Customizing pgstar for your models

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Download the ~15 MB MESA work directory from

http://cococubed.asu.edu/mesa_market/ewExternalFiles/
mesa_ss_2018_timmes.zip

unzip mesa_ss_2018_timmes.zip where you do your MESA work.
Issue the terminal commands:

% cd mesa_ss_2018_timmes

% ./mk

One slide on the astrophysics …KIC 8626021 …
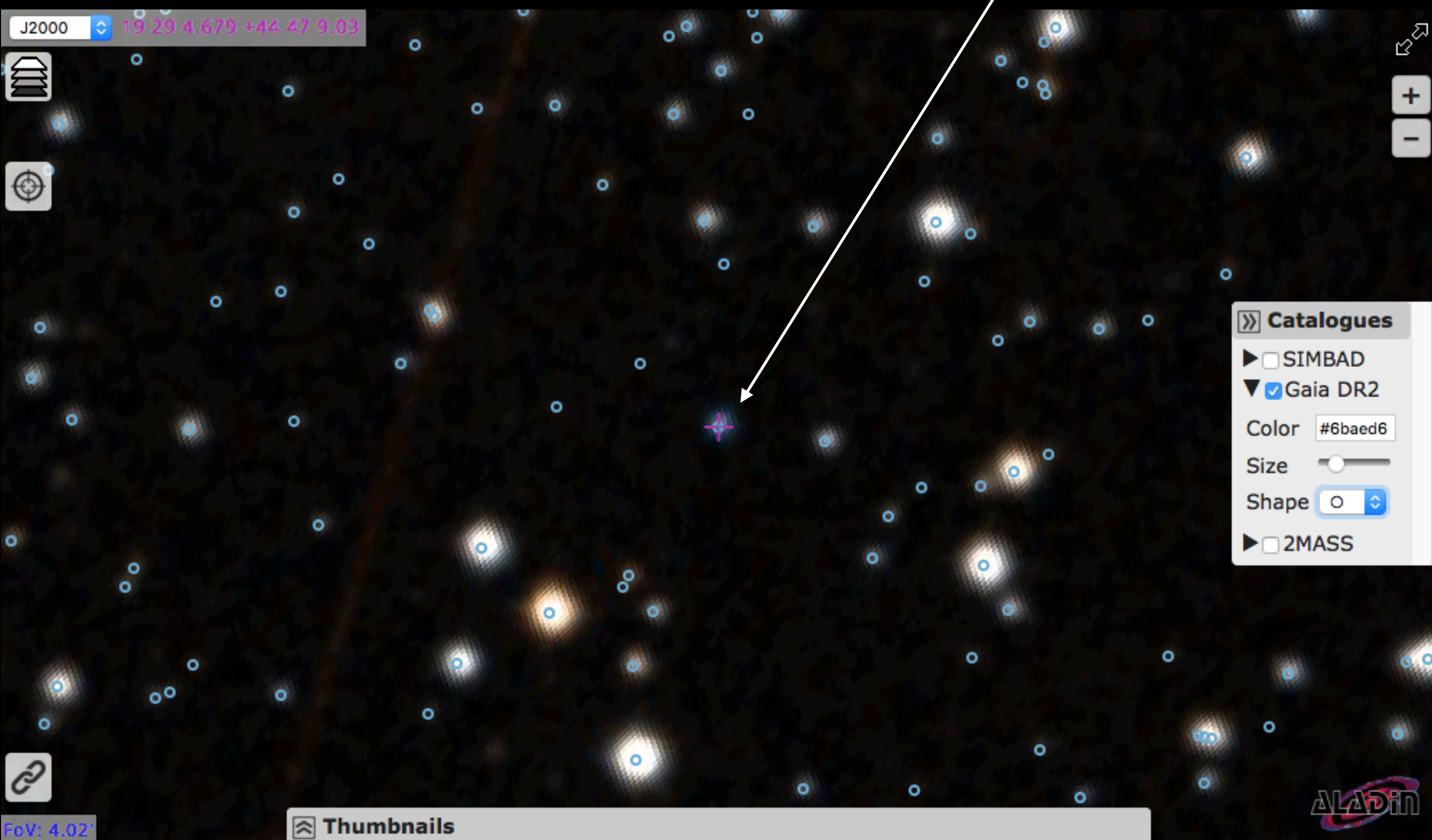
edit inlist_project, and change the multiplier on the 12C(a,g) reaction rate

