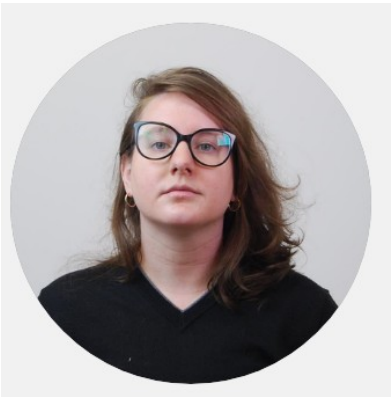


# Beyond Inlists

MESA

Summer School 2022  
Lecture 1



Dr Meridith Joyce  
Lasker Fellow, Space Telescope Science Institute  
Incoming: Marie Curie Widening Fellow, Konkoly Observatory  
MESA developers team (2019-present)

 @MeridithJoyceGR  
[www.meridithjoyce.com](http://www.meridithjoyce.com)

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Visit [http://cococubed.asu.edu/mesa\\_market/guides.html](http://cococubed.asu.edu/mesa_market/guides.html) for video guides on how to set up these variables for other systems

# Setting environment variables the bad way

```
mjoyce@marsha: ~/MESA/mesa-r22051
-rw-rw-r-- 1 mjoyce mjoyce 15366 Jan 3 2022 mesa-logo-200.png
-rw-rw-r-- 1 mjoyce mjoyce 126204 Jan 3 2022 mesa-M-only.odg
-rw-rw-r-- 1 mjoyce mjoyce 40456 Jan 3 2022 mesa-M-only.png
drwxrwxr-x 8 mjoyce mjoyce 4096 Jan 6 2022 work_magnetic_15140plus_just-mlt
drwx----- 7 mjoyce mjoyce 4096 Jan 7 2022 work_magnetic_15140plus_Bfield
drwx----- 8 mjoyce mjoyce 4096 Jan 7 2022 work_magnetic_15140plus_delta
-rw-rw-r-- 1 mjoyce mjoyce 1109 Jan 7 2022 sync.sh
-rw-rw-r-- 1 mjoyce mjoyce 313 Jan 7 2022 screens_threads.log
drwxr-xr-x 11 mjoyce mjoyce 4096 Jan 21 2022 work_magnetic_15140plus_run_star_extras_15140
-rw-rw-r-- 1 mjoyce mjoyce 487604 Mar 23 05:44 MIST_iso_623b161702601.iso.zip
drwxrwxrwx 18 mjoyce mjoyce 180224 Apr 11 09:25 work_thermohaline_grid
drwx----- 27 mjoyce mjoyce 274432 Jul 6 07:25 bulge_isochrones
drwxrwxr-x 4 mjoyce mjoyce 4096 Jul 25 09:07 SummerSchool2022
-rw-rw-r-- 1 mjoyce mjoyce 2098006607 Jul 25 10:08 mesa-r22.05.1.zip
drwxrwxr-x 36 mjoyce mjoyce 4096 Jul 25 10:16 mesa-r22051
drwx----- 8 mjoyce mjoyce 4096 Aug 4 16:59 work_magnetic_15140plus_YREC-spots
drwxrwxrwx 3 mjoyce mjoyce 4096 Aug 5 19:44 MESA_instrument_VI
-rw-rw-r-- 1 mjoyce mjoyce 2132200 Aug 7 16:07 mesa_team_map_jan2022_white.pdf
-rw-rw-r-- 1 mjoyce mjoyce 1036548 Aug 7 16:13 mesa_team_map_jan2022_white.png
mjoyce@marsha:~/MESA$ cd mesa-r22051/
mjoyce@marsha:~/MESA/mesa-r22051$ export MESA_DIR=/home/mjoyce/MESA/mesa-r22051
mjoyce@marsha:~/MESA/mesa-r22051$ export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk_15140
mjoyce@marsha:~/MESA/mesa-r22051$ source $MESASDK_ROOT/bin/mesasdk_init.sh
mjoyce@marsha:~/MESA/mesa-r22051$ export OMP_NUM_THREADS=8
mjoyce@marsha:~/MESA/mesa-r22051$
```



