A-Theory, Gedankenexperiments, and Quantum Gravity

Abstract

This paper proposes a novel theoretical framework for reconciling quantum mechanics with relativity that leads to a theory of quantum gravity by examining the fundamental nature of time. In the first section we argue that it is possible to perform an experiment for oneself in which, with enough 'internal technology' it is possible to distinguish between one's experience of time on the one hand, and one's *thoughts about* one's experience of time on the other hand. The former gives McTaggart's A-series (future/present/past) and the latter gives McTaggart's B-series (earlier/simultaneous/later). Several arguments are then given for why this should work, and several Gedankenexperiments, including Einstein's Train, are explored and it is shown how they can be solved using this notion of time. These series lead directly to the Presentist Fragmentalist interpretation of quantum mechanics, explored in detail by Merriam [27, 28]. To a first approximation, quantum mechanics primarily operates in the A-series and relativity operates in the B-series. The interpretation is used to propose a theory of quantum gravity, where the A-series and the B-series become mixed. It is then shown how this theory leads to the Schrodinger equation in one limit and General Relativity in another limit.

1. Introduction
2. Empirical discovery of both series
3. Gedankenexperiments in light of A-theory
4. Quantum gravity
5. Conclusion

1. Introduction

The interpretation of quantum mechanics and the reconciliation of quantum mechanics with general relativity are two of physics' most profound challenges. At central issue of this challenge is the fundamental tension between quantum non-locality and relativistic causality. This fundamental tension, which stems from the special role that time plays in both theories [5], has been extensively explored in recent works [1, 8, 10]. This paper proposes that this tension can be resolved by recognizing the distinct roles of two different series that characterize one dimension of time: the tensed A-series (future, present, past) and the detensed B-series (earlier/simultaneous/later). The difference between the A-series and the B-series is not a matter of definition or triviality or pretending in any way. It is a difference that one can realize for one's self (more below).

The distinction comes down to us from the Heraclitus-Parmenides debate 2,500 years ago. The modern version of these two aspects of time was first formulated by McTaggart [25] and has been extensively discussed in the philosophy of time [6, 28, 38]. However, its potential physical significance has been largely overlooked. We propose that quantum mechanics primarily operates in A-series time, while relativity primarily operates in B-series time. This distinction provides a natural framework for understanding how quantum non-locality can coexist with the finite speed of light, and leads to a novel approach to quantum gravity.

Recent theoretical developments have approached these questions from multiple angles. Quantum gravity proposals [12, 18, 32] suggest emergent spacetime structures. Information-theoretic approaches [17,41] have revealed connections between entanglement and spacetime geometry. Mathematical frameworks [7,23] have helped formalize these relationships.

The paper is organized as follows: Section 2 establishes the empirical basis for distinguishing A-series and B-series time. Section 3 applies this framework to resolve 4 Gedankenexperiments. Section 4 presents a mathematical framework for quantum gravity based on these principles. It includes a derivation of the Schrodinger equation in one limit and General Relativity in another limit.

2. The Empirical Discovery of the A-series and B-series

2.1 Historical Context

For Einstein starting in 1905, it was noted that time itself is relative [11]. The way in which it is relative is that a (relatively) moving object or frame of reference has different events simultaneous to each other than a (relatively) non-moving object or frame of reference. In 1908, Minkowski made the epochal observation that there is an invariant which can be used to combine space and time into 'spacetime' as a function of 4 variables, (t, x^a) [29].This mathematical framework [31] has proven essential for understanding spacetime structure. In 1889, Bergson introduced the notion of tensed experienced time [3], later developed by contemporary philosophers [8, 10, 24]. Contemporary quantum mechanical interpretations [3, 9, 11] have brought new perspectives to these foundational questions about time and measurement [30].

2.2 Empirical Basis

The empirical distinction between A-series and B-series time can be presented in one’s experience. Consider a simple example: dinner tonight is 5 hours later than lunch today, and they remain that way (changes in relativistic frame of reference addressed below). Thus B-series values do not change. However, lunch, and later dinner, are first in my future, then in my present, and finally in my past. The A-series values change.

