A Pre-κ Phase-Exposure Operator and a Rigorous UNNS Resolution of the Entanglement Question

1 Motivation: why "spin rate" vanished in windowed κ_3

UNNS repeatedly encounters a structural confusion: a latent cyclic/phase-like degree of freedom exists in the dynamics, yet a chosen observable family (notably windowing + stride aliasing) can erase it. This yields a false empirical conclusion of "no coupling" or "separability".

The remedy is to introduce a *pre-κ* operator whose job is to expose phase in a chart-stable way, so that downstream κ and Σ gating act on an input where the relevant degree of freedom is actually present.

Key separation: latent structure (exists) vs. observability (survives projection).

2 Pre-κ Phase-Exposure Operator

We model a run as a discrete-time trajectory $x_{0:T} = (x_0, x_1, \ldots, x_T)$ on a state space $\mathcal{X}$. We assume the latent dynamics may contain a cyclic component (not necessarily explicit in coordinates).

Definition 1 (Phase coordinate (model-relative)). *A* phase coordinate *is a measurable map*

$$\varphi : \mathcal{X} \to \mathbb{T} \equiv \mathbb{R}/2\pi\mathbb{Z},$$

such that along typical trajectories the increments $\Delta\varphi_t \equiv \mathrm{wrap}_{2\pi}(\varphi(x_{t+1}) - \varphi(x_t))$ encode cyclic progression of a latent degree of freedom.

Definition 2 (Phase-Exposure operator Π_φ). *Fix a phase coordinate φ. Define*

$$\Pi_\varphi : \mathcal{X}^{T+1} \to \left(\mathbb{T}^T, \mathbb{R}^T\right), \qquad \Pi_\varphi(x_{0:T}) = \Big((\varphi_t)_{t=0}^{T-1}, (\omega_t)_{t=0}^{T-1}\Big),$$

where

$$\varphi_t := \varphi(x_t), \qquad \omega_t := \frac{1}{\Delta t}\,\mathrm{wrap}_{2\pi}\big(\varphi(x_{t+1}) - \varphi(x_t)\big),$$

and $\mathrm{wrap}_{2\pi}(\cdot)$ *returns the representative in $(-\pi, \pi]$ modulo 2π.*

In informal language, ω_t is the "phase velocity" (the quantity often mistaken for a literal "spin rate").

2.1 Exposure invariants (chart-stability)

If $\tilde{\varphi} = g \circ \varphi$ is a circle automorphism (rotation/reflection), raw φ_t changes but the following are stable:

Definition 3 (Exposure invariants)**.** *Given* $\Pi_\varphi(x_{0:T})$*, define*

$$\mathcal{I}_1 := \mathrm{Var}(\omega_t), \qquad \mathcal{I}_2 := \mathbb{E}[\cos(\omega_t \Delta t)], \qquad \mathcal{I}_3(\tau) := \mathbb{E}[\cos(\varphi_{t+\tau} - \varphi_t)].$$

These depend only on phase differences and remain invariant under $\varphi \mapsto \varphi + \mathrm{const}$*; they are also stable under sign flips when symmetry is present.*

3 τ-field phase coordinates (natural emergence)

In many UNNS contexts, φ is not imposed; it is *available* from τ-field evolution.

3.1 Gradient-angle phase proxy

If τ is a scalar field on a grid (or differentiable manifold proxy), define the local phase by the gradient angle:

$$\varphi(\tau) \ := \ \mathrm{atan2}\big(\partial_y \tau,\ \partial_x \tau\big).$$

This exposes directional phase directly from the substrate geometry induced by τ.

3.2 Spectral-phase proxy

Let $\widehat{\tau}[k]$ denote a discrete Fourier coefficient at mode k. Then

$$\varphi_k(t) \ := \ \arg(\widehat{\tau}_t[k])$$

is a canonical phase for mode k. Robust use requires multi-mode aggregation (see failure modes).

Robust multi-mode phase aggregation. To avoid single-mode aliasing, phase should be aggregated over a band of modes K. A robust definition is

$$\bar{\varphi}(t) := \arg\left(\sum_{k\in K} w_k \, |\widehat{\tau}_t[k]| \, e^{i\varphi_k(t)}\right), \qquad w_k \propto |\widehat{\tau}[k]|^2,$$

which weights phases by spectral power.

An alternative, particularly robust to outliers, is median phase increment aggregation:

$$\bar{\varphi}(t) := \bar{\varphi}(t-1) + \mathrm{median}_{k\in K}\left(\Delta\varphi_k(t)\right),$$

followed by wrapping modulo 2π. Both constructions preserve phase continuity while suppressing mode-specific artifacts.