special_rate_factor(2) = XXXX

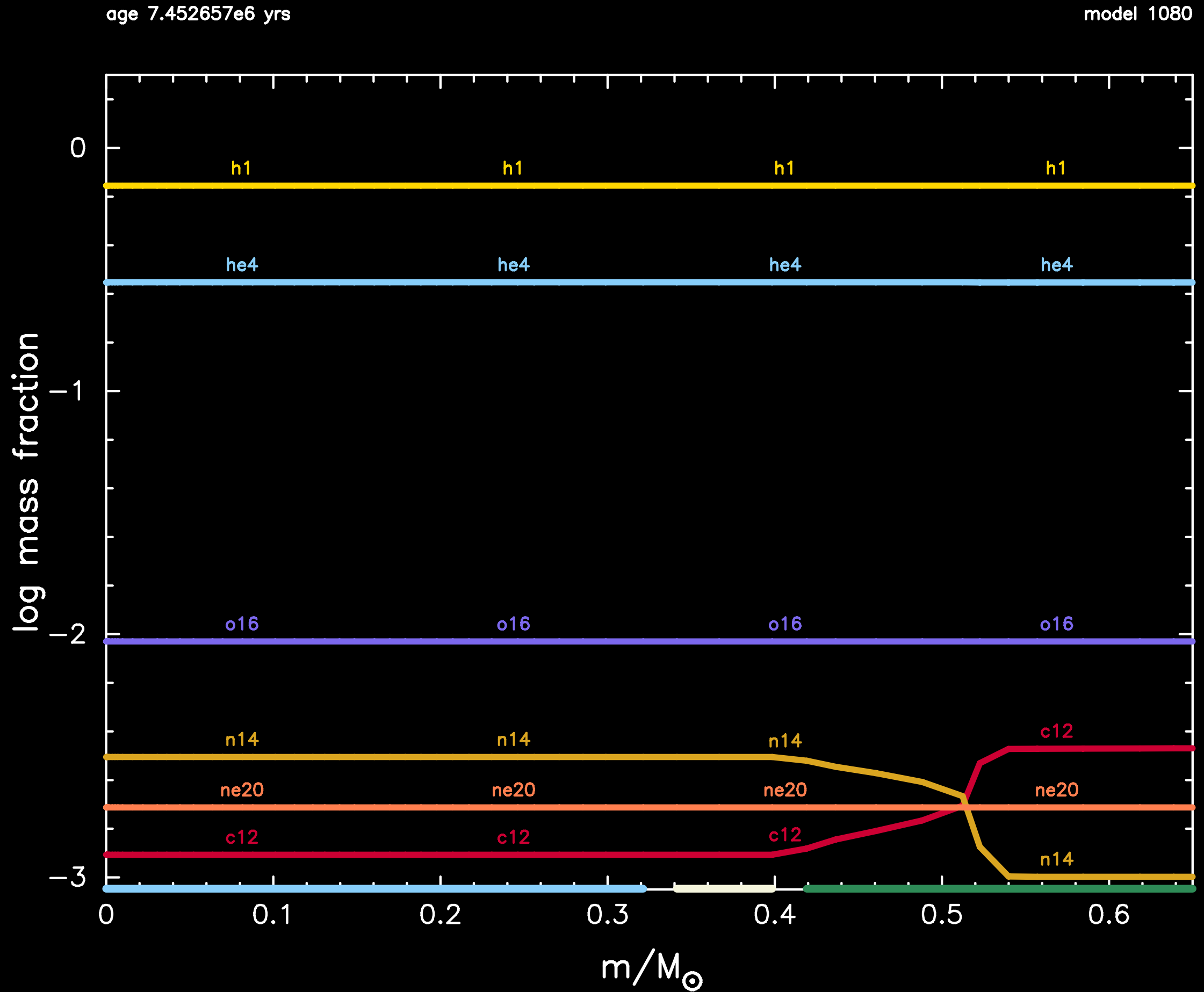to your table's value of 0.75 - 1.50 in 0.05 increments.

We will be interested in the central oxygen mass fraction after core helium depletion.

% ./rn

Leave the job running as MESA will read inlist_pgstar at each timestep; plot changes can be seen live!

If you make a mistake and MESA stops,
do a ./re from the last photo.

You should see something like this:

age 7.452657e6 yrs

model 1080

Edit inlist_pgstar. You will see the abundance plot commands:

```
Abundance_win_flag = .true.

! window properties
Abundance_win_width = 10
Abundance_win_aspect_ratio = 0.75

Abundance_xleft = 0.15
Abundance_xright = 0.85
Abundance_ybot = 0.15
Abundance_ytop = 0.85
Abundance_txt_scale = 0.8
Abundance_title = ''

! isotopes to plot

Abundance_num_isos_to_show = 22

Abundance_which_isos_to_show(1) = 'h1'
Abundance_which_isos_to_show(2) = 'prot'
Abundance_which_isos_to_show(3) = 'he3'
Abundance_which_isos_to_show(4) = 'he4'
Abundance_which_isos_to_show(5) = 'c12'
Abundance_which_isos_to_show(6) = 'n14'
Abundance_which_isos_to_show(7) = 'o16'
Abundance_which_isos_to_show(8) = 'ne20'
Abundance_which_isos_to_show(9) = 'mg24'
Abundance_which_isos_to_show(10) = 'si28'
```

Experiment with changing some of the plot options:
Abundance_num_isos_to_show
Abundance_legend_max_cnt
Abundance_log_mass_frac_min

