October 26, 2006

A102 Fall 2006 Review Exam 3 Solutions

1. (a) Well, if the minimum angular separation detectable is $0.05''$, we can measure parallaxes down to $0.025''$. (Remember that the parallax angle p is actually only half of the angle in the triangle that describes the two vantage points!)
As such, the limiting distance is:

$$d = \frac{1}{p} = \frac{1}{0.025}\,\mathrm{pc}$$
$$\boxed{d = 40\,\mathrm{pc}}$$

(b) The HST can only measure parallaxes which are *greater* than or equal to that limit. (Smaller parallaxes would be smaller than the smallest angular offset that you can measure!) This means stars that are *closer* than 40pc.

2. (a)

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

We don't have the B for this supernova, we only have it relative to Vega. So do this:

$$B_{SN} = 1.6 \times 10^{-7}\,B_V = \frac{L_{SN}}{4\pi\,{d_{SN}}^2}$$

Does this help? We don't know B_V, but we do know that:

$$B_V = \frac{L_V}{4\pi\,{d_V}^2}$$

So:

$$B_{SN} = \frac{L_{SN}}{4\pi\,{d_{SN}}^2} = 1.6 \times 10^{-7}\,B_V = 1.6 \times 10^{-7}\frac{L_V}{4\pi\,{d_V}^2}$$

Now we have everything we need, since we know L_V, L_{SN}, and d_V. Solve away!

$$\frac{L_{SN}}{4\pi\,{d_{SN}}^2} = 1.6 \times 10^{-7}\frac{L_V}{4\pi\,{d_V}^2}$$
$$(L_{SN})\,(4\pi\,{d_V}^2) = 1.6 \times 10^{-7}\,(L_V)\,(4\pi\,{d_{SN}}^2)$$
$${d_{SN}}^2 = \frac{1}{1.6 \times 10^{-7}}\,\frac{L_{SN}}{L_V}\,{d_V}^2$$
$$d_{SN} = \sqrt{\frac{1}{1.6 \times 10^{-7}}\,\frac{L_{SN}}{L_V}}\,d_V$$

Plug in...

$$d_{SN} = \sqrt{\frac{1}{1.6 \times 10^{-7}}\,\frac{5.8 \times 10^9\,L_\odot}{130\,L_\odot}}\,(7.76\,\mathrm{pc})$$
$$d_{SN} = 1.296 \times 10^8\,pc = \boxed{130\,Mpc}$$

(Remembering that 1 Mpc is a million pc.)

(b) This galaxy is 130 Mpc=420 million light-years away. Thus, the light takes 420 million years to reach us. Thus, the first supernova, which we're just now seeing, exploded 420 years ago. If a second supernova explodes 200 years after that, it will have exploded $\boxed{\text{220 years ago}}$.

(c) 200 million years from now. Which means that you probably won't see it, unless you've got a good plan with one of those cryogenic freeze outfits. The second supernova explodes 200 million years after the first, but the light takes the same amount of time to reach us... so the light from the second supernova will reach us 200 million years after the light from the first supernova.

(In fact, it's likely that a lot of supernovae will explode in that galaxy in between those two times, because a big galaxy has about one supernova every century.)

3. **(a)** You would find nothing, or perhaps a big cloud of gas from which stars will form in more than 100 million years. The second supernova is a core-collapse supernova, it comes from the end of the life of a star of mass $M > 8M_{\odot}$. Stars that massive live at most 40 million years. If the death of the star is still 200 million years in the future, its birth is at least 160 million years in the future.

(b) This is a little harder, because there are a few possibilities:

- First, it could be nothing; it could be a star just under $8\,M_{\odot}$ that will form in the future, live through its life, become a white dwarf, accrete enough mass to reach the critical mass, and explode. (In reality, white dwarves probably can't accrete enough mass this fast, but you'd have no way to know that.) All of that could happen in 200 million years.
- It could be a main-sequence star. It could be a star that's living through its life, and will during the next 200 million years become a white dwarf, accrete enough mass to reach the critical mass, and explode.
- It could be a giant star. This is a star in the last 10% of its life. It will (probably) soon be a white dwarf, which will over the next (up to) 200 million years accrete mass and eventually explode.
- It could be a white dwarf. It have been a white dwarf for some time, and it will continue to accrete mass for the next 200 million years until it reaches the critical mass and explodes.

In any event, the star would have to be part of a binary star system— it would need to have a companion to accrete mass from.

4. If the distance between the Earth and the sun were 10% smaller than we thought, then all of the triangles we'd drawn to describe parallax would have been 10% too big. The parallax measurements are the same; to keep the angle the same, both legs of the triangle would have to shrink by the same fraction (10%). Thus, all of the distances we'd measured through parallax would have to be modified to be 10% smaller than we'd previously thought.

Because parallax is the basis of the cosmic distance ladder, and because, eventually, all other distances are based on parallax, the results of pretty much *every other* distance measurement would have to be reduced by 10%. The calibrator Cepheids with parallax measurements were 10% closer than we thought, and therefore less luminous than we'd assumed when we thought they were farther away (given the brightness). If Cepheids are less luminous than we'd thought, then the Cepheid we see in the distant galaxy must be *closer* than we had previously thought for it to have the brightness we observe.