Course Stellar Evolution Project

J. Jackiewicz

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1 Modeling setup

1.1 Assigment of stellar masses

Stellar Mass ($M_\odot$)	Modeler
0.72	Anna
0.91	Bill
1.27	Jason
1.46	Tim
2.94	Maya
3.76	April
5.30	Kevin
7.83	Julio
9.31	Asif
14.53	Jessica

1.2 Evolution parameters

Start your models with metal mass fraction $Z = 0.2$. You will have to create a pre main-sequence model.

1.3 Output parameters

We are going to need high-level control of what gets saved to make appropriate plots. The best way to do this is the following:

1. After you've made a working directoy for this project, copy the file:
`$MESA_DIR/star/defaults/history_columns.list` to your working directory and rename it:
`custom_history.list`.
2. Similarly, copy the file:
`$MESA_DIR/star/defaults/profile_columns.list` to your working directory and rename it:
`custom_profile.list`.
3. Now, in your `inlist_project` file, in the `&star_job` namelist, add the following two lines:
`history_columns_file = 'custom_history.list'`
`profile_columns_file = 'custom_profile.list'`

You can now uncomment any variables, in addition to the ones already uncommented, that you want to save in the model.

1.3.1 Output history parameters

Make sure that all of the following get output to your history data:
`mixing_regions 40`
`burning_regions 80` (these 2 are important to make the Kippenhahn plots.

1.3.2 Output profile parameters

Make sure that all of the following get output to your profiles data (these could be log or linear, however you choose; they also might have different names based on your MESA version): mass, luminosity, radius, X, Y, Z, eps_grav, eps_nuc, sch_stable, ledoux_stable, μ.

1.3.3 Output frequency

You want to save everything you need, but also be slightly mindful of disk space, depending on where you are saving things. You can change the output frequency of the history data, profile data, photos, and figure files (this parameter you would typically change in the pgstar_inlist file).

The values here might vary depending on evolution state. I would place the least importance to the photo interval, saving these maybe every 200 to 500 models.ma

1.4 Plotting

You will need to use Jason's custom pgstar panel plots, which are available on the course website in the MESA Directory and the Defaults. To implement this, all you need to do in the `inlist` file (NOT the inlist_project file) in the `&pgstar` namelist, is add the 2 lines:

```
read_extra_pgstar_inlist(1) = .true.
extra_pgstar_inlist_name(1) = 'inlist_pgstar_jason'
```

To make a movie, you have to save the frames as .png files, and there is a flag to do so in the pgstar file. Then, there is a built in command you can run from the main working directory:
`images_to_movie 'png/grid5_*.png' my_movie.mp4`, for example.
More info here: http://user.astro.wisc.edu/~townsend/static.php?ref=mesasdk#Making_Movies

1.5 Testing

Do a few trial runs to make sure everything gets going and the right plots show up. For some of the plots, specific variables need to be saved, since pgstar reads the saved files to make the plots.

2 Evolution figures

2.1 Main H-R diagram

As you progress, you will want to make a labelled H-R diagram. Unit 18 has examples you can be inspired by. The main labels you are going to want are:

ZAMS (zero-age main sequence), core H burning, TAMS (terminal-age main sequence), H-shell burning onset, subgiant branch, first dredge up, red giant branch luminosity bump, RGB phase, He flash (start, end), horizontal branch, blue loop(s), He core burning completion, AGB (asymptotic giant branch), evolved phases with mass loss and neutrino cooling, white dwarf, etc.

Depending on mass, some of these are more or less important (or present). You'll want to give some estimate of time for these phases, or the time between any two successive phases. Try to make these useful, so that you may use them as a reference for yourself in the future.

The most updated diagram for the $M = 1.27\,M_\odot$ model is in Figure 1.

2.2 Detailed plots of notable evolutionary events

For these, everyone will make each plot described below for their mass.

4. Helium flash (or transition to horizontal branch). See figure 21.4 in notes.

3. First dredge up. 2 figures such as 21.1 and 21.2 in the notes.

2. Hydrogen interior distribution on main sequence. Break up your main sequence lifetime across about 10 evenly spaced time intervals. Plot H mass fraction vs. interior mass, to see how the depletion takes place. Similar to Figure 19.2 in notes, or Figure 3 here.

1. Core size in mass and radius for a given stellar model on the middle main sequence. See Figure 2.

2.3 All-masses plots of events

For these, pairs of students will make one of the following plots, collecting the appropriate data from everyone else.

