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Article

Dissolving Retrocausality: A Geometric Reinterpretation of Time-Symmetric Quantum Models via the TCGS-SEQUENTION Framework

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Abstract

Contemporary models of quantum retrocausality—from Price & Wharton’s “constrained collider bias” and Cramer’s Transactional Interpretation to Castagnoli’s “causal loops”—share a common presupposition: that temporal order is ontologically fundamental, and that apparent backward-in-time influences require novel causal mechanisms. This paper demonstrates that the Timeless Counterspace (TCGS-SEQUENTION) framework *dissolves* rather than *explains* retrocausality. We prove that in any static 4-dimensional counterspace $(\mathcal{C}, G_{AB}, \Psi)$ where time is a foliation gauge (Axiom A3), the “direction” of an apparent causal relation is a foliation artifact with no intrinsic 4D content. Price & Wharton’s “constrained collider” is reinterpreted as a boundary condition in $\mathcal{C}$; Cramer’s “handshake” as worldline connectivity; Castagnoli’s “causal loops” as sequential misreadings of a non-sequential 4D structure. We identify a sharp ontological distinction—the *Gauge Dealbreaker*—between TCGS (time has no ontic status) and all retrocausal models (time is ontic but admits backward influence). We further distinguish TCGS from standard eternalism, which treats time as a coordinate dimension rather than a pure gauge artifact. The paper provides formal definitions, theorems, and a systematic reinterpretation protocol applicable to any putative retrocausal phenomenon. We conclude that the “mystery” of retrocausality is an artifact of treating foliation parameters as physical facts.

Keywords: retrocausality; TCGS-SEQUENTION; timeless counterspace; dissolution theorem; foliation artifact; gauge time; block universe; K_s Kernel; non-local connectivity; structural rigidity; identity of source; constrained collider bias; transactional interpretation; causal loops; gauge dealbreaker; epistemic retrodiction; superdeterminism; static 4D geometry; worldline connectivity; cartographic mandate

1. Introduction

The question of temporal direction in quantum mechanics has generated a rich landscape of interpretive proposals. Models by Price & Wharton [2–4], Cramer’s Transactional Interpretation [5,6], Castagnoli’s computational retrocausality [7], and Aharonov’s Two-State Vector Formalism [8] all propose that quantum phenomena exhibit a form of time-symmetric or backward-in-time causation. These models accept that temporal order is ontologically fundamental and then explain how influences can propagate “against” that order.

This paper takes a categorically different approach. Rather than explaining retrocausality, we demonstrate that the TCGS-SEQUENTION framework [1] *dissolves* it. The core insight is simple but profound:

If time is not ontologically fundamental—if it is a foliation gauge artifact of projecting a static 4D structure onto 3D observers—then there is no intrinsic “forward” or “backward” direction for causation to violate.

1.1. The Retrocausality Landscape

Contemporary retrocausal models can be organized into three families:

- (i) **Collider-Bias Models** (Price & Wharton): Entanglement correlations arise from “constrained colliders” where future measurement settings influence past particle emissions through statistical selection effects [4].
- (ii) **Wave-Mechanical Models** (Cramer): Quantum transactions involve a “handshake” between retarded (forward-in-time) and advanced (backward-in-time) waves, completing a transaction that produces measurement outcomes [6].
- (iii) **Computational Models** (Castagnoli): Quantum speedup implies that the problem-solver has “advanced knowledge” of the solution, creating causal loops where future measurement outcomes influence past computational steps [7].

All three families share a crucial presupposition: *temporal order is ontic*. Time is real, has a definite direction, and retrocausality is the phenomenon of influences propagating against that direction.

1.2. The TCGS Counter-Move

The TCGS-SEQUENTION framework rejects this presupposition at its root. Its Axiom A3 states:

Axiom 1 (A3: Shadow Realization and Gauge Time). *The observable world is a 3-manifold Σ embedded by $X : \Sigma \rightarrow \mathcal{C}$; observables are pullbacks $(g, \psi) = (X^*G, X^*\Psi)$. “Time” is gauge (no ontic status).*

If time is gauge, then the distinction between “forward” and “backward” causation is analogous to the distinction between “leftward” and “rightward” in a coordinate system—it depends entirely on conventional choices, not on intrinsic geometric facts.