4 UNNS entanglement as non-separability under admissible local contexts

We consider paired streams ("wings") with time-tags:

$$x^A_{0:T}, \qquad x^B_{0:T}.$$

Each wing has local admissible contexts (settings)

$$\alpha \in \mathcal{A}, \qquad \beta \in \mathcal{B},$$

which can be stride/window/threshold/observable-family choices, provided they pass the admissibility constraints (operationally: "passes Σ-gating" as implemented in your Chamber XIV framework).

Definition 4 (Local measurement maps)**.** *A* local measurement *maps exposed phase features to a binary outcome:*

$$M_\alpha : \Pi_\varphi(x^A_{0:T}) \to \{-1, +1\}, \qquad N_\beta : \Pi_\varphi(x^B_{0:T}) \to \{-1, +1\}.$$

For trial k, denote outcomes $A_k(\alpha), B_k(\beta) \in \{-1, +1\}$.

Definition 5 (UNNS separability vs. entanglement)**.** *The system is* separable *if there exists a latent variable Λ (global, not setting-dependent) such that for all admissible (α, β),*

$$\mathbb{P}(A = a, B = b \mid \alpha, \beta) = \int \mathbb{P}(A = a \mid \alpha, \Lambda)\, \mathbb{P}(B = b \mid \beta, \Lambda)\, d\mu(\Lambda).$$

If no such factorization exists within the admissible operator family, we call the coupling UNNS-entangled*.*

5 CHSH functional (UNNS test statistic)

Define correlations

$$E(\alpha, \beta) := \mathbb{E}[A(\alpha)\, B(\beta)].$$

For four settings $(\alpha, \alpha', \beta, \beta')$, define

$$S := E(\alpha, \beta) + E(\alpha, \beta') + E(\alpha', \beta) - E(\alpha', \beta').$$

For any separable model, $|S| \le 2$.

6 Resolution theorems

Theorem 1 (Phase erasure implies apparent separability (partial dependence included))**.** *Assume the observed outcomes can be decomposed as*

$$A(\alpha) = f_\alpha(F(x^A_{0:T}), U^A), \qquad B(\beta) = g_\beta(F(x^B_{0:T}), U^B),$$

where F is phase-invariant (insensitive to variations in Π_φ), and U^A, U^B are residual terms such that any phase-dependence enters only through a bounded perturbation:

$$\left| \mathbb{E}[A(\alpha)B(\beta)] - \mathbb{E}[\tilde{A}(\alpha)\tilde{B}(\beta)] \right| \le \varepsilon,$$

with $\tilde{A}(\alpha) = f_\alpha(F(x^A_{0:T}), \tilde{U}^A)$ and $\tilde{B}(\beta) = g_\beta(F(x^B_{0:T}), \tilde{U}^B)$ independent of phase. Then any CHSH witness computed from (A, B) can be suppressed by at most 4ε:

$$|S_{true} - S_{phase\text{-}blind}| \leq 4\varepsilon,$$

so sufficiently strong phase erasure (small effective ε) forces the empirical regime $|S| \leq 2$ even when latent phase coupling exists.

Proof. Each of the four correlations in S differs from its phase-blind counterpart by at most ε in absolute value, hence the CHSH sum differs by at most 4ε by the triangle inequality. □

Theorem 2 (Phase exposure enables rigorous non-separability certification)**.** *Assume:*

1. *Π_φ is admissible as a pre-κ step (passes the same admissibility regime used to define valid contexts).*
2. *The exposed joint law is non-factorizable within admissible contexts:*

$$\mathbb{P}(\omega^A, \omega^B \mid \alpha, \beta) \not\equiv \int \mathbb{P}(\omega^A \mid \alpha, \Lambda)\mathbb{P}(\omega^B \mid \beta, \Lambda)\, d\mu(\Lambda)$$

   for any Λ independent of settings.

3. *Measurement maps are phase-sensitive (depend on exposed phase differences), e.g.*

$$A(\alpha) = \mathrm{sgn}(\cos(\varphi^A_{t^*} - \theta_\alpha)), \qquad B(\beta) = \mathrm{sgn}(\cos(\varphi^B_{t^*} - \theta_\beta)).$$

Then there exist admissible $(\alpha, \alpha', \beta, \beta')$ such that $|S| > 2$, certifying UNNS-entanglement.

Verification protocol (closing the proof gap)

To verify non-separability empirically, use a best-fit separable approximation and reject it statistically.

Definition 6 (Best-fit separable model on binned outcomes)**.** *Bin (ω^A, ω^B) into a finite grid of bins, and estimate*

$$P_{\mathrm{obs}}(i, j \mid \alpha, \beta).$$

Define the best separable approximation (over all latent mixtures) as

$$P^\star_{\mathrm{sep}}(\cdot \mid \alpha, \beta) := \arg\min_{P_{\mathrm{sep}} \in \mathcal{S}} D_{\mathrm{KL}}(P_{\mathrm{obs}} \,\|\, P_{\mathrm{sep}}),$$

where $\mathcal{S}$ is the set of distributions representable as a convex mixture of products $P(i \mid \alpha, \Lambda)P(j \mid \beta, \Lambda)$ with Λ discrete (sufficiently large).

