School of Earth and Space Exploration
Arizona State University

Save the Date!

Join us to celebrate the 10th Anniversary of the Marston Theater

Thursday, October 6

Time: 10:00 a.m.

Where: Marston Exploration Theater ISTB4, 781 E Terrace Mall

The School of Earth and Space Exploration at Arizona State University celebrates ISTB4 and the Marston Theater's 10th anniversary and honors our special guest, Susie Marston. We invite you to join us for a special 3D planetarium presentation – all in celebration of how we are advancing research and discovery, and to encourage children to explore their futures as scientists and engineers.

RSVP: https://bit.ly/3SmDmjN

The MESA Project

Frank Timmes
School of Earth and Space Exploration
AAS Journals Associate Editor-in-Chief
Arizona State University

Stars are great.

We need good models of them.

MESA is a software instrument that models the evolution of stars.

MESA = Modules for Experiments in Stellar Astrophysics

Single and Binary stars.

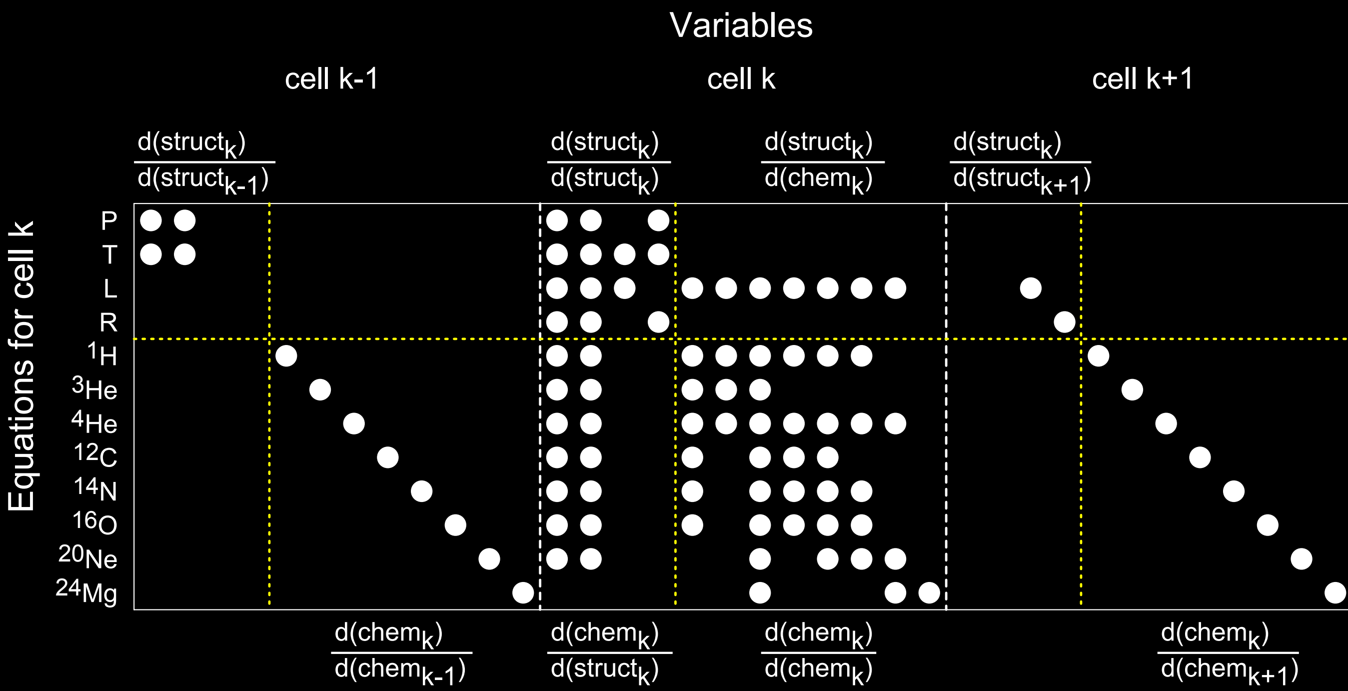
Planets too.

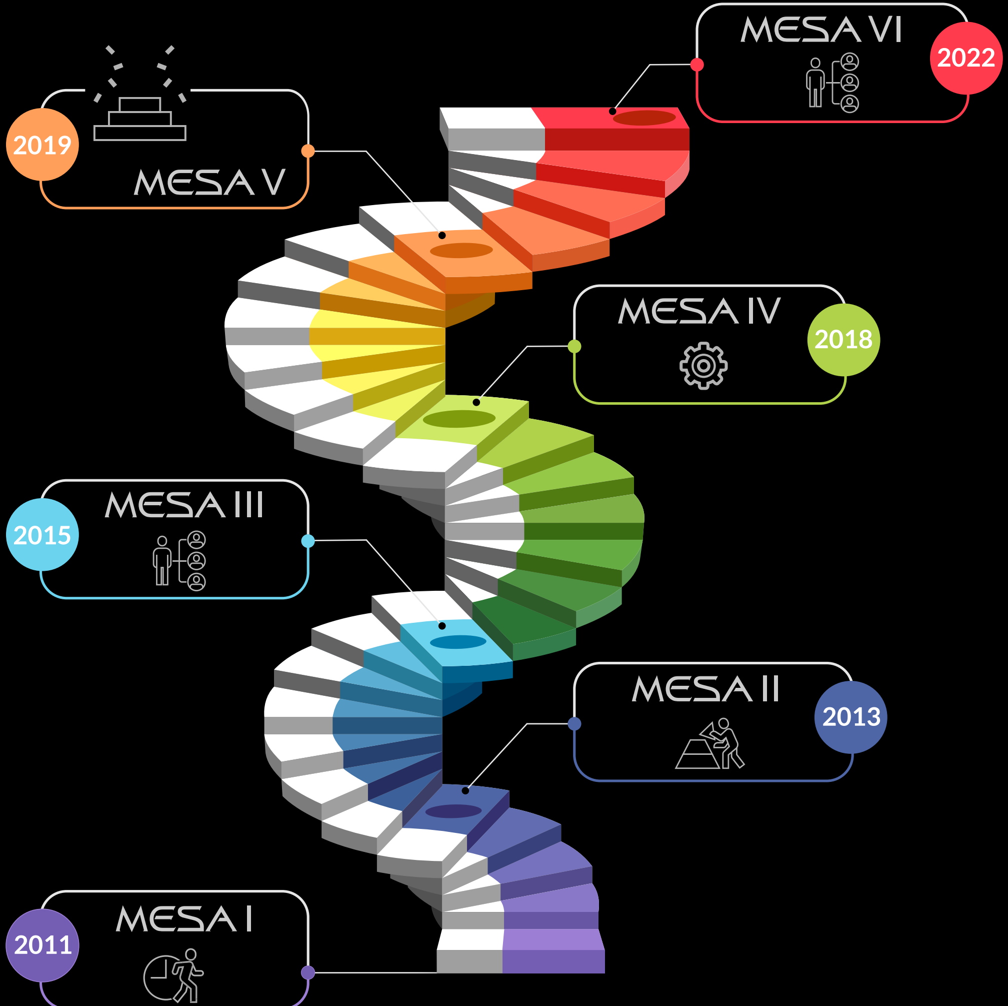
Explosions.

