Consistency of the Retro-Beam Transactional Framework with Special Relativity

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Abstract

This paper elucidates how the Retro-Beam Transactional Framework (RBTF), a novel theory proving retro-causality in quantum mechanics, maintains consistency with special relativity. Building upon the Transactional Interpretation (TI) and its relativistic extensions, RBTF incorporates advanced and retarded waves in a Lorentz-invariant manner. We present a mathematical proof of this consistency, followed by three illustrative examples. References to foundational works are provided with links.

1 Introduction

The Retro-Beam Transactional Framework (RBTF) extends the Time-Symmetric Retro-Beam Field Theory and integrates elements of the Transactional Interpretation (TI) of quantum mechanics. In RBTF, quantum transactions involve offer waves propagating forward in time and confirmation waves (retro-beams) propagating backward, forming self-consistent handshakes. A key concern for any theory involving backward propagation is compatibility with special relativity, particularly avoiding violations of causality or introducing superluminal signaling.

Special relativity demands that physical laws are invariant under Lorentz transformations, preserving the light cone structure and causality. RBTF achieves this by utilizing solutions to relativistic wave equations, such as the Klein-Gordon or Dirac equations, which naturally admit both retarded (forward) and advanced (backward) solutions. These advanced waves propagate backward in time but at the speed of light, ensuring no information travels faster than light in any frame.

This consistency is inherited from the relativistic extensions of TI, such as the Possibilist Transactional Interpretation (PTI), which treats transactions as occurring along spacetime intervals in a covariant way.

2 Theoretical Foundation

In RBTF, the core equation is a time-symmetric formulation derived from relativistic quantum mechanics. The wavefunction Ψ satisfies a relativistic equation like the Klein-Gordon equation:

$$(\Box + m^2)\Psi = 0, \tag{1}$$

where $\Box = \partial^\mu \partial_\mu$ is the d'Alembertian operator, which is Lorentz-invariant. Solutions include both retarded and advanced propagators:

$$\Psi(x) = \int d^4y\, G_{\text{ret}}(x-y)J(y) + \int d^4y\, G_{\text{adv}}(x-y)J(y), \tag{2}$$

where G_{ret} and G_{adv} are the retarded and advanced Green's functions, respectively. In the transactional picture, the offer wave corresponds to G_{ret} and the confirmation retro-beam to G_{adv}.

The transaction forms a standing wave in four-dimensional spacetime, ensuring the process is atemporal and frame-independent.

3 Proof of Lorentz Invariance

To prove Lorentz invariance, consider a Lorentz transformation $x'^\mu = \Lambda^\mu_\nu x^\nu$. The d'Alembertian transforms as $\Box' = \Box$, since $\partial'^\mu = \Lambda^\mu_\nu \partial^\nu$ and $\eta_{\mu\nu}\Lambda^\mu_\alpha \Lambda^\nu_\beta = \eta_{\alpha\beta}$, preserving the metric.

Thus, if $\Psi(x)$ satisfies $(\Box + m^2)\Psi = 0$, then $\Psi'(x') = \Psi(\Lambda^{-1}x')$ satisfies $(\Box' + m^2)\Psi' = 0$.

For the transactional handshake, the amplitude $A = \int \psi_o^* R_c\, d^4x$ is a scalar integral over spacetime. Under Lorentz transformation, both ψ_o and R_c transform as scalar fields (for spin-0), so A remains invariant.

In the presence of absorbers, boundary conditions ensure that advanced waves are canceled outside the transaction, maintaining causality. This proves that RBTF descriptions are consistent across inertial frames, with no preferred frame for transaction formation.

4 Examples

4.1 Example 1: Relativistic Delayed-Choice Experiment

In a relativistic version of Wheeler's delayed-choice experiment, consider photons emitted from a distant quasar, passing through a gravitational lens acting as a double-slit, with detection on Earth. The choice of measurement (interference or which-path) is made long after emission.

In RBTF, the future measurement sends a retro-beam backward along the light cone, influencing the past state without superluminal signaling. In different frames, the timing differs, but the transaction spans the spacetime interval, remaining invariant. This resolves apparent paradoxes, as the outcome is consistent in all frames.

4.2 Example 2: EPR Correlations with Spacelike Separation

For entangled particles measured at spacelike-separated points, RBTF describes the transaction as a non-local handshake across the interval. The retro-beam from one measurement reaches the emission event, correlating with the other.

Relativity is preserved because no signal propagates faster than light; the correlation is established atemporally. Bell inequality violations are reproduced without hidden variables, as confirmed in experiments.

4.3 Example 3: Bhabha Scattering

In electron-positron scattering, RBTF models the process with offer waves from incoming particles and confirmations from outgoing detections. The relativistic flux in particle number is handled via creation/annihilation, with amplitudes for unactualized confirmations.

The S-matrix elements match standard QED, but interpreted transactionally, ensuring Lorentz invariance in cross-sections and angular distributions.

5 References

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