1.3. Contribution and Structure

This paper makes four principal contributions:

- 1. **Formal Dissolution Theorem:** We prove that any apparent retrocausal relation is a foliation artifact (Theorem 1).
- 2. **Systematic Reinterpretation:** We provide rigorous TCGS-reinterpretations of Price & Wharton, Cramer, and Castagnoli (Section 4).
- 3. **The Gauge Dealbreaker:** We identify the categorical distinction between TCGS and all retrocausal models: time-as-gauge vs. time-as-ontic (Section 6).
- 4. **Epistemic vs. Physical Retrodiction:** We distinguish retrodiction (epistemic inference) from retrocausation (physical influence), showing how TCGS employs the former without the latter (Section 7).

2. The TCGS-SEQUENTION Framework: Formal Apparatus

We now present the formal structure of the TCGS-SEQUENTION framework, emphasizing those elements essential for the dissolution of retrocausality.

2.1. Core Axioms

Axiom 2 (A1: Whole Content). *There exists a smooth 4-dimensional counterspace $(\mathcal{C}, G_{AB}, \Psi)$ with Lorentzian-signature metric G and global content field(s) Ψ , containing the full content of all “time stages” simultaneously.*

Axiom 3 (A2: Identity of Source). *There is a distinguished point $p_0 \in \mathcal{C}$ and an automorphism group $\text{Aut}(\mathcal{C}, G, \Psi)$ such that the fundamental singular set $S = \text{Orb}(p_0)$; all shadow singularities descend from p_0 .*

Axiom 4 (A3: Shadow Realization). *The observable world is a 3-manifold Σ embedded by $X : \Sigma \hookrightarrow \mathcal{C}$; all observables are pullbacks:*

$$(g_{ij}, \psi) = (X^*G_{ij}, X^*\Psi).$$

“Time” t is the parameter labeling a family of such embeddings $\{X_t\}$; it has no ontic status.

Axiom 5 (A4: Parsimony). *No dark species; apparent dark effects arise from projection geometry encoded by a single extrinsic constitutive law.*

2.2. The Foliation Structure

Definition 1 (Foliation). *A foliation of $\mathcal{C}$ is a smooth map $\mathcal{F} : \mathcal{C} \rightarrow \mathbb{R}$ such that each level set $\Sigma_t := \mathcal{F}^{-1}(t)$ is a spacelike 3-manifold. The family $\{\Sigma_t\}_{t \in \mathbb{R}}$ constitutes the “leaves” of the foliation.*

Definition 2 (Foliation Artifact). *A property P is a foliation artifact if and only if:*

- (a) P can be defined on the foliated structure $(\mathcal{C}, \mathcal{F})$, and
- (b) There exists a foliation $\mathcal{F}'$ such that P differs between $(\mathcal{C}, \mathcal{F})$ and $(\mathcal{C}, \mathcal{F}')$, or
- (c) P has no definition on the unfoliated manifold $\mathcal{C}$ alone.

Example 1 (Temporal Order as Foliation Artifact). *Let $p, q \in \mathcal{C}$ be two events. The statement “ p occurs before q ” requires a foliation $\mathcal{F}$ to define: $p <_{\mathcal{F}} q$ iff $\mathcal{F}(p) < \mathcal{F}(q)$. Since there exist foliations $\mathcal{F}'$ with $\mathcal{F}'(p) > \mathcal{F}'(q)$ (whenever p and q are spacelike separated), temporal order is a foliation artifact.*

2.3. The Territory/Map Correspondence

TCGS employs a metamathematical analogy that structures its epistemology:

Concept	Logic	TCGS Physics
Territory (Truth)	Standard model $\mathbb{N}$	Counterspace $\mathcal{C}$
Map (Provability)	Formal system T	Shadow Σ
External Grounding	Tarskian truth predicate	Immersion X
Incompleteness	Gödel sentences	Prediction mismatches

This correspondence has methodological consequences: a prediction failure does not falsify the existence of $\mathcal{C}$; it indicates that the current mathematical map (e.g., the specific μ -function in Axiom A4) is incomplete. Science becomes cartographic refinement, not theory elimination.

