

# An Introduction to Modules for Experiments in Stellar Astrophysics



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**Marie Curie, Konkoly Observatory: '22–'24**  
**MESA Developers: 2019 – present**

What is MESA?

**MESA**, after astropy, is the most widely used, open-source software project in astronomy and astrophysics

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**MESA** and **astropy** were named in the Astro 2020 Decadal Survey as critical instruments for the future of astronomy in the next decade



**MESA** is an incredibly versatile  
software instrument

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**MESA** is a team of developers  
and thousands of users worldwide

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**MESA** is a model for open-source and community-driven science

# A Brief History of Time(steps)

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Our story  
begins  
with two  
characters...

# A Brief History of Time(steps)

Bill Paxton



Our story  
begins  
with two  
characters...

Lars Bildsten





## Bill Paxton

### Biographical Sketch



Bill  
Paxton

■ Senior Fellow

KITP, Kohn Hall  
University of California  
Santa Barbara, CA 93106



My academic and career background is in Computer Science. While I was in graduate school, I worked with **Doug Engelbart** at **SRI** where he and his group were busy inventing personal computing (check out the 40th Anniversary Celebration of the "**Mother of All Demos**"). As soon as I got my "union card" from Stanford (Ph.D., 1977), I went to work at the Xerox Palo Alto Research Center (**PARC**) where they were creating new technologies like Ethernet, networked personal computers, bitmap displays, graphical user-interfaces, and laser printers. Two of my colleagues at PARC, **Chuck Geschke** and **John Warnock**, eventually left to form **Adobe Systems**. I joined them soon after (1983), in time to help build the original PostScript and later become one of the Adobe recipients of the **ACM's Software System Award** (1989) for PostScript's design and implementation (among other things, I did the Type 1 font algorithms starting from some of John's great ideas).

Thanks to Adobe I've been "retired" since 1990, and now I'm having fun being an unofficial scholar at the University of California, Santa Barbara (**UCSB**). The people at the Kavli Institute for Theoretical Physics (**KITP**), **Lars Bildsten** in particular, have been most welcoming and tolerant of my eccentricities. The stellar evolution program **EZ** was created as part of a project with Lars. I'm now working on **MESA**, an open source set of modules for software experiments in stellar astrophysics.

Since a physicist can do "astro-physics", I imagine a Computer Scientist can do "astro-computing" or perhaps it could be called "computational-astro-physics". That seems to be a good description of what I'm up to these days, and I'm having a great time! But if I do happen to have a bad day, I can always turn to Calvin for inspiration.

# A Brief History of Time(steps)

2011 – Instrument paper I Paxton et al.

2013 – Instrument paper II Paxton et al.

2015 – Instrument paper III Paxton et al.

2018 – Instrument paper IV Paxton et al.

2019 – Instrument paper V Paxton et al.

2023 – Instrument paper VI Jermyn et al.



Bill Paxton



Lars Bildsten

ADS library containing  
these papers (+errata):

[https://ui.adsabs.harvard.edu/  
user/libraries/  
vT\\_uYj92TP6KMn4QWYBcVQ](https://ui.adsabs.harvard.edu/user/libraries/vT_uYj92TP6KMn4QWYBcVQ)





## Beatrice M. Tinsley Prize



The Tinsley Prize recognizes an outstanding research contribution to astronomy or astrophysics, of an exceptionally creative or innovative character. The prize is normally awarded every two years.

### **2021 – Bill Paxton**

For his inspired work on providing, maintaining, and supporting the use of open-source stellar-evolution codes that have seeped into the foundation of research and education efforts.

We have **6 instrument papers**, and they should each be cited separately if you use MESA in a paper

## Citing MESA

You should cite all of the available MESA instrument papers at the time of the MESA version being used, as MESA is sum of this work. Currently, that is:

```
Modules for Experiments in Stellar Astrophysics  
\citep[MESA][]{Paxton2011, Paxton2013, Paxton2015, Paxton2018, Paxton2019, Jermyn2023}.
```

A bibtex file containing these references is available here:

[https://docs.mesastar.org/en/release-r24.03.1/using\\_mesa/best\\_practices.html](https://docs.mesastar.org/en/release-r24.03.1/using_mesa/best_practices.html)

# Also!! cite the works corresponding to significant infrastructure that has been shared with the project

MESA critically rests on the hard work of many researchers who have generated the input microphysics data that underpins the `eos`, `kap`, `net`, and `neu` modules. We therefore encourage users to briefly summarize these, including appropriate citations.

```
The MESA EOS is a blend of the OPAL \citep{Rogers2002}, SCVH  
\citep{Saumon1995}, FreeEOS \citep{Irwin2004}, HELM \citep{Timmes2000},  
PC \citep{Potekhin2010}, and Skye \citep{Jermyn2021} EOSes.
```

```
Radiative opacities are primarily from OPAL \citep{Iglesias1993},  
Iglesias1996}, with low-temperature data from \citet{Ferguson2005}  
and the high-temperature, Compton-scattering dominated regime by  
\citet{Poutanen2017}. Electron conduction opacities are from  
\citet{Cassisi2007} and \citet{Blouin2020}.
```

```
Nuclear reaction rates are from JINA REACLIB \citep{Cyburt2010}, NACRE \citep{Angulo1999} and  
additional tabulated weak reaction rates \citet{Fuller1985}, Oda1994,  
Langanke2000}. Screening is included via the prescription of \citet{Chugunov2007}.  
Thermal neutrino loss rates are from \citet{Itoh1996}.
```

A bibtex file containing these references is available here:

[https://docs.mesastar.org/en/release-r24.03.1/using\\_mesa/best\\_practices.html](https://docs.mesastar.org/en/release-r24.03.1/using_mesa/best_practices.html)