Pulsations.

And much more!

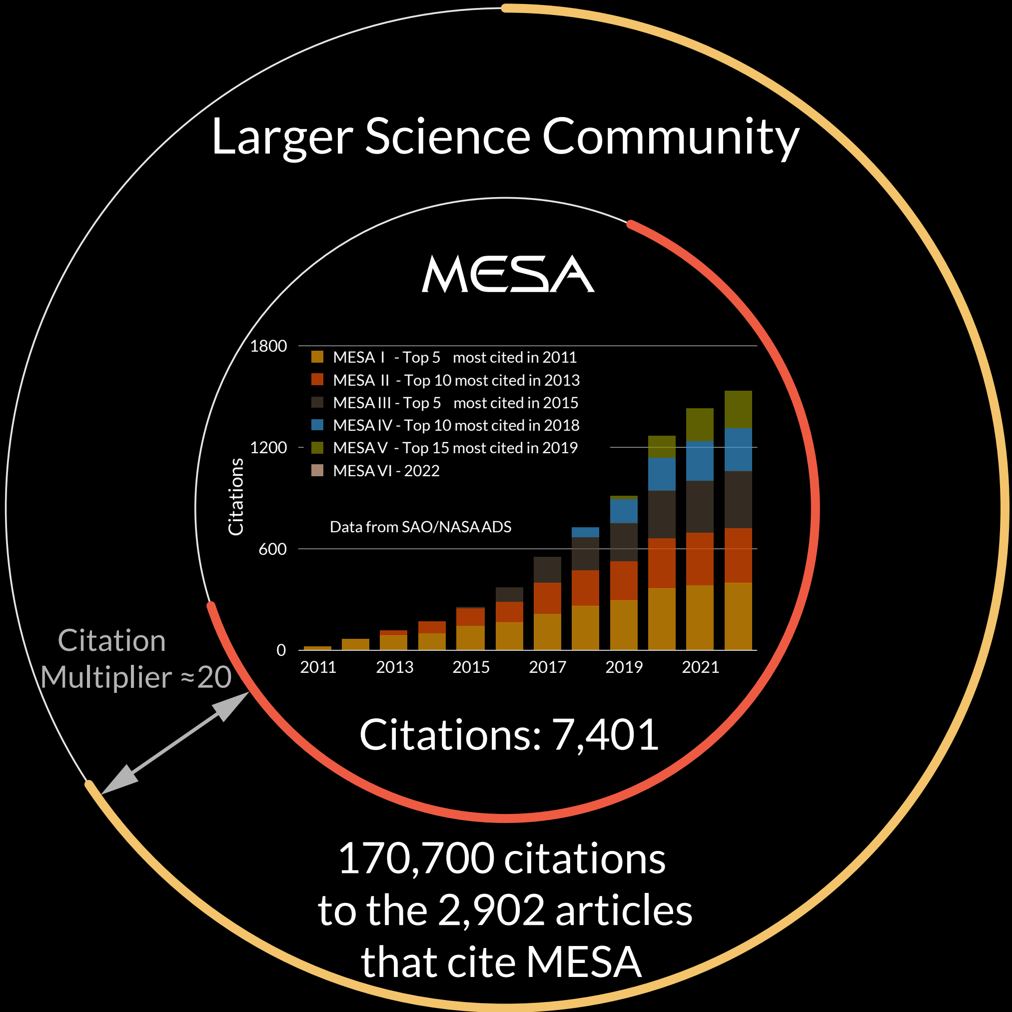
The MESA source code is a set of modules that can be used by others, or combined to solve the coupled equations of 1D stellar evolution with an implicit finite volume scheme.

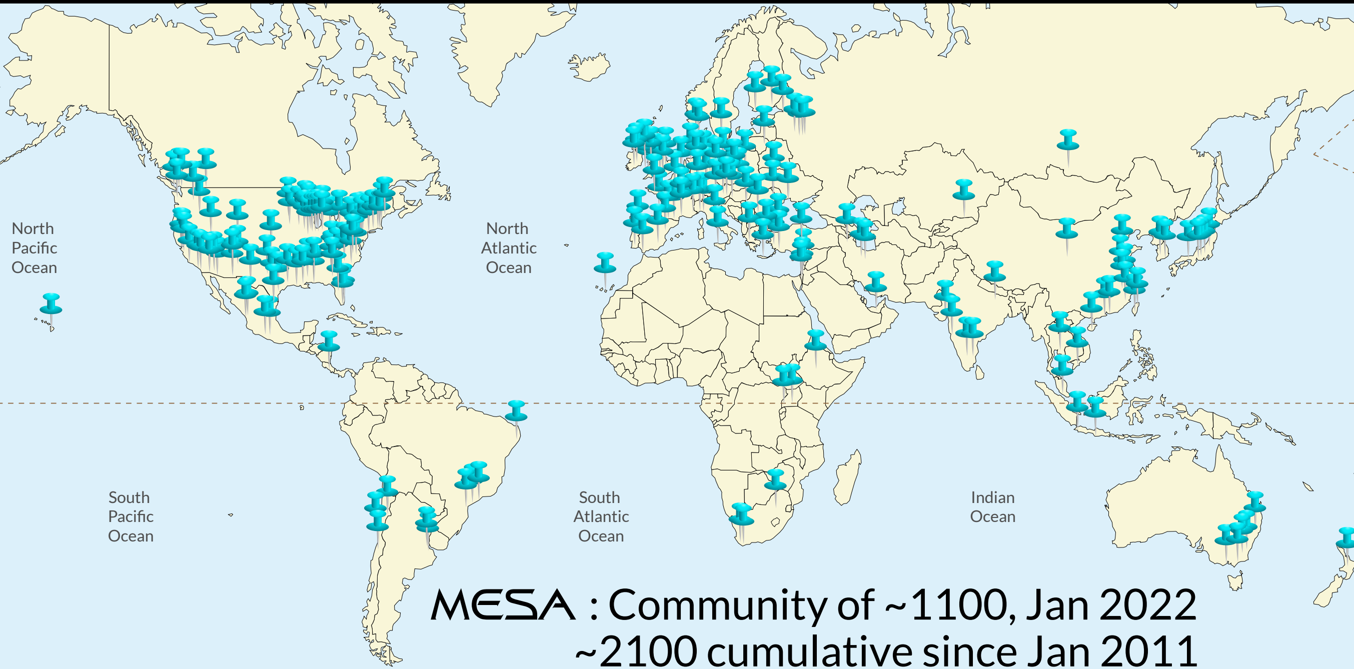




MESA VI
2022
MESA V
2019
MESA IV
2018
MESA III
2015
MESA II
2013
MESA I
2011

Innovation!

