Physics 167 – Astronomy

Homework #9

Chapter 16

1. Estimate how many galaxies are pictured in Figure 16.1 in the text. Explain the method you used to arrive at this estimate. This picture shows about $1/3.0 \times 10^7$ of the sky, so multiply your estimate by 3.0×10^7 to obtain an estimate of how many galaxies like these fill the entire sky.

2. Scientists using the Hubble Space Telescope have observed Cepheids in the galaxy M100. Here are the actual data for three Cepheids in M100:

- Cepheid 1: luminosity = 3.9×10^{30} watts, brightness 9.3×10^{-19} watts/m^2
- Cepheid 2: luminosity = 1.2×10^{30} watts, brightness 3.8×10^{-19} watts/m^2
- Cepheid 3: luminosity = 2.5×10^{30} watts, brightness 8.7×10^{-19} watts/m^2

Compute the distance to M100 with data from each of the three Cepheids. Do all three distance computations agree? Based on your results, estimate the uncertainty in the distance you have found.

3. Imagine that you have obtained spectra for several galaxies and have measured the redshift of each galaxy to determine its speed away from us. Here are your results:

- Galaxy 1: Speed away from us is 15,000 km/s.
- Galaxy 2: Speed away from us is 20,000 km/s.
- Galaxy 3: Speed away from us is 25,000 km/s.

Estimate the distance to each galaxy from Hubble's law. Assume that $H_0 = 22$ km/(s·Mly). (Note: A Mly is a megalight-year, so 1 Mly = 10^6 ly.)

4. Suppose you fell into an accretion disk that swept you into a supermassive black hole. On your way down, the disk radiates 10% of your mass-energy, $E = mc^2$.
a. If your mass were 65 kg, calculate how much radiative energy will be produced by the accretion disk as a result of your fall into the black hole.
b. Calculate approximately how long a 100-watt light bulb would have to burn to radiate this same amount of energy. Express your answer in years.

Chapter 17

5. The total annual U.S. power consumption is about 2×10^{20} joules. Suppose you could supply that energy by combining pure matter with pure antimatter. Estimate the total mass of matter-antimatter fuel you would need to supply the United States with energy for 1 year. How does that mass compare with the amount of matter in your car's gas tank? (A gallon of gas has a mass of about 4 kilograms.)

6. What will the temperature of the cosmic microwave background be when the average distances between galaxies are twice as large as they are today? (Hint: The peak wavelength of photons in the background will then also be twice as large as it is today.)

7. According to Olbers' paradox, the entire sky would be as bright as the surface of a typical star if the universe were infinite in space, unchanging in time, and the same everywhere. However, conditions would not need to be quite that extreme for the "nighttime" sky to be as bright as the daytime sky.

a. Using the inverse square law for light, determine the apparent brightness of the Sun in our sky.

b. Using the inverse square law for light, determine the apparent brightness our Sun would have if it were at a distance of 10 billion light-years.

c. From your answers to parts a and b, estimate how many stars like the Sun would need to exist at a distance of 10 billion light-years for their total apparent brightness to equal that of our Sun.

d. Compare your answer to part c with the estimate of 10^{22} stars in our observable universe (from Section 1.1). Use your answer to explain why the night sky is much darker than the daytime sky. How much larger would the total number of stars need to be for "night" to be as bright as day?