Josiah Schwab



Adam Jermy



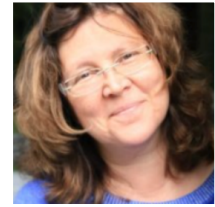
Meredith Joyce



Evan Bauer



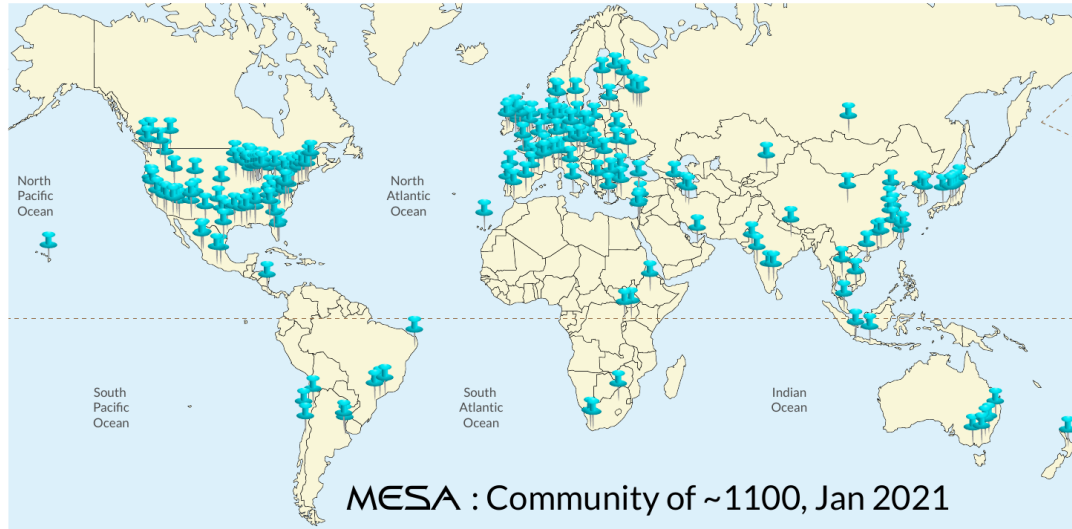
Earl Bellinger



Anne Thoul



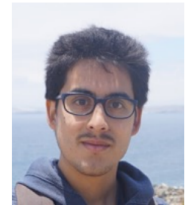
Radek Smolec



Bill Wolf



Rob Farmer



Pablo Marchant



Warrick Ball



Aaron Dotter



Rich Townsend



Frank Timmes



Bill Paxton



Lars Bildsten



Matteo Cantiello



Josiah Schwab



Adam Jermyn



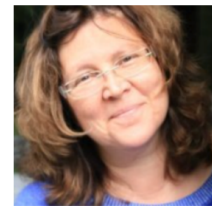
Meredith Joyce



Evan Bauer



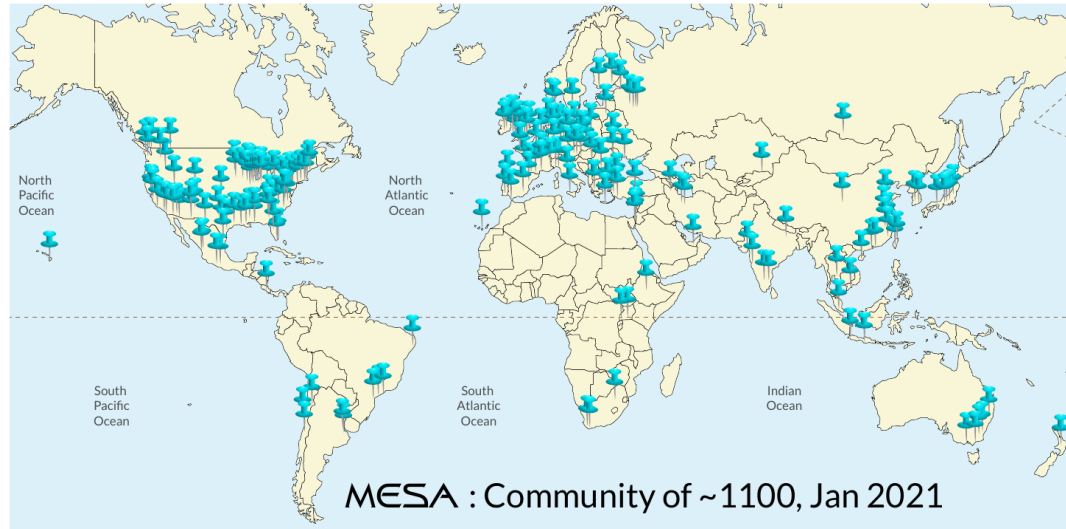
Earl Bellinger



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Rob Farmer



Pablo Marchant



Warrick Ball



Aaron Dotter



Rich Townsend



Frank Timmes



Bill Paxton



Lars Bildsten



Matteo Cantiello





Joey Mombarg



Ebraheem Farag



Meredith Joyce



Evan Bauer



Earl Bellinger



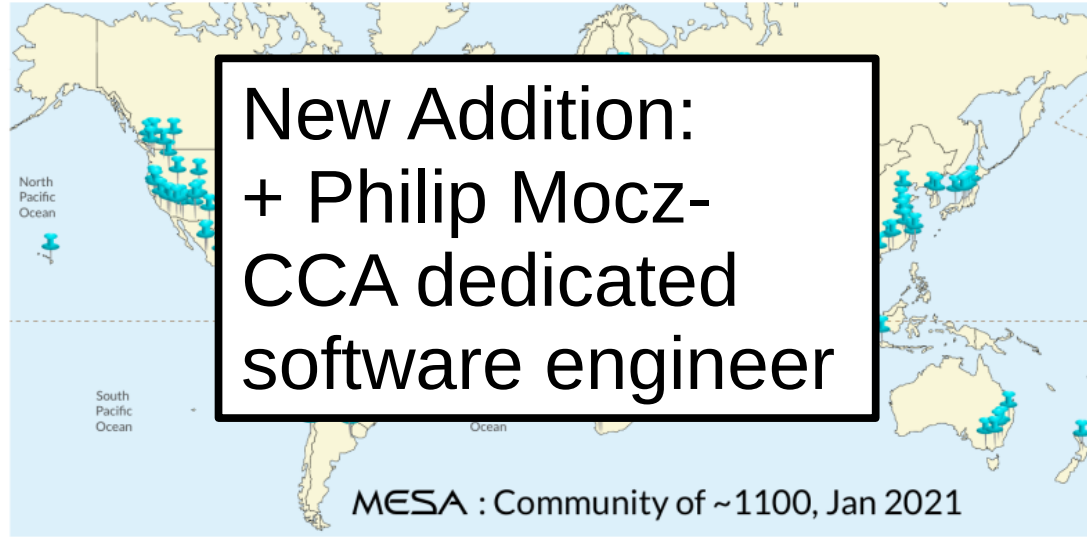
Anne Thoul



Radek Smolec



Matthias Fabry



Bill Wolf



Pablo Marchant



Warrick Ball



Philip Mocz



Rich Townsend



Frank Timmes



Lars Bildsten



Matteo Cantiello

You can check out the past  
and current developers at:

<https://docs.mesastar.org/en/release-r24.03.1/about.html#the-mesa-team>

# MESA Summer Schools

Historically hosted at the University of California,  
Santa Barbara (11 years)...



