Astron 299/L&S 295 Problem Set 9

Given: Nov 30. Due: Wednesday, Dec 7 at the beginning of class

Homework Policy: You can consult class notes and books. Always try to solve the problems yourself; if you cannot make progress after some effort, you can discuss with your classmates or ask the instructor. However, you cannot copy other's work: what you turn in must be your own. Make sure you are clear about the process you use to solve the problems: partial credit will be awarded.
Reading: Kutner Chapter 17, 18, 19

Problem 1 Redshift surveys and K-corrections

This problem explores some complications associated with selecting galaxies for redshift surveys.

Because redshift increases the wavelength of light propagating from distant galaxies,

$$\lambda_{\rm obs} = (1+z)\lambda_{\rm rest}, \tag{1}$$

when we measure the light from a distant galaxy we are actually measuring light emitted at bluer wavelengths. This is important, because galaxies don't emit the same amount of light at all wavelengths.

The following is a list of the wavelength centers and ranges of the five filters used in the Sloan Digital Sky Survey (SDSS):

Filter	$\lambda_{\rm center}$ (Å)	FWHM (Å)
u	3585	556
g	4858	1297
r	6290	1358
i	7706	1547
z	9222	1530

a. Suppose we select galaxies using their magnitudes in the r filter. At what approximate redshift would a galaxy be if our r-band observations are actually detecting light which the galaxy emitted in the center of the g filter? At what redshift would the galaxy be if we are detecting light which the galaxy emitted in the center of the u filter?

b. Astronomers routinely detect galaxies at redshifts of $z \sim 2$. At this redshift, what wavelength of light would we need to detect in order to measure the i-band light output of the galaxy? What wavelength of light would we need to detect in order to measure the Hα emission line from one of these galaxies? Would these measurements require observations in the optical, infrared or submillimeter part of the spectrum?

c. Briefly discuss how this effect might change how we should interpret observations of galaxies at different redshifts (e.g. star formation rates, relative brightnesses, morphologies).

d. Assuming no change in the frequency of different types of galaxies with redshift, would we be more likely to detect a higher fraction of spiral galaxies at low or at high redshifts?

Problem 2 Quasar number densities and lifetimes

From deep galaxy counts, it is estimated that there are about 40 billion galaxies in the observable universe (not including probable multitudes of dwarf galaxies too faint to observe). Assuming that the mean age of these galaxies is 10 Gyr, and that each one goes through an AGN episode once, with a mean duration of 10^8 yr, estimate the projected surface density of quasars on the sky (the number per square degree).

Problem 3 Matter and Energy Density in the Universe

Suppose that all of the baryonic (non-dark) matter in the universe were converted into energy in the form of blackbody radiation. Take the average density of matter to be $\rho = 4.17 \times 10^{-28}$ kg m^{-3}; this is the baryonic matter density found by the Wilkinson Microwave Anisotropy Probe (WMAP) studies of the cosmic microwave background radiation.

a. What would the temperature of the universe be in this situation? (Hint: Consider the energy density of blackbody radiation.)

b. At what wavelength would the blackbody spectrum peak? Would we be able to see the sky glow due to this radiation?

Problem 4 Baryonic dark matter

Suppose that the universe were full of cats, each of mass $m_{\rm cat} = 4$ kg and radius $r_{\rm cat} = 0.3$ m.

a. If the cats were distributed uniformly throughout the universe, what number density of cats would be required to make the density equal to the current critical density? (Assume nonrelativistic cats.)

b. Given this density of cats, how far on average would you be able to see in any direction before your line of sight intersected a cat?

c. In fact, we can see galaxies at a distance $d \approx c/H_0 \approx 4300$ Mpc. Does the transparency of the universe on this length scale place useful limits on the number density of intergalactic cats?

Problem 5 Order of Magnitude: 747s

(remember to estimate: don't just look up the final answer)

a. What is the fuel consumption, in passengermiles per gallon, of a 747 jumbo jet?

b. What is the data rate (bits/s) of a 747 filled with DVDs crossing the Atlantic?

c. Is it cheaper to send a 747 full of DVDs across the Atlantic or to send the same amount of data using your cellphone as a modem? How about using SMS?