Material for test 2

Things I want you to know:

I) How do we know what we know about stars? This is the checklist. **These are the *tools* we use to understand stars.**

a) How hot are stars? Generally, color; blue=hot, red=cooler. Specifically, we can use Wien's Law: $T = 2.9x10^6/\lambda_{Max}$

b) How big are stars? From eclipsing binaries or parallax.

c) How massive are stars? From binary stars only (using gravity)

d) What are stars made of? We use absorption lines to know this. They are about ¾ H, ¼ He, and a smidge of 'metals' which is everything else.

e) How much energy do stars emit? Luminosity, related to temperature and size: $L \sim R^2T^4$

f) Where does the energy come from? Mostly from fusion of H → He, but other stages have other energy sources.

g) How far away are stars? Really, really, really far away. We use Parallax and eclipsing binary stars to determine this.

II) What makes stars different from one another? **This is what we've learned by using the tools.**

A) Intrinsically: Mass and evolutionary stage only!

a) Mass:

1) More massive stars are blue, are brighter, and evolve faster.

2) Less massive stars are redder, evolve slower, and unless they are on the giant branch, they are fainter.

3) On the main sequence we can determine luminosity and lifetime:

$L_{MS}= M^{3.5}$ (answer in L_{Sun})

$t_{MS}=1x10^{10}/M^{2.5}$ (answer in years)

b) Evolutionary stage: The flow chart of stellar evolution.

1) Stars of different mass ranges have different paths.

2) Stars at different evolutionary stages use different sources of energy for support against collapse.

B) Extrinsically: How we view them: Their brightness depends on 3 things:

1) Temperature (color),

2) size (radius), and

3) distance.

So if we know 2 of those things, we can determine the third based on brightness. This allows us to compare stars in pictures to one another.

C) We examine properties of stars using the HR diagram.

1) We can determine ages for groups of stars by the length of the main sequence. Shorter main sequences are older because the blue stars have evolved off already.

2) Different stages of evolution appear in different locations on the HR diagram.

D) Stars have 'populations' based on fraction of 'metals' present.

Population I: Have metals >0.1% (the most metal-rich star known is about 4%, though most Pop I stars have 1-2%)

Population II: Have metals >0 and <0.1%

Population III: No metals at all.

E) All stars are made in groups. (Types not important here.)

III) How do stars behave (evolve)

1) Stars evolve. They have to because they are emitting energy, which means using fuel, which has a limited supply.

2) Stars have to constantly counter gravity, since gravity is always pulling towards their centers (trying to collapse them).

IV) End products of stars (all stars end up somewhere)

a) White dwarf: All stars with main sequence masses <8 M_{Sun} This is 98% of all stars.
- about the size (radius) of the Earth-size
- support is electron degeneracy pressure. Requires no energy generation.
- about 0.6 M_{Sun} on average. Maximum mass of 1.4 M_{Sun}
- If their mass goes over 1.4 M_{Sun}, they explode.

b) Neutron stars: All stars with main sequence masses between 8 and 25 M_{Sun}
- about the size of a city (Radius ~10-20 km)
- average mass of 1.4 M_{Sun}, Maximum mass around 2.5 M_{Sun}
- support is neutron degeneracy pressure. Requires no energy generation.

c) Black holes: All stars with main sequence masses >25 M_{Sun}
- No support mechanism that we know of. Material collapses to the center.
- Size is the Schwarzchild Radius (also called an event horizon) inside of which nothing gets out, not even light. $R_{Sch}=3M$ (answer in kilometers for masses in solar units)

V) Energy sources

a) Fusion: Only main sequence (H $\rightarrow$ He) and horizontal branch (He $\rightarrow$ C)

b) Gravity: Protostars (pre-main sequence), red giant & AGB stars (both red and giant)

Note: degeneracy pressure is NOT an energy source. White dwarfs (electron) and neutron stars (neutron)