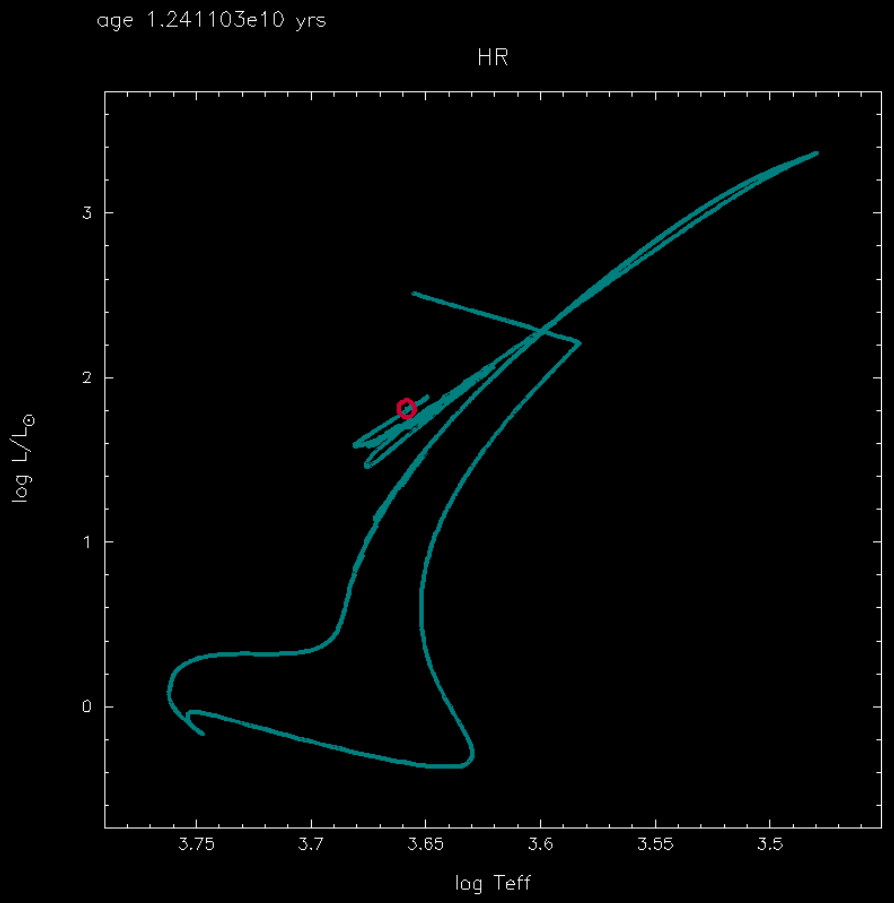
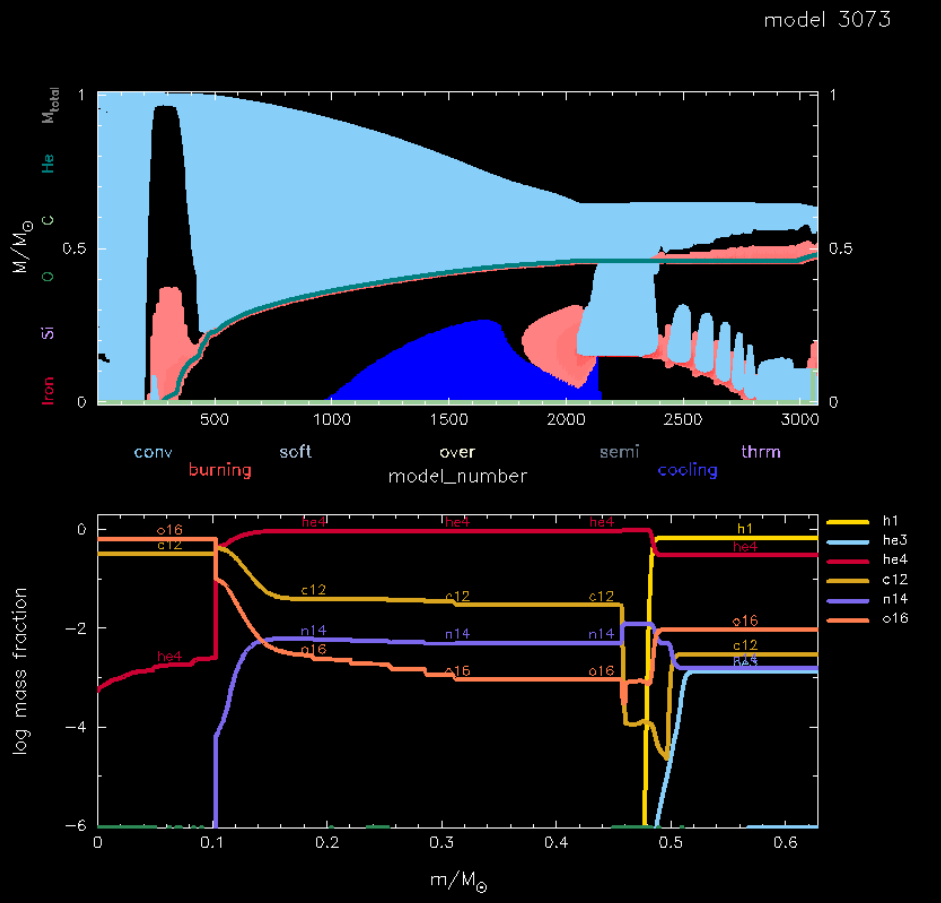
TSI, July 24, 2017

