General Astronomy - Spring 2007
Home work #11 - Due April 25

**1.** Calculate the distance to a quasar which is receding at a velocity of $0.05c$.

Use the Hubble expansion law, $v = Hd$, with $H = 71\,\mathrm{km/s/Mpc}$. Solve for $d = v/H = (0.05 * 300000\,\mathrm{km/s})/(71\,\mathrm{km/s/Mpc}) = 210\,\mathrm{Mpc}$.

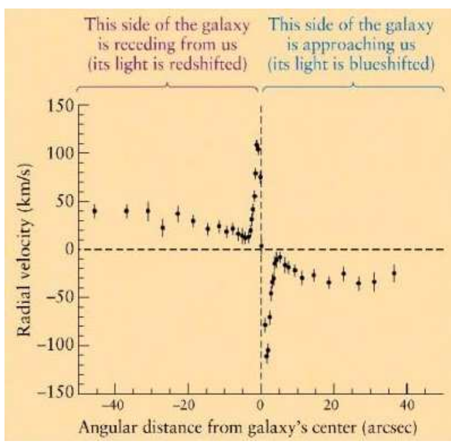
**2.** The brightness of a quasar varies by a factor of 10 over 2 days. What does this tell us about the quasar?

The time scale of the variations indicates that the physical size of the region producing the light seen from the quasar must be 2 light-days or smaller.

**3.** Name three types of active galactic nuclei and the approximate angle (relative to the normal to the accretion disk) at which we view them.

1) Blazar - viewed along jet axis, 2) Radio loud quasar - viewed around 15 to 30 degrees from the jet axis, 3) Radio galaxy - viewed at an angle roughly perpendicular the jet axis.

**4.** Estimate the mass of the black hole at the center of the galaxy with the rotation curve below. Assume the distance is 770,000 parsecs.




We want to use the formula $v = \sqrt{GM(r)/r}$ which relates the mass enclosed inside a star's orbit, $M(r)$, at a distance, $r$, from the center of mass to the orbital speed, $v$, of the star.

The best points for estimating the black hole mass are those closest to the center of the galaxy, otherwise we would be including mass other than the central black hole. First, read off a data point. I get a radial velocity of $v = 70\,\mathrm{km/s} = 7.0 \times 10^4\,\mathrm{m/s}$ for a point which is about $\theta = 0.5''$ from the center. We have the velocity directly. We need to convert the angular distance from the center to a physical distance from the center using the small angle formula, $r = D\theta/206265$ for $\theta$ in arcseconds. So, $(r = 770000\,\mathrm{pc})(0.5/206265) = 1.9\,\mathrm{pc} = 5.8 \times 10^{16}\,\mathrm{m}$.

Solve the equation above for $M = rv^2/G = (5.8 \times 10^{16}\,\mathrm{m})(7.0 \times 10^4\,\mathrm{m/s})^2/(6.67 \times 10^{-11}\, m^3\, kg^{-1}\, s^{-2}) = 4.3 \times 10^{36}\,\mathrm{kg} = 2.1 \times 10^6 M_\odot$. This is a reasonable estimate.