

# **Time Crystals, Holography, and Quantum Information: Minimal Common Ground**

## **Abstract**

This publication provides a structured synthesis for Time Crystals, Holography, and Quantum Information: Minimal Common Ground, with claim-to-evidence framing and a validation path for downstream readers.

## **Keywords**

cosmos, research, publication

## **Main Content**

# Time Crystals, Holography, and Quantum Information: A Minimal Coherence Framework

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## Abstract

We present a compact synthesis connecting Floquet time-crystal dynamics, holographic coarse-graining, and operator-level coherence constraints. Rather than over-claiming unification, we construct a minimal testable scaffold that separates established results from speculative bridges. The framework defines measurable coherence criteria and explicit falsification hooks suitable for numerical and conceptual evaluation.

**Keywords** time crystals; Floquet dynamics; holography; quantum information; coherence operators

## 1 Introduction

Time-crystal discourse often blends distinct layers: equilibrium no-go results, non-equilibrium Floquet order, and broader information-theoretic interpretations. This paper imposes a minimal common language so each claim is tied to assumptions, observables, and failure conditions.

## 2 Coherence Functional

Let  $\rho_t$  denote a reduced state over a bounded operator algebra. We define a periodic coherence witness over one drive period  $T$ :

$$\mathcal{C}_T = \frac{1}{T} \int_0^T \text{Tr}(\rho_t \mathcal{O}_c) dt, \quad (1)$$

where  $\mathcal{O}_c$  is a coherence-sensitive bounded observable.

For perturbation family  $\{\epsilon\}$ , coherence drift is

$$\Delta_\epsilon = |\mathcal{C}_T(\epsilon) - \mathcal{C}_T(0)|. \quad (2)$$

## 3 Stability Threshold

With stroboscopic map  $\Phi_T$ , robust regime membership is declared only when

$$\sup_{\epsilon \in [0, \epsilon_0]} \Delta_\epsilon < \delta_*, \quad (3)$$

for pre-registered tolerance  $\delta_*$ . Violations indicate fragile coherence and block strong interpretive claims.

## 4 Emergent Geometry Protocol

We compare boundary and reconstructed proxies using a coarse-graining channel  $\mathcal{R}$ . Consistency is evaluated by

$$\left| \mathcal{C}_T^\partial - \mathcal{C}_T^{\text{bulk}} \right| \leq \eta, \quad (4)$$

where  $\eta$  is reported as model error (not absorbed narratively). In local parameter chart  $\theta$ , geometry diagnostics can be approximated through Fisher information:

$$g_{ab}(\theta) = \sum_x p(x \mid \theta) \partial_a \log p(x \mid \theta) \partial_b \log p(x \mid \theta). \quad (5)$$

## Validation and Falsification

- Sweep drive-noise amplitude and detect breakdown of the stability threshold.
- Replace  $\mathcal{O}_c$  with orthogonal witness families to test basis sensitivity.
- Reject holographic interpretations if boundary–bulk coherence mismatch remains high in controlled toy models.

## Conclusion

The manuscript provides a cleaner publication baseline: assumptions are explicit, equations are legible, and interpretive claims are paired with concrete failure criteria.