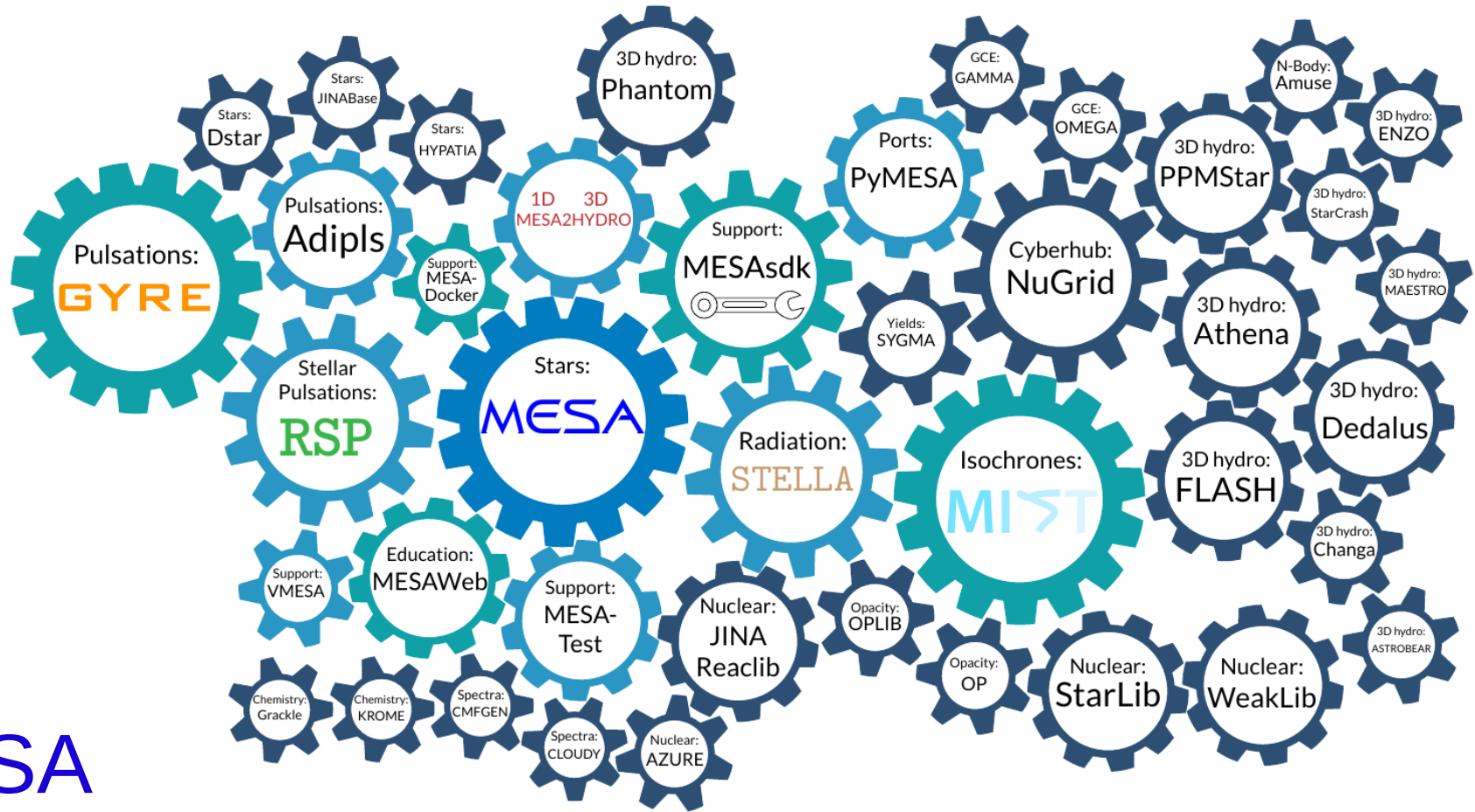
# Last year: MESA@Konkoly



**MESA@Konkoly Summer School  
Budapest, 2023.08.28-09.01**



Gaia LIGO SDSS Hubble JWST LSST TESS LCOGT NuSTAR



MESA  
ecosystem

Laboratory Astrophysics

MESA Open knowledge philosophy

# MESA Open knowledge philosophy

## **Open Source**

The code is freely available, but that's only one piece of the picture. In order for a product to be truly open source, it also has to be usable

# MESA Open knowledge philosophy

## **Open Source**

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MESA's documentation is thorough, and extensive tutorials and pedagogical materials are freely available along with the software itself. The team is highly responsive to user questions

MESA Open knowledge philosophy

**Open Knowledge**



# MESA Open knowledge philosophy

## Open Knowledge

MESA “best practices” encourage the sharing of your parameter control files (inlists) as well as analysis scripts, numerical data, code for making figures, etc. The aspiration is *complete reproducibility* of science that uses MESA.

# MESA Open knowledge philosophy

## Open Knowledge

MESA “best practices” encourage the sharing of your parameter control files (inlists) as well as analysis scripts, numerical data, code for making figures, etc. The aspiration is *complete reproducibility* of science that uses MESA.

We can't personally enforce this, but we hope the value of this level of scientific accountability is obvious. This is the way the world is heading, and grant agencies are adapting their funding priorities accordingly (e.g., open source/data sharing requirements in the EU)



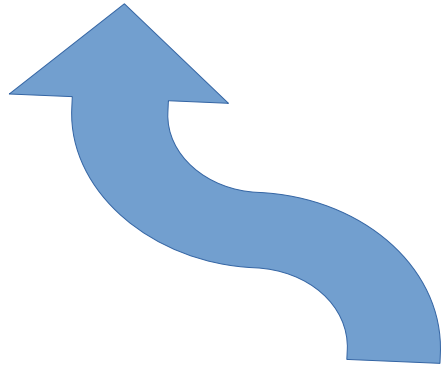
Zenodo repository:  
<https://zenodo.org/records/10783349>

# Core Resources

# Core Resources

Zenodo repository:

<https://zenodo.org/records/10783349>



This is where you should  
download the code from!

# Core Resources

zenodo.org/records/10783349



Search records...



Communities

My dashboard

MESA Modules for Experiments in Stellar Astrophysics (MESA)

Published March 5, 2024 | Version r24.03.01

Software

Open

## Modules for Experiments in Stellar Astrophysics (MESA)

Paxton, Bill<sup>1</sup>

Show affiliations

Release versions of Modules for Experiments in Stellar Astrophysics (MESA) in ZIP format.

### Files

mesa-r24.03.1.zip



mesa-r24.03.1.zip



# Core Resources

Zenodo repository:

<https://zenodo.org/records/10783349>

Github repository:

<https://github.com/MESAHub/mesa>

Software Development Kit (SDK):

<http://user.astro.wisc.edu/~townsend/static.php?ref=mesasdk>

The code itself:

**Mesa-r24.03.1/star/test\_suite**

**Mesa-r24.03.1/star/defaults/\*.list ; \*.defaults**

The web-hosted documentation:

<https://docs.mesastar.org/en/release-r24.03.1/>

# Core Resources

inlists used in academic papers:

[https://cococubed.com/mesa\\_market/inlists.html](https://cococubed.com/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) (2011-2022)

<https://mesahub.github.io/summer-school-2023/agenda/> (2023)

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)

What can MESA do?

