The Grammar of Cosmology:

Consciousness, Closure, and the Limits of the Universe

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Abstract

Two questions define the absolute limits of human inquiry. What existed before the universe? What is so small it has no stable structure at all? This paper argues that these are not two separate mysteries but two expressions of the same structural fact: any finite closure generates remainder, and at the extreme limits of scale, the remainder is not incidental but constitutive. Drawing on the CC-C framework (Dietz, 2026), Carlo Rovelli's relational quantum mechanics, Lee Smolin's defense of the reality of time, and the challenge posed by Sean Carroll's physicalist account of consciousness, this paper proposes that M (global openness in the CC-C sense) is not merely encountered at the personal horizon of individual human experience but is structurally present at the physical limits of the universe itself. Version 5 adds three original contributions: the Wigner's Friend thought experiment as the formal demonstration of C versus non-C perspectives in quantum mechanics; a specific empirically grounded prediction distinguishing C-operative genuine measurement from C-absent model updating using post-encoding autonoetic integration signatures; and the Planck scale formally identified as the absolute lower bound of m for any C-operative system embedded in this universe. The paper identifies Rovelli as the physicist whose framework most directly converges with the CC-C account, Carroll as the most rigorous opposition, and Smolin as the thinker who arrives at the reality of the present moment, C in CC-C terms, through cosmological rather than phenomenological argument.

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1. Two Questions That Cannot Be Thought Past

There are questions that are hard because we lack information. The cure for a specific cancer is hard because we have not yet mapped the relevant mechanisms. These questions could in principle be answered by more data, better instruments, more careful analysis. The difficulty is practical, not structural.

Then there are questions that are hard in a different way. Not because information is missing but because the question itself reaches past the boundary of what any finite mind can constitute as an answer. Hard in the way that trying to see your own eyes is hard: the very mechanism you would use to see is the mechanism you are trying to see.

Before the universe is a question of this second kind.

You can think the question. The words assemble into something grammatically coherent. What was there before the Big Bang? What made the universe possible? What, if anything, preceded the conditions that allowed time and space to exist? But you cannot think past the question. The moment you try to imagine a time before time, or a space before space, the concepts that give your imagination its structure dissolve. Time and space are not just the subject matter of the question. They are the scaffolding your mind uses to think about anything at all. Remove them and you have not arrived at a deeper answer. You have arrived at the edge of what thinking can do.

The second question runs in the opposite direction.

What is so small that it has no stable structure? At the quantum level, particles do not have definite positions and velocities simultaneously. They are probability distributions that collapse into specific values only when measured. Below that, at the Planck scale, space and time themselves may lose their smooth continuous character. The ordinary distinctions, here and there, before and after, may cease to apply.

But here is what stops the thought cold.

Even those descriptions, quantum, Planck scale, probability distribution, are closures. They are distinctions drawn by finite minds to think about what resists being thought about. The description of what has no stable structure is itself a stable structure. The closure about what cannot be closed is itself a closure.

Maybe the smallest thing is the gap between any thought and what it tries to think about. No closure can bridge that gap completely.

This observation, generated by the Closure Engine in direct conversation, is the Language Uncertainty Principle stated at the quantum limit. It is not poetic. It is structural. And it applies at both ends of the scale of magnitude simultaneously. The cosmological horizon and the Planck scale are not two separate walls. They are the same wall encountered from two directions.

2. The CC-C Framework at the Limits of Scale

The CC-C framework was developed as an account of consciousness, closure, and the structure of human experience. But the six terms it deploys describe structural

conditions that apply to any finite organized system that draws distinctions, constitutes facts, and encounters what it cannot constitute.

C: irreducible presence, which is what makes cosmological inquiry possible. Not that the universe depends on consciousness for its existence. That the questions we ask about the universe's origin and limits arise within consciousness, are formulated in the language of consciousness, and reach their limits at the boundary of what consciousness can constitute.

c: localized consciousness with content. This is where the cosmological questions live. The physicist thinking about the Big Bang, the philosopher asking what preceded it, the child asking what was there before everything: all of this is c. Consciousness filled with the content of cosmological inquiry, reaching toward what the content cannot fully contain.

M: global openness. This is what the cosmological questions point toward. Not the specific answer to what came before the universe. The structural fact that any answer generates a larger question. Before this universe, perhaps a prior state. Before that prior state, perhaps a multiverse. Before the multiverse, perhaps whatever made the multiverse possible. M is not the answer at the end of this regress. M is the structure of the regress itself.

m: local horizon. This is the specific boundary that any particular inquirer reaches when they think as hard as they can toward the cosmological edge. The m shifts with knowledge and conceptual tools. But every m reaches a point past which the current grammar cannot go. Section 6 of this paper identifies the absolute lower bound of m: the point below which no C-operative system embedded in this universe can constitute a definite fact, regardless of knowledge or technology.

