The Block Universes of Quantum Gravity: Eternalism and Fragmentalism Beyond Spacetime

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Abstract

Relativity supports a block-universe view on which past, present and future entities coexist within spacetime. Quantum gravity complicates this picture by suggesting that spacetime may be emergent. I distinguish spacetime emergence from block emergence: the former concerns the emergence of spatiotemporal structure, while the latter concerns the emergence of a unified domain of spatiotemporal existence *simpliciter*. This distinction clarifies three positions: standard eternalism, atemporal eternalism and atemporal fragmentalism. I argue that eternalism remains the default option once the existence of spacetime is accepted. Atemporal fragmentalism, however, remains a sound interpretation of certain approaches to quantum gravity.

Contents

1. The Block Universe in Modern Physics

The so-called *block universe* has become a popular metaphysics of spacetime and this popularity is largely due to relativistic physics (see, e.g., Earman 1995; Putnam 1967; Saunders 2002; Smeenk 2013; Wüthrich 2013). On this view, reality is a four-dimensional whole: entities construed as past, present and future coexist within spacetime, and their temporal—or more precisely, timelike—relations are tenseless.[1] On the standard B-theoretic reading, past, present and future are distinguished only relationally by their positions in an ordering of entities encoded in the geometry of spacetime; they are equally real. This existential claim is usually dubbed *eternalism*.[2] Overall, the notion of a *block* can be understood as a claim about the domain of natural existence *simpliciter*: the existential quantifier ranges not only over entities spatially located in a putative universal present, but also over entities located along an additional physical dimension—typically, but not necessarily as we will see, the temporal dimension of four-dimensional spacetime.[3]

Two alternative families of views have historically been contrasted with the block universe. *Presentism* asserts that only present entities exist: past and future entities do not exist at all (see, e.g., Bourne, 2006; Ingram, 2019; Zimmerman, 2011). Its cousin, the *growing block theory*, claims that past and present entities exist but the future does not yet exist; the world grows as new entities come into being (see, e.g., Briggs and Forbes, 2016; Correia and Rosenkranz, 2018; Tooley, 1997).[4] Both views attempt to capture an intuitive idea of temporal passage that seems absent from the block.

However, once *special relativity* and *general relativity* are taken seriously, it becomes exceedingly difficult to maintain a global present or a privileged foliation of

1 "Timelike" is used here in the relativistic sense: it refers to timelike directions or relations within the four-dimensional spacetime manifold. In the language of metaphysics, such relations are B- or C-relations. B-relations are intrinsically orientated, while C-relations are not intrinsically orientated, the orientation of phenomena coming instead from other entities or processes such as causal relations (see, e.g., Farr, 2020; Le Bihan, 2015). This nuance will not play a role in this work.

2 The moving spotlight theory (Cameron, 2015; Miller, 2019) combining eternalism with an A-theory is sometimes classified as a block. This distinction will not play a role in this chapter, however, since A-, B- and C-theoretic blocks will be discussed together under the broader category of the spatiotemporal block.

3 I use "existence *simpliciter*" in the standard metaphysical sense in which eternalism is contrasted with presentism, but restricted here to the natural or physical domain relevant to spacetime physics. To exist *simpliciter* in this sense is to belong to the non-present-indexed domain of physical entities, rather than to exist only relative to a time, perspective, frame, fragment, or other restricted parameter. This usage is neutral on whether abstract entities, such as numbers, sets or propositions, exist. Some authors dispute whether the presentism/eternalism debate is best formulated in terms of existence *simpliciter*, unrestricted quantification, temporal location, or the distinction between temporaryism and permanentism (Ingram and Tallant, 2026; Williamson, 2013). I will not enter that debate here. What matters for present purposes is whether physical reality contains a global domain of entities not restricted by a privileged present, and whether such a domain is spatiotemporal, non-spatiotemporal, or absent altogether.

4 In my terminology, no-futurism refers to the existential claim, while the growing block refers to the conjunction of no-futurism and the view that reality grows by adding new entities.

spacetime underwriting such views. Special relativity shows that simultaneity is frame-dependent: there is no invariant separation of events into what is absolutely present, what is absolutely past and what is absolutely future. General relativity deepens the difficulty, not simply by relativising simultaneity further, but by making the spacetime geometry itself dynamical and by allowing models whose global causal structure is not well behaved. In special relativity, there is no privileged global present, but there remains a fixed Minkowski background and many admissible inertial foliations. In general relativity, by contrast, some spacetimes do not even admit a suitable global foliation into three-dimensional hypersurfaces, and some contain causal pathologies such as closed timelike curves. Some continue to resist the conclusion that relativity undermines presentism and no-futurism views (e.g. Craig, 2001; Zimmerman, 2011), but the prevailing consensus is that these positions require substantial additional structure not supported by the physics (see, e.g., Wüthrich, 2010, 2013). Overall, our best empirically confirmed spacetime physics strongly supports, at the very least, the block universe view.

However, granting that relativity favours a four-dimensional block does not settle the matter once and for all. General relativity is not expected to be absolutely fundamental (in the sense of being final), and quantum mechanics is waiting in the wings. Our best attempts at formulating a *theory of quantum gravity*—unifying *general relativity* with *quantum physics*—increasingly suggest that spacetime may not be fundamental (Huggett and Wüthrich, 2013, 2025). Instead, spacetime may emerge from a more fundamental non-spatiotemporal structure. What exactly this amounts to depends on which spacetime features are denied fundamentality, and varies significantly across approaches to quantum gravity. In such a context, the traditional block universe picture cannot simply be assumed to carry over: if spacetime is derivative, then the spatiotemporal block, at least in its standard form, would also be derivative. And if there is no spacetime at all, then, perhaps, there is no block at all.

The central question of this chapter is therefore what becomes of the block universe once spacetime is no longer assumed to be fundamental. Does the block survive merely as an emergent spatiotemporal structure? Does it reappear at the fundamental level in a non-spatiotemporal form? Or can quantum gravity motivate the more radical possibility that no unified block exists at all? I will argue that quantum gravity requires distinguishing between several concepts of blocks. The relevant existential domain(s) could indeed be spatiotemporal or non-spatiotemporal, fundamental or derivative and, in some physically possible cases, could fail to exist altogether. The chapter thereby extends my earlier work on eternalism and quantum gravity (Le Bihan, 2020) by introducing fundamental fragmentation as a further option, and by asking whether a real derivative block can be recovered from a fundamentally fragmented ontology.

The rest of the chapter proceeds as follows. Section 2 revisits the lessons of special and general relativity, motivating the block universe and explaining why presentism and the growing block require additional structure not supplied by relativistic physics. Section 3 introduces spacetime emergence and distinguishes conservative from radical forms. Section 4 develops three existential interpretations of the block—standard eternalism, atemporal eternalism and atemporal fragmentalism—and connects them to reductionist, derivativist and eliminativist accounts of spacetime emergence. Section 5 returns to string theory, loop quantum gravity and causal set theory in order to examine how different quantum-gravitational frameworks motivate different combinations of these existential and emergence claims. Section 6 argues that eternalism broadly construed remains the default position once spacetime is accepted as real, whether derivatively or by reduction, while fragmentalist alternatives face either overdetermination or a problem of existential integration. Section 7 summarises.

2. Relativity

2.1. Special Relativity

Einstein's special relativity revolutionised our understanding of space and time by showing that they are proper objects of empirical investigation. In his 1908 "Raum und Zeit" lecture (translated as "Space and Time"; 1923), Minkowski proposed a four-dimensional formulation of the theory in which space and time are unified within a single geometrical structure equipped with a flat Lorentzian metric. The resulting spacetime structure exhibits symmetries governed by the Lorentz rather than the Galilean group of Newtonian physics. Lorentz transformations relate inertial frames and imply that judgments of simultaneity depend on the observer's state of motion: two entities simultaneous in one inertial frame are generally not simultaneous in another. The spacetime structure instead determines a light-cone geometry dividing pairs of entities into timelike, spacelike and lightlike separations. Later philosophical interpretations of relativity took these features to undermine the idea of a unique global present (Putnam, 1967; Rietdijk, 1966). If there is no invariant notion of *now*, then presentism or the growing block theory appear difficult to sustain, since the content of the present (and the past) would itself become frame-dependent.