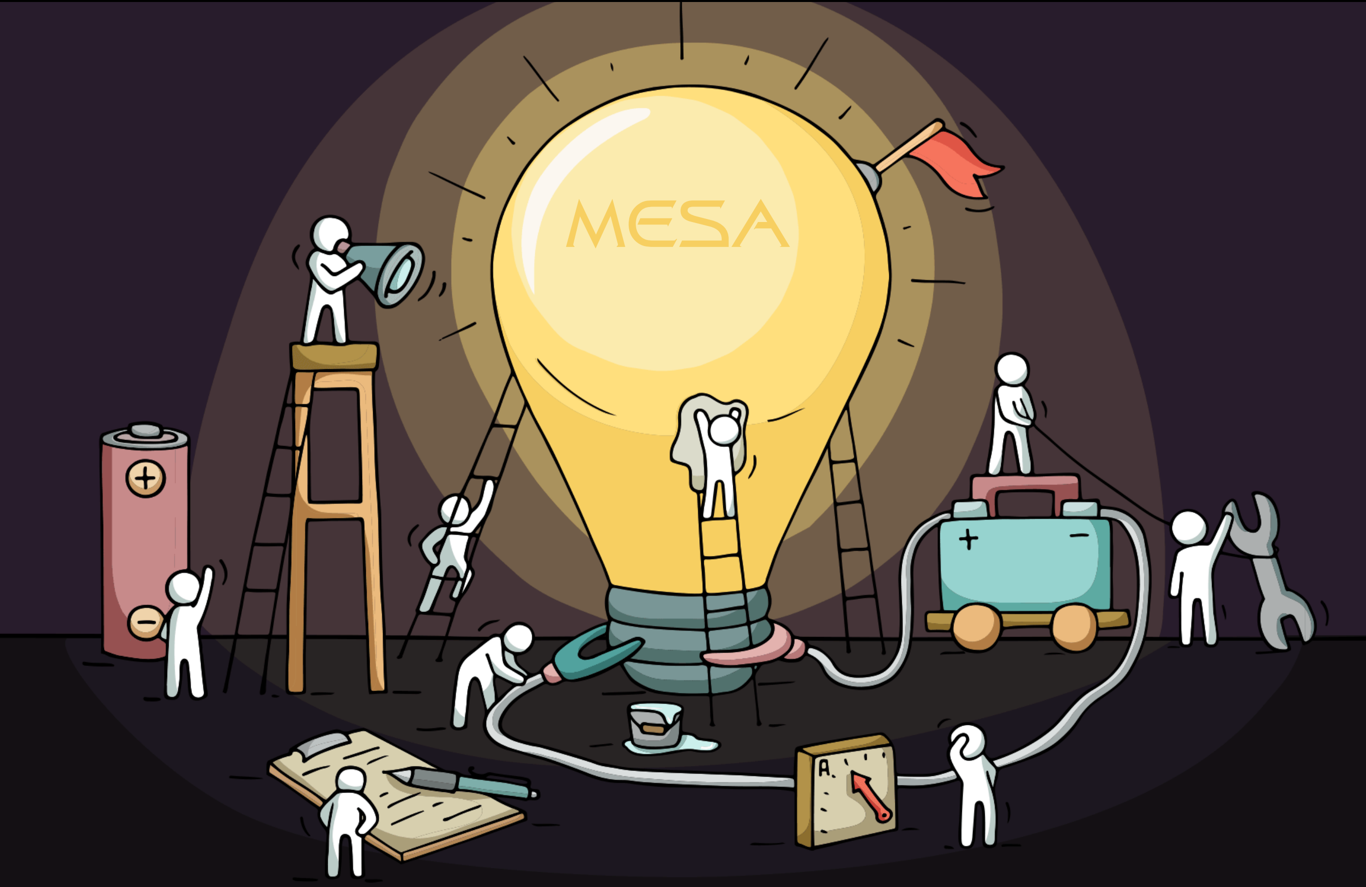

Larger Science Community
MESA
1800
1200
600
0
Citations
MESA I - Top 5 most cited in 2011
MESA II - Top 10 most cited in 2013
MESA III - Top 5 most cited in 2015
MESA IV - Top 10 most cited in 2018
MESA V - Top 15 most cited in 2019
MESA VI - 2022
Data from SAO/NASA ADS
2011
2013
2015
2017
2019
2021
Citations: 7,401
Citation
Multiplier ≈20
170,700 citations
to the 2,902 articles
that cite MESA



