Astronomy 1140 Quiz 3 Review

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I Hertzsprung-Russell Diagram and Luminosity Relations

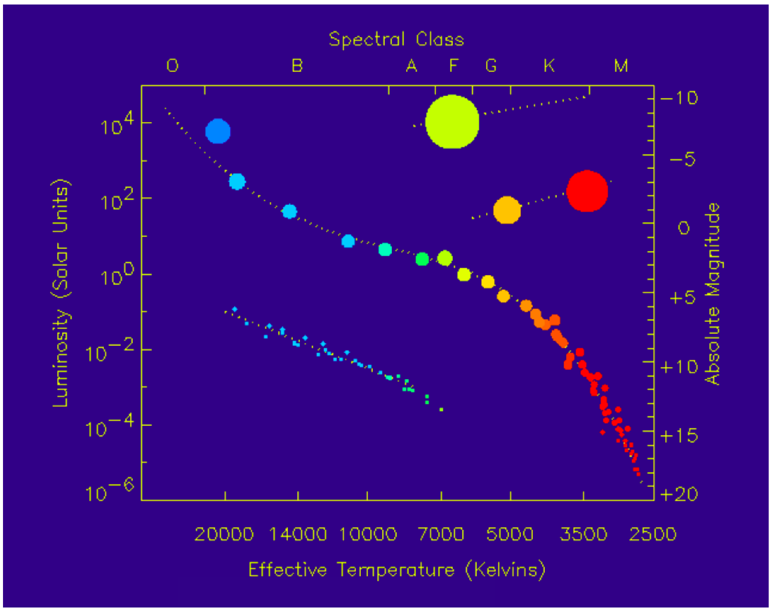

Figure 1: The Hertzsprung-Russell diagram. Note that temperature increases to the left. The line through the middle is the main sequence, the lower line is the white dwarf sequence, and the lines in the upper right are the red giant and supergiant sequences (supergiant is on top).

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.

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.
   • They are stars that have puffed up (larger radius and cooler, but still more luminous than they were as Main Sequence stars) after fusing all the hydrogen in their cores. Later lifetime stage of stars.

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 the temperature, and σ the Stefan-Boltzmann constant.
   • Note that a star's luminosity is independent of how far away it is; it is an intrinsic property of the star!

6. How does a star's apparent brightness relate to its luminosity?
   • $F = L/(4\pi d^2)$, where F is the flux, or relative brightness, L the luminosity, and d the distance to the star.

7. What is the distance modulus?
   • $m - M = 5log(\frac{d}{10pc})$, where m is the apparent magnitude, M 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, light years, or meters!
   • This formula holds because the distinction between apparent 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 or 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 pulsational 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 what they are, Cepheids are stars that are in the instability strip after moving off of the main sequence.

   • The longer the period of a Cepheid, the larger its luminosity!

II 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.

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 (note: has nothing to do with planets, that's just the name!).

• The core that is left behind becomes a white dwarf, essentially the exposed core of the star that slowly cools itself off without generating new energy through fusion.

5. 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 from gravity into a neutron star or, if the mass is exceeded by enough, a black hole. This means that white dwarfs absolutely can not be more massive than 1.4 Solar masses! At this point, gravity will always beat the electron degeneracy pressure that is trying to support the white dwarf!

6. What is a white dwarf?

• A white dwarf is the core of a low-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.

7. What is the largest element a low mass star can fuse in its core?

• Carbon or oxygen.

III 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 becomes heavier elements, it is surrounded by successive shells of lighter elements.

• 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, which generates many of the heavier elements in the universe.

• It leaves behind either a neutron star or a black hole.

2. What is a neutron star?

• The core of a dead massive star that is so dense that no elements exist in it, just neutrons.

• It is supported by neutron degeneracy pressure.

IV 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 big, 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.

V 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 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 betn as much as blue light, so there can be **chromatic aberrations** where the image separates into a read image and s blue image.

• 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 palace to put a telescope?

- Space! Then we don't have to deal with the Earth's atmosphere, which absorbs most UV light.
- If we can't put a telescope in space, then any place where the atmosphere doesn't cause many problems: dry, high, dark palces.

5. How does the power of a telescope scale with its diameter?
    - Power $= \pi(\frac{D}{2})^2$, where D is the diameter of the objective lens/mirror. So doubling the diameter will quadruple ($2^2 = 4$) the power. Ignoring atmospheric distortions, a telescope's usefulness is dictated by the power, so size is key.

6. What is the purpose of a telescope's eyepiece?
    - To magnify the focused image. The telescope itsself does not magnify anything.

7. List a few 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 throgh the atmosphere.
    - Arecibo: In Puerto Rico, 1000 foot radio telescope.