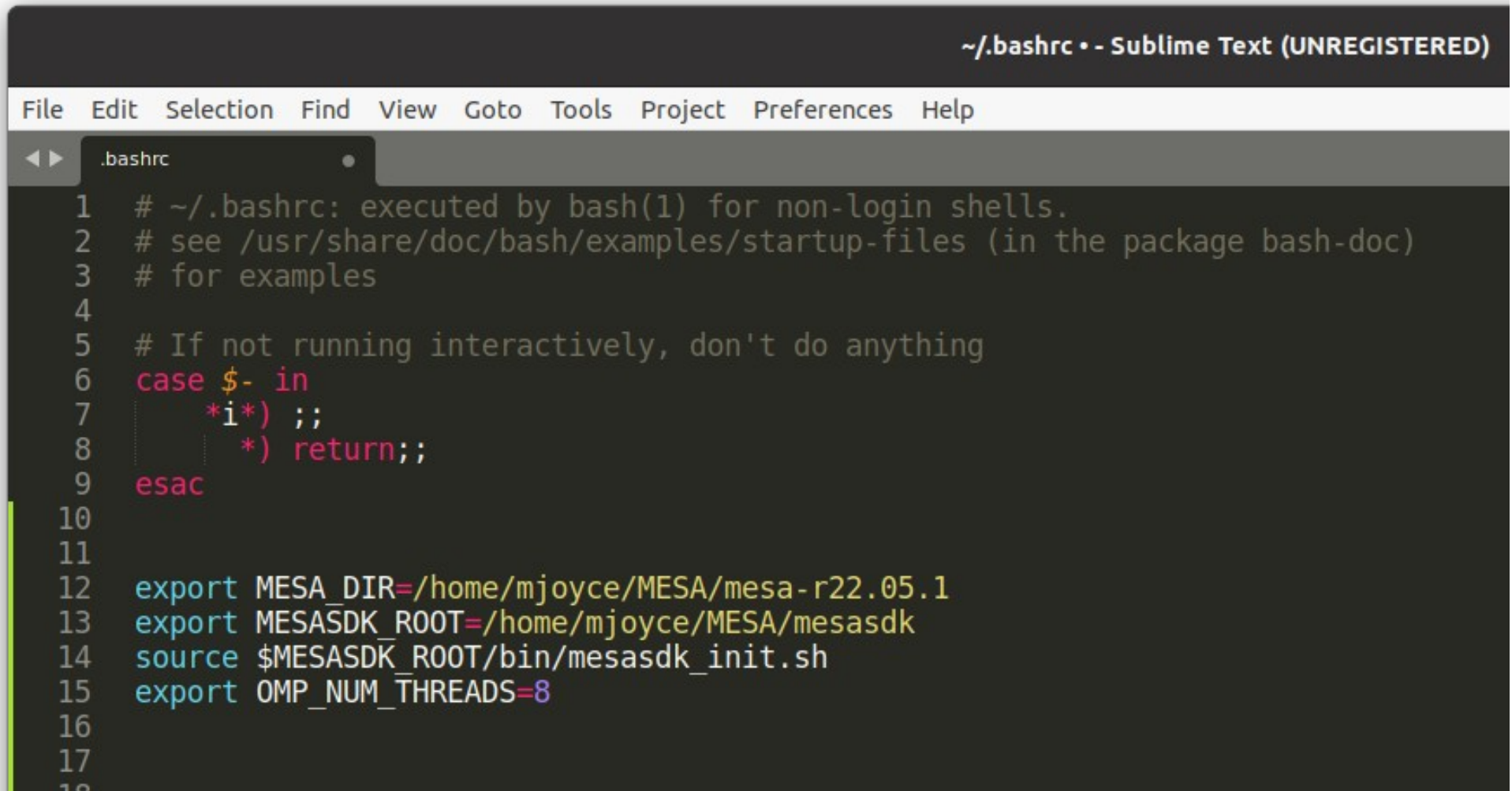
# Setting environment variables the good way: `.bashrc` file

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```
~/.bashrc • - Sublime Text (UNREGISTERED)
File Edit Selection Find View Goto Tools Project Preferences Help
.bashrc
1 # ~/.bashrc: executed by bash(1) for non-login shells.
2 # see /usr/share/doc/bash/examples/startup-files (in the package bash-doc)
3 # for examples
4
5 # If not running interactively, don't do anything
6 case $- in
7     *i*) ;;
8     *) return;;
9 esac
10
11
12 export MESA_DIR=/home/mjoyce/MESA/mesa-r22.05.1
13 export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk
14 source $MESASDK_ROOT/bin/mesasdk_init.sh
15 export OMP_NUM_THREADS=8
16
17
18
```

# Best way: functions in .bashrc

```
354
355 function mesa-12778 {
356 export MESA_DIR=/home/mjoyce/MESA/mesa-r12778
357 export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk_12778
358 source $MESASDK_ROOT/bin/mesasdk_init.sh
359 export OMP_NUM_THREADS=8
360 echo "environment set for MESA version 12778"
361 }
362
363
364 function mesa-15140 {
365 export MESA_DIR=/home/mjoyce/MESA/mesa-r15140
366 export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk_15140
367 source $MESASDK_ROOT/bin/mesasdk_init.sh
368 export OMP_NUM_THREADS=8
369 echo "environment set for MESA version 15140"
370 }
371
372
373 function mesa-22051 {
374 export MESA_DIR=/home/mjoyce/MESA/mesa-r22.05.1
375 export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk
376 source $MESASDK_ROOT/bin/mesasdk_init.sh
377 export OMP_NUM_THREADS=8
378 echo "environment set for MESA version 22.05.1"
379 }
380
```

# Best way: functions in .bashrc

