such as Huw Price (1996) and Craig Callender (2017) have argued that this question reveals a deep gap between physical theory and experiential temporality.

Quantum theory offers a path toward resolving this difficulty. The material world may be regarded as the disclosure of an underlying quantum domain. On this view, the future is not fully actualized but exists as encoded quantum information—wavefunctions defined in Hilbert space and, more broadly, holographically inscribed at the boundaries of spacetime ('t Hooft, 1993; Susskind, 1995; Maldacena, 1998). This resonates that time itself may not exist fundamentally, but that change is encoded in the configuration space of possible states . The progressive emergence of the future into the present may thus be understood as the sequential transition of quantum potentialities into classical actuality. Time, conceived as the measure of change, expresses this stepwise unfolding of encoded possibilities into realized states.

On this basis, a new ontological proposal is advanced: time is not a continuous flow but a sequence of discrete existential pulses. Each pulse marks the transition from one quantum state to another, disclosing actuality out of latent possibility. As in cinematic projection, where static frames produce the impression of motion, or in perception, where oscillatory neural processes integrate discontinuous events into a coherent flow, these pulses generate the appearance of continuity. Even elementary particles may be interpreted as rhythmically disclosing structures, their behavior shifting between successive states.

The arrow of time, accordingly, need not be attributed to improbable initial conditions or contingent hypotheses. Rather, it follows from the sequential structure of disclosure itself. Causality is secured through quantum entanglement, which orders these pulses into lawful relations (Rovelli, 2018). Determinism is preserved at the level of unitary evolution, while becoming is realized through the rhythmic disclosure of actuality. In this framework, the block universe is not denied but reinterpreted: geometrically complete, yet phenomenologically revealed only through discrete temporal succession.

The purpose of this paper is to develop and defend this pulse ontology of time as a philosophical and physical framework. By situating the arrow of time within the ontology of discrete disclosure, the analysis aims to reconcile the tension between relativity's eternalist geometry, quantum indeterminacy, and lived experience. On this account, the arrow of time is not Illusory but a structural necessity of physical reality.

Historical Background

The problem of time has been a recurring challenge across both philosophy and physics, with each era offering partial insights yet leaving the fundamental tension unresolved.
In Aristotle's account (Roark, 1999), time was defined as "the number of change in respect to before and after." This tied temporality directly to motion: time was inseparable from physical processes. The strength of Aristotle's view lay in its grounding of time in change, preserving the connection between ontology and becoming. Yet its limitation was clear: it reduced time to a derivative measure of motion, without offering an explanation of its irreversibility or its independence as a structural feature of reality.

The Newton–Leibniz controversy of the 17th century sharpened this divide. Newton's absolute time flowed uniformly, a universal stage on which events occurred. This conception had the advantage of securing a single cosmic order, but it reified time as a metaphysical container, detached from events themselves. Leibniz, by contrast, reduced time to mere relations of succession—an elegant relational ontology, but one that collapsed under the weight of physics, since it offered no mechanism for measurable dilation or for the universality of causal order. Both positions therefore failed: Newton's by positing a metaphysical surplus, Leibniz's by evacuating structure from temporality.

The revolution of relativity in the early 20th century dissolved absolute simultaneity, fusing time with space into a four-dimensional continuum. In Minkowski's formulation (1908), space and time "fade into mere shadows," replaced by spacetime geometry. Einstein's relativity gave this geometry empirical teeth: time dilates with velocity and gravitational potential(Einstein, 1952). The conceptual power of relativity was immense: time was no longer a container, nor merely relational, but geometrical. Yet its cost was equally significant: it gave rise to the block universe, in which past, present, and future coexist with equal ontological weight. This ontology, while elegant mathematically, effaced the very phenomena of passage and becoming. As Einstein himself admitted in his letter to Besso (1955), "the distinction between past, present, and future is only a stubbornly persistent illusion." Relativity thus solved the problem of measurement but deepened the problem of meaning: it explained how time behaves but denied that time flows.

Quantum mechanics reopened the question. By introducing indeterminacy, probability, and superposition, it re-injected novelty and openness into the cosmos. Unlike relativity's frozen manifold, the quantum wavefunction seemed to encode potentialities awaiting disclosure. Yet here, too, the solutions fractured: the Copenhagen interpretation invoked an observer-dependent collapse, sacrificing ontological clarity; Everett's many-worlds secured determinism but at the cost of multiplying realities beyond necessity; collapse models posited stochastic dynamics that remain empirically tenuous. In all cases, quantum mechanics made becoming conceivable, but it left the ontology of time ambiguous: is the future genuinely open, or merely distributed across branches? Quantum theory clarified dynamical rules but failed to specify whether time itself is emergent, fundamental, or illusory.

