SUM OF NEUTRINO MASSES

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

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

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

where g_{ν} is the number of spin degrees of freedom for ν plus $\overline{\nu}$: $g_{\nu} = 4$ 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

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

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

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

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

$$m_{\rm tot} < 24 \, {\rm eV}$$
 .

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