MESA
Modules for Experiments in Stellar Astrophysics

MESA Council - Bill Paxton, Lars Bildsten, Aaron Dotter, Falk Herwig, Frank Timmes

Contributors - Ed Brown, Raphael Hirschi, Pierre Lesaffre, Lorne Nelson, Georgios Magkotsios, Saul Rappaport, Steinn Sigurösson, Jon Tomshine, Don VandenBerg,
+ dozens of others - it's a community code.

mesa.sourceforge.net/

What is MESA?

MESA provides
robust, efficient,
thread-safe, parallel,
open source modules,
usable individually or in combination,
for a wide range of applications in
stellar astrophysics.

Paper I - “Project description and demonstration of basic capabilities” is in preparation - Paxton et al 2010.

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MESA is designed around the module data structure in Fortran 90/95. Each MESA package is responsible for a different aspect of numerics or physics.

Each module has an explicitly defined public interface that acts as an interpreter between a program that uses the module and the calculations carried out within the module.

Modules are constructed to be thread-safe – more than one thread or process can access the module at the same time – so they can take advantage of modern multicore processors.

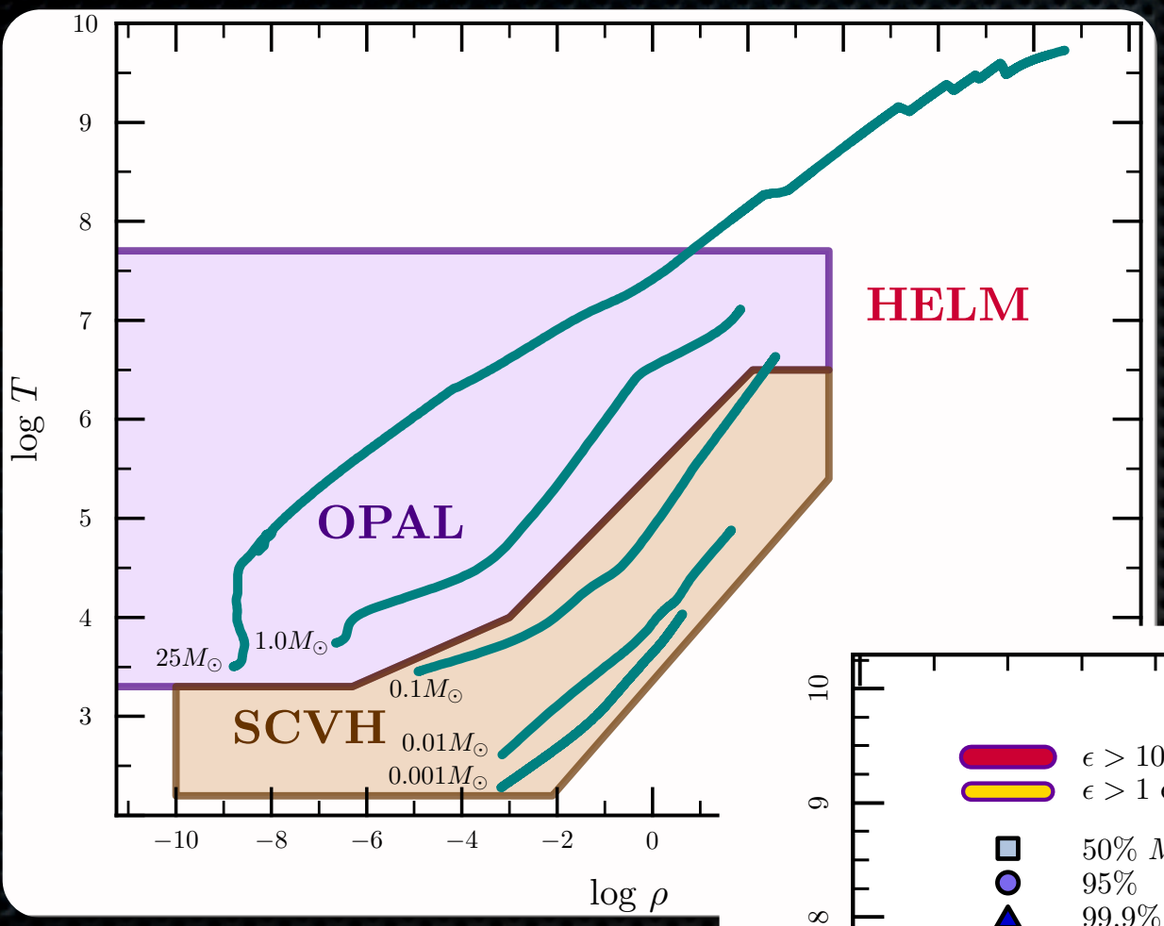
Stellar evolution is perfect for making use of many cores since the star is partitioned into a large number of zones whose equation of state, opacity, and nuclear reaction network calculations can be processed independently.

