Day 1 - Pgplot Lab

An introduction to MESA

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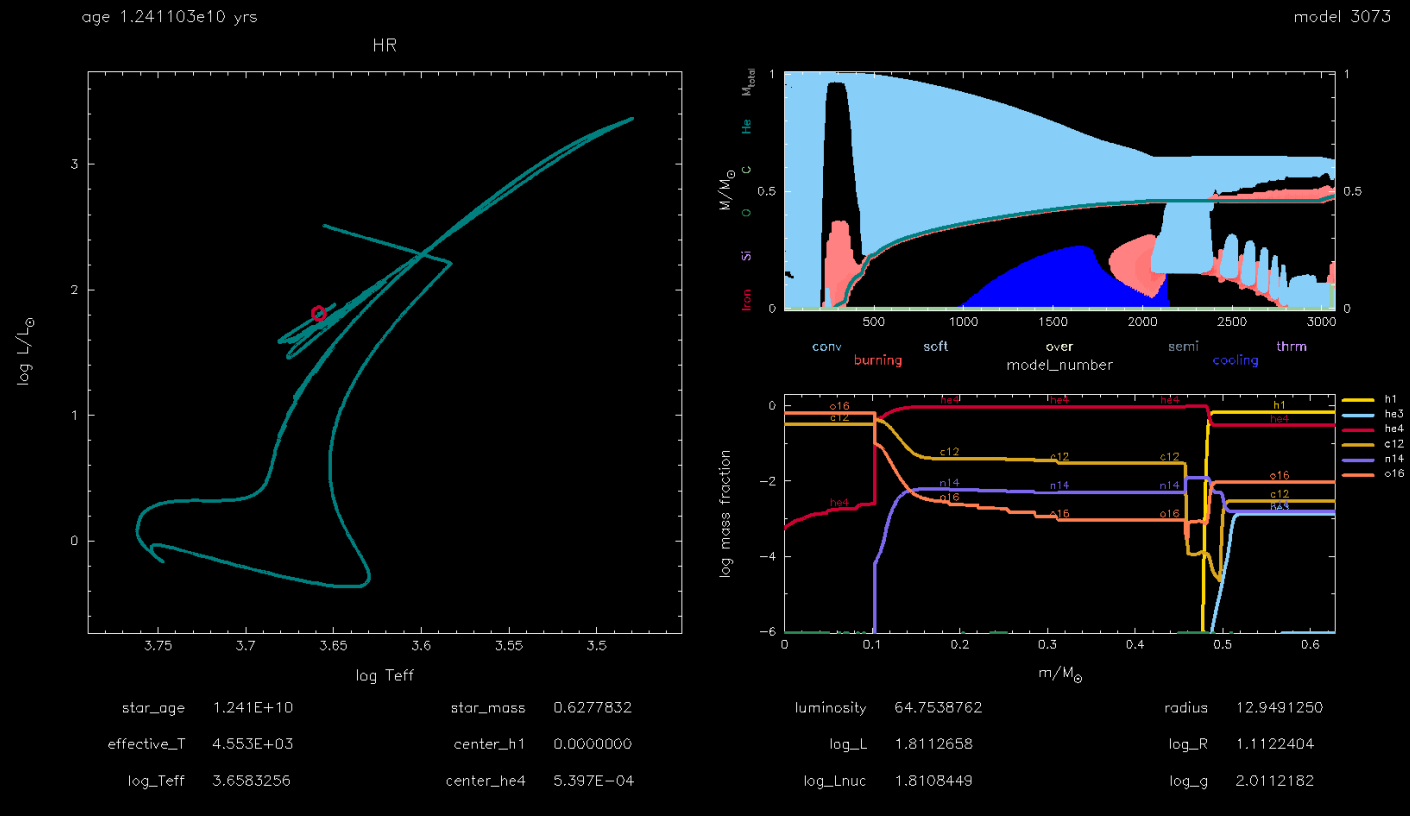


A special thanks to Frank Timmes for letting us use his examples!

Take a look at the test_suite

- The easiest way to learn how to use MESA and to learn what mesa can do is to look at the test_suite:

$MESA_DIR/star/test_suite/

Where you can find examples for many of the stellar evolution problems that MESA can tackle.

Take a look at the test_suite

- From your mesa folder, copy $MESA_DIR/star/test_suite/1M_pre_ms_to_wd to another directory.

NEVER EDIT TEST_SUITE FOLDERS DIRECTLY!

Take a look at the test_suite

The inlists

A MESA run always read the file called inlist first. You can either edit it directly, or write different files for the different sections.

You can find all the commands at:

http://mesa.sourceforge.net/

```
&star_job

      mesa_dir = '../../..'

      read_extra_star_job_inlist2 = .true.
      extra_star_job_inlist2_name = 'inlist_1.0'

/ ! end of star_job namelist


&controls

      read_extra_controls_inlist1 = .true.
      extra_controls_inlist1_name = 'inlist_1.0'

/ ! end of controls namelist


&pgstar

      read_extra_pgstar_inlist1 = .true.
      extra_pgstar_inlist1_name = 'inlist_1.0'

/ ! end of pgstar namelist
```

Take a look at the test_suite

The inlists are divided into three sets of commands:

- star_job: options for the program that evolves the star.
  options listed in the file $MESA_DIR/star/defaults/star_job.defaults
- controls: options for the MESA star module.
  options listed in the file $MESA_DIR/star/defaults/controls.defaults
- pgstar: options for on-screen plotting.
  options listed in the file $MESA_DIR/star/defaults/pgstar.defaults

Take a look at the test_suite

There are some commands that work only in the test_suite folder and that we have to get rid of:

- cd 1M_pre_ms_to_wd_COPY/
- from the file inlist, delete the line

  mesa_dir = '../../..'
- from the next 2 lines in the same file change inlist2 with inlist1

- cd 1M_pre_ms_to_wd_COPY/make
- from the file makefile, delete the line

  MESA_DIR = ../../../..