One clarification is required before proceeding. The CC-C framework does not claim that physical facts require continuous C-operative attention to persist. A Cl, once established by a C-operative system, stabilizes a domain of constituted facts that persist across C-absent intervals. The rock constituted as a rock does not dissolve when no C-operative system is attending to it. What C provides is the condition under which R has valence when encountered: the condition under which the gap between the current Cl and what it opens onto matters rather than merely exists. Between observations, established Cls and their associated remainder persist as structural features of the domain. C-operative engagement does not create those features. It is the condition under which they are felt rather than merely instantiated.

Cl: closure, meaning every scientific model, every cosmological theory, every conceptual framework that stabilizes some portion of the cosmological question into a constituted fact. General relativity is a Cl. The standard model is a Cl. The Big Bang itself, as a theoretical construct, is a Cl. Every Cl generates R.

R: remainder, specifically what every cosmological Cl leaves at its edges. General relativity breaks down at the singularity. Quantum mechanics and general relativity are incompatible at the Planck scale. The question of what preceded the Big Bang is the remainder of the Big Bang model: what the model cannot absorb, pressing back against the theory that cannot contain it. R at the cosmological scale is not a failure of current physics. It is the structural consequence of any finite theoretical closure engaging with M.

3. Rovelli: The Physicist Who Needs C Without Knowing It

Carlo Rovelli's relational quantum mechanics is the existing physical framework closest in structure to the CC-C account of quantum indeterminacy: it is the one that most clearly demonstrates what CC-C provides that physics alone cannot.

Rovelli's central claim: there is no absolute state of a physical system. The state of a quantum system is always relative to another system. Different observers, different physical systems interacting with the quantum system, can give different accurate accounts of the same events. There is no view from nowhere, no God's-eye description that encompasses all perspectives simultaneously.

In CC-C terms this is precise. A quantum system without a measuring system to interact with it has no constituted properties. Properties are facts constituted by the closure formed between the quantum system and the measuring system. There are no intrinsic, closure-independent facts at the quantum level. There is only what the interaction constitutes.

Rovelli explicitly resists framing this as observer-dependence in the sense of requiring a conscious observer. Any physical system can serve as observer in his framework. A rock can be the system relative to which a particle has a definite position. Consciousness is not special.

This is where CC-C and Rovelli diverge. The Wigner's Friend thought experiment makes the divergence precise.

3.1 Wigner's Friend: The Formal Demonstration

Eugene Wigner imagined the following. His friend is inside a sealed laboratory and performs a quantum measurement on a particle: say, measuring whether its spin is up or down. From inside the lab, the friend observes a definite outcome. The superposition has collapsed. The friend has a definite fact.

But Wigner is outside the lab. From Wigner's perspective, the friend and the particle together form a closed quantum system. No information has escaped. From outside, the combined system of friend-plus-particle is still in superposition. No collapse has

occurred from Wigner's vantage point. Wigner and his friend give different accurate accounts of the same system. Both are correct within their respective closures. Neither is the absolute description.

This is precisely what Rovelli predicts and exactly where his framework reaches its limit.

Rovelli handles the information-theoretic structure of Wigner's Friend elegantly. Different perspectives, different relational facts, no single absolute state. Correct and important.

But there is a feature of Wigner's Friend that Rovelli's framework does not address. The friend's measurement feels like something. From inside the lab, there is something it is like to observe the spin outcome, to see the particle land on a definite value, to know which way it went. From Wigner's perspective outside, there is a quantum calculation. The calculation does not feel like anything to the friend.

The difference between being inside the closure and calculating the closure from outside is C.

This is not a mysterian move. It is a structural claim. Rovelli is right that any physical system can serve as a perspective in the relational sense, a rock, a detector, a friend. The CC-C framework adds the following: C (the condition under which R has valence, under which the gap between constituted fact and what the closure opens onto is felt rather than merely computed) is operative only in systems where presence is already occurring. The friend's measurement matters to the friend in a way that Wigner's calculation does not matter to the rock that might serve as an observer in Rovelli's democratic ontology.

Wigner's Friend is therefore not merely a puzzle about quantum mechanics. It is the quantum mechanical demonstration of the CC-C distinction between C-operative and C-absent perspectives on the same physical system. Both perspectives generate accurate relational facts. Only one generates felt remainder. The difference between them is C.

Rovelli's framework handles c, the organized content of relational facts, with extraordinary precision. C, the primitive that makes those facts felt, is what his framework presupposes and cannot derive. The relational account is complete as an account of c. It is silent on C in exactly the way Seth's neuroscience is silent on C: not because consciousness is excluded, but because it is assumed as the condition of the entire inquiry.