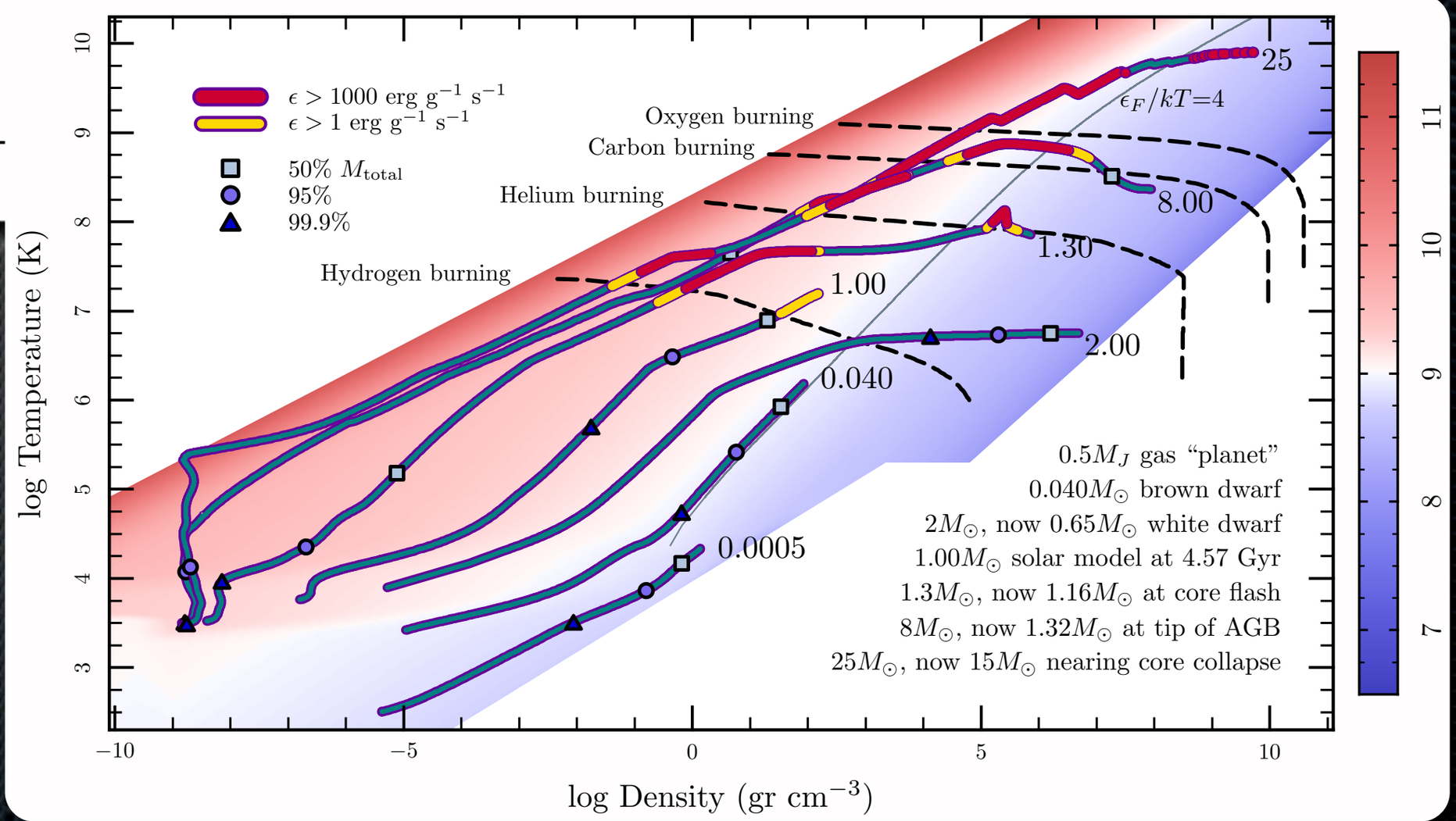
Modules harness shared-memory, parallel computing on multicore processors through OpenMP.