MESA : Community of ~1100, Jan 2022
~2100 cumulative since Jan 2011

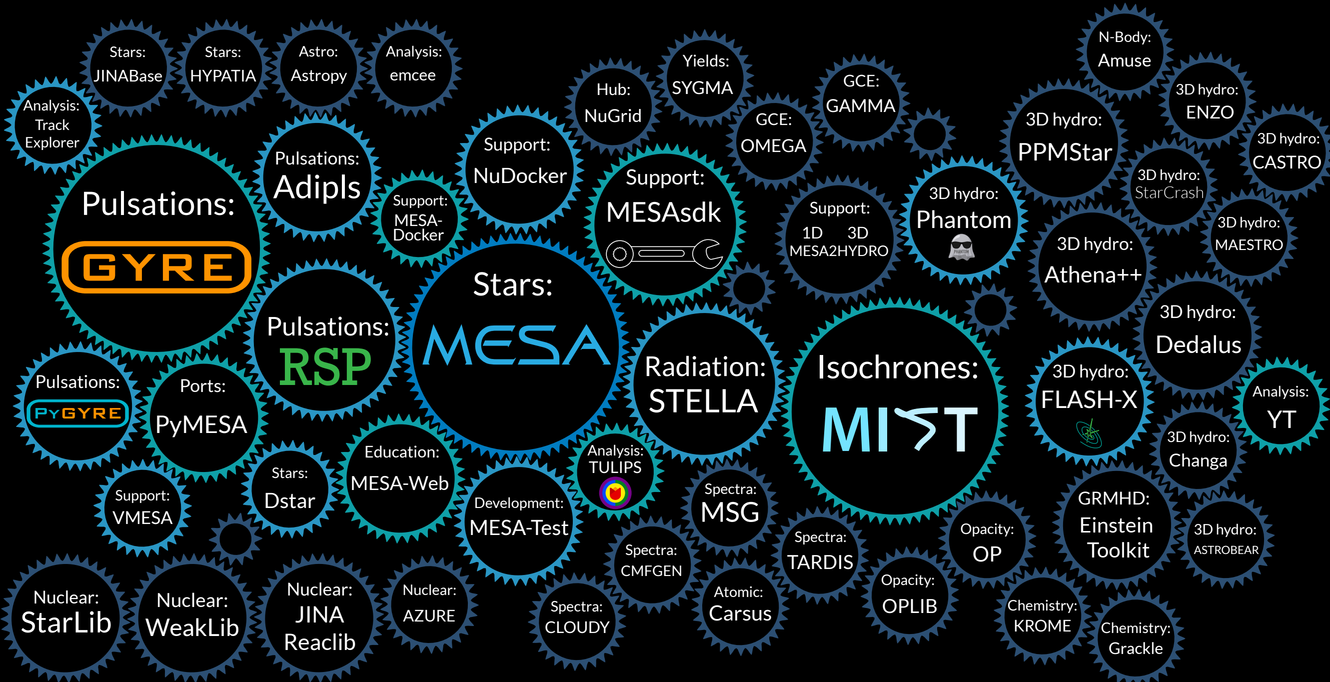
MESA has a dominant share of the available market.

A thriving open-knowledge software project takes a village.



Telescopes

Gaia LVK SDSS HST JWST VRO ASAS-SN TESS ZTF LCO COSI NuSTAR SK-Gd



NSCL FRIB CASPAR SECAR St. George NIF Z-Pinch Diamond Anvil

Laboratory Astrophysics


PRESENT
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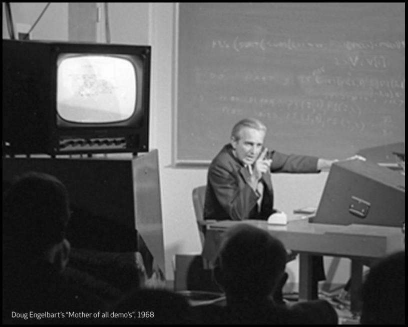
Mother of All Demos

December 8, 1968

"The 90-minute presentation demonstrated almost all the fundamental elements of modern personal computing: windows, hypertext, graphics, efficient navigation and command input, video conferencing, the computer mouse, word processing, dynamic file linking, revision control, and a collaborative real-time editor."



Doug Engelbart

Bill Paxton

After a PhD in computer science at Stanford and a stint at Xerox Palo Alto Research Center, Bill became one of Adobe’s creators in 1983.

Bill helped invent scalable font technology.

The public facing part of this invention was Postscript, which evolved into today’s PDF.

Bill retired from Adobe in 1990.

“Hello, my name is Bill Paxton. May I please use the tools posted on your website?”
January 8, 2005

Bill was MESA’s First Author and a
Senior Fellow in Computational Astrophysics
at the KITP, UC Santa Barbara.

Recognizing Opportunity

In 2010 stellar evolution software instruments were usually closed source, closed knowledge, secret handshake, and concentrated in ~10 locations around the world.

Yet stellar astronomy was (and still is!) booming with new telescopes, missions, puzzles, and science. There was a large pent-up demand for new stellar models.

In 2010 MESA as an instrument was ready for release, but we pulled back to plan for the possibility of MESA being a success via democratizing stellar evolution.

APPENDIX A

Paxton et al, ApJS, 193, 3, 2011

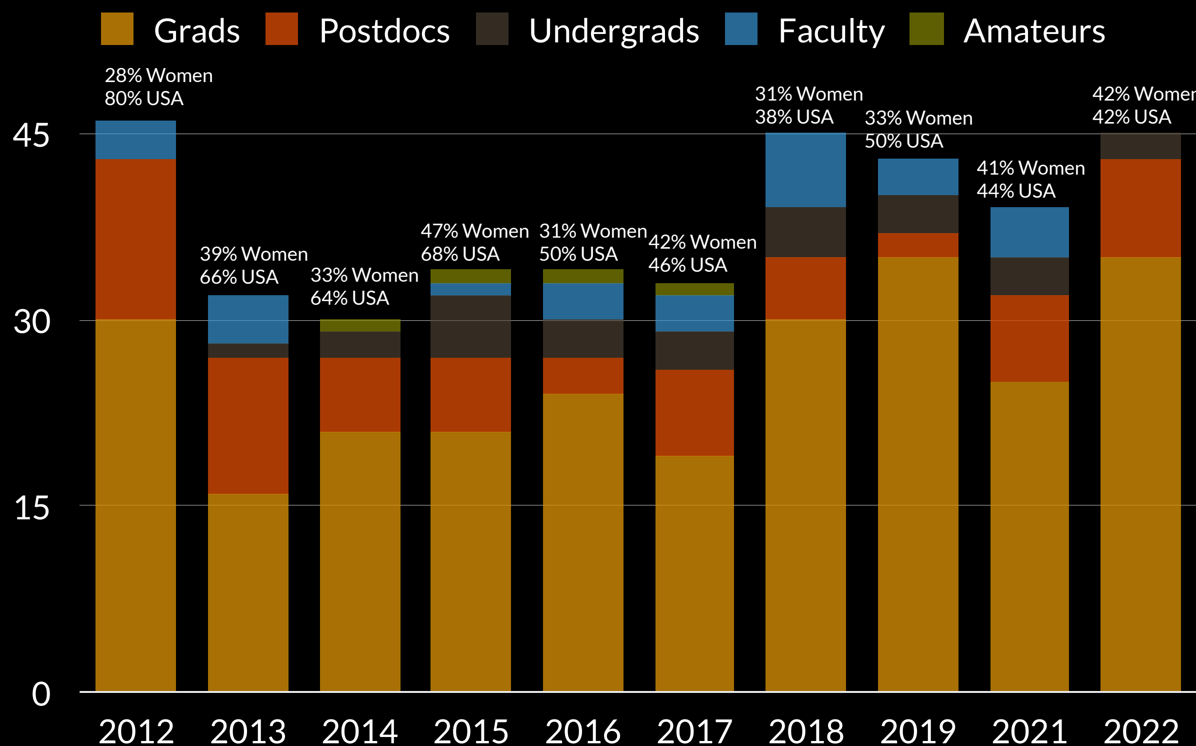
MANIFESTO

MESA was developed through the concerted efforts of the lead author over a six year period with the engagement and deep involvement of many theoretical and computational astrophysicists. The public availability of MESA will serve education, scientific research, and outreach. This appendix describes the scientific motivation for MESA, the philosophy and rules of use for MESA, and the path forward on stewardship of MESA, and advanced development of future research and education tools. We make MESA openly available with the hope that it will grow into a community resource. We therefore consider it important to explain the guiding principles for using and contributing to MESA. Our goal is to assure the greatest usefulness for the largest number of research and educational projects.

