Temporal Necessity in Relational Mathematical Realism: A Gödelian Argument Against the Block Universe

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February 2026

Abstract

The standard Block Universe interpretation of general relativity treats time as a static dimension, with the passage of time relegated to psychological illusion. In this paper, we present a novel argument against the Block Universe derived from the framework of Relational Mathematical Realism (RMR), which identifies physical existence with mathematical structure. We demonstrate that if reality is a sufficiently complex, locally consistent mathematical structure, then Gödel's First Incompleteness Theorem renders a static, completed universe logically impossible. The resolution of this impossibility requires the structure to undergo a non-terminating sequence of state extensions, which we identify with the passage of time. We conclude that time is not a dimension within which the universe exists, but rather the logically necessary process by which a complex mathematical structure maintains consistency. This result, if sound, constitutes the first derivation of temporal passage from mathematical logic and ontology alone.

1 Introduction

General relativity, in its standard interpretation, admits a four-dimensional Block Universe in which past, present, and future coexist as a static manifold [5, 6]. Under this view, the experienced passage of time is an illusion—a psychological artifact of conscious beings embedded within the manifold. While this interpretation is mathematically consistent with the field equations, it faces persistent philosophical objections, most notably the difficulty of explaining why we experience temporal flow at all if no such flow exists in the fundamental ontology.

In this paper, we present a novel argument against the Block Universe that is neither phenomenological nor thermodynamic but *logical*. Drawing on the framework of Relational Mathematical Realism (RMR)—which identifies physical existence with mathematical structure [3]—we demonstrate that Gödel's First Incompleteness Theorem [1] renders a static, completed universe logically impossible, provided certain ontological axioms are accepted. The resolution of this impossibility yields a non-terminating sequence of state extensions, which we identify with the passage of time.

The central insight can be stated informally as follows. Gödel's theorem is standardly interpreted as a *limitation* of formal systems—a proof that mathematics cannot fully capture all truths about itself [8]. We propose an alternative reading: incompleteness is not a defect but a *structural feature* revealing that sufficiently complex mathematical structures are inherently open. They cannot be bounded without severing logical connections. When this insight is combined with an ontology that identifies existence with mathematical structure, the openness of mathematics becomes the openness of reality, and temporal passage emerges as the mechanism by which consistency is preserved in an incomplete system.

Section 2 motivates the reinterpretation of Gödelian incompleteness as evidence of structural openness. Section 3 presents the formal axioms and the derivation of temporal necessity. Section 4 addresses anticipated objections. Section 5 discusses implications for physics. Section 6 concludes.

2 Incompleteness as Structural Openness

Gödel's First Incompleteness Theorem (1931) establishes that any consistent formal system capable of expressing basic arithmetic contains statements that are true but not provable within the system [1]. The standard interpretation treats this as a limitation: mathematics is incomplete, and this incompleteness is a barrier to the formalist programme of grounding all mathematical truth in axiomatic derivation [7, 8].

We propose that this interpretation, while technically correct, misidentifies the source of the phenomenon. Consider an analogy. Imagine a network of nodes connected by strings, where each string has two endpoints, each terminating at a knot. The network is fully connected and internally consistent. Now impose an arbitrary closed boundary through this network. Some strings will cross the boundary—from inside the boundary, these strings appear to have only one endpoint. They seem incomplete.

But the incompleteness is not a property of the network. It is an artifact of the boundary. The strings are fully connected; it is the act of imposing a finite boundary that creates the *appearance* of dangling ends. Remove the boundary, and the apparent incompleteness vanishes.

Gödel's theorem, in this reading, is proving something positive: that the relational structure of mathematics *cannot be bounded*. Any attempt to enclose it within a finite set of axioms (a boundary) will necessarily sever connections, producing statements that are true of the larger structure but unprovable within the enclosed portion. The "incompleteness" is the mathematical signature of an inherently open, unbounded relational structure.

This reinterpretation has an immediate and consequential implication. If physical existence is grounded in mathematical structure—as proposed by mathematical realist ontologies [3]—then the structural openness of mathematics is inherited by reality itself. A universe grounded in mathematics cannot be closed, because closure would require precisely the kind of boundary that Gödel proved always leaves connections severed.

3 The Theorem of Temporal Necessity

3.1 Definitions

Let **U** denote the totality of physical existence (the Universe). Let **S** denote a formal relational mathematical system. Let t denote the ordinal index of recursive structural extension.

