

Photon Propagation as Microscopic Wave-form Reconstruction

An Ontological Reading of the Photon's Identically-Zero Proper Time,
Wheeler–Feynman Absorber Theory, and Feynman Path Integration

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Abstract

I argue that the photon's act of propagation between an emission event A and an absorption event B is best understood not as the flight of a particle through a background spacetime, but as a single microscopic wave-form reconstruction event in which the electromagnetic field configuration is deconstructed at A and reconstructed at B . The reading is supported by three independently accepted physical facts: (i) the photon's proper time along its null world-line is identically zero; (ii) Wheeler–Feynman absorber theory binds the emission–absorption pair through symmetric retarded and advanced contributions of the electromagnetic field; (iii) the Feynman path integral assigns the propagation amplitude to a phase-coherent superposition over all kinematically permitted paths rather than to any single trajectory. Under this reading, the constant c is reinterpreted as the coupling constant relating an external observer's spacetime scale to the wave-form reconstruction process, rather than as a particle velocity. I situate the proposal in relation to the standard textbook picture, Cramer's transactional interpretation, Aharonov's two-state vector formalism, Bohm's pilot wave, and Wheeler's delayed-choice experiments. I close with a discussion of empirical status, falsifiability in principle, and implications for the foundational ontology of light. The proposal is a conceptual reorganization of accepted quantum-electrodynamic content, not a new physical mechanism; its claim is ontological, not predictive.

Keywords: photon proper time; Wheeler–Feynman absorber theory; Feynman path integral; ontology of light; transactional interpretation; two-state vector formalism; speed of light; foundations of quantum electrodynamics.

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1 Introduction: A Question Hiding in Plain Sight

The propagation of a photon between two events is, in textbook quantum electrodynamics, taken as straightforward. A source at event A emits a photon; the photon travels along a null

geodesic; an absorber at event B measures it. The story has the form of a particle traveling through a background spacetime at the speed c . The mathematics works. The predictions are confirmed to absurd precision.

Yet there is a question hiding inside this textbook story, and it is rarely asked seriously: *from whose perspective does the photon “travel”?* The answer cannot be the photon’s own, because the photon has no proper time along its worldline (Section 2.1). It cannot be a single privileged external observer’s, because there is no such privileged observer in special relativity. What we standardly call “photon propagation” is a description offered by some particular external observer with respect to whose proper time the photon’s null trajectory takes a particular coordinate duration. The propagation, in other words, is observer-relative in a strong sense: it is not a fact about the photon, it is a fact about the relationship between the photon’s null trajectory and an external observer’s reference frame.

This already suggests a reorientation. If propagation is not the photon’s own activity but rather an external observer’s coordinate description of a null relation between A and B , then what *is* the photon doing between A and B ?

Two further accepted physical facts give the same suggestion from independent angles. Wheeler–Feynman absorber theory [1, 2] establishes that the electromagnetic interaction between an emitter and an absorber is naturally written as a symmetric sum of retarded and advanced field contributions, so that A and B are bound together by a single field-theoretic structure rather than connected by a one-directional transmission. Feynman’s path integral formulation [3, 4] establishes that the amplitude for propagation between A and B is a phase-coherent superposition over all kinematically permitted paths, not the amplitude associated with any single trajectory. Both these results are textbook quantum electrodynamics. Neither is controversial.

What I argue in this paper is that taking all three of these facts seriously, simultaneously, leads to a reorganization of how we should ontologically describe photon propagation. The reorganization is this:

The photon’s act of propagation between A and B is a single microscopic wave-form reconstruction event in which the electromagnetic field configuration is deconstructed at A and reconstructed at B . The constant c is the coupling constant between an external observer’s spacetime scale and the structure of this reconstruction event; it is not a particle velocity.

The thesis is ontological, not physical. I propose no new equations, predict no new observations, and modify no calculation in quantum electrodynamics. What I propose is a reading of accepted results that changes *what we are taking those results to be about*.

