

# ASTR 401/501: “Stellar Astrophysics”

Fall 2006

Final Exam

Note on Grading:

Undergraduate students will be graded on a scale of 0 – 90 Pts.

(i.e., 90 points = 100 %).

Some useful constants:

$$h = 6.626 \cdot 10^{-27} \text{ ergs s}$$

$$k = 1.38 \cdot 10^{-16} \text{ ergs K}^{-1}$$

$$\sigma = 5.67 \cdot 10^{-5} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ K}^{-4}$$

$$a_0 = 0.529 \text{ \AA}$$

$$\frac{e^2}{2a_0} = 13.6 \text{ eV}$$

$$1 \text{ eV} = 1.6 \cdot 10^{-12} \text{ ergs}$$

$$1 \text{ AU} = 1.5 \cdot 10^{13} \text{ cm}$$

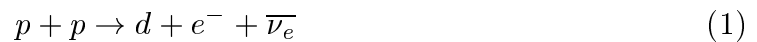
$$L_{\odot} = 3.8 \cdot 10^{33} \text{ ergs s}^{-1}$$

$$M_{\odot} = 2 \cdot 10^{33} \text{ g}$$

$$M_{\text{Bol},\odot} = 4.76$$

$$T_{\text{eff},\odot} = 5,770 \text{ K}$$

1) The pp chain is predominantly going through 3 steps:



a) What is the characteristic temperature required for the complete pp chain to ignite under typical conditions of a solar-mass star near the beginning of its main-sequence life?

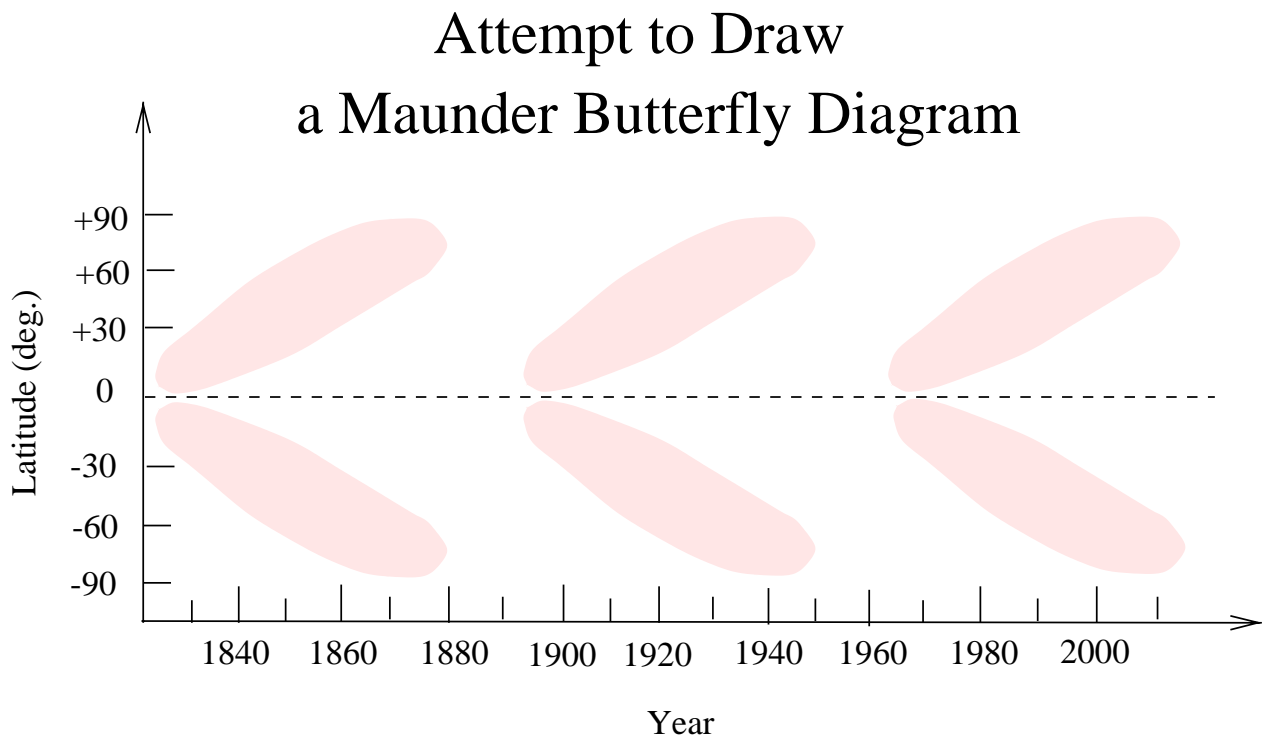
[2]

- b) Which of the three steps of the pp chain requires the lowest, which requires the highest temperature to be ignited? Give a brief, qualitative explanation for your answer.

[8]

- c) Sketch a plot of the  ${}^3\text{He}$  abundance as a function of radius in the solar interior, and relate this to your answer to part b).

