Astronomy 1143 Quiz 3 Review

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Hertzsprung-Russell Diagram and Luminosity Relations

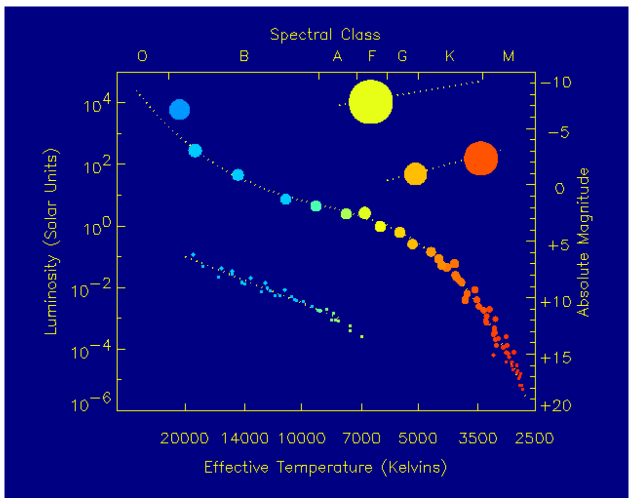

Figure 1: The Hertzsprung-Russell diagram. Note that temperature increases to the left. The line through the middle is the main sequence, the lower line is the white dwarf sequence, and the lines in the upper right are the red giant and supergiant sequences (supergiant is on top).

1. What does a star's location on the HR diagram tell us?
   - Its abolute magnitude, from which you can get its luminosity, and its spectral color, from which you can get its temperature. Indirectly, you can also get its mass by how far up or down it is on the main sequence, if it is on the main sequence.
2. What is the main sequence?
   - The sequence on the HR diagram of the main hydrogen-burning phase of a star's life. More massive stars are up and to the left, less massive stars down and to the right.
   - It is a sequence of temperature (or color), luminosity, mass, and absolute magnitude.
3. Where is the red giant sequence on the HR diagram? What does this location mean?
   - It is up and to the right of the main sequence.
   - Red giants on this sequence are cooler and more luminous than stars on the main sequence.
4. What is the most important stellar property that determines all other properties of a star?

- Its mass!

5. How does a star's radius and temperature relate to its luminosity?
   - $L = 4\pi R^2 \sigma T^4$, where R is the radius, T is the temperature, and σ is the Stefan-Boltzmann constant.
6. How does a star's aparent brightness relate to its luminosity?
   - $B = L/(4\pi d^2)$ where B is the relative brightness, or flux, L is the luminosity, and d is the distance to the star.
7. What is the distance modulus?
   - $m - M = 5log(d/10pc)$, where m is the apparent magnitude and M is the absolute magnitude of the star. Note that the quantity inside the log must be unitless, so the distance you get out will be in parsecs, not kilometers, lightyears, or meters!
   - This formula holds because the distinction between apparenet and absolute magnitude is that the absolute magnitude is a measure of a star's luminosity while the apparent magnitude is a measure of its flux of brightness. And, as we saw above, an object's flux is related to its luminosity and the inverse square of its distance from the observer.
8. What are Cepheid stars? Why are they useful?
   - A type of variable star whose pulsation period is directly related to its luminosity (the period luminosity relationship).
   - As the period is easy to measure, it gives us the luminosity as well. Since the flux is given and we know the luminosity, we can thus determine the distance to these objects very easily. Breaking the distance degeneracy is a big problem in astronomy, so these variables are very useful!
   - in terms of where they are, Cepheids are stars that are in the instability strip after moving off of the main sequence. They can be found above the main sequence.
   - The longer the period of a Cepheid, the larger its luminosity!

Spectral Types of Stars

1. What is the spectral sequence of stars, from hottest to coolest?
   - O, B, A, F, G, K, M, L (Helpful mnemonic: "Oh, Be A Fine Girl/Guy, Kiss Me Lovingly")
2. What color are hot stars? Cool stars?
   - Hot stars are bluer.
   - Cool stars are redder.
3. What causes stars to have a specific color?
   - A star's color is just the wavelength at which its emission is strongest, the peak of its spectral distribution.
4. Do O and B type stars show hydrogen lines in their atmospheres?
   - No, they do not. Even though they, like all stars, are made up mostly of hydrogen, they're so hot that hydrogen is ionized and thus doesn't absorb light from the star in spectral lines.
5. What spectral type is the Sun? What is the Sun's effective temperature?
   - The Sun is a G star.
   - The Sun has a temperature of 5800 K.

Life of Low Mass Stars

1. What is the mass cutoff for a "low mass" star?
   - Low mass stars are any stars with a mass less than 3 times the mass of the Sun, so the Sun is considered a low mass star.
2. How does a low mass star spend most of its life?
   - Fusing hydrogen into helium in its core, staying on the main sequence.
   - The process of forming elements more complex than Hydrogen is refered to as nucleosynthesis
3. What is the PP Chain?
   - The process by which protons (ionized hydrogen) are fused into Helium nuclei to generate energy on the Main Sequence.
   - It begins and ends with two protons, hence the name.
   - In its most basic form (where noting that a superscript denotes number of particles,neutrons and protons, in the nucleus, and that a lone proton is ^1H):
   - $^1H +^1 H > (combine)^2He + energy$
   - $^2H2 > (decays)^2H + positron + neutrino$ (noting that ^2H is a hydrogen with a neutron, also known as deuterium)
   - $^2H +^1 H > (combine)^3He + energy$
   - $^3He +^3 He > (combine)^4He +^1 H +^1 H + energy$
4. What happens when a low mass star stops fusing hydrogen?
   - It moves off the main sequence and swells up into a red giant. It moves into the red giant branch of the HR diagram, then the asymptotic giant branch (AGB).
   - The outer shells of the star get thrown off and create a planetary nebula.
   - The core that is left behind becomes a white dwarf.
5. What is a white dwarf?
   - A white dwarf is the core of a low or intermediate mass star that is left behind after the star dies.
   - It is made up of either helium or carbon and oxygen.
   - It is supported against its own gravitational collapse by electron degeneracy pressure.
6. What is the maximum mass that a white dwarf can have? What is this mass called? What happens if this mass is exceeded?
   - 1.4 times the mass of the Sun.
   - This is called the Chandrasekhar limit.
   - If the Chandrasekhar limit is exceeded, the white dwarf collapses under its own weight into a neutron star or, if the mass is exceeded by enough, a black hole.
   - White dwarfs absolutely can *not* be more massive than 1.4 Solar masses! At the Chandrasekhar limit, gravity will always beat the electron degeneracy pressure that is trying to suppor the white dwarf.
   - More massive stars (greater than 1.4 solar masses) must lose mass in order to become a WD
7. What is the largest element a low mass star can fuse in its core?
   - Carbon or oxygen.