An introduction to MESA





star_age	1.241E+10	star_mass	0.6277832	luminosity	64.7538762	radius	12.9491250
effective_T	4.553E+03	center_h1	0.0000000	log_L	1.8112658	log_R	1.1122404
log_Teff	3.6583256	center_he4	5.397E-04	log_Lnuc	1.8108449	log_g	2.0112182

Ilaria Caiazzo

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:

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
  star/test_suite/1M_pre_ms_to_wd
  to another directory.

NEVER EDIT TEST_SUITE FOLDERS DIRECTLY!
EVER!

Take a look at the test_suite

The inlists

You can find 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

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 = ../../../..

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Take a look at the test_suite

- in the file inlist_1.0, uncomment the line

!pgstar_flag = .true.

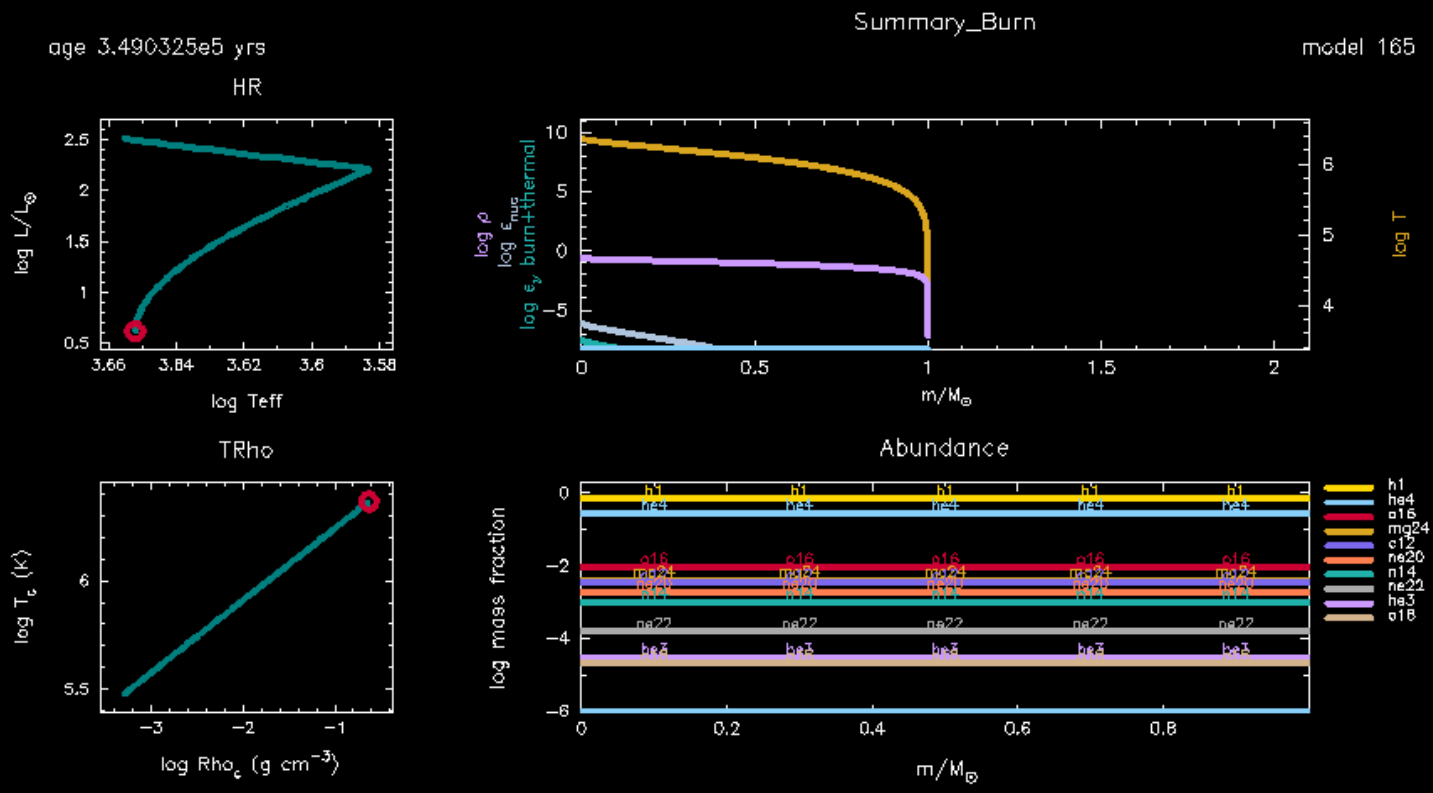
This command, set by default as false, activate pgstar

