Homework #3

The Sun

Assigned: March 1, 2021 Due: March 8, 2021

Percentages for each problem of the total grade (100%) as given. Sub-problems, if present, split the problem's percentage equally. Please show your work!

Problem 1 The Salpeter process (20%)

a. Create a figure comparing the energy generation rates of the pp-chain, the CNO cycle, and the triple-α reaction (similar to Figure 4.5 in the lecture notes). Assume a core density for the Sun of $\rho = 150\,\mathrm{g\,cm^{-3}}$ and a triple-α screening factor of 1. Hint: If you are using python, the script to generate Figure 4.5 in the lecture notes is available on GitHub.

b. Discuss why the triple-α process does not take place in the center of the Sun.

c. 5% bonus: What is the physical meaning of the triple-α screening factor?

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Problem 2 Why do we have carbon (20%)

The triple-α process is a three-body reaction, which is very rare. Research and discuss why it does in fact happen in stars.

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Problem 3 Fate of the Earth (20%)

How hot will the Earth get when the Sun dies? Multiple answers are possible here, please reason according to your answer.

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Problem 4 Helix nebula (20%)

The Helix nebula is a planetary nebula with an angular diameter of 16′. It is located around 213 pc from Earth.

a. Sketch the distance measurement and calculate the diameter of the Helix nebula.

b. Assuming a constant expansion rate of the nebula gases of $20\,\mathrm{km\,s^{-1}}$, calculate its age.

(Problem adopted after problem 13.8 in Carroll & Ostlie (2017), "An Introduction to Modern Astrophysics", 2nd edn. (Cambridge University Press)[1])

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Problem 5 Population II stars (20%)

We have frequently discussed ultra-low metallicity, population II stars. Some examples of these stars are halo stars or the members of Reticulum II.

a. Calculate the maximum mass of population II stars assuming they formed around 1 Ga after the Big Bang.

b. Explain why these stars are difficult to observe.

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[1] doi: 10.1017/9781108380980