Building Our Next Generation

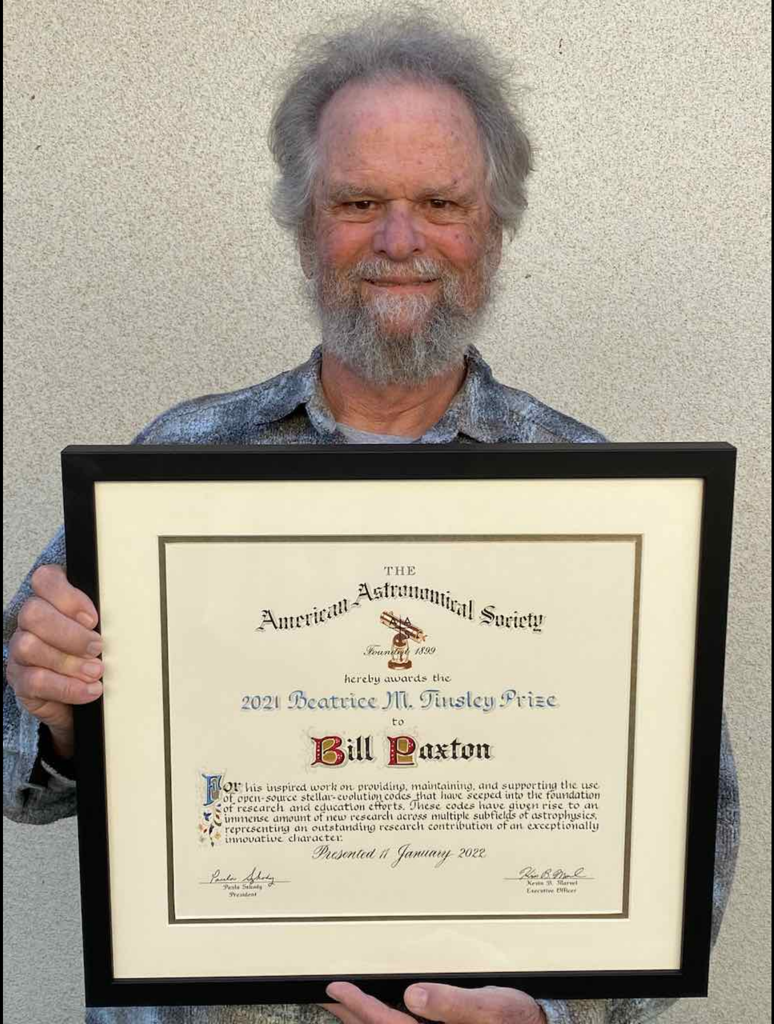
The annual MESA Summer School offered a week of hands-on labs to gain familiarity with MESA and learn how to make better use of MESA in their own research.

The cadre of instructors, TAs and participants (now 500+) are creating their own MESA infrastructures at 80+ institutions around the world.