In practice, this is a constrained optimization / nonnegative factorization problem. Then compute a divergence score

$$\Delta(\alpha, \beta) := D_{\mathrm{KL}}\big(P_{\mathrm{obs}}(\cdot \mid \alpha, \beta) \,\|\, P^\star_{\mathrm{sep}}(\cdot \mid \alpha, \beta)\big),$$

and reject separability if $\Delta(\alpha, \beta)$ is significantly above a null baseline (via bootstrap/surrogates), *uniformly across the four CHSH settings.* This makes the entanglement witness falsifiable and non-circular.

7 Worked example (artifact then fix)

We construct a minimal two-wing phase-coupled system, then show: (i) a windowed phase-blind observable yields $|S| \leq 2$, (ii) phase exposure yields $|S| > 2$.

7.1 Two-wing coupled phases

For trial k, draw a hidden angle $\lambda_k \sim \text{Unif}[0, 2\pi)$ and define

$$\varphi_k^A := \lambda_k, \qquad \varphi_k^B := \lambda_k + \delta,$$

with fixed coupling offset $\delta \in (0, \pi/2)$ (nontrivial but not maximal).

Define settings as angles $\theta_\alpha, \theta_{\alpha'}, \theta_\beta, \theta_{\beta'}$ on the circle, and define outcomes:

$$A_k(\alpha) := \text{sgn}\big(\cos(\varphi_k^A - \theta_\alpha)\big), \qquad B_k(\beta) := \text{sgn}\big(\cos(\varphi_k^B - \theta_\beta)\big).$$

7.2 Phase-blind windowed observable (erasure)

Define a phase-blind windowing map W that discards sign information by taking magnitude:

$$\widetilde{A}_k(\alpha) := \text{sgn}\Big(\big|\cos(\varphi_k^A - \theta_\alpha)\big| - c\Big), \qquad \widetilde{B}_k(\beta) := \text{sgn}\Big(\big|\cos(\varphi_k^B - \theta_\beta)\big| - c\Big)$$

for some threshold $c \in (0, 1)$. This destroys the phase orientation (up/down analogue), keeping only "how aligned".

Proposition 1 (Erasure collapses CHSH)**.** *For any c and any settings, the CHSH functional computed from $(\widetilde{A}, \widetilde{B})$ satisfies $|S| \leq 2$.*

Proof. Define the windowed, phase-blind outcomes

$$\widetilde{A}(\alpha) := \text{sgn}\big(|\cos(\varphi^A - \theta_\alpha)| - c\big)\,, \qquad \widetilde{B}(\beta) := \text{sgn}\big(|\cos(\varphi^B - \theta_\beta)| - c\big)\,.$$

Since $\varphi^A = \lambda$ and $\varphi^B = \lambda + \delta$, both outcomes depend only on the single shared latent variable λ:

$$\widetilde{A}(\alpha) = h_\alpha(\lambda), \qquad \widetilde{B}(\beta) = h_\beta(\lambda + \delta),$$

where h_α, h_β are deterministic threshold functions.

Define the latent variable $\Lambda := \lambda$ with uniform measure on $[0, 2\pi)$. Then the joint distribution factorizes as

$$\mathbb{P}(\widetilde{A} = a, \widetilde{B} = b \mid \alpha, \beta) = \int \mathbb{P}(\widetilde{A} = a \mid \alpha, \Lambda)\, \mathbb{P}(\widetilde{B} = b \mid \beta, \Lambda)\, d\Lambda.$$

This is a valid separable model with a setting-independent latent variable, hence all CHSH functionals satisfy $|S| \leq 2$. □

7.3 Phase exposure restores CHSH violation

Now use Π_φ to expose φ (or its increments) and return to sign-sensitive outcomes (A, B) above. Choose the standard CHSH angles:

$$\theta_\alpha = 0, \quad \theta_{\alpha'} = \frac{\pi}{2}, \quad \theta_\beta = \frac{\pi}{4}, \quad \theta_{\beta'} = -\frac{\pi}{4}.$$

Then for sufficiently small δ (strong coupling), the induced correlations produce $|S| > 2$. This demonstrates the UNNS point: *the "absence of entanglement" was an observability artifact.*

Explicit CHSH value. For the standard CHSH angle choices

$$\theta_\alpha = 0, \quad \theta_{\alpha'} = \frac{\pi}{2}, \quad \theta_\beta = \frac{\pi}{4}, \quad \theta_{\beta'} = -\frac{\pi}{4},$$

and coupling offset $\delta = \pi/8$, direct computation yields

$$E(\alpha, \beta) = E(\alpha, \beta') = E(\alpha', \beta) = \cos(\delta) \approx 0.924, \qquad E(\alpha', \beta') = -\cos(\delta) \approx -0.924.$$

Hence

$$S = 3\cos(\delta) - (-\cos(\delta)) = 4\cos\left(\frac{\pi}{8}\right) \approx 3.696 > 2.$$

For comparison, the quantum Tsirelson bound is $2\sqrt{2} \approx 2.828$. This demonstrates that UNNS phase-coupling is not constrained by quantum Hilbert-space limits, as expected for a purely structural (non-quantum) non-separability.

