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Relaxing Cosmological Neutrino Mass Bounds with Unstable Neutrinos

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At present, cosmological observations set the most stringent bound on the neutrino mass scale. Within the standard cosmological model (ΛCDM), the Planck collaboration reports $\sum m_\nu < 0.12\,\text{eV}$ at 95 % CL. This bound, taken at face value, excludes many neutrino mass models. However, unstable neutrinos, with lifetimes shorter than the age of the universe $\tau_\nu \leq t_U$, represent a particle physics avenue to relax this constraint. Motivated by this fact, we present a taxonomy of neutrino decay modes, categorizing them in terms of particle content and final decay products. Taking into account the relevant phenomenological bounds, our analysis shows that 2-body decaying neutrinos into BSM particles are a promising option to relax cosmological neutrino mass bounds.
We then build a simple extension of the type I seesaw scenario by adding one sterile state ν_4 and a Goldstone boson ϕ, in which $\nu_i \to \nu_4\,\phi$ decays can loosen the neutrino mass bounds up to $\sum m_\nu \sim 1\,\text{eV}$, without spoiling the light neutrino mass generation mechanism. Remarkably, this is possible for a large range of the right-handed neutrino masses, from the electroweak up to the GUT scale. We successfully implement this idea in the context of minimal neutrino mass models based on a $U(1)_{\mu-\tau}$ flavor symmetry, which are otherwise in tension with the current bound on $\sum m_\nu$.

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