Title: Radiation, Clocks, and Relational Nonlocality: From Bell + No-Signalling to an Extended Spacetime Postulate

Abstract
Bell experiments show that nature violates local realism while respecting stringent no-signalling constraints. The minimal "standard quantum package" accounts for this via a global quantum state that encodes nonlocal correlations but leaves open what, if anything, is happening *in spacetime* between distant systems. In this paper we propose a different starting point. We adopt a radiation-first and clock-first perspective on spacetime, in which worldlines are not pre-given 4D curves but growing records of the operation of massive clocks. Within this view, the *latest tick* of a clock acquires a clear physical status as the local boundary between realized past and open future. We then introduce an extended ontological postulate: at any given stage of their operation, there exists a physical relation between the "currently active" segments of the worldlines of distant clocks - segments between their latest and next tick - that underwrites the observed nonlocal correlations, while remaining strictly compatible with no-signalling. This postulate goes beyond the minimal quantum package without modifying any empirical predictions. It instead replaces the bare global quantum state with a more concrete relational spacetime structure. We briefly sketch how a framework we call NIM is intended to implement this structure and discuss how such an approach fits within contemporary work on quantum foundations and spacetime ontology.

Keywords: Quantum nonlocality, Bell inequalities, No-signalling, Clocks and time, Spacetime ontology, Relational quantum mechanics, Primitive ontology

1. Introduction: empirical constraints and ontological underdetermination

Bell experiments have established two central constraints on any fundamental theory of the micro-world. First, correlations between outcomes recorded at space-like separated measurement stations violate Bell inequalities [Bell 1964]. No theory based on local hidden variables can reproduce these correlations. Second, despite this nonlocality, the observed statistics respect operational no-signalling: the marginal outcome distributions at each site are independent of the measurement choices made at the distant site [Shimony 1984, Norsen 2015, Wiseman 2014]. Entanglement therefore cannot be used to send controllable signals faster than light. Any adequate theory must accommodate both aspects: Bell-type nonlocality and strict no-signalling.

Standard quantum theory handles this by postulating a global quantum state for the composite system and using the Born rule to compute joint and marginal probabilities. In what we may call the *minimal quantum package*, the global state - wave function or density operator - lives on a Hilbert space and encodes the nonclassical correlations [Bell 1987, Allori 2015]. The underlying spacetime is typically taken to be Minkowskian (or a curved relativistic background), as in Einstein's original formulation of special relativity [Einstein 1905]. Within this package, the state is not tied to any particular pair of spacetime events, nor is there any additional spacetime structure beyond what is needed to define the settings, outcomes, and their space-time separation. Questions about how the global state is "realized" in spacetime are left to interpretation - Bohmian mechanics, GRW, Everett, relational quantum mechanics, and others - without affecting the empirical predictions [Rovelli 1996, Allori 2015].

From a foundational perspective, this leaves the spacetime picture of nonlocality underdetermined. Bell-type experiments tell us that there is a nonlocal structure of correlations that cannot be explained by local hidden variables [Bell 1964, Norsen 2015]. No-signalling tells us that these correlations cannot be harnessed for superluminal communication [Shimony 1984]. The minimal quantum package summarizes this neatly in the abstract language of global states and local POVMs, but it remains largely silent on what - if anything - is happening *in spacetime* between the relevant systems. In particular, it does not identify any concrete spacetime relation between the physical devices that we actually use to implement measurements: clocks, detectors, and sources.

In this paper we explore a different starting point. We adopt a radiation-first and clock-first perspective on spacetime. On a radiation-first view, spacetime structure is read off from how material systems exchange radiation: null links between emission and absorption events are treated as primary carriers of causal and metrical information, and worldlines emerge as records of these exchanges rather than as pre-drawn curves on a fixed background [Einstein 1905, Gambini & Pullin 2007]. On a clock-first view, physical clocks - massive systems with internal dynamical processes - are the concrete devices that generate time labels. Their worldlines are not ontologically complete four-dimensional curves extending from the infinite past to the infinite future, but *growing records* built tick by tick as the clocks operate.