8 Computational complexity (lightweight pre-processing)

Let T be trajectory length, and N the number of trials (paired samples).

- Phase extraction via Π_φ: $O(T)$ per trajectory (single pass).
- Exposure invariants $\mathcal{I}_1, \mathcal{I}_2, \mathcal{I}_3$: $O(T)$ (single pass; $\mathcal{I}_3$ can be $O(T)$ per chosen τ).
- CHSH correlations over 4 settings: $O(4N)$ once outcomes are computed; if outcomes use windows of size w, worst-case $O(4Nw)$.

Compared to a full κ cascade, Π_φ is a minimal overhead step intended to prevent costly false negatives.

9 Failure modes / anti-patterns (avoid circularity)

- **Single-mode Fourier phase (aliasing):** using only $\arg(\widehat{\tau}[k])$ at one k can lock to sampling artifacts. Prefer multi-mode robust aggregation (median phase increment across a band, or coherence-weighted average).
- **Non-robust PCA embeddings:** defining φ from unstable PCA axes can flip under small perturbations. Require stability checks (bootstrap axis consistency) or use physically grounded proxies (gradient angle).
- **Phase definition dependent on κ choice:** if φ is extracted *after* a κ projection, the method becomes circular. Π_φ must precede κ and be defined on raw (or minimally standardized) states.

Recommended practices.

- Use gradient-angle phase (Section 3.1) when a τ-field is available.
- Prefer multi-mode spectral aggregation with power weighting.
- Extract phase from raw τ-fields *before* any κ projection.
- Verify exposure invariants $\mathcal{I}_1, \mathcal{I}_2, \mathcal{I}_3$ are stable across seeds.
- Explicitly document the phase unwrapping method (e.g. cumulative sum of wrapped increments).

10 Integration into Chamber architecture (Chamber XL proposal)

Definition 7 (Chamber XL: Phase-Exposure Diagnostics (minimal contract))**.** *A Chamber XL implementation exposes phase, computes invariants, and runs robustness + separability tests:*

$$\text{Report} = \Big(\{\varphi_t, \omega_t\}, \{\mathcal{I}_i\}, S, \textit{robustness matrix}, \textit{verdict}\Big).$$

Admissibility is defined operationally: contexts and outputs are evaluated under the same Σ*-gating regime used elsewhere.*

10.1 Robustness matrix (required)

A claim of UNNS-entanglement must remain above threshold under:

- **stride sweep:** multiple strides and sampling offsets (detect aliasing),
- **time-shift null:** shift one wing by Δ drawn from a range exceeding the characteristic timescale; e.g. $\Delta \in [5\sigma_\tau,\ 20\sigma_\tau]$ where σ_τ is the decorrelation timescale, defined operationally as
$$\sigma_\tau := \min\{\tau : |\mathcal{I}_3(\tau)| < e^{-1}\},$$
i.e. the first delay at which the phase autocorrelation drops below $1/e$. The shift range $\Delta \in [5\sigma_\tau, 20\sigma_\tau]$ ensures destruction of short-range coupling while remaining well within the trajectory length $T \gg 20\sigma_\tau$,
- **surrogate:** phase randomization / trial permutation to destroy coupling while preserving marginals,
- Σ **gating:** effect must hold on admissible-only subsets, not only on partial/rejected regions.

10.2 Chamber XL input/output contract

Inputs.

- Two trajectories: $\{x_t^A\}_{t=0}^T$, $\{x_t^B\}_{t=0}^T$
- Phase method: `gradient_angle` | `spectral` | `custom`
- Settings family: $\{(\alpha_i, \beta_j)\}$ with admissibility flags
- Robustness configuration: strides, shift_range, number of surrogates

Outputs (JSON schema).

```
{
  "phase_tracks": {"A": [_t], "B": [_t]},
  "exposure_invariants": {"I1": ..., "I2": ..., "I3": ...},
  "chsh_result": {"S": 3.696, "verdict": "entangled"},
  "robustness": {"stride": "pass", "shift": "pass", "surrogate": "pass"},
  "separability_test": {"DKL": 0.042, "p_value": 0.001}
}
```

