General Astronomy HW4

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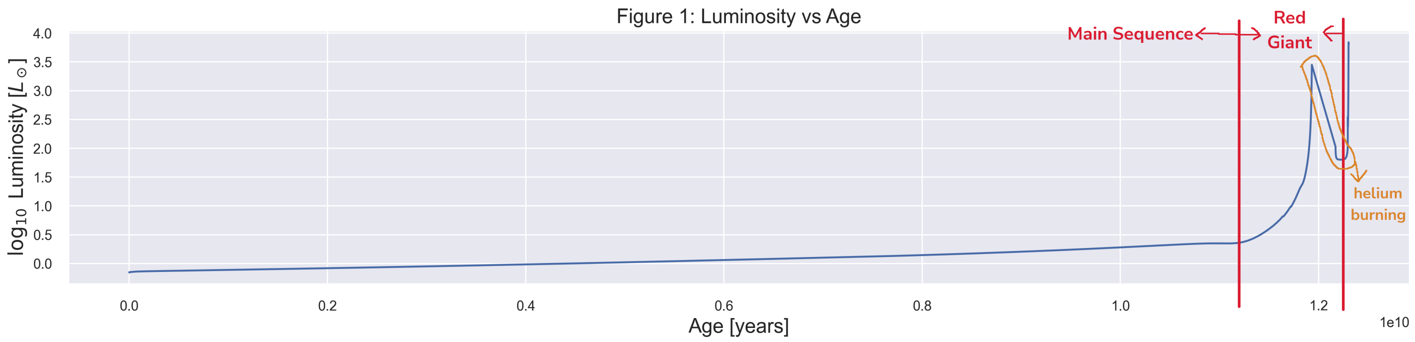
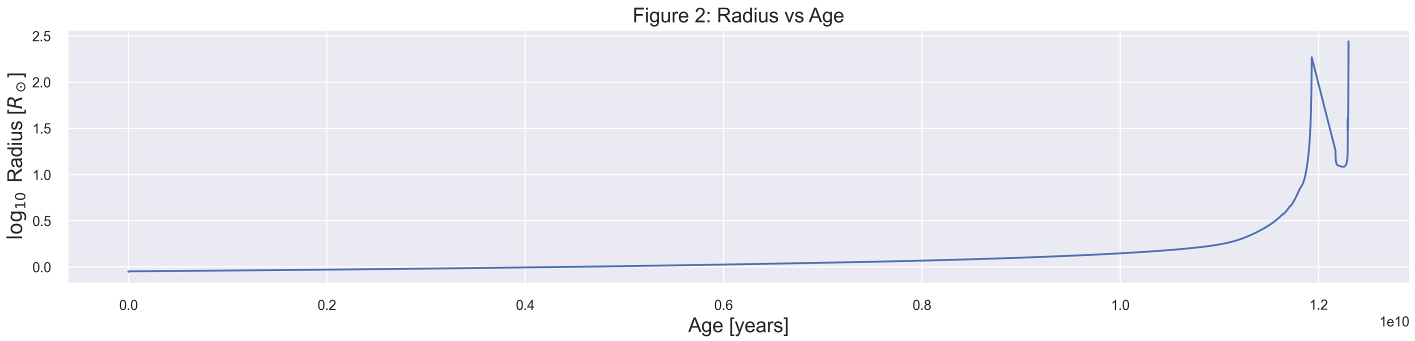
Problem 1

