PHYC 581/480, HW 3

Due: 12-Oct-16

Please don't use answers from books, papers, etc. You can look up integrals, of course, and you can collaborate but at the end it should be your own work.

1. A galaxy has a redshift z=0.12. How far away is it? (5 pts)

2.
a) A feature in the spectrum of a galaxy at 588.0 nm is known to have rest wavelength 485.8 nm. How far away is the galaxy? (5 pts)

b) If, as well as the Hubble flow, galaxies have random motions of about 400 km/s, how precise is the distance you calculated? (5 pts)

3. **Derivations** involving the Cosmic Microwave Background (CMB) radiation, which has one of the most perfect Planck Blackbody spectrum found in nature. Define the BB's energy density per volume in the wavelength range, λ to $\lambda+d\lambda$ to be given by

$du = S_\lambda \, d\lambda$, where:

Energy per unit volume per unit wavelength $$S_\lambda = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}$$

a) Using this expression for the spectral energy density of blackbody radiation (function of λ, T), *derive* the formula for its total energy density, *u*. (10 pts)

b) How many times more photons are present at room temperature than in the cold universe (i.e., at the average temperature of the universe)? (5 pts)

c) Estimate the scale factor corresponding to the time when the universe was at room temperature. (5 pts)

d) How many CMB photons are there today in 1 cm^3 ? Hint: define dn as the number of CMB photons per unit volume in the wavelength range, λ to $\lambda+d\lambda$ and go from there (5 pts)

Redshift

1.
a) (10 pts) A hypothesis once used to explain the Hubble relation is the "tired light hypothesis". It states that the universe is not expanding, but that photons simply lose

energy as they move through space. Naively, the energy loss per unit distance would then be

$$dE/dr = -KE$$

where K is a constant. Show that this hypothesis gives a distance-redshift relation that is linear in the limit of very small z. Using H_0 = 70 km/s/Mpc determine the value of K.

b) Another hypothesis is that redshift could be caused by Compton scattering. Recall the equation for the increase in wavelength due to the Compton effect, whereby photons scatter off electrons:

$$\Delta\lambda = (h/mc)(1 - \cos\theta) = 0{:}0024\ (1 - \cos\theta)\ \text{nm};$$

(i) How many scatterings would be required for a photon of rest wavelegth 500 nm to be seen at 600 nm? (Assume $\theta = 90^{o}$ on average.) (5 pts)
(ii) What electron density would be required to produce this? (Use the Thomson cross-section $\sigma_e = 6{:}65 \times 10^{-29} m^2$.) (5 pts)
(iii) What mass density does this correspond to (assume a charge neutral universe)? (5 pts)
(iv) Compare your answer in (iii) with the critical density and describe what type of universe would this be? (5 pts)