Take a look at the test_suite

- in the file inlist_1.0, uncomment the line

```
!pgstar_flag = .true.
```

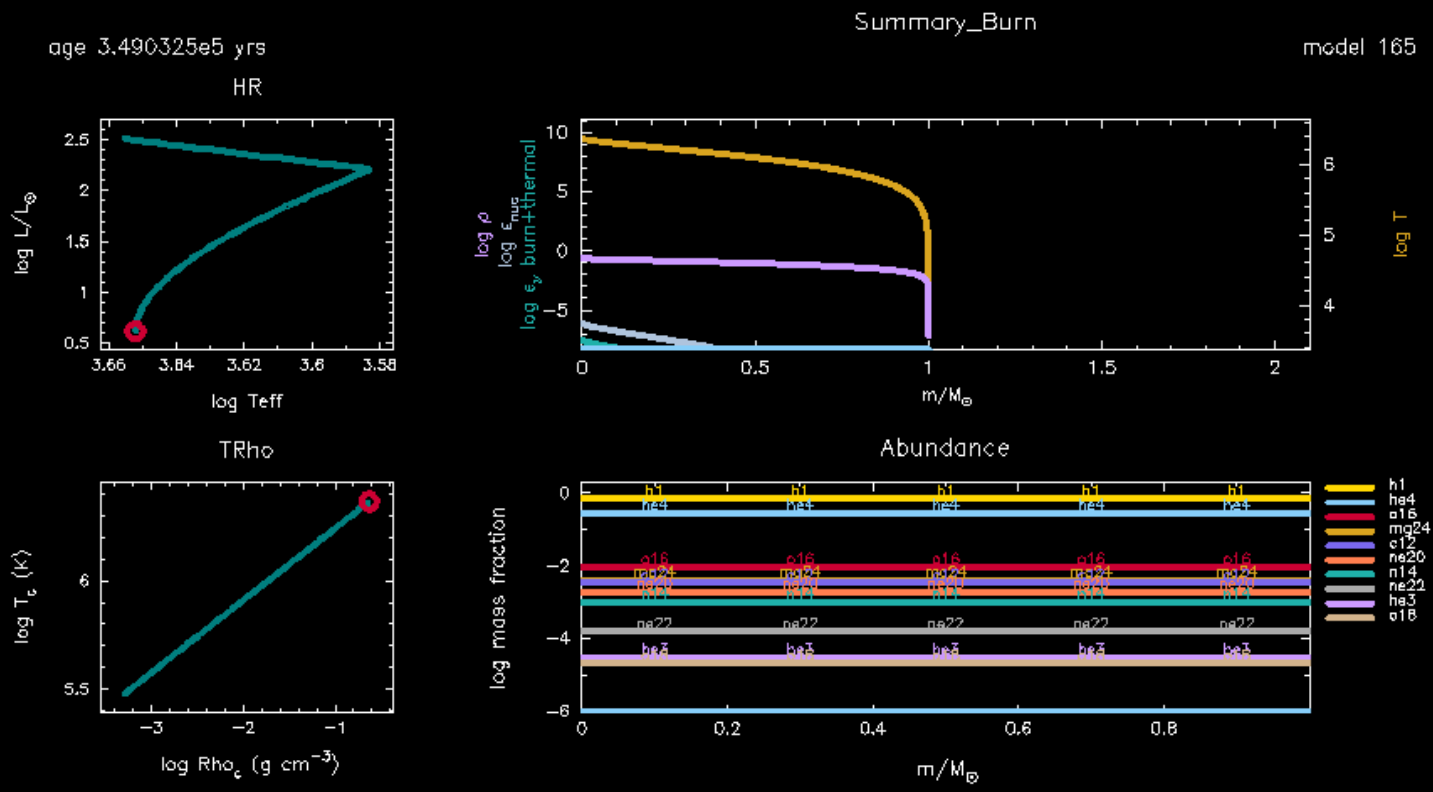
This command, set by default as false, activate pgstar

