PHY 474/374 **Spring 2021**

Week 7—Wednesday, May 12—Discussion Worksheet

Post Main Sequence Evolution

At the end of the Main Sequence stage, the star is left with a core of helium and a small amount of heavy elements. All the hydrogen that used to be in it has fused into helium.

1. At the end of the Main Sequence phase, the temperature of the helium core is not high enough for helium fusion to begin.

(a) If He fusion cannot be initiated, what will happen in the core (in principle)?

Core will contract

The thermal energy leads to ↑ in core temp

It will eventually Become degenerate

(b) Discuss what happens differently in a star from your prediction in part (a)?

Contraction is due to gravity

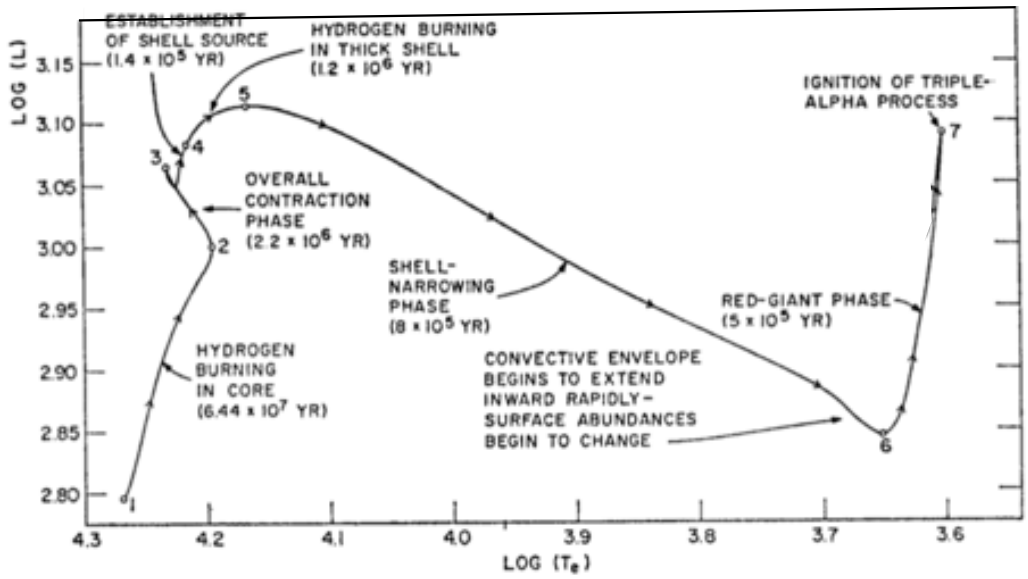
(c) Discuss what Dalsgaard means by the shell-burning law.

temperature in this region is still high enough to

Burn hydrogen, this ↑ mass of inert helium core

↑.

2. Consider the HR diagram of a 5 $M_\odot$ star shown below.



(a) Use the numbers marked in the figure to pick out which part most closely resembles your answer in Question 1(a). How do L and T_e (effective temperature, i.e., surface temperature) change as a result of this?

2. Temperature initially ↓ as the luminocity continues to ↑

(b) What happens past the stage discussed in part (a) above. How do L and T_e change as a result of this?

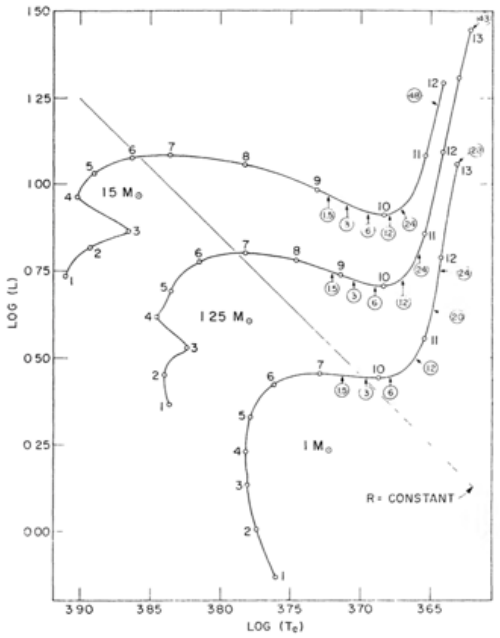
Temp ↑ luminocity will top out

3. Consider now the evolutionary paths for stars of mass 1 $M_\odot$, 1.25 $M_\odot$, and 1.5 $M_\odot$ respectively. The time spans between the numbers marked in the plot is shown on the left hand side.