3.2 Axioms

Axiom 1 (Monist Ontology). *Physical existence is identical to relational mathematical structure. There is no ontological distinction between the formal system S and the physical universe U. There is no separate "abstract realm" in which mathematical truths reside; to be a valid relational structure is to be a component of physical reality.*

Axiom 2 (Local Consistency). *A contradiction—a state in which both A and $\neg A$ obtain simultaneously—cannot be physically instantiated. Therefore, any realized portion of S must be locally consistent.*

Axiom 3 (Complexity Threshold). *The structure S is sufficiently complex to encode arithmetic—that is, it supports self-reference and recursion. This places S within the scope of Gödel's First Incompleteness Theorem [1].*

Axiom 4 (Relational Determination). *The resolution of any undecidable statement φ in S is uniquely determined by the relational topology of S within the broader mathematical reality. The extension of S is not arbitrary; it is a necessary consequence of the existing relational structure.*

3.3 The Realization Lemma

Lemma 1 (The Realization Principle)**.** *In a monist mathematical ontology, every relational implication that is valid within the global structure necessarily constitutes a component of existence. To be valid is to be real.*

Proof. Under Axiom 1, there is no ontological separation between mathematical structure and physical existence. In standard Platonism, a mathematical truth can reside in an abstract realm without physical instantiation—there exists, so to speak, a "waiting room" for uninstantiated truths. Under monist ontology (Axiom 1), no such repository exists. The mathematical structure *is* all of physical reality. Therefore, a relational implication that is valid (true of the structure in the model-theoretic sense) but not structurally instantiated would constitute a truth with no ontological home. Since existence and structure are identified, validity entails instantiation. □

Note: To reject the Realization Principle, one must reject Axiom 1 (the monist ontology). This is a coherent position—one may simply deny that reality is mathematical. However, within the framework of RMR, the Realization Principle is not an independent assumption but a necessary consequence of the foundational ontological identification.

3.4 Derivation

Step 1: The Static Hypothesis (*reductio* assumption). Assume, for contradiction, that U exists as a completed, static entity—a Block Universe [5]—represented by a closed mathematical structure S_{final} in which all truths are decidable.

Step 2: The Incompleteness Conflict. By Axiom 3, S_{final} is subject to Gödel's First Incompleteness Theorem [1]. If S_{final} is consistent (as required by Axiom 2), there exists at least one statement φ such that:

$$S_{\text{final}} \nvdash \varphi \quad \text{and} \quad S_{\text{final}} \nvdash \neg\varphi$$

By Axiom 4 (Relational Determination), the relational topology of the broader structure determines that φ is valid—it is true in the intended model.

Step 3: The Ontological Contradiction. By Lemma 1 (the Realization Principle), since φ is valid, it must be structurally instantiated as a component of U. But S_{final} is defined as the completed totality of U—there is nothing outside it. Therefore:

(i) φ must exist in U (by Lemma 1), and

(ii) φ cannot be contained in S_{final} (by Gödel's theorem applied to the closed system).

Contradiction. **Therefore, a static, completed universe is logically impossible.**

Step 4: The Dynamic Resolution. To resolve the contradiction, U must abandon the property of completion. Rather than existing as a closed structure, U must exist as an ordered sequence of structures. The system must extend its boundary to incorporate φ as realized structure, transitioning from S_t to a supersystem:

$$S_{t+1} = S_t \cup \{\text{structure of } \varphi\}$$

In physical terms, the universe must update its state to explicitly realize the implication that was undecidable in the previous state.

Step 5: Recursive Non-Termination. The new system S_{t+1} is now a defined, consistent structure. Because it remains sufficiently complex (Axiom 3 is preserved under extension), Gödel's theorem applies again. There exists a new statement φ' that is valid but undecidable in S_{t+1}. By identical reasoning, the system must extend to S_{t+2}. Since Gödelian incompleteness is recursive—no finite extension of axioms can close the system [8]—the sequence

$$S_t \to S_{t+1} \to S_{t+2} \to \cdots$$

never terminates.

3.5 Conclusion of the Theorem

A consistent, sufficiently complex relational mathematical structure cannot exist as a static object. It can only exist as a non-terminating sequence of state extensions. We identify the ordinal index t of this sequence with physical time.

Time is not a dimension within which the universe exists. Time is the sequential logical process required for a complex mathematical structure to exist without contradiction. Time is the mechanism of consistency preservation in an incomplete system.