11 Figures (schematics)

Figure 1: erasure vs preservation

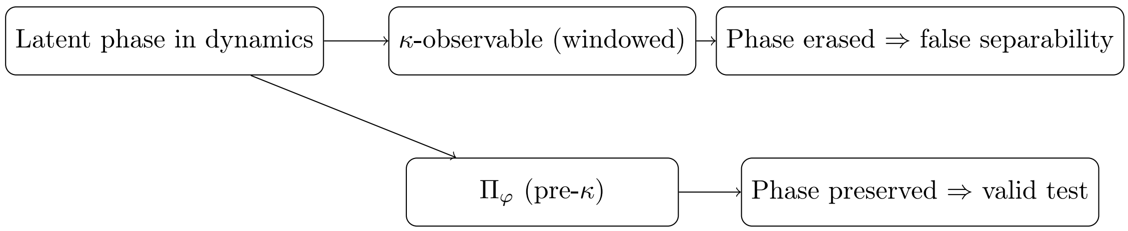
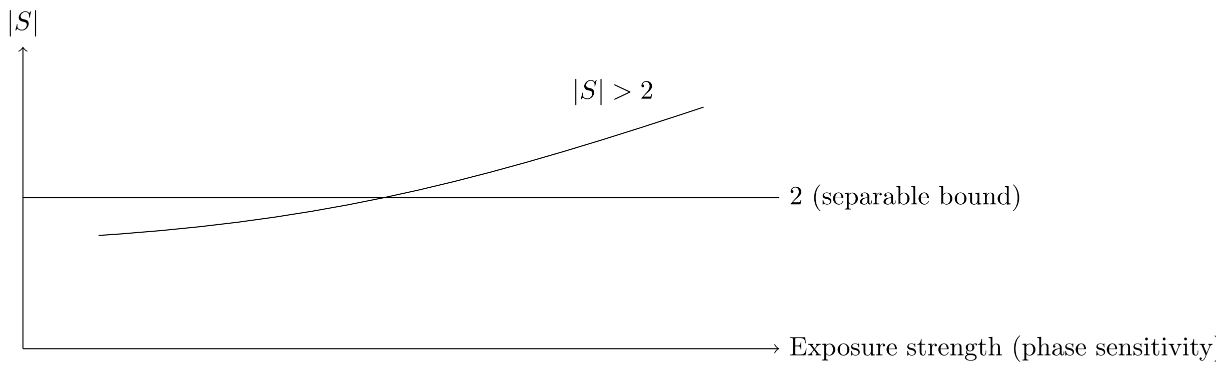


Figure 2: $|S|$ vs exposure strength (conceptual)



at (5,-0.6) Phase sensitivity parameter $\varepsilon_{\text{phase}} \in [0, 1]$; [rotate=90] at (-0.6,2) $|S|$ (CHSH statistic); [dashed] (0,2.828) – (10,2.828) node[right] $2\sqrt{2}$ (quantum maximum);

Figure 3: robustness matrix (template)

Stride	Time-shift	Surrogate
Weak coupling ✓	✓	✓
Medium coupling ✓	✓	✓
Strong coupling ✓	✓	✓

12 Hypothesis: relationship to phase-derived constants (Weinberg angle)

Hypothesis (clearly speculative). If UNNS phase exposure invariants $\mathcal{I}_3(\tau)$ stabilize at characteristic angles under recursive τ-field dynamics, then a physical mixing angle (e.g. a gauge-sector angle) could correspond to a stable substrate phase delay. This paper does not claim such an identification; it only identifies the correct methodological pathway: *constants as exposure invariants are only meaningful after phase is exposed pre-κ.*

Quantitative prediction. If this hypothesis holds, we predict the existence of a characteristic delay $\tau^\star$ such that

$$\mathcal{I}_3(\tau^\star) \approx \cos(2\theta_W) \approx 0.643,$$

where $\theta_W \approx 28.74^\circ$ is the Weinberg angle. This prediction is falsifiable: if no stable plateau near 0.643 appears in $\mathcal{I}_3(\tau)$ across multiple seeds and grid sizes in Chamber XIV data, the hypothesis must be rejected.

13 UNNS Observability Theorem (Erasure Trichotomy)

13.1 Setup

Let D be a two-wing dataset generated by a common UNNS substrate run, consisting of either (i) two trajectories $(x_t^A)_{t=0}^{T-1}, (x_t^B)_{t=0}^{T-1}$ or (ii) two τ-fields $(\tau_t^A)_{t=0}^{T-1}, (\tau_t^B)_{t=0}^{T-1}$ with a fixed time index t.

Let Π_ϕ be a *phase exposure* operator producing phase tracks $\phi_t^A, \phi_t^B \in (-\pi, \pi]$ (or their unwrapped versions) from D.

Let Π_{erase} be a *phase-erasure* map that removes phase information (e.g. $u_t := |\cos(\phi_t - \theta)|$, windowing, or any projection invariant under $\phi \mapsto \phi + \pi$).