- 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

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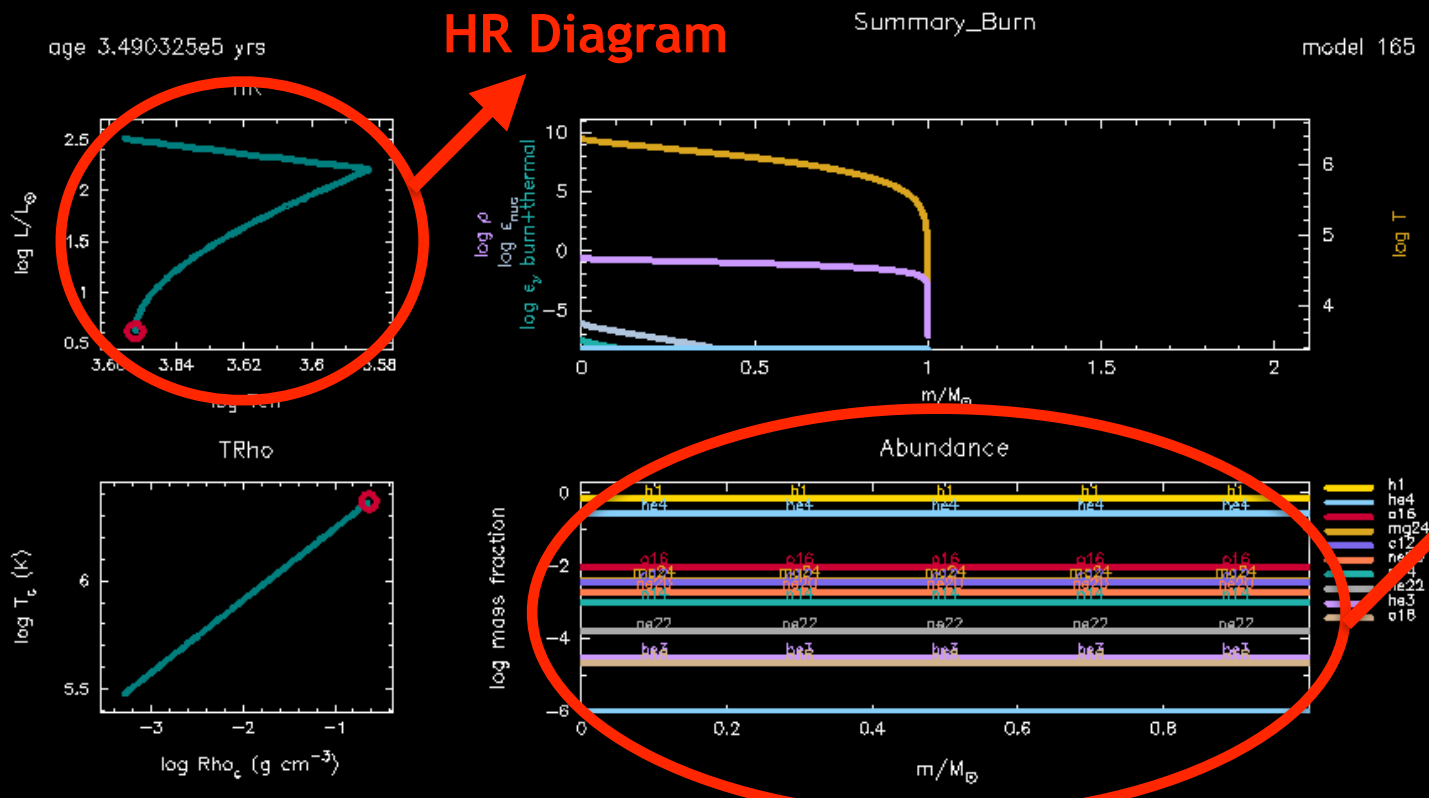
Take a look at the test_suite