- from terminal:

```
./clean
./mk
./rn
```

Take a look at the test_suite

After a couple of output, you should see something like this



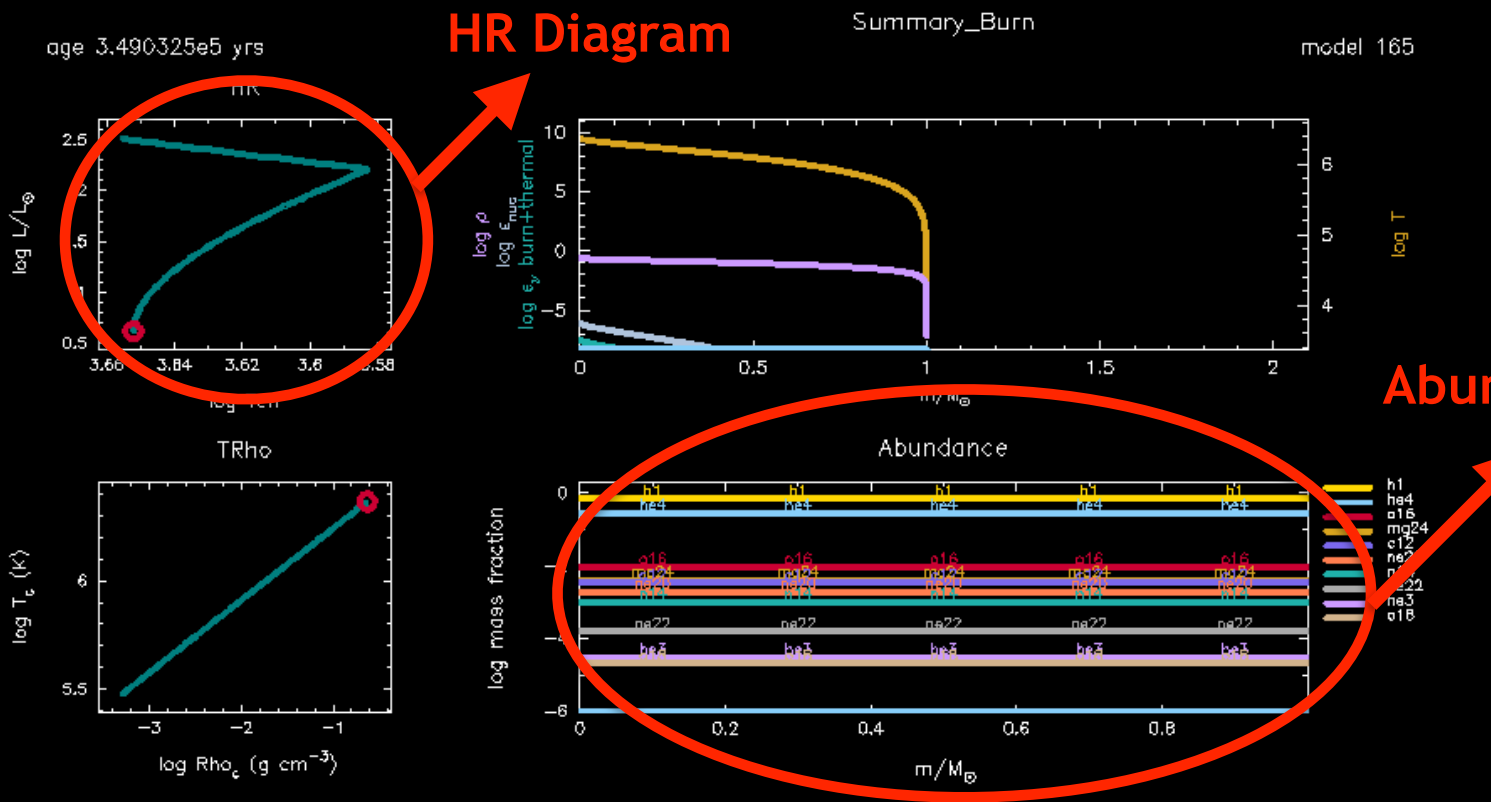
model_number	165	star_mass	0.9999913	log_cntr_T	6.3676479	log_Lnuc	−7.6048222
log_star_age	5.5428658	log_abs_mdot	−11.3778880	log_cntr_Rho	−0.6310383	log_Lneu	−9.0026643
log_dt	4.3498358	he_core_mass	0.0000000	log_center_P	13.8611187	log_LH	−7.6048222
log_L	0.6170745	c_core_mass	0.0000000	center h1	0.7000000	log_LHe	−99.0000000
log_Teff	3.6520576	cz_bot_mass	0.0000000	center he4	0.2799702	log_LZ	−99.0000000
log_R	0.5276809	cz_top_mass	0.9999913	center c12	0.0034416	num_zones	493
log_g	3.3825237	cz_bot_radius	0.0000000	center n14	0.0010082	num_retries	0
log_surf_P	4.2938836	cz_top_radius	3.3685959	center o16	0.0093394	num_backups	0

MESA

Take a look at the test_suite

After a couple of output, you should see something like this

HR Diagram



Abundances

model_number	165	star_mass	0.9999913	log_cntr_T	6.3676479	log_Lnuc	−7.6048222
log_star_age	5.5428658	log_abs_mdot	−11.3778880	log_cntr_Rho	−0.6310383	log_Lneu	−9.0026643
log_dt	4.3498358	he_core_mass	0.0000000	log_center_P	13.8611187	log_LH	−7.6048222
log_L	0.6170745	c_core_mass	0.0000000	center h1	0.7000000	log_LHe	−99.0000000
log_Teff	3.6520576	cz_bot_mass	0.0000000	center he4	0.2799702	log_LZ	−99.0000000
log_R	0.5276809	cz_top_mass	0.9999913	center c12	0.0034416	num_zones	493
log_g	3.3825237	cz_bot_radius	0.0000000	center n14	0.0010082	num_retries	0
log_surf_P	4.2938836	cz_top_radius	3.3685959	center o16	0.0093394	num_backups	0

