

A FIRST TASTE OF MESA

★ Created by: Lieke van Son, Aleksandra Olejak, and Shelley Cheng ★

Meet the MESA-hack Organizers



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**(massive) stars
are awesome**

Massive (Binary) Stars

TRANSIENT
FORMATION

gravitational
waves

supernovae

Luminous
red Novae

CHEMICAL
ENRICHMENT

complex
molecules

metallicity

reionization

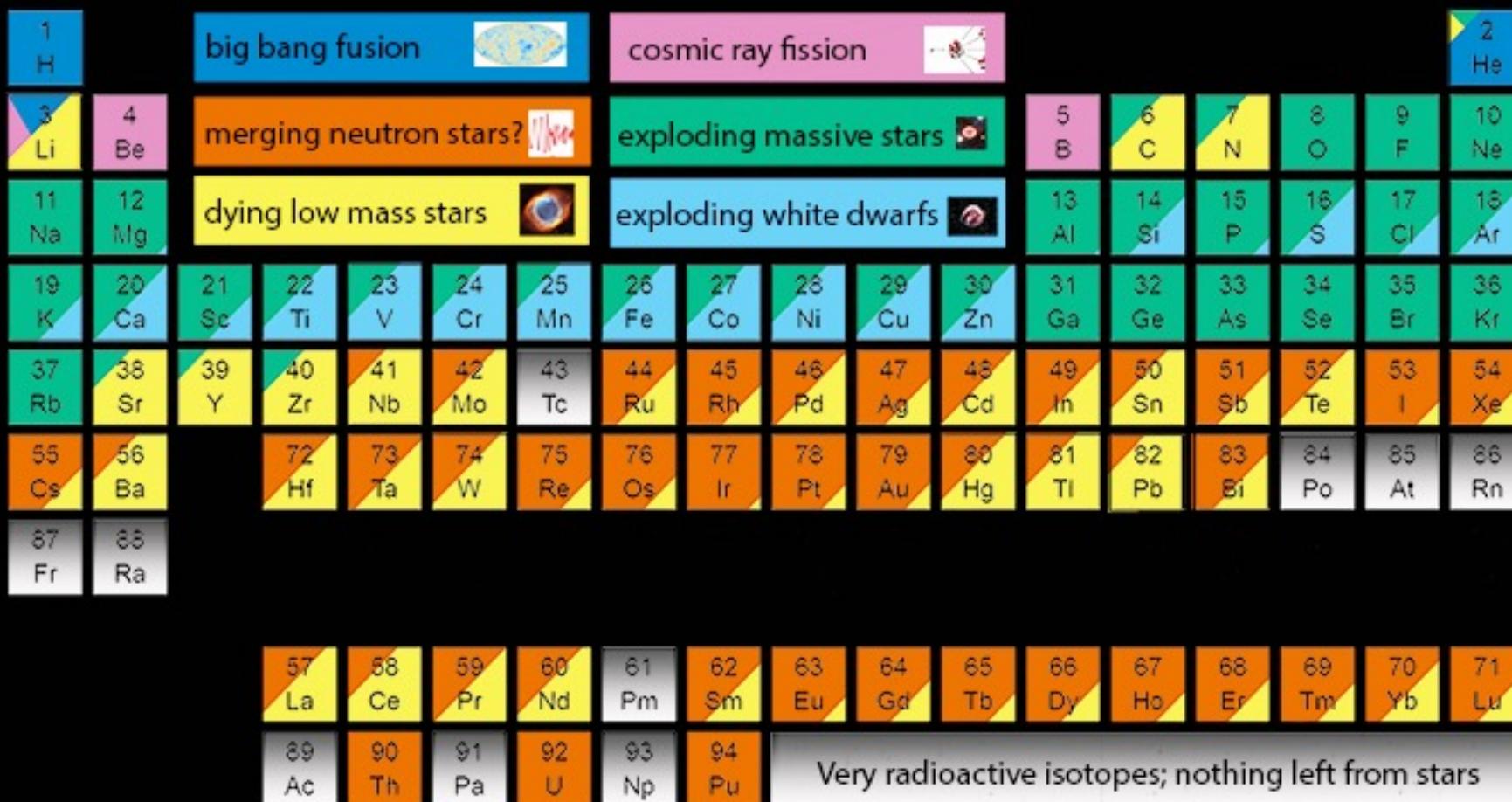
IONIZING
RADIATION

COMPACT
OBJECTS

NS & condensed
matter

black
holes

The Origin of the Solar System Elements