Special relativity also prompts a reconsideration of the relation between geometry and dynamical laws. On the *geometrical* interpretation, often associated with Weyl and later Einstein himself, spacetime geometry is fundamental and dynamical phenomena are explained by geometric facts. Rods contract and clocks dilate the way they do because they inhabit a four-dimensional manifold with a certain metric; Lorentz symmetry is a property of this metric. On this view spacetime stands as a real, physical structure that constrains the behaviour of matter and light.

An alternative, the *dynamical* interpretation championed by Brown (2005), rejects the explanatory primacy of spacetime geometry. It takes the laws governing rods, clocks and fields as fundamental and understands Lorentz invariance as a symmetry of those laws. On this view, the metric codifies the dynamical behaviour of matter rather than constituting a primitive spacetime structure. The relativity of simultaneity still holds, but it is explained dynamically rather than geometrically. The dynamical interpretation does not reintroduce a preferred frame. Even if the metric is derivative, there remains no invariant simultaneity relation; the empirical content of relativity is preserved. Consequently, presentism gains no support from the dynamical interpretation alone and would require additional structure or assumptions. In fact, far from helping to make a case for presentism or the growing block theory, the dynamical approach may prove fruitful, as argued in Le Bihan and Linnemann (2019), for understanding the relation between spacetime and a non-spatiotemporal structure in quantum gravity, precisely because it already demotes spacetime from its privileged status in general relativity and thereby reduces the explanatory gap between general relativity and quantum gravity.

Finally there is the *neo-Lorentzian* interpretation, usually favoured by metaphysicians who wish to reconcile relativity with a privileged present (Craig, 2001; Zimmerman, 2008). This view posits an unseen absolute time and treats Lorentz transformations as disguises for motion relative to this hidden structure. A preferred foliation of spacetime exists but is unobservable. While this restores an objective present and allows presentism or the growing block theory to be maintained, it does so at the cost of positing structure beyond what is required by the theory's empirical content. As such, it functions less as an interpretation of relativity and more as an attempt to preserve pre-relativistic metaphysical intuitions within a relativistic setting. Absent independent motivation for the extra structure, most philosophers and physicists regard the neo-Lorentzian approach as *ad hoc*.

Despite their differences, these three readings agree on a crucial point: special relativity offers no natural home for an objective, universal present. The relativity of simultaneity and the lack of a frame-independent foliation mean that any global division of entities into past, present and future must be imposed by hand. The block of special relativity, consisting of all entities in the Minkowski manifold, thus emerges as the simplest metaphysical reading.

2.2. General Relativity

Einstein's general relativity supports further the block picture by replacing the fixed spacetime background of special relativity with a dynamical spacetime geometry (one that reacts to the matter distribution). This matters metaphysically because general relativity is not merely an extension of special relativity, but the broader framework within which its lessons about space, time and simultaneity must ultimately be mulled over. Gravity is now reconceptualised as the curvature of spacetime rather than as a force on a fixed background (Earman, 1989; Friedman, 1983). The metric tensor $g_{\mu\nu}$ becomes a dynamical field determined by the distribution of stress–energy via the Einstein field equations. As a result, spacetime becomes dynamical: it can stretch, bend, and develop singular structures under appropriate conditions. This is radically different from Newtonian space and time, and even from Minkowski spacetime, which are fixed backgrounds.

General relativity also brings into focus the issue of spacetime *substantivalism* versus *relationalism* (Earman and Norton, 1987). On a straightforward substantivalist reading, spacetime is a real entity with its own existence and properties: the metric field is part of the ontology, and matter fields inhabit and interact with it. On relationalist or structuralist readings, by contrast, spacetime is understood less as a substance than as a relational or structural entity, possibly grounded in matter, fields, or the laws governing them.[5] For present purposes, the important point is that both sides typi-

[5] I am here presenting the standard dialectic. My own view is that general relativity does not

cally treat general relativity as describing a unified four-dimensional structure. The later question will be whether that structure is fundamental, derivative, or absent altogether.

A further, sometimes neglected, consequence of general relativity for block metaphysics is that not all general-relativistic spacetimes admit the kind of global foliation into spacelike hypersurfaces that presentist and growing-block views naturally require. This creates a serious difficulty for such views, which naturally rely on the existence of a privileged global present (Wüthrich, 2013). Global hyperbolicity is sufficient for such a foliation, and many physically interesting spacetimes (including realistic cosmological models) are globally hyperbolic, but this is not guaranteed by the field equations. There exist solutions representing rotating universes (e.g. Gödel's universe) or certain types of black holes that admit closed timelike curves or other causal anomalies (Earman et al., 2009). In such spacetimes there may be no slicing of the manifold into a family of three-dimensional surfaces that intersect every timelike worldline exactly once.

Thus, even if one wished to identify a global present with some foliation of spacetime, general relativity does not single out any candidate. To retain presentism or the growing block, one must restrict attention to spacetimes admitting suitable global foliations, and supplement the theory with additional structure or laws selecting one foliation as physically privileged. Such moves are widely regarded as unmotivated by the physics. In the absence of such considerations, general relativity lends further support to the block universe interpretation.

Moreover, the problem is not merely that general relativity fails to select a preferred foliation. As I argued in Le Bihan (2014), if non-foliable spacetimes such as Gödel-like universes are physically possible, then presentism and the growing block can be at best contingently true, and more specifically nomologically contingent. The skeptical challenge is then immediate: if the local physics of our universe is compatible with physically possible worlds in which no global present can exist, and if accessible physical evidence underdetermines whether the universe is globally foliable, how could one be justified in believing that presentism or the growing block is true? A priori arguments for these views therefore face a serious epistemic challenge: they must explain not only how a privileged present could be added to relativistic physics, but also how we could be justified in believing that our world is one of the special worlds in which such a structure exists.

A related pressure comes from black holes. General relativity predicts the existence of black holes, and this prediction is now strongly supported by observational evidence. Yet black holes are not ordinary localised entities, or at least not completely localisable ones. Their boundary, the event horizon, is defined globally: the present location of an event horizon depends on the causal structure of the whole spacetime, including the future development of the black-hole region. As Baron and Le Bihan (2023) argue, this creates a further difficulty for alternatives to eternalism that deny

simply adjudicate between substantivalism and relationalism, but rather invites a reconception of the terms of the debate. I have defended elsewhere a form of super-relationism, according to which spacetime is a genuine entity, but a relational rather than substantial one (Le Bihan, 2016).

the existence of future entities. If future regions do not exist, how can the present boundary of an apparently existing black hole depend on their future properties?

The upshot of the relativistic analysis is that a four-dimensional block is the natural metaphysical reading of our best spacetime physics. Presentism and the growing block theory are not ruled out by relativity as logical impossibilities, but they are not supported by it either: one must go beyond, and importantly against, the natural interpretation of the theory's content to make them work. This conclusion sets the stage for the question of what happens when we move beyond general relativity. If the block is an ontological lesson of relativity, does it survive when general relativity and its spacetime are no longer fundamental? The answer turns on two parameters: the *metaphysics of spacetime emergence* and the *ontology of quantum gravity*.

3. Quantum Gravity and the Emergence of Spacetime

Unifying general relativity with quantum mechanics is one of the great challenges of contemporary physics. A recurring theme across many candidate theories is that *spacetime is not fundamental* (Huggett and Wüthrich, 2013, 2025). What this means exactly depends greatly on a number of parameters, and especially on settling the more fundamental ontology, which is yet to be fully articulated and empirically confirmed. But one can start to understand the claim by realising that the smooth four-dimensional manifold description used in relativity is expected to break down at very small scales. In its place, different approaches postulate discrete or more exotic mathematical structures, difficult to interpret in familiar metaphysical categories, which give rise to spacetime only in an appropriate limit. In this section I survey how spacetime emergence arises in a few programmes and distinguish *conservative* from *radical* forms of emergence. My goal is not to decide between these theories, or fully introduce them, but to highlight how they might motivate different species of blocks.