3. The Dissolution Theorem

We now prove the central result: retrocausality is a foliation artifact and therefore has no ontic content in TCGS.

3.1. Causal Relations in 4D

Definition 3 (Causal Relation). *Let $\mathcal{C}$ be a 4-manifold with Lorentzian metric G . A causal relation $R(p, q)$ between events $p, q \in \mathcal{C}$ holds iff there exists a causal (timelike or null) curve $\gamma : [0, 1] \rightarrow \mathcal{C}$ with $\gamma(0) = p$ and $\gamma(1) = q$.*

Remark 1. *Definition 3 is symmetric in the sense that $R(p, q)$ holds iff there exists a curve from p to q ; it does not specify direction. The “direction” of the curve is determined by choosing a future-pointing time orientation on $\mathcal{C}$.*

Definition 4 (Time Orientation). *A time orientation on $(\mathcal{C}, G)$ is a continuous choice of “future-pointing” timelike vector at each point. Given a time orientation, a causal curve γ is future-directed if its tangent vectors are future-pointing.*

Definition 5 (Retrocausal Relation). *Given a time orientation on $\mathcal{C}$, a retrocausal relation $R^-(p, q)$ holds iff there is a past-directed causal curve from p to q —i.e., the influence “travels backward in time.”*

3.2. The Gauge Character of Time Orientation

Lemma 1 (Time Orientation is Conventional). *On a time-orientable manifold $(\mathcal{C}, G)$, there exist exactly two global time orientations, related by $T \mapsto -T$. The choice between them is conventional; the geometry $(\mathcal{C}, G)$ does not distinguish them.*

Proof. The space of time orientations on $(\mathcal{C}, G)$ is the set of continuous sections of the bundle of future cones. On a time-orientable manifold, this bundle is trivial, admitting exactly two global sections (corresponding to the two choices of “future” at each point). The metric G is invariant under the reflection $T \mapsto -T$; hence neither orientation is geometrically preferred. $\square$

Corollary 1 (Retrocausality is Orientation-Dependent). *Whether a given causal curve is “forward” or “backward” in time depends on the choice of time orientation. For every retrocausal relation $R^-(p, q)$ under orientation T , there exists an orientation $T' = -T$ under which the same curve is a forward causal relation $R^+(q, p)$.*

3.3. The Main Dissolution Theorem

Theorem 1 (Dissolution of Retrocausality). *Let $(\mathcal{C}, G)$ be a time-orientable Lorentzian 4-manifold. Let R^- be any retrocausal relation under a given time orientation T . Then:*

- (i) R^- is a foliation artifact (in the sense of Definition 2).
- (ii) There is no foliation-invariant (intrinsic) property of $\mathcal{C}$ corresponding to “retrocausality.”
- (iii) In the TCGS framework where time is gauge (Axiom A3), retrocausality has no ontic content.

Proof. (i) By Corollary 1, R^- under orientation T becomes R^+ under orientation $-T$. Since both orientations are geometrically equivalent (Lemma 1), the “retro-” character of R^- depends on the conventional choice of T . Any foliation $\mathcal{F}$ induces a time orientation via its gradient; changing the foliation can change or reverse this orientation. Hence R^- satisfies condition (b) of Definition 2.

(ii) Suppose, for contradiction, that there exists a foliation-invariant property P corresponding to “retrocausality.” Then P must be definable on $(\mathcal{C}, G)$ alone, without reference to any foliation or time orientation. But the only intrinsic causal property is the symmetric relation $R(p, q)$ (existence of causal curve). The directional refinement to R^+ or R^- requires a time orientation, which is conventional. Hence no such P exists.