The plan of the paper is as follows. Section 2 reviews the three foundations of the proposal. Section 3 states the reconstruction interpretation formally and analyzes its main claim about c . Section 4 relates the proposal to five other interpretive frameworks for quantum electrodynamics. Section 5 discusses empirical status, falsifiability in principle, and connections to quantum gravity. Section 6 draws out the principal philosophical implications, particularly for the identity and “location” of a photon. Section 7 concludes.

2 Three Independent Foundations

The reconstruction reading rests on three results, none of which is original to this paper. I review each in turn.

2.1 The Photon’s Identically-Zero Proper Time

Consider a Lorentzian spacetime $(\mathcal{M}, g_{\mu\nu})$ and an observer with worldline $\gamma(\lambda)$. The observer’s proper time is defined by

$$d\tau^2 = -\frac{1}{c^2} g_{\mu\nu} dx^\mu dx^\nu. \quad (1)$$

A photon’s worldline is a null geodesic of the metric. By the null condition,

$$g_{\mu\nu} \dot{x}^\mu \dot{x}^\nu = 0, \quad (2)$$

so along the worldline $d\tau = 0$ identically. Whatever affine parameter we use to describe a photon’s trajectory, that parameter cannot be the photon’s proper time, because there is no nontrivial proper time. The photon has no internal clock that ticks during its trajectory. From the photon’s own perspective—to the extent that the phrase has any meaning—the emission event and the absorption event *share the same proper-time coordinate*.

Proposition 1 (Photon Simultaneity). *For any photon, all events along its worldline share the same proper-time coordinate within the photon’s rest frame—a frame which is, however, ill-defined as a Lorentzian boost limit. In this sense, for the photon, the emission event A and the absorption event B are the same event.*

This is a standard consequence of special relativity [5, 6]. It is not novel. But its ontological import has, in my reading, been systematically underplayed in the literature. If two events are the same event from a certain perspective, then asking “what happens during the propagation” is, from that perspective, ill-posed. There is no “during.”

One should not over-read the photon-frame talk. The photon’s null worldline is the limit of a sequence of timelike worldlines whose Lorentz factors diverge, and quantities defined in inertial frames do not all continuously extend to the limit. But the proper-time vanishing is robust: it follows directly from the null condition, not from a delicate limit. The robust statement is: *no parameter intrinsic to the photon distinguishes A from B .*

2.2 Wheeler–Feynman Absorber Theory

In their landmark 1945 and 1949 papers, Wheeler and Feynman [1, 2] formulated classical electrodynamics as a theory of direct interparticle action rather than as a theory of charges interacting through a mediating field. In the standard Maxwell formulation, a charge produces a field, the field propagates outward at the speed c , and the field is absorbed elsewhere; the field is the carrier of the interaction. In the Wheeler–Feynman formulation, the interaction between an emitter at event A and an absorber at event B is written symmetrically:

$$F_{\mu\nu}^{\text{total}}(A, B) = \frac{1}{2} \left(F_{\mu\nu}^{\text{retarded}}(A \rightarrow B) + F_{\mu\nu}^{\text{advanced}}(B \rightarrow A) \right). \quad (3)$$

The retarded field F^{retarded} propagates forward in time from A to B in the usual sense. The advanced field F^{advanced} propagates backward in time from B to A , vanishing outside the past light cone of B . The symmetric average, with appropriate boundary conditions imposed by the assumption that all radiation is eventually absorbed somewhere in the universe (the absorber condition), reproduces standard radiation reaction and standard Maxwell predictions [1, 7].

The Wheeler–Feynman formulation is widely regarded as a viable rewriting of classical electrodynamics. It has well-known issues with realistic boundary conditions in cosmologies that do not absorb all radiation [7, 8], but as an internal mathematical reformulation it is unimpeachable.

What I want to draw out is the ontological reading the formulation invites. In Eq. (3), the event A and the event B are not source and target. They are two endpoints of a single field-theoretic structure. The field, taken as a whole, is the relation between A and B . It is not something *at* A , propagating, and then arriving *at* B . It is a thing whose existence spans the pair $\{A, B\}$ as a unit.