A relatively conservative form of spacetime emergence occurs when a theory preserves much of the global organisation of relativistic spacetime while modifying the local separation between spatial and temporal directions.[6] *Loop quantum gravity* (see Rovelli and Vidotto, 2015) could provide a concrete implementation of this conservative possibility, through the *Euclidean–Lorentzian shift* approach (Bojowald and Brahma, 2020; Brahma, 2020). In this scenario, spatial geometry is no longer represented fundamentally by a smooth continuum, but by spin networks: graph-like quantum states encoding discrete geometrical information such as areas and volumes. Their covariant dynamics is described by spin foams, which assign amplitudes to histories or transitions between such quantum-geometrical states. In certain regimes,

[6] This distinction cuts differently from the distinction in Le Bihan and Linnemann (2019), where the local split between timelike and spacelike directions was treated as central to a minimal notion of spacetime. Here, since the focus is on the block rather than on spacetime as such, the relevant notion is instead *minimal spatiotemporal blockhood*: the existence of a unified domain of spatiotemporal existence. Thus, the local disappearance of a spacetime split need not by itself undermine the existence of a unified blocklike structure, even if it matters for whether that structure counts as spacetime in the stricter sense.

particularly near cosmological or black-hole singularities, one obtains a *signature change*: the effective metric transitions from Lorentzian to Euclidean signature. At the level of the local line element, the change may be represented schematically as a transition from a Lorentzian metric,

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

to a Euclidean one,

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

so that the distinguished negative-sign direction associated with time disappears. The change of sign associated with time renders the time variable indistinguishable from the three spatial variables. Locally, in Euclidean regions, there are then no timelike directions and no standard timelike ordering. However, away from these regimes, Lorentzian structure re-emerges, and the effective description recovers, at large scales, a four-dimensional spacetime with the expected relativistic properties.

From a metaphysical point of view, such cases do not significantly threaten the block universe. The relevant complication concerns the status of the *space-time split* in the effective description: in Lorentzian regimes, the structure distinguishes spacelike and timelike directions, while in Euclidean regimes this distinction disappears. One could then ask whether a structure that contains both Lorentzian and Euclidean regions should still count as spatiotemporal in the sense required for a block universe. But nothing here obviously undermines the existence of a unified blocklike structure. At most, the case shows that some familiar spatiotemporal features, including the local distinction between space and time, may be contingent or regime-dependent. The concept of spatiotemporal block might not require every familiar spatiotemporal feature to hold everywhere. It might require only that the relevant ontology still constitute a unified spatiotemporal domain, or something sufficiently close to one.

However, this relatively conservative picture of spacetime emergence does not exhaust the possibilities suggested by quantum gravity, even within loop quantum gravity, far from it. A further feature of loop quantum gravity is *disordered locality* (Huggett and Wüthrich, 2013, 2025): the possibility that the adjacency or ordering relations defined at the fundamental level fail to align with those of the emergent spacetime. In such cases, the mismatch between fundamental and effective structures may extend beyond spatial relations to spatiotemporal organisation more generally. Even if the deviations are more the exception than the rule, their existence raises a concern: the emergent spacetime ordering may no longer track any single coherent ordering at the fundamental level. This threatens the status of the block not merely as locally modified, but as genuinely spatiotemporal. At least this is the case if temporal ordering is regarded as an essential property of a spacetime block.

This suggests a transition to more radical forms of spacetime emergence. If the fundamental structure does not sustain a unified ordering corresponding to spacetime, then the *spacetime block* may fail to be fundamental. In such cases, one must consider whether the block survives in a non-spatiotemporal form, or whether no unified block exists at all. In the case of loop quantum gravity, this question cannot be settled merely by pointing to discreteness, or even to the possibility of disordered locality. One also needs to specify the relevant ontology, the interpretation of quantum mechanics being assumed, and the account of the quantum-to-classical transition. Depending on how these issues are settled, loop quantum gravity may support a non-spatiotemporal blocklike structure, or a weaker and less unified ontology. Moreover, if cases of disordered locality are more the exception than the rule, they may be construed as local or exceptional failures of spatiotemporal ordering rather than as threats to the existence of a fundamental blocklike structure. The same is true, even more straightforwardly, of discreteness: whether the ontology is discrete or continuous is tangential to the existential question.

String theory and *causal set theory* provide other illustrations of this more radical possibility. String theory is formulated in ten or eleven dimensions, depending on the version, and incorporates supersymmetry and extended entities such as strings and branes (see, e.g., Blumenhagen et al., 2013; Tomasiello, 2022; and Le Bihan, forthcoming for a presentation designed for metaphysicians). In certain regimes, dualities imply that different descriptions involving different manifolds can be physically equivalent (for an introduction with an eye to the ontology, see Le Bihan and Read, 2018). T-duality, mirror symmetry and related results suggest that the number, size, and even topology of spatial dimensions may fail to be determinate at the fundamental level (Huggett, 2017). The geometry of the phenomenal spacetime (the one we measure with rods and clocks) thus becomes a derived concept: the fundamental ontology is represented somehow by a web of distinct theories, models and representations. In such a picture, the spacetime block of relativity is not fundamental but, at best, a coarse-grained description related to more fundamental ontology we do not really understand. But although we do not understand the nature of this structure, there are strong reasons to deny that the underlying structure could be spatiotemporal,[7] raising the question of whether the replacement ontology can support any unified domain of physical existence at all, in the guise of a non-spatiotemporal block.

Causal set theory (see, e.g., Surya, 2019 and Wüthrich, 2024 for an introduction aimed at philosophers) takes discreteness seriously by positing that the basic structure of the physical world is a locally finite partially ordered set $\langle C, \prec \rangle$, where $\prec$ represents causal precedence. In the sequential growth formulation, the causal set is described as generated by stochastic rules governing the birth of new elements, added one by one and related, or not, to elements already present at earlier stages, although this need not be interpreted as a literal metaphysical becoming.

However, generic causal sets are highly non-manifoldlike: they lack dimension, continuity, and (at least a metrical sense of) locality, and cannot always be put into correspondence with an effective general-relativistic spacetime structure. The causal set theory programme is partly motivated by results in general relativity showing that the causal structure of spacetime determines most of its geometric structure. In particular, results from Hawking et al. (1976) and Malament (1977) establish that, under suitable

[7] Or at least not spatiotemporal in the robust sense associated with relativistic spacetime. As discussed in Section 4.1, whether certain interpretations of string theory should count as preserving a minimal form of spacetime depends partly on which features are taken to be constitutive of spacetime.

conditions, the causal relations between events determine almost the full structure of spacetime, including the distinction between timelike, lightlike, and spacelike directions. What is not fixed by the causal structure alone is the overall metric scale, that is, absolute lengths and durations. In causal set theory, this missing information is supplied by the discrete cardinality of the causal set ('number'), yielding the slogan: "order + number = geometry". Intuitively: the general-relativistic geometry emerges approximately from causal relations and their relata.

However, causal set theory is causal in a stronger sense than the mere dynamical connectibility found in general relativity, as can be shown by using interventionist machinery as an intellectual probe for causation (Baron and Le Bihan, 2025). Such an ontology of causal relations opens the way to a concept of *non-spatiotemporal causal block*. This would be the case if the right interpretation of causal set theory were one in the spirit of the block universe approach, where a unified domain of physical existence corresponds to the maximally complete causal set, with a web of causal relations replacing the web of (spatio)temporal relations. I return to this possibility below.

The lesson of radical emergence is therefore not that there cannot be a block at the fundamental level, if spacetime turns out to be radically emergent. Rather, it is that there cannot be a unified domain of *spatiotemporal* existence at that level. Whether a non-spatiotemporal domain of physical existence still survives depends on the details of the specific quantum gravity approach one examines. The traditional block universe thus gives way to a menu of possibilities, ranging from emergent spatiotemporal blocks, to non-spatiotemporal blocks, to the absence of any unified block structure altogether.