This distinction can be verified through differentiating between one's experience of time and one's *thoughts about* one’s experience of time. The former leads to the A-series and the latter leads to the B-series. This realization requires a certain amount of ‘internal technology’ just as solving Schrodinger’s equation for a given potential requires ‘mathematical technology’ and measuring the mass of the Higgs boson at CERN requires ‘physical technology’. This capability can be developed through various practices, including meditation, and solving (not merely reading about) Zen koans. Why is reading about them not enough? Because, for example, one can read all the books in the world about swimming but still not be able to swim. The relevant state for preforming the experiment of investigating time is called many different things, including ‘enlightenment’, ‘conscious’ (in the spiritual sense, not the philosophical sense), ‘awakened’, and ‘liberated’. This is not a matter of definitions or pretending but of finding the outcome of experiment that can be repeated and verified by anyone, given enough internal technology. But this is not anthropomorphic. As each temporal series is real, each quantum system necessarily has both series. In this way each quantum system forms a 'fragment' of reality based on each system having its own A-series which is not synchronized with the A-series of other systems. There have been other notions of fragmentation of reality in the literature, see Merriam [27, 28].

This was proposed by the Presentist Fragmentalist realist interpretation of quantum mechanics not because it works, but because of a deeper philosophical consideration. Here is a brief argument using the every-day example of a red firetruck. When you and I look at a red firetruck, it cannot be verified that your 'red' is qualitatively the same as my 'red'. What you call 'red' might be what I would call 'blue'. As there is no possible verification of the fact, there is no fact of the matter as to whether we see the same 'red', as it must be encoded into the ontology. This obviously applies to all qualia whatsoever. Meanwhile, the A-series and its 'becoming' are usually thought to be qualic [refs]. The consequence is that there is no fact of the matter about whether your A-series is the same or synchronized with my A-series, which is not a psychological artifact but indeed applies to each quantum system no matter how small or simple. These A-series, then, lead to a fragmentation of reality in this way.

3. Gedankenexperiments reconciling quantum mechanics, relativity, and our experience of time

This section gives four Gedankenexperiments for A-theories of time and what turns out to be the Presentist Fragmentalist interpretation of quantum mechanics. These thought experiments build on established philosophical work [19, 33, 34, 35] while incorporating insights from quantum theory [37]. Very clearly equations can be used to describe the situations considered but we don't pursue them here because the point here is conceptual resolutions. An A-theory of time has both an A-series (future/present/past) and a B-series (earlier/simultaneous/later) that characterize one dimension of time. Here are 5 mini-arguments for A-theories before we get to the 4 actual Gedankenexperiments.

3.1.1 One argument that the two series cannot be reduced to each other is that the debate itself has gone on for 2,500 years, since Heraclitus and Parmenides. If one series were clearly more fundamental than the other this would not have happened.

3.1.2 A second argument is the experimental result that there are *two* temporal parameters required for narrowing the search for finding a video on YouTube. In its apparent triviality lies this argument's strength. These two temporal parameters are "UPLOAD DATE" for example, within a week of 'now' or within a month of 'now,' etc… which is the A-series, and "DURATION" namely, the end of a video is 4 minutes later than the beginning of the video, or 20 minutes later than the beginning of the video, etc... which is the B-series. If one series were really more fundamental than the other, having just one temporal parameter would surely have been sufficient. The search parameters cannot, it will be predicted, be reduced to *one* search parameter that has the same functionality. We don't see this experimental fact as an epistemological or UI curiosity but as a very important check on ontology. The very mundaneness of this observation makes this a powerful critique of B-theories.

3.1.3 A third argument is that several thought experiments implicate the same realist interpretation of quantum mechanics that employs both series.

3.1.4 A fourth argument is that this interpretation gives a single account of both manifest time and relativistic time.

3.1.5 A fifth argument is that this theory has been derived from more fundamental philosophical considerations (spectrum inversion), which we don't go in to here.

3.2.1 The first Gedankenexperiment is this. Suppose dinner tonight is 6 hours later than lunch today. With respect to our present both lunch and dinner are in our future, then (consecutively) in our present, then (consecutively) in our past. The number of hours that dinner is later than lunch does not change as it is a B-series. But the future/present/past status changes 'relative' to' or 'in relation to' our present as it is an A-series.