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

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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:

&pgstar

/ ! 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’

pgstar defaults

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

star/defaults/pgstar.defaults

HR Diagram

From pgstar.defaults, copy

```
!# 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'
```

into your inlist_pgstar

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HR Diagram

From pgstar.defaults, copy

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

    HR_win_flag = .true.

    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'
```

into your inlist_pgstar

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Kippenhahn diagram

In order to plot a Kippenhahn diagram, we have to keep track of where the star is burning and where it's convective in our history_column.list file.

- 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

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MESA

Kippenhahn diagram

From pgstar.defaults, copy

```
!# "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'
      Kipp_xaxis_name = 'model_number' ! xaxis coordinates. Sensible choices are model_number or star_age
      Kipp_xaxis_log=.false. ! Whether xaxis should be reported as a log10 value
      Kipp_xmin=-101d0 ! Min of x value to plot. -101d0 means use min(x)
      Kipp_xmax=-101d0 ! Max of x value to plot. -101d0 means use max(x)
      Kipp_xmargin=0.0
      Kipp_xaxis_reversed=.false. ! Whether to reverse the direction of the xaxis
      Kipp_xaxis_in_seconds=.false. ! Whether to plot time in seconds
            ! Requires Kipp_xaxis_name='star_age'
      Kipp_xaxis_in_Myr=.false. ! Whether to plot time in units of 10^6 years
```

into your inlist_pgstar

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Abundances

From pgstar.defaults, copy

```
!# 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'

Abundance_num_isos_to_show = 6
Abundance_which_isos_to_show(1) = 'h1'
Abundance_which_isos_to_show(2) = 'he3'
Abundance_which_isos_to_show(3) = 'he4'
Abundance_which_isos_to_show(4) = 'c12'
Abundance_which_isos_to_show(5) = 'n14'
Abundance_which_isos_to_show(6) = 'o16'
```

into your inlist_pgstar

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Abundances

You can also show only isotopes with a mass fraction grater than a certain amount by copying:

Abundance_log_mass_frac_min = 101 ! only used if < 0

and changing it into

Abundance_log_mass_frac_min = -3

for example

Profile Panels

Now a little exercise.

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 logP on the y-axes
- Add a third panel with the net nuclear energy 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_xmin = -101d0 ! only used if /= -101d0
      Profile_Panels1_xmax = -101d0 ! only used if /= -101d0
      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) = 'logP'
      Profile_Panels1_yaxis_name(3) = 'net_nuclear_energy'
      Profile_Panels1_other_yaxis_name(3) = 'opacity'
```