Limited testing indicate the execution time of MESA modules that use OpenMP scale almost linearly with the number of cores when minimal disk access is used.

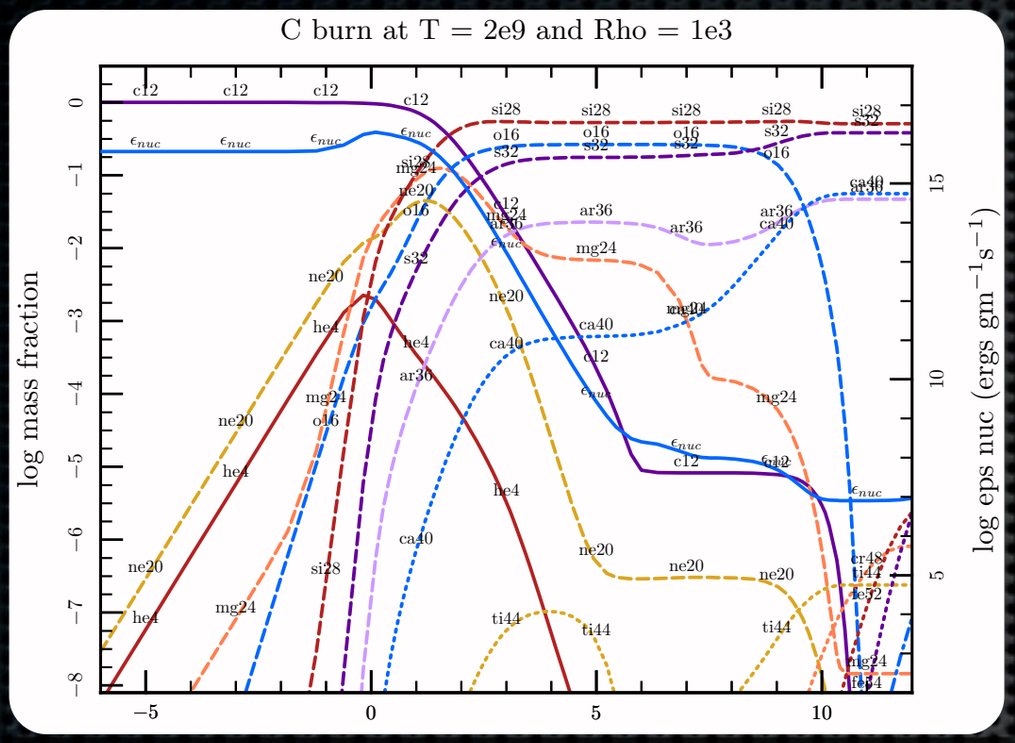
Two Module Examples

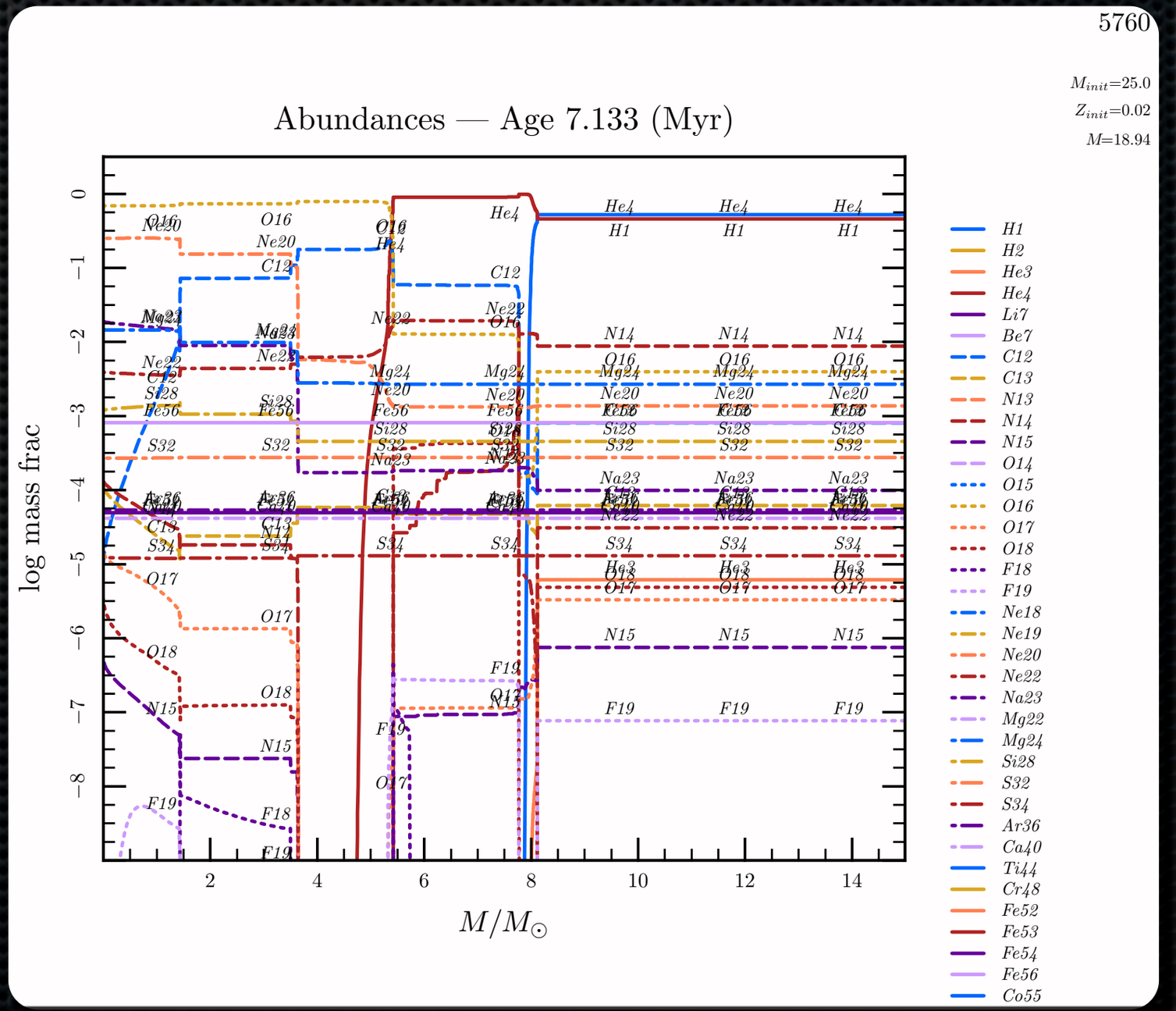
EOS tables are built from the OPAL, SCVH and HELM. Tabulated quantities are smoothly blended over the region of intersection and checked for consistency.





MESA/jina, as one network module, implements a full set of nuclear networks and reaction rates from the JINA Reaclib database to facilitate creation of very large nuclear networks, and is based on the “netJINA” package by Ed Brown (MSU).

