Astronomy 102: Stars and Galaxies

Fall, 2003

Sample Review Examination 2 Solutions

REVISION 3

1. (f)

2. (e)

3. (e)

4. (d), (e), and (h)

5. (e). You can work out the math and your calculator may tell you that (d) is the best answer, , but because you only have the distance to two significant figures, you only know the answer to two significant figures!

6. (a)

7. (c) (only)

8. (a)

9. **(a)** Mass density is Mass/Volume. The total mass here is (30 galaxies)($10^{12}\,M_\odot$/galaxy), or $3 \times 10^{13}\,M_\odot$. The voume of a sphere is:

$$V = \frac{4}{3}\pi\, r^3$$

$$V = \frac{4}{3}\pi\, (1.5 \times 10^6\,\mathrm{pc})^3$$

$$V = 1.41 \times 10^{19}\,\mathrm{pc}^3$$

(keeping extra significant figures for an intermediate calculation). The density is then:

$$d = \frac{3 \times 10^{13}\,M_\odot}{1.41 \times 10^{19}\,\mathrm{pc}^3}$$

$$\boxed{d = 2 \times 10^{-6}\,\frac{M_\odot}{\mathrm{pc}^3}}$$

(b) The calculation is the same, only the mass and the size of the sphere is different.

$$M = (23\,\mathrm{stars})(0.6\,M_\odot/\mathrm{star}) = 13.8\,M_\odot$$

$$V = \frac{4}{3}\pi\,(3.5\,\mathrm{pc})^3 = 180\,\mathrm{pc}^3$$

$$d = \frac{13.8\,M_\odot}{180\,\mathrm{pc}^3}$$

$$\boxed{d = 0.08\,\frac{M_\odot}{\mathrm{pc}^3}}$$

(c) We have discussed in class that stars are *enormously* farther apart compared to their sizes than galaxies are compared to *their* sizes. As such, galaxies are more likely to collide than stars are. Another way of saying this is that galaxies are much more densely packed than stars are. And yet, we've now just calculated that the mass density of stars in the solar neighborhood is an awful lot higher than the mass density of galaxies in a galaxy cluster! This would seem to be contradictory.

Neglect the possible explanation that the professor gave you bogus numbers (which isn't the case anyway). When you compare the size/distance ration of stars or galaxies, you are really talking about "number density", i.e. "how many galaxies are there in a box which is (say) 30 times the size of a galaxy on each side". This is a very different question from asking how much mass of galaxies there is in the same box. One might make a comparison to big fluffy balls of cotton candy and to ball bearings. A big fluffy ball of cotton candy may weigh about the same as a ball bearing, but if you put ten of each type of item in a box 1m on a side, the big fluffy balls of cotton candy will take up much more space than the ball bearings will, and are much more likely to be touching each other than the ball bearings are. Galaxies are like big fluffy balls of cotton candy—they are on the average much, much less dense than individual stars, but they're a whole lot bigger compared to how far apart they are than stars are.

Mostly, I just like to say "big fluffy balls of cotton candy" a lot.

10. (a)

$$c = \lambda f$$

$$f = \frac{c}{\lambda}$$

$$f = \frac{3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}}{6563 \times 10^{-10}\,\mathrm{m}}$$

$$\boxed{f = 4.57 \times 10^{14}\,\mathrm{s^{-1}}}$$

Remeber that s^{-1} is the same as Hz.

(b)

$$E = h f$$

$$E = (6.626 \times 10^{-34}\mathrm{J\,s})(4.571 \times 10^{14}\,\mathrm{s^{-1}})$$

$$\boxed{f = 3.03 \times 10^{-19}\,\mathrm{J}}$$

(c)

$$n\,E_{\mathrm{H}\alpha} = E_{\mathrm{fb}}$$

$$n = \frac{E_{\mathrm{fb}}}{E_{\mathrm{H}\alpha}}$$

$$n = \frac{120\,\mathrm{J}}{3.03 \times 10^{-19}\,\mathrm{J}}$$

$$\boxed{n = 4.0 \times 10^{20}\ \text{photons}}$$

(d) This question is deceptively simple. Luminostiy is just energy per time. Given that you're told the energy (enough photons to make 120 J every second), you don't have to mess with Hα photons at all!

