

# ASTR121

## Homework 5 – Solutions

### Ch. 26, Prob. 32.

The distance modulus equation :  $m - M = 5 \log (d) - 5$ .

a.  $m - M = 29.2 = 5 \log (d) - 5 \Rightarrow d = 6.9 \times 10^6 \text{ pc} = 6.9 \text{ Mpc}$

b.  $m - M = 29.6 = 5 \log (d) - 5 \Rightarrow d = 8.3 \times 10^6 \text{ pc} = 8.3 \text{ Mpc}$

c.  $\Delta d = 8.3 - 6.9 = 1.4 \text{ Mpc} = 1.9 d_{M31}$

### Ch. 26, Prob. 36.

$$V_{\text{rec}} = 7500 \text{ km/s} = H_0 d$$

$$H_0 = \frac{V_{\text{rec}}}{d} = \frac{7500 \text{ km/s}}{140 \text{ Mpc}} = 53 \text{ km/s/Mpc}$$

### Ch. 26, Prob. 38.

Given :  $z = 5.34$ .

a. Since  $z$  is much greater than 1, we will need to use the relativistic form of the velocity equation to calculate  $V_{\text{rec}}$ . From text :

$$\frac{V_{\text{rec}}}{c} = \frac{(z+1)^2 - 1}{(z+1)^2 + 1} = \frac{(5.34+1)^2 - 1}{(5.34+1)^2 + 1} = 0.95. \text{ Therefore, } V_{\text{rec}} = 0.95 c = 2.9 \times 10^5 \text{ km/s}$$

b. If we had used the non-relativistic form of the equation, we would've found the velocity to be  $V_{\text{rec}} = cz = 5.34 c = 1.6 \times 10^6$ . The error is very large, as we would've found that the velocity of the galaxy exceeds the speed of light!

c.  $d = \frac{V_{\text{rec}}}{H_0} = \frac{2.9 \times 10^5 \text{ km/s}}{71 \text{ km/s/Mpc}} = 4084 \text{ Mpc} = 1.3 \times 10^{10} \text{ lightyears}$

### Ch. 26, Prob. 39.

Given :  $M_{\text{gas}} = 10^{13} M_{\text{Sun}}$ ; spherical volume with  $R = 3 \text{ Mpc}$

a. We know that the hydrogen atom weighs  $1.67 \times 10^{-27} \text{ kg}$ . Knowing the mass of the cluster gas, we can find the total number of hydrogen atoms in the gas :

$$N = \frac{M_{\text{gas}}}{M_{\text{H}}} = \frac{(10^{13}) (2 \times 10^{30} \text{ kg})}{1.67 \times 10^{-27} \text{ kg}} = 1.2 \times 10^{70} \text{ hydrogen atoms}$$

b. We first need to find the volume and then find the number density of the cluster :

$$n = \frac{N}{V} = \frac{N}{\frac{4}{3} \pi R^3} = \frac{1.2 \times 10^{70}}{\frac{4}{3} \pi (3 \times 10^6 \times 3.086 \times 10^{18})^3} = 3.6 \times 10^{-6} \text{ H atoms cm}^{-3}$$

c. From the above value, we find that the number density of the Coma cluster IGM is about  $10^{25}$  times less dense than our atmosphere,  $10^8$  times less than the ISM of the Milky Way, and  $10^{11}$  times less dense than the corona of the Sun.

### Ch. 27, Prob. 28.

For this problem, we will assume  $H_0 = 71 \text{ km/s/Mpc}$ . According to Table 27.1 of the text, a redshift of 0.75 gives a distance of  $6.57 \times 10^9$  lightyears. This implies that it takes light  $6.57 \times 10^9$  years to travel from that quasar to us. If light could get here instantaneously, we would probably see the quasar as a galaxy that is not very active. The central engine of the quasar will most likely have consumed most, if not all, of its fuel. This means that the accretion rate of the central black hole is low, which reduces the amount of synchrotron radiation it can produce. We would see a radio-quiet quasar or something that's similar to the nearby Seyfert galaxies.

**Ch. 27, Prob. 36.**

Given :  $M = 3.7 \times 10^6 M_{\text{Sun}}$

a. The maximum luminosity an AGN can produce is the Eddington limit. Given the mass :

$$L_{\text{Edd}} = 30,000 \left( \frac{M}{M_{\text{Sun}}} \right) L_{\text{Sun}} = 30,000 (3.7 \times 10^6) L_{\text{Sun}} = 1.1 \times 10^{11} L_{\text{Sun}} = 4.4 L_{\text{Milky Way}}$$

b. If the black hole at the center of the Milky Way were to be producing this large amount of luminosity, it must be accreting mass and is an AGN. From our viewpoint, we might have to look through a dusty torus of material to see the central black hole. Our view to the center will most likely be obscured. The spectral of the central engine would have many narrow lines similar to a Seyfert 2 galaxy. The center would be very bright in X - Ray from the heat produced from the accretion. We might also see jets emanating from the center toward the north and south Galactic poles. We may also see radio lobes above the north and south Galactic poles due to the jets of material hitting the intergalactic medium.

**Ch. 27, Prob. 37.**

$$M = \frac{Rv^2}{G} = \frac{(16 \times 3.086 \times 10^{16}) (2 \times 10^5)^2}{6.67 \times 10^{-11}} = 3 \times 10^{38} \text{ kg} = 1.5 \times 10^8 M_{\text{Sun}}$$

**Ch. 27, Prob. 38.**

$$R_{\text{Sch}} = \frac{2GM}{c^2} = \frac{2G(10^9 M_{\text{Sun}})}{c^2} = \frac{2(6.67 \times 10^{-11})(10^9)(1.989 \times 10^{30})}{(3 \times 10^8)^2} = 3 \times 10^{12} \text{ m}$$

$$= 20 \text{ AU} = 0.5 \text{ Sun - Pluto Distance}$$

**Extra Credit :**

Given :  $z = 1$ , fluctuations on timescale of 1 week (168 hours)

a. From Table 27.1, a redshift of 1 gives  $V_{\text{rec}} = 0.6c = 1.8 \times 10^5 \text{ km/s}$

b.  $t = \frac{t_0}{\sqrt{1 - (\frac{v}{c})^2}}$ . Since we're trying to find the time in the moving frame, we want to solve

for the proper time,  $t_0$ . Therefore :  $t_0 = t \sqrt{1 - (\frac{v}{c})^2} = (168 \text{ hr}) \sqrt{1 - (0.6)^2} = 134.4 \text{ hours}$

c. In the frame of the galaxy, the fluctuations vary on a timescale of 134.4 hours. This means that the emitting region is 134.4 light - hours across (see Figure 27 - 17). So in terms of AU we find :

$$d = 134.4 \text{ light - hour} = (134.4 \text{ hours}) (3 \times 10^8 \text{ m/s}) (3600 \text{ s/hour}) = 1.4 \times 10^{14} \text{ m} = 970 \text{ AU}$$