Hw 8

Astron 715
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A1

The Schonberg-Chandrasekhar limit is an upper limit to the core-mass of an isothermal non-fusing core with a surrounding envelope. A star will have an isothermal core if it is massive enough to avoid becoming degenerate, $M > 1.5\,M_\odot$, and not too massive so that fused He is inert (non-fusing), $M < \sim 6\,M_\odot$. If the core mass exceeds this upper limit of about 10% the stellar mass, the core will collapse.

A2

The mass of the outer envelope ditctates the upper limit to the isothermal core mass. The limit is a fraction of the initial stellar mass, $\frac{M_{core}}{M_*} \sim 0.1$. Once the core mass reaches the SC limit, the core begins a thermal collapse. The core will establish a temperature gradient which will cause heat flow out of the core. The core will continue collapsing in near hydrostatic equilibrium. The thermal timescale for the core is very short compared to the other phases of the star's lifetime, leading to a gap in the HR diagram which is a snapshot of a stellar population at various ages.

A3

High-mass OB stars do not build up isothermal cores. Instead they fuse He immediately when He falls to the core. The nuclear timescales are much longer than the thermal timesscales. The OB stars will populate the HR diagram in a more smooth distribution because they do not undergo a thermal core collapse.

B1

Red clump stars are a metal-rich counterpart of a horizontal branch star. A red clump star has a He burning core and an H burning shell and inert H envelope, while a HB star has only an He burning core and inert H envelope. Because RC stars are metal-rich, their opacities will be much dominated by bound-free and bound-bound transitions which will lead the star to balance its envelope at a particular size and temperature. This will correspond to a particular luminosity. These high-metal massive stars will thus clump together on the HR diagram. HB stars however, are much less opaque, and thus are smaller and hotter. The temperature of a HB star will be much more sensitive to the He core mass.

B2

The M2 Iab supergiant Betelgeuse is thought to be a Red Super Giant (RSG) with about $M \sim 20\,M_\odot$ (Dolan et al. 2014). The models used to determine the evolutionary state and mass of Betelgeuse depend heavily on the abundance ratios of C, He, N, Li and Be. Dredge ups will occur for different mass stars at different stages of evolution, leading to a unique surface composition of each stage. We propose to observe Betelgeuse with the WIYN bench spectrograph with λ - coverage from 300 - 1000 nm. We will establish abundances of C, He, N, Li, and Be. If $^{12}C/ {}^{13}C$ and C/N ratios are lowered, the star has undergone its first dredge-up on the RGB stage. If over-abundances of He and s-process elements are found, the star has undergone a second dredge-up and is an AGB star. If abundant ^{4}He and ^{14}N are found, whereas the amount of ^{12}C and ^{16}O decreases, the star is a 4-8 solar mass star is in the Red Supergiant phase.

B3

At the end of high-mass MS lifetime, significant H shell burning and He core burning will cause the star to expand to a red super giant. A red super giant is unstable and will shed its outer layers. The star will then move back to a blue super giant. This process of expansion and contraction between the BSG and RSG will recurr. An observation of L and temperature of a yellow supergiant cannot establish whether the star is going from the BSG to the RSG or the RSG to the BSG.

C1

The dust formation

$\kappa \sim 50\ \mathrm{cm}^2\, g^{-1}$
$\sigma \sim 50\ \mathrm{cm}^2$

The Eddington luminosity is given by

$$L_{\mathrm{edd}} = \frac{4\pi G M c}{\kappa}$$

and the ratio L/M above which a star is unbound is

$$\frac{L_{\mathrm{edd}}}{M} = \frac{4\pi G c}{\kappa} = 500\ \mathrm{erg}\ s^{-1}\, g^{-1}$$

L_{edd} for a 3 $M_{\odot}$ star is ~ 1,000 $L_{\odot}$. AGB stars of this mass may reach this luminosity at the end of their lifetime when they are shedding off layers. This implies that AGB stars are unstable.

C2

A RSG star's main source of opacity will be ionized H, thus we can use the thompson cross section to calculate L_{edd}.

$$L_{\mathrm{edd}} = \frac{4\pi G m_p c}{\sigma_T} \sim 7 \times 10^4\ L_{\odot}$$

This implies that RSG stars will not be as unstable as AGB stars and retain their mass.

C3

The luminous blue variable stage will experience the most mass loss. The star will expand due to He and beyond core fusion. The outer layers will cool off. Once a layer reaches ~10,000 K, e^- will bind with H, leading to a large increase in opacity as bound-free opacity. This suddenly opaque layer will be pushed away from the star.

```
G = 6.67*10^-8;
c = 3*10^10;
κ = 50;
LMratio = 4 π * G * c / κ
L = 4 π * G * c / κ * 3 * 1.9 × 10^33
```

```
In[26]:= mp = 1.9 × 10^-24;
σ = 6.65 × 10^-25;
L = 4 π * G * c * mp / σ

Out[28]= 71 843.7
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