

Ay123 – Fall 2007

STELLAR STRUCTURE AND EVOLUTION

Problem Set 7

Due Wednesday, November 28, 2007

1. (5 pts) Provide a flow chart for a program that computes model stellar atmospheres under the classical simplifying assumptions discussed in class. Your flow chart should contain at least 10 and not more than 25 subroutines. Provide a brief (2 sentences maximum) description of the function of each of the subroutines in your program. List the input and output variables for each of your subroutines.

2. (10 pts) We are considering an intermediate mass star in the superwind phase rapidly losing its envelope. Its mass when this phase begins is $5 M_{\odot}$. The mass loss rate is episodic, we take it to be $10^{-4} M_{\odot}$ per year for 5,000 years, then 5,000 years with mass loss rate $10^{-8} M_{\odot}$ per year. This cycle repeats 4 times, after which most of the envelope is lost, and the residual star becomes very hot with a very high flux in the ultraviolet. The mass is lost from the surface, assumed to be at $20R_{\odot}$, and consists of pure H.

a) What is the escape velocity from the surface of this star at the beginning of the superwind phase ?

b) Assume the ejection velocity is 10 km/sec, and the mass lost coasts out at that velocity with no further acceleration or deceleration. Plot the surface density as a function of r outward from R_* at a time 5,000 years after the fourth episode of mass loss ended. What is the mass of the star itself after the 4 superwind ejection phases ?

b) Plot the expected emission surface brightness for a recombination line formed by the

radiative cascade after an ionized H atom captures an electron. Clearly indicate the assumptions you have made in your calculation.

3. (a) (10 pts) Consider a $0.6 M_{\odot}$ carbon-oxygen white dwarf. In class we derived a cooling rate for white dwarfs, $d(T_c)/dt$ as a power of T_c , where T_c is the temperature of the approximately isothermal core. We also derived a relationship between the emitted luminosity and T_c . From this derive T_c as a function of time. Then use the mass – radius relation for white dwarfs (ignore the thickness of the radiative envelope) to derive the effective temperature of the white dwarf surface as a function of time.

(b) (15 pts) We are studying a cluster of 10^6 stars all of which formed in a single burst of star formation 10 Gyr ago and all of which have the the Solar composition. (The last part is unrealistic, they would be metal poor.) Assume all stars are single, ignore binaries.

We assume the stars in this cluster are formed in accordance with the Salpeter initial mass function, $n(M) = AM^{-(1+x)}$, where $x = 1.35$ and A is a normalization constant. We adopt as lower and upper limits for star formation of 0.1 and $100 M_{\odot}$. Assume that all stars with $M > 8M_{\odot}$ have become supernovae. Assume that all phases of stellar evolution after the main sequence, except for the white dwarf phase, last such a short time that we can ignore them. Assume all white dwarfs have the characteristics of those discussed in part (a) of this problem.

How many SNII have there been in this cluster up to the present ? At the present time, how many white dwarfs are there ? How many stars are still on the main sequence ? What is the fraction of the original mass which is now in main sequence stars ?

Construct a luminosity function for the white dwarfs.

Construct a HR diagram (L vs. T_{eff}) for the white dwarfs and also plot on it the main sequence for this cluster, both as would be seen today at a cluster age of 10 Gyr.