Further down in inlist_pgstar are power plot commands. Change the Power_win_flag to true.

```
Power_win_flag = .false.

Power_win_width = 10
Power_win_aspect_ratio = 0.75
Power_title = ''

Power_xleft = 0.15
Power_xright = 0.85
Power_ybot = 0.15
Power_ytop = 0.85
Power_txt_scale = 1.0
Power_title = ' '

Power_xaxis_name = 'mass'
Power_xaxis_reversed = .false.

Power_legend_max_cnt = 16
Power_legend_txt_scale_factor = 1.0

Power_xmin = 0.0
Power_xmax = 1.0    !  -101d0

Power_ymin = -101 !  only used if /= -101d0
Power_ymax = -101 !  only used if /= -101d0
```
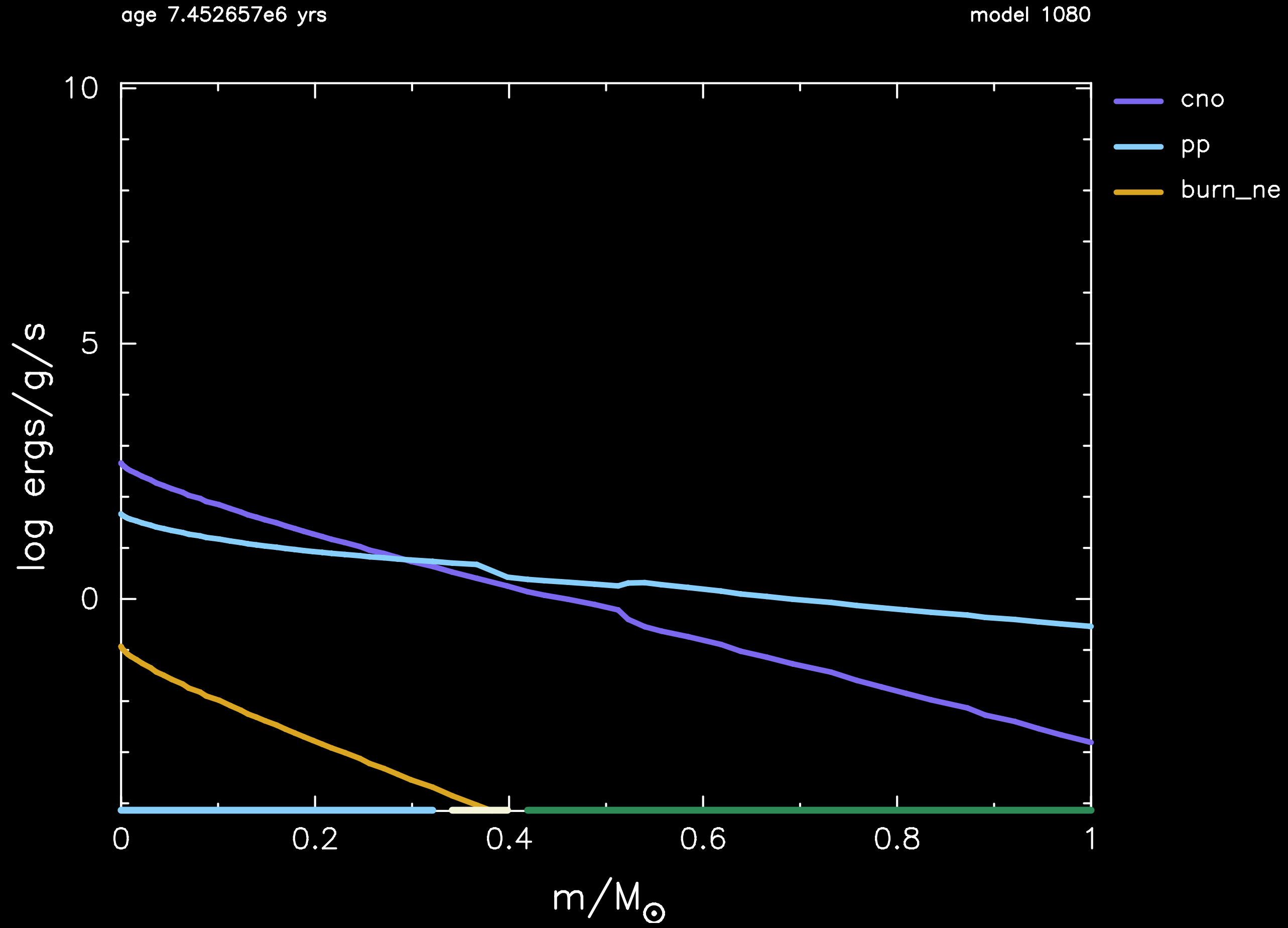
Experiment with changing some of the plot options:
Power_xmax
Power_win_width

You should see something like this:

age 7.452657e6 yrs   model 1080

Further down in inlist_pgstar are Kippenhahn plot commands. Change the Kipp_win_flag to true.

```
Kipp_win_flag = .false.

! window properties
Kipp_win_width = 10
Kipp_win_aspect_ratio = 0.75
Kipp_title = ''

! y axis limits
Kipp_mass_max = 2.1
Kipp_mass_min = 0
Kipp_show_mass_boundaries = .true.

! x axis limits
Kipp_xmax = -101         ! maximum step number
Kipp_xmin = 0            ! minimum step number
Kipp_max_width = -1      ! only used if > 0.
causes xmin to move with xmax.

Kipp_show_mixing = .true.
Kipp_show_burn = .true.
Kipp_show_luminosities = .false.

! file output
Kipp_file_flag = .false.
```

Experiment with changing some of the plot options:
Kipp_show_mixing
Kipp_show_burn
Kipp_show_luminosities

You should see something like this:

age 7.452657e6 yrs

model 1080
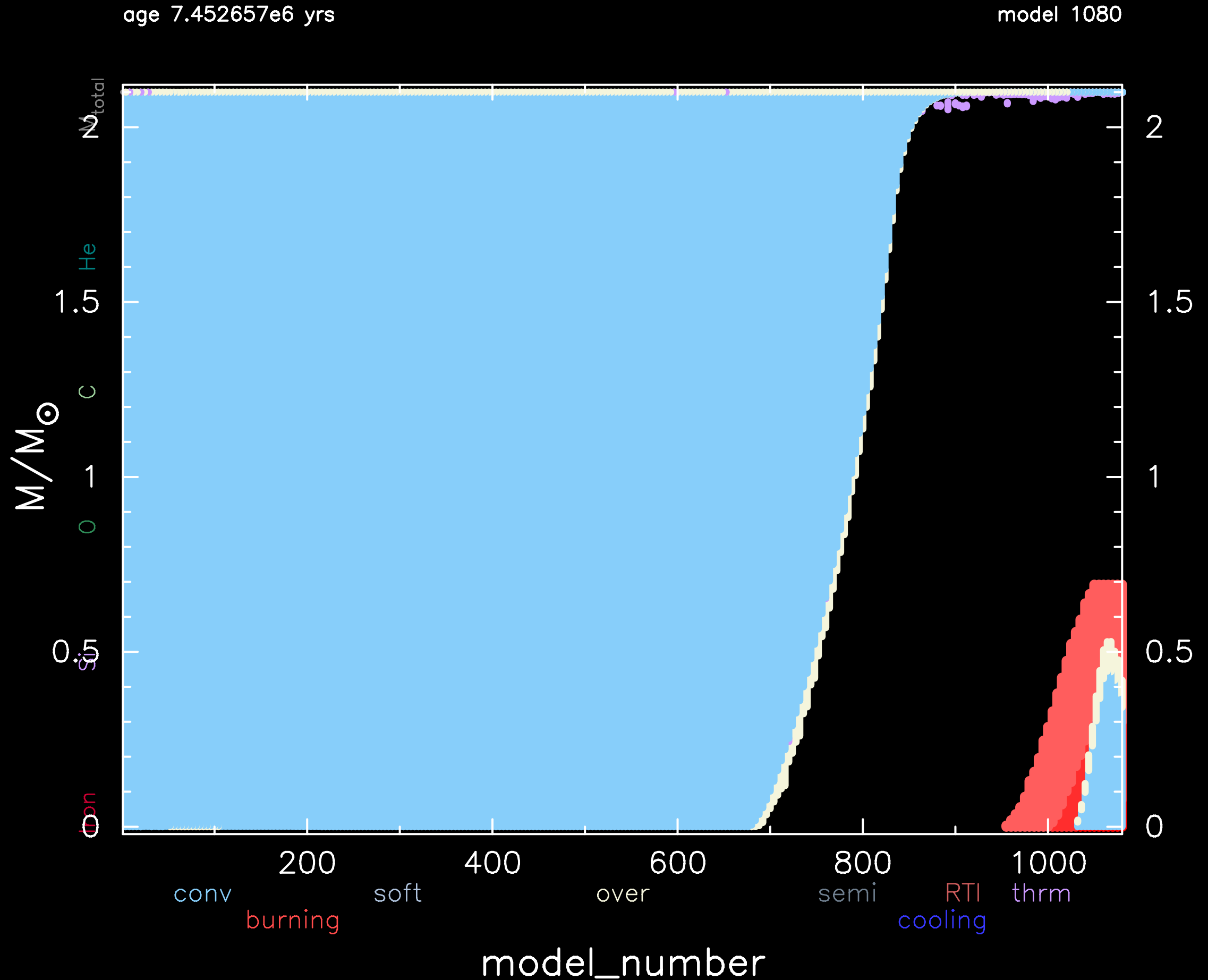
History plots show information in your history_columns.list. The name for a history item must be the same as one of the column headings in your LOGS/history.data.

