Relational Time and Intrinsic Temporal Stochasticity

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Abstract

Swirl-String Theory reformulates physical time as a relational observable associated with a conserved event current rather than as an external parameter. We explore the phenomenological consequence that clock readouts may exhibit intrinsic temporal broadening, independent of environmental noise or relativistic time dilation. We introduce an operational ansatz for time-of-arrival fluctuations and discuss how such effects could scale with gradients of the clock foliation field. Finally, we outline exploratory clock-comparison experiments capable of constraining this temporal stochasticity and discuss implications for quantum measurement and decoherence.

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1 Relational Time in Swirl–String Theory

In Swirl–String Theory (SST), physical time is not introduced as a fundamental external parameter. Instead, time is defined operationally through a conserved event current associated with the underlying foliation field. Clock readings correspond to the accumulation of discrete events along integral curves of a preferred timelike vector field u^μ.

This construction is fixed canonically in SST–31 and Canon v0.7.7 and is equivalent in the infrared to hypersurface–orthogonal Einstein–Æther (khronometric) theory. No stochasticity is postulated at the level of the action.

2 Intrinsic Temporal Broadening

While the event current is conserved, its operational realization in physical clocks involves counting discrete microscopic processes. As a consequence, clock readouts need not be perfectly sharp even in the absence of environmental noise.

We define *intrinsic temporal broadening* as a fundamental variance in time–of–arrival measurements that persists after all known classical, thermal, quantum, and relativistic corrections are removed.

Operationally, the observed time–of–arrival distribution $P_{\text{obs}}(\Theta)$ is modeled as

$$P_{\text{obs}}(\Theta) = \int dt\, P_{\text{cl}}(t) \frac{1}{\sqrt{2\pi\sigma_\tau^2}} \exp\left[-\frac{(\Theta - t)^2}{2\sigma_\tau^2}\right], \tag{1}$$

where σ_τ^2 parametrizes intrinsic temporal stochasticity.

3 Scaling Ansatz and Physical Interpretation

Canon v0.7.7 implies that relational time is defined relative to the clock–foliation field. Accordingly, intrinsic temporal broadening may depend on spatial inhomogeneities of the foliation.

We therefore adopt the phenomenological ansatz

$$\sigma_\tau^2 = \sigma_\tau^2(\nabla\chi), \tag{2}$$

where χ denotes the scalar foliation (clock) potential.

Physically, this dependence reflects fluctuations in the local event rate induced by gradients of the clock field. No claim is made regarding the microscopic origin or spectral structure of this noise, which remains an open parameterization.

4 Experimental Search Channels and Falsification

Intrinsic temporal broadening predicts observable consequences only in high–precision differential clock experiments. Suitable search channels include:

- co–located optical lattice clocks operated in differential mode,
- entangled clock pairs sensitive to phase decoherence,
- controlled modulation of local clock–field gradients.

A null result at sensitivity $\sigma_\tau \lesssim 10^{-19}\,\text{s}/\sqrt{\text{Hz}}$ places direct bounds on the admissible stochastic sector of SST. Conversely, observation of clock decoherence correlated with $\nabla\chi$ would constitute evidence for relational time fluctuations distinct from standard quantum or gravitational noise.

This work therefore defines a falsifiable experimental program rather than a prediction of detectability.

5 Discussion and Outlook

5.1 Summary of Results

This work reformulates physical time in Swirl–String Theory (SST) as a relational observable associated with a conserved event current rather than as an external evolution parameter. Within this framework, clock readouts are not assumed *a priori* to correspond to a perfectly smooth variable, even in isolated systems.

We introduced an operational ansatz for intrinsic temporal broadening, modeled as a convolution of ideal clock evolution with a stochastic kernel characterized by a variance σ_τ^2. This quantity parametrizes intrinsic clock noise that is conceptually distinct from environmental disturbances, relativistic time dilation, or measurement backaction.

No claim has been made regarding the magnitude or detectability of σ_τ^2 with existing technology. The purpose of this work is to define a consistent phenomenological framework and an associated experimental search channel.

5.2 Relation to Other SST Results

The temporal stochasticity discussed here is logically independent of velocity-dependent mass effects and preferred-frame corrections addressed elsewhere. In particular, gravity-sector tests of foliation-referenced mass anisotropy are treated separately and do not enter the present analysis.

Accordingly, this work should be read as complementary to, but distinct from, operational follow-ups of the SST mass functional. The results presented here depend only on the relational definition of time fixed in the SST Canon and do not modify the gravitational sector.

5.3 Falsification and Outlook

The framework presented admits clear falsification pathways.

A null result in high-precision differential clock experiments constrains the allowed stiffness and smoothness of the SST clock foliation. Conversely, observation of excess decoherence or time-of-arrival broadening that scales with controlled gradients of the clock field, while surviving standard noise rejection protocols, would provide evidence for intrinsic temporal stochasticity.

Future work may refine the spectral properties of σ_τ^2, investigate its coupling to quantum coherence, and explore its implications for foundational questions in quantum measurement and time observables.

The present analysis establishes the minimal phenomenological groundwork required for such investigations, without extending beyond empirically testable statements.