This menu cannot be assessed by looking only at the ontology of quantum gravity. One must also ask how the familiar spacetime description relates to the fundamental ontology: whether spacetime is reduced to it, eliminated in favour of it, or derivatively grounded in it. I turn to these metaphysical options in the next section, where they will be connected to the existential interpretations of the block.

4. Existential Interpretations of the Block

The previous section distinguished conservative and radical forms of spacetime emergence. It also suggested that the absence of fundamental spacetime does not decide the fate of the block. Once spacetime is no longer assumed to be fundamental, the question is no longer simply whether the block exists, but at what level and in what form. Two questions must now be separated. First, does the fundamental ontology support a unified domain of physical existence at all, and if so is this domain spatiotemporal or non-spatiotemporal? Second, how does the first question relate to the ontological status of emergent spacetime and the exact nature of the cross-level relation? Depending on how these questions are answered, different existential interpretations of the block become appropriate. I begin with three such interpretations: standard eternalism, atemporal eternalism and atemporal fragmentalism.

4.1. Standard Eternalism, Atemporal Eternalism and Atemporal Fragmentalism

According to standard eternalism, the *fundamental* ontology is spatiotemporal: reality is fundamentally identical with a four-dimensional spacetime structure, and all entities located within spacetime exist *simpliciter*. Timelike relations are tenseless relations grounded in spacetime geometry. On this view, the block is fundamental rather than emergent.

Standard eternalism corresponds to the traditional metaphysical reading of relativity theory. It takes the lessons of special and general relativity at face value: there is no privileged present, no objective and universal temporal becoming, and no ontological distinction between past, present and future entities. The four-dimensional spacetime constitutes the arena of the global domain of physical existence. As noted above, this view is compatible with certain conservative forms of spacetime emergence, provided that the fundamental ontology remains sufficiently spatiotemporal and unified. What matters is that the physical world still forms a unified spatiotemporal block.

A second option is *atemporal eternalism*. Here the central eternalist commitment to a fundamental, global domain of physical existence is retained, but the block is no longer identified with spacetime. Instead, the fundamental ontology forms a *unified non-spatiotemporal structure*. The block may be made of relations, or facts, or other sorts of entities, as long as they are non-spatiotemporal and involve some existential glue distinct from the old-fashioned spatiotemporal glue. Spacetime is not fundamental, but existence *simpliciter* still ranges over all fundamental physical entities together.

Atemporal eternalism thereby generalises the core intuition of eternalism beyond spacetime. The central idea is that the rejection of a privileged present does not require reality to be fundamentally temporal or spatiotemporal. What matters is instead the existence of a unified existential domain. If quantum gravity suggests that spacetime is derivative, then the block may survive in a non-spatiotemporal form at the level of the fundamental ontology. The derivative spatiotemporal block would then emerge from a more fundamental atemporal block.

A third option is *atemporal fragmentalism*. According to this view, there is no single unified domain of physical existence at the non-spatiotemporal fundamental level. There are at least two, and typically a high number: their number and nature will depend on the details of the approach to quantum gravity under scrutiny. Existence claims hold only *relative to fragments* of the underlying ontology. Atemporal fragmentalism thereby rejects not merely fundamental spacetime, but the standard or atemporal eternalist assumption that there exists a single, global, unified domain to which existence *simpliciter* attaches. Different fragments of the ontology may possess internal structure and ordering relations without composing an integrated existential domain. The view is inspired by Fine's *fragmentalism* (Fine, 2005), though the adaptation is substantial: the fragmentation here is not temporal, the fragments are not tensed facts, and the issue concerns existential domainhood rather than tense realism. By a fragmented ontology, I mean an ontology lacking any global domain of physical existence unifying all physical items into a single whole. The view, I believe, should not merely be regarded as a metaphysical curiosity but as a useful metaphysical framework for elaborating metaphysical interpretations of certain approaches to quantum gravity.

This taxonomy builds on previous work in Le Bihan (2020), where I introduced and defended a distinction between *standard eternalism* and *atemporal eternalism*. There I argued in favour of eternalism in a broad sense, understood as the rejection of a privileged present together with the acceptance of a global domain of physical existence, and explained that whether one should adopt standard or atemporal eternalism depends on whether spacetime survives the transition to quantum gravity. I maintain here the general rejection of presentism and no-futurism; see also Huggett and Wüthrich (2025, Section 6.5), who reach a similar conclusion. However, I now think that moving from the rejection of presentism and no-futurism, on the one hand, to the endorsement of standard or atemporal eternalism, on the other, was too quick.

Indeed, one may ask whether rejecting presentism and no-futurism immediately commits us to either standard or atemporal eternalism. That would amount to assuming that these existential positions exhaust the available options. But once spacetime emergence enters the picture, one should become cautious about such an assumption and consider the possibility that alternative existential views might instead be motivated by physics rather than by common-sense temporal intuitions. In particular, one may ask whether physical existence is governed by a single global domain at all, or whether it is instead structured by a plurality of existential domains whose number, relations and possible organisation depend on the underlying physical theory. This is the possibility I call atemporal fragmentalism.

Usually, the familiar presentist/eternalist debate treats time as the privileged structure determining the extension of existence: in the pre-relativistic debate, there is just one enduring existential domain with things coming in and out of existence (continuous presentism); existential domains are switched on once at a time as time flies by (discrete presentism); or the one and only existential domain extends over the whole temporal dimension (standard eternalism). But there is no reason in principle why the domain of physical existence must be temporal, linear or dynamically ordered in this way—the non-fundamentality of spacetime precisely opens alternative possibilities. A fragmentalist picture may instead involve non-temporal patterns of existential division, dynamic or not, depending on the details of the quantum gravity approach considered.

It is useful here to distinguish *common-sense fragmentation* from *naturalistic fragmentation*. Common-sense fragmentation construes reality as being fragmented along the joints of ordinary or manifest concepts, as in Fine's tense-based fragmentalism, where fragments correspond to incompatible tensed perspectives on what is present, past or future. Naturalistic fragmentation, by contrast, construes reality as being fragmented along the joints supplied by the ontology of a physical theory. In the present context, the relevant fragments are not common-sense temporal standpoints, but structures suggested by quantum-gravitational frameworks: for instance, as we will see in Section 5, relational facts in loop quantum gravity combined with relational quantum mechanics, dual descriptions in string theory, or growth stages in causal set theory. Atemporal fragmentalism, as understood here, is a form of naturalistic rather than common-sense fragmentation.

At least two versions of atemporal fragmentalism can be distinguished. According to *self-sufficient fragmentalism*, each fragment contains enough resources to recover an emergent spacetime structure independently of the others. There is more than one domain of physical existence at the fundamental level, but each has enough structure to ground, one way or another, an emergent spacetime. According to *collective fragmentalism*, no fragment is sufficient on its own; spacetime emerges from at least two by definition, and concretely, from a very high number of fragments taken together. As we will see below, *string-theoretic duality pluralism* suggests a possible form of self-sufficient fragmentalism, while certain *relational interpretations of loop quantum gravity* and causal set theory could, in principle, be interpreted as a form of collective fragmentalism.

Overall, the present paper therefore extends the earlier 2020 framework in two main ways. First, it introduces and explores atemporal fragmentalism as a serious metaphysical option for certain quantum gravity scenarios. Second, it moves beyond an earlier argument directed primarily against derivative presentism and derivative no-futurism grounded in a non-spatiotemporal ontology. I will examine the possibility that a block, spatiotemporal or non-spatiotemporal, might be real and emergent while nevertheless being grounded in, or mereologically identified with, a fundamentally fragmented ontology; in other words, the possibility of a derivative eternalist ontology emerging from a relatively more fundamental fragmented ontology. I will argue that this combination is problematic. Once a unified spatiotemporal domain of physical existence is admitted, recovering it from a mere plurality of disconnected fragments requires further—rather costly, as we shall see—metaphysical machinery. Either the relevant base is unified, or the fragmentalist owes us a primitive cross-fragment relation strong enough to recover the unity of the physical domain of spatiotemporal existence.