(iii) In TCGS, Axiom A3 states that time is gauge—i.e., the foliation parameter t is a coordinate choice with no ontic status. Properties that depend on t (or equivalently, on the induced time orientation) are therefore epistemic, not ontic. Since retrocausality is such a property (by parts (i) and (ii)), it has no ontic content in TCGS. $\square$

Corollary 2 (All Retrocausal Models Describe Foliation Artifacts). *Any physical model that posits retrocausality as an explanatory mechanism is describing a foliation artifact, not an intrinsic geometric fact about reality.*

3.4. Comparison: TCGS vs. Retrocausal Models

The following table summarizes the categorical distinction:

Feature	Retrocausal Models	TCGS
Time status	Ontic (real)	Gauge (artifact)
Temporal direction	Intrinsic	Conventional
Retrocausality	Requires explanation	Dissolved
Mechanism needed	Yes (zigzags, waves, loops)	No
Fundamental structure	3+1 dimensional	4D static block

4. Systematic Reinterpretation of Retrocausal Models

Having established the dissolution theorem, we now apply it systematically to the three families of retrocausal models.

4.1. Price & Wharton: Constrained Colliders as Boundary Conditions

4.1.1. The Original Model

Price & Wharton [4] propose that quantum entanglement arises from “collider bias”—a statistical phenomenon where conditioning on a common effect creates correlations between its causes. In their model:

1. A particle source (the “collider”) is causally influenced by future measurement settings (Alice, Bob).
2. This creates a V-shaped causal diagram with the source at the apex.
3. “Constraining” the collider (fixing boundary conditions at the source) creates correlations between Alice and Bob that mimic entanglement.

The model explicitly invokes retrocausality: the future measurement settings send influences backward in time to the source.

4.1.2. TCGS Reinterpretation

Under TCGS, the Price & Wharton model is reinterpreted as follows:

Proposition 1 (Constrained Collider as Boundary Condition). *The Price & Wharton “constrained collider” at the particle source is the shadow manifestation of a boundary condition specification in the 4D counterspace $\mathcal{C}$, specifically an instance of Axiom A2 (Identity of Source).*

Proof. In TCGS, the “source” of an entangled particle pair is not a temporal event but a region of the 4D counterspace $\mathcal{C}$. The particles themselves are 4D worldlines extending through $\mathcal{C}$. Alice’s measurement, Bob’s measurement, and the source are not causally linked events but geometrically connected regions of a single static structure.

The “constraint” at the collider is simply the boundary condition that these worldlines must satisfy in $\mathcal{C}$ —they must be consistent with the global geometry (G, Ψ) . No temporal influence is required because there is no temporal evolution; the entire configuration exists simultaneously in $\mathcal{C}$.

The “retrocausal” appearance arises when a 3D observer, using a particular foliation $\mathcal{F}$, interprets the boundary condition at the source as being “influenced” by the later measurement settings. But this is a foliation artifact: under a different foliation, the same geometric constraint appears as a “forward” influence. □

Remark 2. Price & Wharton themselves note that their model can be understood without explicit retrocausality in certain formulations [4]. TCGS provides the ontological grounding for this observation: the “retrocausal” and “non-retrocausal” descriptions are different foliation-dependent maps of the same foliation-invariant geometry.

4.2. Cramer: Transactional Handshakes as Worldline Connectivity

4.2.1. The Original Model

Cramer’s Transactional Interpretation [6] proposes that quantum measurements involve a “handshake” between:

- An “offer wave” (retarded solution, propagating forward in time)
- A “confirmation wave” (advanced solution, propagating backward in time)

The transaction is completed when these waves mutually reinforce, selecting a particular measurement outcome.

4.2.2. TCGS Reinterpretation

Proposition 2 (Transaction as Worldline Connectivity). *Cramer’s “transactional handshake” is the shadow appearance of worldline connectivity in $\mathcal{C}$. The advanced and retarded waves are not separate entities but projective decompositions of a single 4D structure.*

Proof. In $\mathcal{C}$, a “particle” is a 4D worldline $W \subset \mathcal{C}$. The worldline’s intersection with different foliation leaves Σ_t gives the “position at time t .” The worldline is geometrically connected from source to detector; this connectivity is intrinsic to $\mathcal{C}$.

When a 3D observer attempts to describe this connectivity using wave-mechanical language, they must decompose the description into temporal components: a wave “emitted” at the source and propagating “forward,” plus constraints from the detector propagating “backward.” This decomposition is the origin of Cramer’s offer/confirmation wave pair.