[6]



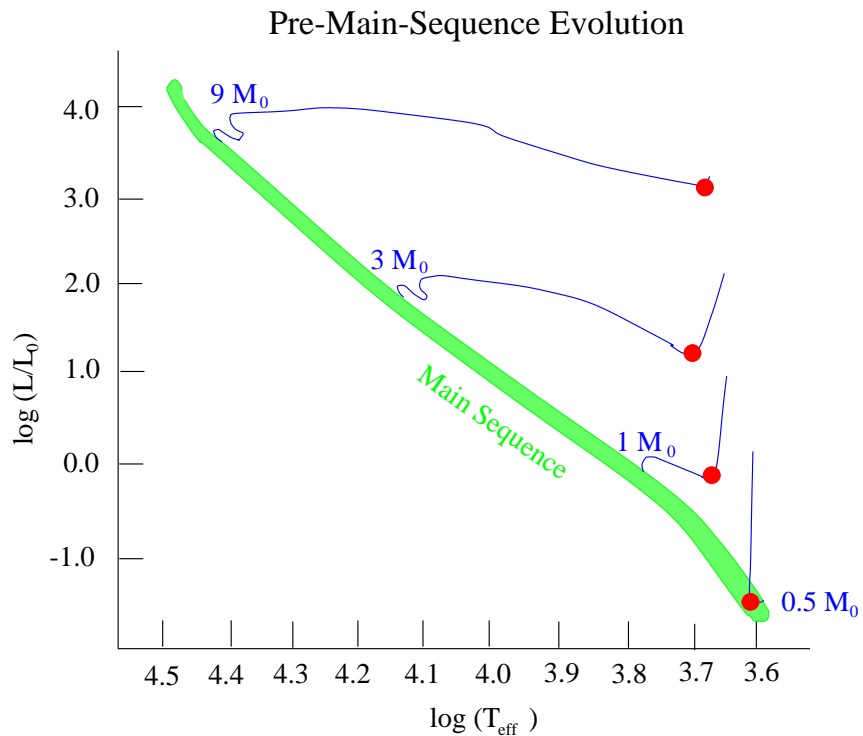
- 2) Assume that somebody who did obviously not pay attention in this class, tried to sketch the Maunder Butterfly Diagram above. Identify 4 crucial mistakes in it, and describe how the correct diagram should look instead.

[12]

3)

- a) Explain qualitatively why a  $100,000 M_{\odot}$  giant molecular cloud does not collapse to one single, giant star of thousands of solar masses? Name the astrophysical process that prevents this from happening.

[6]

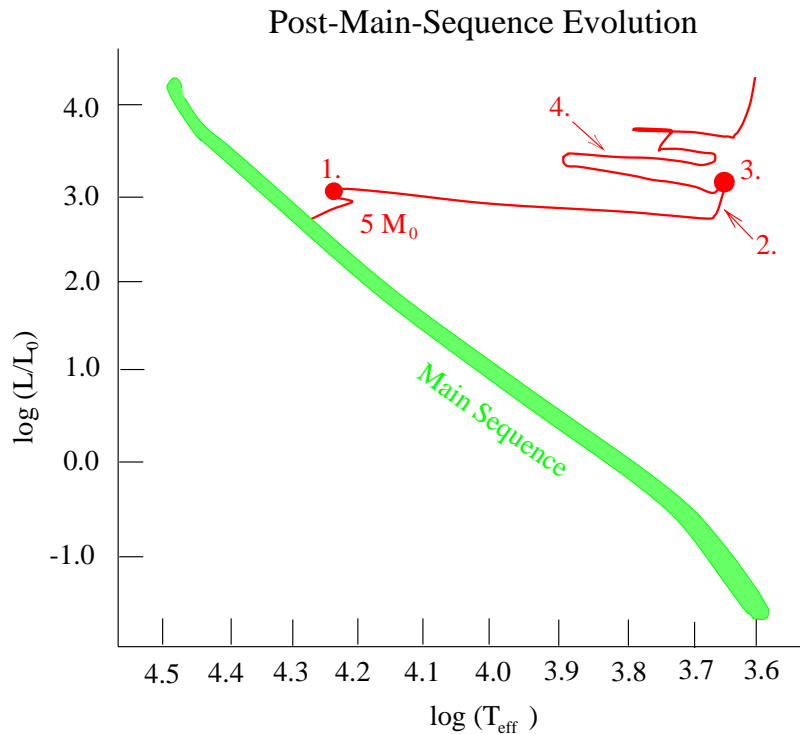


- b) In the sketch of the pre-main-sequence evolution of representative stars above, what happens at the points marked by the red dots? Why is the leftward shift so much larger for high-mass stars than for low-mass stars?

[6]

- 4) An O5V star with surface temperature of  $T_{\text{eff}} = 44,000 \text{ K}$ , located within a GMC with an average density of  $n = 10^3 \text{ cm}^{-3}$ , is producing a Strömgen sphere with Strömgen radius  $R_s = 1.4 \text{ pc}$ . Using a recombination coefficient of  $\alpha_{\text{rec}} = 3 \times 10^{-13} \text{ cm}^3 \text{ s}^{-1}$  and assuming that the star is emitting all of its photons at the wavelength  $\lambda_{\text{max}}$  according to Wien's displacement law, calculate the luminosity of the star.

[12]



5) In the sketch of the post-main-sequence evolution of a  $5 M_{\odot}$  star, explain what happens on the numbered track segments / points.

[12]

6) Explain how

a) Hertzsprung-Russell Diagrams of star clusters

[5]

b) monitoring observations of Cepheid variables

[5]

can be used as distance indicators.

7) Concerning the phenomenon of He flashes, answer the following specific questions.

a) In which stage of stellar evolution do He flashes occur?

[3]

b) Are all stars expected to evolve through a He flash phase? If not, what kind of stars would or would not, respectively?

[6]

- c) Which regions within the interior of the star are interacting to cause He flashes?  
[4]
- d) What is the characteristic repetition time scale for He flashes in  $\sim 5 M_{\odot}$  stars (to within  $\sim 1$  order of magnitude)?  
[3]
- 8) Assume you observe a supernova that shows strong Balmer lines in its spectrum.
- a) What type of supernova is this?  
[2]
- b) What is the approximate mass limit on the progenitor star of this supernova, and what is the mechanism (core-collapse of a massive star vs. a white dwarf exceeding the Chandrasekhar limit via mass accretion)?  
[4]
- c) Sketch a characteristic light curve of such a supernova.  
[4]