# What can MESA do?

**MESA is BROAD, not  
necessarily DEEP**

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**MESA is BROAD, not necessarily DEEP**

**➔ Depth comes from contributors improving small components of MESA relevant to their expertise**



# What can MESA do?

A tour of the `test_suite`

After installation, navigate to:  
[mesa-r24.03.1/star/test\\_suite/](https://github.com/MESA-team/mesa-r24.03.1/tree/main/star/test_suite)

# A tour of the test\_suite

```
mjoyce@burbridge: ~/MESA/mesa-r24.03.1/star/test_suite
drwxrwxr-x 5 mjoyce mjoyce 4096 Mar  5 13:19 12M_pre_ms_to_core_collapse
mjoyce@burbridge:~/MESA/mesa-r24.03.1/star/test_suite$ ls
12M_pre_ms_to_core_collapse  custom_rates                make_co_wd                  rsp_gyre
1.3M_ms_high_Z              debugging_stuff_for_inlists  make_env                   rsp_RR_Lyrae
1.4M_ms_op_mono             diffusion_smoothness         make_he_wd                 rsp_save_and_load_file
15M_dynamo                  do1_rsp_test_source         make_metals                rsp_Type_II_Cepheid
1.5M_with_diffusion         do1_test_source             make_o_ne_wd              semiconvection
16M_conv_premix             each_test_clean             make_planets              simplex_solar_calibration
16M_predictive_mix          each_test_compile           make_pre_ccsn_13bvn       split_burn_big_net
1M_pre_ms_to_wd             each_test_do                make_sdb                   starspots
1M_thermohaline            each_test_run               make_zams                  test_case_template
20M_pre_ms_to_core_collapse extended_convective_penetration make_zams_low_mass        test_memory
20M_z2m2_high_rotation     gyre_in_mesa_bcep          make_zams_ultra_high_mass test_suite_helpers
5M_cepheid_blue_loop       gyre_in_mesa_envelope      ns_c                       timing
7M_premis_to_AGB           gyre_in_mesa_ms            ns_h                       T_tau_gradr
accreted_material_j        gyre_in_mesa_rsg           ns_he                      twin_studies
adjust_net                  gyre_in_mesa_spb           other_physics_hooks       tzo
build_and_run               gyre_in_mesa_wd            pispn                     wd_acc_small_dm
c13_pocket                  hb_2M                      radiative_levitation      wd_aic
carbon_kh                   high_mass                   R_CrB_star                wd_c_core_ignition
cburn_inward                high_rot_darkening         relax_composition_j_entropy wd_cool_0.6M
ccsn_IIP                    high_z                      report                     wd_diffusion
check_pulse_atm             hse_riemann                rsp_BEP                   wd_he_shell_ignition
check_redo                  irradiated_planet          rsp_BLAP                  wd_nova_burst
conductive_flame            list_tests                  rsp_Cepheid               wd_stable_h_burn
conserve_angular_momentum  low_z                      rsp_Cepheid_6M            zams_to_cc_80
conv_core_cpm              magnetic_braking           rsp_check_2nd_crossing
count_tests                 make_brown_dwarf          rsp_Delta_Scuti
custom_colors               make_co_wd
mjoyce@burbridge:~/MESA/mesa-r24.03.1/star/test_suite$
```

# Using MESA

# Environment Variables

## Environment variables

To run MESA, you must set *environment variables* that point your system to the correct paths for dependent packages

The variables are:

**MESA\_DIR** – the location of your top-level MESA directory

**MESASDK\_ROOT** – the location of the SDK

**OMP\_NUM\_THREADS** – the number of threads (= 2x number of cores) you choose to devote to MESA calculations.

*Note that most laptops have between 2 and 8 threads available, or 1 to 4 cores. Setting **OMP\_NUM\_THREADS** above this will result in overextending the capabilities of your system, causing the calculations to run very slowly or crash*

# Environment Variables

The syntax for setting these variables differs between MacOS and Linux and depends on your shell environment (ex. I use Linux and bash shell)

Visit

[https://www.youtube.com/watch?v=NmaLHFxpALg&ab\\_channel=FrankTimmes](https://www.youtube.com/watch?v=NmaLHFxpALg&ab_channel=FrankTimmes)

for video guides on how to set up these variables for other systems

Other video installation guides also available at my website:

<https://www.meridithjoyce.com/talks.html>

# Setting environment variables: the bad way

```
mjoyce@burbridge: ~/MESA/mesa-r24.03.1
drwxrwxr-x 11 mjoyce mjoyce 4096 Mar  5 13:19 binary
drwxrwxr-x  8 mjoyce mjoyce 4096 Mar  5 13:19 auto_diff
drwxrwxr-x  8 mjoyce mjoyce 4096 Mar  5 13:19 atm
drwxrwxr-x  9 mjoyce mjoyce 4096 Mar  5 13:19 astero
drwxrwxr-x  6 mjoyce mjoyce 4096 Mar  5 13:19 adipls
-rw-rw-r--  1 mjoyce mjoyce  172 Jun 16 15:27 testhub.yml
drwxrwxr-x 16 mjoyce mjoyce 4096 Jun 16 15:27 eos
drwxrwxr-x 11 mjoyce mjoyce 4096 Jun 16 15:33 kap
drwxrwxr-x  8 mjoyce mjoyce 4096 Jun 16 15:34 ionization
drwxrwxr-x 14 mjoyce mjoyce 4096 Jun 16 15:35 data
drwxrwxr-x  5 mjoyce mjoyce 4096 Jun 16 15:35 sample
drwxrwxr-x  6 mjoyce mjoyce 4096 Jun 16 15:35 gyre
drwxrwxr-x  2 mjoyce mjoyce 4096 Jun 16 15:39 lib
drwxrwxr-x  2 mjoyce mjoyce 4096 Jun 16 15:39 include
-rw-rw-r--  1 mjoyce mjoyce 67377 Jun 16 15:39 build.log
mjoyce@burbridge:~/MESA/mesa-r24.03.1$ export MESA_DIR=/home/mjoyce/MESA/mesa-r24.03.1
mjoyce@burbridge:~/MESA/mesa-r24.03.1$ export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk_Jul2023
mjoyce@burbridge:~/MESA/mesa-r24.03.1$ source $MESASDK_ROOT/bin/mesasdk_init.sh
mjoyce@burbridge:~/MESA/mesa-r24.03.1$ export OMP_NUM_THREADS=2
mjoyce@burbridge:~/MESA/mesa-r24.03.1$
```