TABLE 1

EVOLUTIONARY LIFETIMES (10^9 yr)

Point	1 $M_\odot$	1 25 $M_\odot$	1 50 $M_\odot$
1 .	0 05060	0 02954	0 01821
2	3 8209	1 4220	1 0277
3	6 7100	2 8320	1 5710
4	8 1719	3 0144	1 6520
5	9 2012	3 5524	1 8261
6 .	9 9030	3 9213	1 9666
7	10 195	4 0597	2 0010
8		4 1204	2 0397
9	.. ...	4 1593	2 0676
10	10 352	4 2060	2 1059
11	10 565	4 3427	2 1991
12	10 750	4 4505	2 2628
13	10 875	4 5349	



(a) Discuss how these tracks are similar and different from each other. Include in your discussion the time spans listed in the table.

1 $M_\odot$ does not have electron phase

(b) Discuss how the 1 $M_\odot$ evolutionary track is similar to and different from the 5 $M_\odot$ track.

1 $M_\odot$ The 1 to 2 point takes longer as well as Points 2 to 5

4. Helium fusion takes place through the triple-α process:

$$3\ {}^4\mathrm{He} \rightarrow {}^{12}\mathrm{C} + \gamma$$

(a) Since there is very little probability that three He will come together at the same time, the triple-α process occurs via the following chain:

$${}^4\mathrm{He}\,({}^4\mathrm{He},)\,{}^8\mathrm{Be}\ ({}^4\mathrm{He},\gamma)\ {}^{12}\mathrm{C}$$

Write out the reactions in full.

Time scale is very short

$$\begin{cases} {}^4He + {}^4He \rightarrow {}^8Be \\ {}^8Be + {}^4He \rightarrow {}^{12}C + \gamma \end{cases}$$

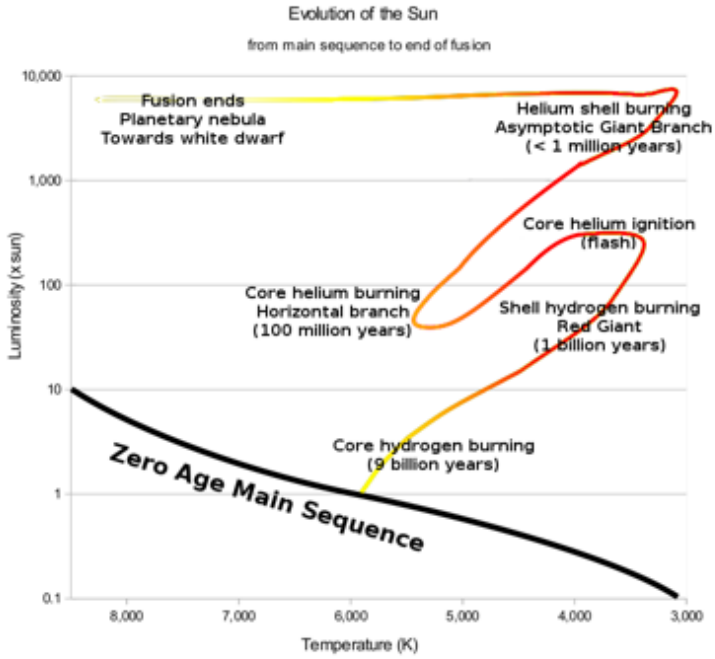
(b) The energy generation rate is given by

$$\epsilon = \epsilon_0\, \rho^2\, Y^3\, T^{30}$$

Explain why the energy generation rate is proportional to Y, rather than [redacted].

It is the Helium Reaction that matters
Not the Hydrogen

5. Use the figure below (source: UNLV) to discuss the subsequent stages of evolution of a Sun-like star.



Starting From Zero Age Main Sequence

→ Start with hydrogen core

→ Shell hydrogen

→ Elemental change, Helium core

→ Helium shell, Elemental change

→ Life end as a Dwarf Star