Within this clock-first picture, each well-functioning clock has, at any stage of operation, a latest tick and an upcoming next tick. The interval on the clock's worldline between its latest and next tick naturally marks a local boundary between realized past and open future. Operationally, this is where we locate the "time now" for that clock. Standard relativity explains how the numerical readings of different clocks compare once they are synchronised, but it does not ascribe any special physical role to these latest-tick segments themselves [Einstein 1905]. Likewise, the minimal quantum package treats clocks as background resources and does not privilege the intervals between successive ticks in its ontology.

Our central proposal is that these *currently active* worldline segments - for example, the intervals between the latest and next ticks of distant clocks used in Bell experiments - are precisely the right place to anchor the nonlocal correlations in spacetime. We formulate an extended relational postulate: at any given stage of their operation, there exists a physical relation between the active segments of distant clocks, sufficient to underwrite the observed Bell-type correlations while remaining strictly compatible with operational no-signalling. In the language of standard quantum theory, the effects of this relation can still be represented by a global quantum state, but ontologically the state is treated as a summary of a more concrete relational spacetime structure.

The remainder of the paper develops this idea in three steps. First, we sharpen the empirical and conceptual background (Bell nonlocality, no-signalling, and the underdetermination of spacetime ontology by the minimal quantum package). Second, we articulate the radiation-first and clock-first perspectives in more detail, explaining why latest-tick segments are natural candidates for local temporal boundaries. Third, we state the extended relational postulate and outline the objectives of a framework we call the Emergent Distributed Generative Edge (EDGE), , which aims to implement this postulate while respecting relativistic constraints and all existing experimental data.

2. A radiation-first perspective on spacetime

The standard relativistic picture often starts with a fixed Minkowski manifold: a four-dimensional arena endowed with a metric of signature $(+,-,-,-)$. Worldlines of particles, lightcones of signals, and foliations into "instants" are then drawn *in* this arena. On this view, spacetime is ontologically prior; matter and radiation merely trace curves within it.

A radiation-first perspective inverts this order of priority:

- We begin with *material systems* and *radiative connections* between them.
- Systems exchange electromagnetic signals that can be idealized as light rays or photons following null directions.
- From patterns of emission, propagation, and absorption, we reconstruct notions of causal order, simultaneity conventions, and (in the limit) a metric structure.

In this spirit, one can think of null links - idealized light signals between events - as the primitive carriers of causal structure. Two events are "null-related" if there exists a radiative connection between them; they are timelike- or spacelike-related according to whether a chain of such links can or cannot connect them within physically realizable processes.

This perspective is not meant to deny the usefulness of the Minkowski manifold. Rather, it suggests that the manifold and its metric are *derived* objects: they summarize, in a smooth continuum language, the more concrete facts about how matter and radiation interact. This resonates with the operational construction of simultaneity in Einstein's 1905 paper, where clock synchronisation is defined in terms of idealized light signals, and with work in quantum foundations that emphasizes operational constraints such as no-signalling.

If we take radiation as primary in this way, we are led naturally to ask: how do *clocks* - physical systems that generate time labels - fit into this picture?

3. Clocks and worldlines: from pre-drawn curves to growing records

In standard presentations of special relativity, a worldline is treated as a fully extended curve in spacetime. A point particle follows a timelike curve from the infinite past to the infinite future; clocks are associated with such curves and "measure" proper time along them.

From a clock-first perspective, this picture is reversed. Instead of assuming a fully drawn worldline, we emphasize that:

- A *clock* is a concrete physical system: typically a massive device with an internal oscillatory or at least regular dynamical process.
- At any given stage of operation, the clock has produced only a *finite number* of ticks. Each tick is a physical event in the device, recorded in some register or readout.
- The clock's worldline is not ontologically "there in full" from the outset. It is better seen as a growing record: a sequence of realized tick events, each associated with a concrete spacetime location.

On this view, what exists at a given stage for a particular clock $C$is:

- The finite set of its past tick events $\{T_1, T_2, \dots, T_n\}$.
- The current internal state of the clock between tick T_n and the next tick T_{n+1}, which has not yet occurred.

We can still *mathematically* fit a smooth worldline through these tick events, and we can use the dynamical laws to extend that curve into the future as a prediction. But ontologically, there is a clear distinction between:

- The realized segment of the worldline: up to (and including) the latest tick event.
- The merely lawful continuation: the part of the curve that would be traced if the clock continues to operate according to its governing dynamics.

