

Basics of the MESA evolution code

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What is MESA?

- Modules for Experiments in Stellar Astrophysics
- Main author: Bill Paxton
- Modern stellar evolution code with wide applications
- Modular approach
- Written in Fortran 95

Instrumental papers

- Paxton et al. 2011, <http://adsabs.harvard.edu/abs/2011ApJS..192....3P>
- Paxton et al. 2013, <http://adsabs.harvard.edu/abs/2013ApJS..208....4P>

System requirements

- Linux with GLIBC ≥ 2.7
- OS X 10.6.8 or newer
- 64-bit machine and OS!
- At least 4 GB of RAM
- Over 7 GB of disc space
- The more CPU cores, the better

MESA SDK

- Created and maintained by Rich Townsend
- Collection of compilers and runtime libraries required by MESA
- Created to dramatically simplify installation process
- <http://www.astro.wisc.edu/~townsend/static.php?ref=mesasdk>

MESA-users

- Mailing list dedicated for MESA
- <https://lists.sourceforge.net/lists/listinfo/MESA-users>
- Join now!

Websites

- <http://mesa.sourceforge.net>
- <http://mesastar.org>
- [http://www.astro.wisc.edu/~townsend/
static.php?ref=mesasdk](http://www.astro.wisc.edu/~townsend/static.php?ref=mesasdk)

Materials

- Materials related to this course
- <http://mesastar.org/teaching-materials/basics-of-the-mesa-evolution-code>

Installation guide

- Simple and detailed guide
- <http://mesastar.org/teaching-materials/basics-of-the-mesa-evolution-code/installation-guide/view>

Modules

Table 2
MESA Module Definitions and Purposes

Name	Type	Purpose	Section
alert	Utility	Error handling	3
atm	Microphysics	Gray and non-gray atmospheres; tables and integration	5.3
const	Utility	Numerical and physical constants	4.1
chem	Microphysics	Properties of elements and isotopes	4.1
diffusion	Macrophysics	Gravitational settling and chemical and thermal diffusion	5.4
eos	Microphysics	Equation of state	4.2
interp_1d	Numerics	One-dimensional interpolation routines	3
interp_2d	Numerics	Two-dimensional interpolation routines	3
ionization	Microphysics	Average ionic charges for diffusion	5.4
jina	Macrophysics	Large nuclear reaction nets using reaclib	4.5
kap	Microphysics	Opacities	4.3
karo	Microphysics	Alternative low- T opacities for C and N enhanced material	4.3
mlt	Macrophysics	Mixing length theory	5.1
mtx	Numerics	Linear algebra matrix solvers	3
net	Macrophysics	Small nuclear reaction nets optimized for performance	4.5
neu	Microphysics	Thermal neutrino rates	4.5
num	Numerics	Solvers for ordinary differential and differential-algebraic equations	3
package_template	Utility	Template for creating a new MESA module	2
rates	Microphysics	Nuclear reaction rates	4.4
screen	Microphysics	Nuclear reaction screening	4.5
star	Evolution	One-dimensional stellar evolution	6
utils	Utility	Miscellaneous utilities	3
weaklib	Microphysics	Rates for weak nuclear reactions	4.5

Paxton et al. 2011

- And the new ones: binary, colors

MESA *star* module

- Module responsible for calculating stellar structure and evolution
- *star* calls other modules when they are needed
- The main subject of this course

\$MESA_DIR/star/work directory

- Work directory for stellar evolution projects
- Make a copy of this directory for every new project (stellar evolution run)
- The copy could be put wherever you like and named however you wish

\$MESA_DIR/star/work directory

- **LOGS** - a history file and profiles
- **photos** - machine-dependent snapshots which can be used to resume the run
- **src** - a place for user's code

input files - inlists

- inlists - input files in work directory
- **inlist** - the main inlist
- **inlist** file should only contains locations of other, more specific inlists

inlists - recommendations

- **inlist** - the main inlist
- **inlist_project** - a place for your *star_job* and *controls* settings. The name of this file should be changed for something meaningful, e.g.
`inlist_15m_opal`
- **inlist_pgstar** - a place for your *PGstar* settings

Settings' types

- **star_job** - they must be determined at the beginning of the run
- **controls** - they might be changed during the run
- **pgstar** - settings of PGstar, they might be modified on the fly

running an evolution

- After all inlists are set up you can compile the files in your copy of `star/work` directory:
- `./mk`
- and then run the code:
- `./rn`
- If you want to restore the project from a photo:
- `./re name_of_photo`
- If you want to recompile project the folder should be cleaned:
- `./clean`

star/defaults directory

- Default values for input parameters and output files
- `star_job.defaults`, `controls.defaults` and `pgstar.defaults` contain default values for the input parameters
- `history_columns.list` and `profile_columns.list` can be used for adjusting the output files

output files

- output files are produced to **LOGS** directory by default
- **history.data** - it contains info about one model per row
- profiles - they contain an internal structure of calculated models. The following lines of the profile contain info for one zone per row, surface to center
- **profiles.index** - this file relates the numbers of profile files to the actual number of models they represent
- there might be also other output files, e.g. input files for pulsation codes

modifying output files

- `history_columns.list` and `profile_columns.list` define the default look of `history.data` and profiles
- you probably want different set of columns
- copy the files to your work directory (you can rename them but it's not necessary)
- comment, uncomment or reorder the names of columns as you like
- use the new lists in your project with the following `star_job` parameters:

```
history_columns_file = 'history_custom.list'  
profile_columns_file = 'profile_custom.list'
```


ZAMS

- ZAMS can be created with `create_zams` test
- Go to `$MESA_DIR/star/test_suite/create_zams`
- Edit `inlist_zams_specification`
- There are only handful of parameters which might be changed

inlist_zams_specification

- `create_z` and `create_y` - set Z and Y
- `zams_name` - set the name for your ZAMS
- Set the range of masses for your ZAMS and the step between them (remember that the values are logarithmic). These settings work well:
 - `mlo = -0.5`
 - `mhi = 2.0`
 - `dmass = 0.6`
- Compile and run: `./mk ; ./rn`

ZAMS

- Use new ZAMS with the following setting in your *controls* inlist:
- `zams_filename = 'path_to_your_zams'`
- More informations: http://mesastar.org/documentation/tutorials/zams-test-cases/create_zams/view