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

Since `.bashrc` (or equivalent) is read automatically each time you open a new terminal window, assigning environment variables in `.bashrc` (*or the equivalent profile of your local system*) means you do not need to assign them manually

# Setting environment variables the good way: .bashrc file

```
.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 ## for screenshots only
12 export MESA_DIR=/home/mjoyce/MESA/mesa-r24031
13 export MESA_SDK_ROOT=/home/mjoyce/MESA/mesasdk
14 source $MESA_SDK_ROOT/bin/mesasdk_init.sh
15 export OMP_NUM_THREADS=2
16
```



# Best way: functions in .bashrc

```
function mesa-24031 {  
export MESA_DIR=/home/mjoyce/MESA/mesa-r24.03.1  
export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk_Jul2023  
source $MESASDK_ROOT/bin/mesasdk_init.sh  
export OMP_NUM_THREADS=8  
echo "environment set for MESA version 24.03.1"  
echo "SDK version 23.7.3 in use"  
echo "OMP_NUM_THREADS set to 8"  
}
```

Because  
then you  
can toggle  
between  
**MESA**  
versions, if  
you ever  
have reason  
to do that...

```
371
372 function mesa-15140 {
373 export MESA_DIR=/home/mjoyce/MESA/ mesa-r15140
374 export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk_15140
375 source $MESASDK_ROOT/bin/mesasdk_init.sh
376 export OMP_NUM_THREADS=8
377 echo "environment set for MESA version 15140"
378 }
379
380
381 function mesa-22051 {
382 export MESA_DIR=/home/mjoyce/MESA/ mesa-r22051
383 export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk_15140
384 source $MESASDK_ROOT/bin/mesasdk_init.sh
385 export OMP_NUM_THREADS=8
386 echo "environment set for MESA version 22.05.1"
387 }
388
389
390 function mesa-23051 {
391 export MESA_DIR=/home/mjoyce/MESA/ mesa-r23051
392 export MESASDK_ROOT=/home/mjoyce/MESA/mesasdk
393 source $MESASDK_ROOT/bin/mesasdk_init.sh
394 export OMP_NUM_THREADS=2
395 echo "environment set for MESA version 23.05.1"
396 }
397
```

Now it is straightforward to set up your **MESA** environment:

```
mjoyce@burbridge: ~/MESA/mesa-r24.03.1
-rwxr-xr-x 1 mjoyce mjoyce 461 Mar 5 13:19 each_package_do
xyfile
cs
ta
CONTRIBUTING.rst
drwxrwxr-x 8 mjoyce mjoyce 4096 Mar 5 13:19 const
drwxrwxr-x 7 mjoyce mjoyce 4096 Mar 5 13:19 colors
-rw-rw-r-- 1 mjoyce mjoyce 5195 Mar 5 13:19 CODEOWNERS
-rw-rw-r-- 1 mjoyce mjoyce 1910 Mar 5 13:19 CODE_OF_CONDUCT.rst
-rwxr-xr-x 1 mjoyce mjoyce 356 Mar 5 13:19 clean
-rw-rw-r-- 1 mjoyce mjoyce 21100 Mar 5 13:19 CITATIONS.bib
drwxrwxr-x 8 mjoyce mjoyce 4096 Mar 5 13:19 chem
drwxrwxr-x 11 mjoyce mjoyce 4096 Mar 5 13:19 binary
drwxrwxr-x 8 mjoyce mjoyce 4096 Mar 5 13:19 auto_diff
drwxrwxr-x 8 mjoyce mjoyce 4096 Mar 5 13:19 atm
drwxrwxr-x 9 mjoyce mjoyce 4096 Mar 5 13:19 astero
drwxrwxr-x 6 mjoyce mjoyce 4096 Mar 5 13:19 adipls
mjoyce@burbridge:~/MESA/mesa-r24.03.1$ source ~/.bashrc
mjoyce@burbridge:~/MESA/mesa-r24.03.1$ mesa-24031
environment set for MESA version 24.03.1
SDK version for July 2023 in use
OMP_NUM_THREADS set to 8
mjoyce@burbridge:~/MESA/mesa-r24.03.1$
```

# **Microlab 0:** **Check and set** **environment variables** **(~3 minutes)**

# **Microlab 0:** **Check and set** **environment variables** **(~3 minutes)**

**Show of thumbs when complete!**

# 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'**

**Parameter libraries-** *all of the possible values for your parameters can be found in the module defaults files*

**Mesa-r24.03.1/star/defaults/** contains

controls.defaults  
star\_job.defaults  
pgstar.defaults  
history\_columns.list  
profile\_columns.list