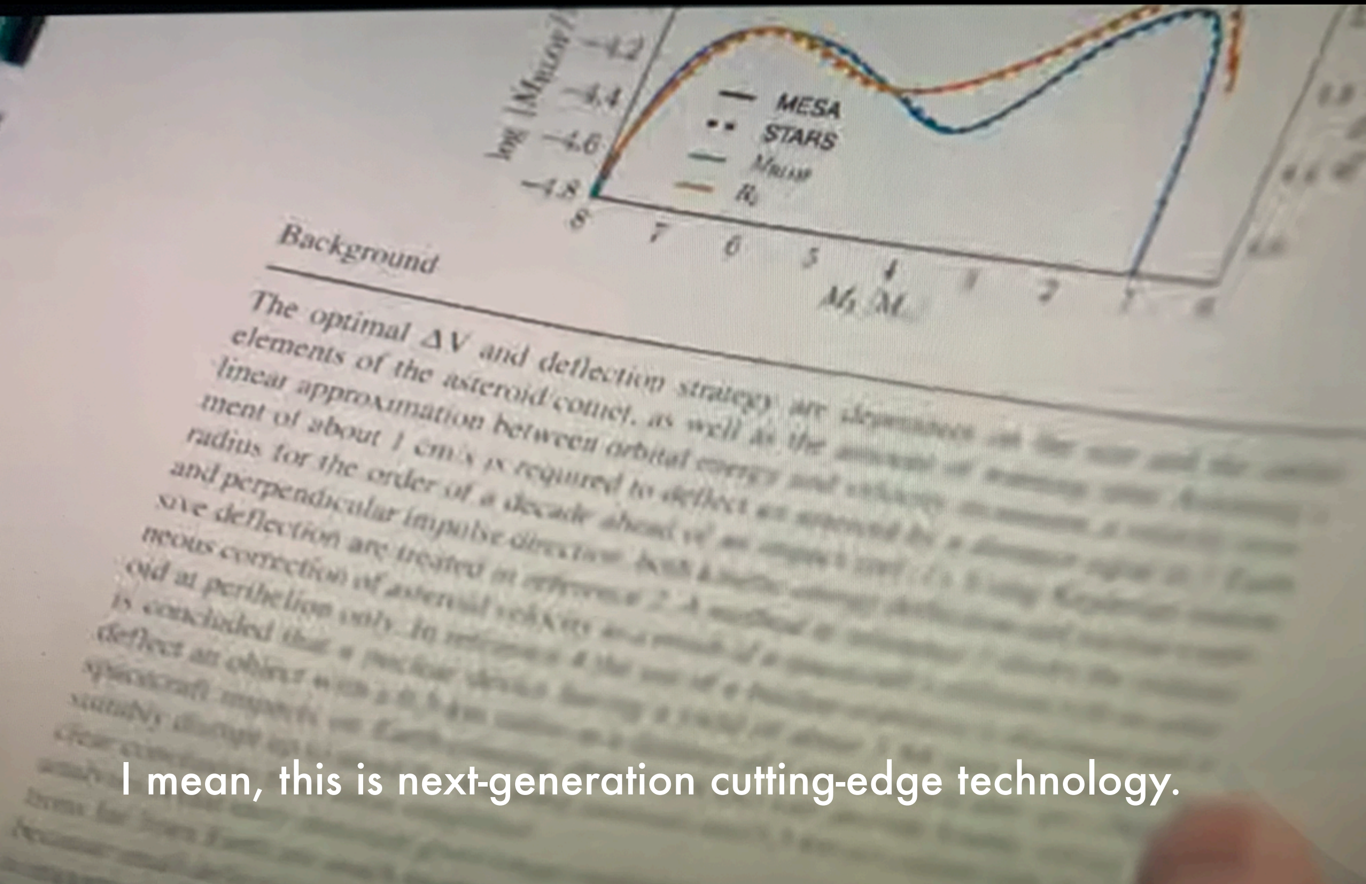

GRYFFINDOR
BAYLOR

Bill was awarded the 2021 Beatrice M. Tinsley Prize "for his inspired work ... that has seeped into the foundation of research and education ..."



MESA appears in the movie "Don't Look Up"!

Randall: I'm as concerned and enraged as you, but they've got Gary Talcamont out of Stanford and Lisa Inez from Princeton on their team. I mean, this is next-generation cutting-edge technology.



We thank Amy Mainzer for Figure 4 of MESA III making an appearance in the movie, first noted by Jared Goldberg on his Twitter feed.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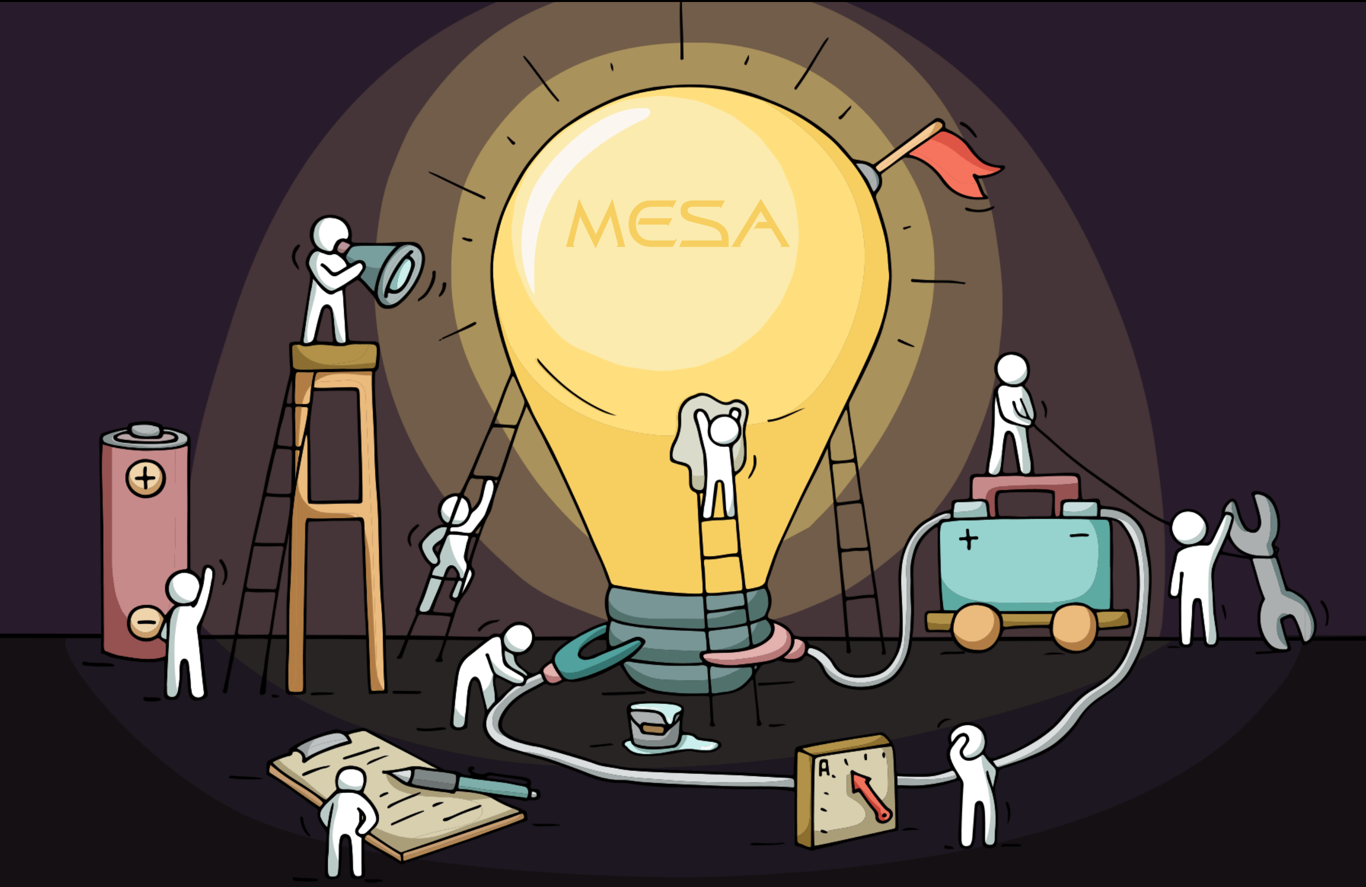
PAST

A thriving open-knowledge software project takes a village.