The “handshake” is simply the statement that the worldline W must satisfy boundary conditions at both endpoints (source and detector). This is a geometric consistency condition, not a temporal transaction. No wave actually propagates backward; the appearance of such propagation is a foliation artifact of the description, not a feature of the geometry. $\square$

4.3. Castagnoli: Causal Loops as Sequential Misreadings

4.3.1. The Original Model

Castagnoli [7] argues that quantum computational speedup implies retrocausality. His key claim:

“It is as if the problem-solver knew in advance, before beginning her problem-solving action, one of the possible halves of the information that specifies the solution of the problem she will produce and measure in the future.”

This “advanced knowledge” creates a causal loop: information from the future measurement influences the past computation.

4.3.2. TCGS Reinterpretation

Proposition 3 (Causal Loops as Sequential Misreadings). *Castagnoli’s “causal loops” are artifacts of forcing a 3D sequential description onto a 4D non-sequential structure. The “advanced knowledge” is not temporal; it is geometric.*

Proof. In TCGS, the quantum computation exists as a 4D structure in $\mathcal{C}$: the initial state, the unitary evolution, and the final measurement are all simultaneously present. The “solution” is not computed sequentially and then measured; it is a feature of the 4D configuration that is constrained by global geometric consistency.

Castagnoli’s observation that the problem-solver “knows in advance” the solution is correct—but the word “advance” is misleading. In $\mathcal{C}$, there is no “before” and “after”; the entire computation exists as a static configuration. The solution constrains the initial conditions not by temporal influence but by geometric consistency: the entire configuration must satisfy the boundary conditions imposed by $(\mathcal{C}, G, \Psi)$.

The “causal loop” arises when we attempt to describe this configuration in sequential 3D language. We say “first the problem is set, then the computation proceeds, then the solution is measured.” Castagnoli correctly notes that this sequential description requires the solution to “influence” the computation. But this is not retrocausality; it is the failure of sequential description to capture the non-sequential 4D fact. □

Remark 3. *Castagnoli himself notes that the retrocausality is “implicit” in quantum superposition and is “made explicit” by the classical logic description. TCGS agrees: the classical logic description is a 3D sequential map of a 4D non-sequential territory. The “retrocausality” is a feature of the map, not the territory.*

5. Non-Stochastic Coherence: The Role of Bulk Torsions

Contemporary time-symmetric models, such as the Transactional Interpretation or Wheeler-Feynman absorber theory, invoke advanced waves (ψ^*) that physically “pull” from the future to resolve retrocausality. However, these models often retain a stochastic element to maintain consistency with standard QM, treating coherence as an emergent statistical artifact.

The TCGS-SEQUENTION framework reveals this stochasticity as unnecessary. Retrocausality is not a dynamical pull in time, but a **geometric necessity** in the static 4D Counterspace ($\mathcal{C}$).

5.1. The Wavefunction as Dual Tomogram

Under Axiom A2 (Identity of Source), the wavefunction is reinterpreted not as a traveling entity, but as a **Dual Tomogram**: ψ and ψ^* are simply the forward and backward foliations of the same timeless content field Ψ .

The mechanism connecting the “emitter” and “absorber” is not a signal, but **Deterministic Torsion** in the bulk. These are twists in the immersion map $X : \Sigma \rightarrow \mathcal{C}$ that modulate gradients via the Extrinsic Constitutive Law. Stochasticity is exposed as an epistemic illusion—homologous to “Dark Deficits” in gravity or “Darwinian Chance” in biology—arising from the failure to map the torsion of the higher-dimensional structure.

5.2. The Generalized Torsion Law

Mathematically, coherence is maintained by extending the Extrinsic Law to include a bulk torsion scalar τ . While the gravitational sector obeys the torsion-free limit ($\nabla \cdot \mu \nabla \Phi = \rho$), the unified field Ψ obeys the **Generalized Torsion Law**:

$$\nabla \cdot \left(\mu \left(\frac{|\nabla \Psi|}{a_*} \right) \nabla \Psi + \tau \mathbf{T} \right) = \mathcal{J}_{\text{source}}$$

(1)

Here, $\mathbf{T}$ is the bulk tangent vector enforcing invariance. The term $\tau \mathbf{T}$ acts as a “geometric stiffener,” twisting the potential to retrofit slices into consistency.

