Astronomy 253 — Group Problems 5

Friday, February 20

Do the problems on separate sheets of paper. Each group will turn in only one set of solutions. Make sure your solutions are clear enough that I can understand what you were doing and what you were thinking! You probably won't get through all of these problems in an hour; that is OK. Do all problems in order.

1. Consider the interstellar cooling curve (plot passed out in class). The variable Λ comes in units of erg cm^{-3} s^{-1} (where 1 erg is 10^{-7} J). It tells you the rate at which 1 cubic centimeter of gas will lose energy.

   The curve plotted is actually $\Lambda/{n_H}^2$; you need to multiply it by the square of the interstellar hydrogen density (in units of cm^{-3}, or particles per cubic centimeter) to get just Λ.

   (a) Consider a gas cloud which is 10% ionized (so n_e/n_H is 0.1). It is at a temperature of 2×10^3 K. Assume that the gas cloud is a sphere of radius 10 pc, and it has a density of $n_H = 0.5$ cm^{-3}. What is the rate (in both erg/s and J/s) at which this gas cloud loses energy? Compare this to the luminosity of the Sun.

   (b) Can you explain why the cooling rate goes up as the ionization fraction goes up? Why do all of the curves come together at about 10^4 K?

   (c) Can you explain why the cooling rate of a gas is dependent on the *square* of the density of the gas?

2. **(a)** A car is traveling at 60 mph. What is the characteristic time scale for the car to travel 120 miles?

   (b) A car is traveling at 60 mph. The driver slams on the brakes, and is initially decelerating at 20mph/s. What is the characteristic timescale for the car to reach 0 speed as the deceleration begins?

   (c) Develop an expression for the characteristic timescale for a gas to lose energy in terms of the energy density of the gas ρ (in erg/cm^3) and Λ. Make sure the units of the expression you come up with work, and that it makes sense!

3. Consider a gas with temperature $T = 10^7$K and density $n_H = 1\,\mathrm{cm}^{-3}$.

   (a) What is the energy density (in erg/cm^3) of this gas? (Ignore mass energy! We're not being relativistic here.) (Also ignore the self-gravitation of the gas.)

   (b) What is the cooling timescale for this gas?

   (c) Comment on the right-side axis of Figure 6.23 in your textbook. When you get back to your room, look up the textbook errata on the web page to see if your comment is correct.

Continued on back

4. Use typical numbers for an elliptical galaxy to estimate the cooling time for the gas in the galaxy.

5. This problem will take you through the general idea of the *Surface Brightness Fluctuations* method of measuring the distance to an elliptical galaxy. In this method, you measure the pixel-to-pixel fluctuations in the surface brightness of a galaxy (as measured with a CCD), and from that deduce how far away the galaxy is.

   Make the assumption that when you look at an elliptical galaxy, all of the light you are seeing is coming from "red clump" stars with absolute magnitude M_{RG}... or, equivalently, a luminosity L_{RG}. (You can estimate these values by finding the red clump in Figure 2.2 of your text.) This is actually not such a terrible approximation, since those stars will dominate the light you see; the "blue fork" in Figure 2.2 represents short-lived main sequence stars, who have all died since an elliptical galaxy last made stars.

   Finally, you need to know something about "counting statistics." If you count N objects, you will have an uncertainty of $\Delta N = \sqrt{N}$. This means that if you (say) repeatedly fill up a glass with approximately 100 marbles, about 2/3 of the time you will get between 90 and 110 marbles in the glass. You can imagine doing this with a lot of glasses side by side; the number of marbles in each glass will usually vary between 90 and 110 marbles.

   (a) Write down an expression for F_{pix}, the flux coming from *one pixel* of the galaxy in terms of "known" quantities, the distance to the galaxy, and the number of stars which you're looking at in one pixel.

   (b) What is ΔF_{pix}, the scatter you should expect in the flux of one pixel? Express your answer in terms of the same quantities as you used for (a).

   (c) Now suppose that you measure F_{pix} (by looking at the average brightness of the pixels in a given region of the galaxy) and ΔF_{pix}, the fluctuations in the flux from one pixel to the next in this region, making F_{pix} and ΔF_{pix} known quantities. Derive an expression for the distance to the galaxy.