```
mjoyce@marsha:~/MESA/mesa-r22051$  
mjoyce@marsha:~/MESA/mesa-r22051$  
mjoyce@marsha:~/MESA/mesa-r22051$ source ~/.bashrc  
mjoyce@marsha:~/MESA/mesa-r22051$ mesa-22051  
environment set for MESA version 22.05.1  
mjoyce@marsha:~/MESA/mesa-r22051$
```

**Do microlab 0**  
**(~3 minutes)**

# Core Resources

The code itself:

**Mesa-r22.05.1/star/test\_suite**

**Mesa-r22.05.1/star/defaults/\*.list ; \*.defaults**

The web-hosted documentation:

<https://docs.mesastar.org/en/release-r22.05.1/>

inlists used in academic papers:

[http://cococubed.asu.edu/mesa\\_market/inlists.html](http://cococubed.asu.edu/mesa_market/inlists.html)

Past MESA Summer School lectures and labs (including solutions):

[http://cococubed.asu.edu/mesa\\_market/education.html](http://cococubed.asu.edu/mesa_market/education.html)

Mesa-users email list:

<https://lists.mesastar.org/mailman/listinfo/mesa-users>

**py\_mesa\_reader** by Bill Wolf:

[https://github.com/wmwolf/py\\_mesa\\_reader](https://github.com/wmwolf/py_mesa_reader)

# Setup and output

**Inlists** – Fortran namelists that contain **value** definitions for all of the **parameters** of your run

ex) `history_filename = 'history_my_run.data'`

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**mesa-r22.05.1/kap/defaults/kap.defaults**

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**star** or **binary**; this is the program that is built by the compiler and runs your simulation

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## **Scripts**

clean, mk, rn, re – these are shell scripts that build and manipulate your program

# Setup and output

By default, MESA keeps track of the full stellar structure of your model across evolutionary time

Output is stored in the LOGS/ directory

**history.data** traces evolutionary quantities

**profileX.data** gives you the structural model at some time step  $dt$ .  
you can adjust the frequency of these outputs in the inlists

**profiles.index** provides a mapping between the integer in the profile output names and the model number from the evolutionary run (in cases where a profile is not generated at every time step)

You can also store binary snapshots of the models: **photos**

# Setup and output

History output should look something like this:

```
~/MESA/mesa-r15140/star/work/LOGS/history.data - Sublime Text (UNREGISTERED)
File Edit Selection Find View Goto Tools Project Preferences Help
inlist_start_header x inlist_start x bashrc x history.data x
1 | 1 2 3
4 5 6
7 8
version_number compiler build
MESA_SDK_version math_backend date
burn_min1 burn_min2 "CRMATH"
"15140" "x86_64-linux-20.12.1" "10.2.0" "20211101"
5.000000000000000E+001 1.000000000000000E+003

1 2 3
4 5 6
7 8
10 11 12
13 14 15
16 17 18
19 20 21
22 23 24
25 26 27
28 29 30
31 32 33
34 35 36
37 38 39
40 41 42
43 44 45
46 47 48
49 50 51
52 53 54
55 56 57
58

6 model_number num_zones star_age log_abs_mdot
log_dt star_mass log_xmstar conv_mx1_bot conv_mx1_top
mass_conv_core conv_mx2_bot conv_mx2_top mx1_bot mx1_top
conv_mx2_bot mx2_top mx2_bot log_LZ
log_LH log_LHe pp cno
log_Lnuc epsnuc_M_1 epsnuc_M_2
tri_alfa epsnuc_M_4 epsnuc_M_5
epsnuc_M_6 epsnuc_M_7 epsnuc_M_8
he_core_mass c_core_mass o_core_mass
si_core_mass fe_core_mass neutron_rich_core_mass
log_Teff log_L log_R log_g
v_div_sound_surf log_cntr_P log_cntr_Rho
log_cntr_T center_mu center_ye
center_abar center_h1 center_he4
center_c12 center_o16 surface_c12
surface_o16 total_mass_h1 total_mass_he4
num_retries num_iters