In other words, worldlines are *constructed* out of clock behaviour rather than pre-given templates along which clocks must run.

This clock-first view does not conflict with special relativity at the level of empirical predictions. Proper time along a timelike curve is still a well-defined mathematical quantity, and good clocks still approximate it. What changes is the ontological reading: we do not assume that each worldline is fully drawn from $-\infty$ to $+\infty$; we let clocks build their worldlines tick by tick.

4. Why the latest tick matters for time

Within this clock-first picture, the latest tick of a clock acquires a natural significance.

Consider a well-functioning clock C. At any stage of its operation:

- There is a last tick event T_n in its history.
- The device is in some internal state between T_n and the next tick T_{n+1}.

It is tempting to regard the interval on the worldline between T_n and T_{n+1} as representing the clock's currently active temporal segment. From the point of view of the clock itself (and any apparatus directly coupled to it), this segment marks the boundary between:

- A settled past, represented by the register of ticks $\{T_1, \dots, T_n\}$.
- An open future, represented by the not-yet-realized tick T_{n+1} and beyond.

In ordinary practice, this distinction shows up implicitly whenever we say "the time now is τ" and mean: the clock has just ticked at τ, or its hand/phase is between tick τ and $\tau + 1$. Operationally, the latest tick is where:

- we can safely attach a time label to events "up to now";
- we cannot yet attach definite labels to events that would lie beyond T_{n+1}.

From a conceptual perspective, then, the latest tick provides a natural candidate for a local temporal boundary condition. It plays a role analogous to a local "present" for that clock: not an absolute metaphysical present, but a well-defined local interface between realized and merely predicted segments of the worldline.

This becomes particularly interesting when we consider *multiple* clocks, especially in relativistic and quantum contexts. For two distant clocks A and B:

- Each has its own latest tick, T_n^A and T_m^B.
- Each has an active segment between its latest and next tick.

Standard relativity tells us how to compare the numerical readings of these clocks given a synchronisation convention and a choice of frame, but it is silent on the question of whether there is any *physical relation* between the "currently active" segments as such. The minimal quantum package also does not privilege these segments: it speaks instead of a global state.

In the remainder of the paper, we suggest that the latest-tick segments of clocks are precisely the right place to localize the nonlocal correlations observed in Bell experiments, via an extended relational postulate that goes beyond the minimal quantum package.

5. Bell nonlocality and no-signalling revisited

Before stating the extended postulate, it is useful to summarize the empirical background in a way that will slot neatly into our clock-based picture.

In a typical Bell experiment, two measurement stations A and B are arranged so that their measurement events are spacelike separated. At each station:

- An experimenter chooses a measurement setting (e.g., a detector orientation) x at A, y at B.
- A binary outcome $a \in \{\pm 1\}$ is registered at A, and similarly b at B.

Repeated runs produce a joint probability distribution $P(a, b \mid x, y)$. Bell inequalities constrain this distribution under the assumption of local hidden variables. The observed violation of these inequalities shows that no such local realistic model can reproduce the data.

At the same time, the experiments confirm no-signalling: for all x, y, y',

$$\sum_b P(a, b \mid x, y) = \sum_b P(a, b \mid x, y'),$$

and similarly for the marginals at B. This means the distribution of outcomes at A is independent of the choice of setting at B, and vice versa. No choice of measurement basis at one wing can be used to modulate the statistics at the other in a way that would carry a controllable message faster than light.

The minimal quantum package reproduces these features by postulating:

- A *global entangled state* $\mid \psi\rangle$of the composite system,
- Local measurement operators $M_{a|x}^{A}$, $M_{b|y}^{B}$ acting on the two subsystems,
- Joint probabilities $P(a, b \mid x, y) = \langle\psi \mid M_{a|x}^{A} \otimes M_{b|y}^{B} \mid \psi\rangle$ (or the density-operator equivalent).

This description is silent, however, about *where* in spacetime the "nonlocality" resides. It tells us that the global state encodes correlations that cannot be decomposed into local causes, but it does not assert any spacetime relation between specific worldpoints associated with A and B.