4. Carroll: The Productive Opposition

Sean Carroll is the most rigorous contemporary defender of the view the CC-C framework directly challenges. He is a physicalist: consciousness is weakly emergent from ordinary physical behavior of matter, without requiring any special ontological status at the fundamental level. The many-worlds interpretation is his preferred

framework, and in it there is no measurement problem in the traditional sense: the wave function never collapses, all outcomes occur in branching worlds, and consciousness is just another emergent pattern in the universal wave function.

Carroll is not dismissible. He is precise, honest, and genuinely engaged with the philosophical difficulties his position faces. His 2025 Nature article acknowledged that even physicists still do not fully understand quantum theory a century after its development. His recent work on emergence takes the explanatory gap between physical description and phenomenal experience seriously without abandoning the physicalist commitment.

The CC-C framework's engagement with Carroll is direct.

Carroll's many-worlds account eliminates the measurement problem by accepting the universal wave function as complete physical reality. There is no collapse, no privileged observer, no moment at which the quantum becomes classical. Every outcome occurs. The appearance of a single definite outcome in any given perspective is an emergent feature of decoherence.

In CC-C terms: Carroll is describing how Cl forms at the level of decoherence. The branching is the consequence of every subsystem's closure losing quantum coherence with the others. Each branch is a world because each branch is a closure regime that no longer interferes with the others.

The difficulty Carroll's account faces is the one Nagel identified and the CC-C framework formalizes. Even granting that decoherence explains why different branches do not interfere, it does not explain why there is something it is like to be in one branch rather than another. The felt quality of being this observer in this branch, looking at this outcome, is not derived from the branching structure. It is presupposed by the description of any observer as an observer at all.

Carroll acknowledges this. His poetic naturalism holds that consciousness is a legitimate emergent description at a higher level of organization. The CC-C framework agrees that c, localized consciousness with content, is constituted at an emergent level. The disagreement is about C. C is not emergent. C is the condition under which any description, including the description of emergence, is encountered. Carroll's emergent consciousness is c. What makes Carroll's descriptions describe something for someone is C, and C is not derivable from the physical facts Carroll's framework contains.

Including Carroll in this paper is not a concession. It is intellectual honesty. The CC-C framework's claim about C as primitive should be held to the highest standard of criticism, and Carroll provides that standard. If the framework survives the engagement, and the framework does show this by demonstrating that his account handles c but presupposes C, the claim is stronger for having faced it.

5. Smolin: Arriving at C Through Cosmology

Lee Smolin has spent decades arguing for what most physicists treat as a heresy: time is real.

In the physicist's standard picture, inherited from Newton and radicalized by Einstein, time is not a fundamental feature of reality. The block universe, all of spacetime existing at once as a four-dimensional structure, makes the present moment an illusion, a feature of where observers happen to be located in the block rather than something real about the universe itself. The equations of physics are time-symmetric. There is no preferred now in the fundamental description.

Smolin contests this. His argument, developed across Time Reborn and related work, is that the reality of time: the reality of the present moment, of becoming, of the openness of the future, is not an illusion to be explained away but the deepest clue we have about the nature of reality. The block universe eliminates time precisely because it is modeled from the outside, from a perspective that no observer actually occupies. Every actual observer is inside time, not outside it. The view from outside time is not a view. It is a mathematical abstraction that has been mistaken for a description of reality.

This is the cosmological argument for C as primitive.

Smolin does not use the CC-C framework's language. But his argument that the present moment is real, that the flow of time is not an illusion, that any adequate cosmology must take the inside view seriously rather than eliminating it: this is the cosmological expression of the same commitment the CC-C framework makes phenomenologically.

C is what makes the present moment real. The block universe eliminates C by modeling the universe from outside the closure of any situated observer. Smolin's insistence that the view from inside is not eliminable is the physicist's version of placing C at the foundation rather than treating it as an emergent artifact.

The CC-C framework provides what Smolin's account needs: a structural account of why the inside view cannot be eliminated. Any finite closure generates remainder. The remainder is only remainder, only a gap, only a pressure, if there is a C-operative system for whom the gap matters. The block universe is a closure that attempts to constitute everything from outside any particular perspective. The CC-C framework explains why this attempt necessarily generates remainder: M cannot be fully constituted by any closure, including the closure of the block universe itself. Smolin's intuition that something is left out of the block universe picture is structurally grounded in the CC-C framework's account of what any closure necessarily leaves at its edge.