Profile plots show information about a current model. You can plot anything that can be in a profile_columns.list. You are not limited to items in your local profile_columns.list.

Single panel plots contain one graph, optionally with a 2nd y-axis. Our Kipp diagram is an example of a single panel plot.

Multiple panel plots stack several graphs using the same x-axis. We will be building two custom multiple panel plots.

Grid plots combine several plots in a user-specified grid layout. Our goal is to build a custom grid plot.

Let's put some thermodynamic gauges on our star.

Copy & paste these history plot commands from the supplied plot_commands.txt file to inlist_pgstar, and save inlist_pgstar.

```
! Profile Panel - thermodynamics

Profile_Panels1_win_flag = .true.
```

Gorgeous as this default beauty is, let's tune it to our needs.

Tasks:
   1) put mass on the x-axis and range from 0 to 2.1 M_☉

   2) for panel 1:
      put "logT" on the upper panel y-axis
      put "entropy" on the upper panel other y-axis

   3) for panel 2:
      put "logRho" on the upper panel y-axis
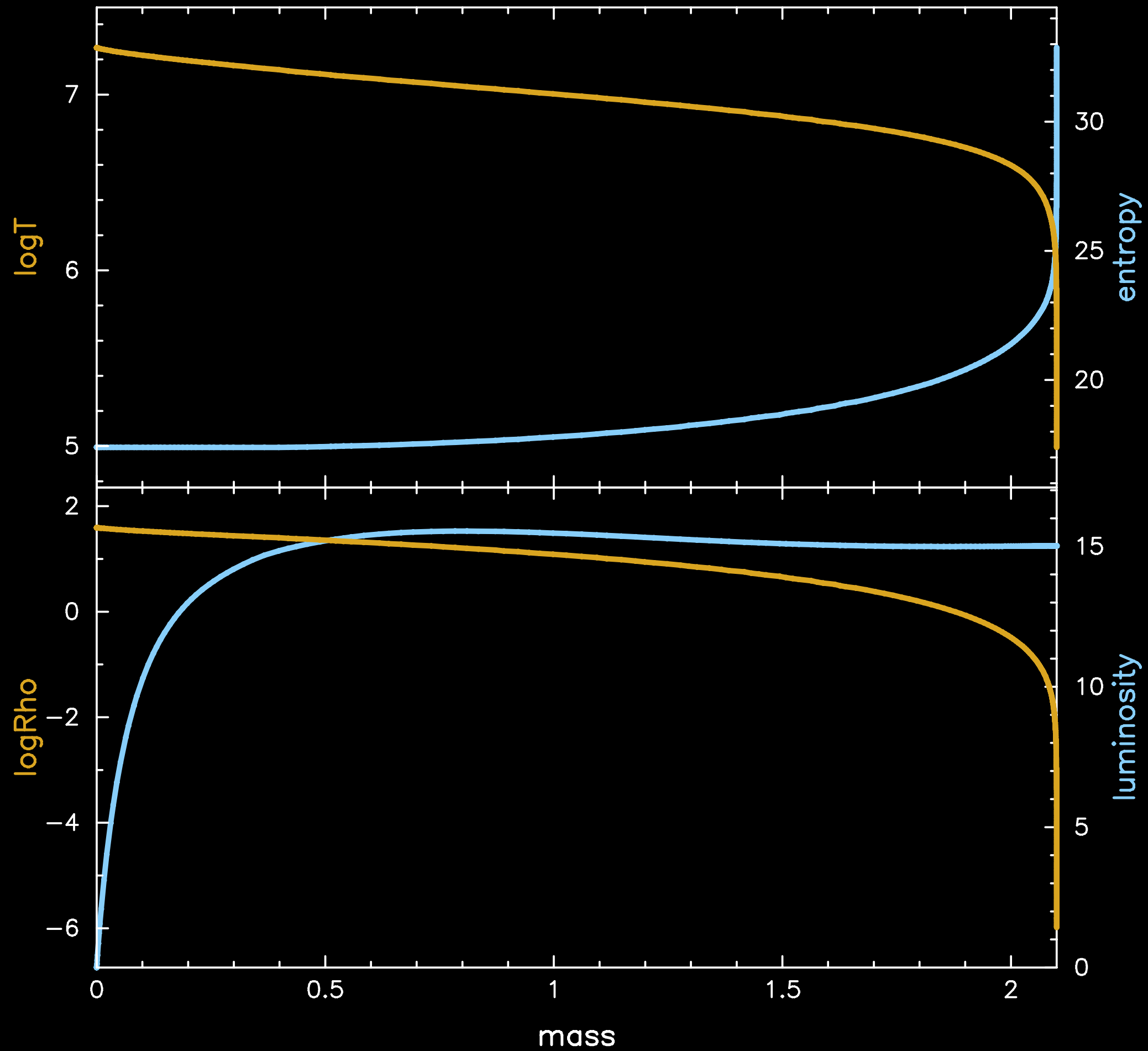   put "luminosity" on the upper panel other y-axis

