PHYSICS 162 Prof: Kim Griest

HOMEWORK 1

Due: Monday April 4, 2016

1. Suppose you are standing in the middle of a deep forest. In every direction you see trees. If you shot a gun in a random direction, on average how far would the bullet go before hitting a tree? To calculate assume that trees all have a radius of 0.2m, and the density of trees is 1 tree per every 50 square meter.

2. Now do the same problem as above for the night sky. Assume an infinite Universe filled with stars whose radii are $R_* = 4 \times 10^8$ meter and whose density is $n_* = 2 \times 10^{-59}$ stars/meter^3. Looking out in a random direction how far can you see on average before seeing a star?

3. Finally, do the same problem again using galaxies and units of parsecs (pc) and Megaparsecs (Mpc). Suppose galaxies are spherical with a radius of 6000 pc, and have a density of 1 per Mpc^3. How far can you see on average before seeing a galaxy?

4a. Suppose a galaxy is 90 Mpc away from us. How fast it moving away from us due to the expansion of the Universe? (give answer in km/s); you may assume a Hubble constant of $H_0 = 70$km/s/Mpc.
b. Next suppose the redshift of a different galaxy is $z = 0.015$. How fast is this galaxy moving away from us (give answer in km/sec).
c. Using the Hubble law with $H_0 = 70$ km/s/Mpc, how far away is this galaxy? (give answer in Mpc).

5. The approximation used in the Hubble law breaks down at larger redshift. Solve the equation

$$z = \sqrt{\frac{1 + v/c}{1 - v/c}} - 1$$

for v in terms of z and plug the result into Hubble's linear relation between velocity and distance to find a more accurate formula for distance vs redshift. [This formula also breaks down for $z > 2$ because we need general relativity, not just special relativity.]

6. Suppose the redshift of a galaxy is is $z = 1.5$. Now how fast is the galaxy moving away? How far away is it? Be sure to use the formula you derived in problem 5, since the approximation used in problem 4 is not very accurate at this redshift.