

Technical Addendum: Frame Specification, SME Mapping, and Interpretation Logic

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Abstract

This addendum clarifies a structural interpretation gap in the main text. The observable $\cos(2(\theta - \theta_0))$ modulation admits two physically distinct reference-frame scenarios—laboratory-fixed (Case A) and inertial (Case B)—which imply different experimental strategies, different relations to existing Standard-Model Extension (SME) bounds, and logically independent sensitivity benchmarks. We specify the bifurcation, map each case to its appropriate falsification channel, and provide explicit benchmark inequalities.

1 Preamble: The Interpretation Gap

The main text introduces an observable modulation

$$\propto \cos(2(\theta - \theta_0))$$

with a preferred axis θ_0 in the laboratory frame. However, the physical nature of the signal—and consequently its relation to existing bounds and its falsification logic—depends critically on the reference frame against which the angle θ is measured. We state the guiding principle explicitly:

A positive signal is uninterpretable without frame specification, and a null result is inconclusive without a proper mapping to established Standard-Model Extension (SME) channels.

2 Reference-Frame Bifurcation

We distinguish two conceptually distinct limiting scenarios that produce the same mathematical signature but imply entirely different experimental strategies and interpretations.

2.1 Case A: Laboratory-Fixed Structure (Non-Inertial)

The preferred axis θ_0 is anchored to the local apparatus or laboratory environment, for example to the optical table, the cavity orientation, or the local plumb line.

The angle θ is the actively controlled rotation angle of the setup.

Observational consequence. At a fixed orientation, the signal does not appear as a time-varying modulation; it manifests as a static contribution to the measured phase or frequency. Without active rotation, such an offset is experimentally indistinguishable from a calibration constant, a systematic bias, or an apparatus-intrinsic anisotropy.

A genuine geometry-related signal should remain tied to the defined laboratory frame under controlled reconfiguration tests, such as remounting of components or reversal of the optical

axis. By contrast, many instrumental artefacts track specific hardware realizations rather than the abstract laboratory frame.

2.2 Case B: Inertial Structure (Sun-Centered, SME-Type)

The preferred axis θ_0 is fixed in a distant inertial frame, for example the cosmic microwave background rest frame or a sun-centered celestial frame.

The angle $\theta(t)$ varies due to Earth’s rotation.

Observational consequence. The modulation appears at least with a sidereal periodicity, potentially with additional sidebands due to the motion of the laboratory relative to the chosen frame. No active rotation of the apparatus is required.

3 Why Frame Must Precede SME Mapping

Mapping the model to photon-sector SME coefficients before specifying the frame is logically unsound.

- **If Case B (Inertial) applies:** The model reduces to a subset of standard SME searches, for example channels involving coefficients of the form $\tilde{\kappa}_{e-}^{JK}$ [1]. The published bounds at the 10^{-17} to 10^{-18} level [2, 3, 4] then apply directly. A new experiment that merely records data passively would be redundant; its value would lie solely in improved sensitivity.
- **If Case A (Laboratory-Fixed) applies:** The signal is complementary to the SME. Standard SME analyses are not optimized as a search pipeline for this channel. They are designed to extract time-dependent, frame-induced modulations and typically treat or subtract apparatus-fixed contributions as part of the systematic error budget. A laboratory-fixed effect would therefore not survive a classical sidereal demodulation as a positive signal; it would be absorbed into the instrumental offset.

4 The Specific Systematic Burden of Case A

It is essential to recognize that Case A is not simply a variant of an SME coefficient. Because the signature is rigidly attached to the apparatus, its phenomenological description is formally identical to that of a rotating instrumental artefact.

The interpretation must therefore separate two levels strictly:

1. Effective signal parametrization:

$$\frac{\delta\nu}{\nu} \sim \epsilon\chi \cos(2(\theta - \theta_0))$$

describes the data.

- ### 2. Fundamental interpretation:
- This modulation could arise from a local space-time structure, but it could equally arise from mechanical stress release, thermal gradients co-rotating with the mount, or magnetic pickup.

For Case A, reversal tests, null channels, verification of L -scaling, and controlled variation of mechanical and thermal boundary conditions are not optional refinements. They are integral parts of the physical interpretation itself.

5 Decision Matrix and Implications for Experimental Design

Table 1 summarizes the experimental consequences of the two reference-frame scenarios. The entries make explicit that the two cases differ not only in signal morphology but also in the applicable exclusion limits and the dominant systematic backgrounds.

Feature	Case A: Laboratory-Fixed	Case B: Inertial (SME-Type)
Required motion	Active rotation (turntable)	Passive data taking (Earth rotation)
Signal character	Static at fixed orientation	Periodic, at least sidereal
Relevance of existing SME bounds	Not directly constrained by standard sidereal SME searches	Direct, with already strong limits
Dominant systematics	Mechanically/thermally co-rotating effects	Long-term drift on 24-hour timescales
Interpretation of a positive finding	Reproducible local coupling (apparatus or spacetime)	Candidate Lorentz-violation signature

Table 1: Decision matrix for the two reference-frame scenarios.

6 Sensitivity Benchmarks by Channel

The two cases defined above imply distinct benchmark inequalities that must not be collapsed into a single sensitivity window.

Case B (inertial). If the signal projects onto standard SME photon-sector coefficients, existing cavity and interferometer bounds constrain the effective coupling to

$$\epsilon\chi \lesssim 10^{-17}$$

from sidereal analyses, e.g. in $\tilde{\kappa}_{e-}^{JK}$ channels [2, 3, 4]. Any new experiment operating in this channel competes directly with these limits and is scientifically productive only if it improves the bound.

Case A (laboratory-fixed). Because standard sidereal searches absorb apparatus-fixed contributions into the systematic baseline, the relevant benchmark is not the SME bound but the systematics-cleaned rotational sensitivity of the specific setup,

$$\epsilon\chi \lesssim \sigma_{\text{rot}},$$

where σ_{rot} denotes the achieved uncertainty on the $\cos 2\theta$ amplitude after null-channel subtraction, reversal tests, and L -scaling verification. For current-generation optical cavities with turntable rotation, published results place σ_{rot} in the range 10^{-15} to 10^{-13} , depending on the dominant co-rotating systematic [2, 4].

The two benchmarks are logically independent. A null result in Case B at 10^{-17} does not constrain Case A, and a positive signal in Case A at 10^{-14} does not contradict existing SME bounds.

7 Conclusion of the Addendum

The laboratory-fixed case (Case A) defines a distinct search channel with its own logic of falsification. It is not directly constrained by standard sidereal SME bounds because those analyses explicitly target a different symmetry, namely temporal modulation rather than spatial orientation. However, this freedom comes at the cost of a substantially heavier systematic burden.

The protocol outlined in the main text—specifically the requirement for active rotation, blind analysis, and geometric scaling—is therefore the minimal necessary condition for turning a $\cos 2\theta$ observation in this channel into a result that can be meaningfully interpreted beyond apparatus-specific systematics.

References

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