a b

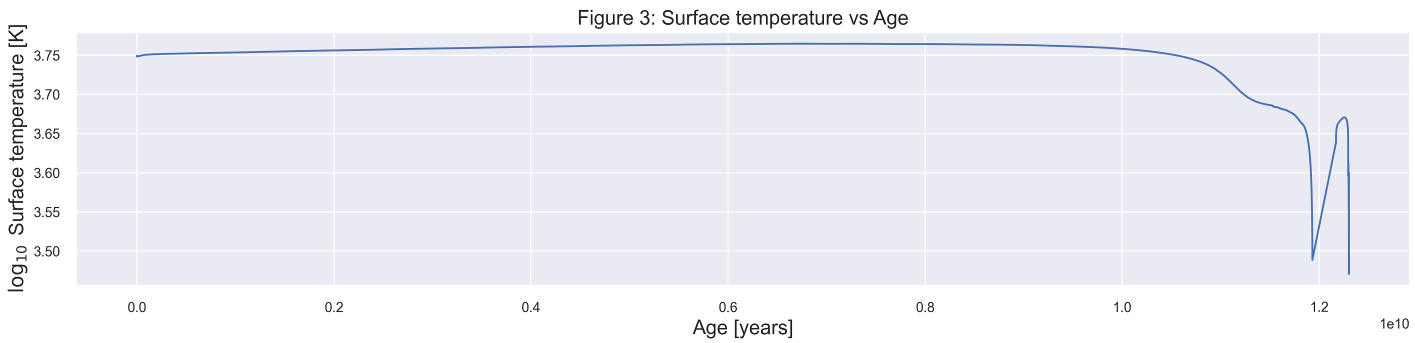


c

Radius:



Surface temperature:



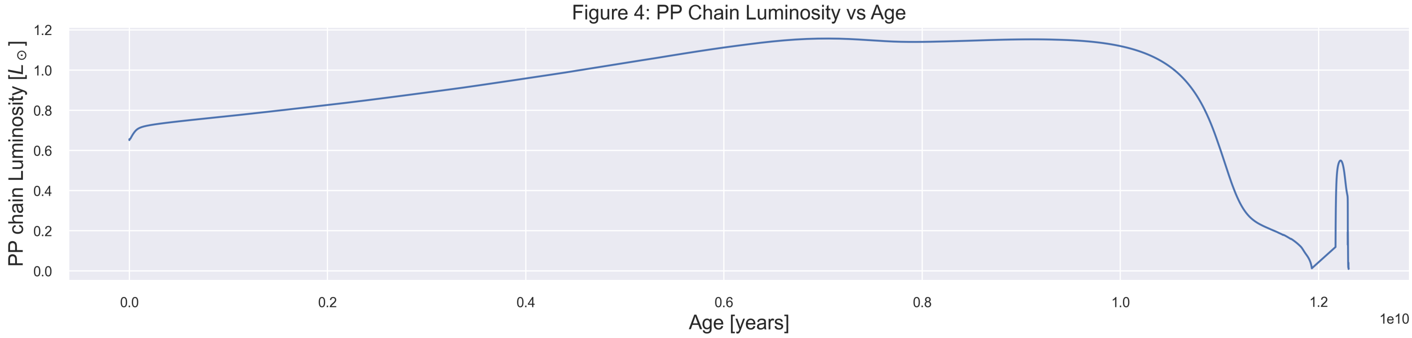
d

The surface temperature increases very slightly with time, then starts to decrease when the star leaves main sequence. There is also a sudden dip right at the beginning of helium fusion.

As for the size, it increases gradually during main sequence, then grows rapidly when the star becomes a red giant. The size shrinks as the helium fusion begin, and finally expands again after the fusion ended.