7 1 492 1.000000000000000E-005 -4.999999999999999E+000
1.500000000000000E+001 3.4474597169416349E+001 -9.899999999999999E+001
0.000000000000000E+000 9.9998828386135030E-001 3.0124054712287992E-003
0.000000000000000E+000 0.000000000000000E+000 9.9998828386135030E-001
3.0124054712287992E-003 0.000000000000000E+000 0.000000000000000E+000
-1.7113671445755475E+001 -9.899999999999999E+001 -9.899999999999999E+001
-1.7113671445755475E+001 -1.7113671445755475E+001 -9.899999999999999E+001
-9.899999999999999E+001 -2.000000000000000E+001 -2.000000000000000E+001
```

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File Edit Selection Find View Goto Tools Project Preferences Help
inlist_start_header x inlist_start x bashrc x history.data x
1 | 1 2 3
4 5 6
7 8
version_number compiler build
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burn_min1 burn_min2 "CRMATH"
"15140" "x86_64-linux-20.12.1" "10.2.0" "20211101"
5.000000000000000E+001 1.000000000000000E+003

1 2 3
4 5 6
7 8
10 11 12
13 14 15
16 17 18
19 20 21
22 23 24
25 26 27
28 29 30
31 32 33
34 35 36
37 38 39
40 41 42
43 44 45
46 47 48
49 50 51
52 53 54
55 56 57 58

model_number num_zones star_age log_abs_mdots