Take a look at the test_suite

- If your run stops for any reason, you can restart it using the command:

```
./re photo#
```

where photo# is the number of the last saved model (you can find them in the folder called photos)

Take a look at the test_suite

In the folder LOGS, you can see how the output files look like:

- history.data: saves global quantities like logL, logTeff, R, M etc. for every model number; you can change the output by COPYING the file

  star/defaults/history_columns.list

  in your work folder and uncomment what you want to be saved
- profile#.data: saves radial profiles every few models; you can change the output by COPYING the file

  star/defaults/profile_columns.list

  in your work folder and uncomment what you want to be saved

pgstar inlist

- in the file inlist_1.0, delete the pgstar section (from &pgstar to the end).
- create a new inlist, inlist_pgstar, for the pgstar commands and write:

&pgstar

/ ! end of pgstar namelist

Remember to leave a blank line at the end after "/ ! end of pgstar namelist"

- in the file inlist, change the line in the section &pgstar:

extra_pgstar_inlist1_name = 'inlist_1.0'

in

extra_pgstar_inlist1_name = 'inlist_pgstar'

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pgstar inlist

When you save the main inlist file, the run will pause and ask you to hit RETURN.

This happens every time you change something major your pgstar inlist. Just hit RETURN and the run will start again.

Since your new pgstar inlist is blank, the plot will disappear. We need to write instructions for the plots we want.

MESA

pgstar defaults

All the commands you need for pgplot are contained in the file

star/defaults/pgstar.defaults

Open the file and take a look at it. There are some general instructions at the beginning and then a list of all the possible plots with their specific commands.

The HR diagram is a very useful one to study how a star evolves, so let's start with that. Look into the pgstar.defaults file for HR.

HR Diagram

In the pgstar.defaults, you can see a section that looks like this:

```
!# HR window
   ! history of `lg_L` vs. `lg_Teff`

      HR_win_flag = .false.

      HR_win_width = 6
      HR_win_aspect_ratio = 0.75 ! aspect_ratio = height/width

      HR_xleft = 0.15
      HR_xright = 0.85
      HR_ybot = 0.15
      HR_ytop = 0.85
      HR_txt_scale = 1.0
      HR_title = 'HR'
      ....
```

HR Diagram

These are the default settings, so if you copy them into your inlist_pgstar nothing is going to happen. The reason why MESA is not outputting the HR diagram is because this command

```
HR_win_flag = .false.
```

Is set to .false.

Copy it into your inlist_pgstar and set it to .true.

```
HR_win_flag = .true.
```

If you want to change any other settings, just copy them into your inlist_pgstar and change them there.

Kippenhahn diagram

The Kippenhahn diagram is another very useful plot, as it shows the different burning and convective regions of the star. However, MESA doesn't save this information in the history.data file automatically, we have to tell it to do it.

- COPY the file history_column.list from star/defaults/ into your folder
- Change:

!mixing_regions <integer>

into

mixing_regions 40

- Change:

!burning_regions <integer>

into

burning_regions 80

Kippenhahn diagram

After you copy and modify the history_column.list in your folder, your run will continue ignoring the new file. That's because MESA reads the history_column.list at the beginning of the run. If you stop the run now and restart it from a photo, you'll get an error because MESA will try to read the history_column.list, but we cannot change the history.data file format on the fly.

In other words, to have any new information stored in the history.data file, we'll have to restart the run from the beginning.

- Stop your run with Ctrl ^C
- Restart it from the beginning with ./rn

MESA

Kippenhahn diagram

In the pgstar.defaults, you can see a section that looks like this:

```
!# "Kippenhahn" window
    Kipp_win_flag = .true.

    Kipp_win_width = 7
    Kipp_win_aspect_ratio = 0.75 ! aspect_ratio = height/width
    Kipp_xleft = 0.15
    Kipp_xright = 0.85
    Kipp_ybot = 0.15
    Kipp_ytop = 0.85
    Kipp_txt_scale = 1.0
    Kipp_title = 'Kipp'
    .....
```

As before, copy the win_flag command into your inlist_pgstar and set it to .true.

If you want to change other settings, just copy them into your inlist_pgstar and change them.

MESA

Abundances

In the pgstar.defaults, you can see a section that looks like this:

```
!# Abundance window
   ! current model abundance profiles

      Abundance_win_flag = .true.

      Abundance_win_width = 6
      Abundance_win_aspect_ratio = 0.75 ! aspect_ratio = height/width

      Abundance_xleft = 0.15
      Abundance_xright = 0.85
      Abundance_ybot = 0.15
      Abundance_ytop = 0.85
      Abundance_txt_scale = 1.0
      Abundance_title = 'Abundance'
       ......
```

As before, copy the win_flag command into your inlist_pgstar and set it to .true.

Abundances

As a default, the abundance plots shows all the isotopes present in your net.

We want now to plot a smaller number of isotopes and only when their mass fraction is greater than something.

- Look again into the pgstar.defaults to find the commands that set the number and type of isotopes in the Abundances plot and copy them into your inlist_pgstar. Change the settings in a way that only 5 isotopes are plotted: hydrogen, helium, carbon, oxygen and neon.
- Find the right command and copy it into your inlist_pgstar to set the minimum mass fraction to -3.