Statistical mechanics added another layer. Boltzmann's entropy provided an arrow of time: disorder increases, explaining irreversibility. Yet this explanation was fragile: it depended on the Past Hypothesis of an improbably low-entropy initial state at the Big Bang. Critics such as Huw

Price (1996) and David Albert (2000) argued that this reduced the arrow of time to a brute cosmological accident, not a structural necessity. The arrow remained empirically valid but metaphysically contingent—a deeply unsatisfactory state of affairs for a fundamental feature of reality.

In the late 20th century, the rise of holographic and informational approaches offered fresh perspectives. The holographic principle ('t Hooft, 1993; Susskind, 1995; Maldacena, 1998) suggested that spacetime itself is emergent from information encoded on a boundary. This opened the possibility that time, too, is not fundamental but projected. Simultaneously, research on entanglement entropy revealed that quantum correlations grow irreversibly under unitary evolution, hinting at an intrinsic informational arrow. Yet here again the interpretation falters: does information disclosure equate to temporal becoming, or does it merely redescribe the block universe in different terms? Without an explicit ontological account, these insights remain suggestive but incomplete.

Finally, neuroscience and phenomenology provide a crucial corrective. From Augustine's reflections on the "present of things past" (Confessions, XI) to Bergson's critique of spatialized time, philosophy has long recognized that lived duration differs from geometric temporality. Modern neuroscience reinforces this: temporal continuity is not directly perceived but constructed.The phi phenomenon, cinematic motion, and temporal binding windows demonstrate that the brain stitches discrete inputs into the illusion of flow(Engel & Singer, 2001; Decostre-Voisin & Meulders, 1981). Julian Barbour (1999) radicalizes this insight, arguing that time itself may be an illusion, with reality consisting only of "Nows." Yet this position, while powerful in critique, risks dissolving temporality entirely, leaving unexplained the apparent necessity of becoming.

Across this historical arc, one theme recurs: every framework captures part of the truth but fails to reconcile the dual demands of physics and experience. Aristotle tied time to change but lacked irreversibility; Newton reified time but severed it from events; relativity geometrized time but erased becoming; quantum theory introduced openness but left ontology unsettled; statistical mechanics grounded the arrow in probability but made it contingent; holography hinted at informational emergence but stopped short of metaphysical clarity; phenomenology insisted on lived flow but lacked physical grounding.

This cumulative failure suggests that the problem of time requires a new ontological synthesis. It is this gap that motivates the present proposal: an ontology of existential pulses, in which time is neither a smooth continuum nor a mere illusion, but the rhythmic disclosure of quantum potentialities into realized actuality.

2 The Physical Landscape of Time

The scientific study of time unfolds along two primary axes: relativity and quantum theory. Each provides indispensable insights, yet each leaves unresolved contradictions that, when brought into dialogue, define the contours of the problem this paper addresses.

2.1 Relativity and the Block Universe.

Einstein's theories of special and general relativity dissolved the Newtonian picture of absolute time. Temporal intervals became inseparably linked to spatial intervals through the invariant spacetime interval:

$$ds^2 = -c^2dt^2 + dx^2 + dy^2 + dz^2,$$

Where encodes the geometry of spacetime itself. Time is not universal but relative: it dilates with velocity and gravitational potential. Minkowski's reformulation crystallized this into the block universe ontology: spacetime is a four-dimensional manifold in which all events—past, present, and future—coexist with equal ontological status.

This picture achieves mathematical elegance and empirical confirmation, yet at the cost of becoming. If all events are equally real, what explains the asymmetry of experience—the apparent flow from past to future? As Carlo Rovelli (2018) notes, relativity gives us a universe "without a present," dissolving the privileged status of the now. Relativity thus secures geometry but erases passage.

2.2 Quantum Mechanics and Indeterminacy.

Quantum mechanics introduces precisely what relativity suppresses: openness and novelty. The wavefunction evolves unitarily according to the Schrödinger equation,

$$i\hbar \frac{d}{dt}|\Psi(t)\rangle = \hat{H}|\Psi(t)\rangle$$

Yet measurements yield stochastic outcomes distributed by the Born rule. The formalism encodes a tension: global determinism at the level of the wavefunction, but local indeterminism at the level of outcomes. This duality suggests that the future is not pre-written in the same sense as in relativity's block, but rather exists as a horizon of potentialities awaiting disclosure.

