Simulating Stars 2018

Novae Lab 1: A First Nova Model

In this lab, we will make a first model of a nova by accreting hydrogen and helium onto a $0.6\,M_\odot$ white dwarf. We'll look at one model in some detail first before going on to study the larger parameter space in the next lab.

Part 1: What happens when you accrete hydrogen onto a white dwarf?

We've provided a starting white dwarf model `mesa_wd_M0.6_L-1.mod` that we made by running `make_co_wd` in the MESA test suite. This evolves a $\approx 3\ M_\odot$ main sequence star through the main sequence, RGB, AGB and eventually creates a white dwarf with mass $0.6\ M_\odot$. Because this takes some time to run, we've given you the final white dwarf model here to save time. We used the default parameters as specified in the test suite except that we made a small change to stop the run when the white dwarf luminosity is $10^{-1}\ L_\odot$ rather than $10^{-2}\ L_\odot$.

We've provided two inlist files `inlist_flash` and `inlist_pgstar`. The first turns on accretion at a rate $10^{-9}\ M_\odot\ \mathrm{yr}^{-1}$, and the second makes a pgstar window tailored to this problem, so you will be able to see what is happening.

- Copy the files `mesa_wd_M0.6_L-1.mod`, `inlist_flash` and `inlist_pgstar` into a new MESA `work` directory.
- If you try running MESA using these inlists, you should find that MESA complains about not being able to find `h_rich_layer_mass` and `max_eps_h_lgT` in the history files, so you will need to add these to get it to run. Note that the option to write out png files is turned on in `inlist_pgstar`, so that you can make a movie of the run (using `images_to_movie.sh`).
- Watch carefully to see what happens!

Part 2: Looking at the model in more detail

Use your model to answer the following questions:

- What is the recurrence time and ignition mass of the novae? Is this model gaining or losing mass over time? How does the rate of change of mass compare with the mass accretion rate?

- Plot the lightcurve $L(t)$ of one of the flashes, as well as the nuclear luminosity $L_{\rm nuc}(t)$, and Eddington luminosity $L_{\rm Edd}$. By how much does L exceed the Eddington luminosity? At this luminosity, how much time would it take for the super-Eddington wind to eject the ignition mass? Compare this with the time it would take to burn the hydrogen away at the nuclear luminosity.

- How does the radius of the star and the effective temperature evolve over time? How would you expect the visual lightcurve to compare with the bolometric lightcurve?

- How does the temperature and pressure in the burning layer, the pressure scale height H there, and aspect ratio H/R evolve during the flash?

To help you, we've made a Jupyter notebook that plots the lightcurve of the last nova in the run, look at `plot_lightcurve.ipynb`. Remember that if a quantity you need is not being output in the history.dat files, you can look in `mesa/star/defaults/history_columns.list`. MESA probably already calculates it for you and you can just add it to your history file and rerun the model.