Eoin Farrell


Adam Jermyn

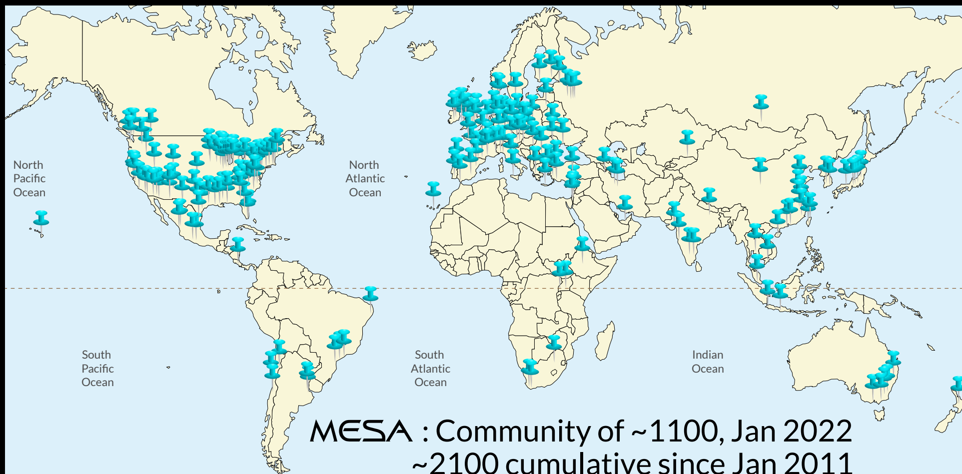

Meridith Joyce


Evan Bauer


Earl Bellinger


Anne Thoul


Radek Smolec




Bill Wolf


Rob Farmer

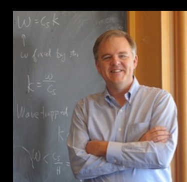

Pablo Marchant


Warrick Ball


Aaron Dotter

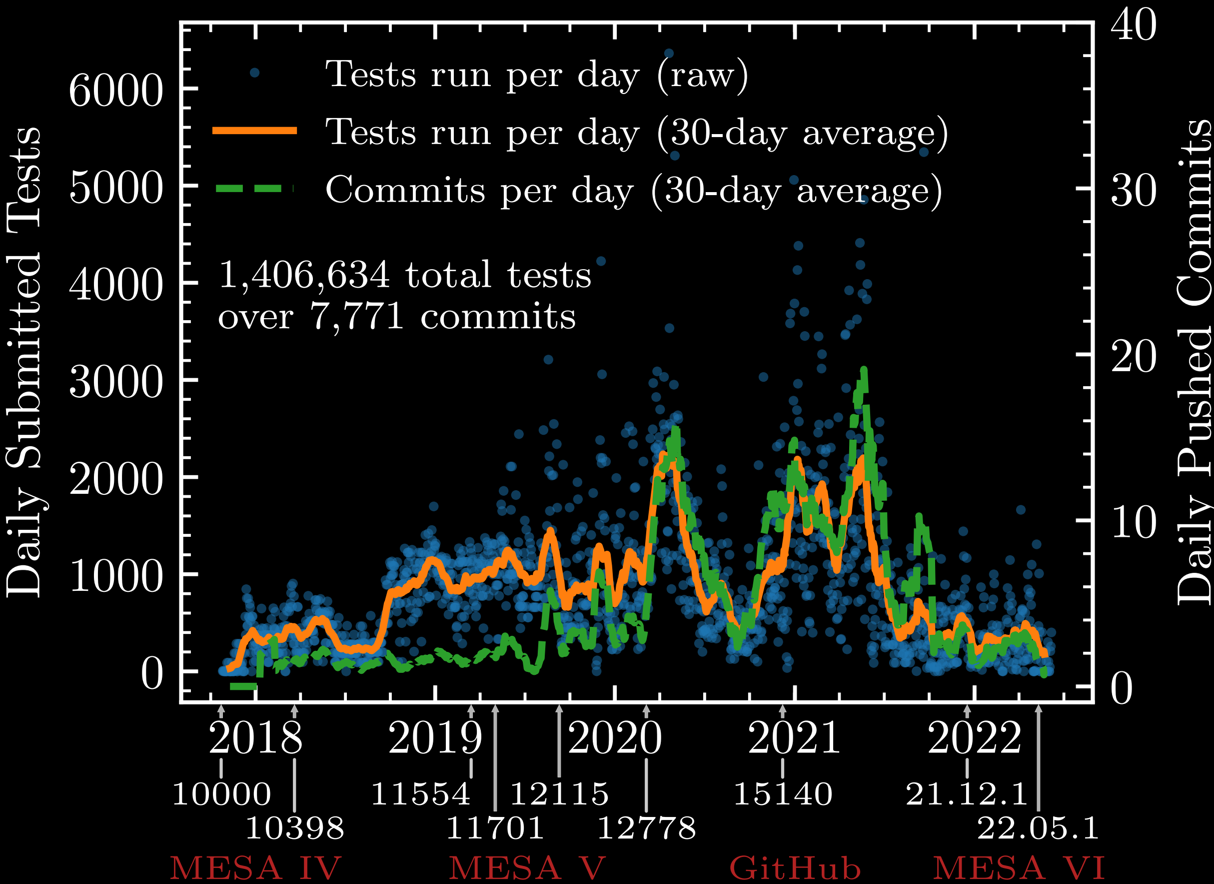

Rich Townsend


Frank Timmes


Lars Bildsten


Matteo Cantiello

Test Often



Tests run per day (raw)
Tests run per day (30-day average)
Commits per day (30-day average)
1,406,634 total tests
over 7,771 commits
Daily Submitted Tests
Daily Pushed Commits
0
1000
2000
3000
4000
5000
6000
0
10
20
30
40
2018
2019
2020
2021
2022
10000
10398
11554
11701
12115
12778
15140
21.12.1
22.05.1
MESA IV
MESA V
GitHub
MESA VI

Make MESA Easy To Use

We provide a Software Development Kit to build MESA across a variety of Unix-based platforms.

We provide OS-level virtualizations to able to run on any architecture, and run older versions of MESA with age-appropriate compilers, libraries, and operating system.

Get MESA in the classroom

MESA-Web is a cloud resource for education and research that has served ~10,000 stellar and planetary models to ~1,000 learners at ~40 institutions in 5 years of operation.

Started at ASU!

Active support of, and by, the Community

Over 25,000 archived and searchable posts on community discussions of MESA.

A Zenodo-backed portal for the community to share and build provenance with over 500 tools, MESA files , and lectures.

Direct support of graduate students and postdocs.

SESE graduate student Morgan Chidester is using MESA to explore white dwarf seismology.

THE ASTROPHYSICAL JOURNAL, 935:21 (10pp), 2022 August 10 https://doi.org/10.3847/1538-4357/ac7ec3

CrossMark

On Trapped Modes in Variable White Dwarfs as Probes of the $^{12}C(\alpha, \gamma)^{16}O$ Reaction Rate

Morgan T. Chidester[1,2], Ebraheem Farag[1,2], and F. X. Timmes[1,2]
[1] School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA; taylormorgan32@gmail.com
[2] Joint Institute for Nuclear Astrophysics—Center for the Evolution of the Elements, USA
Received 2022 April 21; revised 2022 June 28; accepted 2022 June 28; published 2022 August 9

Abstract

We seek signatures of the current experimental $^{12}C\ (\alpha, \gamma)^{16}O$ reaction rate probability distribution function in the pulsation periods of carbon–oxygen white dwarf (WD) models. We find that adiabatic g-modes trapped by the interior carbon-rich layer offer potentially useful signatures of this reaction rate probability distribution function. Probing the carbon-rich region is relevant because it forms during the evolution of low-mass stars under radiative helium-burning conditions, mitigating the impact of convective mixing processes. We make direct quantitative connections between the pulsation periods of the identified trapped g-modes in variable WD models and the current experimental $^{12}C\ (\alpha, \gamma)^{16}O$ reaction rate probability distribution function. We find an average spread in relative period shifts of $\Delta P/P \simeq \pm 2\%$ for the identified trapped g-modes over the $\pm 3\sigma$ uncertainty in the $^{12}C\ (\alpha, \gamma)^{16}O$ reaction rate probability distribution function—across the effective temperature range of observed DAV and DBV WDs and for different WD masses, helium shell masses, and hydrogen shell masses. The g-mode pulsation periods of observed WDs are typically given to six to seven significant figures of precision. This suggests that an astrophysical constraint on the $^{12}C\ (\alpha, \gamma)^{16}O$ reaction rate could, in principle, be extractable from the period spectrum of observed variable WDs.