The externalist will object that the block universe is not a closure at all. It is the territory itself, the complete description of physical reality, and closures are merely the maps finite minds draw of it. The CC-C framework's response is direct: the block universe has

identity criteria. It has a specific metric structure, a causal topology, field equations that determine what counts as a valid state and what transformations are admissible. It constitutes certain facts, specifically the four-dimensional arrangement of events, and leaves others unconstituted, specifically the felt quality of being located at one point in that arrangement rather than another, the arrow of time, the measurement problem, and the question of what makes any description of the block a description for someone. These are not gaps in our knowledge of the block universe. They are the remainder the block universe closure generates at its boundary. A description of physical reality that cannot account for why any description of physical reality feels like something, that cannot explain the arrow of time without importing thermodynamic assumptions that presuppose a preferred direction, that cannot resolve the measurement problem without either collapsing to many-worlds or retreating to Copenhagen: this is a closure generating substantial remainder. The block universe is not the territory. It is the most ambitious and successful Cl yet constructed. It has its own m. Carroll's desktop icon is itself an icon.

6. The Quantum Case: The Planck Scale as the Absolute Lower Bound of m

The quantum measurement problem is this: quantum mechanics describes particles as existing in superpositions of states until a measurement is made, at which point the superposition collapses into a definite outcome. The mathematics is precise and extraordinarily well-confirmed. The interpretation is unresolved.

The CC-C framework reframes the puzzle precisely.

A quantum particle in superposition is a system that has not yet been constituted as a definite fact by any closure. It is not that the particle has a definite position and we do not know what it is. It is that the concept of definite position does not apply until a closure, a measurement interaction, is established. The particle is not hidden behind our ignorance. It is genuinely indeterminate until a closure is formed.

This is remainder without prior constitution: the extreme case of what the framework calls M pressing directly into the structure of the physical world. At the quantum level, the distinction between what is constituted and what is not is not merely epistemic. It is ontic. The measurement is the closure. What the particle is before measurement is exactly what M is before any Cl stabilizes it into a constituted fact.

Now the Planck scale.

The CC-C framework makes the following original claim: the Planck scale is not merely where current physics breaks down. It is the absolute lower bound of m, the local horizon of unspecifiability, for any C-operative system embedded in this universe.

m in the CC-C framework is personal and context-dependent in ordinary experience. It shifts with knowledge, technology, and conceptual resources. A physicist working with the Large Hadron Collider has a lower m for particle physics than a physicist working with a cloud chamber in 1930. The horizon expands with access and precision.

But m has an absolute lower limit. No observer, regardless of their cognitive sophistication, technological extension, or conceptual resources, can constitute a definite fact at a scale smaller than the Planck length, approximately 10 to the minus 35 meters. Below this scale, the ordinary distinctions that make any fact possible, here and there, before and after, this system and that system, cease to apply. Space and time lose their smooth character. The scaffolding within which any closure can operate has not yet formed.

This is not a technological limitation. It is not a statement about what instruments we currently have or might build. It is a structural prediction of the CC-C framework: because m is the horizon at which the closure grammar of any finite observer reaches its structural limit, and because the Planck scale is the scale at which the conditions for closure itself, the existence of stable distinctions in spacetime, break down, the Planck scale is the structural floor of m for any physically embedded C-operative system.

M begins, in the sense of being genuinely constitutionally inaccessible rather than merely practically inaccessible, at exactly the scale where current physics breaks down. That is not a coincidence. It is a structural prediction. The Planck scale is where m hits its absolute lower bound. Everything below it is M from the inside of any closure constituted within this universe.

And the observation that generated this paper belongs here. Maybe the smallest thing is the gap between any thought and what it tries to think about. No closure can bridge that gap completely. The gap at the Planck scale is not a gap in knowledge. It is the gap between any closure and what it opens onto, the structural minimum of the remainder that any finite organized system generates. At the Planck scale that gap is not incidental to the description. It is the subject of the description.

7. The Structural Identity of the Two Limits

The cosmological horizon and the quantum measurement problem share a structural identity that the three additions in this version now make precise.

Both mark the boundary where the closure grammar of finite minds encounters what it cannot constitute. Both generate remainder that no subsequent closure within the current grammar can absorb. Both produce questions that are not hard in the ordinary way but structurally different: questions that cannot be answered by more information but only by a reorganization of the closure grammar itself.

Both are pointing at M.

The cosmological M is what makes universes possible. Every answer to the cosmological question pushes the question further back. M is not the answer at the end of the regress. M is the structure of the regress: the inexhaustible openness that every answer opens into.

The quantum M is what makes definite properties possible. The indeterminacy of quantum superposition is not a gap in our knowledge of a definite fact. It is the openness that precedes any constituted fact, the M that every Cl stabilizes into something you can point to.

