Introduction to Cosmology

HW5

to be handed on Friday noon, Nov. 27, 2014

Problem 1: Massive neutrinos (taken from "An Introduction to the Science of Cosmology", Derek Raine, E. G. Thomas, p162)

Massive neutrinos which are relativistic at the time that the weak interactions freeze out will have a number density at the present time equal to that of massless neutrinos,

$$n_{\nu\bar{\nu}} = \frac{3}{11}n_\gamma, \tag{1}$$

and will contribute a mass density $\rho_{\nu\bar{\nu}} = m_{\nu\bar{\nu}}n_{\nu\bar{\nu}}$ (here $n_{\nu\bar{\nu}}$ is the number density for just one neutrino family). If one neutrino family contributes the critical density, compute the mass of this neutrino type. Use $H_0 = 67.8$ km s^{-1}Mpc^{-1} (Planck 2013) and $T_{CMB} = 2.725$K. (The masses of the neutrinos are not known, but non-zero values of less than 1 eV seem to be suggested by present evidence, insufficient to provide the critical density.)

Problem 2: Big Bang Nucleosynthesis (BBN)

According to the Big Bang theory, the universe expended from a very high density and high temperature state. During the first 3 minutes, the universe experienced a series of rapid and important changes. Nucleosynthesis took place within that era and produced the light elements we observe in the universe. The cosmological nucleosynthesis is first calculated by Ralph Alpher, George Gamow, and Robert Herman in the late 1940s. The BBN theory has been very successful in predicting the abundance of light elements in the universe and provides us an important way to test the standard Big Bang cosmological model and other modified gravity theories.

Write a short essay about your understanding about the Big Bang nucleosynthesis. It is not necessary to write something with full knowledge of particle physics. Just write something about what you have read in the books and literatures, or learned from the lecture. Try to focus on one specific problem you are interested in, for example "why the visible matter of the universe is composed of roughly 26% Helium and 74% Hydrogen", "why there are more baryons than antibaryons in the current universe", etc. You can work in group of 2 or 3 persons. Each group is encouraged to find a representative to present their essay next Monday.