e

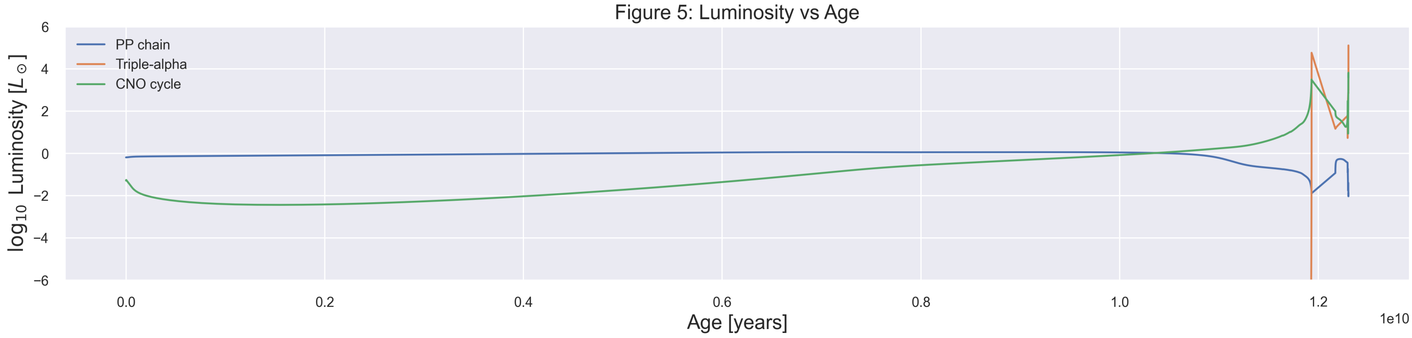
Figure 4: PP Chain Luminosity vs Age



f

The p-p chain serves as the main source of energy until about 10^{10} years into the life cycle. Then the CNO cycle takes places as hydrogen shell burning starts. Finally the triple-alpha reaction begins and generates comparable luminosity to the CNO cycle.

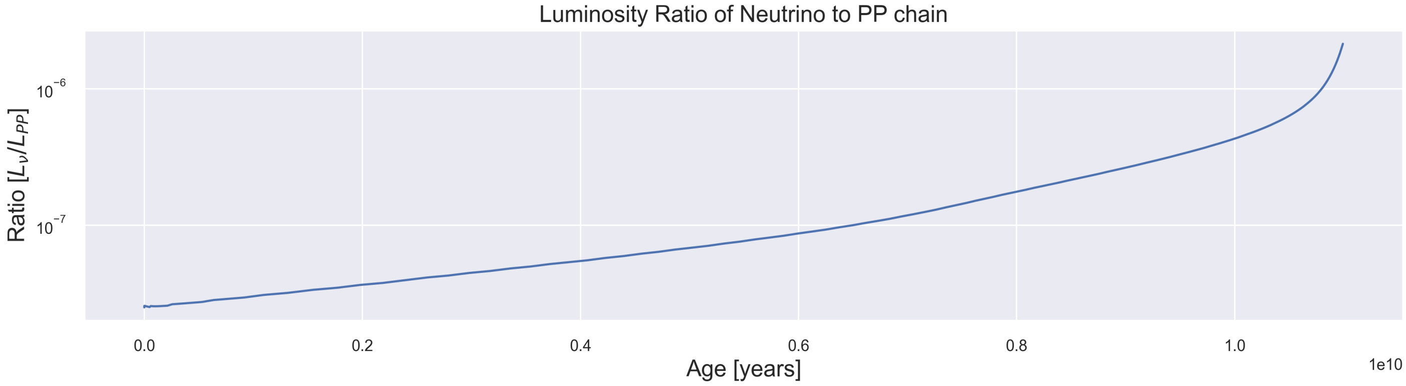
Figure 5: Luminosity vs Age



g

During main sequence, the neutrino luminosity stays between 10^{-7} and 10^{-6} the luminosity from p-p chain.

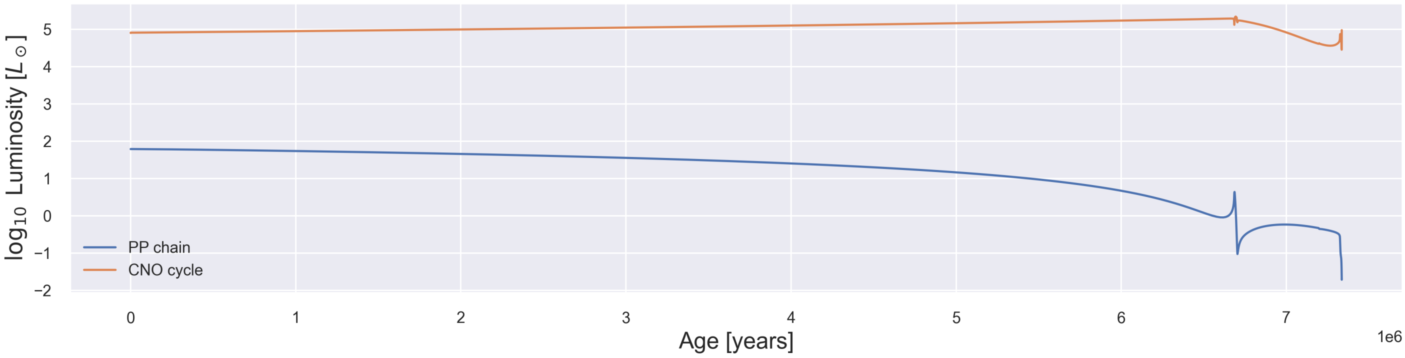
Luminosity Ratio of Neutrino to PP chain



