Astronomy 120 "Galaxies and the Universe" Summer 2018
Homework Assignment #10 LAST ONE!! DUE: Thursday June 28, 2018

HOMEWORK PROBLEMS:

1. (44 points)
You have discovered a protogalaxy at z=12 on the Keck telescope! (Yale buys time on the Keck telescopes, which are twin 10-meter optical telescopes located on Mauna Kea in Hawaii).

a.) The light from this protogalaxy contains the Lyman α (Lyα) emission line of Hydrogen, which originates when the electron falls from the 2nd to the 1st orbital energy level. The rest wavelength of the Lyα line is 0.1216 microns. In what part of the electromagnetic spectrum is this? Can an optical-infrared telescope on earth's surface (like the Keck telescope) observe the Lyα line of a nearby galaxy at z-0, if the telescope can observe from 2.2-0.3 microns?

b.) Calculate the wavelength that we would observe the Lyα line from the protogalaxy at z=12. Can the Keck telescope observe its Lyα line?

c.) What was the average density of matter at the time corresponding to z=12? Assume that in today's universe, the density of matter is 2.4×10^{-27} kg m^{-3}.

d.) What was the temperature of the cosmic background radiation at the time corresponding to z=12?

e.) What was the equivalent mass density of radiation at the time corresponding to z=12?

f.) At this time in the remote past, was the universe matter-dominated or radiation-dominated? Explain.

2. (24 points)

a.) What was the peak wavelength in the spectrum of the Cosmic Background radiation at a time in the universe corresponding to a redshift z=1100, at the era of recombination (or decoupling)?

b.) Calculate the wavelength of a photon that has just enough energy to ionize a Hydrogen atom, if this energy is 13.7eV.

c.) Given that these are different, why is the Cosmic Background radiation at z=1100 able to ionize all the Hydrogen?
[HINT! Do all the photons have the same energy?]

3. (32 points)
a.) What is the peak wavelength of the cosmic background radiation for an observer at rest with respect to the cosmic background radiation? Calculate this (to 4 significant figures) from the present temperature of the cosmic background radiation and Wien's Law.

b.) Suppose you live in a galaxy which is orbiting at high speeds through a cluster, and is therefore moving at speeds of 1777 km/s with respect to the cosmic background radiation. [Ignore the effects of the rotation of the galaxy.] What is the peak wavelength of the cosmic background radiation measured from a point on the sky that is in the direction of motion?

c.) For the observer moving at 1777 km/s with respect to the cosmic background radiation, what is the peak wavelength of the cosmic background radiation measured from a point on the sky in the direction which is opposite that of the direction of motion?

d.) For the observer moving at 1777 km/s with respect to the cosmic background radiation, what is the peak wavelength of the cosmic background radiation, in a direction which is 90 degrees (at right angles) from the direction of motion?