Standard eternalism, atemporal eternalism and atemporal fragmentalism differ primarily over two questions: whether a single, unified domain of physical existence exists at all, and whether that domain is fundamentally spatiotemporal. This already indicates an important asymmetry. Standard eternalism and atemporal eternalism are species of eternalism in the broad sense: both commit to the existence of a unified domain of fundamental physical existence. Atemporal fragmentalism denies that such a domain exists. The most fundamental opposition is therefore not between standard eternalism, atemporal eternalism and fragmentalism as three symmetrical alternatives, but between eternalism broadly construed and fragmentalism.

4.2. Reductionism, Derivativism, Eliminativism

The preceding ontological options regarding the (non-)existence of a single, unified fundamental domain of physical existence do not by themselves determine the status of emergent spacetime. Following the taxonomy developed in Le Bihan (2018b, 2021), whether a spatiotemporal block genuinely exists also depends on the metaphysics of spacetime emergence.

On a *reductionist* interpretation, spacetime is identical with the fundamental ontology, or with part of it, under another description. The emergent and the fundamental are not genuinely distinct levels of reality, yielding what may be called a flat ontology. In such cases, the spacetime block is not eliminated. It exists, but not as an additional entity over and above the fundamental ontology. This reductionist option can be developed in different ways. One possibility, explored in my own work, is to understand spacetime emergence in terms of non-spatiotemporal composition: spacetime is composed of, or decomposes into, non-spatiotemporal entities or structures (see Baron and Le Bihan, 2022; Le Bihan, 2018a,b). This yields a reductionist view if the relevant compositional relation is understood in identity-theoretic terms, in the spirit of composition as identity or decomposition as identity (Le Bihan, 2018b). If, however, non-spatiotemporal composition is instead understood as a non-identity dependence relation, then the same general picture points toward derivativism rather than reductionism, since mereological composition is just a sort of small-g grounding relation, as in Baron and Le Bihan (2022). I remain neutral here on whether non-spatiotemporal composition should ultimately be understood in identity or non-identity terms.

Spacetime reductionism has, prima facie, significant implications for the metaphysics of the blocks, but perhaps less so than one may have originally thought—meaning here, certainly less so than *I* originally thought. For think of spacetime as being a scattered non-spatiotemporal proper part in the fundamental non-spatiotemporal ontology, along the lines described in Le Bihan (2018a), and let us admit further that it is a unified domain of physical existence. What are the implications for the rest of the structure, the non-spatiotemporal parts that do not compose spacetime? Do they form a block as well, or not? As far as I can tell, it could be, in principle, that those remaining parts do not form a unified domain of physical existence. However, this fragmented domain would then be shielded from the non-spatiotemporal parts composing spacetime. A distinct question is whether the collection of non-spatiotemporal parts composing spacetime could fail to generate such a unified domain. I will provide an argument against this view in the last section, when discussing the possibility for a fragmented ontology to ground a unified spacetime, underlining that this conclusion applies as well to spacetime reductionism.

On a *derivativist* interpretation, spacetime genuinely exists but as a non-fundamental structure grounded in a more fundamental ontology. Here grounding is understood in a broad small-g sense encompassing any non-identity dependence relation, including big-g Grounding, functional realisation, mereological composition and related forms of ontological dependence. In such cases, a derivative spatiotemporal block may exist even if the fundamental ontology is non-spatiotemporal. In this context, existential claims should be indexed to ontological levels. Claiming that all entities located in spacetime exist in a single unified domain of physical existence is not equivalent to claiming that all *fundamental* entities belong to a unified domain of physical existence. Spacetime emergence, when interpreted in derivativist terms, forces these claims apart. A derivative spatiotemporal block may exist even if the fundamental ontology is non-spatiotemporal, and perhaps even if the fundamental level is only partially unified. Conversely, a unified non-spatiotemporal ontology may ground derivative structures exhibiting only local or approximate spacetime organisation. The metaphysics of the block therefore becomes level-sensitive: existential unity may hold at one level while failing, or taking a different form, at another.

Finally, on an *eliminativist* interpretation, spacetime does not genuinely exist at all (see Baron, 2021 for a defence of the plausibility of the view). Spatiotemporal descriptions are useful representational devices but fail to correspond to autonomous mind-independent structures. In that case, the spacetime block disappears with spacetime. Whether any form of block remains then depends entirely on the structure of the fundamental ontology, and the discussion gets significantly simplified. Instead of having two discussions about the nature and existence of a block at the fundamental and derivative levels, one simply needs to discuss the metaphysical nature of the fundamental.

The upshot is that the fate of the block cannot be read off directly from the claim that spacetime is non-fundamental. If spacetime is reduced or derivative, a spatiotemporal block may still exist; if spacetime is eliminated, the question shifts entirely to the fundamental ontology. What matters, in either case, is whether there remains a unified domain of physical existence. Where such unity is preserved, eternalism remains the natural interpretation; where it is absent, atemporal fragmentalism becomes a live option.

A single possible world could therefore contain more than one block structure. At a derivative level, there could exist a spatiotemporal block corresponding to the effective spacetime described by general relativity. At a more fundamental level, there could exist in addition a distinct non-spatiotemporal block, at least in principle. The relation between these blocks depends on the metaphysics of emergence: under reductionism they collapse into a single ontology, whereas under derivativism they correspond to genuinely distinct levels of reality. The next section examines how different approaches to quantum gravity motivate different combinations of these existential and emergence claims.

5. Back to the Physics

5.1. Conservative and Radical Emergence

With these concepts and distinctions in hand, let us return to the physics of quantum gravity. Different approaches motivate different combinations of existential and emergence claims. In relatively conservative cases, such as the Euclidean–Lorentzian shift in loop quantum gravity, spacetime structure is modified locally while a four-dimensional organisation exists globally. Such scenarios naturally support standard eternalism, since the block structure survives despite local losses of spatiotemporality. Of course, one could interpret signature-change scenarios differently, arguing that spacetime is an all-or-nothing matter. If certain regions of the structure are not spatiotemporal, then the structure as a whole is not genuinely spatiotemporal, and the resulting view should instead be construed as belonging to the atemporal eternalist family. In my view, however, this question is largely terminological. What matters is that, if atemporally eternalist, the resulting position remains extremely close to standard eternalism. Either way, such scenarios do not by themselves undermine the existence of a unified domain of physical existence.

More radical forms of emergence arise when the fundamental ontology ceases to possess central structural features of relativistic spacetime. In such cases, the natural question is no longer whether standard eternalism survives unchanged, but whether the fundamental ontology still constitutes a unified domain of physical existence. In many quantum-gravitational contexts, the most natural answer remains affirmative. What changes is not the existence of a block, but its character: the block is no longer fundamentally spatiotemporal.

5.2. String Theory

String theory provides one route to this possibility. Dualities suggest that spacetime geometry may be underdetermined by the underlying ontology. Since dualities mark the perimeter of what we presently know about string theory, and offer clues as to what a more fundamental non-perturbative string theory might look like, they do not by themselves deliver a decisive ontological framework for block metaphysics. Still, by casting doubt on the fundamental existence of the four-dimensional spacetime of general relativity, they suggest an important block lesson: the relativistic spacetime block is unlikely to be fundamental.

