Homework 1 Supplemental Questions

Due Friday, April 11 in class

In addition to the problems from the book (1.R.15, 1.R.18, 1.E.7; R means review, E means exercises, P means problems—none this time), the following questions are a required part of the first (week 2) homework. For some of the following problems, there is no need to carry more than 1 or 2 significant digits: **approximate numbers are okay**.

1. Since there are 100 billion stars in a typical galaxy, and since there are at least 100 billion galaxies in the visible universe, how many stars are there in the visible universe? Write this number out in all its glory.

2. If each star is the size of a grain of sand (you provide a reasonable estimate of this), how large would a cube of sand be containing as many grains of sand as the number of stars found in our galaxy? (Hint: treat each sand grain as a little cube to make the math easier.)

3. We will go one step further and estimate how much beach you would need to represent all the stars in the visible universe by grains of sand. Use numbers from the previous two problems—feeling free to round generously. Assume that the sand on the beach is 10 meters deep and that the beach is 1000 meters wide (lots of sand under the water). How long is the beach with enough grains of sand to represent stars in the Universe? In your estimation, is this more sand or less sand than all the beaches on the earth?

4. Okay, last sand problem: if a star like our sun is reduced to a grain of sand, how far is the nearest star? Give a familiar example of something this far apart. Use numbers from the assigned reading supplement on the Universe to construct your answer.

5. The sun—representing a typical star—is made mostly of hydrogen, as is most of the universe.

   (a) Making the approximation that the sun is entirely made of hydrogen, how many atoms of hydrogen are in the sun if the mass of the sun is 2×10^{30} kg, and a single hydrogen atom has a mass of 1.67×10^{-27} kg?

   (b) Combine this answer with the one from problem 3 to estimate the number of atoms in the entire visible universe. When numbers are this big, only the exponent really matters: whether it's 1.0 or 2.0 or 3.3 out front makes very little difference—it's all an approximate estimate anyway.

6. You're thoroughly convinced by now that space within our solar system and galaxy is incredibly sparse. Let's switch gears and ask about galaxy distributions. Let's represent our galaxy by a nickel (about 2 cm).

   (a) Roughly how far away is the nearest large galaxy (which would be about the size of a quarter)—the Andromeda galaxy—on this scale.

   (b) Hold a nickel and quarter this far apart and appreciate the scene. How do you get credit for this part? Just do it—and don't just *say* you did!

   (c) On this scale, about how big is the visible universe (14 billion light years in radius)? Name a familiar object or locale that is about this size. Imagine filling this space with coins separated like the ones in the previous part to get an idea of the filling of the universe by galaxies.

7. Briefly, what are the three possible long-term fates of the universe, and what physical properties of the universe determine which way it will go?

8. Briefly, what are current observations telling us about the geometry and ultimate fate of our universe? Which observations are primarily responsible for each of these results? What is your gut reaction to this news?

9. Give an anthropic-type argument for why the earth is *just* at the right distance from the sun to support our life? Venus is too close, Mars is too far, but Earth is *just right*. Don't just say: this makes the temperature right. This isn't in itself an *anthropic* statement. Look to the last section of the reading supplement to understand this concept.