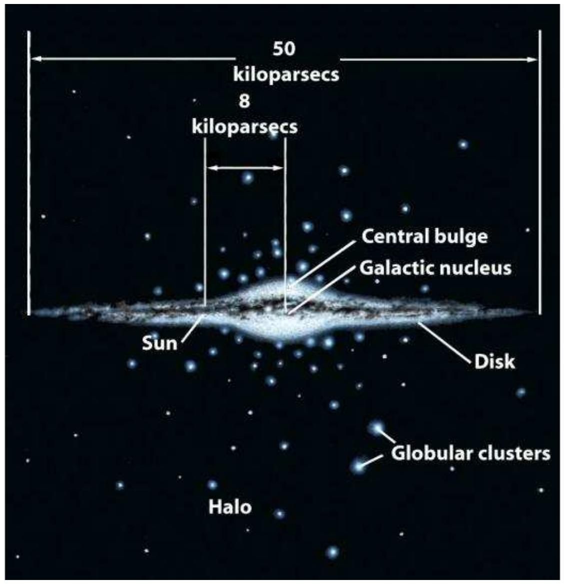
General Astronomy - Spring 2007
Home work #7 - Due March 21

1. Draw a sketch of the Milky Way including the center, the disk, the halo, and the bulge. Mark the location of the Sun and its approximate distance from the center.



2. List three types of objects which are mainly found in spiral arms.

Molecular clouds, O and B stars, supernovae.

3. Imagine that the orbital period of the Sun around the center of the galaxy is found to be 1 billion years, instead of the currently accepted 230 million years. Estimate the mass of the Milky Way inside the orbit of the Sun using this longer orbital period.

Use the equation

$$M \approx \frac{a^3}{P^2}$$

where M is the mass in solar masses, a is the orbital radius in AU, and P is the orbital period in Earth years. From the lecture notes, we know that the distance from the Sun to the center of the Milky Way is $a = 1.8 \times 10^9$ AU. Therefore, with the revised orbital period, we have

$$M \approx \frac{(1.8 \times 10^9)^3}{(1 \times 10^9)^2} = 5.8 \times 10^9$$

and the mass of the Milky inside the orbit of the Sun would be $5.8 \times 10^9 M_\odot$.

4. A Cepheid is found to have the same oscillation period, but is 800,000 times dimmer than a Cepheid at a known distance of 1 kpc. How far away is the dimmer Cepheid?

For Cepheids, the luminosity depends on the oscillation period, so if two Cepheids have the same period, then they have the same luminosity. Therefore, using the flux equation, the ratio of the observed fluxes is equal to the square of the opposite ratio of the distances,

$$\frac{\text{Flux}_\text{A}}{\text{Flux}_\text{B}} = \left(\frac{\text{Distance}_\text{B}}{\text{Distance}_\text{A}}\right)^2$$

We call the nearby star A and the distant star B. Solving for Distance_B, we find

$$\text{Distance}_\text{B} = \text{Distance}_\text{A}\sqrt{\frac{\text{Flux}_\text{A}}{\text{Flux}_\text{B}}} = (1000\,\text{pc})\sqrt{\frac{800,000}{1}} = 900,000\,\text{pc}$$

5. The central region of the spiral galaxy NGC 4395 (distance 4.3 Mpc) has a massive black hole. Gas is seen orbiting around the central object with a velocity of 30 km/s at an angular distance of 0.15 arcsec from the central object. Estimate the mass of the black hole.

We want to use the equation

$$M \approx \frac{a^3}{P^2}$$

where M is the mass in solar masses, a is the orbital radius in AU, and P is the orbital period in Earth years. We need to figure out the orbital radius and period.

Think of the gas as a ring. We see the ring extending out to an angular distance of 0.15 arcsec from the central object. The ring (and the galaxy) are at a distance of 4.3 Mpc. Using the small angle formula, the physical radius of the ring is then $0.15 \times 4.3 \times 10^6\,\text{pc}/206265 = 3.125\,\text{pc} = 9.64 \times 10^{16}\,\text{m}$. We need to convert this to AU, or $a = 6.45 \times 10^5\,\text{AU}$.

Now for the orbital period. The gas travels in a circular orbit, i.e. the ring mentioned above. The time it takes the gas to complete one orbit is the circumference of the ring divided by the velocity, or $P = 2\pi r/v = (2\pi \times 9.64 \times 10^{16}\,\text{m})/(30 \times 10^3\,\text{m/s}) = 2.02 \times 10^{13}\,\text{s}$. We need to convert this to years, $P = 6.40 \times 10^5$ years.

We are finally ready to use our original formula.

$$M \approx \frac{a^3}{P^2} = \frac{(6.45 \times 10^5)^3}{(6.40 \times^5)^2} = 6.5 \times 10^5$$

So the central black hole has a mass of 6.5×10^5 solar masses.