

Impostor Among ν s: Dark Radiation Masquerading as Self-Interacting Neutrinos

Multiple cosmological observations hint at neutrino self-interactions beyond the Standard Model, yet such interactions face severe constraints from terrestrial experiments. We resolve this tension by introducing a model where active neutrinos resonantly convert to self-interacting dark radiation after BBN but before CMB epoch. This exploits the fact that cosmological observables cannot distinguish between neutrinos and dark radiation with the same abundance and free-streaming properties. Our mechanism, based on a simple Type-I seesaw framework along with a keV-scale scalar mediator, achieves two objectives: (1) it produces strongly self-interacting dark radiation that imitates neutrino self-interactions favored by cosmological data, and (2) it depletes the active neutrino energy density, relaxing cosmological neutrino mass bounds and easing the tension with neutrino oscillation data. The model naturally evades laboratory constraints through suppression of the neutrino-mediator coupling by the squared mass ratio of active and sterile neutrinos. We demonstrate how this scenario is favored over Λ CDM by the combined Planck and DESI data, while being consistent with all other constraints. Our mechanism is testable in future laboratory probes of absolute neutrino mass and searches for sterile neutrinos.

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