SUM OF NEUTRINO MASSES

Revised September 2013 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

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

While an upper limit to the matter density of $\Omega_m h^2 < 0.12$ would constrain $m_{\rm tot} < 11$ eV, much stronger constraints are obtained from a combination of observations of the CMB, the amplitude of density fluctuations on smaller scales from the clustering of galaxies and the Lyman- α forest, baryon acoustic oscillations, and new Hubble parameter data. These combine to give an upper limit of around 0.3 eV, and may, in the near future, be able to provide a lower bound on the sum of the neutrino masses.