log_dt star_mass log_xmstar conv_mx1_bot conv_mx1_top
mass_conv_core conv_mx2_bot conv_mx2_top mx1_bot
conv_mx2_top mx2_top mx2_bot
log_LH log_LZ
log_LHe pp cno
log_Lnuc epsnuc_M_1 epsnuc_M_2
tri_alfa epsnuc_M_4 epsnuc_M_5
epsnuc_M_6 epsnuc_M_7 epsnuc_M_8
he_core_mass c_core_mass o_core_mass
si_core_mass fe_core_mass neutron_rich_core_mass
log_Teff log_L log_R
v_div_sound_surf log_cntr_P log_cntr_Rho
log_cntr_T center_mu center_ye
center_abar center_h1 center_he4
center_c12 center_o16 surface_c12
surface_o16 total_mass_h1 total_mass_he4
num_retries num_iters

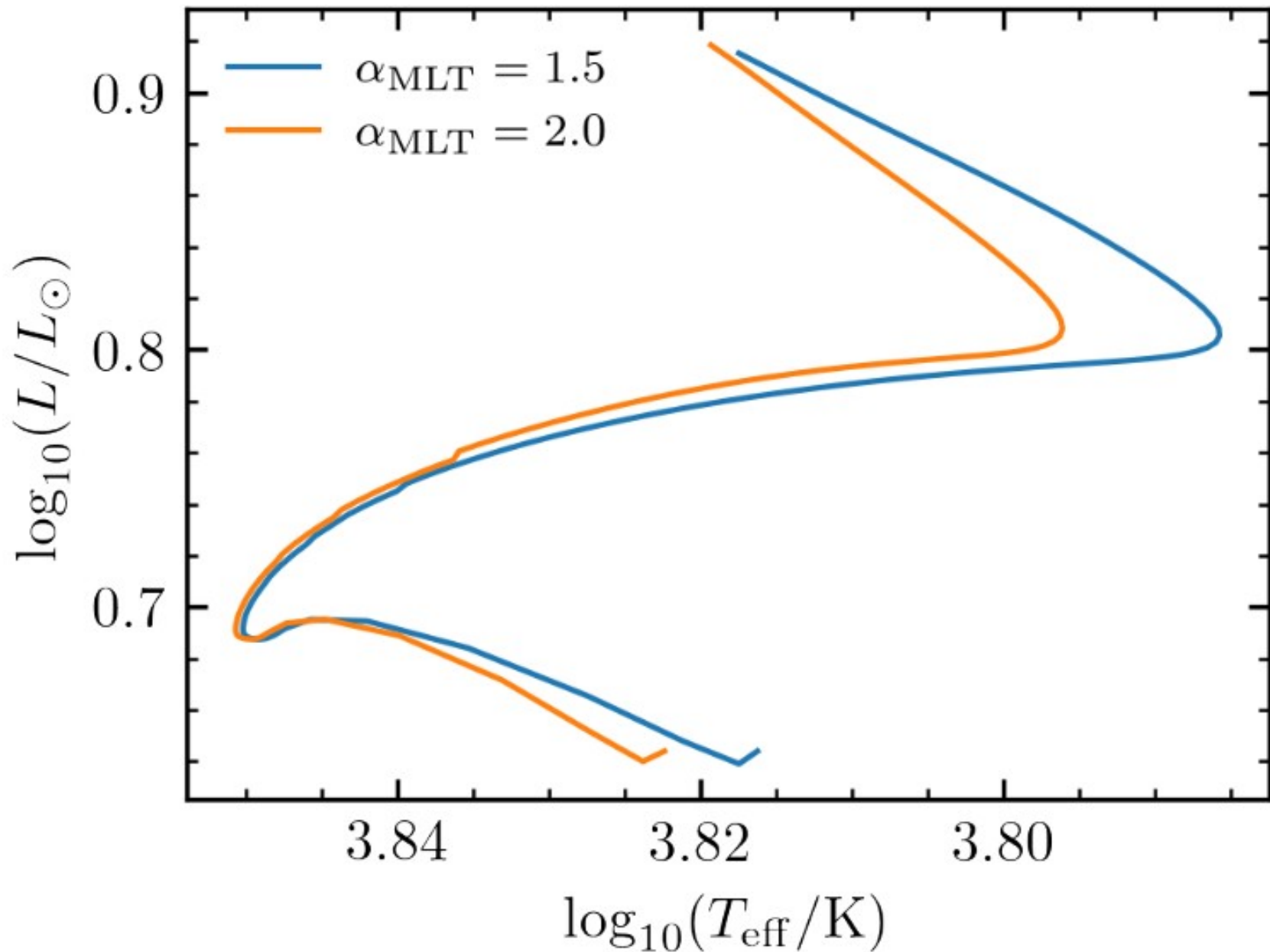
1 492 1.000000000000000E-005 -4.999999999999999E+000
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```



**Do up through Minilab 2**

**Reconvene for  
discussion at 10:25  
(~25 minutes)**

# Discussion up through Minilab 2



**Coffee break**

**Return at 10:45**

# Using run\_star\_extras.f90

Using run\_star\_extras.f90, we can introduce our own

- project-specific physics**, or

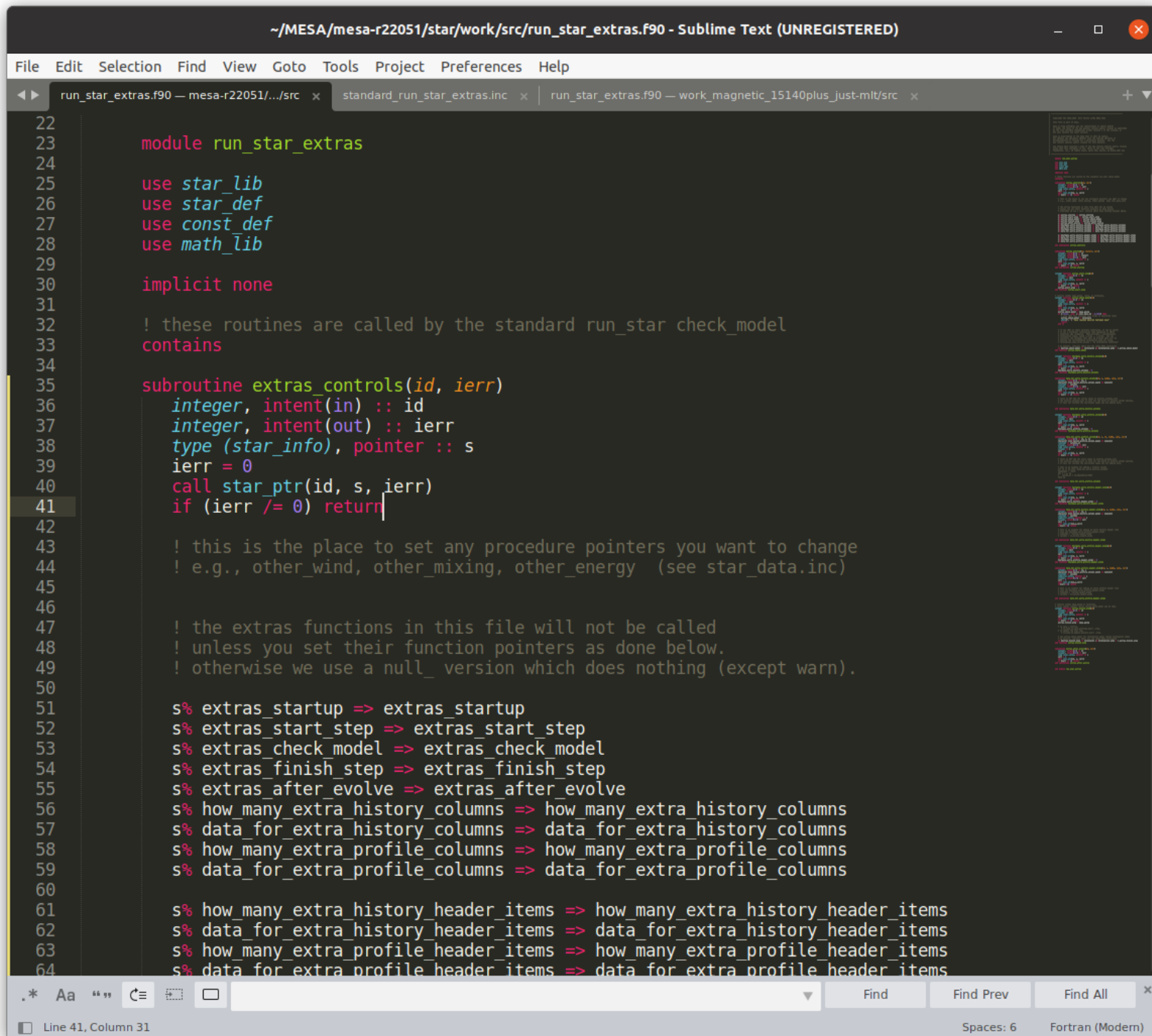
- additional functionality**

without compromising the entire MESA source code base

# run\_star\_extras.f90: default