What follows from this depends on how duality is interpreted. One option, perhaps the most popular one, is to regard dual descriptions as pointing toward a common non-spatiotemporal structure (see, e.g., Huggett, 2017; Huggett and Wüthrich, 2025). On this reading, string theory naturally supports atemporal eternalism: the spatiotemporal block is not fundamental, but it is grounded in a unified non-spatiotemporal domain.[8]

There are, however, ways of developing fragmentalist interpretations—but, as I will show, the cost is high. A view of this sort has been gestured at as a possible interpretation of duality in string theory under the name of *duality pluralism* in Le Bihan and Read (2018), the thought being that each theoretically equivalent description latches onto a distinct fundamental fragment. Such a view provides a possible example of what I have called *self-sufficient fragmentalism*: each fragment would independently contain enough resources to ground the emergent spacetime structure. The cost, however, is a significant inflation of the ontology and a problem of overdetermination of the derivative spacetime by the fundamental structure: each fragment would be sufficient, on its own, to generate the same approximate GR spacetime. Fragmentalism would therefore buy metaphysical plurality at the price of overdetermination.[9]

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8 This point matters for how the present paper relates to my earlier discussion of string theory in Le Bihan (2020). There, the preservation of quasi-temporal structure suggested an interpretation in terms of standard eternalism, because the temporal ordering was not under pressure in string theory. The present paper shifts the criterion from the preservation of temporal or quasi-temporal structure to the more demanding question of whether the fundamental ontology is spatiotemporal in the robust sense relevant to a spatiotemporal block. If minimal spacetime is sufficient for spacetime realism, then some interpretations of *string theory* may still support standard eternalism. If, however, duality considerations and common-core interpretations make the quasi-spatial structure too remote from physical space, then the same framework is more naturally interpreted in terms of atemporal eternalism. I take this classification issue to be largely terminological.

9 This fragmentalist option should not be confused with a route back to presentism or the growing

For this reason, the common-core, atemporal eternalist reading is more economical, though not forced by the physics alone.

5.3. Relational Loop Quantum Gravity

A different route to atemporal fragmentalism may be suggested by combining *loop quantum gravity* with *relational quantum mechanics* (see, e.g., Rovelli, 1996 for the original introduction of the view, and Healey, 2021 for a philosophical discussion in the context of loop quantum gravity). On a relational interpretation, physical states are not assigned absolutely, from a God's-eye point of view, but only relative to interacting systems. If this idea is combined with a quantum-gravitational ontology in which spacetime is reconstructed from quantum networks of relations, one might be tempted by a collective form of atemporal fragmentalism. Recent work on relational quantum mechanics provides a possible route to this thought: Riedel (2024), for instance, argues that relational quantum mechanics is committed to a relativisation of facts. If this relativisation of facts is given a metaphysical reading, it becomes natural to ask whether existence should also be understood fragmentally. On such a view, no single fragment would contain enough resources to ground the derivative spacetime block on its own. Instead, spacetime would emerge only from a plurality of relational fragments taken together.

Rovelli (2019) has argued against both presentism and eternalism in the context of general relativity, and pushed for a third way. His use of these labels, however, differs from the standard philosophical usage. By "presentism" he primarily means the package view combining an objective global present with a standard A-theoretic picture of becoming; by "eternalism" he primarily means the block-universe package on which becoming is absent, or at least illusory. In this sense, Rovelli's argument is best understood as targeting eternalism only if eternalism is identified with a strong anti-becoming interpretation of the block universe, since Rovelli defends local non-oriented becoming. But eternalism is not that view, at least as usually defined (see Huggett and Wüthrich, 2025, Section 6.5). It is an existential thesis: past, present and future entities are equally real. It does not by itself decide whether becoming is real or unreal, global or local, A-theoretic, B-theoretic, C-theoretic, or captured by views more difficult to categorise, such as Oaklander's R-theory (Oaklander, 2014). Rovelli's local becoming is therefore not a rejection of eternalism in the usual sense. It is a rejection of a particular anti-becoming package often associated with the block universe.

Interestingly, however, Rovelli's broader relational programme may still have consequences for the metaphysics of existence underlying the eternalism/presentism de-

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block theory. The fragments at issue are not temporal fragments ordered by an objective becoming relation, but structural fragments associated with distinct but theoretically equivalent descriptions. Nothing in the duality structure selects one fragment as present, nor does it generate a privileged boundary between what already exists and what does not yet exist. Fragmentation of this sort undermines global unity, but it does not restore temporal becoming. It therefore supports, at most, atemporal fragmentalism, not presentism, the growing block, or A-theoretic fragmentalism.

bate. If the relational lesson is extended from states, facts, or observables to domains of physical existence, then the view is better understood as a form of atemporal fragmentalism: not presentism, not standard eternalism, but a relativisation of reality to non-spatiotemporal fragments. What this implies for the spacetime world at the emergent level is a further question, depending on whether spacetime is eliminated, reduced, or derivatively grounded.

Note that this atemporal fragmentalist interpretation of loop quantum gravity combined with relational quantum mechanics should be presented neither as Rovelli's own view, nor as the only possible interpretation of the resulting framework. In principle, the relevant relational fragments could instead be understood as proper parts of a uniquely existing and integrated domain of physical existence. On that reading, loop quantum gravity combined with relational quantum mechanics would remain compatible with atemporal eternalism in the sense defined here: reality would be fundamentally non-spatiotemporal, but still unified into a single domain of physical existence.

This differs from the string-theoretic case previously discussed. Duality pluralism suggests self-sufficient fragmentalism: each fragment is rich enough to generate the same approximate GR spacetime, yielding overdetermination. The relational loop-quantum-gravity-inspired picture instead suggests collective fragmentalism: no fragment is independently sufficient, but the plurality of fragments is supposed to ground or compose spacetime jointly. This avoids straightforward overdetermination, but it raises a different worry: if the fragments do not belong to any unified existential domain, it is unclear in what sense they are jointly available as grounds or parts of a single derivative spacetime block. I return to this problem of existential integration in the next section.

5.4. Causal Set Theory

Causal set theory could either be interpreted in an eternalist or fragmentalist way. Remember that a causal set is fundamentally a partially ordered structure whose primitive relation is causal precedence rather than spatiotemporal distance. If the completed causal set is taken as fundamental, rather than the sequential growth dynamics sometimes used to construct it, the resulting ontology naturally lends itself to an atemporal eternalist interpretation. All elements coexist within a single causal block, even though spacetime emerges only in suitable manifoldlike regimes. In such a picture, the fundamental block is not spatiotemporal but causal: a global dependence structure from which derivative spacetime relations arise. The sequential growth formulation does not restore the growing block, since the order of birth is not a privileged temporal becoming in the classical metaphysical sense; it is constrained by discrete general covariance and does not supply a unique global present.

One might try to push causal set theory in a similarly fragmentalist direction by taking the growth stages of the sequential growth programme metaphysically seriously. On such a reading, the successive stages would not merely be gauge-related descriptions of proper parts of the one completed, maximal causal set, but distinct and incompatible fragments of reality. The derivative spacetime structure would have to emerge from a plurality of mutually incompatible growth stages taken together. This would amount to another possible form of collective atemporal fragmentalism. In a way, that would amount to a spatiotemporal block universe emerging from a non-spatiotemporal causal growing block.

Such an interpretation is perhaps motivated by the physics, or at least by the way certain causal set theorists present the programme (see, e.g., Dowker, 2014), but it remains metaphysically challenging. It abandons the idea of a single completed causal-set block. If the growth stages are genuinely incompatible existential fragments rather than partial descriptions of one unified causal structure, it becomes unclear how they could collectively ground a single emergent spacetime. The next section examines this difficulty directly.

6. Eternalism, Grounding and Fragmentation

The preceding section returned to certain approaches to quantum gravity in light of three possible attitudes toward the block: standard eternalism, atemporal eternalism and atemporal fragmentalism. I now turn to the main pressure on atemporal fragmentalism. The issue does not arise in the same way if spacetime is eliminated: if there is no spatiotemporal block, then no such block has to be grounded or reduced. Eliminativism may not be the most obvious approach, but it remains consistent and interesting. Indeed, I will argue, it may be the best hope for defending atemporal fragmentalism as a viable alternative to eternalism. The difficulty for atemporal fragmentalism arises once spacetime is admitted as real, whether derivatively or through identification with a relevant part of the fundamental ontology. For then the atemporal fragmentalist must explain how a unified spatiotemporal domain can be grounded in, or mereologically identified with, a fundamentally fragmented non-spatiotemporal base.