Graphic created by Jennifer Johnson
<http://www.astronomy.ohio-state.edu/~jaj/nucleo/>

Astronomical Image Credits:
ESA/NASA/AASNova

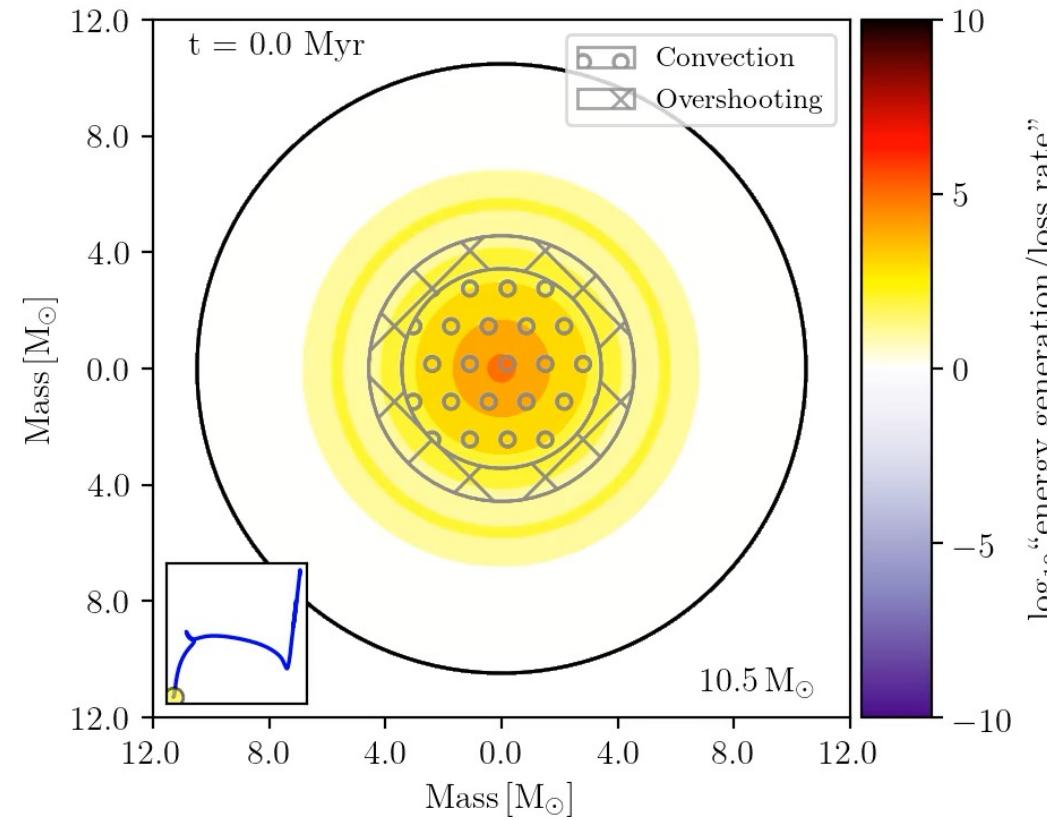
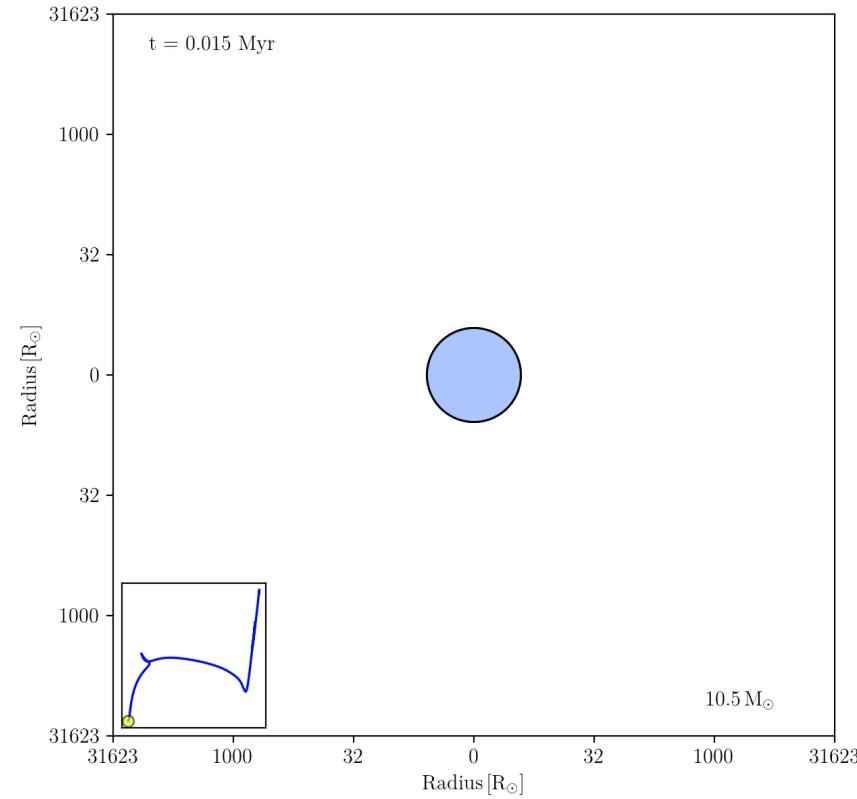
The challenge: Massive binary stars are complicated