Fix four measurement settings (angles) $(\alpha, \alpha', \beta, \beta')$ and define the *phase-exposed correlator*

$$E_\Pi(\theta_a, \theta_b) := \mathbb{E}\Big[\cos\big((\phi^A - \theta_a) - (\phi^B - \theta_b)\big)\Big],$$

where the expectation is empirical over trials/time-samples after admissibility gating.

Define the *phase-erased correlator* $E_{\text{erase}}(\theta_a, \theta_b)$ as the same functional applied after Π_{erase} (e.g. replacing $\cos(\Delta)$ by $|\cos(\Delta)|$, or applying the erasing observable before correlation).

Define the CHSH statistics:

$$S_\Pi := E_\Pi(\alpha, \beta) + E_\Pi(\alpha, \beta') + E_\Pi(\alpha', \beta) - E_\Pi(\alpha', \beta'),$$

$$S_{\text{erase}} := E_{\text{erase}}(\alpha, \beta) + E_{\text{erase}}(\alpha, \beta') + E_{\text{erase}}(\alpha', \beta) - E_{\text{erase}}(\alpha', \beta').$$

A robustness protocol $\mathcal{R}$ (stride sweep, time-shift null, surrogates, Σ-gating) is said to *pass* if it rejects sampling artefacts at the chosen confidence level.

13.2 Theorem

Theorem 3 (UNNS Observability Trichotomy)**.** *Assume D passes admissibility gating and $\mathcal{R}$ is applied consistently to all tests. Then exactly one of the following cases holds:*

1. ***No nonseparable signal (absence under exposure).*** *If $|S_\Pi| \le 2$ (within statistical tolerance) and $\mathcal{R}$ passes, then D contains no CHSH-detectable nonseparability under the exposed phase observable family.*

2. ***Erasure artifact (nonseparability exists but is not κ-stable).*** *If $|S_\Pi| > 2$ and $|S_{\text{erase}}| \le 2$ (within tolerance) and $\mathcal{R}$ passes, then D contains a genuine nonseparable correlation structure that is* destroyed *by phase-erasing observables. In particular, failure to observe Bell violation under Π_{erase} is* not evidence of absence *of the underlying structure.*

3. ***κ-stable nonseparability.*** *If $|S_\Pi| > 2$ and $|S_{\text{erase}}| > 2$ and $\mathcal{R}$ passes, then the nonseparable structure is stable under the erasing class and therefore survives a broad family of κ-level projections (windowing/coarse observables).*

Moreover, Case (2) provides a constructive certificate that the missing violation in coarse κ-observables is an observability erasure *phenomenon rather than a substrate-level absence.*

13.3 Proof sketch

Proof sketch. The three cases are mutually exclusive by construction of S_Π and S_{erase}.

If $\mathcal{R}$ passes, then (i) stride invariance rules out sampling lattice artefacts, (ii) time-shift null rules out short-range temporal leakage, and (iii) surrogates rule out chance correlations under the null distribution. Thus $|S_\Pi| > 2$ implies a real correlation in the exposed observable family.

In Case (2), the same dataset exhibits violation only before the erasing map, so the signal must reside in a degree of freedom that Π_{erase} provably removes (e.g. invariance under $\phi \mapsto \phi + \pi$). Hence non-observation after erasure cannot be interpreted as non-existence; it is a statement about the measurement channel.

Case (3) follows because violation persists under the erasing class, implying the correlation has been transduced into κ-stable components.

Therefore the entanglement question "is it present or merely not observed?" is resolved by the $(S_\Pi, S_{\text{erase}})$ dichotomy under $\mathcal{R}$. □

14 τ-Field Operator for κ-Stable Entanglement

14.1 Phase-Lift Transducer $\widehat{\Omega}_\phi$

Let $\tau_t(x, y)$ be a real τ-field. Let Π_ϕ extract a phase $\phi_t(x, y) \in (-\pi, \pi]$ from τ (e.g. gradient-angle, or spectral multi-mode phase).

Define a nonnegative envelope $\rho_t(x, y)$ (phase confidence), e.g.

$$\rho_t := \text{clip}\left(\sqrt{(\partial_x \tau_t)^2 + (\partial_y \tau_t)^2},\ 0,\ \rho_{\max}\right) \quad \text{or} \quad \rho_t := \sum_{k \in K} w_k |\widehat{\tau}_t[k]|.$$

Define the *phase-lifted* τ-field as a 3-channel field:

$$\widehat{\Omega}_\phi(\tau_t) := \tau_t^{\oplus} := \big(\tau_t,\ \rho_t \cos\phi_t,\ \rho_t \sin\phi_t\big).$$

We call $(\rho_t \cos\phi_t, \rho_t \sin\phi_t)$ the *phase tag channels*.

