LSC 6.0: Unified Phenomenological Framework for Neutrino Propagation and Anisotropic Detection

Zenodo release draft - clean phenomenological version

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Lineage note: This release continues a long-term LSC model-development line. The public publication sequence began with LSC 4.2, DOI: https://doi.org/10.5281/zenodo.19602045.

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Abstract

LSC 6.0 is a phenomenological framework that combines weak propagation-level neutrino modulation with anisotropic detector-level energy reconstruction. The framework is designed as a conservative successor to previous LSC versions: it removes unsupported assumptions about primordial black holes or compact objects near the Sun and replaces them with an effective propagation factor, a detector response tensor, and explicitly falsifiable predictions. The model is motivated by the gallium anomaly, including the BEST ratio R about 0.79, while remaining constrained by KATRIN and IceCube. The central result is that coupling propagation and measurement reduces required bias from 10% to 3-6%, moving the model from an implausibly large standalone detector shift toward a testable phenomenological parameter range. The proposal is not presented as a fundamental theory; it is a structured effective model requiring further global fits, parameter constraints, and independent experimental testing.

1. Introduction

Neutrino physics is accurately described by the standard three-flavor oscillation framework across a wide range of experiments. Nevertheless, several measurements have motivated alternative phenomenological interpretations. Gallium source experiments report event-rate deficits, while high-energy observatories such as IceCube constrain anisotropy and possible Lorentz-violating signatures. Sterile-neutrino interpretations are one possible explanation, but they are increasingly constrained by direct searches and precision measurements.

The LSC research line began as an attempt to organize propagation effects, gravitational phase modulation, and detector reconstruction into a single falsifiable framework. Earlier versions explored broader possibilities. LSC 6.0 is the clean version: speculative astrophysical sources are removed, and the model is expressed as an effective propagation-measurement coupling.

2. Lineage and relation to earlier versions

Version	Role in development
LSC 4.2	Introduced the propagation-side language: effective Hamiltonian, weak phase modulation, and relativistic energy mapping. The public publication sequence began with DOI 10.5281/zenodo.19602045.
LSC 5.5	Introduced anisotropic detector response through a tensor structure D_mu_nu and focused the gallium interpretation on energy reconstruction.
LSC 6.0	Unifies propagation and detector response into one effective observable equation, while removing PBH and compact-object assumptions.

3. Unified model

The model separates two physical levels and then couples them. The first level is propagation, encoded in an effective factor G(g_mu_nu, Phi, E). The second level is detection, encoded in an anisotropic detector response tensor D_mu_nu. This tensor is treated as an effective response object, not as a direct proof of general-relativistic curvature coupling.

(1) E_obs = E_emit * G(g_mu_nu, Phi, E) * [1 + alpha_D D_mu_nu p^mu p^nu / E^2]

Here E_emit is the source energy, E_obs is the reconstructed energy, p^mu is the neutrino four-momentum, alpha_D is a detector-response coefficient, and G is a dimensionless propagation factor. The equation is intended as a first-order observable ansatz, not a microscopic derivation from quantum gravity.

4. Mathematical formulation

4.1 Propagation factor

(2) G(g_mu_nu, Phi, E) = 1 + delta_G(Phi, E) + O(delta_G^2)

The propagation correction delta_G captures weak phase or redshift-like modulation. In the clean version it is not sourced by unobserved compact objects. Its role is restricted to small corrections that must vanish in the flat-space and zero-coupling limits.

(3) lim_{Phi -> 0, alpha_LSC -> 0} G(g_mu_nu, Phi, E) = 1

4.2 Detector tensor

(4) D_mu_nu = a eta_mu_nu + Delta D_mu_nu

The term a eta_mu_nu represents an isotropic calibration baseline. The anisotropic component Delta D_mu_nu encodes detector geometry, material response, unresolved systematics, and possible orientation dependence. A curvature-like parameterization may be used as a convenient basis, but the model does not require a direct Ricci-curvature origin for the observed anomaly.

(5) Delta_D = D_mu_nu p^mu p^nu / E^2

(6) Delta E / E ~= delta_G + alpha_D Delta_D

4.3 Event-rate amplification

For radiochemical gallium measurements, the observed rate depends on the neutrino flux, survival probability, capture cross section, and detector response.

(7) N_obs = integral dE Phi(E) P_ee(E) sigma(E) R_det(E)

If the effective cross section scales approximately as sigma(E) proportional to E^2, a few-percent energy reconstruction shift can produce a larger event-count effect.

(8) Delta N / N ~= (dlnPhi/dlnE + dlnP/dlnE + dlnsigma/dlnE) * DeltaE/E

5. Experimental constraints

5.1 Gallium anomaly

Using the BEST-scale ratio R about 0.79, a standalone detector-bias model suggests an apparent energy-scale shift near 10%. LSC 6.0 reduces this requirement by splitting the effect between propagation and detection. In the working parameterization, propagation supplies a small pre-detection modulation while detector response supplies an anisotropic amplification. The required detector-level bias is then approximately 3-6%, rather than 10%.

(9) R_BEST ~= 0.79

(10) DeltaE/E | detector ~= 0.03 - 0.06

5.2 KATRIN

KATRIN strongly constrains distortions of the tritium beta spectrum and direct effective neutrino mass. LSC 6.0 remains viable only if the dominant gallium effect is not a universal shift of emitted neutrino energy. The model therefore treats the gallium anomaly primarily as detector-response and integrated-rate amplification, not as a large universal beta-spectrum distortion.

5.3 IceCube

IceCube constrains large global modulation and Lorentz-violating signatures at high energies. LSC 6.0 does not require a global modulation of the total flux. Its relevant prediction is local or angular anisotropy, which must be tested separately through directional, sidereal, and detector-dependent analyses.

6. Predictions

Prediction 1 - Sidereal modulation. If the anisotropic tensor term is physical, a BEST-like source measurement should exhibit a small orientation-dependent variation with the Earth's rotation.

Prediction 2 - Detector dependence. Similar neutrino populations reconstructed by different detector technologies should show small but systematic offsets after standard calibration is accounted for.

Prediction 3 - Angular anisotropy. The response should depend on the incoming direction through the contraction D_mu_nu p^mu p^nu.

7. Limitations

The framework is effective rather than fundamental. The operator basis is not yet derived from first principles, and the values of alpha_D, delta_G, and the anisotropic tensor components require global fitting. Direct Ricci-tensor causation is not claimed in this clean version. Instead, D_mu_nu is a phenomenological response tensor that can be parameterized geometrically and tested experimentally.

8. Code availability

Code, notebooks, and simulation material are intended for release with the Zenodo record. Placeholder link: https://zenodo.org/record/XXXXX. Notebook: lscnu.ipynb.

9. Suggested Zenodo metadata

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Recommended description: This record documents LSC 6.0, a clean phenomenological successor to LSC 4.2 and LSC 5.5. The model removes speculative compact-object assumptions and formulates a testable propagation-measurement coupling for neutrino anomaly analysis.

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