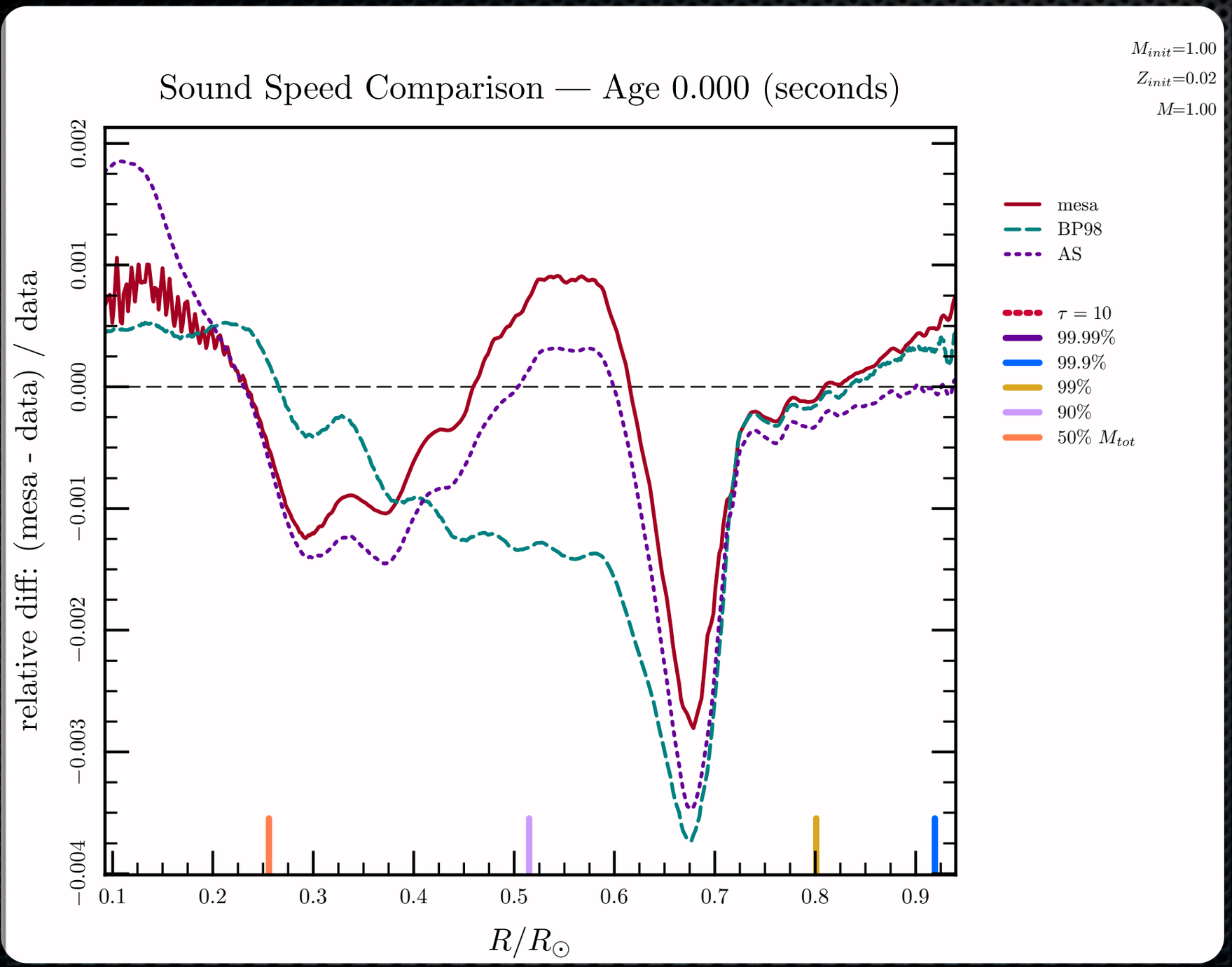




Some current features of MESA

1. full coupling of mixing, burning and structure operators
2. both hydrodynamic and hydrostatic option
3. range of networks, including those needed for massive star collapse
4. convection MLT (different flavors), overshooting, Ledoux criterion, semi-convection
5. mass accretion and mass loss - several prescriptions
6. several atmosphere options, including atmosphere tables from the Phoenix code
7. diffusion/gravitational settling via Thoul et al. (1994); recently verified against VandenBerg's code with diffusion treated according to Michaud & Proffit.
8. pulsation module (LAWE via Christensen-Dalsgaard's ADIPLS, 1997)
9. thermohaline mixing module
10. individual module level verification for eos, kap, atm, mlt
11. verified, as in code comparisons with established research codes, for low mass stars, the sun, AGB, massive stars, including nucleosynthesis predictions
12. passes Stellar Code Calibration (Achim Weiss et al) project test cases
13. compatible with NuGrid nucleosynthesis codes.

How does it compare to other proprietary and non-proprietary stellar evolution codes?



RMS error:

MESA : 7.75e-4

BP98 : 1.01e-3

La Plata : 1.03e-4

15 $M_\odot$ Z=0.02 Lifetime & Masses Comparison

Lifetime	Hirschi Thesis	Woosley et al 2002	Limongi et al 2000	MESA
H	1.13(7)	1.11(7)	1.07(7)	1.14(7)
He	1.34(6)	1.97(6)	1.4(6)	1.25(6)
C	3.92(3)	2.03(3)	2.6(3)	3.47(3)
Ne	3.08	0.732	2.00	4.74
O	2.43	2.58	2.43	4.16
Si	2.14(-2)	5.01(-2)	2.14(-2)	7.91(-3)

Masses	Hirschi Thesis	Rauscher et al 2002	Heger et al 2000	Limongi et al 2000	MESA
Total	13.232	12.612	13.55	15	12.77
He	4.168	4.163	3.82	4.10	4.40
C+O+Ne	2.302	2.819	1.77	2.39	2.30
“Iron”	1.514	1.452	1.33	1.429	1.527

Is MESA a useful path forward for JINA scientists that want stellar nucleosynthesis data?