However, quantum mechanics leaves time itself undefined. It presupposes an external time parameter , but does not explain what time is. Attempts to resolve this—through timeless formulations like the Wheeler–DeWitt equation,

$$\hat{H}\Psi = 0,$$

Or through emergent-time approaches grounded in entanglement entropy—remain incomplete. Quantum theory thus secures novelty but lacks an ontological account of temporal becoming.

2.3 Statistical Mechanics and Entropy.

The arrow of time has been traditionally explained through the second law of thermodynamics: entropy increases in closed systems. Boltzmann provided a probabilistic grounding, yet the explanation hinges on the Past Hypothesis—an extraordinarily low-entropy initial condition of the universe. As David Albert (2000) and Huw Price (1996) argue, this renders the arrow contingent rather than necessary. Statistical mechanics explains why entropy increases given a special beginning, but not why time itself has directionality.

2.4 Quantum Gravity and Holography.

More recent work in quantum gravity introduces the holographic principle ('t Hooft, 1993; Susskind, 1995; Maldacena, 1998), according to which the information contained in a volume of spacetime is encoded on its boundary. In the AdS/CFT correspondence, bulk dynamics are dual to a boundary conformal field theory:

$$Z_{bulk}[\phi] = Z_{boundary}[\phi|\partial].$$

This radical framework suggests that spacetime itself may be emergent from information, and with it, time. Entanglement entropy has been shown to play a key role in reconstructing spacetime geometry (Ryu & Takayanagi, 2006), hinting that time's arrow may be tied to the monotonic growth of quantum correlations. Yet holography, while mathematically rigorous, does not by itself resolve the phenomenological tension: why does the future disclose itself sequentially rather than all at once?

2.5 Neuroscience and the Illusion of Flow.

Complementary to physics, neuroscience provides crucial evidence that the continuity of time is a cognitive construction. Temporal binding windows, sustained by oscillatory neural activity, stitch discrete perceptual events into a seamless flow (Engel & Singer, 2001; VanRullen & Koch, 2003). Julian Barbour (1999) draws the radical conclusion that time itself is an illusion, a sequence of "Nows" with no genuine passage. Yet this position, while powerful, risks reducing becoming to mere phenomenology, leaving unexplained the structural necessity of the arrow of time.

Critical Synthesis

Relativity secures geometry but denies becoming. Quantum mechanics secures novelty but leaves time undefined. Statistical mechanics grounds irreversibility but makes it contingent. Quantum gravity hints at informational emergence but does not yet integrate phenomenology. Neuroscience shows that flow is an illusion, but this risks collapsing time into subjectivity.

The scientific context therefore reveals a fractured landscape: each framework addresses part of the problem but fails to unify the physical and experiential dimensions of temporality. This paper situates itself within this gap, proposing a pulse ontology of time: a discrete, rhythmic disclosure of quantum potentiality into actuality. Unlike prior accounts, this framework seeks to reconcile the geometrical determinism of relativity, the probabilistic openness of quantum theory, and the phenomenological continuity of experience into a single ontological model.

3 Philosophical Fault Lines in Theories of Time

The problem of time has not only divided physics but fractured philosophy. Competing accounts attempt to explain temporality either by denying its reality, subordinating it to geometry, or reducing it to statistical contingencies. Yet none of these accounts fully explains the arrow of time or reconciles the tension between the block universe and the phenomenology of becoming. The pulse ontology emerges as a response to these failures, proposing that temporality is a sequence of existential disclosures—quantum pulses through which potentiality becomes actuality. This section critically examines rival views and demonstrates why only the pulse ontology secures a coherent reconciliation.

3.1 Barbour and the Denial of Time

Julian Barbour (1999) famously argued that time does not exist; reality is a collection of static "Nows" or configurations. Temporal passage, on his account, is a psychological illusion emerging from the ordering of static states. While this radical denial clarifies why physics can describe the universe without invoking a fundamental flow, it collapses temporality into mere subjectivity. If becoming is purely illusory, then the arrow of time has no ontological basis, and our irreducible experience of change is left unexplained.

The pulse ontology agrees with Barbour that continuity is not fundamental but constructed. However, it rejects his eliminativism: becoming is not illusory but discretized. Pulses provide an ontological grounding for what Barbour leaves as mere phenomenology. Rather than dissolving time into a timeless landscape, pulse ontology anchors temporality in the rhythm of disclosure, rescuing both physics and experience from nihilism about time.

