Astronomy 102, Fall 2003

Exam 4 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. (c)

2. (b)

3. (a)

4. (c)

5. (e)

6. (a)

7. (d)

8. (d)

9. **Red Dwarf** Both. I realized as I graded this that I must never have used this terminology; a red dwarf is just a small red star, or a red, low-mass main sequence star. Those last a really long time, and are present in abundance in both clusters.

Blue Supergiant A or Neither. (Full credit for either answer.) These are post-main-sequence high-mass stars. You'll only find them in a very young cluster, as high-mass stars don't live very long. Cluster B is an old cluster, and thus won't have any.

5 $M_\odot$ star A. Cluster B is old; indeed, as a globular cluster, it's older than the lifetime of the Sun, so no star more massive (and thus shorter lived) than the Sun will still be around.

An 8-billion-year-old Star I got this one wrong myself! The right answer is Neither; the cluster on the left is very young, so no stars will have lived that long yet. The cluster on the right is older than 8 billion years, so all of the stars in it have already lived longer than that. (Since I got it wrong and thought B, I gave full credit to anybody who answered B.)

A neutron star Both. Although only the cluster on the left might still have the high-mass stars necessary to go supernovae and make more neutron stars, Cluster B was *once* young enough (though no longer) to have high-mass stars that would supernova. Any neutron stars produced then would still be around.

A spiral galaxy Neither. Both of these star clusters are found in spiral galaxies (in this case, specfically, our own), but spiral galaxies aren't found in them. (The reasoning is the same as the reasoning that you won't find a parking garage in in a car.)

A Nova B or Both (I accepted either answer). For a Nova, you need to make a white dwarf. B is clearly old enough that some white dwarfs have been made. While A is a younger cluster, it's not obvious if it's too young to have started making white dwarfs yet (which is why I accepted eitehr answer).

A Type Ia Supernova B or Both. Same reasoning as Nova.

A Type II Supernova A or neither. You need high-mass stars for this. Cluster B is old enough that any high mass star is long gone.

Prof Knop's cats Neither. We aren't living in a cluster of stars all at the same age, but rather in the disk of the Milky Way which has a mix of stars all at different ages. What's more, the Sun is 5 billion years old, which is older than Cluster A but younger than Cluster B.

10. **(a)** The supernova must have happened first. Supernovae are much more luminous than novae, yet both appeared the same peak brightness to us. For this to be so, the supernova must have been much farther away. That means that it took the light a lot longer to reach us from the supernova, because it had much farther to go . . . but to arrive within three days of the nova, it must have had a huge head start.

Note: A few of you said that the supernova was higher energy, so its light would travel faster. This is wrong! All light goes at the same speed (the speed of light, unsurprisingly). Many of you also confused flux and luminosity; be careful.

(b) The nova. Type II supernovae come from massive, short-lived stars. Novae come from white dwarfs, which are the end points of less massive stars that are longer lived than stars that turn into supernovae.

(c) At the nova: a white dwarf. (The nova does *not* destroy the star.) It is *possible* that we would find nothing, if the white dwarf has managed to explode in a Type Ia supernova in the mean time, but this is unlikely. At the supernova: a neutron star or a black hole.

11.

(a) It would get redder with time. The bluer, short lived stars will die out, leaving the redder stars.

Note: many of you answered this as if you were talking about the evolution of one star (main sequence, then redder as a red giant, then bluer again as a white dwarf). However, all the stars don't evolve at once; the higher mass stars go first, and the lower mast stars take longer. At any given moment, only stars of a certain mass will have reached their "timeout" to become red giants. (When they become white dwarfs, they are so low lumnosity that they won't contribute appreciably to the light observed from the cluster.)

The cluster gets redder because of stellar evolution *not* because of a redshift. Clusters of stars tend to be in our own Galaxy, and as such stay bound to our galaxy. They will not redshift along with the expansion of the Universe.

(b) It will stay the same. After the first few billion years (in fact, even long before that), all of the high-mass stars that can explode and leave behind a neutron star will have already done so, and thus no new ones will be produced. The neutron star is the endpoint of a high-mass star's evolution; the ones made will just stay around.

Note: A few of you were very confused, and said things like "when the neutron star leaves the main sequence", which doesn't make any sense. Neutron stars are *not* main sequence stars! They are extremely different objects.

(c) The number will continue to go up. Stars of moderate and low mass end their life as a white dwarf. As more and more of these die, they will leave behind more and more white dwarfs. Indeed, although I didn't require you to say this, the rate of production of white dwarfs will increase, because the lower the mass, the more stars there are in a typical cluster. Thus, as you get to the time when lower and lower stars will go into white dwarfs, there will be more and more stars available to do so.

Note: Some of you said that white dwarfs cool to brown dwarfs. We haven't talked about brown dwarfs in this class, but I wanted to mention that brown dwarfs are *very* different things from white dwarfs. If you want to give a white dwarf a different name once it's cooled off so much that it's hardly radiating, you might call it a "black dwarf". As white dwarfs cool off, they do change color, and indeed they will eventually be red, but we still call them "white dwarfs" just to be perverse.

12. **(a)** You would expect all of them to go down. Luminosity would go down because the source of energy that ultimately results in the luminosity has been removed. Radius would go down because there is nothing generating energy at the core to keep the particles moving and thus supply the pressure that counteracts gravity and holds up the star. Temperature would go down because there is nothing suppling new energy to keep the star hot as it radiates away from its surface.

(In fact, it's more complicated than that. You would definitely expect radius to go down, but in so doing you are releasing some gravitational potential energy that might do other things to the Luminosity and the Temperature. What's more, the opacity of the star would buffer the temperature and luminosity change on the surface for a little while. I gave full credit to anybody who gave answers different from what I said above so long as they had decent reasoning and indicated an understanding of what holds up stars.)

(b) This is very much not reasonable. The mass of the star is still there, and therefore all the gravitational effect would still be there.

(In the movie, the star actually explodes. Even so, all the mass is still there, it's just expanding away. Stars are typically light-years apart, so even if it was a truly extreme explosion, it would take a few years (longer than the time in the story of the movie) for some of the matter from the star to have moved far enough away from the star to change the gravitational effect. The instant change depicted in the movie is one of that movie's long list of physics gaffes. . . .)

13. All four. The Big Bang, because *everything* comes from there. A supernova, because that's the only place you can make the heaviest elements, including the iron in your blood. (Yes, you get iron at the core of a very massive star at the end of it's giant phase, but such a star *will* go supernova. . . and the supernova is the only way to get that iron out. In fact, *that* iron doesn't come out, but mostly gets lost into the neutron star. However, the abundant energy released generates all sorts of other fusion, creating elements includng iron and heavier elements.)

A supernova is the death of a star. Stars spend their lives first on the main sequence, then as red giants. Even if it's a Type Ia supernova, that comes from a white dwarf, which must have been through main sequence and red giant phases before it got there. Therefore, if some of the atoms in your body have been through a supernova, then they must have first been through a main sequence and a red giant star.