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Massive Free-Streaming Neutrinos and Rise of N_ν at Recombination[1] J. BIRRELL, Program in Applied Mathematics, The University of Arizona, C. YANG, P. CHEN[2], Leung Center for Cosmology and Particle Astrophysics(LeCosPA),Department of Physics and Graduate Institute of Astrophysics, National Taiwan University, J. RAFELSKI, Department of Physics, The University of Arizona — We present the Einstein-Vlasov solution for the momentum distribution of the relic free-streaming neutrinos. We show that it is possible to explain a rise in the effective number of neutrinos (N_ν) from those present at the end of big bang nucleosynthesis (BBN) $N_\nu(T_{BBN}) = 3.046$ (theoretical) or $N_\nu(T_{BBN}) = 3.71^{+0.47}_{-0.45}$ (measured) towards $N_\nu(T_r) = 4.34^{+.086}_{-0.88}$ (measured) at the time of electron-ion recombination (r). The effect is due to the ambient temperature, $T_r = 0.253$ eV, being near to the neutrino mass. If a thermal equilibrium distribution is inadvertently used, one instead expects a decrease in N_ν between BBN and recombination. We present explicit values for m_ν needed to account for the observed increase in N_ν. The smaller the number of dominant mass neutrinos and the larger the change in N_ν needed between BBN and recombination, the larger is the value of m_ν we find. If no new mechanism is discovered to increase the theoretical value $N_\nu(T_{BBN}) = 3.046$ then the relic neutrinos are predicted to have $0.528 \leq \sum m_{\nu_i} \leq 2.26$ eV and will contribute between 5% and 22% of the matter inventory in the Universe.

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