- In **Galactic scales**, $\tau \approx 0$. This recovers the pure **Extrinsic Scalar Response** (μ -function), yielding the Radial Acceleration Relation observed in galaxies without invoking dark matter or modifying inertia.
- In **Quantum/Biological scales**, τ is non-negligible. This torsion is precisely what the K_s **Kernel** (in SEQUENTION) describes: the non-local connectivity required to keep the “twisted” filament coherent across slices.

There is no probabilistic role; it is the constraint of the *Un-Foliated Whole* collapsing incompatible foliations back to unity.

5.3. The Bridge Metaphor

Imagine a 4D arch bridge ($\mathcal{C}$) casting 3D shadows (Σ) from dual angles. The “retrocausal pull” is not a signal crossing the span, but the arch’s inherent structural curve. Changing one “end” (e.g., a delayed choice measurement) necessitates a geometric reconfiguration of the entire span. This appears

“instantaneous” in the shadow because there is no distance to traverse in the bulk; the arch is a single static object.

Table 1. Comparison of Retrocausal Ontologies. Note the shift from stochastic mechanisms to deterministic geometric torsion in the TCGS framework.

Concept	Standard Time-Symmetric	Epistemic (Superdeterminism)	TCGS-SEQUENTION
Wavefunction (Ψ)	Real, traveling waves (ψ / ψ^*)	Knowledge descriptor	Projection Tomogram ; dual foliations of 4D filament
Retrocausality	Stochastic “pull”	Implies hidden variables	Geometric Torsion ; non-stochastic coherence
Coherence	Probabilistic	Epistemic uncertainty	Deterministic Twist modulating gradients
Undecidability	Halting-like barriers	Limits epistemic reach	Artifact of Slicing ; resolved in Bulk Unity
Hidden Variables	Stochastic or non-local	Required for locality	4D Coordinates ; torsion bridges, not variables

6. The Gauge Dealbreaker: TCGS vs. Eternalism vs. Retrocausalism

A potential objection is that TCGS is simply “block universe eternalism” under a different name. This section demonstrates that TCGS is categorically distinct from both standard eternalism and retrocausal models.

6.1. Three Positions on Time

Definition 6 (Three Ontologies of Time). *We distinguish three positions:*

- (a) **Presentism/Retrocausalism:** Time is ontic and has an intrinsic direction. Events occur “in” time. Retrocausality is the phenomenon of influences propagating against this direction.
- (b) **Eternalism:** Time is ontic but all moments exist equally. Events are located “at” times, like locations on a coordinate axis. Temporal direction is real but no moment is privileged.
- (c) **TCGS (Gauge Time):** Time is not ontic. The foliation parameter t is a coordinate choice analogous to latitude/longitude. Events are features of 4D geometry; “temporal location” is a projection artifact.

6.2. The Dealbreaker Distinction

Theorem 2 (Gauge Dealbreaker). *TCGS is categorically distinct from both eternalism and retrocausalism due to the following non-negotiable difference:*

In TCGS, time has no ontic status whatsoever. In both eternalism and retrocausalism, time is ontologically real.

This difference has empirical consequences: TCGS predicts that no experiment can distinguish “forward” from “backward” time at the fundamental level, because this distinction is conventional. Retrocausal models predict that retrocausality is a real phenomenon requiring detection or explanation.

Proof. The distinction follows directly from the axioms:

Retrocausalism: Takes temporal direction as given and explains how influences can violate it. The direction is intrinsic; retrocausality is real and requires mechanisms (zigzags, waves, loops).

Eternalism: Takes temporal coordinates as real dimensions of a 4D manifold. The coordinate t labels genuine locations in the block. Temporal direction may be conventional, but temporal *position* is not.