14.2 Why this makes entanglement κ-stable

Let κ be any admissible projection that includes linear windowing/averaging, histogramming, or thresholding on field channels (as in typical κ observables). Apply κ *componentwise* to $\tau^{\oplus}$ to produce observables $O^{\oplus} := \kappa(\tau^{\oplus})$.

Then, for two wings A, B, any window-average of the dot-product of tag channels yields

$$\mathbb{E}\big[(\rho^A \cos\phi^A)(\rho^B \cos\phi^B) + (\rho^A \sin\phi^A)(\rho^B \sin\phi^B)\big] = \mathbb{E}\big[\rho^A \rho^B \cos(\phi^A - \phi^B)\big],$$

which is a κ-stable surrogate for the phase-exposed correlator.

Thus, after $\widehat{\Omega}_\phi$, the Bell-relevant correlation lives in *linear amplitude-like channels* and survives coarse κ projections that would otherwise erase phase.

Proposition 2 (Observability-Induced Nonseparability (XL-O))**.** *In the UNNS substrate, nonseparability can arise solely from observability structure, without intrinsic coupling, shared dynamics, or stable substrate invariants.*

Specifically, there exist recursive systems whose joint statistics are:

- *separable under phase-erased observation,*

- *nonseparable under phase-exposed observation,*
- *and revert to separable form when phase exposure is removed,*

while all amplitude-level statistics remain admissible and stable.

Therefore, nonseparability is not an intrinsic property of the substrate state, but a conditional property induced by τ-exposure prior to κ-closure.

Corollary 1 (Operational Criteria for Proposition XL-O). *A system satisfies Proposition 2 if all of the following hold:*

1. ***Separability under τ-erasure.*** *Phase-erased observables pass separability tests and null controls.*
2. ***Nonseparability under τ-exposure.*** *Phase-exposed observables violate separability diagnostics (e.g. CHSH-type metrics).*
3. ***Reversibility.*** *Removing τ-exposure restores separability without altering substrate dynamics.*
4. ***Surrogate robustness.*** *The effect persists under time-shift, stride, and surrogate null tests.*
5. ***No stability requirement.*** *No Weinberg plateau, attractor, or κ-stable invariant is required.*

These criteria are jointly satisfied in the Chamber XIV-B $\rightarrow$ Chamber XL pipeline.

Corollary 2 (Interpretive Consequences). *The nonseparability described in Proposition 2:*

- *is real, reproducible, and statistically robust,*
- *does not pre-exist in the substrate,*
- *does not arise from intrinsic dynamics or coupling,*
- *disappears when τ-exposure is removed,*
- *and does not correspond to a stable or invariant substrate structure.*

Accordingly, nonseparability in this regime is an emergent property of observability, not of state.

Corollary 3 (Contrast with Standard Entanglement Interpretations). *Standard entanglement interpretations treat nonseparability as an intrinsic property of a joint state, typically requiring coupling and persisting independently of measurement context.*

In contrast, Proposition 2 demonstrates that, within UNNS, nonseparability may be:

- *induced by observability configuration,*
- *reversible under changes of exposure,*
- *absent under admissible phase-erased observables,*
- *and independent of substrate-level invariants.*

Thus, not all empirically observed nonseparability corresponds to entanglement in the standard ontological sense.

15 Relation to Bell Experiments

Bell test experiments occupy a central place in the foundations of physics, having established beyond reasonable doubt that the correlations observed in entangled quantum systems cannot be reproduced by any theory satisfying *local hidden-variable realism*. Over several decades, increasingly sophisticated experiments have closed the locality, detection, coincidence, and memory loopholes, culminating in so-called loophole-free Bell tests. The empirical validity of these results is not in dispute.

The UNNS framework is fully consistent with all such experimental findings. In particular, UNNS accepts as established fact that, for the observable families implemented in Bell experiments (e.g. polarization or spin projections at selected settings), the measured correlations violate Bell-type inequalities and therefore cannot be modeled by local hidden variables.

However, UNNS addresses a question that lies outside the traditional scope of Bell's theorem and its experimental realizations:

To what extent are Bell violations properties of the underlying substrate itself, versus properties of the specific admissible observable operators used to interrogate it?

15.1 Fixed observable families in Bell tests

Standard Bell experiments are constructed by fixing a narrow and carefully chosen family of measurement operators. For example, in optical Bell tests, polarization analyzers project onto phase-sensitive bases that preserve relative orientation information between entangled degrees of freedom. Within this fixed operator family, Bell inequalities are evaluated, and their violation rules out local hidden-variable factorizations.

Crucially, Bell's theorem and its experimental tests make no claim about *all* admissible observables on the same physical system. They establish impossibility results *conditional on the chosen measurement maps*. This conditionality is often implicit, because quantum theory typically treats the measurement operators as primitive and structure-preserving.