From our clock-first perspective, this is precisely the gap we want to fill: we aim to replace the bare global state by a concrete relational structure relating the "currently active" segments of the clocks that implement the measurements at A and B.

6 EDGE as a primitive ontology for Bell nonlocality

In this section I place the EDGE framework within the primitive-ontology program, and show how the extended spacetime postulate applies to a standard Bell scenario in a relativistically acceptable way. The aim is not to provide a fully fledged dynamics, but to make precise what the beables are, how they underwrite nonlocal correlations, and why they do not introduce an operationally preferred frame.

6.1 Primitive beables and the status of the wavefunction

The primitive-ontology approach insists that a quantum theory must specify "what there is in space and time" - a distribution of primitive beables to which all measurement outcomes ultimately refer (Allori 2012). In GRWf the beables are discrete space-time "flashes" (Tumulka 2006); in GRWm they are a continuous mass-density field; in Bohmian mechanics they are particle configurations guided by a wavefunction. In each case, the primitive ontology lives in ordinary (or relativistic) space-time, while the wavefunction plays a nomological or law-like role.

EDGE follows this pattern. The primitive beables are:

1. The sequence of *tick events* along each macroscopic clock worldline, which forms a growing record of realized proper-time intervals.

2. The *radiative closures* that connect tick events on different worldlines via emission–absorption processes, recording null relations between them.
3. The *relational structure* between the most recent segments of different clocks - their latest-tick intervals - as encoded in the extended spacetime postulate introduced earlier.

The first two items specify a growing, radiation-anchored spacetime record: worldlines are not pre-drawn curves but aggregates of realized ticks and their radiative links. The third item is the genuinely new ingredient: it asserts that, at any stage of this growth, there exists a nonlocal relational structure among the currently active segments of distant clocks. This structure is constrained by relativistic causal order and by no-signalling, but is rich enough to underwrite Bell-type correlations.

Within this picture, the quantum state ψ is not itself a primitive object. It functions as a compact representation of the probabilistic constraints that the relational structure imposes on future tick events and radiative closures. In this respect, EDGE sides with those versions of primitive ontology that treat ψ as nomological or statistical - encoding dispositions or propensities for primitive events, rather than directly describing matter in space-time (Allori 2012; see also Norsen 2010; Esfeld et al. 2013). The wavefunction lives in a high-dimensional configuration space, but its job is to summarize, in a unified way, the allowed patterns of joint tick outcomes across the distributed network of clocks.

This stance is close in spirit to relational interpretations that take interactions between systems as fundamental (Rovelli 1996; Gambini and Pullin 2007), but it is more explicit about the underlying beables. In EDGE, the facts that are relative between systems are realized as concrete tick events and radiative closures in space-time, and the global quantum state summarizes the statistics of these relational events rather than constituting an additional ontic layer.

6.2 A Bell experiment in terms of latest ticks

Consider now a standard CHSH-type Bell experiment with two spatially separated stations, A and B. Each station includes a macroscopic clock that records a sequence of ticks along its worldline. We idealize such that:

- The source emits a pair of entangled systems toward A and B, with the emission event lying in the common past light cone of the relevant tick events on both clocks.
- At A, a measurement setting $a$is chosen and an outcome $A \in \{-1, +1\}$ is registered. At B, an independent setting $b$is chosen and an outcome $B \in \{-1, +1\}$ is registered.
- The respective measurement events occur within spacelike separation, as in the usual Bell arrangements.

In the usual textbook story, the joint probabilities $P(A, B \mid a, b)$ are obtained from ψ via the Born rule, and Bell's theorem shows that there is no underlying *local* hidden-variable model reproducing these probabilities (Bell 1964; Wiseman 2014). In EDGE, the focus shifts to how these probabilities are implemented in the growing spacetime record.

Let γ_A and γ_B be the worldlines of the macroscopic clocks at A and B. Let L_A be the latest tick on γ_A just before the measurement interaction at A begins, and let L'_A be the next tick after the outcome has become irreversibly recorded in the local environment. The interval $[L_A, L'_A]$ is the *active segment* of clock A for this measurement. Similarly, $[L_B, L'_B]$ is the active segment of clock B associated with the measurement at B.