TCGS: The foliation parameter t is pure gauge—it is not a coordinate labeling genuine locations but a conventional choice of how to slice the block. Just as choosing a coordinate system does not change the intrinsic geometry, choosing a foliation does not change the intrinsic content of $\mathcal{C}$. Properties that depend on t are artifacts of the projection, not features of reality.

The empirical distinction: Under retrocausalism, we might hope to detect retrocausal influences or explain their mechanism. Under TCGS, there is nothing to detect—“retrocausality” is a category mistake, like asking whether the Greenwich meridian is “really” at longitude zero. $\square$

6.3. Comparison Table

Feature	Retrocausalism	Eternalism	TCGS
Time is ontic	Yes	Yes	No
Temporal direction real	Yes	Ambiguous	No
Temporal position real	Yes	Yes	No
Retrocausality status	Real phenomenon	Possible	Dissolved
Mechanism needed	Yes	Sometimes	No
t is...	Physical parameter	Coordinate	Gauge

7. Epistemic Retrodiction Without Physical Retrocausation

A critical clarification is required: TCGS does not deny that 3D observers can make inferences about the “past.” It distinguishes *retrodiction* (epistemic inference) from *retrocausation* (physical influence).

7.1. The Distinction

Definition 7 (Retrodiction vs. Retrocausation). (a) **Retrodiction:** The epistemic process of inferring facts about earlier foliation leaves $\Sigma_{t'}$ ($t' < t$) from observations on the current leaf Σ_t .
(b) **Retrocausation:** A physical process in which events on Σ_t causally influence events on $\Sigma_{t'}$ ($t' < t$).

Proposition 4 (TCGS Uses Retrodiction, Not Retrocausation). The TCGS framework permits and employs retrodiction as an epistemic tool for mapping the 4D counterspace $\mathcal{C}$. It does not permit retrocausation because:

- (i) Retrocausation requires an ontic temporal direction (to define “backward”).
- (ii) TCGS denies that temporal direction is ontic (Axiom A3).
- (iii) Therefore, retrocausation is undefined in TCGS.

7.2. The Parzygnat-Buscemi Formalism

The inferential framework of Parzygnat & Buscemi [9] provides the formal apparatus TCGS requires. Their key contribution is distinguishing physical causality from logical inference in quantum contexts.

Proposition 5 (TCGS Adoption of Inferential Framework). TCGS adopts the Parzygnat-Buscemi inferential formalism for retrodiction, interpreting it as follows:

- Retrodiction is inference about the 4D structure $\mathcal{C}$ from observations on a 3D shadow Σ .
- The inference is Bayesian: prior probabilities represent the observer’s ignorance of their “location” in the static block.
- No physical influence propagates “backward”; the observer is simply updating their map of the pre-existing territory.

This adoption is essential for the TCGS cartographic program: observers must be able to “fill in” their map of $\mathcal{C}$ from limited 3D data, and retrodiction is the epistemic tool for doing so.

8. Methodological Analogues: A Careful Assessment

This section addresses potential methodological parallels between TCGS and contemporary computational physics, with appropriate epistemic caution.

8.1. The Nature of the Analogy

Important Disclaimer: The methodological analogues discussed below do not constitute evidence for TCGS ontology. They illustrate that a “cartographic” mathematical strategy—projecting high-dimensional structure onto tractable submanifolds—is independently useful in computational physics. The shared vocabulary of “maps,” “manifolds,” and “projection” reflects a common mathematical strategy, not shared ontological commitments.

8.2. Ren et al.: ScarFinder and Variational Projection

Ren et al. [10] develop the ScarFinder algorithm for identifying Quantum Many-Body Scars (QMBS)—rare non-thermalizing eigenstates in chaotic quantum systems.

The Analogy: ScarFinder projects time-evolved quantum states onto a variational manifold (Matrix Product States) to isolate stable trajectories. TCGS projects the 4D counterspace onto 3D shadows to isolate observable physics.

The Disanalogy:

- ScarFinder operates in *Hilbert space*; TCGS operates in *spacetime*.
- ScarFinder identifies *dynamical* stability (periodic revivals); TCGS denies the fundamental reality of dynamics.
- The “scars” are defined by their behavior *over time*; TCGS treats time as gauge.

