3C74: TOPICS IN MODERN COSMOLOGY

Problem Sheet 3: Answers to be handed in by 10 March 2005

Question 1 [Total 15 marks]

Briefly explain why we know that the Big Bang was hot. [4]

Show how temperature scales with time for a matter-dominated universe with $k = 0$ and $\Lambda = 0$. [2]

Hence calculate the age of the universe at decoupling if the temperature of the microwave background is 2.725 K today at an age of 14 Gyr. [Assume that the temperature of the radiation at decoupling was 3000 K.] [4]

At what age was the temperature of the microwave background twice its current value? What redshift does this correspond to? [5]

Question 2 [Total 15 marks]

Radiation in the present universe, corresponding to a thermal background at 2.725 K, contributes an energy density corresponding to a density parameter of $\Omega_{\rm rad} = 2.47 \times 10^{-5} h^{-2}$. The typical energy of a photon in a thermal distribution is given by $3k_BT$ (where $k_B = 8.6 \times 10^{-5}$ eV K^{-1}). Assuming that the number of neutrinos equals the number of photons, calculate the mass-energy (in eV) that these neutrinos would need to contribute a critical density. [Assume that the thermal energy of the neutrinos is negligible compared to their mass-energy.] [10]

Briefly discuss whether the neutrino can be considered a serious dark matter candidate by comparing your derived mass-energy with recent experimental values for the neutrino mass. [5]