Opacity defaults can be found in  
**mesa-r24.03.1/kap/defaults/kap.defaults**

EOS defaults in  
**mesa-r24.03.1/eos/defaults/eos.defaults**

# Setup and output

## Executable

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

## 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**



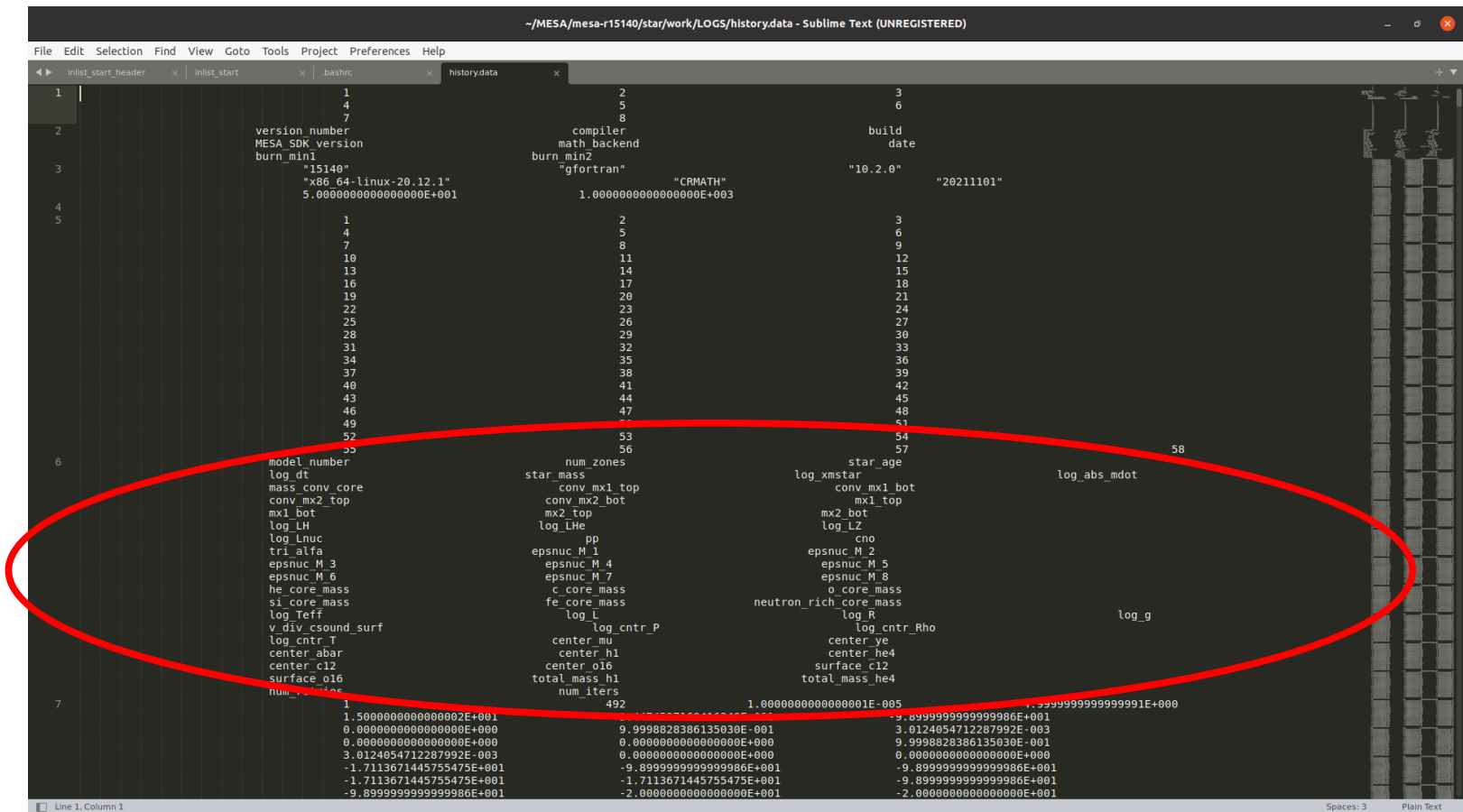
# Setup and output

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
2 | 4 5 6
3 | 7 8 9
4 | version number compiler build
5 | MESA_SDK version math backend date
6 | burn_min1 burn_min2 "10.2.0" "20211101"
7 | "15140" "gfortran"
8 | "x86_64-linux-20.12.1" "CRMATH"
9 | 5.0000000000000000E+001 1.0000000000000000E+003
10 | 1 2 3
11 | 4 5 6
12 | 7 8 9
13 | 10 11 12
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30 | model_number num_zones star_age
31 | log_dt star_mass log_xmstar log_abs_mdot
32 | mass_conv_core conv_mx1_top conv_mx1_bot
33 | conv_mx2_top conv_mx2_bot mx1_top
34 | mx1_bot mx2_top mx2_bot log_LZ
35 | log_LH pp cno
36 | log_Lnuc epsnuc_M_1 epsnuc_M_2
37 | tri_alfa epsnuc_M_4 epsnuc_M_5
38 | epsnuc_M_3 epsnuc_M_6 epsnuc_M_7 epsnuc_M_8
39 | he_core_mass c_core_mass o_core_mass
40 | si_core_mass fe_core_mass neutron_rich_core_mass
41 | log_Teff log_L log_R log_g
42 | v_div_csound_surf log_cntr_P log_cntr_Rho
43 | log_cntr_T center_mu center_ye center_ye
44 | center_abar center_h1 center_he4
45 | center_c12 center_o16 surface_c12
46 | surface_o16 total_mass_h1 total_mass_he4
47 | num_retries num_iters
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49 | 1.5000000000000002E+001 3.4474597169416349E+001 -9.8999999999999998E+001
50 | 0.0000000000000000E+000 9.9998828386135030E-001 3.0124054712287992E-003
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53 | -1.7113671445755475E+001 -9.8999999999999998E+001 -9.8999999999999998E+001
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```

# 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
2 | 4 5 6
3 | 7 8 9
4 | version number compiler build
5 | MESA_SDK version math backend date
6 | burn_min1 burn_min2 "10.2.0" "20211101"
7 | "15140" "gfortran"
8 | "x86_64-linux-20.12.1" "CRMATH"
9 | 5.0000000000000000E+001 1.0000000000000000E+003
10 | 1 2 3
11 | 4 5 6
12 | 7 8 9
13 | 10 11 12
14 | 13 14 15
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24 | 43 44 45
25 | 46 47 48
26 | 49 50 51
27 | 52 53 54
28 | 55 56 57 58
29 | model_number num_zones star_age
30 | log_dt star_mass log_xmstar log_abs_mdott
31 | mass_conv_core conv_mx1_top conv_mx1_bot
32 | conv_mx2_top conv_mx2_bot mx1_top
33 | mx1_bot mx2_top mx2_bot log_LZ
34 | log_LH pp cno
35 | log_Lnuc epsnuc M 1 epsnuc M 2
36 | tri_alfa epsnuc M 4 epsnuc M 5
37 | epsnuc M 3 epsnuc M 7 epsnuc M 8
38 | epsnuc M 6 c_core_mass o_core_mass
39 | he_core_mass fe_core_mass neutron_rich_core_mass
40 | si_core_mass log_L log_R log_g
41 | log_Teff v_div csound_surf log_cntr_P log_cntr_Rho
42 | log_cntr_T center_mu center_mu center_ye
43 | center_abar center_h1 center_he4
44 | center_c12 center_o16 surface_c12
45 | surface_o16 total_mass_h1 total_mass_he4
46 | num_iters num_iters
47 | 1 492 1.0000000000000001E-005 7.9999999999999991E+000
48 | 1.5000000000000002E+001 9.9998828386135030E-001 9.8999999999999986E+001
49 | 0.0000000000000000E+000 0.0000000000000000E+000 3.0124054712287992E-003
50 | 0.0000000000000000E+000 0.0000000000000000E+000 9.9998828386135030E-001
51 | 3.0124054712287992E-003 0.0000000000000000E+000 9.9998828386135030E-001
52 | -1.7113671445755475E+001 -9.8999999999999986E+001 -9.8999999999999986E+001
53 | -1.7113671445755475E+001 -9.8999999999999986E+001 -9.8999999999999986E+001
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Line 1, Column 1 Spaces: 3 Plain Text
```

# **Microlab 1:**

- 1) Explore your inlists
- 2) Run MESA out-of-the-box

**(~10 minutes)**

# Microlab 1: Exploring MESA & inlists (10 min)

- (1) What is the initial mass of the model that runs when you launch a simulation in `mesa-r24.03.1/star/work/` ?
- (2) What causes this model to stop?
- (3) Does MESA create a starting model for this simulation, or does it load an existing model?
- (4) Try to run this model using **`./clean; ./mk; ./rn`**  
Ask a TA for help if you cannot! What do these scripts do?
- (5) How hot is the star at step number 35 of this run?

# 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