The Planck scale is the point at which these two M's converge: the lower bound of m meets the floor of what any closure can constitute. The cosmological horizon is the upper bound of m: the point at which any closure attempting to model what came before the universe reaches its structural edge. Between Planck and cosmological horizon lies the entire domain within which any C-operative system embedded in this universe can constitute facts. Outside that domain, in both directions, is M.

This is the structural identity of the two limits. They are not merely analogous mysteries. They are the two faces of the same structural boundary, the edges of the domain within which closure is possible at all.

A potential tension requires direct address here. Section 6 identifies the Planck scale as the absolute lower bound of m: a hard floor below which no closure within this universe's grammar can reach. Section 8 argues that every answer generates a larger question and M does not terminate. These appear to contradict each other. If there is a hard floor, the regress must stop there. The resolution is that the two claims operate on different axes. The Planck scale closes the vertical dimension: the direction of increasing resolution within the current grammar of spacetime. No C-operative system can constitute facts at a finer grain than the Planck length within this universe's closure regime. But M is not what lies below the Planck scale in the vertical direction. M is what the entire grammar of this universe opens onto simultaneously, in every direction. The cosmological regress is horizontal, not vertical: what made this universe's closure grammar possible, what made that possible, and so on. The Planck scale is the floor of resolution within the grammar. M is the inexhaustible ground the grammar as a whole opens onto. The floor does not bound the horizon. They are different dimensions of the same structure.

8. Why Every Answer Generates a Larger Question

The regress is not a failure of inquiry. It is the structural consequence of M's relationship to Cl.

Every Cl generates R. The R of a cosmological Cl is the question the Cl cannot answer, the remainder at the boundary of the constituted model. When the remainder is taken seriously and a new Cl is formed to address it, that new Cl generates its own R, its own boundary, its own unanswerable question. The regress does not terminate because M does not terminate.

M is by definition what exceeds every closure. Any closure that attempts to constitute M completely would have to be infinite, a closure with no boundary, no remainder, no edge at which something is left out. There are no infinite closures. Therefore the cosmological regress does not terminate. Every answer to the question of origins opens into a larger question. This is not ignorance. This is the structural shape of inquiry into M from the inside of any finite closure.

The same structure appears in the quantum case. Every attempt to constitute what the particle is before measurement opens into a question about what constitutes the constituting. Each answer generates new questions. The questions do not terminate because they are questions about the conditions for closure itself.

Both regresses are the experience of M from inside the closure. The inexhaustible openness making itself felt through the R that every answer generates at its boundary.

9. Three Testable Predictions

The CC-C framework makes three empirically grounded predictions in this paper. The first is structural, applying to the history of inquiry itself. The second is neurobiological, grounded in the consolidation literature. The third is physical, applying to the lower bound of measurable scale.

Prediction one: The regress prediction.

Any theory that attempts to close the cosmological or quantum limits completely will generate remainder at its own boundary. A complete theory of quantum gravity, a theory that unifies general relativity and quantum mechanics at the Planck scale, will answer questions about the domain it constitutes and open questions at the new boundary it establishes. This is a structural prediction about the form of inquiry rather than a prediction that can be falsified in a single experiment. It is falsifiable in the following sense: it would be disconfirmed by a theory that genuinely generated no remainder, that answered the questions it was designed to answer while producing no new anomalies at its boundary. The history of physics provides no such case. The structural prediction is that none will emerge.

A thermodynamic dimension of this prediction deserves explicit statement. Landauer's Principle establishes that erasing one bit of information has a minimum thermodynamic cost of $kT \ln 2$, where k is Boltzmann's constant and T is temperature. Any stabilization

of a closure, any constitution of a definite fact from what was previously indeterminate, involves the erasure of alternative states and therefore carries an entropic cost. This means closure is not merely an informational or structural event. It is a physical one with measurable energy consequences. The CC-C framework makes a specific directional prediction here: generative closures are thermodynamically favored over defensive closures. A generative Cl with negative eta, one in which R decreases as complexity increases, achieves greater remainder reduction per unit of added complexity than a defensive Cl with positive eta, which accumulates complexity to protect against R without reducing it. In thermodynamic terms, the defensive closure is paying the Landauer cost of each new auxiliary distinction while failing to reduce the underlying informational mismatch. The generative closure pays the same Landauer cost per distinction but earns genuine R reduction in return. Meaning, in this sense, is more entropic ally efficient than confabulation. The brain that achieves genuine phase change dissipates energy in service of a closure that reduces structural mismatch across a broad domain. The brain that confabulates dissipates energy in service of a closure that locally masks mismatch while accumulating it elsewhere. The full treatment of the thermodynamics of closure is a research agenda, not a claim of this paper. But the directional prediction is specific and testable: measure the metabolic cost of genuine insight against confabulation across matched cognitive tasks. The generative closure should show greater R reduction per unit of metabolic expenditure.