   4) Show the underlying mass grid

      $MESA_DIR/star/defaults/pgstar.defaults
      $MESA_DIR/star/defaults/profile_columns.list
                  are your friends.

You should see something like this:

age 7.452657e6 yrs

model 1080

Let's put some energy and rotation gauges on our star.

Copy & paste these history plot commands from the supplied plot_commands.txt file to inlist_pgstar, and save inlist_pgstar.

```
! Profile Panel - energetics,rotation

Profile_Panels2_win_flag = .true.
```

Let's tune this default beauty to our needs.

Tasks:
   1) put mass on the x-axis and range from 0 to 2.1 M$_\odot$

   2) for panel 1:
      put "net_nuclear_energy" on the upper panel y-axis
      put "vel_km_per_s" on the upper panel other y-axis

   3) for panel 2:
      put "omega" on the upper panel y-axis
      put "log_j_rot" on the upper panel other y-axis

   4) Show the underlying mass grid

         $MESA_DIR/star/defaults/pgstar.defaults
      $MESA_DIR/star/defaults/profile_columns.list
                     are your friends.

You should see something like this:
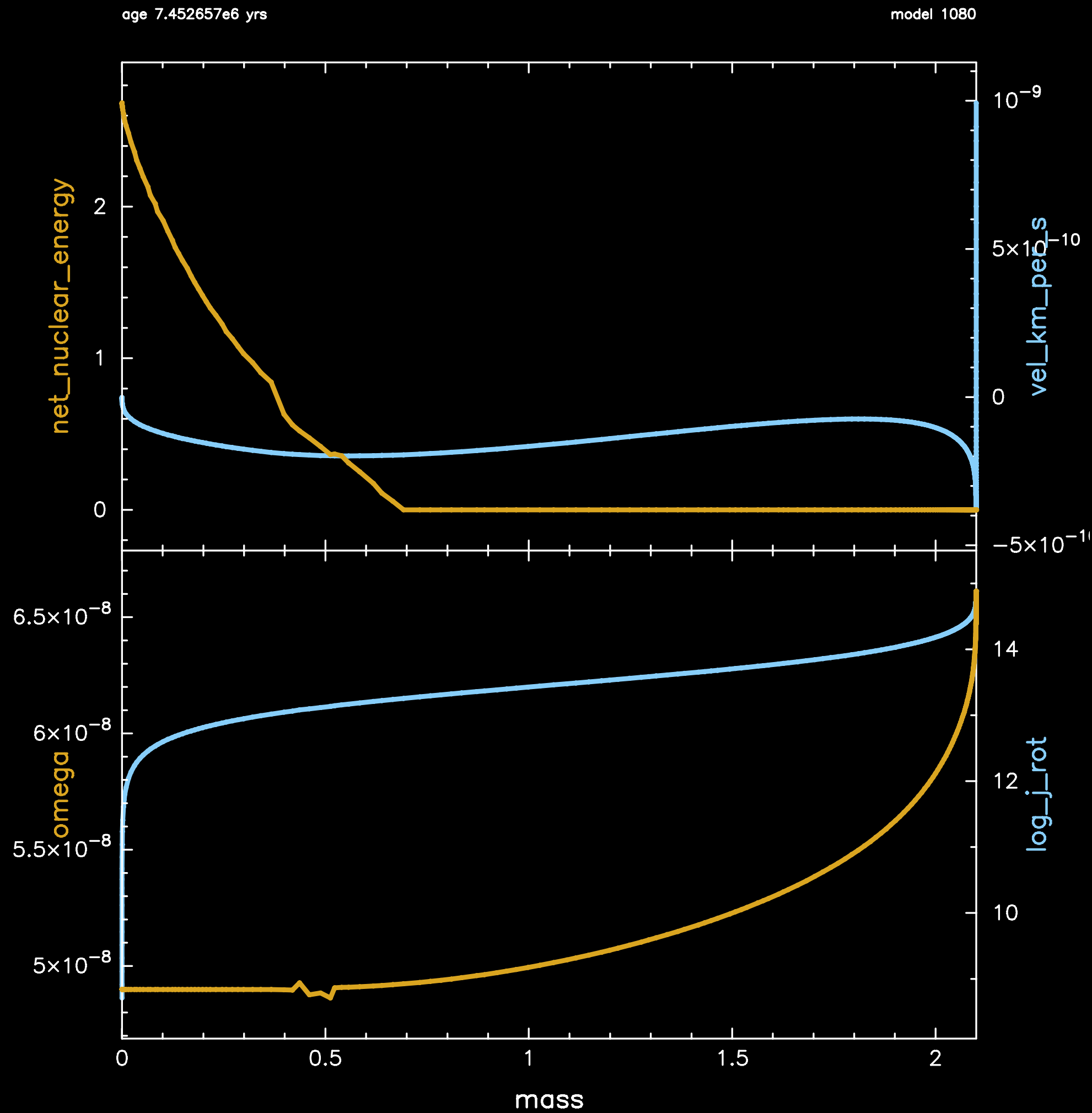
How do the central temperature and density change with time?
Let's add a TRho history plot window:

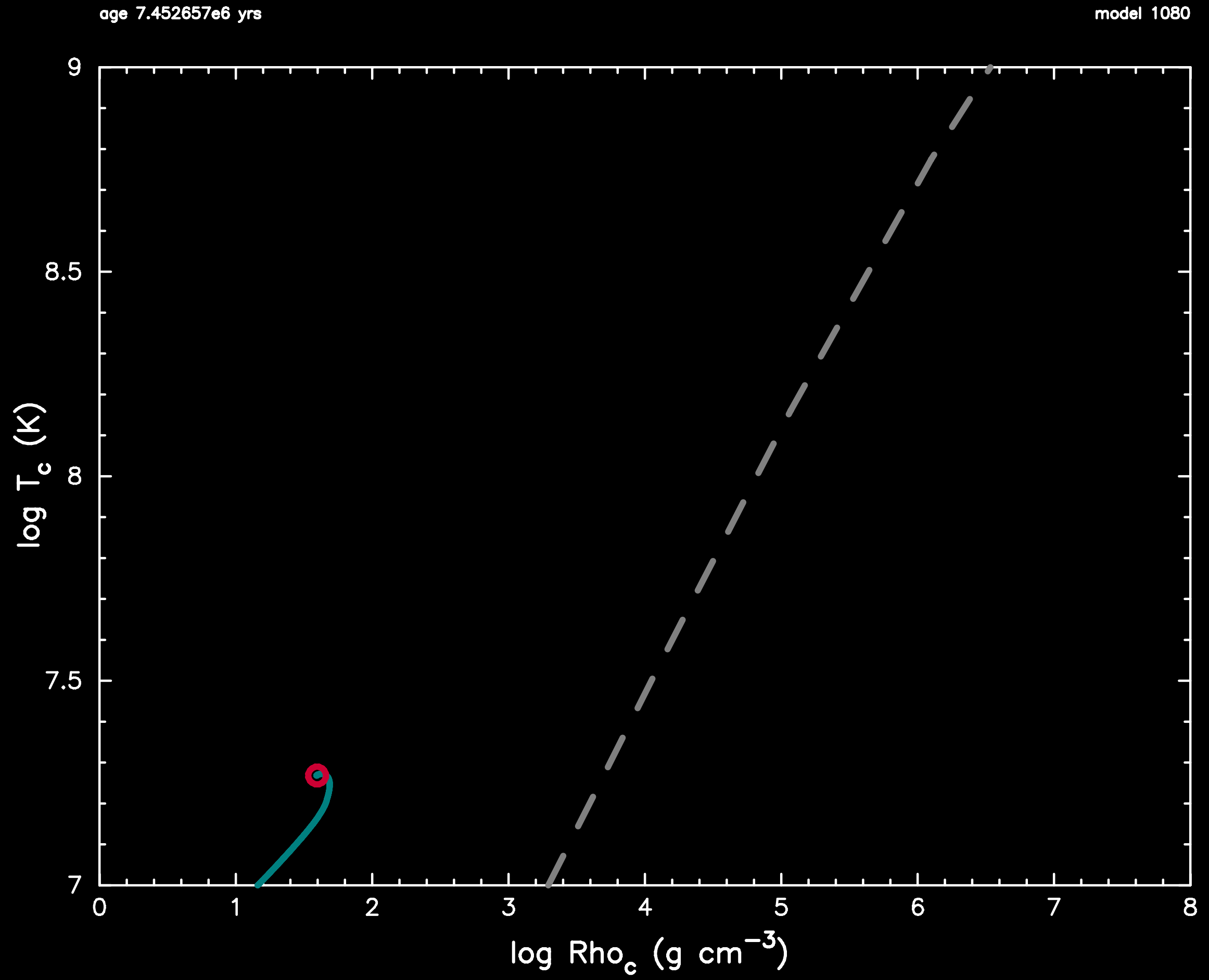Copy & paste from plot_commands.txt into inlist_pgstar.

```
! central temperature and density history

TRho_win_flag = .true.
```

Task:
1) set T_c range from 7.0 to 9.0
2) set ρ_c range from 0.0 to 8.0
3) show the degeneracy curve

You know where your friends are.