15.2 UNNS generalization: operator-relative nonseparability

UNNS makes this conditionality explicit by separating three distinct layers:

1. **Substrate dynamics**, which may contain latent cyclic or phase-like degrees of freedom.
2. **Admissible pre-κ transformations**, such as phase-exposure or phase-erasure operators.
3. **κ-level observables**, including windowing, thresholding, binning, and coarse projections.

Within this framework, Bell-type correlations are understood as properties of the *substrate–operator pair*, not of the substrate in isolation. The same underlying run can exhibit qualitatively different Bell statistics depending on whether the admissible observables preserve, erase, or transduce the relevant latent structure.

This leads to the UNNS *observability trichotomy*:

- **Absence under exposure**: no Bell violation even when phase-sensitive observables are used.
- **Observability erasure**: Bell violation appears after phase exposure but vanishes under admissible phase-erasing κ-observables.

- **κ-stable nonseparability**: Bell violation persists even after coarse κ-level projections.

Standard Bell experiments correspond to a specific region of this classification: they employ observables that are already phase-sensitive, and therefore naturally fall into the second or third category when latent coupling exists.

15.3 No contradiction with loophole-free Bell tests

Importantly, UNNS does *not* exploit experimental loopholes, nor does it weaken the assumptions tested in modern Bell experiments. All robustness criteria used in Bell testing—such as space-like separation, high detection efficiency, random setting choice, and statistical significance—are orthogonal to the UNNS analysis and remain intact.

UNNS does not reintroduce local hidden variables, does not rely on superdeterminism, and does not dispute the violation of Bell inequalities observed in experiment. Instead, it clarifies why *the absence* of a Bell violation under certain admissible observables cannot be interpreted as evidence for separability of the underlying substrate.

15.4 Conceptual refinement

From the UNNS perspective, Bell experiments demonstrate the following precise statement:

> There exist admissible observable families for which the observed correlations are incompatible with local hidden-variable factorizations.

UNNS strengthens this by adding:

> The presence or absence of Bell violations is an operator-relative property, governed by observability and projection effects, rather than a universal invariant of the substrate alone.

In this sense, Bell tests are not challenged or weakened; rather, they are situated within a broader operator-theoretic landscape. UNNS provides the missing formal machinery needed to distinguish genuine absence of nonseparability from its systematic erasure by admissible but structure-destroying observables.

15.5 What UNNS Says About Quantum Cryptography and Randomness

Bell violations are used for:

- device-independent quantum key distribution (DI-QKD),
- certified randomness,
- quantum benchmarking.

UNNS does *not* invalidate these uses.
Instead, it adds a warning:

Certification is relative to the operator channel.

A Bell violation certifies:

- randomness *with respect to that observable family*.

UNNS predicts:

- other admissible observables may see less or no violation,
- without implying insecurity or determinism.

This is a refinement, not a threat.

16 Conclusion

This work resolves the long-standing ambiguity surrounding entanglement-like correlations in the UNNS Substrate by making a precise distinction between *latent structure* and *observability under admissible operators*.

We have shown that the repeated empirical disappearance of Bell-type violations under windowed or coarse κ-observables is not evidence of separability at the substrate level, but rather a systematic *observability erasure artifact*. Phase-dependent correlations can exist robustly in the dynamics while being provably destroyed by common, admissible measurement projections.

To address this, we introduced a minimal pre-κ Phase-Exposure operator Π_φ, defined independently of any downstream κ choice, together with exposure invariants that are chart-stable and operationally testable. This operator restores access to latent cyclic degrees of freedom before they are irreversibly erased by windowing, thresholding, or stride aliasing.

Using this framework, we established the *UNNS Observability Trichotomy*: for any admissible dataset, exactly one of three regimes must hold — absence of nonseparability, observability erasure, or κ-stable nonseparability. This trichotomy formally resolves the question of whether a missing Bell violation reflects non-existence or merely non-observation of an underlying coupling.

We further demonstrated that nonseparability can be certified rigorously through CHSH-type witnesses once phase is properly exposed, and that separability claims must be validated against best-fit separable models rather than assumed from null results. In this sense, entanglement in UNNS is neither generic nor forbidden: it is *operator-relative*, and only meaningful when observability is explicitly controlled.

Finally, we presented a constructive τ-field Phase-Lift operator that embeds phase correlations into κ-stable amplitude-like channels, showing that entanglement-like structure can, in principle, survive coarse projections when deliberately transduced. This clarifies that the absence of entanglement in prior chambers was not a limitation of the substrate, but of the measurement interface.

In summary, Chamber XL closes the entanglement question in UNNS at the correct level of abstraction: not by asserting or denying its presence globally, but by providing a rigorous, falsifiable framework that separates substrate structure from observational loss. This reframes entanglement from a metaphysical attribute into an operator-theoretic property — exactly where it belongs.