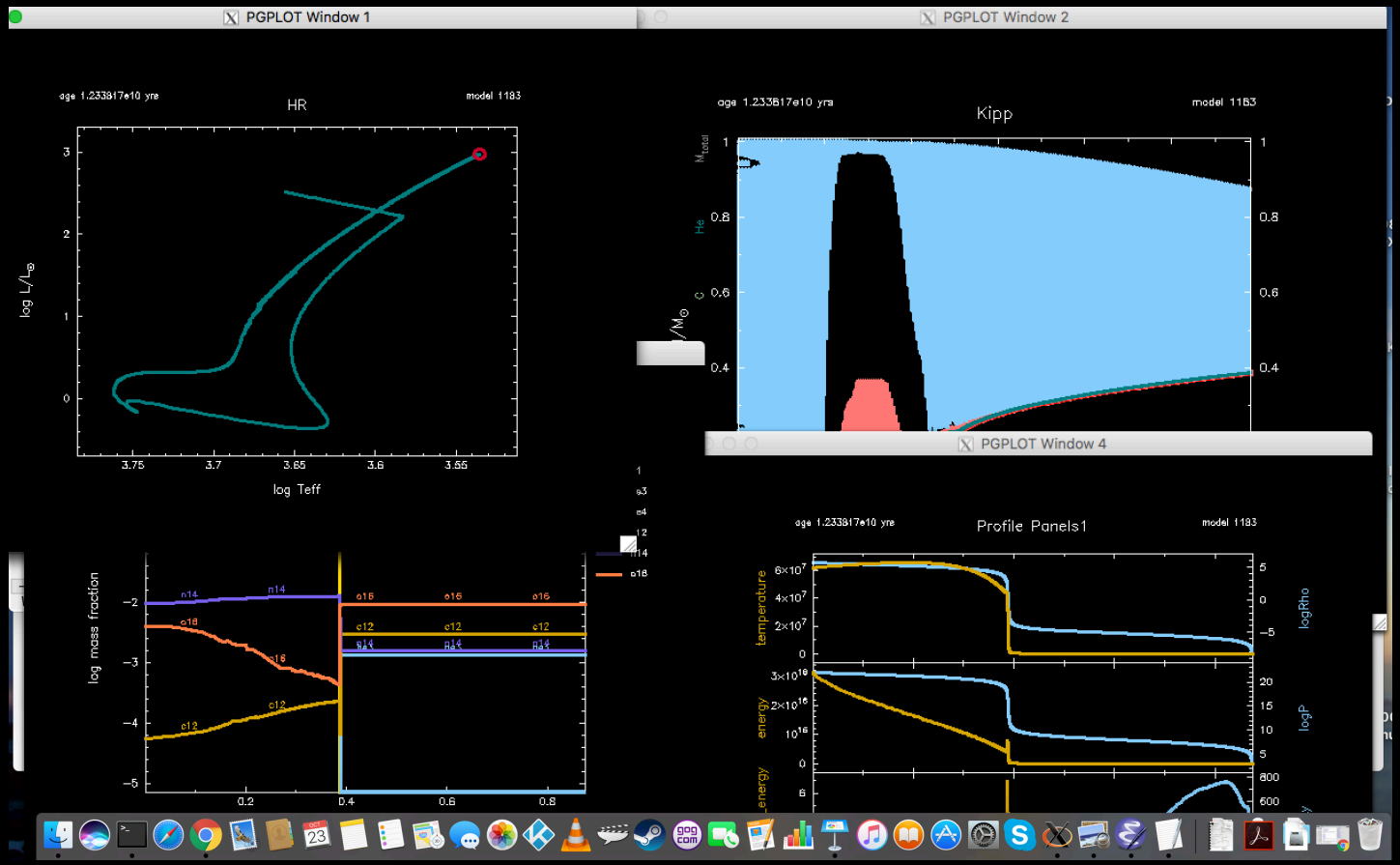
Last Plot: Text Summary

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!

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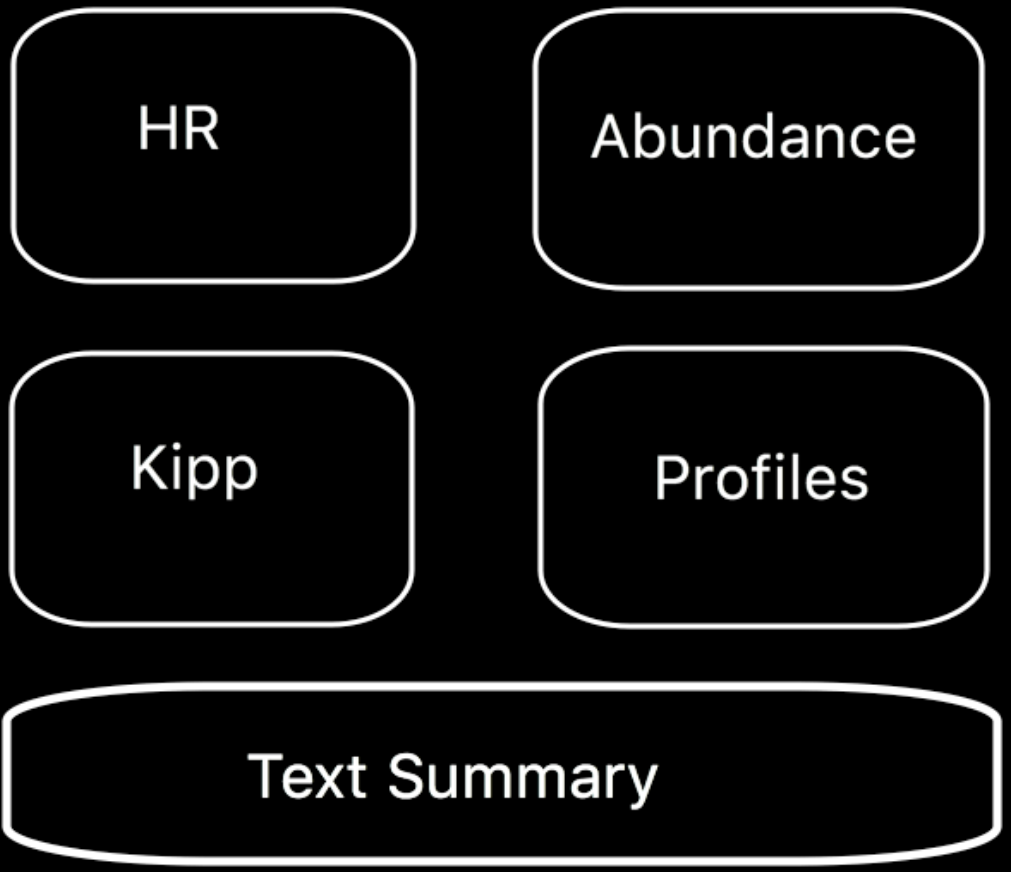
Grid

