ASTRONOMY 020

Problem Set #22
Due: April 2, 2004

1. For very distant galaxies with high redshifts, we must be careful to use the relativistic Doppler shift equation (24-1) in your text and the modified Hubble Law given by equation (22-3d). Use these to calculate the recession velocity and the distance to a quasar that is observed to have a redshift $z = 3.5$.

2. You observe a galaxy cluster with 100 galaxies of mean mass $10^{11} M_\odot$, cluster radius 1 Mpc, and rms velocity 1000 km/s of the individual galaxies. What mass would you estimate the cluster to have based on its being in gravitational equilibrium? Compare this estimate with the optically determined mass $M = 100 \times 10^{11} M_\odot = 10^{13} M_\odot$. What do you conclude?

3. Estimate the rate at which energy would be released from the infall of 1 $M_\odot$ of material per year onto a $10^8 M_\odot$ black hole at the center of an AGN or quasar. Assume complete conversion of gravitational potential energy into radiation.

Practice problems:

1. At what redshifts will the Hydrogen Balmer line be shifted out of the visible and into the infrared ($\lambda > 720$ nm) part of the spectrum?
   Answer: $z > 0.097$.

2. Most of the nearest galaxies do not obey Hubble's Law. Explain why.
   Answer: Most nearby galaxies have "random" motions which overwhelm the velocity attributable to the expansion fo the universe. These motions are often also due to systematic gravitational motions of galaxies within clusters, or the motions of the clusters themselves within a supercluster. Only galaxies at sufficient distances d have expansion velocity $v = H_0 d$ large enough to overwhelm the local random velocities.

3. Zeilik and Gregory, Chapter 22, problem 3.
   Answers: (a) $d \approx 250$ Mpc, (b) $d \approx 125$ Mpc.

4. What is the maximum size of a region of emission that shows variability on the timescale of 1 day?
   Answer: 174 AU.