h

The result matches what was described in the lecture. Most of the luminosity comes from the CNO cycle.

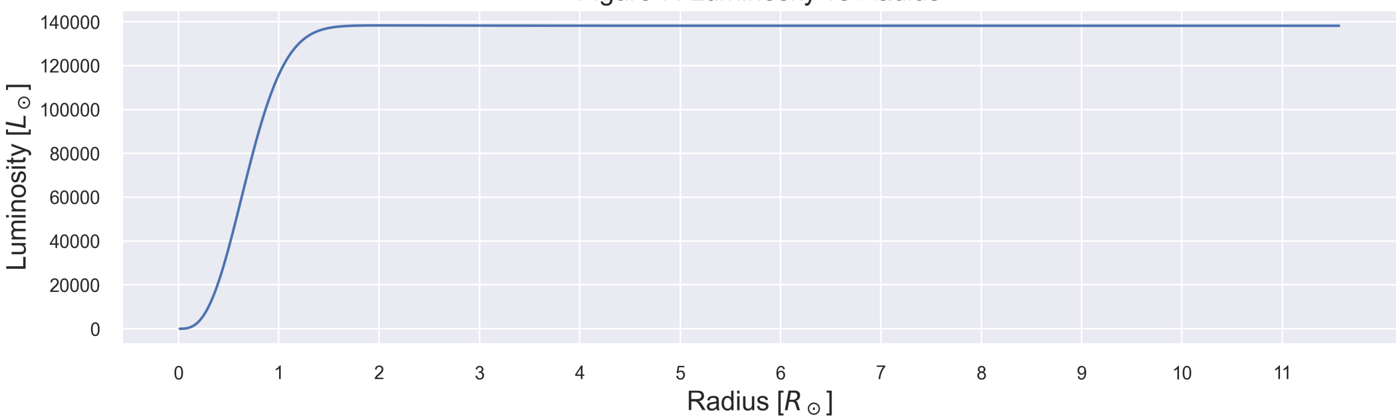
Figure 6: Luminosity vs Age



i

Most of the luminosity comes from fusion between $0.2\ R_{\odot}$ and $1.5\ R_{\odot}$.

