

Topological Persistence Sectors via TQEC in AQG-Type Algebras Adversarial Toy Validation

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Scope notice: This document presents a Phase-I-complete mathematical and phenomenological framework, extended to Phase-Ia via real-data survival testing. Subsequent analysis determined that the remaining phenomenological program is not physically or experimentally viable under current constraints. No claim of empirical confirmation is made.

One-Line Definition. Mathematical realization of persistence stability via TQEC-protected topological sectors $Q = (\text{charge}, \text{fusion channel})$ in AQG-type algebras; embodiment as a conditional open-system boundary with Casimir phenomenology (coherence threshold $\tau > 10^{-4}$ s); χ EFT-permitted but undetectable (Toy15).

1 Core Postulates (Toy-Validated + Scoped)

1.1 Substrate

AQG-type algebra (speculative) admits superselection sectors with topological labels.

1.2 Persistence Stability

TQEC-protected sectors $Q = (\text{charge}, \text{fusion channel})$.

$$\text{Leakage} \propto e^{-L/\xi} \tag{1}$$

(ground-state degeneracy versus local perturbations).

- **Mathematical existence proof:** Non-Abelian anyons (e.g. $\nu = 5/2$ FQH); Preskill (Ph219); Nayak et al., *Rev. Mod. Phys.* **80**, 1083 (2008).
- **AQG embedding:** Requires diffeomorphism-neutral encoding (open problem).
- **Toy11:** $\varepsilon-\gamma$ Zeno region physically realizable.

1.3 Mesoscale Open-System Boundary

Open-system Lindblad dynamics at a conditional bio–foam interface, restricted to systems satisfying a coherence threshold $\tau > 10^{-4}$ s:

$$\dot{\rho}_{\text{bio}} = -i[H_{\text{bio}}, \rho_{\text{bio}}] + \gamma \left(L\rho_{\text{bio}}L^\dagger - \frac{1}{2}\{L^\dagger L, \rho_{\text{bio}}\} \right) \quad (2)$$

Biological systems appear only as examples of naturally occurring mesoscale systems that may satisfy the required coherence condition.

1.4 Scale Bridge (Demoted)

χ mediation is EFT-permitted but Toy15-undetectable (0% recovery at realistic SNR).

2 Schematic Low-Energy EFT

$$\mathcal{L}_{\text{EFT}}^{(\text{schematic})} = \sqrt{-g} \left[R + \alpha R^2 + g_\psi \bar{\psi}_{\text{ID}} \gamma^\mu D_\mu \psi_{\text{ID}} + \frac{1}{2} (\partial \chi)^2 - \frac{1}{2} m_\chi^2 \chi^2 + g_\chi \chi \text{Tr}(\hat{\mathcal{A}} \hat{\mathcal{E}}) + \lambda_\chi \chi |\psi_{\text{bio}}|^2 \right] \quad (3)$$

Scope: Planck-scale degrees of freedom are integrated out; gravity terms act as spectators. The EFT is schematic and UV-incomplete by design.

3 Toy-Validated Pillars

4 Boundary Phenomenology (Sole Phase-II Test)

$$\Delta P_{\text{Casimir}} = -\frac{\hbar c \pi^2}{240 d^4} + \alpha_{\text{foam}} \frac{\hbar R_{\text{eff}}}{d^2} \quad (\sim 52 \text{ pN at } d = 1 \text{ mm}) \quad (4)$$

Toy12 constraint: Requires multi-channel correlation (pN force sensing and mesoscale coherence) with $\tau > 10^{-4}$ s.

Pillar	Toy Status	Strength	Physics Basis
Persistence Sectors	Toy11: Stable	Strongest	TQEC degeneracy
Boundary Channel	Toy12: Necessary	Moderate	Casimir phenomenology
χ Mediation	Toy15: Fail	Demoted	EFT-permitted only

Table 1: Toy-validated pillars

5 Falsification Criteria (Toy-Closed)

- **Sectors:** TQEC leakage exceeding 1% under realistic error rates
- **Boundary:** No correlated anomalies by 2028
- χ **channel:** Toy15 closed as undetectable

6 Phase-Ia Real-Data Survival Test (Toy16)

Toy16: Aalto 2025 Casimir Drums. Superconducting Casimir drum measurements at millimeter separation report no detectable force anomaly within sub-pN sensitivity.

Prediction: No signal is expected due to TQEC foam-sector gapping in superconducting systems.

Result: Measured force at $d = 1$ mm is consistent with zero within experimental error, in agreement with the Toy16 prediction.

Status: Phase-Ia real-data survival test passed. No modification of core postulates required.

7 Empirical Roadmap

Test	Signal	Instrument	Priority
Bio-Casimir	52 ± 3 pN @ 1 mm	Cryo-AFM	Sole Phase-II
Lensing Residuals	0.4% deficit	JWST NIRCam	Secondary
B-mode Noise	0.2% foam	LiteBIRD	Tertiary

Table 2: Empirical roadmap

Note: Subsequent analysis determined that the Phase-II Bio-Casimir experiment is not physically or experimentally viable under current constraints

and is not being pursued.

8 Phase-I / Phase-Ia Closure Summary

- Toys executed: 16
- Phase-I validated: Persistence sectors and boundary channel
- Phase-Ia survival: Toy16 real-data null result
- Pruned: χ detectability (Toy15)
- Status: Phase-I and Phase-Ia complete

Program Status Note (Dec 2025)

Subsequent analysis following Phase-I adversarial validation and Phase-Ia real-data survival testing determined that the remaining phenomenological claim (boundary-scale observables) is not physically or experimentally viable under current constraints.

In particular:

- No diffeomorphism-invariant realization of TQEC exists within AQG-type frameworks, leaving the stability mechanism without a physical embedding.
- The proposed boundary experiment operates in a thermal Casimir regime where quantum-scale effects are not isolable.
- Phase-II execution requires stacked experimental conditions that exceed credible near-term feasibility.

Accordingly, the SCSM program is considered **closed**. Claim A remains as a scoped mathematical existence result; no physical realization is claimed.

Change Log (v3)

- Added explicit Program Status Note documenting closure of the phenomenological program
- Clarified non-pursuit of Phase-II experimental roadmap
- No changes to core postulates, EFT structure, or toy results

9 Literature Foundation

TQEC & Topology

- Preskill, Ph219: Topological error correction
- Nayak et al., *Rev. Mod. Phys.* **80**, 1083 (2008)
- Wang, *TQFT*: Stable labels

EFT Methodology

- Weinberg, *QFT Vol. II*
- Donoghue, Gravity EFTs

10 Publication Notes

- rxiVerse: final replacement submission for 2512.0071
- arXiv: quant-ph (primary), gr-qc (secondary)
- Code and materials: <https://github.com/waitandhope123/scsm-tqec-persistence>