Flavor-weighted energies in the framework of composite quantum systems

A. E. Bernardini*

Departamento de Física, Universidade Federal de São Carlos,

PO Box 676, 13565-905, São Carlos, SP, Brasil

(Dated: May 19, 2011)

Abstract

We argue that the notions of operations and effects derived from the quantum measurement theory affect the predictions for the astrophysical limits of neutrino masses. Identifying flavor-*averaged* and flavor-*weighted* energies respectively with *selective* and *non-selective* quantum measurement schemes allows us to resolve all the ambiguities that eventually modify the predictions for neutrino mass values from cosmological data. Describing three neutrino generations as a composite quantum system through the generalized theory of quantum measurement provides us with the tool to set the probabilistic correlation between observable energies and neutrino flavor eigenstates. Our results agree with the quantum mechanics viewpoint that asserts that the cosmological background neutrino energy density is obtained from a coherent sum of mass eigenstate energies, for normal and inverted mass hierarchies.

PACS numbers: 03.65.Ta, 14.60.Pq, 98.80.-k

*Electronic address: alexeb@ufscar.br

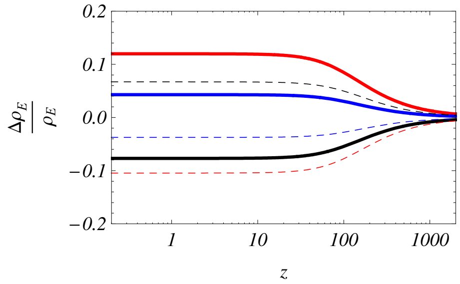

FIG. 1: Energy density deviations, $\Delta\rho_E/\rho_E$ as a function of redshift, z. Solid curves are for $m_1 \simeq 300\,k_B T_0^\nu = 50$ meV in the normal neutrino mass hierarchy and dashed curves are for $m_3 \simeq 300\,k_B T_0^\nu = 1.67$ meV in the inverted hierarchy. We have assumed that $\Delta m^2_{\mathrm{atm}} \simeq 2.4 \times 10^{-3}\,\mathrm{eV}^2$ and $\Delta m^2_{\odot} = m_1^2 - m_2^2 \simeq 7.6 \times 10^{-5}\,\mathrm{eV}^2$. We reproduce the relative difference between the *total* averaged and flavor-*weighted* energies, $\langle E_{(t)}\rangle$ and $(\sum_\alpha E^\alpha)$ (black lines), between the quantum mechanical mass averaged and the *total* averaged energies, $\bar{E}$ and $\langle E_{(t)}\rangle$ (red lines), and between the quantum mechanical mass averaged and the flavor-*weighted* energies, $\bar{E}$ and $(\sum_\alpha E^\alpha)$ (blue lines). The results are for a pure state of electronic neutrinos, i. e. $w = w_e = 1$ and the current phenomenological values for the neutrino mixing angles, i. e. $\theta_{12} \approx 0.5905$, $\theta_{23} \approx \pi/4$, and $\theta_{13} = 0$.

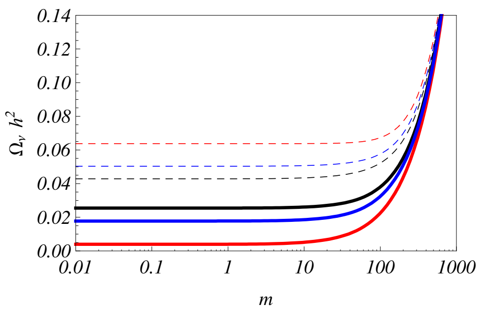

FIG. 2: Total neutrino energy density, $\Omega_\nu h$, in correspondence with the lightest mass eigenvalue m in units of $k_B T_0^\nu = 0.167$ meV. Solid curves are for the normal neutrino mass hierarchy and dashed ones for the inverted hierarchy. Again we have assumed that $\Delta m^2_{\mathrm{atm}} \simeq 2.4 \times 10^{-3}\,\mathrm{eV}^2$ and $\Delta m^2_{\odot} = m_1^2 - m_2^2 \simeq 7.6 \times 10^{-5}\,\mathrm{eV}^2$. The line colors, the input parameters and the phenomenological assumptions are in correspondence with Fig. 1.

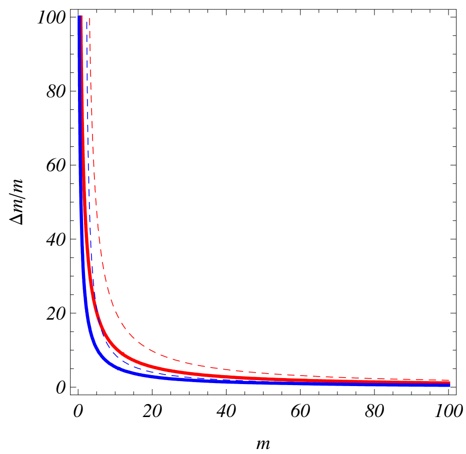

FIG. 3: Fractional error, $(\Delta m)/m$, for the neutrino mass value predictions as a function of the lightest mass eigenvalue, m, in units of $k_B T_0^\nu = 0.167$ meV. The solid line is for the normal neutrino mass hierarchy and the dashed one for the inverted hierarchy (assumptions are in correspondence with Figs. 1).