$$L = 120 \frac{\mathrm{J}}{\mathrm{s}}$$

Remember that J/s is just W (Watts).

$$\frac{L}{L_\odot} = \frac{120\,\mathrm{W}}{3.85 \times 10^{26}\,\mathrm{W}}$$

$$\boxed{3.1 \times 10^{-25}}$$

11. Start by writing what we know. We're told that both stars are equally bright, so:

$$F_A = F_B$$

We also know:

$$d_A = \frac{1}{0.1}\,\mathrm{pc}$$
$$d_B = \frac{1}{0.02}\,\mathrm{pc}$$

given the two parallaxes. Finally, we have the flux/luminosity/distance equation for each star:

$$F_A = \frac{L_A}{4\pi\, {d_A}^2}$$
$$F_B = \frac{L_B}{4\pi\, {d_B}^2}$$

We want the luminosity ratio, so solve both of these for luminosity:

$$L_A = 4\pi\, {d_A}^2\, F_A$$
$$L_B = 4\pi\, {d_B}^2\, F_B$$

Divide the two to get the ratio:

$$\frac{L_A}{L_B} = \frac{4\pi\, {d_A}^2\, F_A}{4\pi\, {d_B}^2\, F_B}$$

$$\frac{L_A}{L_B} = \left(\frac{d_A}{d_B}\right)^2 \left(\frac{F_A}{F_B}\right)$$

$$\frac{L_A}{L_B} = \left(\frac{0.02}{0.1}\right)^2 (1)$$

$$\boxed{\frac{L_A}{L_B} = 0.04}$$

Sanity check: A is closer, but both are equally bright. Thus, you should expect A to be less luminous, which it is— so we can have confidence that at least this answer *can* be right. . . .

12. First of all, the star is *dimmer* as a result of the dust. If you don't know the dust is there, and it looks dimmer, you will conclude that it is further away than it really is, thus you get a value which is $\boxed{\textit{too large}}$ for the distance. Knowing that flux goes as one over distance squared, if your flux is wrong by a factor of 100, then your distance must be wrong by $\sqrt{100}$ or $\boxed{\text{you are of by a factor of 10 in distance}}$.

If you prefer to do this more mathematically, if we define F_{nodust} as the flux which would be observed had there been on dust, and F as the actual flux observed, we have $F = 0.01\,F_{\text{nodust}}$. Define d_{est} as the distance estimate you get from your measured flux, and d as the real distance to the star. Then:

$$F_{\text{nodust}} = \frac{L}{4\pi\,d^2} \qquad \text{thus :} \qquad d = \sqrt{\frac{L}{4\pi\,F_{\text{nodust}}}}$$

$$F = \frac{L}{4\pi\,{d_{\text{est}}}^2} \qquad \text{thus :} \qquad d_{\text{est}} = \sqrt{\frac{L}{4\pi\,F}}$$

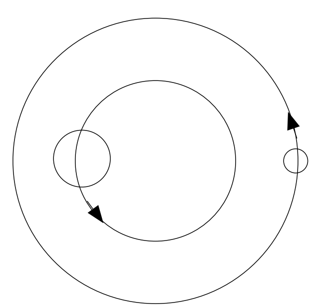
$$\frac{d_{\text{est}}}{d} = \sqrt{\frac{\frac{L}{4\pi\,F}}{\frac{L}{4\pi\,F_{\text{nodust}}}}}$$

$$\frac{d_{\text{est}}}{d} = \sqrt{\frac{F_{\text{nodust}}}{F}}$$

$$\frac{d_{\text{est}}}{d} = \sqrt{\frac{F_{\text{nodust}}}{0.01\,F_{\text{nodust}}}}$$

$$\boxed{\frac{d_{\text{est}}}{d} = 10}$$

14. **(a)**



(b) Physical separation of the star, in AU. (Note: if you just said "distance" without saying the distance *to* or *between* what, that wouldn't be enough to fully answer the question.)

(c) Distance to the star (measured via parallax) and the angular separation. Put those to together to get the physical separation.