```
~/MESA/mesa-r22051/star/work/src/run_star_extras.f90 - Sublime Text (UNREGISTERED)
File Edit Selection Find View Goto Tools Project Preferences Help
run_star_extras.f90 x
1 ! *****
2 !
3 ! Copyright (C) 2010-2019 Bill Paxton & The MESA Team
4 !
5 ! this file is part of mesa.
6 !
7 ! mesa is free software; you can redistribute it and/or modify
8 ! it under the terms of the gnu general library public license as published
9 ! by the free software foundation; either version 2 of the license, or
10 ! (at your option) any later version.
11 !
12 ! mesa is distributed in the hope that it will be useful,
13 ! but without any warranty; without even the implied warranty of
14 ! merchantability or fitness for a particular purpose. see the
15 ! gnu library general public license for more details.
16 !
17 ! you should have received a copy of the gnu library general public license
18 ! along with this software; if not, write to the free software
19 ! foundation, inc., 59 temple place, suite 330, boston, ma 02111-1307 usa
20 !
21 ! *****
22 !
23 module run_star_extras
24
25 use star_lib
26 use star_def
27 use const_def
28 use math_lib
29
30 implicit none
31
32 ! these routines are called by the standard run_star check_model
33 contains
34
35 include 'standard_run_star_extras.inc'
36
37 end module run_star_extras
38
39
```

# run\_star\_extras.f90: include