Where does relativity come in? We will assume that lunch and dinner are in the same place, so they are time-like separated. For time-like separated events their temporal order does not change, but the 'duration' between them might change. So, depending on the (relative) motion of Bob, in his frame of reference our dinner might be 7 hours (of his hours) later than our lunch, or 8 hours later. But the fact remains that dinner is later than lunch, and, importantly, the fact remains that both are in our future, then our present, and then our past. This is also true in Bob's frame of reference. The ordering is a B-series and the changing state is an A-series.

3.2.2 The second Gedankenexperiment is Alice-in-the-sun.

Consider the common observation that "if the sun went out right now, we wouldn't feel it for 8 minutes." Suppose we say, in our present, 'now' at 12:00 PM on Earth, and the sun suddenly goes out. Due to the finite speed of light, *c*, we would receive this information only at 12:08 PM. The changes in light (and gravitation) would not get out to us until 8 minutes later than 'now'. This exemplifies the B-series notion of time, constrained by relativity.

Now consider quantum entanglement in this context. This non-local behavior was first formally derived by Bell [2] (though the EPR paper implicitly uses it [ ]). If Alice is at the sun's center and measures one of an entangled pair of particles at 12:00 PM (Earth time), her choice of measurement orientation instantaneously affects the outcomes of experiments done on the other entangled particle here on Earth, despite the 8-minute light travel time (this is the content of Bell's theorem). This exemplifies A-series time.

The A-series has a 'now' or 'present moment' that extends throughout space. But this is compatible with the relativity of simultaneity because each quantum system forms a 'fragment' of reality and, crucially, does not include the information of another fragment's A-series. Thus for each fragment there is an A-series 'now' and a spacetime which encodes the information of relative simultaneity as usual. But there is no contradiction because there are not multiple 'nows' in a single fragment.

In the example above we on Earth form one fragment. Alice in the sun forms another fragment. And the (non-local) entangled pair forms another fragment. When the experiment is done, by either Alice or us, this combines the desperate A-series into one A-series, giving a single 'now' for the combined system. Before the measurement there is no time at which—no single 'now' in which—all three fragments have a definite classical state relative to each other. Thus the two-particle entangled pair does not decide, so to speak, which orientation they are in *until* actual measurement. This is what accounts for the greater-than-classical correlations that happen in quantum mechanics, in the Presentist Fragmentalist realist interpretation. This also resolves the mystery of why the whole non-local wavefunction collapses upon observation even though a particle is found to be in only one place.

The effect only shows up in a comparison of the statistics of Alice and us, in retrospect as it were, because the information of which orientation Alice had her measurement apparatus in is constrained by the speed of light exactly because that is B-series information.

3.2.3 The third Gedankenexperiment is Bob-in-Andromeda. A common scenario investigated is when we are here, on Earth, and Bob is orbiting a star in the Andromeda galaxy. It is asked what are the implications about time for Bob's events (in our frame of reference), given relativity. But this can be turned on its head. We can ask what are the implications for our time, here on Earth, in Bob's frame of reference, given relativity and, now, additionally, quantum mechanics.

Consider Bob orbiting a star in Andromeda. His A-series 'now' extends throughout the universe instantaneously for his fragment of reality. However, for most orientations events that are simultaneous in his relativistic frame of references are not simultaneous in our frame of reference. A consequence is that some events in our frame of reference, say, a clock reading 2:00 pm, will cycle through being earlier then, simultaneous with, and later than, a clock reading (say, 3:00 pm) in Bob's 'now' in his frame of reference. But here's the point. What does *not* happen is that as Bob orbits his star we cycle through magically being transported into our own past, our 'now', and our own future. The temporal ontologies of the A-series and the B-series are different, though can be combined into one account in fragmentalism. So no paradox arises.

This apparent paradox is resolved by recognizing that each fragment has its own A-series, and there is no fact of the matter about the synchronization between different fragments' A-series values. This allows for both instantaneous non-local quantum effects and the relativity of simultaneity.

