

SUM OF NEUTRINO MASSES

Revised April 1998 by K.A. Olive (University of Minnesota).

The limits on low mass ($m_\nu \lesssim 1$ MeV) neutrinos apply to m_{tot} given by

$$m_{\text{tot}} = \sum_{\nu} (g_\nu/2) m_\nu ,$$

where g_ν is the number of spin degrees of freedom for ν plus $\bar{\nu}$: $g_\nu = 4$ for neutrinos with Dirac masses; $g_\nu = 2$ for Majorana neutrinos. Stable neutrinos in this mass range make a contribution to the total energy density of the Universe which is given by

$$\rho_\nu = m_{\text{tot}} n_\nu = m_{\text{tot}} (3/11) n_\gamma ,$$

where the factor 3/11 is the ratio of (light) neutrinos to photons. Writing $\Omega_\nu = \rho_\nu/\rho_c$, where ρ_c is the critical energy density of the Universe, and using $n_\gamma = 412 \text{ cm}^{-3}$, we have

$$\Omega_\nu h^2 = m_{\text{tot}} / (94 \text{ eV}) .$$

Therefore, a limit on $\Omega_\nu h^2$ such as $\Omega_\nu h^2 < 0.25$ gives the limit

$$m_{\text{tot}} < 24 \text{ eV} .$$

The limits on high mass ($m_\nu > 1$ MeV) neutrinos apply separately to each neutrino type.