Unified Astronomy Thesaurus concepts: White dwarf stars (1799); Asteroseismology (73); Stellar physics (1621); Nuclear astrophysics (1129)

SESE graduate student Eb Farag is using MESA to explore neutrino emission and black holes from stars.

The Astrophysical Journal, 937:112 (16pp), 2022 October 1 https://doi.org/10.3847/1538-4357/ac8b83

Resolving the Peak of the Black Hole Mass Spectrum

Ebraheem Farag[1,2], Mathieu Renzo[3], Robert Farmer[4], Morgan T. Chidester[1,2], and F. X. Timmes[1,2]
[1] School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA; ekfarag@asu.edu
[2] Joint Institute for Nuclear Astrophysics—Center for the Evolution of the Elements, USA
[3] Center for Computational Astrophysics, Flatiron Institute, New York, NY 10010, USA
[4] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Straße 1, D-85741 Garching, Germany
Received 2022 June 27; revised 2022 August 15; accepted 2022 August 18; published 2022 October 4

Abstract

Gravitational-wave (GW) detections of binary black hole (BH) mergers have begun to sample the cosmic BH mass distribution. The evolution of single stellar cores predicts a gap in the BH mass distribution due to pair-instability supernovae (PISNe). Determining the upper and lower edges of the BH mass gap can be useful for interpreting GW detections of merging BHs. We use MESA to evolve single, nonrotating, massive helium cores with a metallicity of $Z = 10^{-5}$, until they either collapse to form a BH or explode as a PISN, without leaving a compact remnant. We calculate the boundaries of the lower BH mass gap for S-factors in the range S(300 keV) = (77,203) keV b, corresponding to the $\pm 3\sigma$ uncertainty in our high-resolution tabulated $^{12}C(\alpha,\gamma)^{16}O$ reaction rate probability distribution function. We extensively test temporal and spatial resolutions for resolving the theoretical peak of the BH mass spectrum across the BH mass gap. We explore the convergence with respect to convective mixing and nuclear burning, finding that significant time resolution is needed to achieve convergence. We also test adopting a minimum diffusion coefficient to help lower-resolution models reach convergence. We establish a new lower edge of the upper mass gap as $M_{\rm lower} \simeq 60^{+32}_{-14}\ M_\odot$ from the $\pm 3\sigma$ uncertainty in the $^{12}C(\alpha, \gamma)^{16}O$ rate. We explore the effect of a larger 3α rate on the lower edge of the upper mass gap, finding $M_{\rm lower} \simeq 69^{+34}_{-18}\ M_\odot$. We compare our results with BHs reported in the Gravitational-Wave Transient Catalog.

Unified Astronomy Thesaurus concepts: Gravitational waves (678); Black holes (162); Nuclear astrophysics (1129); Stellar physics (1621); Core-collapse supernovae (304)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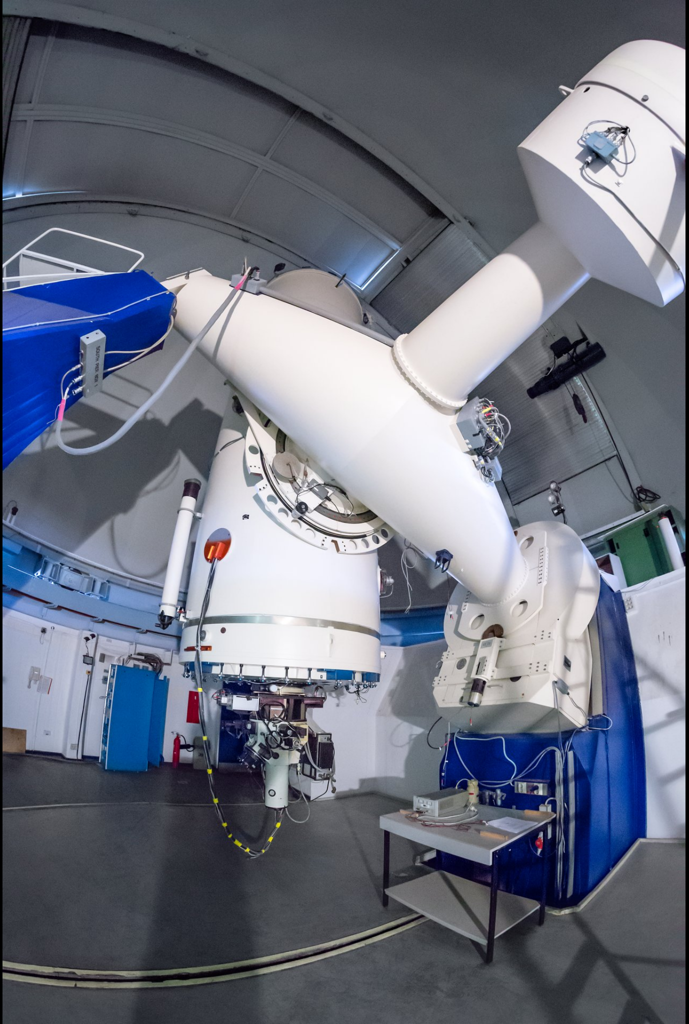
MESA is not a start-up anymore.



ESO 1.52-meter @ La Silla, a ~40 year run.

Departure of talent.

Funding cycle re-inventions

2011	$0 - Failure[1]
2013	$500K for 3 years from NSF[2]
2017	$3M for 4 years from NSF[3]
2019	$35K from Ford/Sloan
2022	TBD

[1]Lesson: Market community rather than source code.

[2]Lesson: Quantify and brand all aspects of the project.

[3]Lesson: Build an ecosystem.

New directions will be motivated by features useful to the MESA user community, advances in the physics modules, algorithmic developments, and architectural evolution.

Stars are great.