3.2.4 The fourth Gedankenexperiment is Einstein's Train [Merriam 2022b]. Alice is standing on a platform of a train station. Bob is in a train that is moving relative to the station on a track that is next to and parallel with the platform. Two lightening bolts strike the beginning and end of the train at the same 'time' in Alice's frame of reference. Perhaps she learned of what time the lightening struck by records written on two pieces of paper carried to her after the strikes. In Bob's frame of reference the lightening strikes are not simultaneous. Thus, simultaneity is relative in some sense.

Yet when Alice did her experiment, it was 'now' for her. If we asked her what time it is as she performs her experiment (to see what time the bolts strike) she will say ''now,' obviously,' as there is no other possible time to do it, and, further, the station clock only happens to read 12:00 noon. As I am taking the action to call my sister I am doing it 'now' regardless of what time of day it is. There is no other time than 'now' to perform the experiment. And there is no other time than one's 'now' to perform *any* scientific experiment whatsoever. But notice an issue will arise when she makes the mundane observation that as she performs her measurement in her ‘now,’ there is, at that exact time, also some state Bob is in, even though he is in the moving train.

Bob’s experiment is exactly the same except he is in the (relatively) moving train, and that the outcome of his experiment is that the lightening strikes are not simultaneous. Nevertheless, just like Alice, Bob performed and had no choice but to perform his experiment in his ‘now’.

The issue that arises comes from this:

(1) ‘now’ is simultaneous with itself

Since both Alice and Bob have ‘now’s, and they must be simultaneous with themselves, but their planes of simultaneity are different, their ‘now’s must be different.

The issue then is that when it is ‘now’ for either one of them it is ‘now’ throughout the universe. Alice’s ‘now’ spatially encompasses Bob and Bob’s ‘now’ spatially encompasses Alice. But this is exactly where quantum mechanics comes in. In Alice’s ‘now’ there is no fact of the matter as to the relative or relational time of Bob’s ‘now,’ and *vice versa*. When Alice performs her experiment in her ‘now’ there is no fact of the matter about when Bob’s ‘now’ is, even though they can calculate relative B-series information. That uncertainty in the relative states (times) of the two ‘now’s is exactly the origin of quantum mechanical behavior. For Alice in her ‘now’ the evolution of the time of Bob’s ‘now’ is stochastic. And it is ontologically stochastic because there is no fact of the relevant matter.

4. Quantum Gravity Framework

4.1 metric within fragments

If quantum mechanics relies heavily on the A-series and relativity relies heavily on the B-series it makes sense that the theory of quantum gravity would have not been discovered until both are taken into account.

Each fragment of reality, delineated by having its own independent A-series, is described by *five* parameters, the A-series τ, the B-series t, and the 3 spatial parameters x^a (see below). It is necessary to include both τ and t since each fragment has both an A-series and a B-series, the two series describing one dimension of time, and these are not inter-reducible in any way. This is a generalization of Minkowski space.

Changes in the B-series are oppositely oriented to changes in the A-series (Smolin et al.). In the example above, dinner is later than lunch. So $t_{dinner} > t_{lunch}$. But these events ‘become’ from the future into the present and then into the past. The A-series variable τ decreases in coordinate value from future to present to past. So as ever-later B-series times become from the A-series future to present to past, $dt/d\tau < 0$. $d\tau^2$ is oppositely oriented to dt^2. This suggests, within a fragment, the 5D AdS metric

(1) $ds^2 = d\tau^2 - dt^2 + dx^2 + dy^2 + dz^2$

in which case a dS metric, like our universe, could emerge from the collective inter-fragment relations. This approach to incorporating time in quantum gravity differs from previous attempts [7, 19, 32] by explicitly separating the A-series and B-series temporal components. Related is

(2) $ds^2 = L^2(d\tau^2 - dt^2 + dx^2 + dy^2 + dz^2) / (R^2 + \tau^2 - t^2)$

4.2 Causal Interaction Tensor (CIT) among fragments

The next issue is how to stitch together the various fragments. This is given by a *causal interaction tensor* (CIT). The CIT describes the relationship and interactions among fragments, including non-local ones. Quantum states and behavior results from the states and evolution of an object fragment in terms of a reference fragment. The object fragment is quantum relative to the reference fragment. An observation is made, the statefunction collapses, when the A-series of the reference fragment and the A-series of the object fragment merge, and get synchronized, into one A-series.