The transactional interpretation of quantum mechanics [9, 10] extends this view systematically to quantum electrodynamics. I return to the transactional interpretation in Section 4.2. For now, the relevant point is that Wheeler–Feynman, as an accepted formulation of classical electromagnetism, is friendlier to a relational ontology of photon propagation than the standard Maxwell story is.

2.3 Feynman Path Integration and the No-Trajectory View

Feynman’s third foundation is the path integral [3, 4]. The propagator for a photon (or any quantum particle) from event A to event B is given by

$$K(B, A) = \int \mathcal{D}\gamma \, e^{iS[\gamma]/\hbar}, \quad (4)$$

where the sum (more precisely, the path-space integral) ranges over all paths γ that begin at A and end at B , and $S[\gamma]$ is the action along γ .

The path integral has a feature that, taken seriously, undermines any naive “particle traveled along trajectory γ_0 ” reading. The propagator is given by summing contributions from *every* kinematically permitted path—including non-classical paths, looping paths, and paths whose proper time interpretation would be problematic. The classical trajectory $\gamma_{\text{classical}}$ corresponding to the stationary phase point is privileged only insofar as it dominates in the classical limit $\hbar \rightarrow 0$. For a single photon transmitted through a quantum-optical apparatus, the dominant contribution comes from a phase-coherent superposition over many paths, not from any single path.

This is normally summarized by saying that quantum particles “have no definite trajectory.” The more careful ontological statement is sharper: *the trajectory of a quantum particle is not an intrinsic feature of the particle; it is a structure that an external observer can extract under appropriate measurement procedures.* In the absence of trajectory-fixing measurements, the path-integral language describes the propagator as a relation between A and B , not as the behavior of a moving object along a curve between them.

This is the third foundation. None of these three results—photon proper-time vanishing,

Wheeler–Feynman symmetric formulation, path-integral over all paths—is novel. Each is textbook quantum electrodynamics. What I propose to do, in the next section, is take all three of them seriously simultaneously, and ask what ontology of photon propagation they jointly support.

3 The Reconstruction Interpretation

3.1 Statement of the Hypothesis

I now state the central claim formally.

Hypothesis 1 (Photon Propagation as Wave-form Reconstruction). *The propagation of a photon between an emission event A and an absorption event B is a single microscopic wave-form reconstruction event. The electromagnetic field configuration is deconstructed at A and reconstructed at B , with the events A and B bound together by the field-theoretic structure (in the Wheeler–Feynman sense) and by phase-coherent superposition over kinematically permitted paths (in the path-integral sense). The photon does not “travel between A and B ” in any ontologically robust sense; rather, A and B are the two facets of the same reconstruction event, accessed by an external observer through their respective coordinate locations.*

A few clarifications about what this hypothesis claims and does not claim.

It does *not* claim that the standard quantum-electrodynamic mathematics is wrong. The path integral formulation, Maxwell’s equations, the standard photon propagator, the standard predictions for interference, coherence, and quantum optics—all of these remain unmodified.

It does *not* claim that “light moves backward in time” or that one can use this hypothesis to construct closed timelike curves. The Wheeler–Feynman symmetric formulation, in the absorber-condition setup, gives the same causal structure as standard retarded Maxwell theory. No causality violation is permitted.

It does *not* claim that the photon “has no existence” between A and B . The hypothesis is precisely about what kind of existence the photon has between A and B : it has the existence of a wave-form structure binding A and B into a single reconstruction event, rather than the existence of a particle traversing a trajectory.

What the hypothesis *does* claim is ontological. It tells us what to take photon propagation to be. It says: the entity whose existence corresponds to “a photon transmitted from A to B ” is not a particle on a worldline; it is a reconstruction event whose two facets are A and B . The external observer’s experience of “a photon traveling at speed c ” is the external observer’s coordinate-relative description of one such reconstruction event.

3.2 The Constant c as a Coupling Constant

Under the reconstruction reading, the universal constant c requires reinterpretation.

In the standard reading, c is a particle velocity: it is the rate at which a photon traverses spatial distance per unit external coordinate time. In the reconstruction reading, this picture is not quite right, because the photon is not traversing anything. What, then, is c ?