3.2 Price and the Symmetry of Time

Huw Price (1996) emphasizes that the fundamental laws of physics are time-symmetric; the asymmetry of experience, he argues, is a perspectival artifact rooted in boundary conditions. This view explains irreversibility without breaking physical laws but at the cost of reducing the arrow of time to epistemic bias. If all asymmetry is perspectival, why does entropy reliably increase for all observers, regardless of perspective?

Pulse ontology accepts Price's critique of naïve asymmetry but goes further: the arrow of time is not perspectival but structural. Each pulse irreversibly increases entanglement entropy, thereby embedding the arrow within quantum ontology itself. Unlike Price's perspectivalism, this account makes the arrow a physical necessity, not a cognitive artifact.

3.3 Callender and the Problem of the Past Hypothesis

Craig Callender (2017) highlights the dependence of statistical mechanics on the Past Hypothesis—the assumption of a finely tuned, low-entropy initial condition. He argues that such reliance undermines explanatory depth: if time's arrow requires an improbable beginning, then temporality is contingent, not necessary.

Here, pulse ontology provides a decisive advantage. It does not invoke improbable boundary conditions. Instead, each pulse structurally expands the horizon of uncertainty by disclosing novelty from the universal wavefunction. The arrow of time follows from the internal logic of quantum disclosure, not from arbitrary initial conditions. In this respect, pulse ontology transforms the arrow from contingency into necessity.

3.4 Eternalism, Presentism, and Process Philosophy

Philosophical debates about time are often framed as a trilemma: eternalism preserves determinism but denies becoming;

presentism affirms becoming but collapses under relativity's block

structure; process philosophy secures novelty but lacks physical grounding.

Pulse ontology avoids this trilemma by integrating elements of each view without inheriting their weaknesses. From eternalism, it accepts the completeness of the block universe, but reinterprets it as encoded potential rather than static actuality. From presentism, it adopts the primacy of the present, but grounds it not in metaphysical fiat but in quantum disclosure. From process philosophy, it affirms novelty and becoming, but secures them with the rigor of quantum mechanics, entanglement entropy, and holography.

The Philosophical Payoff

The comparative analysis shows why the pulse ontology is superior to its rivals. Barbour denies time but cannot explain the ontological weight of becoming; Price reduces asymmetry to perspective, undermining its universality; Callender exposes the contingency of statistical mechanics but leaves no positive alternative; classical metaphysical camps split between determinism and novelty, each sacrificing half the truth.

Pulse ontology reconciles what others divide: it preserves determinism at the global level of the wavefunction, secures novelty through discrete pulses, grounds the arrow of time in entanglement entropy rather than initial conditions, and explains the phenomenology of continuity as a cognitive integration of discretized disclosure. Causality emerges from entanglement, ensuring lawful succession, while the block universe is reanimated as a rhythmic disclosure of encoded potential into actuality.

In short, pulse ontology transforms the philosophy of time. Rather than illusion, denial, or contingency, it makes temporality a structural necessity of existence itself. The universe does not merely exist—it pulses.

4 Toward a Pulse Ontology of Temporal Becoming

The preceding sections established the problem in its full scope: relativity yields a block universe where all events coexist, quantum mechanics injects indeterminacy and becoming, and philosophy has oscillated between timeless ontologies (Barbour, 1999), statistical hypotheses (Albert, 2000), and deflationary accounts (Callender, 2017). None of these approaches fully dissolves the paradox of the arrow of time. If time is an illusion, as McTaggart and Einstein provocatively suggested, why does physics treat it as a genuine dimension? If the block is ontologically complete, how does novelty emerge? If quantum indeterminacy guarantees becoming, why does it not violate determinism?

The contribution of this paper is to develop a pulse ontology of time—an account that reconciles these tensions by treating time not as a continuous flow but as a sequence of discrete quantum disclosures. This framework does not merely reinterpret prior ideas but integrates physical formalism with phenomenological and philosophical analysis to provide a coherent ontology of temporal becoming. Five lines of argument substantiate this claim:

4.1 Quantum Field Excitations as Temporal Pulses

Quantum field theory (QFT) grounds the discreteness of time. Reality is constituted by fields whose excitations produce observable events. As Weinberg observes, "particles are just waves in a field" (1995). Each excitation,

$$|1k\rangle = a\frac{\dagger}{k}|0\rangle,$$

Is constrained by the energy–time uncertainty relation,

$$\Delta E \Delta t \gtrsim \frac{\hbar}{2}$$

This implies that becoming occurs only within finite temporal windows: every excitation is a pulse. Empirical confirmations—from atomic transitions to Hawking radiation—demonstrate that time's rhythm is inseparable from excitation. On this basis, the ontology of pulses acquires its strongest physical foundation.