In what follows, I will use *spacetime realism* for this disjunctive commitment: either spacetime is derivative but real, or it is identical to a scattered proper part of the fundamental ontology. The rest of the fundamental ontology may well be fragmented without this threatening the reality of the spatiotemporal block. What matters is whether the relevant base itself—the grounding base in the derivativist case, or the non-spatiotemporal proper part in the reductionist case—can fail to form a unified existential domain while nevertheless generating a unified spatiotemporal block. Call the view resulting from a positive answer to this question *existential dualism*.

There is, however, a significant pressure on existential dualism. If spacetime realism is true, then there must exist a unified spatiotemporal domain of existence: the spatiotemporal block. Since this block is either grounded in, or identical with, the relevant base, that base must somehow account for its unity. But if atemporal fragmentalism is true at the fundamental level, then the relevant fundamental items do not jointly constitute a single existential base. The fragments may each possess their own internal structure, but they do not, merely by being fragments, belong to one unified domain of physical existence. Thus the two commitments pull in opposite directions: spacetime realism requires the relevant base or proper part to give us an emergent, unified domain, while fundamental fragmentalism denies the availability of a fundamental unified domain corresponding to such a unified, emergent domain. Call this *prima facie* tension between fundamental existential fragmentation and the unity of the derivative spatiotemporal block the *problem of existential integration*.

The distinction between self-sufficient and collective fragmentalism clarifies the dialectic. Self-sufficient fragmentalism avoids this problem by allowing each fragment to ground the spatiotemporal block independently. But this leads to overdetermination, as illustrated by duality pluralism in string theory: the same spatiotemporal, emergent block appears to be grounded or composed many times over by distinct dual fragments. Collective fragmentalism avoids overdetermination by requiring several fragments to ground, or compose, spacetime together. But it then faces the problem of existential integration.

Of course, one may respond by taking cross-fragment grounding, or cross-fragment composition, as a primitive many-to-one connecting relation. There would be no domain of physical existence unifying the fragments, but there would still be a primitive relation powerful enough to make them work together as the basis of one unified domain of spatiotemporal existence. Overall, the existential integration problem requires either an account of this primitive relation, or an independent reason for thinking that this relocation of unity is preferable to the atemporal eternalist alternative.

The problem can be sharpened by comparison with a structurally parallel case, namely *cross-temporal grounding* (Correia and Merlo, 2024). Cross-temporal grounding allows present facts about the past to be explained by past facts, in the context of discussions of challenges facing presentism. Correia and Merlo introduce the notion as a way to articulate an appeasing response to what they call the problem of grounding, which goes beyond both the problem of truth (how propositions about the past can be true) and the problem of truthmaking (what makes them true) for presentism. The problem of grounding is as follows: how can facts about the past themselves have suitable metaphysical grounds if reality is restricted to the present? Their proposal is that past facts, despite no longer obtaining, can still figure as explanantia in a distinctive kind of metaphysical explanation. One can already see how the analogy could be used: if an appeasing solution based on cross-temporal grounding is really an option, then perhaps a distinctive kind of metaphysical explanation, backed by cross-fragment grounding, could analogously connect the fragments to the emergent eternalist domain of existence.

A subtle difficulty in this analogy lies in coordinating a philosophical approach based on facts and explanation with one like mine, based on entities and building relations among them. I will assume that the analogy can still remain fruitful, provided that the discussion is adjusted accordingly. The force of the analogy also depends on whether cross-temporal grounding is considered against an eternalist or a presentist background. Correia and Merlo explicitly introduce the view in connection with presentism and the problem of past-directed facts, but they do not frame their discussion as a contrast between eternalist and presentist readings of cross-temporal grounding. On an eternalist reading, past facts, or the entities and states of affairs corresponding to them, are already available within a unified temporal block; cross-temporal grounding may still raise interesting questions about explanation, but it does not raise the same problem of existential availability. On a presentist reconstruction of the case, by contrast, the existential structure of the temporal order is broken: past facts are not members of the present domain of existence, and yet they are supposed to do explanatory work. A primitive cross-temporal grounding relation may then be understood as doing for a temporally fragmented ontology what cross-fragment grounding is supposed to do for non-spatiotemporal fragmentalism. In both cases, the problem is one of joint availability generated by a fragmented domain of physical existence.

The analogy is therefore structural. The difference concerns the target of the primitive relation—present facts about the past in one case, the emergent spacetime in the other—not the form of the difficulty. In the presentist cross-temporal case, the primitive relation is supposed to make what is no longer included in the present domain available for grounding facts about the past. In the non-spatiotemporal case, the primitive relation is supposed to make fragments that do not form a unified existential domain jointly available as grounds, or parts, of one spatiotemporal block. I suspect that the two difficulties can be addressed by a similar move: committing to a structurally analogous cross-domain primitive notion, and being a full-blown realist about a corresponding many-to-one building relation creating unity out of existentially disconnected domains. What matters here is that non-spatiotemporal fragmentalism must pay for the absence of a unified existential domain with a primitive relation strong enough to recover the unity of the domain of spatiotemporal existence.

Perhaps a sufficiently developed account of cross-fragment grounding, or cross-fragment composition, could make the required transition from fragmented grounds or parts to a unified spatiotemporal block intelligible, in a way structurally similar to what Correia and Merlo suggest for cross-temporal grounding. But this is precisely the cost of the view: the combination of atemporal fragmentalism and spacetime realism imposes a condition of joint availability that fragmentalism does not automatically satisfy. Perhaps there is no contradiction here, but the problem of existential integration is at least a genuine metaphysical oddity, and one that calls for a positive account rather than a promissory note. The problem of existential integration is therefore specific to the conjunction of atemporal fragmentalism with spacetime realism in the sense introduced above. Once spacetime is admitted as real in this sense, (standard or atemporal) eternalism remains a more natural interpretation of the fundamental ontology.

7. Conclusion

Relativity theory puts under pressure the idea of an objective present and motivates a block-universe metaphysics in which entities naturally construed as past, present, and future coexist within a four-dimensional spacetime. Quantum gravity complicates this picture by suggesting that spacetime may be emergent, either in the deflationary sense of being an illusion of some sort or in the more robust sense of being grounded in, or mereologically identified with, a more fundamental non-spatiotemporal structure.

The central result of this chapter is that the fate of the block depends on both the ontology of quantum gravity and the metaphysics of spacetime emergence. When the concept of four-dimensional spacetime continues to apply at the fundamental level, granted a few light-touch modifications, standard eternalism remains the natural interpretation. When spacetime is radically modified and merely survives as an emergent, non-fundamental structure, atemporal eternalism provides the appropriate extension of eternalist commitments.

Still, the world could fail to be eternalist, lacking any unified domain of physical existence: a view I have dubbed atemporal fragmentalism, and that might find a home in a number of specific approaches to quantum gravity. But this option is attractive for the actual world only either at the price of spacetime eliminativism, or at the cost of substantial metaphysical complications such as overdetermination or a primitive cross-fragment relation strong enough to recover the unity of the emergent domain of spatiotemporal existence.

Here is a saying from somewhere, or from nowhere perhaps: the only way to escape eternity is to escape spacetime. And not merely fundamental spacetime. Any spacetime.

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References

Baron, S. (2021). Eliminating spacetime. *Erkenntnis 88*(3), 1289–1308.

Baron, S. and B. Le Bihan (2022). Composing spacetime. *The Journal of Philosophy 119*(1), 33–54.

Baron, S. and B. Le Bihan (2023). Trouble on the horizon for presentism. *Philosophers' Imprint 23*.

Baron, S. and B. Le Bihan (2025). Causal set theory is (strongly) causal. *Foundations of Physics 55*(63).

Blumenhagen, R., D. Lüst, and S. Theisen (2013). *Basic Concepts of String Theory*. Springer.

Bojowald, M. and S. Brahma (2020). Loop quantum gravity, signature change, and the no-boundary proposal. *Physical Review D 102*(10), 106023.

Bourne, C. (2006). *A Future for Presentism*. Oxford: Oxford University Press.

Brahma, S. (2020). Emergence of time in loop quantum gravity. In N. Huggett, K. Matsubara, and C. Wüthrich (Eds.), *Beyond Spacetime: The Foundations of Quantum Gravity*. Cambridge: Cambridge University Press.