You should see something like this:
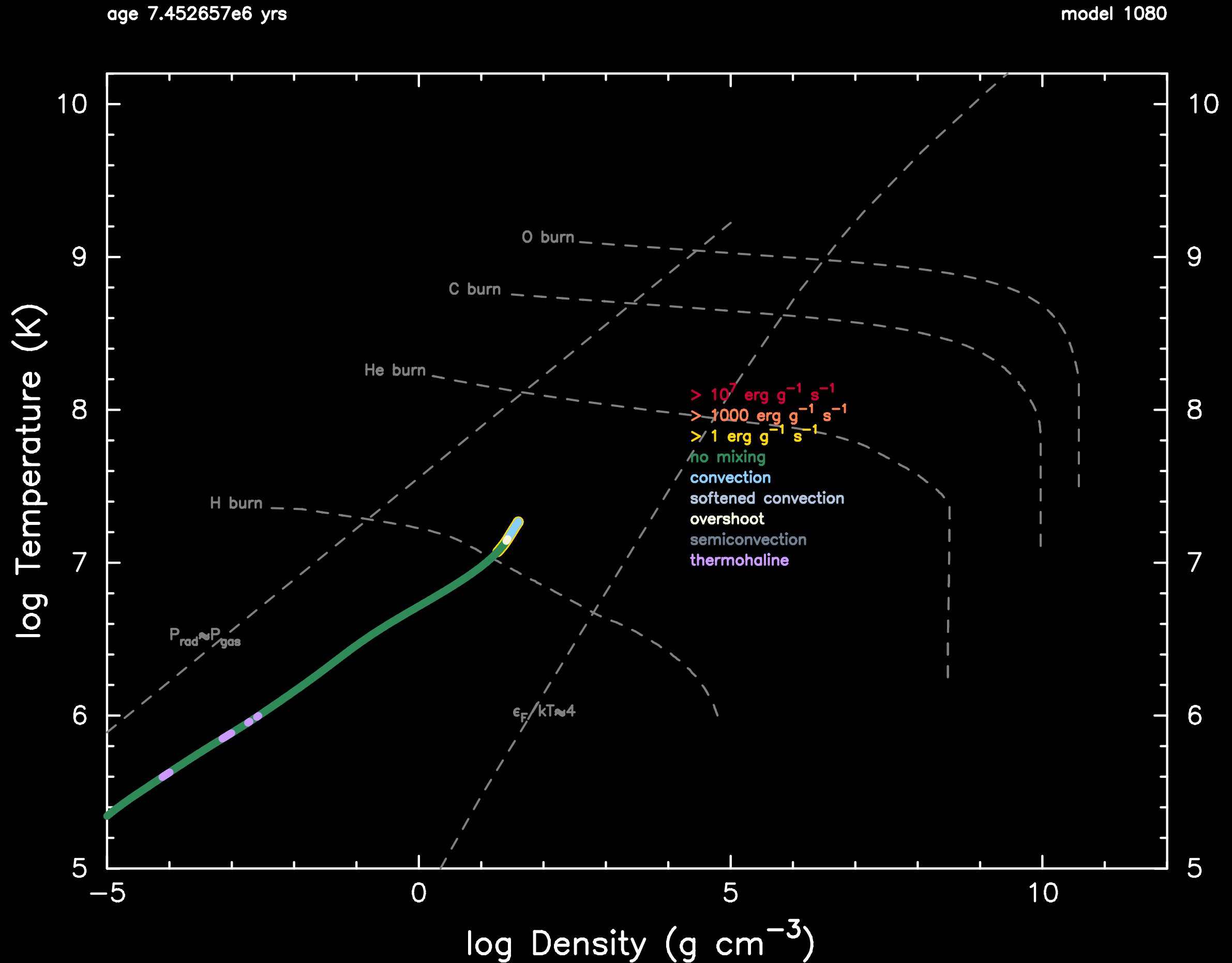

age 7.452657e6 yrs

model 1080

What is the temperature and density profile over the star?
Add a TRho_Profile plot. Copy & paste from plot_commands.txt
 into inlist_pgstar.

```
TRho_Profile_win_flag = .true.

TRho_Profile_win_width = 10
TRho_Profile_win_aspect_ratio = 0.75

TRho_Profile_xleft = 0.15
TRho_Profile_xright = 0.85
TRho_Profile_ybot = 0.15
TRho_Profile_ytop = 0.85
TRho_Profile_txt_scale = 0.8
TRho_Profile_title = ' '

TRho_switch_to_Column_Depth = .false.
TRho_switch_to_mass = .false.

show_TRho_Profile_legend = .true.
 TRho_Profile_legend_coord = 0.55
 TRho_Profile_legend_fjust = 0.0
 TRho_Profile_legend_disp1 = -20.5
 TRho_Profile_legend_del_disp = -1.3

show_TRho_Profile_text_info = .false.
```

Experiment with changing
some of the plot options:
show_TRho_Profile_legend
show_TRho_Profile_eos_regions
show_TRho_Profile_Pgas_Prad_line

You should see something like this:

age 7.452657e6 yrs

model 1080

log Temperature (K) vs log Density (g cm^{-3})

O burn

C burn

He burn

H burn

$P_{rad} \approx P_{gas}$

$\epsilon_F / kT \approx 4$

> 10^7 erg g^{-1} s^{-1}
> 1000 erg g^{-1} s^{-1}
> 1 erg g^{-1} s^{-1}
no mixing
convection
softened convection
overshoot
semiconvection
thermohaline

Let's get some useful text information on the screen.

Copy & paste from plot_commands.txt into inlist_pgstar.

Experiment with Text_Summary1_win_width Text_Summary1_txt_scale but return them to the set values when you are done.

```
Text_Summary1_win_flag = .true.
Text_Summary1_win_width = 10
Text_Summary1_win_aspect_ratio = 0.15

Text_Summary1_xleft = 0.01
Text_Summary1_xright = 0.99
Text_Summary1_ybot = 0.0
Text_Summary1_ytop = 1.0
Text_Summary1_txt_scale = 1.0
Text_Summary1_title = ''

Text_Summary1_num_rows = 4 ! <= 20
Text_Summary1_num_cols = 5 ! <= 20
Text_Summary1_name(:,:) = ''

Text_Summary1_name(1,1) = 'time_step'
Text_Summary1_name(1,2) = 'num_zones'
Text_Summary1_name(1,3) = 'species'
Text_Summary1_name(1,4) = 'star_mass'
Text_Summary1_name(1,5) = 'star_mdot'

Text_Summary1_name(2,1) =
'total_angular_momentum'
Text_Summary1_name(2,2) = 'effective_T'
Text_Summary1_name(2,3) = 'photosphere_L'
Text_Summary1_name(2,4) = 'photosphere_r'
Text_Summary1_name(2,5) = 'log_g'

Text_Summary1_name(3,1) = 'surf_avg_v_rot'  !
km/sec rotational velocity at equator
```

You should see something like this:

time_step	4.531E+04	num_zones	441	species	49	star_mass	2.0999930	star_mdot	−5.600E−13
total_angular_momentum	1.915E+47	effective_T	8.140E+03	photosphere_L	15.0226114	photosphere_r	1.9516911	log_g	4.1792850
surf_avg_v_rot	0.0869929	center_c12	0.0012382	center_o16	0.0093352	surface he4	0.2799702	surf_avg_omega	6.415E−08
he_core_mass	0	c_core_mass	0	o_core_mass	0	surface c12	0.0034003	log_center_Rho	1.5961691

Is your screen crowded with plot windows?

Let's clean up this mess by putting all 8 plots on a Grid Plot.

