Astronomy 102, Fall 2003

Exam 3 Solutions

Note that I include some commentary on some of these problems. This is *not* to say that I expected you to write this much on the exam. I merely do this to help explain why I graded the way I did, to help you understand why the answer is what it is, or to let you know what many of you did wrong.

1. (e)

2. (f). Note that the "towards" was a red herring, as was the whole opposite direction thing. The Universe is homogenous and isotropic— which is a fancy way of saying it looks the same everywhere. If galaxies in one direction look like they're moving way from us, then galaxies in the opposite direction look like they're moving away from us in the sam eway.

3. (a), (c), and (e)

4. (a), (c), and (d)

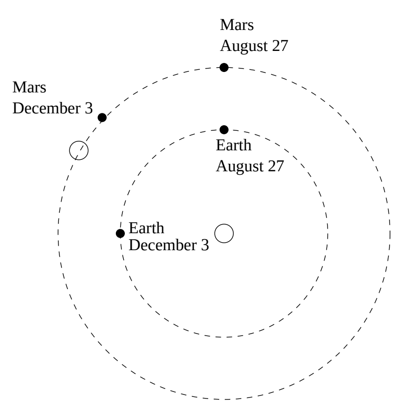
5. (d)

6. (c) only

7. (a)

8. (c). The most important point was to rule out a and b, because those showed the galaxies getting bigger as the Universe expanded. (See a previous homework problem about galaxies, solar system, etc. being bounded!) I gave you one point of partial credit if you answered (d). (The difference between (c) and (d) is that (c) is an accelerating expansion— it's expanding faster later— which is what we currently believe the Universe's expansion is doing.)

9. The key observation that shows us there is dark matter in our galaxy is that stars which are farther out are moving *too fast* compared to what we would expect from the light we see (which is already faster than what we would expect if all the mass were right at the center, which is the case with the Solar System). Thus, if the Solar System had a distribution dark matter like the galaxy, and it was set up so that something close (i.e. the Earth) moved as the same speed as it does in our solar system, somthing farther out (i.e. Mars) would be moving *faster*, and thus would have gotten farther along in its orbit by December 3:



11. (a)

$$\lambda_{\rm peak} = \frac{2900\,\rm K}{T}\,\mu\rm m$$
$$\lambda_{\rm peak} = \frac{2900\,\rm K}{2.728\,\rm K}\,\mu\rm m$$

$$\boxed{\lambda_{\text{peak}} \;=\; 1,063\,\mu\text{m} \;=\; 1.063\,\text{mm} \;=\; 10,630,000\,\text{Å}}$$

(b)

$$1+z \;=\; \frac{\text{size now}}{\text{size then}} \;=\; 1089$$

$$\boxed{z \;=\; 1088}$$

(c)

$$z \;=\; \frac{\lambda_{\text{obs}} \;-\; \lambda_{\text{em}}}{\lambda_{\text{em}}}$$

$$z \;=\; \frac{\lambda_{\text{obs}}}{\lambda_{\text{em}}} \;-1$$

$$1+z \;=\; \frac{lambda_{\text{obs}}}{\lambda_{\text{em}}}$$

$$\lambda_{\text{em}} \;=\; \frac{\lambda_{\text{obs}}}{1+z}$$

$$\lambda_{\text{em}} \;=\; \frac{1,063\,\mu\text{m}}{1,089}$$

$$\boxed{\lambda_{\text{em}} \;=\; 0.9762\,\mu\text{m}}$$

(d)

$$\lambda_{\text{peak}} \;=\; \frac{2900\,\text{K}}{T}\,\mu\text{m}$$

$$T \;=\; 2900\,\text{K}\left(\frac{1\,\mu\text{m}}{\lambda_{\text{peak}}}\right)$$

$$T \;=\; 2900\,\text{K}\left(\frac{1\,\mu\text{m}}{0.9762\,\mu\text{m}}\right)$$

$$\boxed{T \;=\; 2970\,\text{K}}$$

(e)

$$L \;=\; A\,\sigma\,T^4 \;=\; (1\,\text{m}^2)\,(5.67\times10^{-8}\,\frac{\text{W}}{\text{m}^2\,\text{K}^4})\,(2970\,\text{K})^4$$

$$\boxed{L \;=\; 4.41\times10^{6}\,\text{W}}$$

12. (a)

$$d \;=\; \frac{1}{0.130}\,\text{pc} \;=\; \boxed{7.69\,\text{pc}}$$

(b)

$$F_f \;=\; fracL_f 4\,\pi\,{d_f}^2$$

$$L_f \;=\; 4\,\pi\,{d_F}^2\,L_f$$

Similarly for the Sun. Divide the two to get the ratio:

$$\frac{L_f}{L_\odot} \;=\; \frac{4\,\pi\,{d_f}^2\,L_f}{4\,\pi\,{d_\odot}^2\,L_\odot}$$

$$L_f \;=\; L_\odot\left(\frac{d_f}{d_\odot}\right)^2\left(\frac{F_f}{F_\odot}\right)$$

We know the distance to the sun ($d_\odot$) is 1 AU, so we'll need to convert that to parsecs when we use it.

$$L_f \;=\; (3.85\times 10^{26}\,\mathrm{W})\left(\frac{7.69\,\mathrm{pc}}{1\,\mathrm{AU}}\right)^2\left(\frac{206265\,\mathrm{AU}}{1\,\mathrm{pc}}\right)^2\left(\frac{1}{1.3\times 10^{11}}\right)$$

$$\boxed{L_f \;=\; 19.37\,L_\odot \;=\; 7.46\times 10^{27}\,\mathrm{W}}$$

(c)

$$L_f \;=\; 4\,\pi\,{R_f}^2\,\sigma\,T^4$$

$$R_f \;=\; \sqrt{\frac{L_f}{4\,pi,\sigma\,T^4}}$$

$$R_f \;=\; \sqrt{\frac{7.46\times 10^{27}\,\mathrm{W}}{4\pi\,(5.67\times 10^{-8}\,\mathrm{W/m^2\,K^4})\,(8500\,K)^4}}$$

$$\boxed{R_f \;=\; 1.4\times 10^9\,\mathrm{m} \;=\; 2\,R_\odot}$$

(d) If they are at the *same* distance, then their apparent brightness ratio is the same as the luminosity ratio:

$$\frac{F_s}{F_f} \;=\; \frac{L_\odot}{L_f}$$

$$\frac{F_s}{F_f} \;=\; \frac{1\,L_\odot}{19.37\,L_\odot}$$

So Fomalhaut would be brighter by 19.37 times.

13. First: the Cosmic Microwave Background (CMB). The simplest steady-state model never had the hot, dense Universe that would create the glow that we see as the CMB, where as the Big Bang very naturally predicts this. Second: nucleosynthesis. The Big Bang theory gives us a very hot, dense Universe when we can make the lightest nuclei, and the calculations of the Hydrogen/Helium ratio we'd expect from the Big Bang matches well what is observed. The simplest steady state model as described doesn't give us a framework for predicting element abundance ratios. Third: galaxy population evolution. No, we didn't talk about this in class, which is why this problem only asked for two reasons! But, it is true that if you look at higher redshifts (i.e. far back in time), you see a different population of galaxies than you see nearby (i.e. around today). For instance, there are many more quasars at higher redshift. This indicates a Universe which is evolving (getting different) with time, which is at odds with this simplest steady state Universe.

A few of you mentioned the accelerating Universe. The evidence indicates that the Universe's expansion is accelerating. However, this isn't a prediction of the Big Bang theory. It *fits* within the Big Bang theory, but so would a decelerating Universe.