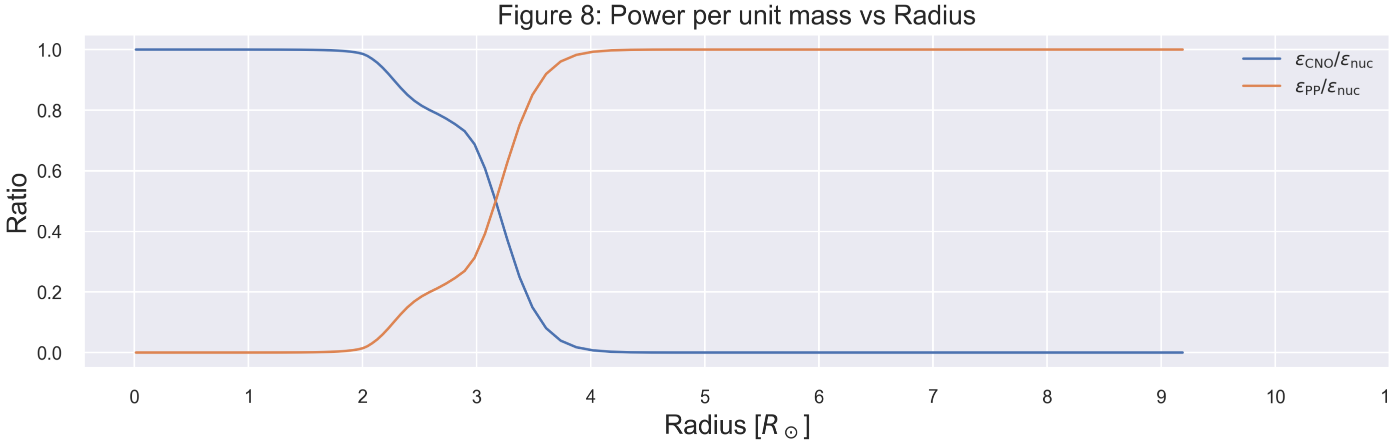
Figure 7: Luminosity vs Radius



j

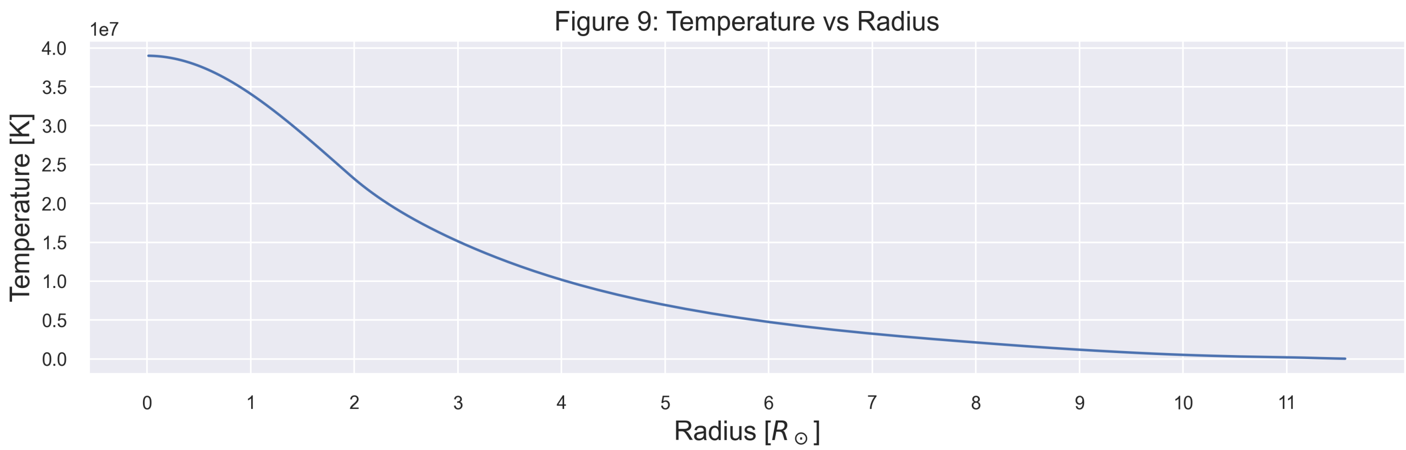
$\epsilon_{\mathrm{CNO}}/\epsilon_{\mathrm{nuc}}$ drops to 50% at around 3.17 $R_{\odot}$ from the center.

