Homework #3

Due: Friday, March 1, 2019

1. Helium abundance. [10 points; 5 points each]
Using the arguments discussed in class, estimate how much the primordial helium abundance Y would change if:

- There were a 4th species of neutrino;
- The baryon abundance η were doubled.

2. Short problems. [20 points; 5 points each]

(a) *Practice with magnitudes*: Suppose someone were a distance D from Earth, and shone a laser pointer directly at you (the observer). To an order of magnitude, what is the maximum distance D at which your eye could see the laser? What if we used the Sloan Digital Sky Survey (which scanned much of the Northern Hemisphere sky to a depth of 22nd magnitude) instead of your eye?

(b) *Densities*: The Sun orbits the Milky Way at about 220 km/s, at a distance of about 8.6 kpc from the center. What is the approximate mass interior to the Sun's orbit, and the mean density (in kg/m^3) of that region? [For the sake of this problem, you can neglect the fact that the Milky Way's mass distribution is not spherical.] Compare this to the cosmological mean density of matter; what is the ratio $\rho_{\text{Milky Way}}/\bar{\rho}$?

(c) *Intergalactic gas*: We believe that the baryonic matter in the Universe today is mostly ionized intergalactic hydrogen. Under this assumption, and the values given in the notes for $\Omega_b h^2$, compute the number density n_e of intergalactic electrons. What is the plasma frequency ν_p that this corresponds to, and what is the physical interpretation of this number?

(d) *Scattering of intergalactic photons*: The electron density obtained in (c) implies some probability per unit path length dP/dx of scattering due to Thomson scattering. What is this probability in units of Gpc^{-1}? Thomson scattering will make distant objects appear dimmer. Do you think this is (i) a major effect on $D_L(z)$ inferred from Type Ia supernovae; (ii) a small effect that we might have to correct with future telescopes that will observe 1–2 orders of magnitude more supernovae than we are currently using; or (iii) completely negligible for any conceivable experiment?