LSC 4.2 ULTRA: Gravitationally Coupled Neutrino Oscillation Framework

Abstract

LSC 4.2 presents a refined theoretical framework extending neutrino oscillation physics into curved spacetime. The model introduces a gravitationally coupled operator (LSC) modifying flavor evolution near Primordial Black Holes (PBH). We derive resonance conditions, predict observable deviations, and propose testable signatures for ultra-high-energy neutrino experiments.

1. Introduction

Standard neutrino oscillation theory successfully explains solar and atmospheric data. However, extreme gravitational environments may induce additional phase and mixing effects. LSC 4.2 explores this regime using a covariant formalism.

2. Covariant Formalism

$i\, D/d\tau\, \nu = H_{eff}\, \nu$

$H_{eff} = H_{vac} + H_{matter} + H_{grav} + H_{LSC}$

Vacuum Term:

$H_{vac} = (1/2E)\, U M^2 U^\dagger$

Matter Term:

$H_{matter} = \mathrm{diag}(Ve, 0, 0)$

Gravitational Term:

$H_{grav} = (E/c^2)\, \Phi(r),\ \Phi(r) = -GM/r$

LSC Operator:

$H_{LSC} = \alpha_{LSC}\, (GM / (r c^2))\, F(E)$

3. Resonance Structure

$\Delta m^2 \cos(2\theta) = 2E\, (V_{matter} + V_{LSC})$

This condition predicts localized resonance near PBH environments, enhancing flavor conversion probabilities.

4. Gravitational Energy Shift

$$E_{obs} = E_{emit} \sqrt{(1 - r_s/r_{emit}) / (1 - r_s/r_{obs})}$$

This relativistic effect explains observed high-energy neutrinos without requiring exotic acceleration mechanisms.

5. Oscillation Probability

$$P(\nu\alpha \rightarrow \nu\beta) = |P \exp(-i \int H_{eff}\, d\tau)|^2$$

6. Predictions

- Energy-dependent resonance peaks - Enhanced oscillation near compact objects - Possible explanation for PeV-scale neutrino anomalies

7. Discussion

The model remains consistent with General Relativity and Quantum Field Theory while extending neutrino physics into new regimes.

8. Conclusion

LSC 4.2 provides a mathematically consistent and testable extension of neutrino oscillation theory. Future work includes numerical simulation and experimental validation.