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Astro 531: Stellar Interiors
May 16, 2018

Homework 3

All calculations can be found in the notebook
`https://github.com/meredith-durbin/ASTR531/blob/master/HW4/HW4.ipynb`.

19.2 (a) Assuming no stellar wind and that the change in envelope mass is entirely due to shell fusion, the total energy released should be $E = (M_{\rm end} - M_{\rm start})c^2$, and the timescale should be $E/L_\star$. This gives a timescale of about 4 Myr, which is about a thousand times too long.

(b) The winds of planetary nebulae have velocities consistent with a post-AGB wind.

(c) Assuming this time that the change in envelope mass is only due to mass loss, this time I get crossing times of 1.35×10^6, 1.35×10^5, and 1.35×10^4 years respectively.

20.2 (a) The luminosity of a white dwarf is dependent on mass, $\mu_{\rm ion}$, and cooling time. If we only vary $\mu_{\rm ion}$, then the ratio of luminosities is $(4/1)^{-7/5}$ for He vs. H, and $(6/1)^{-7/5}$ for C vs. H. This means that the He-rich white dwarf will be 0.14 times as bright as the H-rich one, and the C-rich one will be 0.08 times as bright.

(b) The luminosity of a WD is due to cooling, which is dependent on the thermal energy of the ions. Heavier ions have higher specific heat and thus less energy available for cooling.

21.3 The RGB star would have the shorter fundamental period, as period is proportional to dynamical timescales and AGB stars have much longer dynamical timescales due to their lower density.

23.1 (a) The star is on the main sequence while it is fusing hydrogen in the core. The horizontal movement across the HRD happens on such a short timescale that it is barely visible in the diagram, between 12 and 12.4 Myr. The rest of the time is spent as a red supergiant, where it fuses hydrogen in a shell, and initially fuses helium in the core and then eventually moves to helium shell fusion and then core C-fusion.

(b) During hydrogen fusion, the star appears to lose a total of 0.2 $M_\odot$ over a period of about 12.15 Myr, so the mass loss rate is 1.65×10^{-8} $M_\odot$/year.

During helium fusion, the star appears to lose a total of 2 $M_\odot$ over a period of about 1.5 Myr, so the mass loss rate is 1.3×10^{-6} $M_\odot$/year.

(c) Our estimate of the main sequence mass loss is slightly lower than what is stated in the chapter 15 summary (10^{-7} to 10^{-5} $M_\odot$/year). For the core He fusion phase, the Reimers relation predicts a mass loss rate of 1.1×10^{-6} $M_\odot$/year assuming a log luminosity of 4.8 $L_\odot$ and radius of 665 $R_\odot$, which is almost spot on.