# MESA Summer School 2013: Helium Burning Stars Big Lab

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## Objectives

In this exercise, we'll look at a more realistic model of a helium-burning star, which is a star born of a cosmic mix with a core that has been exhausted of hydrogen and contracted to the point of helium ignition. We'll compare these models with those from the mini-lab that were comprised of pure helium. Again, you should be able to use a basic `work` directory from `mesa/star/work` with a very simple inlist to accomplish these tasks.

## Part 1

### Instructions

- Pick a random number between zero and one and use it to determine the mass of your star uniformly between 1.0 $M_\odot$ and 5.0 $M_\odot$.
- Run the model through the Hydrogen burning main sequence (no need to start with a pre-main sequence model) and stop it once helium burning has started in the core. If the star is descending from the tip of the RGB, make sure it gets to its resting place in the HR diagram. Perhaps wait until 10% of the helium fuel in the core has been depleted.
- At the point of Helium core burning, report the stellar mass, $L$, $T_{\rm eff}$, $T_c$, $\rho_c$ (central temperature and density), and the mass of the convective core to Bill Wolf at `wmwolf@physics.ucsb.edu`.
- Plot $L(m)$ and comment on the role of Hydrogen burning when the Helium is also burning.

### Inlist Hints

As always look for useful options/switches in `mesa/star/defaults/star_job.defaults` for the `&star_job` namelist and `mesa/star/defaults/controls.defaults` for the `&controls` namelist.

- This time we want to create a cosmic composition star. Default values for $X$, $Y$, and $Z$ are good enough.
- Be sure to set your initial mass to the one you determined randomly.
- The stopping criterion is pretty much the same as part 1 of the mini-lab, but now the abundance strategy is more difficult since the helium central abundance first rises before falling. Thus, a helium abundance criterion won't work unless you first stop at hydrogen core exhaustion. Can you think of an abundance criterion that is unaffected by this difference? Be sure that the star has "settled" after core burning has begun.

- When you've reached your stopping condition, either save a model to load in part 2 or remember the photo number and restart from it for part 2. If you can't get a model, don't worry. Some pre-prepared models are available to you.

## Part 2

### Instructions

You'll need to use the model you created in part 1. If you were unable to compute part 1, use one of the avilable pre-made models. Either load the model or change your inlist and restart from the last photo (assuming you completed part 1) to do the following:

- Take the model you created in Part 1 (or a surrogate) and run it until the core is exhausted of helium.
- Report the following:
  1. Duration of helium core burning.
  2. Total amount of Hydrogen burned during this phase.
  3. C-O mix in the center at He-exhaustion.
- Send the mass of your model and these three pieces of information to Bill Wolf at `wmwolf@physics.ucsb.edu`.

### Inlist Hint

The stopping condition is now exclusively a central abundance condition. You'll need to use the `xa_central_abundance` business documented in `controls.defaults` under `when to stop`.

### Plotting Hint

For the hydrogen mass, make use of the `total_mass_h1` column in your `history.data`.

## Part 3

### Instructions

Use the ending model from part 2 or a surrogate, if you were unable to complete part 2, to do the following:

- Continue the evolution of the star until it undergoes the first thermal pulse of helium shell burning.
- Plot, as a function of time, the mass of the C-O core.
- Plot, as a function of time, the hydrogen shell and helium shell burning luminosity.

### Inlist Hint

For the stopping condition, check out the `stop_at_TP` condition in `mesa/star/defaults/controls.defaults`. Note the effect of `TP_he_shell_max` on this stopping criterion.

### Plotting Hint

To find the mass of the C-O core, check out the `boundary_mass` columns in your `history.data` file.