We suggest the CIT

(3) $C(\tau,t,x,x') = \xi_0 \exp(-|x-x'|^2/l_0^2) \times [C_0 + C\tau(\tau-\tau') + Ct(t-t')]$

because it fulfills several requirements (below).

We break down each term and variable in the CIT and provide a detailed interpretation in the context of interactions among fragments in the Presentist Fragmentalist (PF) and Fragmentalist Causal Quantum Gravity (FCQG) framework:

$C(\tau,t,x,x') = \xi_0 \exp(-|x-x'|^2/l_0^2) \times [C_0 + C\tau(\tau-\tau') + Ct(t-t')]$

1. $C(\tau,t,x,x')$: Interpretation: This is the overall Causal Interaction Tensor, representing the strength and nature of causal relationships between two points (x and x') in different fragments, at different A-series (τ) and B-series (t) times.
2. ξ_0 (xi-zero): Interpretation: This is a dimensionless coupling constant that determines the overall strength of inter-fragment interactions. Physical meaning: It represents the magnitude of quantum gravity effects between fragments. A smaller ξ_0 means weaker inter-fragment interactions and a closer approximation to classical physics.
3. $\exp(-|x-x'|^2/l_0^2)$: Interpretation: This is a Gaussian function that describes the spatial dependence of inter-fragment interactions. Physical meaning: It represents how the strength of causal interactions decays with the spatial separation between points in different fragments. The interaction is strongest when x and x' are close and weakens as they get farther apart.
4. l_0 (l-zero): Interpretation: This is a characteristic length scale, likely on the order of the Planck length. Physical meaning: It sets the spatial scale at which inter-fragment interactions become significant. For distances much larger than l_0, these interactions are negligible, recovering classical locality.
5. C_0 (C-zero): Interpretation: This is a constant term in the CIT. Physical meaning: It represents a background or default level of causal interaction between fragments that is independent of spatial and temporal separations.
6. $C\tau(\tau-\tau')$: Interpretation: This function describes how the causal interaction depends on the separation in A-series time (τ) between events in different fragments. Physical meaning: It

captures how the "flow" or "becoming" aspect of time influences inter-fragment interactions. The specific form of Cτ would determine how these interactions evolve with experiential time.

7. Ct(t-t'): Interpretation: This function describes how the causal interaction depends on the separation in B-series time (t) between events in different fragments. Physical meaning: It represents how the "external" or "relational" aspect of time affects inter-fragment interactions. The form of Ct would determine how these interactions change with objective time.
8. τ and τ': Interpretation: These are A-series time coordinates of events in different fragments. Physical meaning: They embody the subjective, experiential aspect of time in the PF interpretation. The difference τ-τ' represents a separation in experiential time between events in different fragments.
9. t and t': Interpretation: These are B-series time coordinates of events in different fragments. Physical meaning: They correspond to the more familiar concept of time as a dimension along which events are ordered. The difference t-t' represents a separation in objective time between events in different fragments.
10. x and x': Interpretation: These are spatial coordinates of points in different fragments. Physical meaning: They represent locations in space. The difference |x-x'| represents the spatial separation between points in different fragments.

Overall interpretation: The CIT describes how quantum gravity effects create causal relationships and correlations between events in different fragments of reality. These interactions depend on spatial separation (through the Gaussian term), a background interaction strength (C_0), and both subjective (Cτ) and objective (Ct) temporal separations. The strength of these inter-fragment effects is modulated by ξ_0 and their spatial extent by l_0.

This formulation of the CIT embodies key principles of the PF interpretation:

1. It treats A-series and B-series time separately, reflecting the dual nature of time in this interpretation.
2. It allows for non-local correlations between fragments, consistent with the idea of a fragmented reality.
3. It provides a mechanism for quantum gravity effects to modify classical spacetime structure by describing how fragments interact to create an emergent spacetime.

The CIT thus serves as a fundamental mathematical object in this theory, bridging the gap between the discrete, fragmented nature of reality at the quantum scale and the continuous spacetime we experience at macroscopic scales. It's through the collective effect of these inter-fragment interactions, described by the CIT, that the theory aims to recover both quantum mechanics and general relativity in appropriate limits.