I propose the following. Given a reconstruction event whose two facets A and B have, in an external observer’s coordinates, spatial separation $\Delta x_{\text{external}}$ and temporal separation $\Delta t_{\text{external}}$, we have

$$c = \frac{\Delta x_{\text{external}}}{\Delta t_{\text{external}}} \Big|_{\text{single reconstruction event}}. \quad (5)$$

Read literally as a ratio of the observer’s coordinate intervals, this is just the standard expression. The reinterpretation lies in what the ratio is the ratio *of*. In the standard reading, the ratio is the speed of an object moving through space and time. In the reconstruction reading, the ratio is the coupling constant between the external observer’s coordinate system and the structure of a single reconstruction event: it is the scale at which a wave-form reconstruction event, when projected onto the external observer’s coordinates, manifests as a spatiotemporal separation.

The reinterpretation has bite in three ways.

First, it answers a question that the standard reading leaves opaque: why should the speed of a particle equal the maximum signal speed in special relativity? In the standard reading, this is brute fact—a particle just happens to move at the geometric maximum. In the reconstruction reading, it is a consequence: the reconstruction event is what defines the geometric maximum, because it is the maximally tight coupling between A and B that does not invoke a separate carrier mediating their relationship.

Second, it deflates the question “what would happen if a photon could travel faster than c ?” The question presupposes that the photon is a particle moving through space, and that its velocity is a property that could in principle take some other value. Under the reconstruction reading, the question is malformed: c is not the photon’s velocity, so the photon cannot have “a different velocity” in any straightforward sense. The question dissolves rather than gets answered.

Third, it fits with what one already says when pressed about the photon’s frame. Asked “what is the photon’s experience as it travels?” physicists already concede that the question has no clean answer, because the photon’s proper time is zero. The reconstruction reading explains why: there is no traveling to experience; there is only a reconstruction event whose two facets, from the external observer’s view, appear to be separated by a null interval.

3.3 Where Is the Photon Between A and B ?

A natural objection: under the reconstruction reading, where is the photon while “in flight”? If A and B are bound together as a single event, what occupies the spacetime region between them?

I take this question seriously, because it pinpoints exactly where the reconstruction reading and the standard particle reading diverge ontologically.

My answer is: nothing.

Nothing definite occupies the interior, and this is not a defect of the theory but a correct description of the situation. The field-theoretic structure binding A and B is real, but it is not localized; it is the entire relation between the two events.

Consider an analogy. Asking where the photon is between A and B is like asking, of a

married couple bound by a vow, where the vow is located in space. The vow is not in space in the relevant sense. It is the structure connecting two people; that structure is not a third object occupying a region of space alongside them. We do not feel an explanatory pressure to find the vow somewhere in the kilometers between the two people; we accept that the vow’s mode of existence is relational, not local. The reconstruction reading asks the same patience of the photon.

This is parallel to what one already accepts about quantum-field theory more generally. The vacuum state $|0\rangle$ in quantum electrodynamics is not localized; it pervades spacetime in a manner that does not reduce to a description of any particular spatial region. A photon-state $|1\rangle$ added to the vacuum has a Fock-number, an energy, a momentum, but its spatial localization is given by a wavefunction or wave packet, and only highly localized packets approximate a particle-like localization. The question “where is the photon” is already, in quantum electrodynamics, more subtle than “where is the particle in classical mechanics.” The reconstruction reading takes this subtlety as ontologically constitutive, rather than as a technical embarrassment to be tidied away.

4 Relation to Other Interpretations

The reconstruction reading is not without antecedents. Five existing interpretive frameworks share aspects of its motivation or content, though none, to my knowledge, articulates exactly the same claim. I situate the proposal in relation to each.

4.1 The Standard Particle-on-Null-Geodesic Picture

The standard textbook picture treats a photon as a quantum-mechanical excitation of the electromagnetic field that, in its classical limit, follows a null geodesic from A to B . Propagation is a process along this geodesic. The picture is empirically successful, computationally efficient, and pedagogically simple.

