

Astronomy 102, Spring 2003
Solutions to Review Problems from 203 March 17

1. Chapter 14, Question 8: *When a hydrogen atom is ionized, a single particle becomes two particles.*

(a) *Identify the two particles.*

(b) *If both particles have the same kinetic energy, which moves faster?*

(a) A proton and an electron.

(b) Kinetic energy is energy of motion. You can have more kinetic energy either by going faster, or by being more massive. If two particles of differing masses have the same kinetic energy, then the one with less mass must have more velocity. Thus, the electron moves faster.

2. Chapter 14, Question 11: *You can think of a brown dwarf as a failed star, that is, one lacking sufficient mass for nuclear reactions to begin. What similarities and differences do you see between a brown dwarf and a giant planet such as Jupiter? Would you classify a brown dwarf as a super-giant planet? Explain your answer.*

This may not be as easy a question as it sounds! Indeed, exactly what is a “planet,” both on the high and low end, is a source of some controversy in the scientific community. You may have heard that many don’t consider Pluto to be a planet, and as such say that our solar system has only eight planets. Others might point to the fact that some of the moons of Jupiter and Saturn are larger than both Pluto and Mercury to argue that our solar system has *more* than nine planets. It’s nearly impossible to find a definition of “planet” that will satisfy everybody. If you want to learn a lot more about this fascinating topic, take Astronomy 201 from David Weintraub next spring.

In the mean time, back to the question at hand: what are the similarities and differences? They will both have a gaseous surface, which is only warm either because of left over energy of formation (which Jupiter does in fact have some of), or if they’re heated by a nearby star (which Jupiter definitely has, and which brown dwarves might have if they’re in the same place). As such, they might look quite similar— and, indeed, absorption lines of methane such as are seen in Jupiter were used to conclusively identify some of the first confirmed brown dwarves.

The biggest difference, though, is in where and how they form. A “failed star” is just a star that formed out of a cloud of gas, but wasn’t big enough to ignite hydrogen fusion at its core. (Note that in fact briefly Brown Dwarfs can host lithium fusion, but this is a detail we don’t need to worry about.) A giant planet like Jupiter, in contrast, formed in a protoplanetary disk which collected around a larger star.

You may also have heard of observations of “free-floating” planets in the Orion Nebula star cluster— giant planets (Jupiter or larger sized) which aren’t attached to a star. Are these tiny brown dwarfs? Or planets ripped from their star? Many of these questions are active topics of research in astronomy today.

3. Chapter 14, Question 13: *If a typical hydrogen atom in a collapsing molecular cloud core starts at a distance of 10,000 AU (1.5×10^{12} km) from the core’s center, and falls inward at an average velocity of 1.5 km/s, how many years does it take to reach the newly forming protostar? Assume that a year is 3×10^7 s.*

$$\frac{1.5 \times 10^{12} \text{ km}}{1.5 \text{ km/s}} = 1.0 \times 10^{12} \text{ s}$$

$$1.0 \times 10^{12} \text{ s} \left(\frac{1 \text{ yr}}{3 \times 10^7 \text{ s}} \right) = \boxed{30,000 \text{ years}}$$

4. Chapter 14, Question 16: *The Sun took 30 million years to evolve from a collapsing cloud core to a star, with 10 million of those years spent on the Hyashi track. It will spend a total of 10 billion years on the main sequence. Suppose we were to compress the Sun's main sequence lifetime into just a single year.*

(a) *How long would the total collapse phase last?*

(b) *How long would it spend on the Hyashi track?*

(a) Remembering that million is 10^6 and billion is 10^9 , we have:

$$\left(\frac{30 \times 10^6 \text{ yr}}{10 \times 10^9 \text{ yr}} \right) = \left(\frac{?}{1 \text{ yr}} \right)$$

$$\boxed{0.003 \text{ yr} = 1 \text{ day}}$$

(b) 1/3 as long would be about $\boxed{8 \text{ hours}}$.

5. *Given what we have learned about the interstellar medium and where stars form, consider the following. Spiral galaxies, like our own, have a lot of cool gas (including both atomic and molecular gas). There is another type of large galaxy known as an Elliptical galaxy. Such galaxies usually do not have much cool gas. How would you expect the colors of stars seen in an elliptical galaxy to differ from stars seen in a spiral galaxy, and why?*

Only the most massive stars are ever very blue and very bright. Yes, low mass stars do go through the post-AGB phase in between when they throw off their planetary nebula and when they cool off to be white dwarfs, and during this period they are in fact blue and luminous. However, that's a very brief fraction of the star's life, and looking at a bunch of different stars you aren't likely to see very many of them in that phase.

Given that, the only time you're going to have a lot of bright blue stars is when you have massive stars. Massive stars, however, don't live very long, so if you want to have many of them, you need to have been making stars recently. Therefore, you'd only expect to see blue stars in galaxies which are still making stars, i.e. galaxies that have a lot of cool gas. So, you'd expect to see more bluer stars in spiral galaxies than you do in elliptical galaxies.