A102 Review Exam 4 Solutions

2004-December-01

1. **(a)** Because this would be from the first generation of stars, and no star from the first generation of stars has yet been found.

(b) It must be low mass. We don't see any gas clouds that are pristine (i.e. with no heavy elements), so there's no clouds left to form such a star. Even the oldest stars (e.g. in globular clusters) have *some* heavy elements, which means that there must have been a generation before those oldest stars formed. Any stars left over, then, from this first generation must have been around for most of the age of the Universe, or at least 12 or so billion years. The only stars that live this long are less massive than the Sun.

2. All four. First of all, everything came out of the Big Bang. Next, we know we have iron in our bodies; consider the hemoglobin in our blood. The only place where iron is made is in supernovae. Therefore, the iron in our bodies had to have come out of a supernova. Before a star goes supernova, it's first a main sequence star and then a red giant, so if our atoms have been through supernovae, they have to have been through main sequence and red giant stars first.

We literally are made from the remnants of past stars. You can state this romantically (we are starstuff, or stardust), or less pleasantly (we are made from the cast-off detritus from the death of a distended old-age star).

3. **(a)** Radius and luminosity is straightforward; temperature can be argued either way. With the nuclear reactions at the center of the star turned off, you're no longer generating pressure to hold the star up, so the star will start to collapse. As it does so, you would expect its luminosity to go down. Also, since you're no longer generating energy, it should start to cool off from its radiation. However, gravitational potential energy will be released when the star compresses, which might then heat up the star again. (As long as you give reasons for your answer, I'd accept answers on tempearture in either direction on this.)

If you can't hold a star up by nuclear fusion, assuming a star like the Sun, the core would probably collapse down until it was held up only by electron degeneracy pressure — i.e. leaving behind a white dwarf, only one made of H and He rather than C and O. As the outer layers fell in, you *might* get a bounce similar to what you get in a core-collapse supernova, and get an explosion (which would be impressive, but much smaller than the explosion you get from a true supernova). Some fraction of the infalling mass would be collected on to the white dwarf, though, heating it up.

(b) This is not realistic. Even if some of the mass is thrown off in an explosion, it will take it quite a while to get far eneough away from the rest of the star to mix with the interstellar gas and effectively reduce the total mass of the star system. As such, the gravity of the star should remain exactly the same after the fusion reactions were stopped.

Oh well, so much for Data's bright idea. Maybe that's why he whined so much in Stellar Cartography. All that stuff about not dealing with emotions— what he was *really* saying was, Captain, I can't go on, the bloody scriptwriters don't know any Astronomy and they wrote me these lines that my knowledge of Physics shouldn't let me say, but I have to say them anyway, waah waah waah!

4. **(a)** Not at all. First of all, during the main sequence lifetime of a star, Hydrogen is being fused to Helium, so no heavy elements are being produced anywhere. Second, at least for stars like the Sun, all that fusion is going on at the core; when we look at a star, we look at what's going on at the surface. As such, even the observed Helium abundance won't go up. (It turns out that some very low mass stars have convection going all the way down to the core, so some of the Helium produced gets dredged up.)

(b) Convection. The carbon is formed own in the core where fusion is happening; no fusion happens at the surface. The only way to get it up to the surface is to stir that star up.

5. Increase. As time goes by, the main-sequence turn-off moves down and to the right on the H-R diagram. Since lower mass stars live longer, but all the stars in a cluster were formed at once, over time less and less massive stars will now be reaching the end of their main sequence lifetimes and becoming red giants. Since less massive stars are more common, as the main-sequence turn-off moves toward less massive stars, there will be more stars becoming red giants. (They will also last longer as red giants, since lower mass stars spend more time in all phases of their lives.)