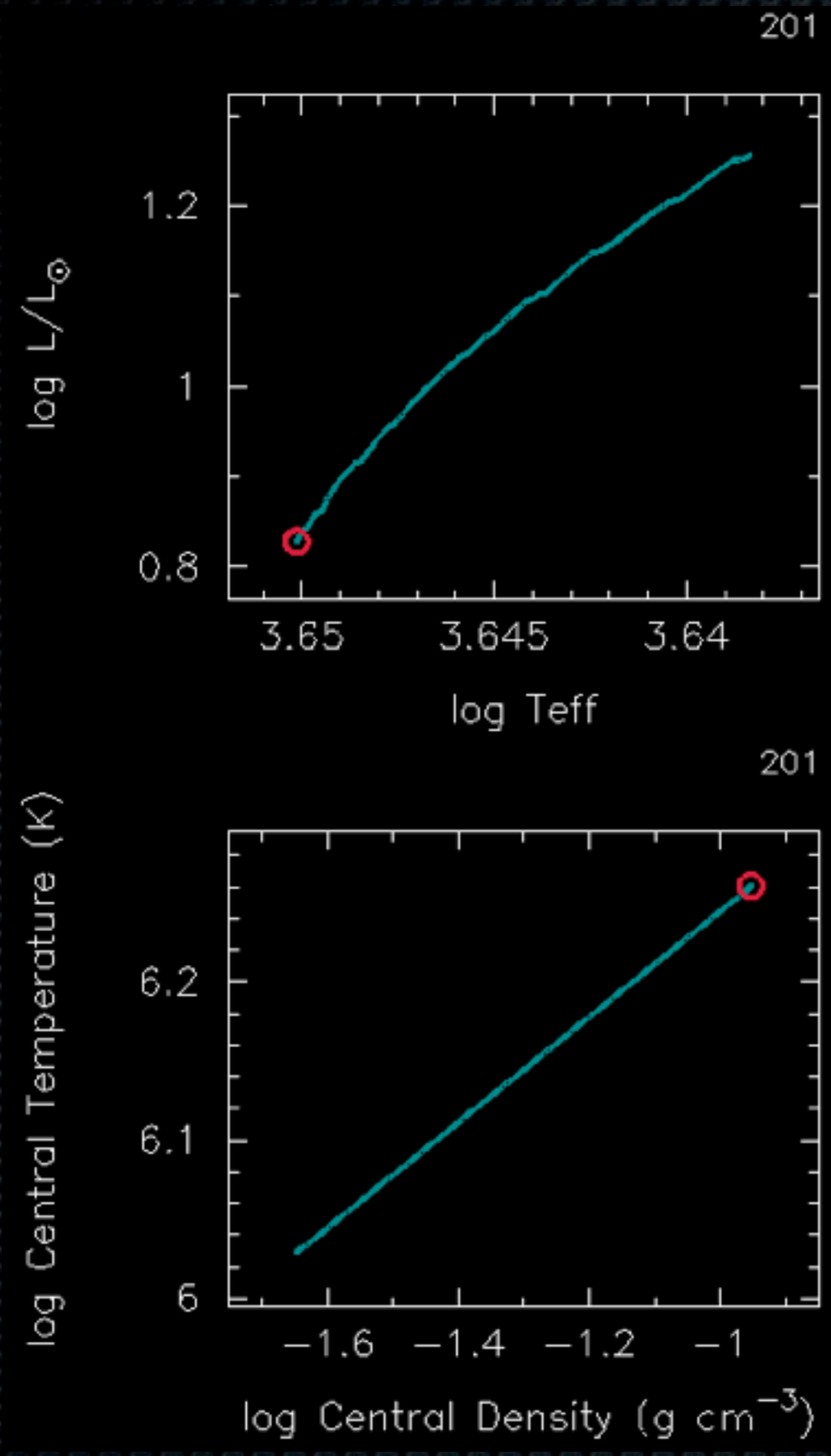
Yes.

