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A cosmological bound on radiative neutrino lifetime

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Abstract. Neutrino oscillation experiments and direct bounds on absolute masses constrain neutrino mass differences to fall into the microwave energy range, for most of the allowed parameter space. As a consequence of these recent phenomenological advances, older constraints on radiative neutrino decays based on diffuse background radiations and assuming strongly hierarchical masses in the eV range are now outdated. We thus derive new bounds on the radiative neutrino lifetime using the high precision cosmic microwave background spectral data collected by the FIRAS instrument on board of COBE. The lower bound on neutrino lifetime is between a few $\times 10^{19}$ s and $\sim 5 \times 10^{20}$ s, depending on the neutrino mass ordering and on the absolute neutrino mass scale. However, due to phase space limitations, the upper bound on the effective magnetic moment mediating the decay is not better than $\sim 10^{-8}\,\mu_B$. We also comment about possible improvements of these limits, by means of recent diffuse infrared photon background data.

The standard cosmological scenario predicts the existence of a diffuse background of low-energy neutrinos, which has been often investigated in the past to probe non-standard neutrino properties. In this talk we use these cosmological neutrinos to revisit the bounds on neutrino radiative lifetime. The results of our study has been published in [1], to which we address the interested reader for further details.

The radiative decay $\nu_i \to \nu_j + \gamma$ can be thought of as arising from an *effective* interaction Lagrangian of the form

$$\mathcal{L}_{\rm int} = \frac{1}{2}\bar{\nu}^i \sigma_{\alpha\beta}(\mu_{ij} + \epsilon_{ij}\gamma_5)\nu^j F^{\alpha\beta} + \text{ h.c.} \tag{1}$$

where ν_i is the neutrino field of mass m_i, and μ_{ij} and ϵ_{ij} are the magnetic and electric transition moments usually expressed in units of the Bohr magneton μ_B. In general, μ_{ij} and ϵ_{ij} are functions of the transferred momentum squared q^2, so that constraints obtained at a different q^2 are independent. In the following, we shall quote the bounds in terms of $\kappa_{ij}^2 = |\mu_{ij}|^2 + |\epsilon_{ij}|$.

From simple kinematical considerations it follows that in a decay $\nu_i \to \nu_j + \gamma$ from a state of mass m_i into one of mass $m_j < m_i$, the photon in the rest frame of the decaying neutrinos is thus monochromatic (two-body decay), with an energy $\varepsilon_{ij} = (m_i^2 - m_j^2)/2\,m_i$. At present, the neutrino mass spectrum is constrained by the well-known values of the two squared mass splittings for the atmospheric (Δm_H^2) and the solar (Δm_L^2) neutrino problems. We take their best-fit values and 2σ ranges from [2]. The remaining unknowns in the neutrino spectrum are the absolute mass scale (equivalently, the mass of the lightest eigenstate $m_1 < 2$ eV) and the mass hierarchy. We have discussed the limits on κ_{ij}^2 as a function of m_1 for the two cases of normal and inverted mass hierarchy.

The neutrino mass splittings squared provided by oscillation experiments and present upper bounds on the neutrino mass scale constrain neutrino mass differences to fall in the microwave energy range ($E \sim 10^{-3}$ eV), in most of the allowed parameter space. So, we have derived our cosmological bounds using the high precision cosmic microwave background (CMB) data collected by the FIRAS instrument on board of COBE, which tested the blackbody nature of the spectrum at better than 1 part in 10^4 [3, 4]. In the presence of neutrino decay, the

original radiance (energy flux per unit of solid angle) of the "theoretical blackbody" at temperature T would gain an additional term. We have thus performed a chi-squared analysis, comparing the experimental measured CMB spectrum, with the theoretical predictions in presence of a radiative neutrino decay.

We obtain a lower bound on neutrino lifetime between a few $\times 10^{19}$ s and $\sim 5 \times 10^{20}$ s, depending on the neutrino mass ordering and on the absolute neutrino mass scale. Since it is customary to parameterize the neutrino electromagnetic decay via an effective operator of the kind reported in Eq. (1), it makes sense to translate the bounds on the lifetime into bounds on the parameter κ. However, due to phase space limitations, the constraints are not better than $\kappa \sim 10^{-8}\,\mu_B$, which at first sight do not appear competitive with astrophysical limits neither with most of the laboratory bounds. Nevertheless, every experimental measure and every cosmological and astrophysical constraint has its own systematic uncertainties and its own recognized or un-recognized loopholes. In this sense it is certainly important to use many different approaches to constrain fundamental neutrino properties. In particular, the cosmological bound is based on the appearance of the daughter photons, and thus is very direct. Each decay model must face with our direct bounds on τ wich are the strongest attainable with direct livetime measurements. Moreover, it also probes the energy scale $q^2 \sim 10^{-3}\,\mathrm{eV}^2$, unaccessible to both laboratory experiments and stellar arguments.

Possible improvements of our limits could be obtained using Cosmic Infrared Background (CIB) data [5]. Although these bounds appear stronger than those obtained by the FIRAS data in the same range of m_1, we emphasize that at present they should be considered only as indicative. In fact, the CIB flux have still strong uncertainties and the precise spectral shape is essentially unknown. If in the future a better measurement of the CIB flux and a more detailed knowledge of the astrophysical sources contributing to it would be available, stronger and more reliable bounds would be settled.

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