4.2 Entanglement Entropy and the Arrow of Time

Statistical mechanics explains irreversibility only by assuming a low-entropy past. Quantum mechanics embeds it structurally. For a bipartite Hilbert space,

$$\rho A = Tr_B(|\ \Psi\rangle\langle\Psi\ |), \qquad S(\rho A) = -Tr(\rho A ln \rho A)$$

Entanglement entropy is generically non-decreasing under successive interactions. Within pulse ontology, each pulse increases correlations, embedding the arrow of time directly in disclosure itself. Rovelli's claim that "the direction of time is the growth of correlations" (2018) is radicalized here: irreversibility is not statistical but intrinsic, since each pulse structurally enlarges the informational horizon of the universe.

4.3 Holographic Projection and Sequential Actualization

Quantum gravity, through the holographic principle ('t Hooft 1993; Susskind 1995; Maldacena 1998), teaches that bulk physics is encoded on a boundary:

$$Z_{bulk}[\phi] = Z_{boundary}[\phi|\partial].$$

Pulse ontology interprets each disclosure as a mapping,

$$D_n: H_\partial \rightarrow H_{bulk},$$

A projection that sequentially actualizes encoded information. The block universe remains geometrically intact, but its phenomenological reality is rhythmically disclosed. Novelty is not metaphysical creation but holographically ordered disclosure.

4.4 Reconciling Causality, Determinism, and Becoming

The universal wavefunction evolves unitarily,

$$i\hbar \frac{d}{dt}|\Psi(t)\rangle = \hat{H}|\Psi(t)\rangle$$

Ensuring determinism. Yet actuality emerges pulse by pulse, preserving becoming. Entanglement enforces causal order, ensuring that disclosures are relationally lawful. The block universe is therefore reinterpreted: geometrically complete, phenomenologically incomplete until disclosed.

4.5 Phenomenology and the Illusion of Flow

Philosophical critiques of temporal passage (McTaggart, 1908; Barbour, 1999) and neuroscientific insights into temporal binding (Engel & Singer, 2001; VanRullen & Koch, 2003) converge. The brain stitches discrete neural events into apparent flow, which can be modeled as:

$$P(t) = \sum_n s(t_n) * K(t - t_n)$$

What consciousness registers as continuity is the perceptual smoothing of discrete pulses. Thus, lived time resonates with pulsed ontology: temporal passage is not fundamental, but an emergent cognitive correlate of disclosure.

Philosophical Synthesis

Taken together, these arguments establish a coherent ontological framework. QFT provides discreteness through excitations; entanglement entropy grounds irreversibility; holography secures sequential disclosure; unitary dynamics preserves determinism; and phenomenology clarifies the illusion of flow. Where prior accounts falter—timeless eternalism, statistical hypotheses, or process metaphysics—pulse ontology unifies the block's stasis with quantum becoming.

The original contribution of this paper is thus clear: the arrow of time is not contingent but necessary, not illusory but structural. Time is the rhythmic disclosure of reality itself—the universe does not merely exist, it pulses.

5 Objections and Replies

No proposal for the ontology of time can avoid engagement with its strongest rivals. Pulse ontology challenges entrenched frameworks—eternalism, presentism, statistical mechanics, and process metaphysics—yet each carries influential arguments. To demonstrate its robustness, the following objections are considered and systematically rebutted.

5.1 Barbour's Timeless Ontology

Julian Barbour (1999) has argued that "time does not exist," claiming that what we call temporal flow is merely the stitching together of a timeless configuration space of "Nows." From this view, the arrow of time is illusory: the universe consists of frozen instants without intrinsic becoming.

Rebuttal. While Barbour is correct that the sense of flow is constructed, he underestimates the role of physical discreteness. Pulse ontology agrees that continuity is illusory, but unlike timelessness, it locates becoming in quantum disclosure. Quantum field excitations and entanglement entropy ensure that new correlations emerge sequentially. Unlike Barbour's frozen landscape, pulse ontology preserves both determinism and genuine novelty, avoiding reduction to static timelessness.