```
22
23 module run_star_extras
24
25 use star_lib
26 use star_def
27 use const_def
28 use math_lib
29
30 implicit none
31
32 ! these routines are called by the standard run_star check_model
33 contains
34
35 subroutine extras_controls(id, ierr)
36   integer, intent(in) :: id
37   integer, intent(out) :: ierr
38   type (star_info), pointer :: s
39   ierr = 0
40   call star_ptr(id, s, ierr)
41   if (ierr /= 0) return
42
43   ! this is the place to set any procedure pointers you want to change
44   ! e.g., other_wind, other_mixing, other_energy (see star_data.inc)
45
46
47   ! the extras functions in this file will not be called
48   ! unless you set their function pointers as done below.
49   ! otherwise we use a null_version which does nothing (except warn).
50
51   s% extras_startup => extras_startup
52   s% extras_start_step => extras_start_step
53   s% extras_check_model => extras_check_model
54   s% extras_finish_step => extras_finish_step
55   s% extras_after_evolve => extras_after_evolve
56   s% how_many_extra_history_columns => how_many_extra_history_columns
57   s% data_for_extra_history_columns => data_for_extra_history_columns
58   s% how_many_extra_profile_columns => how_many_extra_profile_columns
59   s% data_for_extra_profile_columns => data_for_extra_profile_columns
60
61   s% how_many_extra_history_header_items => how_many_extra_history_header_items
62   s% data_for_extra_history_header_items => data_for_extra_history_header_items
63   s% how_many_extra_profile_header_items => how_many_extra_profile_header_items
64   s% data_for_extra_profile_header_items => data_for_extra_profile_header_items
```

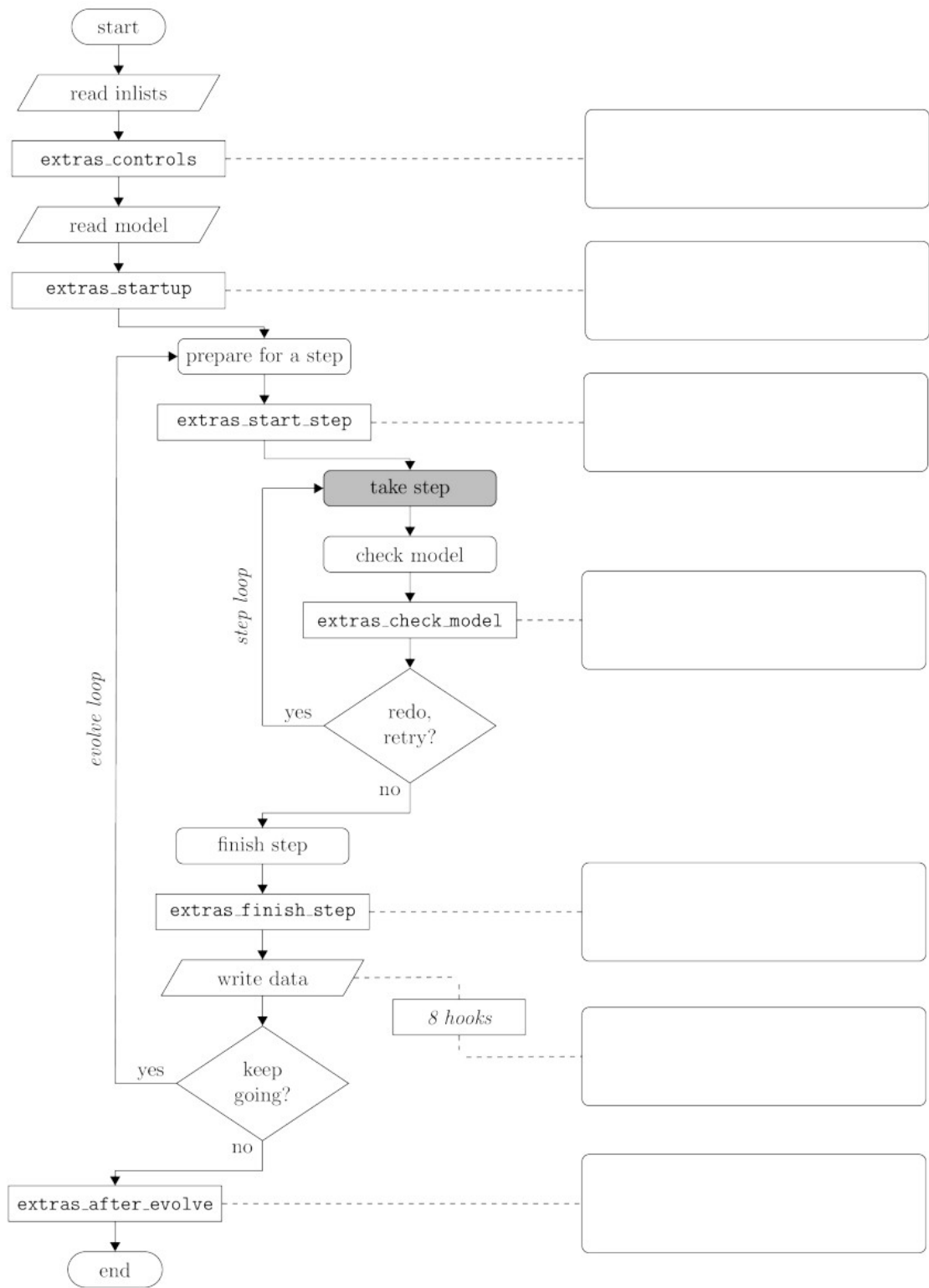
# Using run\_star\_extras.f90

Every time you modify run\_star\_extras, you must **recompile the executable**