4 Anticipated Objections

4.1 The Quiescence Objection

Objection: *"Incomplete systems do not ordinarily do anything about their incompleteness. Peano Arithmetic has undecidable statements and simply remains incomplete. Why can't the universe be a static incomplete structure with some undecidable propositions that remain undecided?"*

Response: This objection has force against standard mathematical Platonism, where undecidable-but-true statements can reside harmlessly in an abstract realm. It has no force against RMR. Under monist ontology (Axiom 1), there is no abstract realm—no ontological parking lot for unrealized truths. In Peano Arithmetic, the Gödel sentence is true-but-unprovable, and this creates no crisis because Peano Arithmetic is a formal system, not a physical reality. But if the formal system *is* physical reality, then a valid-but-unrealized implication is an existent that doesn't exist—a contradiction. The universe cannot "sit quietly" with unrealized implications because, under RMR, there is nowhere for those implications to sit.

4.2 The Metatheory Objection

Objection: *"Gödel's theorem establishes truth from outside the system—from a metatheory. If the universe IS the system, there is no outside. Who evaluates the truth of φ?"*

Response: This is the deepest philosophical challenge to the argument. In standard mathematical logic, the distinction between system and metatheory is between a formal language and a richer formal language used to reason about it [2]. In RMR, the distinction is reconceived: the "metatheory" is not a system above or outside the universe, but the *not-yet-realized implications* of the existing relational structure.

Consider an analogy. A jigsaw puzzle has been partially assembled (S_t). A gap exists among the placed pieces. The shape of that gap is fully determined by the boundaries of the existing pieces—no external observer is needed to evaluate it. The "truth" of the missing piece's shape is encoded in the local geometry of the boundary itself.

Similarly, the truth of φ is not evaluated by an external intelligence; it is determined by the relational topology of the existing structure (Axiom 4, Relational Determination). The "strings" crossing the boundary of S_t have definite shapes at the crossing point—their resolutions are fixed by the structure they emerge from, not by any observer standing outside.

We formalize this as the **Horizon Principle**: The metatheory required to validate the undecidable statements of S_t is contained within the relational topology of S_{t+1}. Truth is not external to the universe; it is trans-temporal. The future validates the present. The metatheory is not above—it is ahead.

4.3 The Rate Objection

Objection: *"Granted that the sequence $S_t \to S_{t+1}$ must exist. But why does each step correspond to a Planck time? Why not infinitely fast? Why not variable speed?"*

Response: The question presupposes a background clock against which the "speed" of the process could be measured. Under RMR, no such background exists. Time *is* the index of the sequence; there is no external temporal metric. The question "How fast does the universe compute?" is malformed for the same reason that "What happened before the Big Bang?" is malformed in standard cosmology—it presupposes a framework that the theory denies.

The Planck time is not the *duration* of each step measured against some background; it is the *definition* of temporal duration. One logical step of the process constitutes one unit of fundamental time. The Planck time ($\approx 5.39 \times 10^{-44}$ s) emerges as the conversion factor between the logical index t and the macroscopic units of measurement, with its specific value determined by the relational structure's own properties (from which the constants c, $\hbar$, and G derive their values).

4.4 The Scope Objection

Objection: *"Gödel's theorem applies to formal axiomatic systems. The physical universe is not a formal axiomatic system."*

Response: This objection is valid against any framework that merely claims the universe is *described by* mathematics. It has no force against RMR, which claims the universe *is* mathematical structure [3]. Under Axiom 1, the universe literally is a formal relational system—not approximately, not analogically, but identically. If one rejects this identification, one rejects RMR, and the theorem does not apply. But within the framework, the application of Gödel's theorem is not metaphorical.

5 Implications

5.1 The Trichotomy of Temporal Ontology

The present argument establishes a third position in the ontology of time, distinct from both the thermodynamic and relativistic accounts:

Thermodynamic time derives temporal asymmetry from the statistical improbability of initial conditions and the Second Law. It explains the *arrow* of time but not the *existence* of time.

Relativistic time (the Block Universe) treats time as a dimension geometrically equivalent to space, with temporal flow as illusion [5, 6]. It accommodates the *structure* of time but denies its *passage*.

RMR time (the present account) derives temporal passage as a logical necessity—the inevitable consequence of consistency preservation in an incomplete mathematical structure. A timeless universe is not merely physically unlikely; it is mathematically impossible.

5.2 The Present as Computational Frontier

The derivation naturally yields a tripartite structure of temporal ontology. The **past** is the set of relational configurations that have been resolved into fixed structure—the strings that have been successfully knotted. The **future** is the space of implications that are determined by the existing topology but not yet realized. The **present** is the active computational frontier: the boundary where the system encounters its Gödelian limit and generates new structure to accommodate it.