The reconstruction reading agrees with the standard picture on every observable prediction. They disagree only on what is being described. The standard reading takes the geodesic as a real trajectory along which a real entity moves; the reconstruction reading takes it as the external observer’s coordinate-relative description of a null relation between A and B . This is the kind of disagreement that foundations of physics is in the business of considering—the standard picture is preferable for calculation, the reconstruction reading may be preferable for understanding.

4.2 Cramer’s Transactional Interpretation

This is the closest existing relative.

John Cramer’s transactional interpretation [9, 10] extends the Wheeler–Feynman symmetric formulation to general quantum mechanics. In Cramer’s account, a quantum measurement involves an “offer wave” from the emitter A propagating forward in time, a “confirmation wave” from the absorber B propagating backward in time, and a “handshake” between them that constitutes the completed transaction. The transaction binds A and B together as a single event in a way structurally identical to what I have called a reconstruction event. The vocabularies differ;

the underlying claim about ontology is, in important respects, the same. The reconstruction reading and the transactional interpretation are siblings.

Where they differ, they differ in scope and in commitment. First, Cramer’s framework is advanced as an interpretation of all of quantum mechanics; the reconstruction reading proposed here is restricted to photon propagation, where Wheeler–Feynman and path integration carry the most direct weight. The restriction is deliberate. Many of the difficulties that the transactional interpretation has faced in the literature [11, 12] concern its extension to multi-particle, multi-time-ordered configurations where the “handshake” temporal logic becomes subtle. By restricting the scope to photon emission–absorption pairs, the reconstruction reading inherits the strengths of the transactional framework while avoiding most of these difficulties.

Second, Cramer’s interpretation has been historically associated with metaphysical commitments—about the reality of advanced waves, about the temporal ordering of transactions, about whether the handshake takes place “in pseudotime” or in some other temporal structure—that have generated extensive debate [12, 13]. The reconstruction reading does not need to take a stand on these commitments. It claims only that, for photons, the emission–absorption pair is bound by a single field-theoretic structure in a Wheeler–Feynman-symmetric way. Whether one wishes to call the binding a “transaction,” whether one wishes to attribute reality to the advanced wave component, whether one wishes to articulate a pseudotemporal logic of transaction-completion—these are further questions on which the reconstruction reading is silent. I take Cramer’s framework as a strong relative and an intellectual debt, but the reconstruction reading does not depend on its more contestable elements.

4.3 Aharonov’s Two-State Vector Formalism

Aharonov, Bergmann, and Lebowitz [14], with later development by Aharonov and Vaidman [15, 16], formalized the two-state vector formalism of quantum mechanics. A fully specified quantum description of a system between preparation and measurement involves two state vectors—one evolving forward from preparation, one backward from measurement—with physical predictions extracted from their joint structure.

The framework shares with the reconstruction reading the principle that a quantum process between A and B is most natural when both events are treated symmetrically. They are compatible. One can in principle articulate the reconstruction reading using two-state vector language, with the photon’s emission state and absorption state jointly defining the reconstruction event.

4.4 Bohm’s Pilot Wave and Implicate Order

Bohm’s pilot-wave theory [17] and his later implicate-order framework [18] represent another family departing from the standard particle picture. The reconstruction reading shares with the implicate-order framework the idea that what appears as photon propagation at the spacetime level is the surface manifestation of a deeper non-localized structure. It does not, however, commit to the pilot-wave claim that quantum particles have definite trajectories guided by waves. On that question the reconstruction reading is agnostic.

4.5 Wheeler’s Delayed-Choice Experiments

Finally, the reconstruction reading dissolves Wheeler’s delayed-choice paradox [19, 20, 21] rather than resolving it. The question of whether the photon has already “decided” to travel as wave or particle before the absorber configuration is fixed does not arise: the photon was never traveling as anything in the first place. The configuration of the absorber facet is part of the reconstruction event itself, not a subsequent intervention on a preexisting particle.

5 Empirical Status and Distinguishability

5.1 Why Current Observations Do Not Distinguish the Readings

A natural question: if the reconstruction reading and the standard reading give the same predictions for all observables, is the disagreement empty?