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 = .true.
Text_Summary1_win_flag = .true.
```

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

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

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Grid

Example:

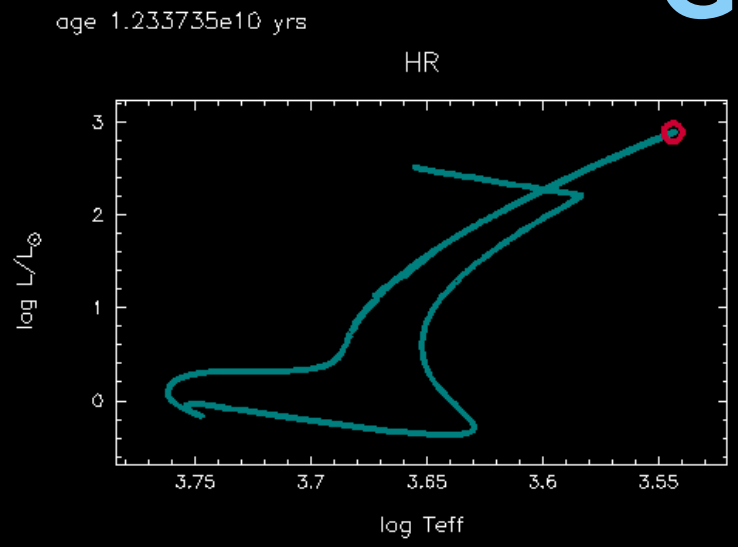
```
Grid1_plot_name(1) = 'HR'
Grid1_plot_row(1) = 1 ! number from 1 at top
Grid1_plot_rowspan(1) = 4 ! plot spans this number of rows
Grid1_plot_col(1) =  1 ! number from 1 at left
Grid1_plot_colspan(1) = 2 ! plot spans this number of columns
Grid1_plot_pad_left(1) = 0.0 ! fraction of full window width 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) = 0.7 ! multiply txt_scale for subplot by this