Close all the windows by setting the plot logicals to false and saving the inlist_pgstar file:

```
Abundance_win_flag = .false.

Power_win_flag = .false.

Kipp_win_flag = .false.

Profile_Panels1_win_flag = .false.

Profile_Panels2_win_flag = .false.

TRho_win_flag = .false.

TRho_Profile_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 are open.

Sketch the layout you want.

Text

Abund

Power

Thermo

Energy

Rotate

Kipp

T - ρ
Profile

T$_c$ - ρ$_c$

Copy & paste from plot_commands.txt into inlist_pgstar.

This will put the Text, Abundance, Power, Kipp, and TRho profile plots in place.

```
Grid1_win_flag = .true.
Grid1_win_width = 16
Grid1_win_aspect_ratio = 0.6

! reset the defaults

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
```

Add the 2 Profile and TRho plots to the Grid.
Don't fuss with aesthetically pleasing spaces at first, adjust
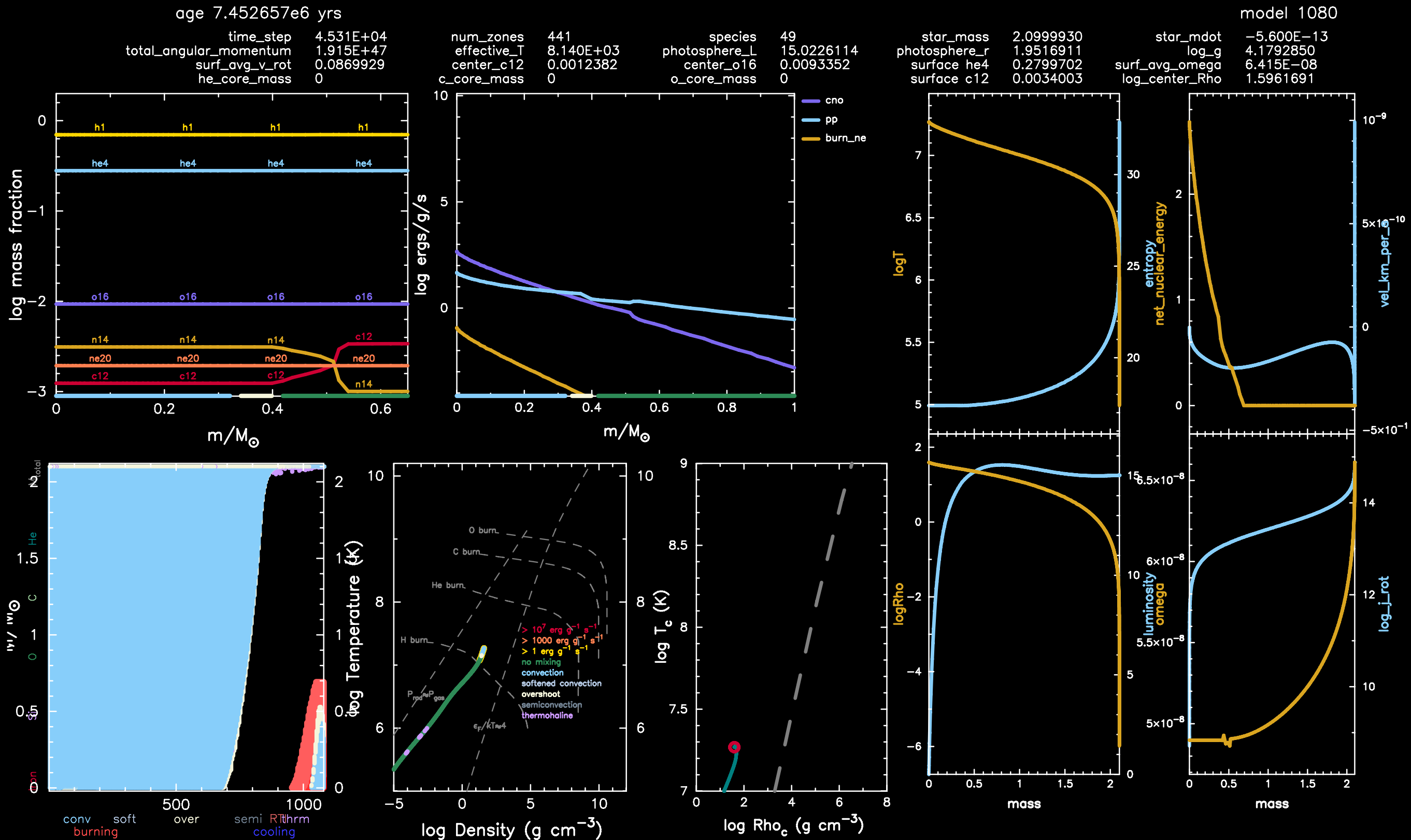spacings after all the plots are in.

Text

Abund

Power

Energy

Thermo

Rotate

Kipp

T - ρ
Profile

T_c - ρ_c

Admire your single window dashboard!

Start saving png files of your dashboard.

```
! file output
Grid1_file_flag = .true.
Grid1_file_dir = 'pms_to_wd_'
Grid1_file_prefix = 'pms_to_wd_'
Grid1_file_interval = 10          ! output when
mod(model_number,Grid1_file_interval)==0
Grid1_file_width = -1             ! (inches) negative means
use same value as for window
!Grid1_file_width = 21            ! (inches) negative means
use same value as for window
Grid1_file_aspect_ratio = -1     ! negative means use same
value as for window
```

Tip: you can save png output without displaying them.

```
Grid1_win_flag = .false.


Grid1_file_flag = .true.
```

This is useful for slow graphics, clutter-free desktops, running on a cluster, etc.

Make a movie from the png files with the images_to_movie.sh script included in the MESA SDK:

```
% images_to_movie.sh "pms_to_wd_/*.png" sum.mp4
```

Watching models evolve is a fun way to learn!

A full inlist_pgstar is in the file magic.txt

Thanks!

MESA