1. (Tim, Anna). Main-sequence track from onset of H burning to H depletion, for each mass. Denote lifetime for each mass as well. Similar to Figure 19.1 in the notes. Also, a plot with main-sequence lifetime as a function of mass. Find a scaling law or fit to this $\tau_{\rm MS}(M_*)$.

2. (April, Julio). Similar to above, but for the red-giant phase. We are interested in the lifetime of the RGB phase as a fraction of the MS lifetime, as a function of mass. This team will need to work closely with the first team.

3. (Maya, Kevin). Convection and radiation zones on the main sequence, halfway through H burning is complete. A guide to this is described in Computer Problem 16.1, which won't be assigned. There are many ways convey this information graphically. One possible way is a pie plot like Figure 4. As in the computer problem directions, somehow pointing out the dominant hydrogen burning process would be very helpful.

4. (Asif, Bill). Similar to above, but now convection and radiation zones on the red-giant branch. Let's define the middle of the RGB to make these plots. That could be near the mid luminosity between the bottom of the RGB and the tip of the RGB.

5. (Jessica, Jason). Burning region locations on the horizontal branch. Where does He-core burning and H-shell burning occur in the interiors for each mass? The point at which to determine this is when the center He4 drops to a mass fraction near 0.5, as the star ascends the asymptotic giant branch. For this, the team will need everyone's history data on the AGB to determine the profile that will then be needed. The profiles should contain eps_nuc, and pp, cno, and tri_alpha will be useful too.

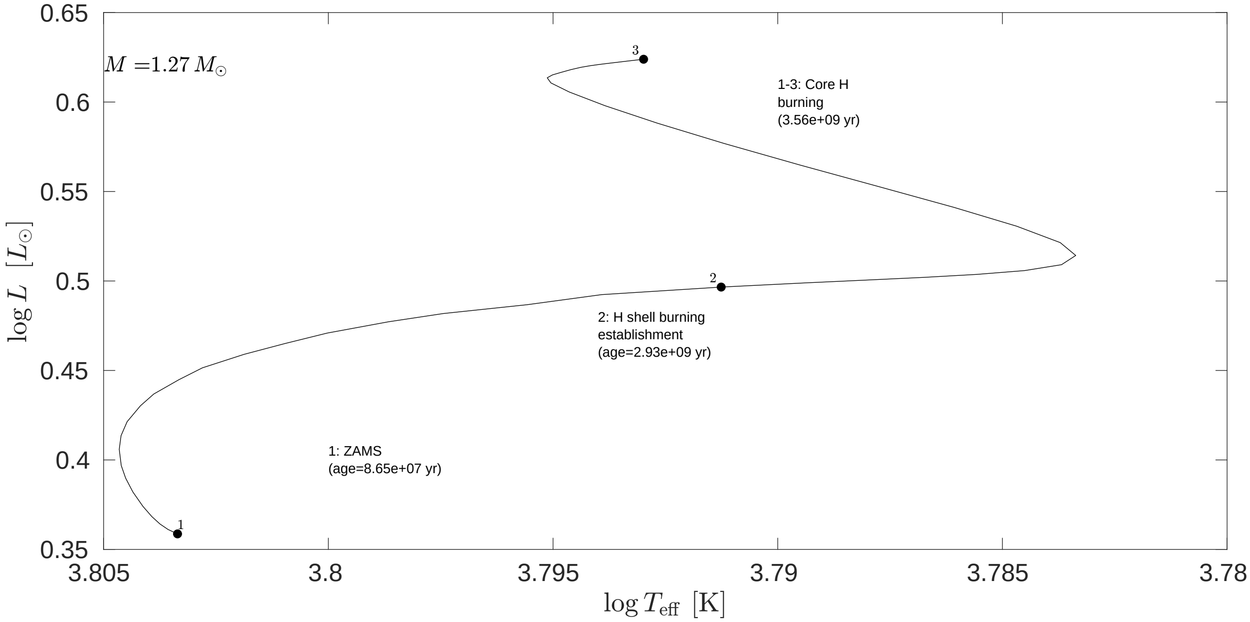

Figure 1: H-R diagram with labels.

