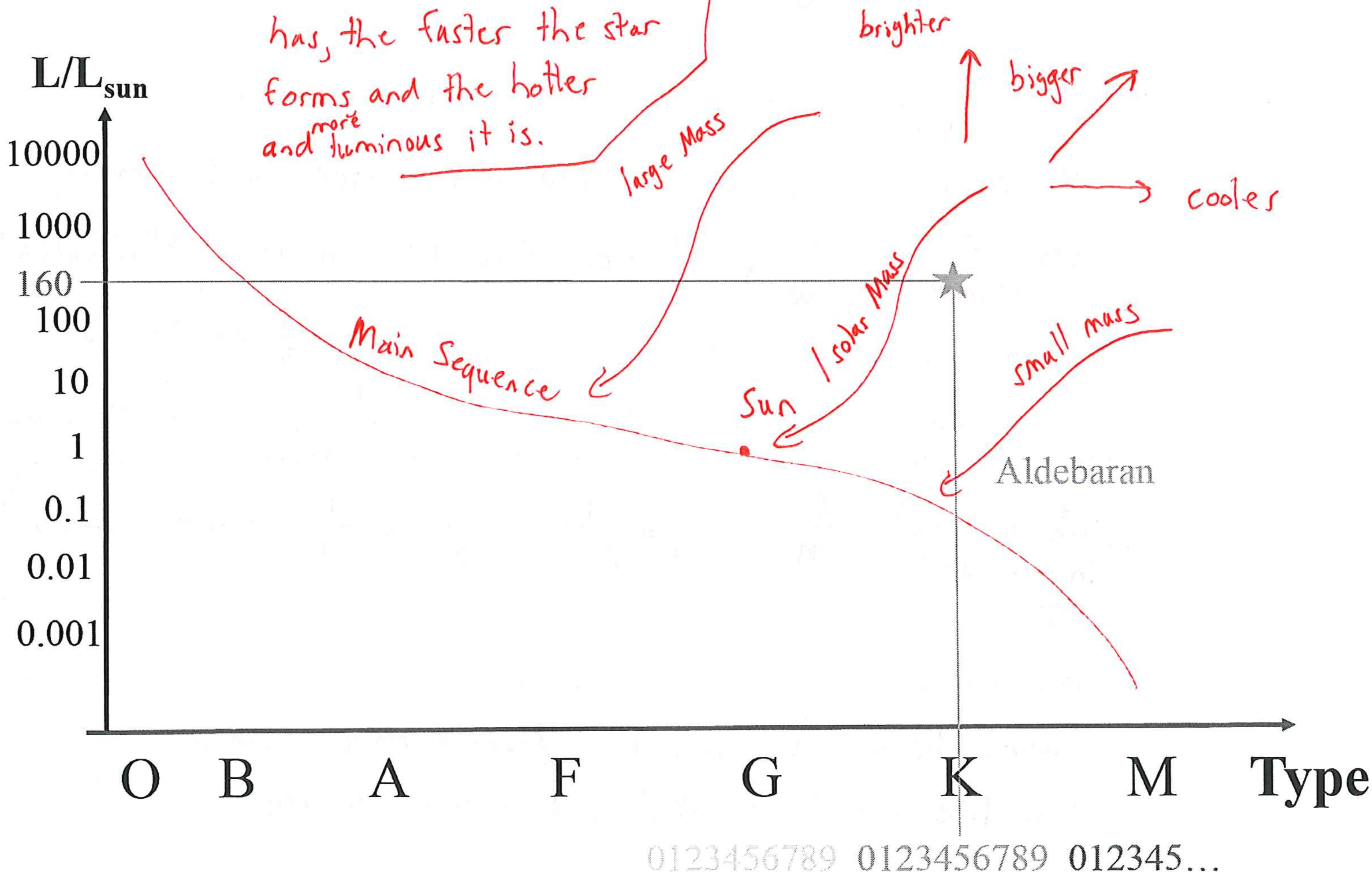
INST 2403 Activity

Early Stellar Life

Here is a very short description of stellar formation. Stars form when a stellar gas and dust cloud contracts under its own gravitational force. As it contracts it becomes denser and smaller while heating up. The center of the collapsing gas cloud eventually becomes so hot and dense that light atomic nuclei (the hydrogen nucleus is but a proton) will bump into each other so forcefully that they can "stick together" and form more complex nuclei. The mass difference between the ingredients and the products of this nuclear reaction is converted into energy. This process is called nuclear fusion and the source of the energy radiated by stars.

1. Draw the main sequence into the Hertzsprung-Russell diagram below.
2. Argue with the Stefan Boltzmann law (luminosity depends on size and temperature) to draw the formation tracks of three stars into the HRD as they develop from a large interstellar gas cloud. One of the stars has a mass bigger than the sun, one has the same mass, and one has a smaller mass.
3. How does the initial mass of the gas cloud influence the formation process and the outcome?

The more mass the cloud has, the faster the star forms and the hotter and more luminous it is.



4. How do stars produce energy? Briefly describe hydrogen fusion.

4 hydrogen nuclei collide, stick together to form a more complex, heavier nucleus of helium.

But $4m_H > m_{He}$, so energy is freed in this process

5. The star Betelgeuse radiates 120,000 more energy per second than the sun. What does this say about the rate at which fusion happens at its core?

Betelgeuse has to convert hydrogen to helium 120,000 x as fast!

6. What is the consequence for the life expectancy of Betelgeuse?

→ Life should be 120,000 x shorter for Betelgeuse

7. Betelgeuse has about 8 times the mass of the sun. How does this influence its life expectancy?

More mass to go though → longer life.

8. The sun has a life expectancy of about 10 billion years = 10,000 million years. Estimate Betelgeuse's life expectancy.

8 x longer due to mass, 120,000 x shorter due to luminosity

⇒ $\frac{8}{120{,}000} = \frac{1}{15{,}000}$ x shorter than the sun, so $\frac{10 \text{ billion}}{15{,}000}$

= 666,000 yrs

⇒ less than a million years!

9. For *main sequence* stars, the *mass-luminosity relation* posits that the luminosity is proportional to the mass of the star to the 3.5th power: $L = k\,M^{3.5}$. For simplicity, let's assume the constant is $k = 1$. Use this information to figure out the life expectancy of a main sequence star with a mass 8 times bigger than the sun's.

$$\left(\text{life expectancy in solar life exp.}\right) = \frac{M}{L} = \frac{M}{M^{3.5}} = \frac{1}{M^{2.5}} = \frac{1}{8^{2.5}} = \frac{1}{181} = 0.0055 = 0.55\%$$

10. Is Betelgeuse a main sequence star? Why or why not?

Cannot be main sequence, b/c it would have a ridiculously low life expectancy of less than a million yrs.