MESA practical assignment

ASBE course 2025 – 2026

Assignment: a case study of stellar evolution

In this final assignment for the computer practicum you are asked to apply what you have learned during the course in a case study. During the first few pacticum sessions you have gained some experience in using MESA to compute the detailed evolution of single and binary stars. Now you can use that experience in a free assignment, to explore a topic in (binary) stellar evolution of your choice in some more depth.

You are free to define the topic of your case study, in fact that is part of the assignment (see below). Some examples are: How does the evolution of a star depend on the initial composition (metallicity)? Or on the rotation rate of the star? How does the evolution change with different assumptions about mixing, or mass loss? How does the evolution of a binary star depend on the mass ratio of the stars, or on the orbital period or eccentricity? Feel encouraged to come up with your own questions!

The assignment consists of three steps. Note that *collaboration* with your fellow students is strongly encouraged. You can do steps 1 and 2 (the proposal, and the execution of the project) in teams of two students. However, the report (step 3) should be written, and will be evaluated, individually.

1. **Write a brief abstract/research proposal**, no more than about half a page. It should consist of two parts:

   (a) A 'science case', in which you briefly describe the (binary) stellar evolution question you want to answer using MESA, and you motivate in a few sentences why this is an interesting problem to study.

   (b) A 'methodology', in which you briefly describe *how* you plan to answer this question using MESA. That is to say: which models do you propose to run? For which set of masses and/or other parameters, and which set of assumptions within the code will you use?

   Writing such a proposal encourages you to *think* about what you want to do, and to *plan* the calculations to be done, before you *start* doing them. Also keep in mind that there is not much time for the project (only 2 computer sessions in the second quarter), so keep it to a simple question.

   Please submit your proposal in Brightspace by the end of the teaching break, i.e. before **01 December**. Then you will receive feedback well before the start of the next MESA practical session.

2. **Perform the MESA calculations** needed for your case study. There will be two designated practical sessions in the second quarter, starting on December 10. Of course, you can also work on the project by yourselves outside the scheduled sessions.

   Here it is important to keep in mind that, whatever topic you choose to study with MESA, it should directly build on what you learn during the course. You should be able to *explain your findings* and *link them to the course contents* (e.g. the lecture notes). Therefore, good plots to concentrate on when you run your MESA models are:

- the evolution of your star(s) in a Hertzsprung-Russell diagram,
- the evolution of your star(s) in a $\log T_c$ versus $\log \rho_c$ diagram,
- a Kippenhahn plot of the convection zones and nuclear burning zones, and plots of the stellar mass(es) and core mass(es),
- plots of the abundance profiles at a few key stages of evolution,

and in the case of binary stars:

- plots of how the orbital period and eccentricity evolve, and
- plots comparing the radius and Roche-lobe radius of each star,
- plots of the mass-loss rates and/or mass-transfer rates.

Not all of these will always be important, it depends on the topic you study and other diagrams may also be relevant. But at least several of these plots should be part of your report, and you should be able to *explain them in your report* in terms of the physical processes we studied in the course.

3. **Write a report** on your project, of no more than 10 pages in length. The report will be graded and it will determine 40% of your final grade. The deadline for handing in the final version of your report is **Monday 27 January 2025**. See below for some guidelines for the report.

Pro Tip

When you do research it is generally *very* good practice separating your code from your data. When you start bigger projects you will want to keep track of your code using a `git` repository for your project folders, but to keep your data (i.e. the output files) excluded from the repository (git cannot handle large data files). You can do this by adding a `.gitignore` file to your project folder that ignores the `LOGS`, `photos`, and `png` directories, as well as any other large output files you do not want to track with `git`.

Guidelines for the report

This section summarizes some general guidelines for your report.

- A good report has a *clear structure*. It starts with an **introduction**. Here you try to convince the reader to read your report, you explain your research question and why your work is relevant to other astronomers. The report ends with a **conclusion/discussion** section. Here you summarize briefly your main points. You also discuss uncertainties. Read the introduction to a real paper and see which elements you can use for your report. Try to subdivide the main body of your report in coherent sections. Think about a good outline. You can include a section "background theory" or a section "models" but this is not obligatory.

- A good report is *concise*. Limit yourself to a maximum of 10 pages, including figures. This also means making a choice of figures, showing those that best illustrate the information you want to convey.

- A good report is one that can be understood by any master student in astronomy that did not take this course. Explain specific terms and introduce abbreviations.

- A good report is written in clear and proper English. Avoid very long sentences. Try to write in the active form and in the present tense. Avoid informal phrasing (e.g. not "isn't" but "is not"). Be clear and quantitative whenever possible.

- Write your report using Latex. Use the proper symbol for solar mass, radius and luminosity, for example $M_\odot$ by `$M_\odot$`. Make sure you use `\ref` and `\label` to refer to your figures in the main text. Write captions for every figure explaining the axes, lines, colors. A good caption is short but self-explanatory. Latex decides where it places the figures in the text, but you can influence the placements with e.g. `\begin{figure}[hbtp]`, where `h`=here, `b`=bottom of the page, `t`=top of the page, and `p`=on a separate page. Using an exclamation mark you can override what Latex considers as good, e.g. `\begin{figure}[h!]`.