Uncertain: wind mass loss, size of the core, nuclear reaction rates, formation of convective regions, mass transfer stability, mass transfer efficiency, common envelopes, birth metallicity, angular momentum transport within the star, birth spin, remnant-mass function, supernova birth kick, tidal interactions, luminous blue variable mass loss, etc..



What is MESA?

Modules for Experiments in Stellar Astrophysics



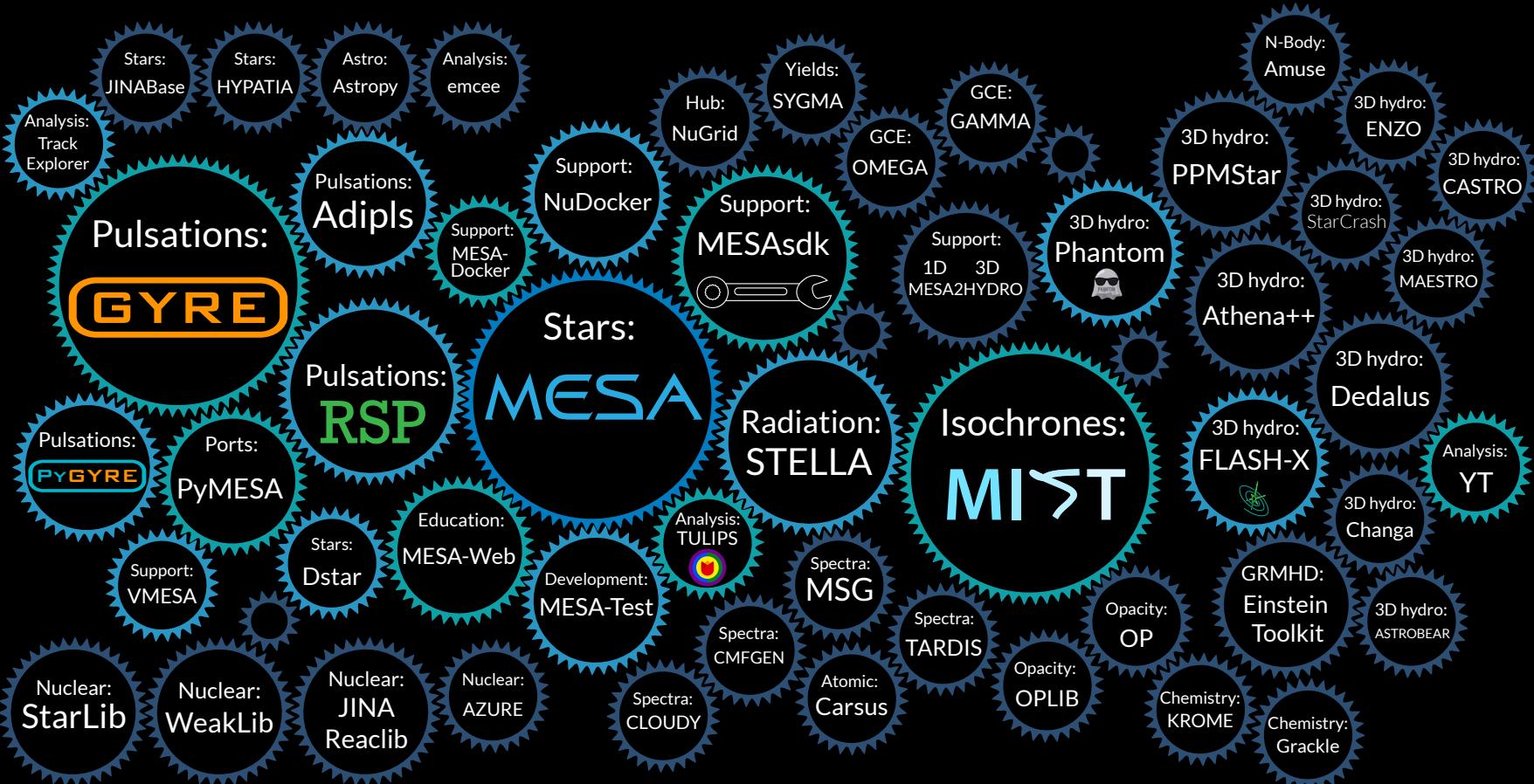
Made using TULIPS Laplace et al. (2021)

MESA == Table mountain



Telescopes

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



NSCL

FRI^B

CASPAR

SECAR

St. George

NIF

Z-Pinch

Diamond Anvil

Laboratory Astrophysics

Slide by Frank Timmes

Solving the stellar structure equations

1) Hydrostatic equilibrium

$$\frac{\partial P}{\partial M_r} = -\frac{GM_r}{4\pi r^4} - \frac{1}{4\pi r^2} \frac{\partial^2 r}{\partial t^2},$$

