Ay21 Winter 2010 Problem Set #5

Due 3/11/10 by 5pm, in Swarnima's mailbox in 249 Cahill. N.B.- THERE WILL BE NO EXTENSIONS for this set aside from those approved by the Dean, given the end of the term frenzy.

(1) The giant elliptical galaxy M87 lies near the dynamical center of the Virgo Cluster, at a distance of $\simeq 20$ Mpc from us. M87 has a super-massive black hole of mass $\simeq 10^9$ $M_\odot$ at its center. Estimate the angular resolution required to directly observe the effects of the black hole on the velocity dispersion as measured by us (i.e., out to what physical distance would the black hole's contribution to the measured velocity dispersion be significant compared to average M87 velocity dispersion of $\simeq 300$ km s^{-1}, and what angle does that physical distance subtend as seen from earth?).

(2) Suppose we live in a standard Friedmann Universe, and we are conducting a survey of absorption line systems containing metals, as a function of redshift, using background QSOs. . If the properties of the galaxies remain fixed (i.e., their physical gas cross-sections are a constant), and the co–moving space density of the galaxies remains constant, show that the expected dependency of dN/dz, the number of "interceptions" per unit redshift range, is

$$dN/dz = N_0(1+z)(1+2q_0z)^{-1/2},$$

where N_0 is a constant. A typical quasar at $z = 2$ has 5 independent (metallic line) redshift systems in its spectrum. Each of these is believed to be associated with a galaxy lying along the line of sight. From this, estimate the typical gaseous size of galaxies. Is it reasonable to associate the absorption with normal galaxies?

(3) A newly discovered gravitational lens candidate has 2 images of a $z = 2$ quasar separated by $1''$ on the sky. The redshift of the lensing galaxy has been determined to be $z = 1$, and it appears to be located midway between the 2 images. Show that the angle through which this galaxy deflects these 2 observed rays is $\alpha = 1''.6$. You may assume that $\Omega_m = 1$ (Einstein-de Sitter).