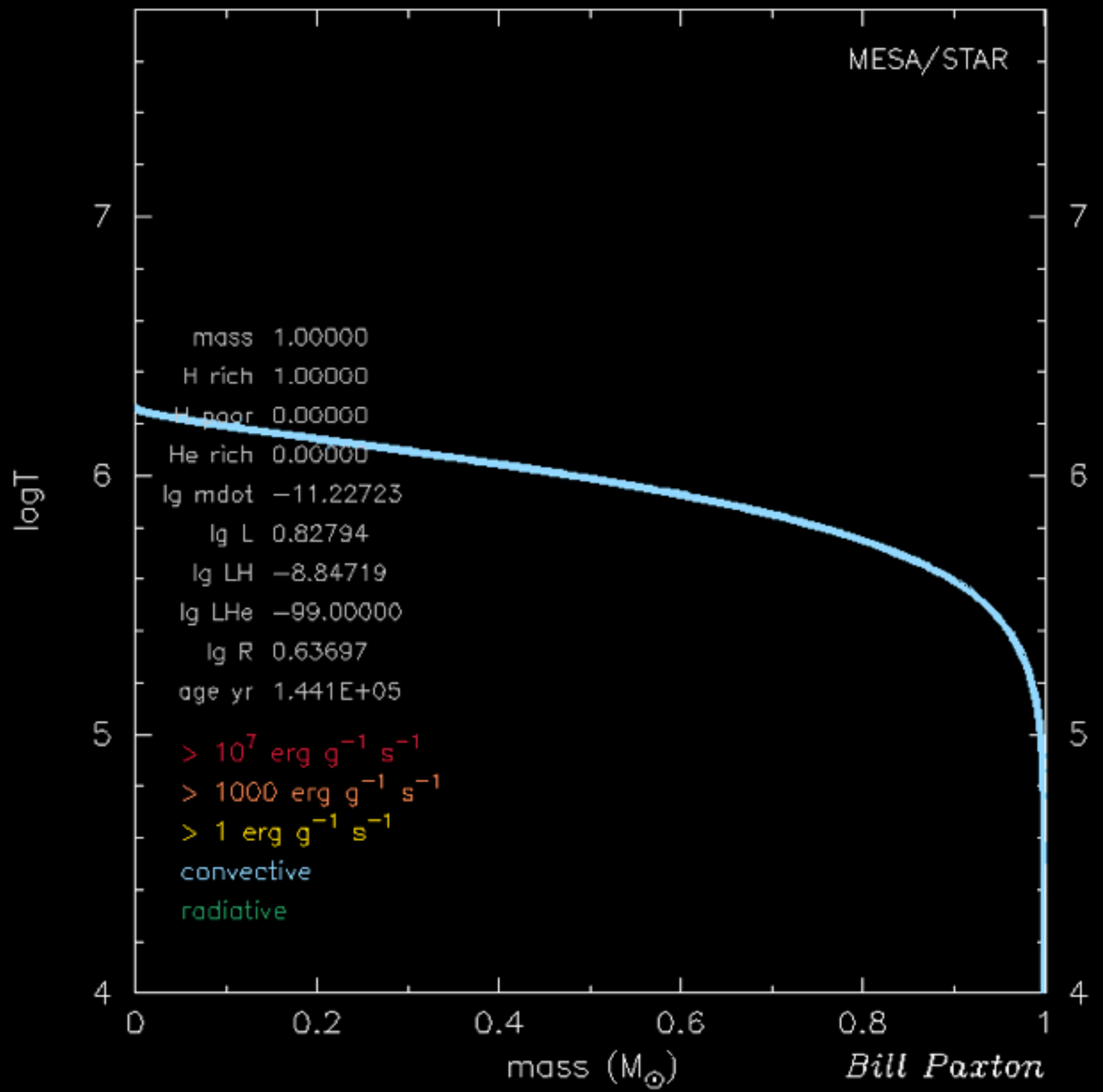
Caveat: MESA is a still a young code. It currently does not do some problems that some proprietary codes can (e.g., core-collapse explosions, SNIa explosions, Novae). In time, with community input and support, it will do these problems.

See Falk Herwig's talk on using MESA for the NuGrid project.

JINA will likely sponsor a summer or winter school on stellar evolution featuring MESA.

Recent 1 $M_\odot$ models go from MS through the He-core flash to WD in 1 day on 2-core MacBook without intervention.





Questions and Discussion