The extended spacetime postulate then asserts that, conditional on the common past of these two segments (including the emission event and any prior radiative closures), there exists a nonlocal relational structure $\mathcal{R}_{AB}$ linking $[L_A, L'_A]$ and $[L_B, L'_B]$. Informally, $\mathcal{R}_{AB}$ encodes joint dispositions for how radiative and matter degrees of freedom will close during these intervals, such that:

1. The marginal probabilities at each wing agree with standard quantum predictions and depend only on the local setting:

$$P(A \mid a, \mathcal{R}_{AB}) = P_{\text{QM}}(A \mid a), P(B \mid b, \mathcal{R}_{AB}) = P_{\text{QM}}(B \mid b),$$

thereby respecting no-signalling operationally.

2. The joint probabilities recover the entangled quantum correlations:

$$P(A, B \mid a, b, \mathcal{R}_{AB}) = P_{\text{QM}}(A, B \mid a, b),$$

which violate a Bell inequality for suitable choices of a, b.

In other words, $\mathcal{R}_{AB}$ plays the role that a nonlocal hidden variable would play in a traditional Bell analysis, but it is defined as a relation between *oriented latest-tick segments* rather than as a point-like parameter λ attached to a single hypersurface. Its content is constrained by ψ, which summarizes the structure of $\mathcal{R}_{AB}$ as far as outcome statistics are concerned, but the ontological weight is carried by the realized tick events and radiative closures.

A full theory would specify a concrete probability measure over patterns of closures along $[L_A, L'_A]$ and $[L_B, L'_B]$ given $\mathcal{R}_{AB}$ and the past record, analogous to how GRWf specifies a distribution of flashes in space-time (Tumulka 2006) or how Bohmian mechanics specifies a deterministic evolution of particle configurations (Dürr et al. 1992). The present proposal is more modest: it identifies where, in the spacetime description, the nonlocal structure must reside if we want to preserve both Bell-type correlations and no-signalling.

6.3 Lorentz invariance and absence of a preferred foliation

A natural concern is whether such a nonlocal relational structure introduces an implicit preferred foliation of space-time. The EDGE framework is designed to avoid this by tying its primitive beables to local worldlines and proper time, rather than to global simultaneity slices.

Each clock worldline $\gamma$is parameterized by its own proper time τ, and its tick events are separated by locally defined intervals $\Delta\tau$. The active segment $[L, L']$ of any clock is simply the oriented interval between two successive ticks along γ. This construction is manifestly invariant under changes of inertial frame: re-describing the physics in a different frame changes the coordinate labels of the events, but not their order along the worldline.

The nonlocal structure $\mathcal{R}_{AB}$ is then defined as a relation between such oriented segments, conditional on their common past as encoded in the already realized parts of γ_A and γ_B and in the radiative closures that link them. Since the common past is itself defined in terms of null and timelike relations that are Lorentz invariant, and since $[L_A, L'_A]$ and $[L_B, L'_B]$ are worldline segments rather than members of a global foliation, the existence of $\mathcal{R}_{AB}$ does not depend on any preferred slicing of space-time.

This strategy is analogous in spirit to how GRWf achieves Lorentz invariance: there, the primitive beables are flashes in space-time, and the stochastic law for their distribution is formulated without reference to a global time function (Tumulka 2006). In EDGE, the primitive beables are ticks and radiative closures, and the nonlocal structure is attached to pairs (or more generally, networks) of local segments. The incompatibility with "local causality" in Bell's sense is acknowledged, but it is implemented in a way that need not conflict with the relativistic symmetry group (Bell 1990; Wiseman 2014).

Relational interpretations have long emphasized that quantum events are defined only relative to other systems (Rovelli 1996; Gambini and Pullin 2007). EDGE builds on this insight but insists on a primitive spacetime ontology: what is relative are the patterns of closures and tick events, and what is nonlocal are the relations among the latest-tick segments of distant clocks. The quantum state summarizes these patterns; it does not compete with them as a second ontology. The extended spacetime postulate thus provides a concrete location in the relativistic spacetime description where Bell nonlocality can "live," without sacrificing the operational content of special relativity.

7. Objectives: minimal and extended postulates

We can now state more precisely the objectives for the framework we call Emergent Distributed Generative Edge (EDGE), phrased at a level suitable for quantum-foundations discussion.