I argue that it is not empty, but its empirical bite is subtle. The two readings agree on the predictions of quantum electrodynamics as a calculational scheme. They give the same answers to questions of the form “what is the probability of detecting a photon at B given an emitter at A and apparatus $\mathcal{O}$?” They disagree on questions of the form “what entity is responsible for this probability, and what is that entity doing between A and B ?”

The latter questions are not, in the standard sense, empirical. They are interpretive. A complete physical theory can have many empirically equivalent interpretations [22, 23], and choosing between them is a question of foundations rather than of observation. This does not make the choice unimportant. What we take an empirically successful theory to be *about* is part of what it means to understand the theory. Hidden behind the question of “which interpretation is correct?” lies the question of what physics describes, and that question has consequences for which directions of theoretical development seem fruitful.

5.2 What Would Distinguish the Readings in Principle

Although the readings agree on standard quantum electrodynamic predictions, they have different theoretical fertility. The reconstruction reading suggests certain extensions and connections that the standard reading does not naturally suggest.

For example, the reconstruction reading is closely related to the holographic and ER=EPR [24, 25] programs in quantum gravity, in which spacetime geometry is taken to emerge from underlying quantum entanglement structure. Under the reconstruction reading, photon propagation is not a process taking place in a pre-given spacetime; it is one of the structures by which spacetime itself is realized. This suggests that quantum gravity at the scale of single photon transmissions might exhibit nontrivial structure—for example, in the dispersion relations of photons over cosmological distances, or in correlations between far-separated absorber events that exceed what standard quantum electrodynamics on a fixed background allows. Current constraints on Lorentz invariance violations [26, 27] bound such effects tightly, but do not exclude them at the scales relevant to fundamental quantum gravity.

The reconstruction reading also makes contact with Wheeler–Feynman absorber boundary conditions in non-trivial cosmologies. If the universe is open (in the sense relevant to absorber

conditions) or contains regions of incomplete absorption, the symmetric formulation makes non-trivial predictions that the standard retarded formulation does not [7, 8]. These distinctions are difficult to test but are not ruled out as testable in principle.

Finally, the reconstruction reading suggests that the boundary between “a photon was emitted” and “a photon was not emitted” is not always sharp—it depends on the absorber structure. This is in line with the well-known fact that the photon-number basis in quantum optics is observer-dependent at curved spacetime backgrounds (the Unruh effect being the standard example [28]). The reconstruction reading takes this dependence as ontologically constitutive rather than as a calculational subtlety.

5.3 The Bekenstein Bound and the Limits of Reconstruction

A final empirical consideration: even at a microscopic scale, a wave-form reconstruction event is bounded by the Bekenstein limit [29]. The information content of the field configuration at A , transferred to B , cannot exceed

$$I \leq \frac{2\pi RE}{\hbar c \ln 2}, \quad (6)$$

where R is the spatial size of the relevant region and E its energy. For a single photon transmission, this bound is enormously larger than the photon’s actual information content—so the bound is not saturated. But it places an in-principle limit on how much can be encoded in any individual reconstruction event, which becomes relevant when one considers extensions to macroscopic wave-form transport [30].

6 Philosophical Implications

6.1 Wave–Particle Duality Reconsidered

Wave–particle duality, as standardly presented, is the claim that a quantum entity exhibits wave-like properties under some measurements and particle-like properties under others, with neither aspect being primary. This presentation is, in my view, philosophically unstable: it asks us to imagine an entity that is neither wave nor particle yet exhibits the properties of both depending on what we do to it.

The reconstruction reading offers a cleaner alternative. The photon is a single kind of entity—a wave-form structure linking emission and absorption events—and the apparent “particle-like” aspect arises in a specific class of measurement contexts where the wave-form reconstruction is highly localized at the absorber facet. The apparent “wave-like” aspect arises in contexts where the reconstruction involves phase-coherent superposition over multiple paths. Neither aspect is more fundamental than the other; both are aspects of a single underlying reconstruction event whose presentation to the observer depends on the measurement context.