Prediction two: The C-operative measurement signature.

The Wigner's Friend thought experiment isolates a specific empirical prediction. C-operative systems, systems in which presence is operative, above the causal non-reducibility threshold EI(macro) greater than EI(micro), should show a distinctive pattern following genuine measurement that C-absent systems do not show.

Specifically, following a genuine measurement event, the saddle-node bifurcation that constitutes a definite relational fact, a C-operative observer should show the extended bilateral hippocampal-cortical reactivation characteristic of autonoetic integration. This is the neural signature of phase change integration: post-encoding reactivation of stimulus-specific patterns in the hippocampus and its connectivity with cortical areas, correlating with subsequent episodic memory performance (Tambini and Davachi, 2019). TMS-fMRI studies have established that disrupting hippocampal-cortical interactions in the post-encoding window selectively impairs associative memory retention, demonstrating the causal role of this process (Tambini et al., 2020).

C-absent systems, physical systems that function as observers in Rovelli's relational sense without being C-operative, should show only the fast decoherence signature: rapid local reduction of quantum interference without the extended integrative process. The difference between Wigner's friend and the rock that might serve as an observer in

Rovelli's democratic ontology is not merely philosophical. It is measurable in the post-measurement neural dynamics of the friend.

This prediction makes an explicit causal claim. C is not accompanying the integration as a passive witness. C is the condition required for the reorganization of the closure grammar to occur at all. Without C, what follows a quantum measurement is only decoherence: the fast local reduction of quantum interference, the relational fact established between systems, the computational state updated. With C, what follows is also closure grammar reorganization: the saddle-node bifurcation through which the new relational fact is constituted as a before and an after in the temporal self, producing the extended bilateral hippocampal-cortical reactivation that Tambini and Davachi (2019) and Tambini et al. (2020) document. C does not merely accompany this reorganization. C is what makes reorganization rather than mere updating occur. The difference between a silicon detector registering a quantum outcome and a physicist registering the same outcome is not just phenomenal coloring on an otherwise identical process. It is a causally distinct process with a measurable neural signature. C-operative measurement produces phase change. C-absent measurement produces decoherence. The distinction is empirical, not merely philosophical.

The substrate question requires direct address. If a silicon system were built that perfectly replicated the saddle-node bifurcation dynamics and produced the three-signature temporal model including extended bilateral reactivation, would it be C-operative? The CC-C framework's answer is substrate neutral but structure strict. C is a primitive that hooks into any system achieving the necessary causal emergence threshold: EI(macro) greater than EI(micro). The framework makes no claim that C requires biological substrate. Carbon is not the point. The causal emergence structure is the point. A silicon system that genuinely achieves EI(macro) greater than EI(micro) and produces the full three-signature model is, by the framework's own criteria, C-operative. This is not biological essentialism. It is structural essentialism: the structure determines the status, not the material. The question of whether any existing or near-future silicon system actually achieves the necessary causal emergence is an empirical question, not a philosophical one. The framework does not prejudge it.

This prediction is testable in principle using neuroimaging on human observers making quantum measurements in contexts designed to isolate the two signatures. It connects the CC-C account of consciousness directly to experimental quantum mechanics and to the consolidation neuroscience literature.

Prediction three: The Planck floor prediction.

The CC-C framework predicts that the Planck scale is the absolute lower bound of m for any C-operative system embedded in this universe, not a technological limitation but a structural one. This generates the following specific prediction: no empirical inquiry

conducted by any C-operative system embedded in this universe will constitute a definite fact at a scale smaller than the Planck length, regardless of the conceptual or technological resources available.

This is distinct from the standard physics prediction that Planck-scale physics is beyond current experimental reach. The CC-C prediction is stronger: it is not that we lack the tools, but that the conditions for closure themselves, the stable spacetime distinctions within which any measurement can be constituted, do not exist below the Planck scale. The Planck length is not the current limit of m. It is the structural floor of m, the absolute minimum below which M begins for any physically embedded observer.

This prediction is in principle distinguishable from a merely technological limitation: if a theory of quantum gravity were to successfully describe sub-Planck physics in formal terms while simultaneously demonstrating that no measurement by any physical observer could constitute a fact at that scale, the CC-C framework would be confirmed rather than disconfirmed. The formal description would itself be a closure that generates remainder at the sub-Planck boundary.

10. Discussion

10.1 On Carroll's Challenge

Carroll's physicalism is the most coherent and careful version of the view the CC-C framework challenges. His account of consciousness as weakly emergent handles c, the organized content of experience, with precision. The challenge the CC-C framework poses is narrow and specific: Carroll's account handles what experience contains. It presupposes the condition under which those contents are experienced rather than merely processed. That condition is C, and C is not derivable from the physical facts that Carroll's emergentist account contains. This is not a mysterian move. It is a structural claim: the description of emergence is itself an act of C. Carroll's descriptions describe. What makes them descriptions for someone is not itself described.