7.1 Empirical basis: Bell nonlocality and no-signalling

Any candidate theory must respect the following empirical bundle:

1. Bell nonlocality. Correlations between outcomes at spacelike separated stations violate Bell inequalities; no local hidden-variable theory can reproduce them.
2. Operational no-signalling. The marginal outcome statistics at each station are independent of the measurement choices at the distant station; no controllable superluminal communication is possible.

The combination of these two facts implies that nature is ontologically nonlocal in Bell's sense, yet operationally local in the no-signalling sense. Any acceptable theory must encode both features.

7.2 Minimal ontological postulate: the standard quantum package

The *minimal quantum package* that fits this empirical basis postulates:

- A global quantum state $\rho$for the composite system of interest,
- Local measurement operations at each station,
- Probabilities extracted by the Born rule.

In this package:

- The state $\rho$is a global object on a Hilbert space.
- It is not tied to any particular pair of spacetime events.
- No extra spacetime structure is assumed beyond the light-cone structure of relativity required to define spacelike separation and causal order of settings and outcomes.

Questions about *how* the global state is "realized" in spacetime are left to interpretation. Crucially, none of the standard interpretations *requires*, at the minimal level of commitment, a special relation between the latest ticks of distant clocks. The shared ontological content is modest: there exists some global structure (the quantum state) that generates the nonlocal correlations, but there is no privileged relational geometry between specific worldpoints.

7.3 Extended ontological postulate: a relation between latest-tick segments

EDGE proposes to add an extended ontological postulate beyond this minimal package.

Consider two spatially separated clocks $A$and B, each associated with a measurement station in a Bell experiment, and each functioning as described in Sections 3–4. At a given stage of operation:

- Clock A has a latest tick T_n^A and a next tick T_{n+1}^A, defining an active segment of its worldline between these two events.
- Clock B has a latest tick T_m^B and a next tick T_{m+1}^B, defining an analogous segment.

We postulate:

Extended Relational Postulate (informal statement).
At any given stage of their operation, there exists a physical relation between a world-point on the active segment of clock A (between T_n^A and T_{n+1}^A) and a world-point on the active segment of clock B (between T_m^B and T_{m+1}^B), such that:

1. This relation is sufficient to underwrite the experimentally observed nonlocal correlations between outcomes when measurements are performed at or near these segments.
2. The relation cannot be exploited to generate controllable superluminal signalling; it is constrained to reproduce the empirically confirmed no-signalling conditions.

In the language of the minimal quantum package, the effects of this relation can still be represented effectively by a global state ρ. Ontologically, however, the proposal is that $\rho$is a *summary* of a more concrete relational spacetime structure tying together currently active worldline segments (e.g., between successive ticks of distant clocks).

The objectives of EDGE can thus be summarized as follows:

- Preserve all empirical successes of the minimal quantum package (Bell violation, no-signalling, standard quantum statistics).
- Add a specific spacetime ontology in which there are not only global states but also physically meaningful relations between particular worldpoints associated with the latest-tick segments of clocks.
- Develop a framework in which such relations are made precise, subject to relativistic constraints and empirical tests.

In the next section, we sketch the conceptual principles that such a framework would obey.

8. Sketch of EDGE principles (conceptual level)

Here we briefly outline the kind of principles that a framework like EDGE would adopt, without attempting a full mathematical development.

8.1 Time anchored in mass and clocks

First, EDGE takes seriously the idea that time is anchored in massive systems, not in radiation alone. Clocks are massive devices with internal dynamics; their ticks are physical events on their worldlines. Time at a given station is represented by the ordered sequence of such events and their associated intervals. Radiation - light signals - serves primarily to *synchronise* clocks and to mediate correlations, not to generate time as such.

This is compatible with relativistic time dilation and gravitational redshift, as those are understood as relations between the proper-time readings of different clocks, not as alterations of some abstract background parameter.

8.2 Radiation as correlation and synchronisation

Second, EDGE treats radiative links (null connections) as the primary means by which distant clocks and systems become correlated and synchronised. Light signals between measurement stations, preparation devices, and reference clocks are the concrete carriers of the operational spacetime structure that underlies experimental practice.