On the next slide you'll find the solution. Try it out yourself first!

Abundances

To change the number of isotopes:

```
Abundance_num_isos_to_show = 5
Abundance_which_isos_to_show(1) = 'h1'
Abundance_which_isos_to_show(2) = 'he4'
Abundance_which_isos_to_show(3) = 'c12'
Abundance_which_isos_to_show(4) = 'n14'
Abundance_which_isos_to_show(5) = 'o16'
```

To change the minimum mass fraction:

```
Abundance_log_mass_frac_min = -3
```

MESA

Profile Panels

In order to understand better the thermodynamics, the Profile Panels are a useful tool. Start with:

! Profile Panel

Profile_Panels1_win_flag = .true.

And then:

- Put the temperature (not the log) and log10 density on the y-axes
- In the second panel, put energy and net nuclear energy on the y-axes
- Add a third panel with the entropy and the opacity on the y-axes

You can find the names you need in star/default/profile_column.list

Profile Panels

```
! Profile Panel
      Profile_Panels1_win_flag = .true.
      Profile_Panels1_num_panels = 3
      Profile_Panels1_xaxis_name = 'mass'
      Profile_Panels1_yaxis_name(1) = 'temperature'
      Profile_Panels1_other_yaxis_name(1) = 'logRho'
      Profile_Panels1_yaxis_name(2) = 'energy'
      Profile_Panels1_other_yaxis_name(2) = 'net_nuclear_energy'
      Profile_Panels1_yaxis_name(3) = 'entropy'
      Profile_Panels1_other_yaxis_name(3) = 'opacity'
```