```
mjoyce@marsha: ~/MESA/mesa-r22051/star/work
drwx----- 2 mjoyce mjoyce    4096 Jul 25 10:26 LOGS
drwx----- 2 mjoyce mjoyce    4096 Jul 25 10:26 photos
mjoyce@marsha:~/MESA/mesa-r22051/star/work$ mesa-22051
environment set for MESA version 22.05.1
mjoyce@marsha:~/MESA/mesa-r22051/star/work$ ./clean; ./mk
gfortran -Wno-uninitialized -fno-range-check -fmax-errors=7 -fprotect-parens -fno-sign-zero -fbacktrace -ggdb -finit-real=snan -fopenmp -fbounds-check -Wuninitialized -Warray-bounds -ggdb -ffree-form -ffree-line-length-none -x f95-cpp-input -I/home/mjoyce/MESA/mesa-r22051/include -I../src -c ../src/run_star_extras.f90
gfortran -Wno-uninitialized -fno-range-check -fmax-errors=7 -fprotect-parens -fno-sign-zero -fbacktrace -ggdb -finit-real=snan -fopenmp -fbounds-check -Wuninitialized -Warray-bounds -ggdb -ffree-form -ffree-line-length-none -x f95-cpp-input -I/home/mjoyce/MESA/mesa-r22051/include -I../src -c /home/mjoyce/MESA/mesa-r22051/star/job/run_star.f90
gfortran -Wno-uninitialized -fno-range-check -fmax-errors=7 -fprotect-parens -fno-sign-zero -fbacktrace -ggdb -finit-real=snan -fopenmp -fbounds-check -Wuninitialized -Warray-bounds -ggdb -ffree-form -ffree-line-length-none -x f95-cpp-input -I/home/mjoyce/MESA/mesa-r22051/include -I../src -c ../src/run.f90
gfortran -fopenmp -o ../star run_star_extras.o run_star.o run.o -L/home/mjoyce/MESA/mesa-r22051/lib -lstar -lgyre -latm -lcolors -lturb -lstar_data -lnet -leos -lkap -lrates -lneu -lchem -linterp_2d -linterp_1d -lnum -lauto_diff -lhdf5io -lmtx -lconst -lmath -lutils `mesasdk_crmath_link` `mesasdk_lapack95_link` `mesasdk_lapack_link` `mesasdk_blas_link` `mesasdk_hdf5_link` `mesasdk_pgplot_link` -lz
mjoyce@marsha:~/MESA/mesa-r22051/star/work$
```



# Code Organization



# Code Organization

There are some actions you will want to compute *once per evolutionary time step* (**evolve loop**)

there are others you may want to compute *once per solver iteration* (**step loop**)

where one evolve step contains several solver iterations

# Code Organization

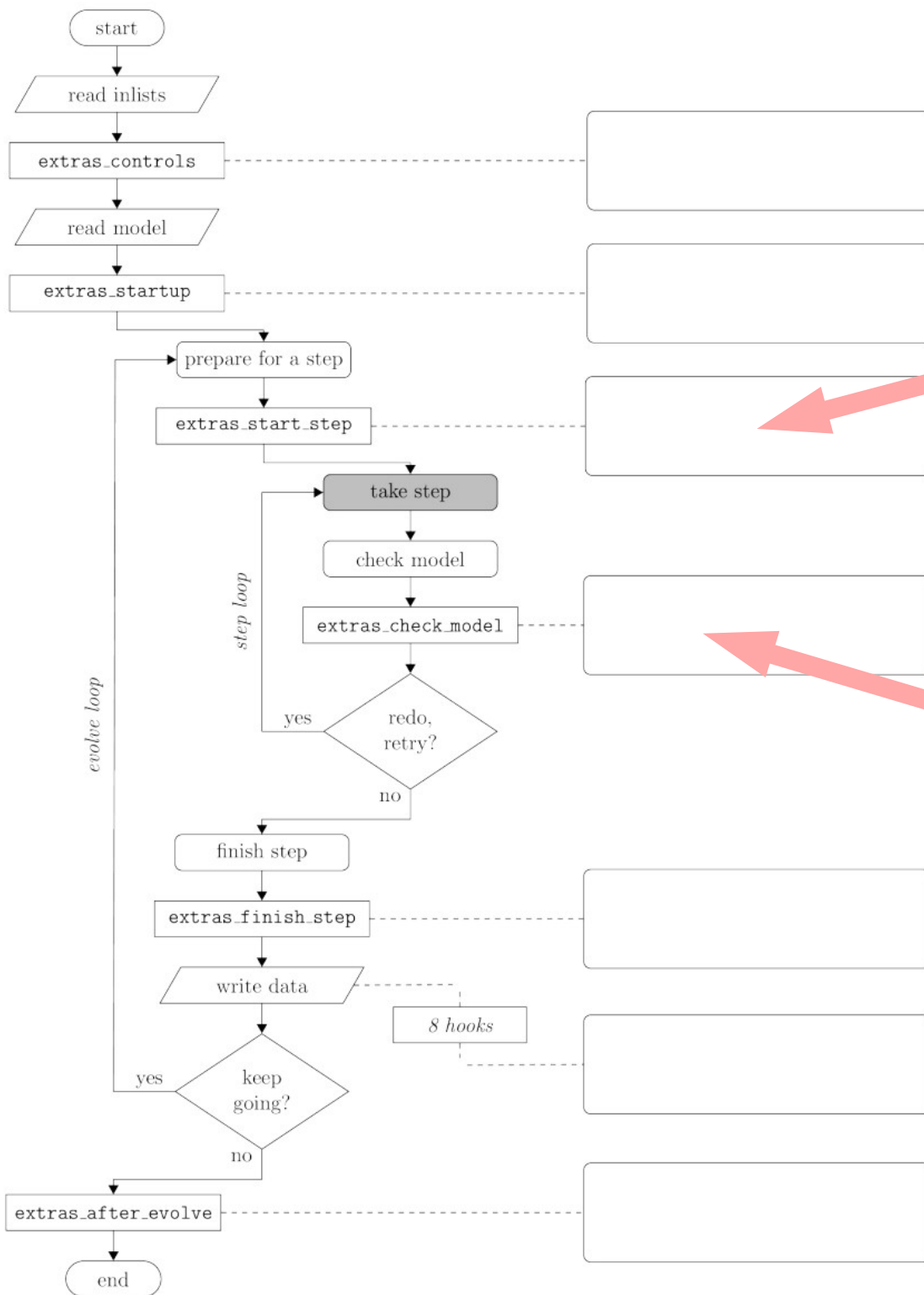
There are some actions you will want to compute *once per evolutionary time step* (**evolve loop**)

there are others you may want to compute *once per solver iteration* (**step loop**)

where one evolve step contains several solver iterations

## Example:

Checking whether your model has satisfied some global physical property (i.e., reaching a certain radius) can take place once per evolutionary step



```

integer function extras_start_step(id)
integer, intent(in) :: id
integer :: ierr
type (star_info), pointer :: s
ierr = 0
call star_ptr(id, s, ierr)
if (ierr /= 0) return
extras_start_step = 0
end function extras_start_step
  
```

```

! returns either keep going, retry, or terminate.
integer function extras_check_model(id)
integer, intent(in) :: id
integer :: ierr
type (star_info), pointer :: s
ierr = 0
call star_ptr(id, s, ierr)
if (ierr /= 0) return
extras_check_model = keep_going
if (.false. .and. s% star_mass_h1 < 0.35d0) then
! stop when star hydrogen mass drops to specified level
extras_check_model = terminate
write(*, *) 'have reached desired hydrogen mass'
return
end if

if (extras_check_model == terminate) s% termination_code = t_extras_check_model
end function extras_check_model
  
```

**Suppose we want MESA to stop when the star reaches a certain luminosity.**

**-When during the step should this condition be checked?**

**-How often should this condition be checked?**

**-In which subroutine should we check this condition?**

**Do Maxilab 1**  
**(~25 minutes)**

**Do Maxilab 2**

**(time remaining)**