Grid1_plot_name(2) = 'Kipp'
Grid1_plot_row(2) = 6 ! number from 1 at top
Grid1_plot_rowspan(2) = 4 ! plot spans this number of rows
Grid1_plot_col(2) =  1 ! number from 1 at left
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
Grid1_txt_scale_factor(2) = 0.7 ! multiply txt_scale for subplot by this
```

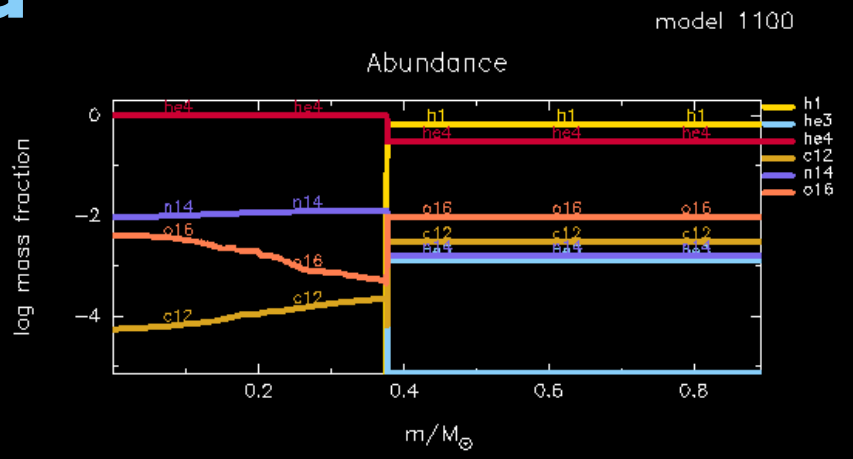
Grid

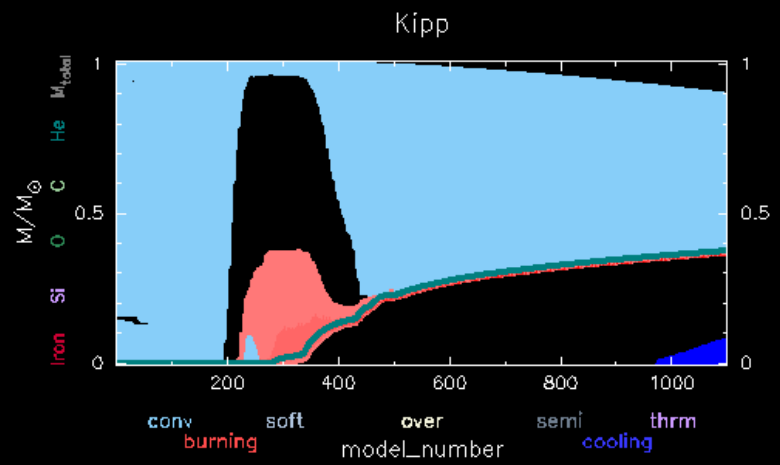
And you have to change the number of columns and rows that you want, and the number of plots, example:

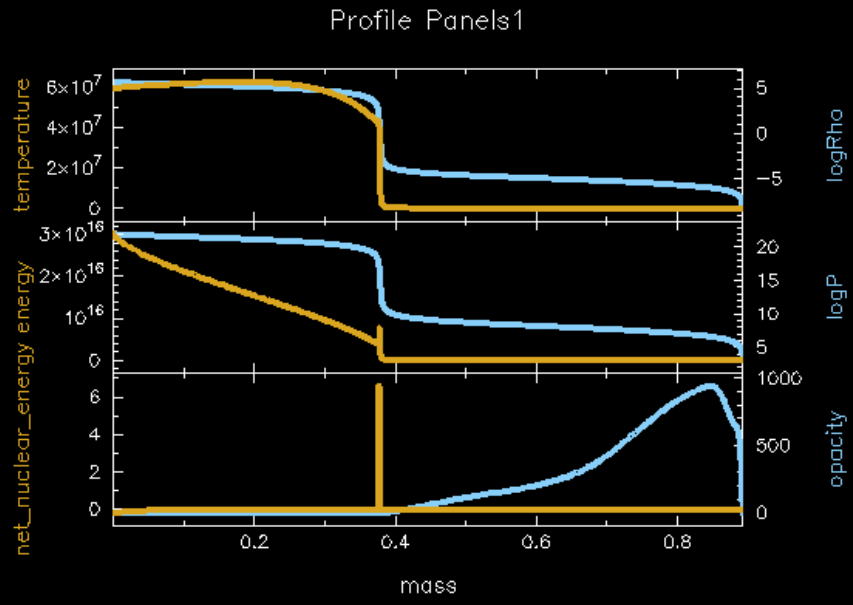
```
Grid1_num_cols = 6 ! divide plotting region into this many equal width cols
Grid1_num_rows = 11 ! divide plotting region into this many equal height rows
Grid1_num_plots = 5 ! <= 10
```

Grid









time_step	1.202E+04	star_age	1.234E+10	star_mass	0.8927884	star_mdot	−1.974E−08
log_Teff	3.5435946	center_h1	1.001E−99	center_he4	0.9801132	log_L	2.8958759
log_Lnuc	2.8922838	log_R	1.8840075	he_core_mass	0.3765307	c_core_mass	0.0000000

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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 = 14 ! negative means use same value as for window
Grid1_file_aspect_ratio = -1 ! negative means use same value as for window
```

...and making a movie!

In the terminal, write the command:

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