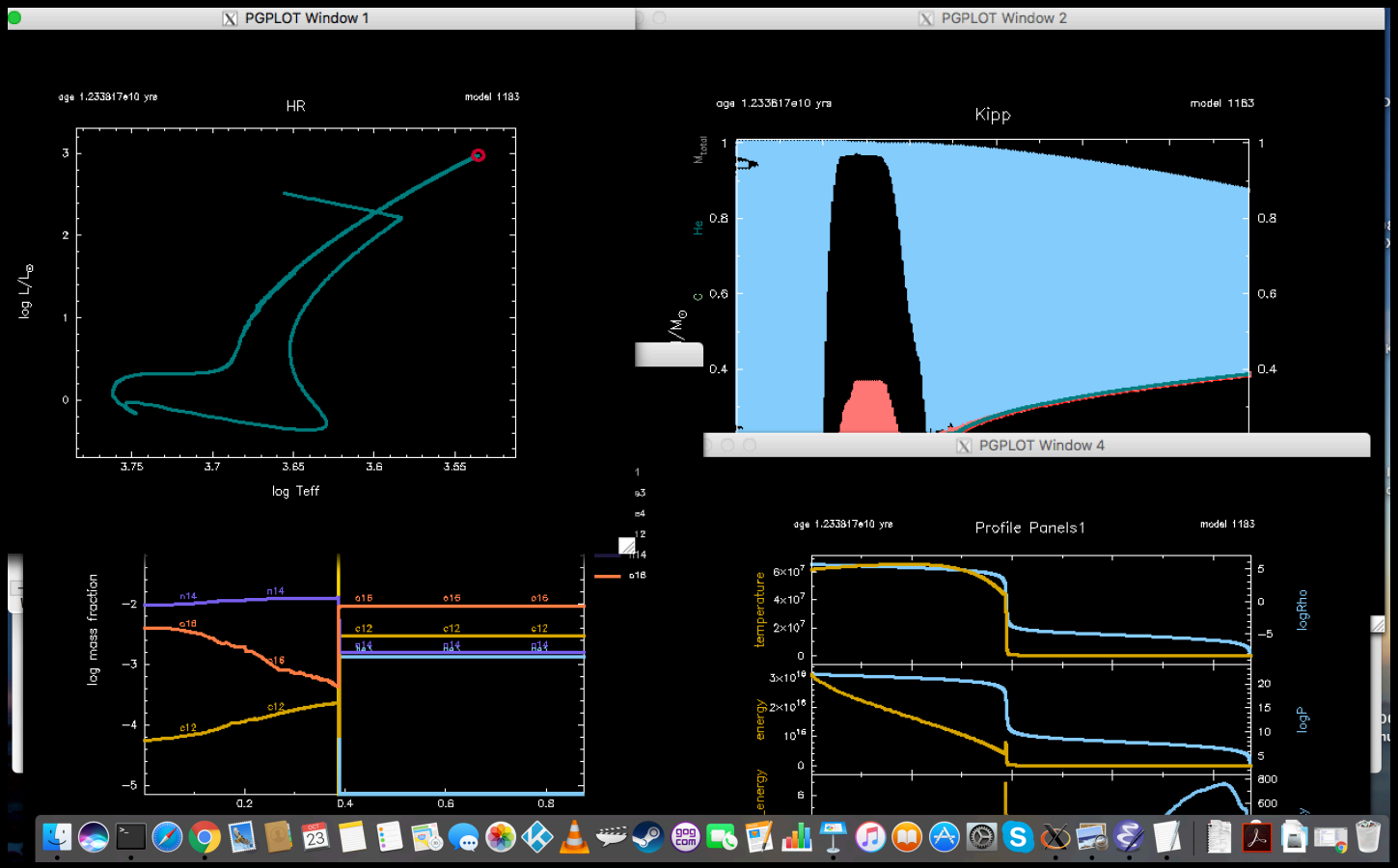
Last Plot: Text Summary

Let's keep track of some useful information:

```
! Text summary window
Text_Summary1_win_flag = .true.
Text_Summary1_win_width = 10
Text_Summary1_win_aspect_ratio = 0.15
Text_Summary1_xleft = 0.06
Text_Summary1_xright = 1.02
Text_Summary1_ybot = 0.0
Text_Summary1_ytop = 1.0
Text_Summary1_txt_scale = 4.0
Text_Summary1_title = ''
Text_Summary1_num_rows = 3 ! <= 20
Text_Summary1_num_cols = 4 ! <= 20
Text_Summary1_name(:,:) = ''
Text_Summary1_name(1,1) = 'time_step'
Text_Summary1_name(1,2) = 'star_age'
Text_Summary1_name(1,3) = 'star_mass'
Text_Summary1_name(1,4) = 'star_mdot'
Text_Summary1_name(2,1) = 'log_Teff'
Text_Summary1_name(2,2) = 'center_h1'
Text_Summary1_name(2,3) = 'center_he4'
Text_Summary1_name(2,4) = 'log_L'
Text_Summary1_name(3,1) = 'log_Lnuc'
Text_Summary1_name(3,2) = 'log_R'
Text_Summary1_name(3,3) = 'he_core_mass'
Text_Summary1_name(3,4) = 'c_core_mass'
```

Grid

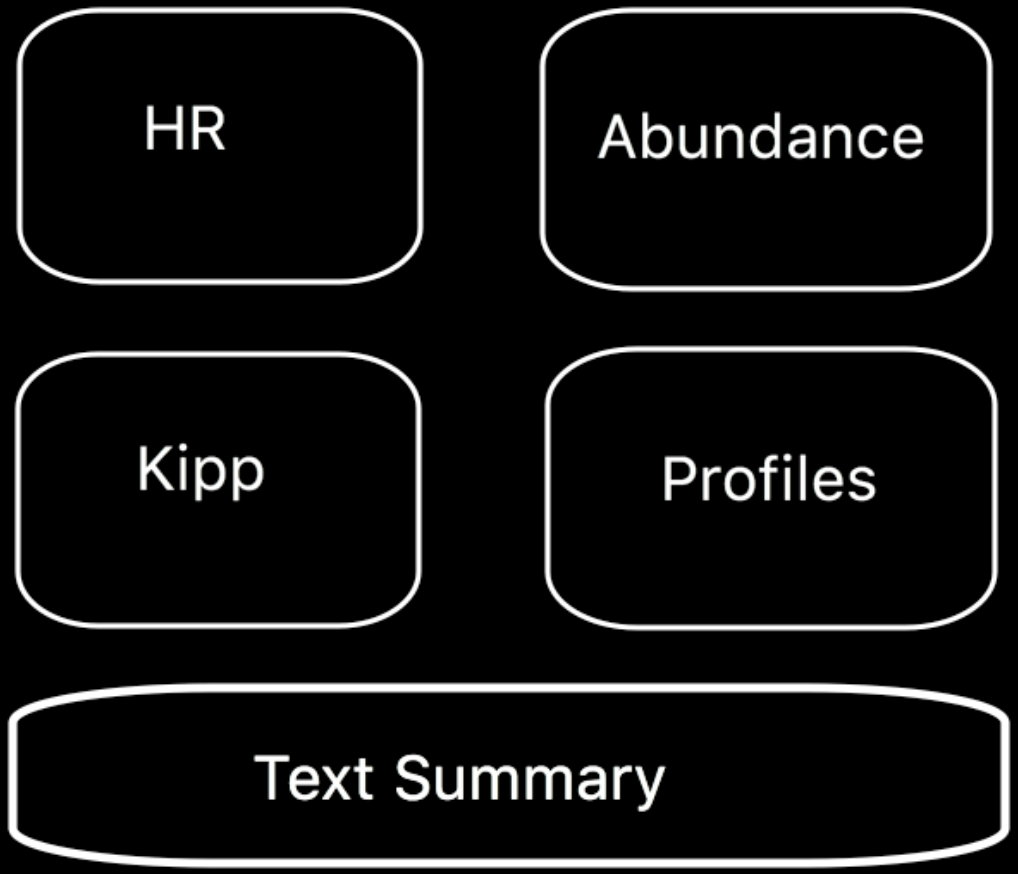
With 5 plots, your screen must look something like this:



Let's tidy up!

Grid

First, plan how you want your grid to look like. Something like:



Grid

Then, close all the individual windows by setting the plot logicals to false:

```
HR_win_flag = .false.
Kipp_win_flag = .false.
Abundance_win_flag = .false.
Profile_Panels1_win_flag = .false.
Text_Summary1_win_flag = .false.
```

PGPLOT will ask you, in the window running the calculation, to hit return to close the X11 windows that were previously open.

