

ASTR 531 - Stellar Interiors and Evolution

Problem Set 3

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12.2 - Early Radii and Timescales

Part a - Radii Estimations

Let's use a couple of different relations from the textbook to get the radii at different times. A protostar becomes ionised and starts the Hayashi concentration phase when it's radius is on the order of (Eq. 12.13)

$$R_{\text{Hayashi,start}} \approx 100 R_{\odot} \left(\frac{M}{M_{\odot}} \right) \quad (1)$$

We find the radius of the protostar once the Hayashi concentration phase comes to an end is approximately a factor of 50 lower (based on assumptions of the temperature and opacity) such that (page 12-8)

$$R_{\text{Hayashi,end}} \approx 2 R_{\odot} \left(\frac{M}{M_{\odot}} \right) \quad (2)$$

The radius at the start of the PMS phase will be the same as the end of the Hayashi concentration phase.

$$R_{\text{PMS,start}} = R_{\text{Hayashi,end}} \quad (3)$$

Finally, the radius at the end of the PMS phase is the same as the radius at ZAMS and so we can write that (Eq. 12.16)

$$R_{\text{PMS,end}} = R_{\text{ZAMS}} = R_{\odot} \left(\frac{M}{M_{\odot}} \right)^{0.7} \quad (4)$$

So now we can plug in numbers for the different masses of stars that we considered

M/M_{\odot}	$R_{\text{Hayashi,start}}/R_{\odot}$	$R_{\text{Hayashi,end}}/R_{\odot}$	$R_{\text{PMS,start}}/R_{\odot}$	$R_{\text{PMS,end}}/R_{\odot}$
0.3	30	0.6	0.6	0.43
3	300	6	6	2.16
30	3000	60	60	10.8

Part b - Timescale estimations

The duration of the Hayashi concentration phase is given in Eq. 12.15 but we also showed that the timescale scales as $1/M$ such that

$$\tau_{\text{Hayashi}} \approx 10^6 \text{ yr} \left(\frac{M_{\odot}}{M} \right) \quad (5)$$

The duration of the PMS phase is given by Eq. 12.17 so we have that

$$\tau_{\text{PMS}} \approx 6 \times 10^7 \text{ yr} \left(\frac{M}{M_{\odot}} \right)^{-2.5} \quad (6)$$

So now we can plug in numbers for the different masses of stars that we considered

M/M_{\odot}	$\tau_{\text{Hayashi}}/\text{yr}$	$\tau_{\text{PMS}}/\text{yr}$
0.3	3.33×10^6	1.22×10^9
3	3.33×10^5	3.85×10^6
30	3.33×10^4	1.22×10^4

15.4 - Metallicity and Mass Loss Rates

16.1 - RGB Radii

17.1 - Helium Flash Duration
