Mini-Lab 1

From Dropbox guzik folder minilab1 directory, download the nominal example Cepheid evolution directory (Under ‘ Mesa_model_to_modify’, labeled blue_loop_8.0) and the terminal-age main-sequence (TAMS, end of core hydrogen-burning) initial models.

A star mass between 4.5 and 11.5 Msun will be assigned to each table.

Review inlist_Cepheid_blue_loop, and modify your inlist to read in your table’s assigned stellar mass (initial_mass) and starting model (saved_model_name). Take note of settings: Y, Z, A09 opacities, special Type 2 opacities, reaction rates, special reaction rate multipliers (set to 1), opacity factors (set to 1), mixing length, convective overshoot, varcontrol_target (set to 1.0e-04), etc.

a) Run Cepheid model and examine blue loops and summary profile as star is evolving. Also look at history file under LOGS to see what is contained there. The models will stop running when core helium is exhausted.

Optional: Create and “tidy” a copy of your directory, and uncomment the mass loss lines in your inlist and rerun Cepheid evolution to see how much mass is lost during this evolution phase.

Optional: Create and “tidy” a copy of your initial directory, and change varcontrol_target to 1.0e-03 and rerun Cepheid evolution. What do you notice about the run time and the blue-loop behavior?

b) Copy your Cepheid directory to a new directory and “tidy” it.

Change reaction-rate multipliers (special_rate_factor) for both the triple-alpha and ^{12}C(alpha, gamma)^{16}O rate to 3 (instead of 1) and run evolution again. Do you see any difference in blue loops (extent of loops, luminosity, age of star when loop starts/ends?

[Note: The multipliers of x3 on both the triple-alpha and ^{12}C(alpha, gamma)^{16}O rates are extreme, but were chosen to produce a noticeable effect on the blue loops.]

Optional: Create and “tidy” a copy of your directory and change multiplier(s) to a different value of your choice, and run evolution again, noting variation.

Mini-Lab 2

a) From Dropbox guzik folder, under minilab2, modified_opacities in the folder TAMS_mod_opac_model_files, download new initial TAMS model file for your table’s assigned mass. [These models have been evolved on the main sequence with an opacity factor of 0.95]

Create and "tidy" a copy of your directory, change the inlists to reset the reaction-rate multipliers back to 1.0, load in the new TAMS model in saved_model_name, and change the opacity_factor =0.95 (do not change "use_other_opacity_factor" yet).
Rerun the evolution and note any changes in the blue loops compared to previous runs. You should also note that the extra_opacity_factor in the profiles window is now 0.95.

b) Create and "tidy" a copy of your opacity multiplier directory. In the src directory, write a subroutine in run_star_extras to implement a temperature-dependent opacity factor of the functional form given by Daszynska-Daszkiewicz et al. (2017) for the evolution run:

$$\kappa(T) = \kappa_0(T) \left[1 + \sum_{i=1}^{N} b_i \exp\left(-\frac{(\log T - \log T_{0,i})^2}{a_i^2} \right) \right]$$

The coefficients are: $\log T_{0,1} = 5.30$, $a_1 = 0.082$, $b_1 = 0.5$
$\log T_{0,2} = 5.46$, $a_2 = 0.082$, $b_2 = 1.5$

Set "use_other_opacity_factor" = .true. and opacity_factor = 1 in inlist_cepheid_blue_loop. Use the TAMS initial models in rse_modified_opacities as a starting point to rerun the blue loops, noting in profiles how the extra opacity factor is changing during the evolution. Do you see any difference in your blue loop compared to previous runs?

Maxilab (rsp_Cepheid)

Divide up runs among those at table: 1) nominal, 2) reaction-rate factors =3, 3) opacity factor = 0.95. Compare HR diagrams stored in your pgstar_out directory and as a group decide on an effective temperature for a model in or near the instability strip to model the nonlinear radial stellar pulsations. Your group can decide to look at first, second, or third crossings of the instability region, or even a model cooler than the red edge if your blue loops do not cross the instability strip.

Look at your history profiles and find the model with the desired Teff on the desired instability strip crossing. Hint: You can look at saved HR diagrams in pgstar_out to get an approximate model number to search near in the history file.

Record the luminosity and Teff of the model. You also need the stellar mass (assigned to your table), and the envelope Y and Z, which will be assumed for these envelope models to be the initial Y = 0.28 and Z=0.02 of our models.

Download from the Dropbox guzik folder the maxilab.zip folder and open and copy the rsp_cepheid_jg folder to your working directory.

Review inlist parameters and change the RSP input in inlist_rsp_Cepheid to the model desired from your history file:

RSP_mass =
RSP_Teff =
RSP_L =
RSP_X = 0.70d0
RSP_Z = 0.020d0

Note: If you are running the model evolved with the 0.95 opacity factor, be sure to also change the opacity factor in inlist_rsp_Cepheid to 0.95!

Start the rsp run, and note the three linear pulsation periods and growth rate solutions output to your screen for the fundamental, first, and second overtone modes. Are any of these periods unstable (growth rate positive)? Do others at your table running models evolved with different physics see the same pattern of stable or unstable modes? If none of the modes are unstable, you may choose to pick models with slightly cooler or hotter temperatures. You could test the approximate results by slightly changing the effective temperature only in your inlist_rsp_Cepheid and "tidying" your directory and rerunning the beginning of the rsp model again.

If the 1st overtone or 2nd overtone is the most unstable (positive growth rate) or only unstable model, you should consider initializing your nonlinear model in this mode by changing the setting in inlist_rsp_common (your inlist file has been modified to point to a local copy of this inlist) to have 1st or 2nd overtone fraction = 1d0. The default is to initialize the model in the fundamental mode:

RSP_fraction_1st_overtone = 0d0
RSP_fraction_2nd_overtone = 0d0

"Tidy" your directory and start run again from the beginning. At first, you might want to look at a few pgstar plots to see what is happening, but then turn off pgstar to run many cycles.

If run converges to a period (it may require thousands of cycles), you can Ctrl-C (kill) the run. As suggested in the comments in inlist_rsp_Cepheid, you could turn on the pgstar plots and restart from the most recent photo file and run a few pulsation cycles to see the final converged light curve shape, radial velocity minimum and maximum, and other quantities of interest. You might want to take a screen shot of your plot after a few cycles to save for future reference.

If/when you have a converged nonlinear pulsation run, record on the google doc spreadsheet provided the details of your model. To find sheet, go to MESA 2019 summer school directory http://cococubed.asu.edu/mesa_summer_school_2019/agenda.html and click on link to Google Sheet.

The desired information is

1) Mass
2) Model type (nominal, reaction-rate multiplier, opacity multiplier)
3) Teff (from rsp plot output)
4) Luminosity (from rsp plot output)
5) Period (days) (from rsp plot output)
6) Whether the mode is fundamental, first, or second overtone (compare final period with initial linear periods when run was started).
7) Maximum or minimum radial velocity (km/sec)

We should have 42 converged models recorded if we are successful!