MESA

Grid

From star/default/pgstar.defaults, copy:

```
!### Grid1

   Grid1_win_flag = .true.

   Grid1_win_width = 6
   Grid1_win_aspect_ratio = 1 ! aspect_ratio = height/width

   Grid1_xleft = 0.12 ! fraction of full window width for margin on left
   Grid1_xright = 0.95 ! fraction of full window width for margin on right
   Grid1_ybot = 0.08 ! fraction of full window width for margin on bottom
   Grid1_ytop = 0.92 ! fraction of full window width for margin on top
   Grid1_title = ''

   Grid1_plot_name(:) = ''
   Grid1_plot_row(:) = 1 ! number from 1 at top
   Grid1_plot_rowspan(:) = 1 ! plot spans this number of rows
   Grid1_plot_col(:) =  1 ! number from 1 at left
   Grid1_plot_colspan(:) = 1 ! plot spans this number of columns
   Grid1_plot_pad_left(:) = 0.0 ! fraction of full window width for padding on left
   Grid1_plot_pad_right(:) = 0.0 ! fraction of full window width for padding on right
   Grid1_plot_pad_top(:) = 0.0 ! fraction of full window height for padding at top
   Grid1_plot_pad_bot(:) = 0.0 ! fraction of full window height for padding at bottom
   Grid1_txt_scale_factor(:) = 0.7 ! multiply txt_scale for subplot by this

   ! set default
   Grid1_num_cols = 2 ! divide plotting region into this many equal width cols
   Grid1_num_rows = 8 ! divide plotting region into this many equal height rows
   Grid1_num_plots = 4 ! <= 10
```

You have to write one of this for every plot

MESA

Grid

Example:

```
Grid1_plot_name(1) = 'HR'
Grid1_plot_row(1) = 1 ! number from 1 at top
Grid1_plot_rowspan(1) = 3 ! plot spans this number of rows
Grid1_plot_col(1) =  1 ! number from 1 at left
Grid1_plot_colspan(1) = 1 ! plot spans this number of columns
Grid1_plot_pad_left(1) = 0.0 ! fraction of full window width for padding on left
Grid1_plot_pad_right(1) = 0.0 ! fraction of full window width for padding on right
Grid1_plot_pad_top(1) = 0.0 ! fraction of full window height for padding at top
Grid1_plot_pad_bot(1) = 0.0 ! fraction of full window height for padding at bottom
Grid1_txt_scale_factor(1) = 0.5 ! multiply txt_scale for subplot by this

Grid1_plot_name(2) = 'Kipp'
Grid1_plot_row(2) = 4 ! number from 1 at top
Grid1_plot_rowspan(2) = 3 ! plot spans this number of rows
Grid1_plot_col(2) =  1 ! number from 1 at left
Grid1_plot_colspan(2) = 1 ! plot spans this number of columns
Grid1_plot_pad_left(2) = 0.0 ! fraction of full window width for padding on left
Grid1_plot_pad_right(2) = 0.0 ! fraction of full window width for padding on right
Grid1_plot_pad_top(2) = 0.05 ! fraction of full window height for padding at top
Grid1_plot_pad_bot(2) = 0.0 ! fraction of full window height for padding at bottom
Grid1_txt_scale_factor(2) = 0.5 ! multiply txt_scale for subplot by this
```

MESA

Grid

You have to change the number of columns and rows that you want, and the number of plots, example:

```
Grid1_num_cols = 3 ! divide plotting region into this many equal width cols
Grid1_num_rows = 7 ! divide plotting region into this many equal height rows
Grid1_num_plots = 5 ! <= 10
```

Then assign a place to your different plots with commands:

```
Grid1_plot_row(2) = 1 ! number from 1 at top
Grid1_plot_rowspan(2) = 3 ! plot spans this number of rows
Grid1_plot_col(2) =  2 ! number from 1 at left
Grid1_plot_colspan(2) = 1 ! plot spans this number of columns
```

Tweak the spacing between them with these commands:

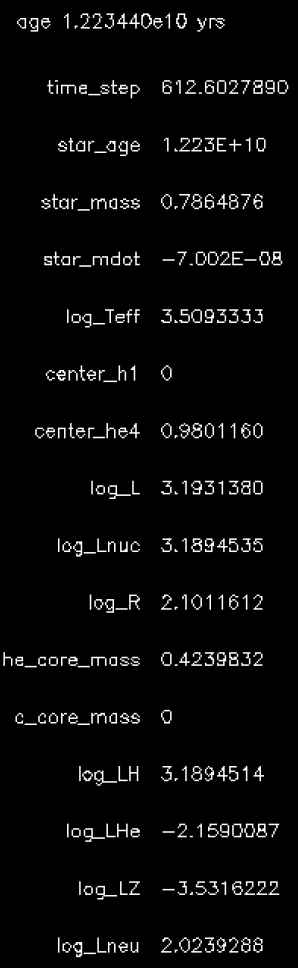
```
Grid1_plot_colspan(2) = 2 ! plot spans this number of columns
Grid1_plot_pad_left(2) = 0.0 ! fraction of full window width for padding on left
Grid1_plot_pad_right(2) = 0.0 ! fraction of full window width for padding on right
Grid1_plot_pad_top(2) = 0.05 ! fraction of full window height for padding at top
Grid1_plot_pad_bot(2) = 0.0 ! fraction of full window height for padding at bottom
```