3 Figures

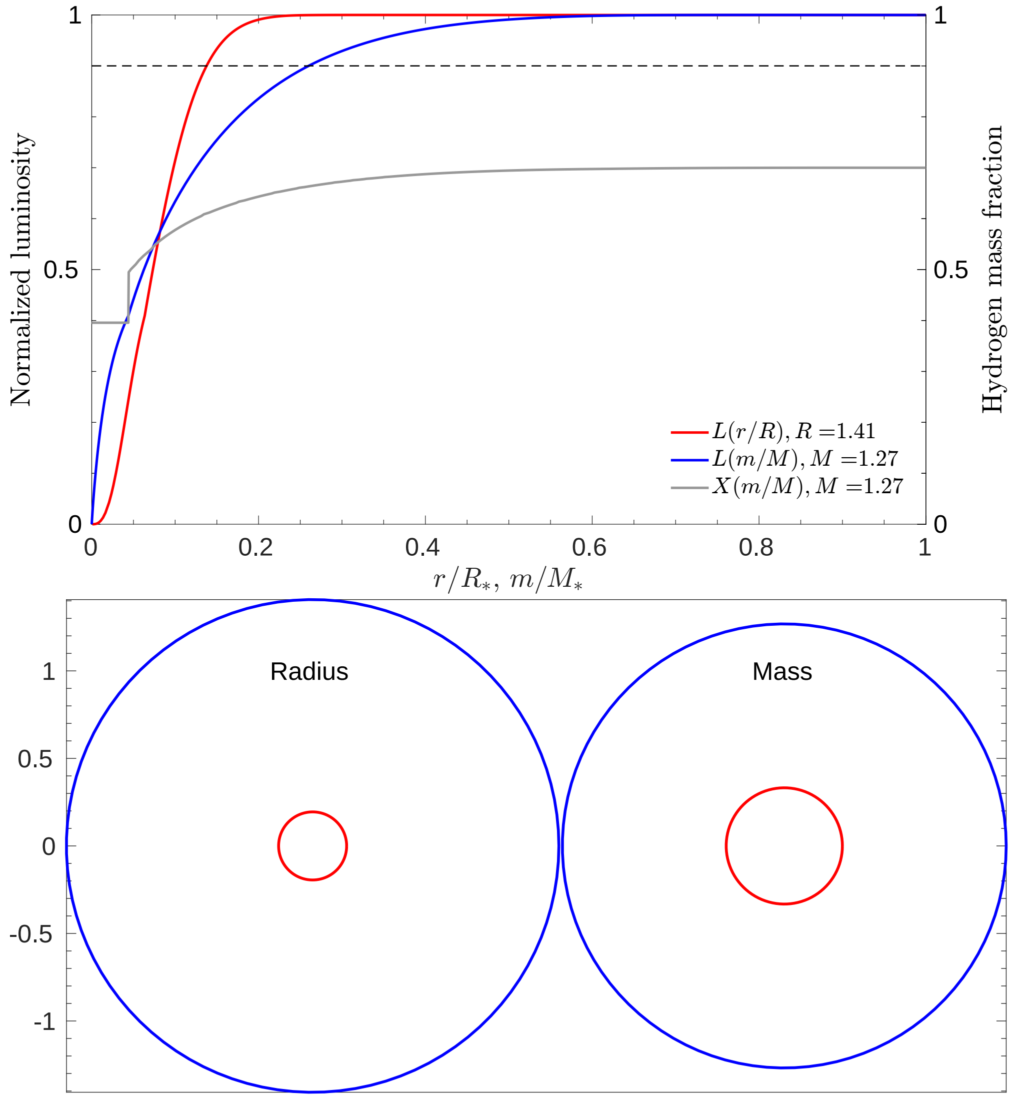

Figure 2: Core size.