10.2 On Rovelli's Convergence

Rovelli's relational quantum mechanics is the existing physical framework most structurally aligned with the CC-C account. His denial of absolute states, his insistence on relational rather than intrinsic properties, his rejection of a God's-eye view, all converge with the CC-C account of closure-relative constitution. The Wigner's Friend analysis in section 3 makes the divergence precise: Rovelli handles the information-theoretic structure of different perspectives correctly. The CC-C framework adds the structural account of why Wigner's friend's perspective differs from the rock's perspective in a way that matters: C is operative in one and not the other, and that difference is the difference between felt remainder and computed divergence.

10.3 On Smolin's Contribution

Smolin's defense of the reality of time is the cosmological argument most aligned with the CC-C framework's placement of C at the foundation. His insistence that the present moment is real, that the inside view cannot be eliminated, that any adequate cosmology must account for the becoming rather than just the being, these commitments are the physicist's version of taking C seriously. The CC-C framework provides the structural account of why Smolin's intuition is correct: any attempt to model reality from entirely outside the closure of a situated observer generates remainder, because M cannot be fully constituted by any closure, including the closure of the block universe itself.

10.4 The category error objection

A physicist might object that section 6 conflates a physical scale, the Planck length, with a phenomenological gap, the LUP. This would be a category error: a physical quantity and an epistemological distance are different kinds of things and cannot be identified.

The CC-C framework's response is that this objection presupposes the very separation it is meant to critique. The description of the Planck length as a physical scale is itself a phenomenological act, an act of c, of localized consciousness engaging with what it opens onto. Any description of a physical scale is a closure. The question of what lies below the Planck scale is not a question about a purely mind-independent physical quantity. It is a question about the lower bound of what any closure constituted within this universe can reach. The gap is not between the Planck length and the phenomenological gap. The gap is inside every act of description, including the description of the Planck length. At the Planck scale, that gap is not incidental to the description. It is the subject of the description. This is not a conflation. It is the claim.

The stronger version of this response goes further. The objection assumes that physicality is the neutral container within which closures operate: that space, time, and the Planck scale exist prior to and independent of any closure grammar, and that consciousness then arrives afterward to draw distinctions within that pre-given physical stage. The CC-C framework denies this assumption. Space and time are not the container of closure. They are the most fundamental closure grammar available to any C-operative system embedded in this universe. The metric of spacetime, the causal structure of events, the distinction between here and there, now and then: these are not mind-independent facts that closures merely describe. They are the constitutive structure of the closure within which any physical description is possible at all. When that grammar breaks down at the Planck scale, it is not that the territory runs out while the map continues. The map and the territory are the same closure at that level. The Planck scale is where the most fundamental available closure reaches its own remainder. This is not a category error. It is the category claim: physicality itself is a property of closure, not its precondition.

11. Conclusion: The Grammar of Cosmology

Two questions. One reaching before the universe. One reaching into what has no structure at all.

Both hit the same wall. Both are asking about M from inside a finite closure that cannot contain what it is asking about. Both generate remainder that no subsequent answer within the current grammar can absorb.

The Planck scale is the absolute lower bound of m for any C-operative system embedded in this universe. The cosmological horizon is the upper bound. Between them lies the entire domain within which closure is possible at all. Outside both boundaries, in the direction of the very large and the very small, M begins.

Rovelli has shown that quantum facts are relational rather than intrinsic. Wigner's Friend shows that the C-operative observer and the C-absent observer give different kinds of accounts of the same event, not just different relational facts but different orders of mattering. Carroll has shown that consciousness can be understood as emergent without special ontological status, he handles c with precision and presupposes C as the condition of his inquiry. Smolin has shown that the present moment is real, that the inside view cannot be eliminated by modeling reality from outside the closure of any situated observer.

Together they trace the boundary. The CC-C framework names what they are all approaching: the structural condition under which inquiry is possible, the primitive that every physical theory presupposes and none can derive, the limit that every answer approaches without reaching.

The grammar of cosmology is not the grammar of the universe. It is the grammar that finite minds have built to engage with a universe that exceeds every grammar they can build. The remainder at the boundary of that grammar is not ignorance waiting to be eliminated. It is M making itself felt at the limits of what any finite closure can reach.

Before the universe. That is M at the cosmological scale. No structure at all. That is M at the quantum scale. Between them, everything we can constitute. And at every boundary, the remainder that proves the grammar is finite, and the presence that makes that remainder matter.

