10 Part 10: Your star

In the final part of the project you will explore the star in your solar system. You can extract the mass, surface temperature and the radius of your star from the AST2000SolarSystem class.

1. Draw a HR-diagram (or copy it from somewhere) with temperature on the x-axis and luminosity on the y-axis and show the position of your star in the diagram. Use the radius and temperature of the star to find its luminosity (explain how you do this and where the expression you use come from). Is it a main sequence star?

2. Use the relations between mass/temperature and mass/luminosity in part 3D and check how well your star follows these relations.

3. Assume that your star started out as a huge GMC (Giant Molecular Cloud), consisting of 75% hydrogen atoms and 25% helium atoms at a temperature of 10K. What is the largest possible radius that your gas cloud could have had (assuming it to be nearly spherical), assuming that it started collapsing to a star by itself without the help of shock waves from supernova explosions. Explain the main principle behind the formula you use.

4. Assume that the cloud had just below this maximum radius: find its luminosity and show its position in the HR-diagram.

5. Now use the equation of hydrostatic equilibrium to make a rough estimate of the temperature in the core of your star. You may use exercise 3D.2 in part 3D to help. Make the same assumption as in that exercise. Explain how you arrive at the expression for the core temperature.

6. Given the core temperature that you calculated in the previous point your task now is to find the luminosity of your star using the nuclear reactions: Assume that all nuclear reactions take place within a sphere of radius 0.2 times the full radius of your star. Assume the density of your star to be uniform. **If the core temperature of your star is below 90 million K:** Assume the core to consist of 74.5% Hydrogen atoms, 25.3% Helium atoms and 0.2% Carbon, Oxygen and Nitrogen. Calculate the total luminosity from the pp-chain and the CNO-cycle. Assume the expressions for energy productions in these reactions in part 3C to hold. **If the core temperature of your star is above 90 million K:** Assume the core to consist of 20% Hydrogen atoms, 80% Helium atoms. Calculate the total luminosity from the 3α reaction. Assume the expression for energy productions in this reaction in part 3C to hold.

7. How well does your luminosity compare to the one calculated in point 1 above? Now calculate the surface temperature of your star assuming the luminosity that you calculated in the previous point is correct. If you get a strange answer, discuss which of your assumption you think may have been very wrong.

8. Explain **briefly, without calculations and with your own words**, the principle behind the calculation of a relation between the main sequence

life time of a star and its mass in part 3D. Use the relation to estimate how long you expect your star to stay on the main sequence.

9. Now explain, step by step and by your own words, what will happen with your star after leaving the main sequence untill it ends its life. Use a HR-diagram where you plot the different stages. At each stage, explain which changes which happen and why. It is strongly recommended that you read section 3 i part 3D as well as the relevant parts of part 3E a few times untill you understand and remember, then you write it with your own words without looking at the text. Drawings are very welcome!

10. **If your star ends as a white dwarf:** If the original mass of your star was M, assume that the mass of your white dwarf is $\frac{M}{8M_\odot}M_{\text{Chandrasekhar}}$. Calculate the radius of your white dwarf using the expression in part 3E. Explain briefly where this equation comes from and which assumptions it relies on. You will need to make some assumptions for A and Z. Assume uniform density and calculate the weight of one litre of weight dwarf material as well as the gravitational acceleration on the surface. Explain **briefly and without equations** what your star consists of and what degenerate matter is.

11. **If your star ends as a neutron star:** If the original mass of your star was M, assume that the mass of your neutron star is $1.5M_\odot + \frac{M-8M_\odot}{17M_\odot}1.3M_\odot$. Calculate the radius of your neutron star using the expression for white dwarf radius in part 3E (you will need some small modifications to the expression). Explain briefly where this equation comes from and which assumptions it relies on and why it may be an equally good approximation for a neutron star as for a white dwarf. You will need to make some assumptions for A and Z. Assume uniform density and calculate the weight of one litre of neutron star material as well as the gravitational acceleration on the surface. Explain **briefly and without equations** what your star consists of and what degenerate matter is.