This is, of course, just a reformulation of standard quantum-electrodynamic content. The point is that the reformulation makes the underlying ontology more coherent. The photon is not an entity straddling two incompatible categories; it is an entity of a single (admittedly unfamiliar) category, whose properties happen to manifest differently under different observational contexts.

6.2 The Identity of a Photon

A photon emitted at A and absorbed at B is, in the standard reading, the same entity that traveled from A to B . Its identity is preserved by the continuity of its worldline.

Under the reconstruction reading, the question of the photon’s identity is subtly different. There is no worldline to preserve continuity along; the photon is the reconstruction event itself. “This photon” is identified by the specification of its two facets A and B , by its energy, momentum, polarization, and other quantum numbers, and by the field-theoretic structure binding the facets.

This raises an interesting consequence. Consider an entangled photon pair, with one photon detected at A_1 and the other at A_2 , where the events are spacelike-separated. In the standard reading, each photon is an individual entity with its own worldline. In the reconstruction reading, the entangled pair is more naturally read as a single reconstruction structure with four facets (two emissions, two absorptions), and the “two photons” picture is a coordinate-relative description rather than an ontological fact about the underlying structure. This fits with what one already says about entanglement—that the constituents of an entangled state are not, strictly speaking, independent entities—and gives that intuition a clean structural realization.

6.3 Macroscopic Generalization and Its Limits

A natural question is whether the reconstruction reading extends to macroscopic objects. Can a macroscopic body, like a person, in principle be described as a wave-form reconstruction structure binding two events that might be far apart in spacetime?

I think the answer is: in principle yes, in practice no, by an extremely wide margin. In principle, every macroscopic body has a quantum-mechanical description, and that description admits a Wheeler–Feynman-style symmetric formulation and a path-integral structure, and there is no point at which the formal apparatus breaks down. In practice, the macroscopic-scale interference suppression by decoherence is so overwhelming [31] that the wave-form structure binding distant facets contributes essentially nothing to observable predictions, and the macroscopic body is effectively a classical object with a well-defined worldline.

The interesting case is the intermediate regime—molecular interferometry, large-molecule diffraction [32, 33]—where wave-form aspects become observable for objects approaching macroscopic scale. The reconstruction reading suggests that this regime should not be thought of as “classical objects exhibiting strange quantum effects,” but as a regime where the wave-form reconstruction structure that is always present (at the level of fundamental quantum description) becomes observationally non-negligible. This is a difference in framing rather than in calculation, but it suggests, I believe, a more honest description of what is happening.

7 Conclusion

The photon does not travel.

This is the claim, in one line. The wave-form structure that links an emission event A to an absorption event B exists; the field-theoretic binding is real; the constant c is the scale at which an external observer’s coordinates pick up the shape of this binding. What does not exist is the

picture of a little point of energy moving from A to B at velocity c . That picture is an external observer's coordinate-relative description, not an ontological fact about the photon.

Why believe this? Because three accepted facts of quantum electrodynamics—the photon's identically-zero proper time, the Wheeler–Feynman symmetric formulation, and the path integral over all paths—each suggest, from their own angle, the same reorientation. The reconstruction reading articulates what those three facts, taken jointly and seriously, are telling us. It modifies no equation; it changes the description of what the equations are about.

Why is it still a hypothesis rather than dogma? Because the empirical content of the reconstruction reading is, within the standard observational regime of quantum electrodynamics, identical to the standard particle-on-null-geodesic picture. Distinguishing the readings empirically requires probing regimes—single-photon quantum gravity, non-trivial absorber boundary conditions, macroscopic interference at the edge of decoherence—that current experiments cannot yet access at the relevant precision. Until they can, the choice between readings is a foundational rather than an empirical decision.

I will close with one image, because I think it captures the proposal more than any of my formal statements. When you stand outside on a clear night and a photon arrives at your eye from a star ten thousand light-years away, the standard reading invites you to imagine that photon as having journeyed across ten thousand years of space. The reconstruction reading invites you to consider instead: that emission, and your absorption, are the two facets of a single event—an event whose proper-time extent is zero, whose binding structure has been quietly holding A and B together all this time. You did not catch a photon at the end of its long flight. You completed a transaction the universe was already in the middle of.

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