5.2 The Eternalist Block Universe

Eternalists argue that relativity entails a four-dimensional block where past, present, and future coexist equally, leaving no room for becoming. This model secures determinism and geometric coherence but renders the passage of time a psychological illusion.

Rebuttal. Pulse ontology reinterprets the block rather than rejecting it. Geometry is fixed, but actuality is not given all at once—it is disclosed pulse by pulse. This preserves the mathematical success of relativity while avoiding its metaphysical stasis. In other words, the block remains complete in structure but incomplete in disclosure until pulsed into reality.

5.3 Statistical Mechanics and the Past Hypothesis

Boltzmann's framework grounds the arrow of time in entropy, but only by positing an improbably low-entropy beginning. David Albert (2000) admits this is explanatorily weak: a contingent assumption rather than a structural necessity.

Rebuttal. Pulse ontology embeds the arrow of time in quantum evolution itself. Each pulse corresponds to an increase in entanglement entropy, securing irreversibility without boundary conditions. This transforms the arrow from contingent cosmology into intrinsic ontology.

5.4 Callender's Deflationary View

Craig Callender (2017) argues that many debates about temporal ontology are pseudo-problems generated by linguistic or conceptual confusions. From this perspective, attempts to explain the arrow of time metaphysically are misguided.

Rebuttal. While linguistic deflation may dissolve superficial puzzles, it does not address the structural asymmetries of physics. Quantum correlations demonstrably grow; excitations unfold discretely; holography projects encoded states sequentially. Pulse ontology grounds its claims in formal physics, not metaphysical speculation, and therefore cannot be dismissed as a linguistic error.

5.5 Process Metaphysics

Whiteheadian and process-based accounts celebrate becoming and novelty but often lack integration with physical theory. They risk divorcing ontology from empirical grounding, treating time as metaphysical creation ex nihilo.
Rebuttal. Pulse ontology preserves the insight that becoming is real, but secures it within quantum formalism. Excitations, entanglement, and holography provide measurable, testable correlates of disclosure. In this way, pulse ontology bridges process and physics, avoiding speculative arbitrariness.

Philosophical Payoff

By addressing these objections, pulse ontology demonstrates that it avoids the pitfalls of its rivals: it does not deny becoming (as eternalism does), does not reduce to timelessness (as Barbour does), does not rely on brute assumptions (as Boltzmann does), does not trivialize ontology (as Callender does), and does not sever from physics (as process metaphysics does).

The strength of the proposal lies precisely in this reconciliation: time is neither a metaphysical illusion nor an unexplained primitive, but a structured sequence of quantum pulses—rhythmic disclosures that secure causality, determinism, and becoming simultaneously.

6 Conclusion

The inquiry into the ontology of time has revealed that neither classical thermodynamics, nor relativity, nor standard quantum mechanics has succeeded in providing a fully satisfactory account of the arrow of time. Each framework either appeals to contingent boundary conditions, collapses into geometrical stasis, or invokes indeterminacy without ontological clarity. The pulse ontology proposed here advances a different path: it interprets temporality as a sequence of quantum pulses, each corresponding to a discrete disclosure of encoded potential into realized actuality.

This framework contributes to the philosophical problem of time by reconciling domains that have traditionally stood in tension. It grounds irreversibility in the structural growth of entanglement entropy rather than in probabilistic assumptions. It situates becoming not outside but within the lawful unfolding of unitary quantum dynamics. It reinterprets the block universe as geometrically complete yet phenomenologically incomplete until disclosed rhythmically through pulses. And it aligns lived phenomenology with physical discreteness by demonstrating how continuity arises as a constructed resonance of discrete events.

Nevertheless, the proposal remains at the level of conceptual ontology. While it is physically motivated by quantum field excitations, the holographic principle, and the constraints of energy–time uncertainty, it has not yet been given a fully rigorous mathematical formulation. Nor has it been subjected to direct experimental confirmation. If the ontology of pulses is to be more than a philosophical synthesis, it must eventually be cast into testable predictions—whether through deviations in entanglement growth, signatures in field excitations, or novel consequences for holographic dualities.

The present contribution, then, is neither a final solution nor a speculative gesture. It is a philosophically grounded framework that reframes the problem of the arrow of time and suggests a path toward its resolution. The rhythm of existential pulses offers a way to reconcile determinism with becoming, but its ultimate validity will depend on whether physics itself—through mathematics and experiment—confirms that time truly beats.

7 References

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