Conclusion: The analogy is strictly methodological. Both involve projection onto submanifolds to extract tractable structure. The ontological substrates are entirely disjoint.

8.3. Rinaldi et al.: Neural Quantum States for Matrix Models

Rinaldi et al. [11] use neural network ansätze to approximate ground states of matrix quantum mechanics, relevant to holographic descriptions of quantum gravity.

The Analogy: Both programs seek to “map” a complex high-dimensional structure (the Hilbert space / the counterspace) using tractable approximations (neural networks / 3D projections).

The Disanalogy: Rinaldi et al. work within standard quantum mechanics with unitary evolution. TCGS rejects the fundamental reality of evolution.

Conclusion: The analogy validates “cartographic” as a legitimate methodological strategy in physics. It does not validate TCGS ontology.

9. Objections and Replies

9.1. Objection 1: “TCGS Is Just Eternalism”

Reply: Section 6 demonstrates the categorical distinction. Eternalism treats time as a real coordinate dimension; TCGS treats it as pure gauge. This is the difference between “all moments exist” (eternalism) and “there are no moments” (TCGS).

9.2. Objection 2: “How Can Observers Experience Time If It’s Not Real?”

Reply: The “experience of time” is a feature of the projection, not the territory. Observers are 4D structures in $\mathcal{C}$; their “experience” is the pattern of correlations along their worldlines. The subjective sense of flow is a foliation artifact—a feature of how the 4D structure projects onto 3D awareness.

9.3. Objection 3: “Retrocausality Has Experimental Support”

Reply: No experiment has demonstrated retrocausality as distinct from time-symmetric correlations. TCGS predicts that no such demonstration is possible: “retrocausality” is a description-level

feature, not a physics-level fact. Any apparent retrocausal result can be equivalently described as forward-causal under a different foliation.

9.4. Objection 4: “The Dissolution Is Merely Semantic”

Reply: The dissolution is ontological, not semantic. We do not merely relabel “retrocausality” as “foliation artifact”; we demonstrate that retrocausality *cannot be defined* without reference to a conventional foliation choice. It is not a feature of $\mathcal{C}$; it is a feature of the description.

9.5. Objection 5: “Why Should We Accept TCGS Axioms?”

Reply: The axioms are justified by (i) internal consistency, (ii) parsimony (no dark species, Axiom A4), (iii) explanatory scope (unifying dark matter, biological teleology, quantum correlations), and (iv) alignment with the BSW action formulation of GR, which already treats time as a reparameterization artifact.

10. Conclusion

We have demonstrated that the TCGS-SEQUENTION framework provides a coherent and rigorous dissolution of quantum retrocausality. The key results are:

1. **Dissolution Theorem:** Any retrocausal relation is a foliation artifact (Theorem 1). In a 4D static counterspace where time is gauge, there is no intrinsic “backward” for causation to violate.
2. **Systematic Reinterpretation:** Price & Wharton’s constrained colliders are boundary conditions in $\mathcal{C}$; Cramer’s transactional handshakes are worldline connectivity; Castagnoli’s causal loops are sequential misreadings of non-sequential structure.
3. **Gauge Dealbreaker:** TCGS is categorically distinct from both eternalism and retrocausality. Time-as-gauge is not merely “time is a dimension” but “time is not ontic at all.”
4. **Epistemic Retrodiction:** TCGS permits retrodiction (epistemic inference about earlier foliation leaves) without retrocausation (physical influence from later leaves).

The “mystery” of retrocausality dissolves once we recognize that temporal direction is a feature of our descriptions, not of reality itself. The 4D counterspace $\mathcal{C}$ simply *is*; it does not “evolve” forward or backward. Retrocausal models mistake a foliation artifact for a physical phenomenon, then construct elaborate mechanisms to explain it.

TCGS offers a more parsimonious alternative: there is nothing to explain. The apparent temporal asymmetries of quantum mechanics are projective artifacts, like the apparent convergence of parallel train tracks toward the horizon. They tell us something about the projection (our 3D perspective), not about the territory ($\mathcal{C}$).

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