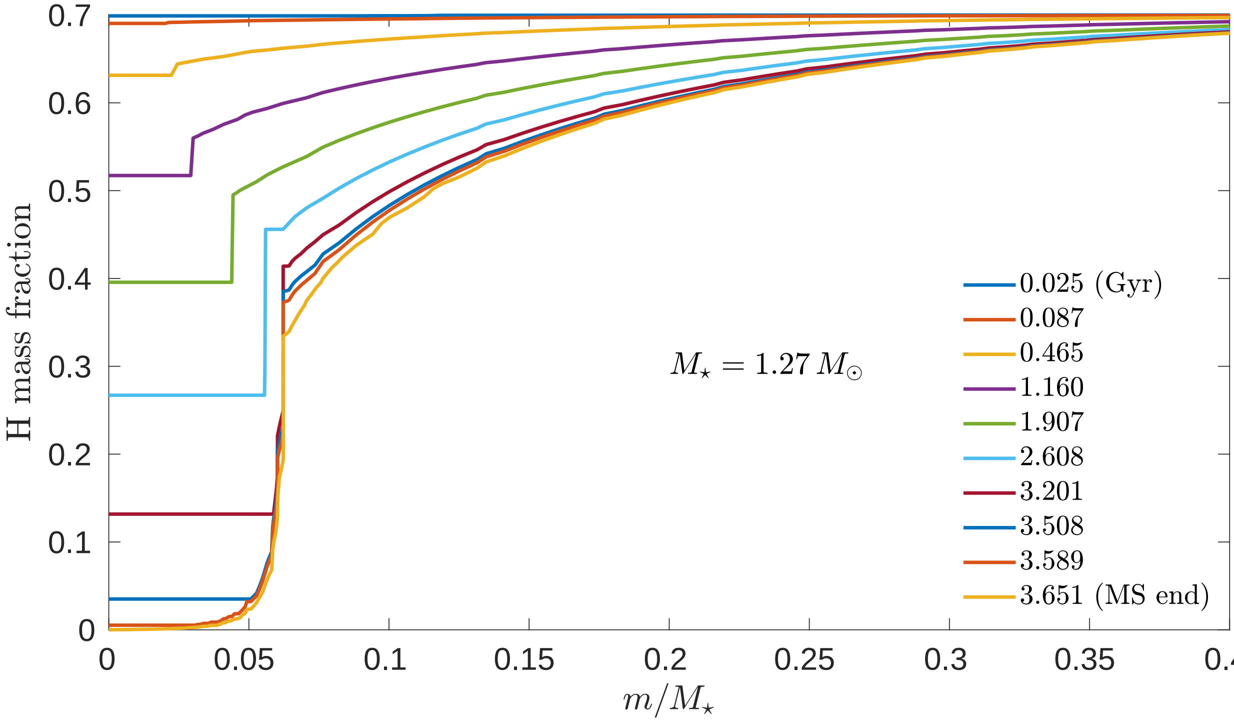

Figure 3: Hydrogen structure profiles on main sequence. The legend denotes the stellar age.

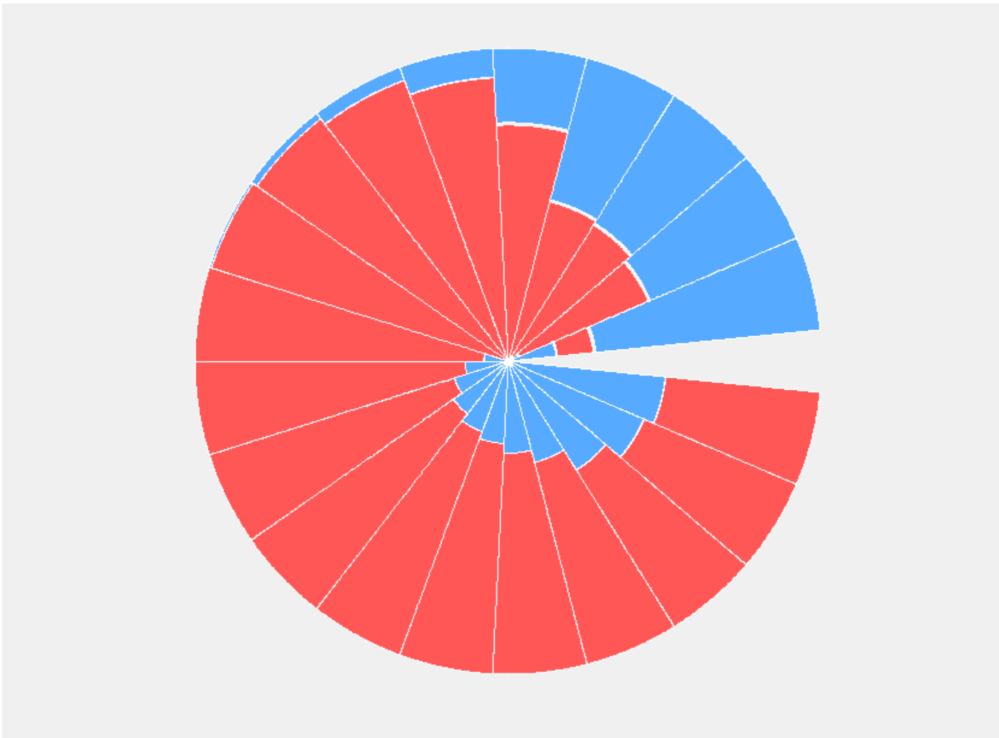

Figure 4: One possible way of representing different interior zones. Appropriate labels would be necessary here.