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Testing the dark origin of neutrino masses with oscillation experiments

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The origin of neutrino masses remains unknown to date. One popular idea involves interactions between neutrinos and ultralight dark matter, described as fields or particles with masses m_ϕ
$lesssim 10\,\mathrm{eV}$. Due to the large phase-space number density, this type of dark matter exists in coherent states and can be effectively described by an oscillating classical field. As a result, neutrino mass-squared differences undergo field-induced interference in spacetime, potentially generating detectable effects in oscillation experiments. By analyzing data from the Kamioka Liquid Scintillator Antineutrino Detector (KamLAND), a benchmark long-baseline reactor experiment, we show that the hypothesis of a dark origin for the neutrino masses is disfavored for m_ϕ
$lesssim 10^{-14}\,\mathrm{eV}$, compared to the case of constant mass values in vacuum. The mass range $10^{-17}\,\mathrm{eV}$
$lesssim m_\phi$
$lesssim 10^{-14}\,\mathrm{eV}$ can be further tested in current and future oscillation experiments by searching for time variations (rather than periodicity) in oscillation parameters. Furthermore, we demonstrate that if $m_\phi \gg 10^{-14}\,\mathrm{eV}$, the mechanism becomes sensitive to dark matter density fluctuations, which suppresses the oscillatory behavior of flavor-changing probabilities as a function of neutrino propagation distance in a model-independent way, thereby ruling out this regime.

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