This framework provides a natural explanation for the asymmetry between past and future that does not rely on thermodynamic considerations. The past is fixed because its relational structure has been determined; the future is open (from the perspective of any observer embedded within S_t) because the cross-boundary implications have not yet been realized. The directionality of time is built into the logical structure of the process.

5.3 Renormalization as Boundary Accommodation

The reinterpretation of incompleteness as boundary-crossing offers a suggestive reframing of renormalization in quantum field theory. When physicists encounter divergences (infinities) in loop calculations, the standard procedure is to impose a momentum cutoff—an artificial boundary in energy space—and then "renormalize" the physical parameters (mass, charge) to absorb the contribution of modes beyond the cutoff [4].

In the present framework, these divergences are the signatures of severed relational connections—the "strings" that cross the boundary imposed by the cutoff. Renormalization succeeds precisely because it is a principled method of accounting for the influence of those severed connections without tracing each one to its endpoint. The renormalization group flow, in this view, describes how the local picture changes as the artificial boundary is moved—it is the same unbounded relational structure viewed through boundaries drawn at different locations.

This interpretation also suggests a reason for the empirical dominance of renormalizable theories: a non-renormalizable theory corresponds to a case where the boundary damage is too severe—too many connections are broken in ways that cannot be locally absorbed. Only theories where the boundary can be drawn "cleanly enough" survive as effective local descriptions. This is a selection principle that emerges from the framework rather than being imposed by hand.

5.4 The Determinacy of Extension

Axiom 4 (Relational Determination) has a significant consequence: the extension from S_t to S_{t+1} is not arbitrary. The relational topology of the existing structure uniquely determines which implications must be realized next. This means the universe does not face a “choice” at each step—the evolution is determined by the structure of the present state.

This has immediate implications for the interpretation of quantum mechanics. If the structural evolution is uniquely determined by the full relational topology, but observers embedded within S_t cannot access the complete topology (being themselves part of the structure), then apparent indeterminacy in quantum mechanics may be an artifact of epistemic position rather than fundamental ontology. The Born rule might emerge as a measure over observers’ ignorance of the cross-boundary relational topology, rather than as irreducible randomness in the structure’s evolution. A full treatment of this conjecture is reserved for future work.

5.5 Cosmological Expansion and the Scaling of Incompleteness

The derivation of time as a recursive extension sequence ($S_t \to S_{t+1}$) implies that the total relational cardinality of the universe must monotonically increase. In a framework where space is not a pre-existing container but the relational network itself, the continuous addition of new structure necessary to resolve undecidable propositions manifests physically as metric expansion. Space expands because the underlying logical graph is gaining nodes.

This perspective suggests a novel mechanism for cosmic acceleration (Dark Energy). As the complexity of the structure S_t increases, the number of logical implications generated by the system—its “Gödelian surface area”—scales combinatorially. If the generation of the next state S_{t+1} is driven by the necessity of resolving these tensions, then a larger system requires a higher rate of structural injection to maintain consistency. Consequently, the expansion rate should not be constant or slowing, but accelerating in proportion to the system’s total complexity. In this model, “Dark Energy” is not an exogenous field, but the physical signature of the increasing computational burden of a growing axiomatic system. A formal derivation of this combinatorial scaling law is in preparation.

6 Conclusion

We have presented an argument that, within the framework of Relational Mathematical Realism, temporal passage is not a contingent feature of our universe but a logical necessity. The argument proceeds by demonstrating that a static, completed mathematical universe of sufficient complexity is self-contradictory: Gödel’s theorem [1] guarantees the existence of valid implications that cannot be contained within any closed boundary, and the monist ontology of RMR demands that valid implications be structurally realized. The only resolution is a non-terminating sequence of state extensions—which is time.

The strength of this result, if sound, is that it derives temporal passage from mathematical logic and ontology alone, without appeal to thermodynamic, cosmological, or phenomenological considerations. It provides a reason for time's existence that is deeper than initial conditions, deeper than entropy, and deeper than the geometry of spacetime: time exists because the alternative is logically forbidden.

The argument rests on its axioms, and the axioms can be challenged—most fundamentally, the identification of physical existence with mathematical structure (Axiom 1). We do not claim to have proven this identification; we claim only that *if* one accepts it, temporal passage follows as a theorem rather than an assumption. The universe cannot be a "box" because no box can be large enough to contain its own logical implications.

Following this interpretation, Gödelian incompleteness should be viewed not as a limitation of mathematics, but as a limitation on the imposition of boundaries—a constraint implying that existence cannot be a closed state, but must be a process of continuous extension.

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