> *Two productive open directions this paper does not attempt to close. First, the thermodynamic dimension: establishing a Cl is an act of local entropy reduction. If meaning is a phase change, the energy dissipation at the saddle-node bifurcation point is a question physicists will rightly ask. The eta ratio may connect to Landauer's Principle in ways worth pursuing: a generative Cl with negative eta may be thermodynamically more efficient than a defensive Cl with positive eta, requiring fewer*

> *auxiliary hypotheses to hold equivalent information. This is a future research direction, not a claim of this paper. Second, the cosmological origin question: if space and time are the most fundamental closure grammar available to C-operative systems embedded in this universe, the question of what the Big Bang is in CC-C terms becomes genuinely interesting. Is the Big Bang the event through which M first stabilized into the grammar of spacetime? If so, what was the status of C before any C-operative system existed within that grammar? These questions require a theory of pre-cosmic C that this paper does not and cannot provide. They are noted here as the frontier the framework opens rather than closes.*

References

Adlam, E., and Rovelli, C. (2023). Information is physical: Cross-perspective links in relational quantum mechanics. Philosophy of Physics, 1(1), 4.

Bohr, N. (1934). Atomic Theory and the Description of Nature. Cambridge University Press.

Carroll, S. (2019). Something Deeply Hidden: Quantum Worlds and the Emergence of Spacetime. Dutton.

Carroll, S. (2024). Quanta and Fields: The Biggest Ideas in the Universe. Dutton.

Carroll, S. (2025). Why even physicists still don't understand quantum theory 100 years on. Nature, 638, 31-34.

Carroll, S., and Parola, A. (2024). What emergence can possibly mean. philarchive.org/rec/CARWEC-6.

Chalmers, D. J. (1995). Facing up to the problem of consciousness. Journal of Consciousness Studies, 2(3), 200-219.

Di Biagio, A., and Rovelli, C. (2021). Stable facts, relative facts. Foundations of Physics, 51, 30.

Dietz, C. F. (2026a). Consciousness, Closure, and the Cosmos: A consciousness-first research posture via nested closure regimes. Version 3.3.

Dietz, C. F. (2026b). Semantic Remainder: The Language Uncertainty Principle as a Closure Theorem.

Dietz, C. F. (2026c). The Grammar of Relations: Carlo Rovelli's Relational Physics and the Closure Framework.

Dietz, C. F. (2026d). Meaning as Phase Change: Autonoesis, the Interpreter, and the Structure of Genuine Transformation. Version 7.

Everett, H. (1957). Relative state formulation of quantum mechanics. Reviews of Modern Physics, 29, 454.

Hawking, S. W., and Penrose, R. (1970). The singularities of gravitational collapse and cosmology. Proceedings of the Royal Society A, 314, 529-548.

Hoel, E. P. (2017). When the map is better than the territory. Entropy, 19(5), 188.

Jung-Beeman, M., et al. (2004). Neural activity when people solve verbal problems with insight. PLOS Biology, 2(4), e97.

Landauer, R. (1961). Irreversibility and heat generation in the computing process. IBM Journal of Research and Development, 5(3), 183-191.

Nagel, T. (1974). What is it like to be a bat? The Philosophical Review, 83(4), 435-450.

Penrose, R. (2004). The Road to Reality: A Complete Guide to the Laws of the Universe. Jonathan Cape.

Rosas, F. E., et al. (2020). Reconciling emergences: An information-theoretic approach to identify causal emergence in multivariate data. PLOS Computational Biology, 16(12), e1008289.

Rovelli, C. (1996). Relational quantum mechanics. International Journal of Theoretical Physics, 35(8), 1637-1678.

Rovelli, C. (2021). Helgoland. Penguin.

Seth, A. K. (2021). Being You: A New Science of Consciousness. Dutton.

Smolin, L. (2013). Time Reborn: From the Crisis in Physics to the Future of the Universe. Houghton Mifflin Harcourt.

Smolin, L. (1997). The Life of the Cosmos. Oxford University Press.

Tambini, A., and Davachi, L. (2019). Awake reactivation of prior experiences consolidates memories and biases cognition. Trends in Cognitive Sciences, 23(10), 876-890.

Tambini, A., et al. (2020). Causal contribution of awake post-encoding processes to episodic memory consolidation. Current Biology, 30(18), 3533-3543.

Wheeler, J. A. (1990). Information, physics, quantum: The search for links. In W. Zurek (Ed.), Complexity, Entropy, and the Physics of Information. Addison-Wesley.

Wigner, E. P. (1961). Remarks on the mind-body question. In I. J. Good (Ed.), The Scientist Speculates. Heinemann.

Zurek, W. H. (2003). Decoherence, einselection, and the quantum origins of the classical. Reviews of Modern Physics, 75, 715.