Figure 8: Power per unit mass vs Radius

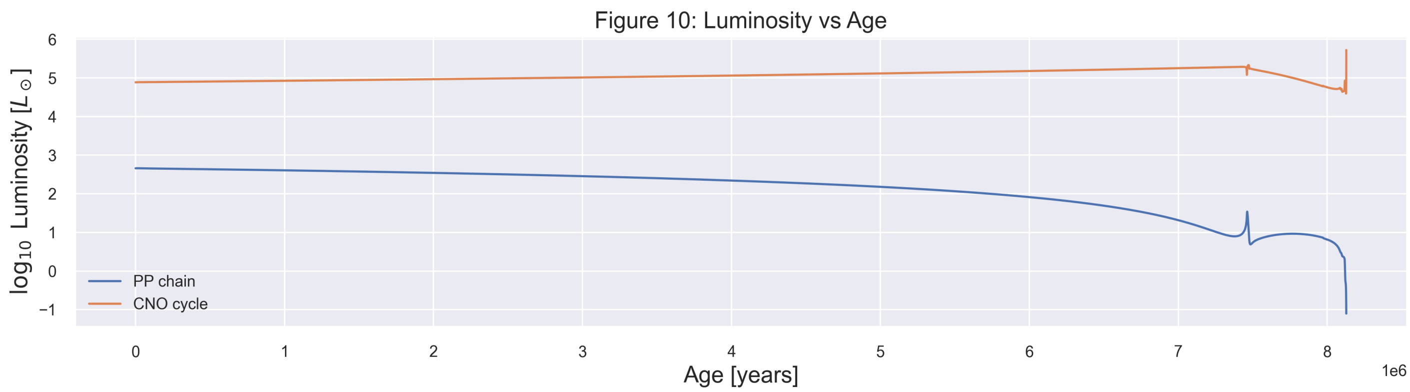


k

The temperature at 3.17 $R_{\odot}$ from the center is about 1.415 x 10^7 K, so not far from 15 million K.



l



For easier comparison, I plotted the data from both initial conditions in 1 figure:

It seems that with lower metallicity, the luminosity from PP chain is about an order of magnitude higher, while the luminosity from CNO cycle is close.

I think the reason for this difference is that the heavier metal atoms might make PP chain more difficult to be triggered.

m

[Source Code (secret gist)]

Problem 2

a

The data were recorded by "chart recorders" on to chart papers. They looked like long, squiggly lines.

b

He thought that it was caused by interference due to some faulty wiring of their self-made radio telescope.

c

I think her determination of becoming an astronomy researcher is really impressive. She had known what she wanted to do ever since a very young age, and didn't let the hostile environment discouraged her.

Problem 3

a

Let the distance to Crab Nebula be r, the angular size be θ, and the physical size be d. Using parallax:

$$\begin{aligned} d &= r\theta \\ &= 6500 \text{ ly} \cdot 7 \text{ arcmin} \\ &= \frac{6500 \text{ ly}}{3.26 \text{ ly}} \text{ pc} \cdot \frac{7 \text{ arcmin}}{(360 \cdot 60)/2\pi \text{ arcmin}} \text{ rad} \\ &\approx 4.060 \text{ pc} \end{aligned}$$

b

Let the speed of exiting gas be v.

$$\frac{d}{2} = v \cdot 1000 \text{ years}$$

$$v \approx \frac{2.030 \text{ pc}}{1000 \text{ years}} \approx \frac{2.030 \cdot 3.086 \cdot 10^{13} \text{ km}}{1000 \cdot 365 \cdot 24 \cdot 60 \cdot 60 \text{ s}} \approx 1986 \text{ km/s}$$

Problem 4

Let the rotation period of the pulsar be T and the radius of it be R. The maximum rotation speed is $v_{\text{rot}} = \frac{2\pi R}{T}$ at the "equator" of the pulsar.

Assuming that we don't have knowledge about how the pulsar's signal is generated, we can naively think that there is a single point source on the surface of the pulsar, thus T is the same as the signal's period: 33 ms.

To keep all mass from escaping:

$$\begin{aligned}
v_{\text{rot}} &< v_{\text{esc}} \\
\frac{2\pi R}{T} &< \sqrt{\frac{2GM}{R}} \\
\frac{4\pi^2 R^2}{T^2} &< \frac{2GM}{R} \\
R^3 &< \frac{GMT^2}{2\pi^2} \\
R &< (\frac{GMT^2}{2\pi^2})^{\frac{1}{3}} \approx (\frac{G(2\times 10^{30}\ \text{kg})(33\ \text{ms})^2}{2\pi^2})^{\frac{1}{3}} \approx 194.6\ \text{km}
\end{aligned}$$