```
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;
8 ! it under the terms of t
9 ! by the free software fo
10 ! (at your option) any la
11 !
12 ! mesa is distributed in
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: default

```
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
```

# run\_star\_extras.f90: include

# Using run\_star\_extras.f90

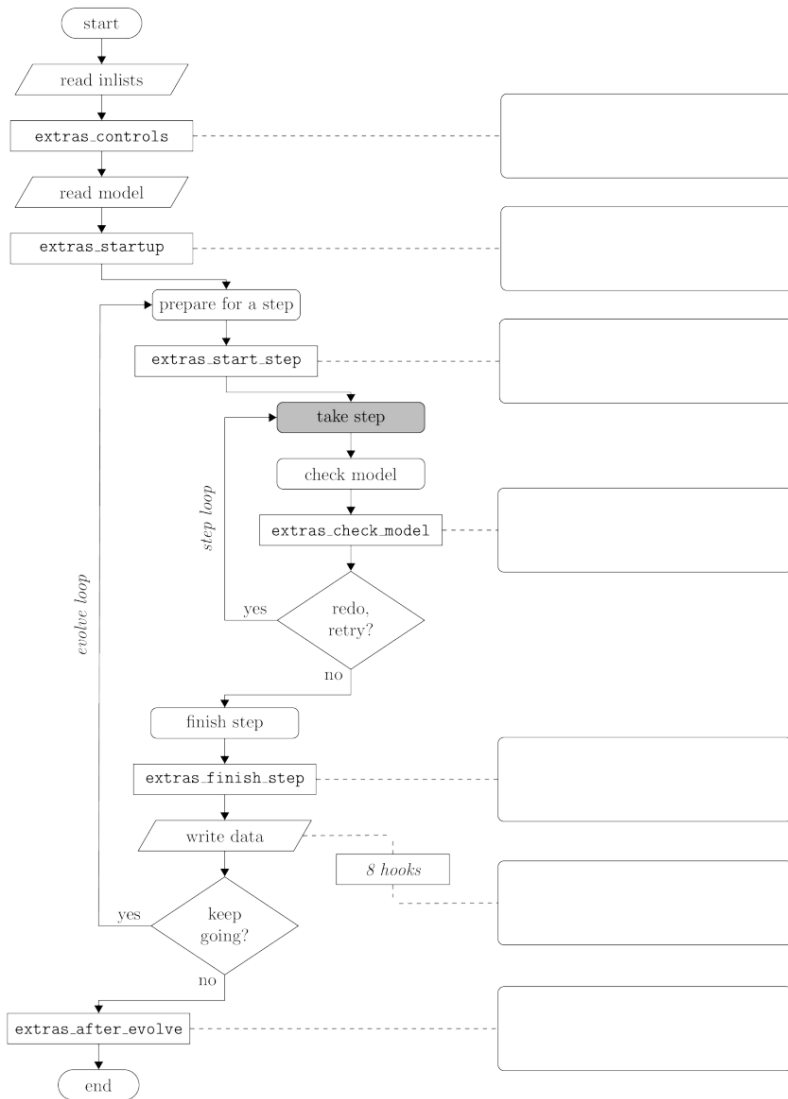
Every time you modify `run_star_extras`, you must

```
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_crm_ath_link` `mesasdk_lapack95_link` `mesasdk_lapack_link` `mesasdk_blas_link` `mesasdk_hdf5_link` `mesasdk_pgplot_link` -lz
mjoyce@marsha:~/MESA/mesa-r22051/star/work$
```

**recompile the executable!!**



# Code Organization



Go to Sunny Wong's Lab 3 for a high-resolution version of this chart!

[https://  
courtclaw.github.io/  
mesadu\\_wdbinaries/  
lab3.html](https://courtclaw.github.io/mesadu_wdbinaries/lab3.html)

# 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 Newton solver iteration* (**step loop**)

where one evolve step contains several solver iterations

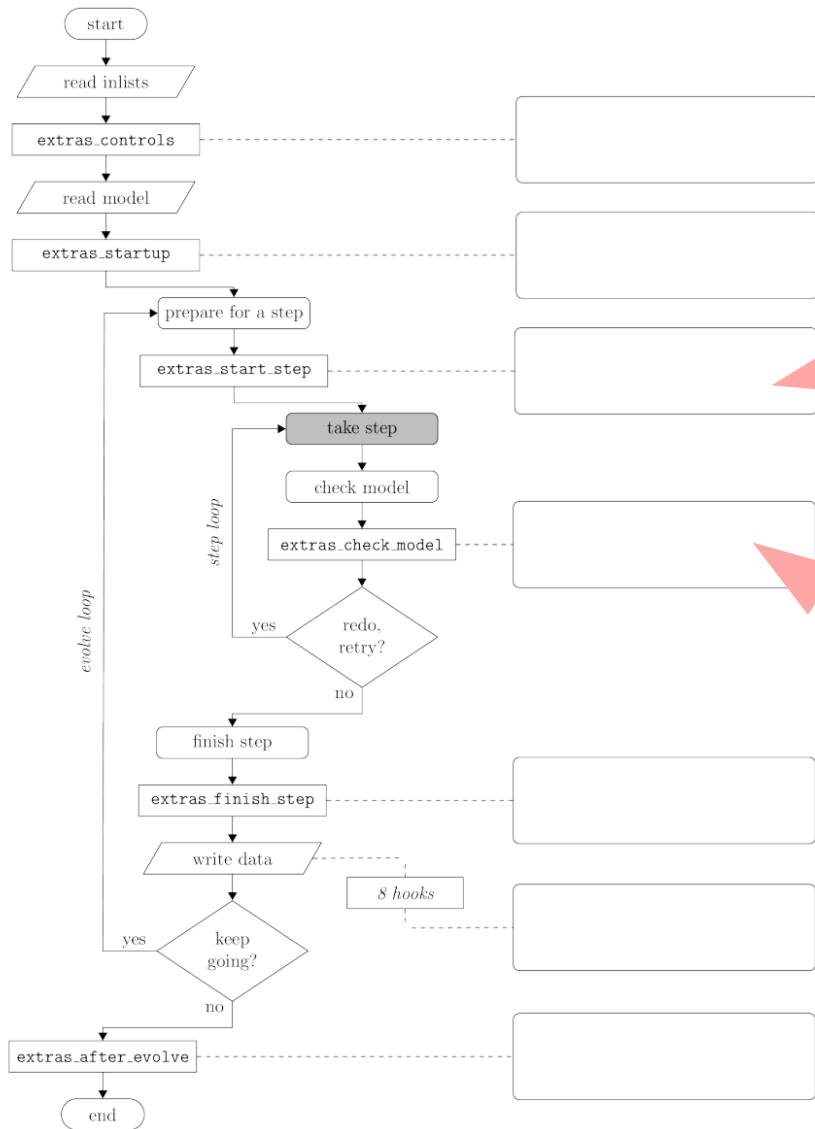
# Code Organization

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 Newton 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?