Briggs, R. and G. A. Forbes (2016). The growing-block: Just one thing after another? *Philosophical Studies 174*(4), 927–943.

Brown, H. R. (2005). *Physical Relativity: Space-Time Structure from a Dynamical Perspective*. Oxford: Oxford University Press.

Cameron, R. P. (2015). *The Moving Spotlight: An Essay on Time and Ontology*. New York, NY: Oxford University Press.

Correia, F. and G. Merlo (2024). Cross-temporal grounding. *Analytic Philosophy 65*(3), 333–352.

Correia, F. and S. Rosenkranz (2018). *Nothing to Come: A Defence of the Growing Block Theory of Time*. Cham, Switzerland: Springer Verlag.

Craig, W. L. (2001). Presentism and the space-time manifold. *Australasian Journal of Philosophy 79*(3), 315–339.

Dowker, F. (2014). The birth of spacetime atoms as the passage of time. *Annals of the New York Academy of Sciences 1326*(1), 18–25.

Earman, J. (1989). *World Enough and Space-Time*. Cambridge, MA: MIT Press.

Earman, J. (1995). *Bangs, Crunches, Whimpers, and Shrieks: Singularities and Acausalities in Relativistic Spacetimes*. Oxford University Press.

Earman, J. and J. D. Norton (1987). What price space-time substantivalism? The hole story. *British Journal for the Philosophy of Science 38*(4), 515–525.

Earman, J., C. Smeenk, and C. Wüthrich (2009). Do the laws of physics forbid the operation of time machines? *Synthese 169*(1), 91–124.

Farr, M. (2020). C-theories of time: On the adirectionality of time. *Philosophy Compass 12*(15).

Fine, K. (2005). Tense and reality. In *Modality and Tense: Philosophical Papers*, pp. 261–320. Oxford: Oxford University Press.

Friedman, M. (1983). *Foundations of Space-Time Theories*. Princeton: Princeton University Press.

Hawking, S. W., A. R. King, and P. J. McCarthy (1976). A new topology for curved space-time which incorporates the causal, differential, and conformal structures. *Journal of Mathematical Physics 17*(2), 174–181.

Healey, R. (2021). The measurement problem for emergent spacetime in loop quantum gravity. In C. Wüthrich, B. Le Bihan, and N. Huggett (Eds.), *Philosophy Beyond Spacetime: Implications from Quantum Gravity*, pp. 222–234. Oxford: Oxford University Press.

Huggett, N. (2017). Target space ≠ space. *Studies in History and Philosophy of Modern Physics 59*, 81–88.

Huggett, N. and C. Wüthrich (2013). Emergent spacetime and empirical (in)coherence. *Studies in History and Philosophy of Modern Physics 44*(3), 276–285.

Huggett, N. and C. Wüthrich (2025). *Out of Nowhere: The Emergence of Spacetime in Theories of Quantum Gravity*. Oxford: Oxford University Press.

Ingram, D. (2019). *Thisness Presentism: An Essay on Time, Truth, and Ontology*. Oxford: Routledge.

Ingram, D. and J. Tallant (2026). Presentism. In E. N. Zalta and U. Nodelman (Eds.), *The Stanford Encyclopedia of Philosophy* (Spring 2026 ed.). Metaphysics Research Lab, Stanford University.

Le Bihan, B. (2014). No-futurism and metaphysical contingentism. *Axiomathes 24*(4), 483–497.

Le Bihan, B. (2015). The unrealities of time. *Dialogue: Canadian Philosophical Review 54*(1), 25–44.

Le Bihan, B. (2016). Super-relationism: Combining eliminativism about objects and relationism about spacetime. *Philosophical Studies 173*(8), 2151–2172.

Le Bihan, B. (2018a). Priority monism beyond spacetime. *Metaphysica 19*(1), 95–111.

Le Bihan, B. (2018b). Space emergence in contemporary physics: Why we do not need fundamentality, layers of reality and emergence. *Disputatio 10*(49), 71–95.

Le Bihan, B. (2020). String theory, loop quantum gravity and eternalism. *European Journal for Philosophy of Science 10*(2), 1–22.

Le Bihan, B. (2021). Spacetime emergence in quantum gravity: Functionalism and the hard problem. *Synthese 199*(2), 371–393.

Le Bihan, B. (forthcoming). String theory for metaphysicians. In B. Le Bihan (Ed.), *Metaphysics of String Theory*. Cambridge University Press.

Le Bihan, B. and N. Linnemann (2019). Have we lost spacetime on the way? Narrowing the gap between general relativity and quantum gravity. *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics 65*, 112–121.

Le Bihan, B. and J. Read (2018). Duality and ontology. *Philosophy Compass 13*(12), e12555.

Malament, D. B. (1977). The class of continuous timelike curves determines the topology of spacetime. *Journal of mathematical physics 18*(7), 1399–1404.

Miller, K. (2019). The cresting wave: A new moving spotlight theory. *Canadian Journal of Philosophy 49*(1), 94–122.

Minkowski, H. (1923). Space and time. In H. A. Lorentz, A. Einstein, H. Minkowski, and H. Weyl (Eds.), *The Principle of Relativity*, pp. 73–91. New York: Dover.

Oaklander, L. N. (2014). Temporal realism and the r-theory. *Defending Realism: Ontological and Epistemological Investigations. Berlin. München. Boston. De Gruyter*, 123–140.

Putnam, H. (1967). Time and physical geometry. *The Journal of Philosophy 64*(8), 240–247.

Riedel, T. (2024). Relational quantum mechanics, quantum relativism, and the iteration of relativity. *Studies in History and Philosophy of Science 104*, 109–118.

Rietdijk, C. W. (1966). A rigorous proof of determinism derived from the special theory of relativity. *Philosophy of Science 33*(4), 341–344.

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

Rovelli, C. (2019). Neither presentism nor eternalism. *Foundations of Physics 49*(12), 1325–1335.

Rovelli, C. and F. Vidotto (2015). *Covariant Loop Quantum Gravity: An Elementary Introduction to Quantum Gravity and Spinfoam Theory*. Cambridge: Cambridge University Press.

Saunders, S. (2002). How relativity contradicts presentism. *Royal Institute of Philosophy Supplements 50*, 277–292.

Smeenk, C. (2013). Time in cosmology. In A. Bardon and H. Dyke (Eds.), *The Blackwell Companion to the Philosophy of Time*, pp. 201–219. Wiley-Blackwell.

Surya, S. (2019). The causal set approach to quantum gravity. *Living Reviews in Relativity 22*(5).

Tomasiello, A. (2022). *Geometry of String Theory Compactifications*. Cambridge: Cambridge University Press.

Tooley, M. (1997). *Time, Tense, and Causation*. Oxford, GB: Oxford University Press.

Williamson, T. (2013). Contingentism and necessitism. In T. Williamson (Ed.), *Modal Logic as Metaphysics*, pp. 1–29. Oxford University Press.

Wüthrich, C. (2010). No presentism in quantum gravity. In V. Petkov (Ed.), *Space, Time, and Spacetime: Physical and Philosophical Implications of Minkowski's Unification of Space and Time*, pp. 257–278. Springer.

Wüthrich, C. (2013). The fate of presentism in modern physics. In R. Ciuni, K. Miller, and G. Torrengo (Eds.), *New Papers on the Present: Focus on Presentism*, pp. 91–131. Munich: Philosophia Verlag.

Wüthrich, C. (2024). The philosophy of causal set theory. In C. Bambi, L. Modesto, and I. Shapiro (Eds.), *Handbook of Quantum Gravity*, pp. 3003–3030. Springer.

Zimmerman, D. (2008). The privileged present: Defending an 'a-theory' of time. In T. Sider, J. Hawthorne, and D. W. Zimmerman (Eds.), *Contemporary Debates in Metaphysics*, pp. 211–225. Oxford: Blackwell.

Zimmerman, D. W. (2011). Presentism and the space-time manifold. In C. Callender (Ed.), *The Oxford Handbook of Philosophy of Time*, pp. 163–246. Oxford University Press.