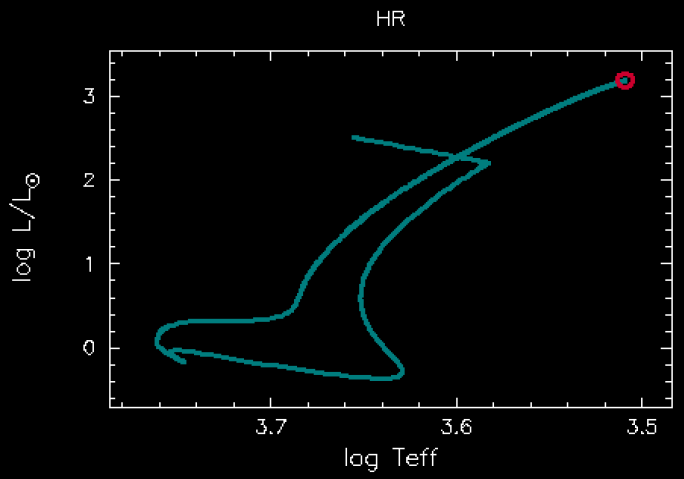
And change the text size with this command:

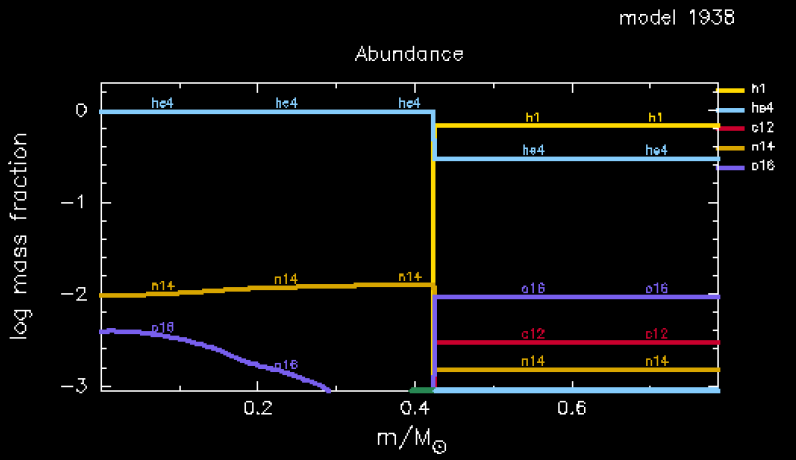
```
Grid1_txt_scale_factor(2) = 0.5 ! multiply txt_scale for subplot by this
```

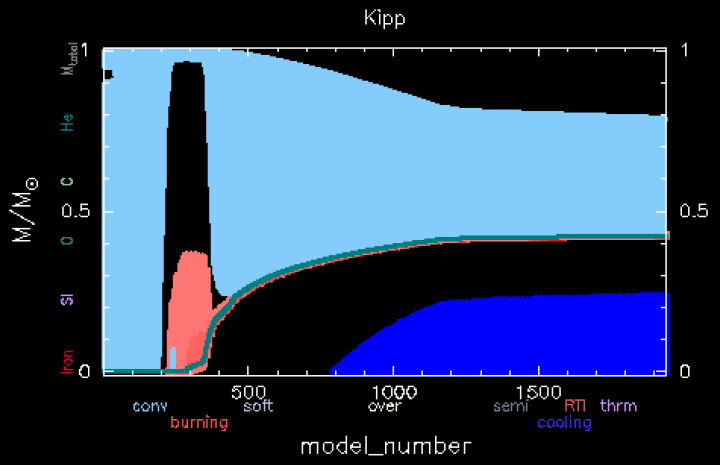
Day 1 - Pgplot Lab

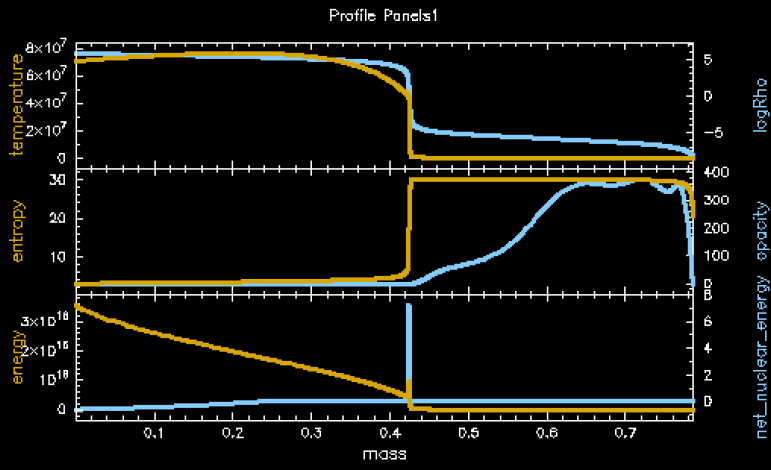
Grid











You can check how I made this grid in the inlist_pgstar included in the folder.

Saving...

You can save your plots by changing this to true:

```
! file output
Grid1_file_flag = .true.
Grid1_file_dir = 'png'
Grid1_file_prefix = 'grid1'
Grid1_file_cnt = 5 ! output when mod(model_number,Grid1_file_cnt)==0
Grid1_file_width = 20 ! negative means use same value as for window
Grid1_file_aspect_ratio = -1 ! negative means use same value as for window
```

MESA

...and making a movie!

In the terminal, write the command:

```
images_to_movie.sh "png/*.png" name.mp4
```