Getting involved in  
the MESA project

# Getting involved in the MESA project

**users-list engagement:** asking and answering questions

**Feature requests**

**Feature development** and sharing your code

**Large contributions**

Becoming a **MESA developer**

“MESA doesn’t work!”

“MESA sucks at X!”

“I want MESA to do something it does not currently do!”

**Raise an issue on github!**



# Raise an issue on github!

<https://github.com/MESAHub/mesa/issues>

[ Website ]

# Becoming a MESA developer

- ➔ Membership to the MESA developers team is done by nomination
- ➔ Any MESA developer can nominate a new member. The existing members of the team have two weeks to approve the nomination or not
- ➔ Typically, nomination is discussed with a candidate before the formal nomination process

# Becoming a MESA developer

## The MESA Team

The missions of the MESA Team are:

- **Stewardship:** supporting contributors, maintaining the access and updates, seeking enabling funding, supporting MESA Summer Schools that allow for continued engagement, documenting MESA development in the refereed literature, and sustaining advanced development.
- **Interface with the User Community:** answering questions from users, developing or accepting new code in an integrated fashion, supporting MESA workshops and events, maintaining a user registry, and identifying new MESA Team members from those most active and engaged in the intelligent use of MESA.
- **Enable Scientific Research and Education:** promoting MESA and its goals, e.g., through scientific contributions at relevant conferences, identifying science opportunities that match MESA capabilities, facilitating and encouraging appropriate scientific collaborative

# Becoming a **MESA** developer

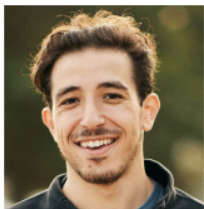
Supporting the **MESA** project is voluntary service work, but it is a prestigious project that opens a lot of opportunities

Writing code—whether developing MESA directly, its support tools, or programs that integrate with it—is a core component of MESA development

But it is not the only way to contribute!



Joey Mombarg



Ebraheem Farag



Meredith Joyce



Evan Bauer



Earl Bellinger



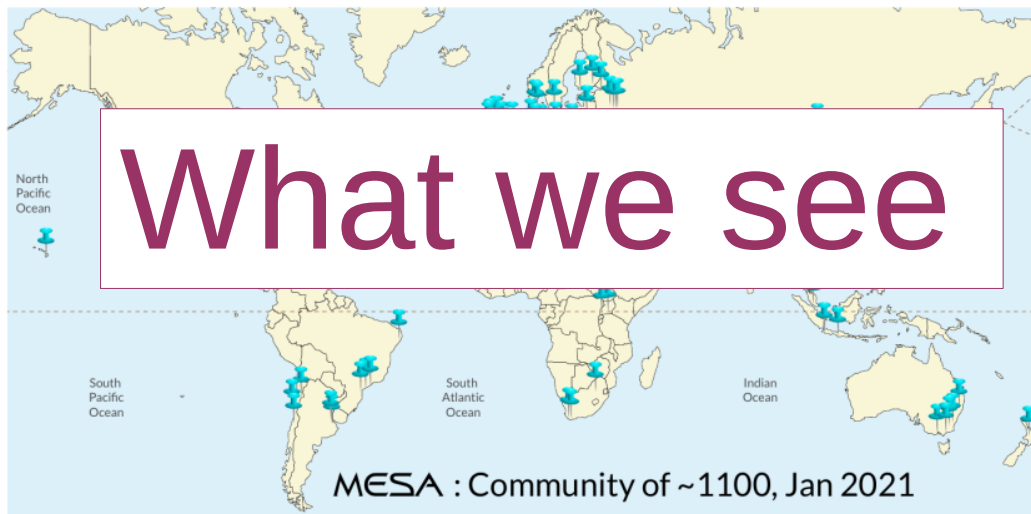
Anne Thoul



Radek Smolec



Matthias Fabry



Bill Wolf



Pablo Marchant



Warrick Ball



Philip Mocz



Rich Townsend



Frank Timmes



Lars Bildsten



Matteo Cantiello



Evan Bauer



Evan Bauer



Meredith Joyce



Evan Bauer



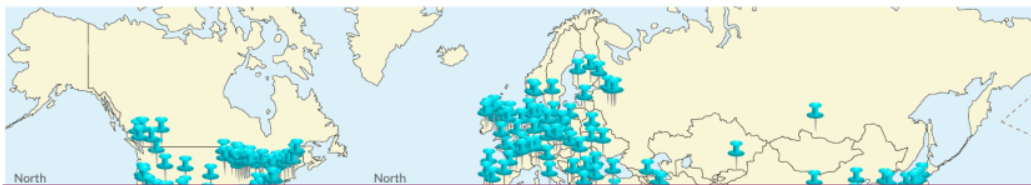
Evan Bauer



Meredith Joyce



Evan Bauer



# What it might as well be



Evan Bauer



Evan Bauer



Evan Bauer



Evan Bauer



Evan Bauer



Evan Bauer



Evan Bauer



Evan Bauer

# Becoming a MESA developer

As developers inevitably move on (or advance to professor, at which point they no longer have time to do anything), it is important to bring outstanding young astrophysicists into the team to keep MESA relevant and ensure that it continues to serve the needs of the research community

# Becoming a MESA developer

As developers inevitably move on (or advance to professor, at which point they no longer have time to do anything), it is important to bring outstanding young astrophysicists into the team to keep MESA relevant and ensure that it continues to serve the needs of the research community

We are especially interested in **recruiting women**. If you would like to know more about what it means to be a **MESA developer**, please talk to me at this workshop!





# SCHOOL OF COMPUTING

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School of Computing

People

Faculty

Meridith Joyce

UNIVERSITY OF WYOMING | SCHOOL OF COMPUTING

### MENU

RESEARCH SCIENTISTS

ELLEN AIKENS | ASSISTANT

PROFESSOR

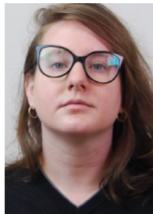
MARGO BERENDSEN | GIS ANALYST

SEAN FIELD | ASSISTANT

PROFESSOR

MERIDITH JOYCE | ASSISTANT

PROFESSOR



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Talk to me about PhD openings at **Wyo** or how to apply to postdocs and fellowships in the **United States and Europe!**