Astro 102
Group Problems #4
2006-June-29

Useful Data

$$1\,\text{year} \;=\; 3.156 \times 10^7\,\text{seconds}$$

$$1\,\text{AU} \;=\; 1.496 \times 10^{11}\,\text{m}$$

$$1\,\text{pc} \;=\; 3.26\,\text{lyr}$$

$$B \;=\; \frac{L}{4\pi\, d^2}$$

$$L \;=\; (4\pi\, R^2)\,(\sigma T^4)$$

$$z \;=\; \frac{d}{c\, t_H}$$

$$c \;=\; 3.00 \times 10^8\,\text{m}\,\text{s}^{-1} \;=\; 1\ \text{lyr}\,\text{yr}^{-1}$$

$$t_H \;=\; 13.8\,\text{billion years} \;=\; 4.35 \times 10^{17}\,\text{s}$$

$$1\,\text{rad} \;=\; 206,265''$$

$$180^\circ \;=\; \pi\,\text{rad}$$

1. My favorite galaxy is VV114. VV114 has an observed redshift of 0.021. Assuming you can ignore proper motion, how far away is it? Unlike the Gemini TAC, would *you* give me time to observe it? Huh? Huh?

2. 250 million years ago on Earth, the Permian Extinction happened. . . lots of species died out. To commemorate the event, you decide to observe a galaxy who was emitting the light you will see right as the Permian Extinction was happening. What is the redshift of this galaxy?

3. You look at a galaxy who emitted its light when the Unvierse was a third of its current size.

(a) What is the redshift you measure for light from this galaxy?

(b) You want to observe the Hβ line from this galaxy, which normally has a wavelength of 4861 Å. What is the observed wavelength of Hβ from this galaxy?

(c) In what region of the spectrum (gamma rays, X-rays, ultraviolet, optical, infrared, or radio) does the Hβ line from this galaxy show up?

(d) Suppose this galaxy is just like the Milky Way — that is, it has the same mass, formed at the same time, and will go through a very similar evolution throughout its existence. Will the neutron star to white dwarf ratio in this galaxy *as you see it through a telescope right now* be similar to, higher than, or lower than the neutron star to white dwarf ratio in the Milky Way?

4. You make the following observations:

- You observe a Cepheid variable with a 10-day period in a very nearby galaxy. Call this Cepheid C1. This nearby galaxy has a measured redshift of $z_1 = 0.001$. (Ignore any proper motion of the galaxy, and assume that all of the redshift is cosmological. This is foolish for a galaxy this close, but we're doing a problem here, not reality.)
- You observe another Cepheid variable, also with a 10-day period, in a somewhat more distant galaxy. Call this Cepheid C2.
- The brightness of C2 is 1/100th the brightness of C1.

What is the redshift of the host galaxy of C2?

5. The Hubble Time t_H characterizes the current expansion rate of the Universe. You can interpret it two ways; either, it is the time it would take for the size to double its current size if the expansion rate stays constant, or it is the time it would have taken any galaxy to reach its current distance if it started a zero distance away, if the expansion rate has always been the current expansion rate.

Suppose you make the following observations:

- A Type Ia supernova (SN1) is in a galaxy that has a redshift $z = 0.04$. From the Supernova's brightness, you measure the distance to this galxay to be 550 million years.
- A second Type Ia supernova (SN2) is in a galaxy that has a redshift $z = 0.08$. This supernova is observed to be 0.25 times as SN1 (that is, $B_{\rm SN2} = 0.25\, B_{\rm SN1}$).
- A third Type Ia supernova (SN3) is in a galaxy that has a redshift $z = 0.18$. You observe $B_{\rm SN3} = 0.0625 B_{\rm SN1}$.

Has the expansion of the Universe changed in the last two billion years? If so, is the expansion speeding up or slowing down?

Hint: This problem might be hard! I could have made it easier on you by breaking it down into parts, but (*evil laugh*) I didn't. Try to break it down into manageable chunks by asking yourself what kinds of things you need in order to figure out what the question is asking for.

6. Suppose that the expansion of the Universe has *only* been slowing down. (Present observations suggest that it's speeding up, but assume for the moment that it's only been slowing down.)

In this case, is the age of the universe greater than, equal to, or less than the Hubble time? Explain, perhaps with pictures. Rest comfortable that this will be discussed in class on Monday.