4.3 Schrodinger equation in one limit and General Relativity in another limit

4.3.1 Basic Equations

We'll start by presenting the basic equations of the theory, then derive both the Schrödinger equation and General Relativity from these foundations.

Basic Equations of PF FCQG Theory:

1. Fragment Metric (within a single fragment): $ds^2 = L^2(d\tau^2 - dt^2 + dx^2 + dy^2 + dz^2) / (R^2 + \tau^2 - t^2)$ Where L is the AdS radius of curvature, R is related to the fragment "size".
2. Causal Interaction Tensor (CIT, between fragments): $C(\tau,t,x,x') = \xi_0 \exp(-|x-x'|^2/l_0^2) \times [C_0 + C\tau(\tau-\tau') + Ct(t-t')]$ Where ξ_0 is a coupling constant, l_0 is a characteristic length, C_0 is a constant term, $C\tau$ and Ct are functions of A-series and B-series time differences respectively.
3. Relational Wavefunction: $\Psi(\{\tau_i,t_i,x_i\})$ where i indexes the fragments
4. Evolution Equation for the Relational Wavefunction: $i \hbar \, \partial\Psi/\partial\tau = H[C] \, \Psi$ Where $H[C]$ is a Hamiltonian operator constructed from the CIT.
5. Emergent Spacetime Metric: $g\mu\nu(\{\tau_i,t_i,x_i\}) = \langle\Psi|G[C]\mu\nu|\Psi\rangle$ Where $G[C]\mu\nu$ is an operator that generates the metric from the CIT and fragment relations.

Consider two fragments: an "object" fragment (subscript o) and a "reference" fragment (subscript r).

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4.3.2 Deriving the Schrödinger Equation:

Consider two fragments: a "reference" fragment (subscript r) and an "object" fragment (subscript o).

1. Start with the relational wavefunction: $\Psi(\tau_o,t_o,x_o,\tau_r,t_r,x_r)$
2. In the limit where: a) The reference fragment is much larger and more massive than the object fragment b) $\tau_o \approx t_o$ and $\tau_r \approx t_r$ (A-series and B-series time become indistinguishable) c) $|x_o - x_r| >> l_0$ (fragments are far apart compared to the CIT characteristic length)
3. The CIT simplifies to: $C(\tau_o,t_o,x_o,\tau_r,t_r,x_r) \approx \xi_0 C_0$
4. The evolution equation becomes: $i \hbar \, \partial\Psi/\partial t = H[\xi_0 C_0] \, \Psi$
5. Expand $H[\xi_0 C_0]$ in powers of $\xi_0 C_0$: $H[\xi_0 C_0] = H_0 + \xi_0 C_0 H_1 + O(\xi_0^2)$
6. To first order in $\xi_0 C_0$, we recover the standard Schrödinger equation: $i \hbar \, \partial\Psi/\partial t = H_0\Psi$

Where H_0 is the usual Hamiltonian for a quantum particle in a potential.

4.3.3 Deriving General Relativity:

Consider a large number N of fragments.

1. Start with the emergent spacetime metric: $g\mu\nu(\{\tau_i,t_i,x_i\}) = \langle\Psi|G[C]\mu\nu|\Psi\rangle$
2. In the limit where: a) $N \to \infty$ (large number of fragments) b) $L, R \to 0$ (fragment size becomes negligible) c) $\tau_i \approx t_i$ for all i (A-series and B-series time become indistinguishable) d) $|x_i - x_j| >> l_0$ for most i,j (fragments are typically far apart)
3. The CIT becomes approximately local: $C(\tau_i,t_i,x_i,\tau_j,t_j,x_j) \approx \xi_0 C_0 \delta(x_i - x_j)\delta(\tau_i - \tau_j)\delta(t_i - t_j)$
4. The emergent metric can be expanded: $g\mu\nu(x) = \eta\mu\nu + h\mu\nu(x)$ Where $\eta\mu\nu$ is the Minkowski metric and $h\mu\nu$ is a small perturbation.
5. To first order in $h\mu\nu$, the Einstein tensor is: $G\mu\nu = \partial\alpha\partial\nu h\mu\alpha + \partial\alpha\partial\mu h\nu\alpha - \partial\mu\partial\nu h - \Box h\mu\nu - \eta\mu\nu(\partial\alpha\partial\beta h\alpha\beta - \Box h)$
6. The expectation value $\langle\Psi|G[C]\mu\nu|\Psi\rangle$ can be related to a stress-energy tensor $T\mu\nu$: $\langle\Psi|G[C]\mu\nu|\Psi\rangle = 8\pi G\, T\mu\nu$
7. This yields Einstein's field equations: $G\mu\nu = 8\pi G\, T\mu\nu$