However, in contrast to views that treat such links as the *only* carriers of physical connection, EDGE allows for an additional, nonlocal relational structure between latest-tick segments, constrained by no-signalling.

8.3 Latest-tick segments as carriers of relational "now"

Third, EDGE attributes a specific physical role to the active worldline segments between a clock's latest and next tick. These segments function as local "now-bands":

- They delimit the portion of the worldline where the clock's internal state is currently evolving toward its next tick.
- They form the natural locus for modelling how the clock can enter into relations with other systems *at this stage of its operation*.

The extended relational postulate then asserts that nonlocal correlations are not merely properties of a global abstract state, but correspond to concrete relations between such now-bands of distant clocks.

This does not impose a global, absolute present; it only posits that for each pair of clocks, there exist relations connecting their respective latest-tick segments.

8.4 Compatibility with no-signalling and relativistic constraints

Finally, any relational structure introduced by EDGE must be strictly compatible with:

Operational no-signalling. The relational links cannot be modulated in a way that allows agents to send messages faster than light. The probabilities at each station, conditioned only on local actions, must remain invariant under distant choices.

Relativistic causal structure. The relations should not pick out a preferred global foliation in a way that manifests in observable violations of Lorentz invariance. At most, they may define hidden or emergent structures that remain empirically indistinguishable from Lorentz-symmetric behaviour at the operational level.

The challenge for EDGE, then, is not to alter quantum statistics but to *realize* them in spacetime in a way that does justice to both nonlocal correlations and relativistic causal constraints, using latest-tick relations as the central ontological device.

9. Discussion and outlook

I have argued that:

i. The combination of Bell nonlocality and no-signalling leaves the spacetime ontology of standard quantum theory significantly underdetermined.

ii. A radiation-first, clock-first perspective on spacetime suggests that worldlines are better viewed as growing records, constructed tick by tick, rather than pre-drawn curves in a fixed 4D block.

iii. Within this view, the latest tick of a clock naturally marks a local boundary between realized past and open future, and the active segment between latest and next tick becomes a natural candidate for a "currently operative" portion of the worldline.

iv. This motivates an extended relational postulate: that there exists a physical relation connecting the active segments of distant clocks, sufficient to underwrite nonlocal correlations while remaining fully compatible with no-signalling.

v. A framework such as Emergent Distributed Generative Edge (EDGE) aims to implement this postulate by making the relational structure precise and dynamical, anchoring time in mass-based clocks and treating radiation as the synchronising and correlating medium rather than the sole bearer of physical connection.

This proposal does not contradict the minimal quantum package; it sits *on top of it* as an additional ontological commitment. All standard quantum predictions are retained. What changes is the picture of what, if anything, corresponds in spacetime to the nonlocal correlations that the global state encodes.

Several directions for further work are immediate:

Formal development: One would like to specify the relational structure more precisely, perhaps in terms of conditional probability assignments or consistent histories attached to latest-tick segments, and to show how the usual Hilbert-space formalism arises as an effective description.

Comparison with existing primitive ontologies: It would be illuminating to compare the latest-tick relational picture with flash ontologies (e.g. GRWf), continuous-matter ontologies (GRWm, Bohmian mechanics), and relational or process-based approaches, to see where it aligns and where it diverges.

Potential empirical constraints:
Although the extended postulate is designed to be empirically conservative, it may suggest subtle constraints or signatures - for example, in high-precision timing networks or relativistic quantum information protocols - that could be used to bound or probe the allowed forms of relational structure.

Conceptual links to the problem of time: The emphasis on clocks creating worldlines and on latest-tick segments as local temporal boundaries may offer a different angle on debates about presentism, growing block views, and the status of the "now" in relativistic settings.

The overall message is modest but, we hope, clear: one can respect both Bell nonlocality and no-signalling, and keep all the computational machinery of standard quantum theory, while still seeking a richer spacetime ontology than that afforded by a bare global quantum state. Anchoring that ontology in radiation, clocks, and relations between their latest ticks is one concrete way to make progress on this front.

We regard the extended relational postulate articulated here as a starting point rather than an endpoint. The detailed construction and assessment of EDGE, as a theory that lives up to these objectives, is left for future work.

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