Life of High Mass Stars

1. What happens to a high mass star after the main sequence?
   - It's done fusing hydrogen in its core.
   - It begins fusing other elements in the core, from helium through carbon, oxygen, neon, magnesium, silicon, etc. all the way up to iron, the last element that you get energy from by fusing. As the core fuses heavier elements, it is surrounded by successive shells of lighter elements, like an onion
   - It enters the supergiant branch of the HR diagram.
   - When it can no longer fuse elements in the core (once it gets to iron), it explodes as a supernova.
   - It leaves behind either a neutron star or a black hole.
   - Though more massive stars have more fuel, they burn this fuel faster than low mass stars. Massive stars have shorter lifetimes.
2. What is a neutron star?
   - The core of a dead massive star that is so dense that no elements, protons, or electrons exist in it, just neutrons.
   - It is supported by neutron degeneracy pressure.
   - Since neutron stars are so massive, two neutron stars orbiting eachother should emit gravity waves.
3. What is a black hole?
   - A region of space with such an intense gravitational field that no matter or radiation can escape.
   - The radius of a black hole's gravitational power is called the Schwarzchild radius and is given by $r_s = \frac{2GM}{c^2}$. Within this radius, nothing can escape the black hole.
   - The Schwarzschild radius of solar-mass black hole would be 3km.

Cosmology and Dark Matter

1. What does a flat rotation curve of galaxies tell us?
   - Flat rotation curve means that galaxies have matter distributions that are roughly spherical, but we only see stars in a disk. Therefore, there must be dark matter making up the sphere.
2. What is the Big Bang Model?
   - The idea that the universe began in a very hot, dense state and then expanded drastically and cooled until what we see today.
3. What is the Hubble law?
   - The observation that galaxies that are far away from us are moving away from us faster than galaxies that are close to us.
   - The Hubble law basically states that the universe is expanding.
4. What do we mean when we say the universe is "expanding?"
   - Space between objects like galaxies is expanding, pushing the galaxies apart from each other. The galaxies themselves are not moving apart, it's just space getting bigger between them.
5. What is Olbers' Paradox? What is the resolution?

- If the universe is infinitely old and space an infinite distance, then the entire sky should be filled with stars.
- It's not, so either the universe isn't infinitely old or isn't infinitely big.
- The resolution is that the universe is not infinitely old. It began about 14 billion years ago with the Big Bang.

6. What is the 21-cm line and why is it useful for cosmology?
    - This is a spectral line of hydrogen that occurs when the hydrogen's electron spontaneously changes its spin from up to down.
    - It is useful for cosmology because all hydrogen emit this line, so we can use it to map where hydrogen is in the universe. Since hydrogen will cluster with other matter (like dark matter), we can then use it to figure out where dark matter is.

Telescopes

1. Why do we use telescopes?
    - The apparent brightness of distant objects decreases with the square of the distance to them, so distant objects are extremely faint.
    - If we can build something that stares at something for a long time and can collect as much light as possible from that thing, then maybe we can see it.
2. What is the difference between a refracting and a reflecting telescope?
    - Refracting: light is bent and focused by passing through glass lenses.
    - Reflecting: light is bent and focused by bouncing off of mirrors.
3. What happens when light passes through a lens?
    - Light travels slower in glass than in air, so the path of light gets bent at the interface between glass and air.
    - Red light doesn't get bent as much as blue light, so there can be **chromatic aberrations** where the image separates into a red image and blue image.
    - chromatic aberations can be eliminated by using a reflecting telescope.
    - This "bending" of light by altering its speed is used to focus a wide area of light down to a pinpoint.
4. Where is the best place to put a telescope?
    - Space! Then we don't have to deal with the Earth's atmosphere.
    - If we can't put a telescope in space, then any place where the atmosphere doesn't cause as many problems: dry, high, dark places.
5. How does the power of a telescope scale with its diameter?
    - Power $= \pi(D/2)^2$, where D is the diameter. So doubling the diameter will quadruple ($2^2 = 4$) the power.
6. What is the purpose of a telescope's eyepiece?
    - To magnify the focused image. The telescope itself does not magnify anything.

7. List a few of the important telescopes in use today.

    - Keck: Largest optical telescope with a 10 meter diameter, in Hawaii.
    - Large Binocular Telescope (LBT): Owned by OSU, has two 8 meter mirrors, in Arizona.
    - Hubble Space Telescope (HST): 2.4 meter, but huge advantage because it's in space and doesn't have to see through the atmosphere.
    - Arecibo: In Puerto Rico, 1000 foot radio telescope.