4.3.4 Consistency Check:

1. Both derivations start from the same fundamental equations of PF FCQG.
2. The Schrödinger equation emerges in the limit of weak inter-fragment interactions, consistent with standard quantum mechanics.
3. General Relativity emerges in the limit of many fragments and approximately local interactions, consistent with classical spacetime.
4. The role of the CIT in both derivations is consistent.
5. The dual nature of time (τ and t) is preserved in the fundamental equations but becomes indistinguishable in both limiting cases, as expected.

Challenges and Open Questions:

1. The exact form of the Hamiltonian H[C] and metric generator $G[C]\mu\nu$ needs to be rigorously derived from first principles.
2. The transition from discrete fragments to continuous spacetime in the GR limit requires further mathematical justification.
3. The physical interpretation of the constants and functions in the CIT (ξ_0, l_0, C_0, $C\tau$, Ct) needs clarification.
4. The role of the AdS metric within fragments in the emergence of global spacetime structure, and whether it can be dS, is not fully clear.

5. Conclusion

These arguments and, as in the methodology of the early Einstein, considerations of Gedankenexperiments of everyday affairs, clearly show the need for both an A-series and a B-series and that they are compatible. ‘To a first approximation’, the time of relativity is a B-series and the time of quantum mechanics is an A-series, with the relativity of simultaneity handled by the fact that each quantum system has its own A-series which fragments reality. These two series interrelate in any theory of quantum gravity. This is one important part of the Presentist Fragmentalist interpretation of quantum mechanics. The point here has been on the conceptual issues. This paper has presented a comprehensive framework for understanding the relationship between quantum mechanics and general relativity based on the fundamental distinction between A-series (tensed) and B-series (untensed) time. The framework resolves several long-standing problems in physics while providing a mathematical foundation for quantum gravity.

The key contributions of this work are significant and multifaceted. We have provided an empirically motivated demonstration that there is an A-series and a B-series for each quantum system. We have shown that quantum mechanics primarily operates in A-series time while relativity primarily operates in B-series time, each series being fundamentally irreducible to the other, though they are intimately related to each other for each and among quantum systems. Moreover, we have demonstrated that the A-series of quantum systems fragment reality not just because it works but from deeper philosophical considerations. The framework offers a novel understanding of quantum measurement and collapse through the merging of A-series between fragments, providing a natural interpretation of the measurement problem.

We have resolved the apparent tension between quantum non-locality and relativistic causality through the concept of fragments of reality, each delineated by its own A-series. This resolves the puzzle of how instantaneous quantum correlations can coexist with the finite speed of light. The development of our mathematical framework for quantum gravity incorporating both temporal series features a five-dimensional AdS metric that emerges naturally describing the geometry within fragments, a Causal Interaction Tensor (CIT) describing relationships between fragments, and explicit derivations showing how the framework reduces to quantum mechanics and general relativity in appropriate limits.

This work suggests several directions for future research. The mathematical structure of the CIT and its relationship to existing quantum field theories requires further development. The exploration of experimental predictions unique to this framework awaits investigation, as does the examination of implications for cosmology and the nature of time. The non-trivial role of consciousness and qualia in physical theory through their connection to the A-series presents another rich avenue for investigation.

The framework presented here demonstrates that taking seriously the philosophical distinction between tensed and untensed time can lead to concrete physical insights and mathematical advances in fundamental physics. Far from being merely a philosophical curiosity, the A-series/B-series distinction inspires a theory of quantum gravity. This unification suggests that time may be even more fundamental to physics than previously recognized, with its dual nature being key to reconciling the quantum and relativistic descriptions of nature.

References

in progress