3) Radiative transport

$$\frac{\partial T}{\partial M_r} = -\frac{3\kappa L_r}{64\pi^2 acT^3 r^4},$$

2) Mass conservation

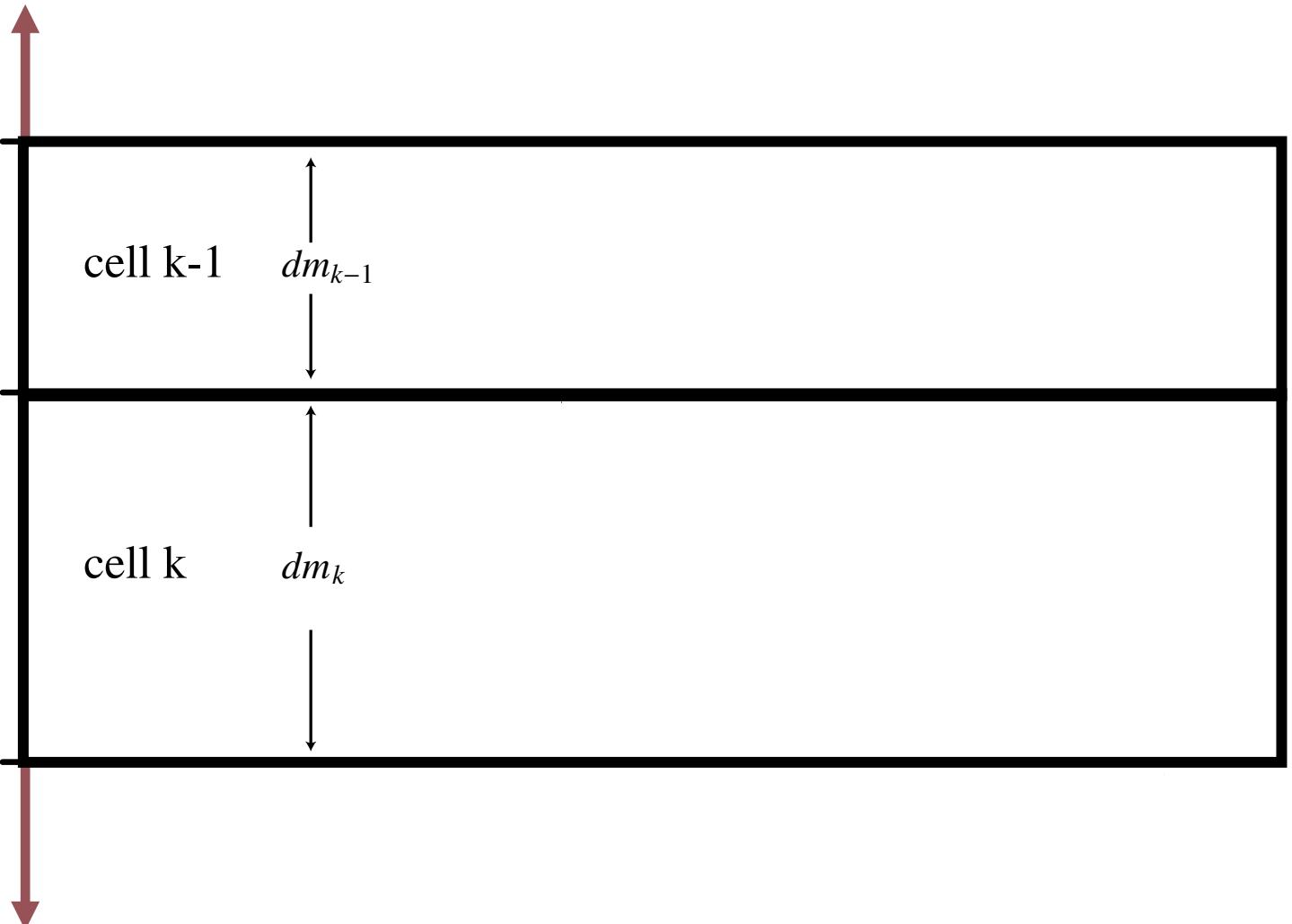
$$\frac{\partial r}{\partial M_r} = \frac{1}{4\pi r^2 \rho},$$

4) Thermal equilibrium

$$\frac{\partial L_r}{\partial M_r} = \epsilon - T \frac{\partial S}{\partial t}.$$

**Structure
divided into
cells
(spherically
symmetric)**

Surface of the star



Center of the star

Five instrument papers to date

1. **Modules for Experiments in Stellar Astrophysics (MESA)**

Paxton, Bill; Bildsten, Lars; Dotter, Aaron et al. (2011) ApJS..192....3P

2. **~(MESA) Planets, Oscillations, Rotation, and Massive Stars**

Paxton, Bill; Cantiello, Matteo; Arras, Phil et al. (2013) ApJS..208....4P

3. **~(MESA): Binaries, Pulsations, and Explosions**

Paxton, Bill; Marchant, Pablo; Schwab, Josiah et al. (2015) ApJS..220...15P

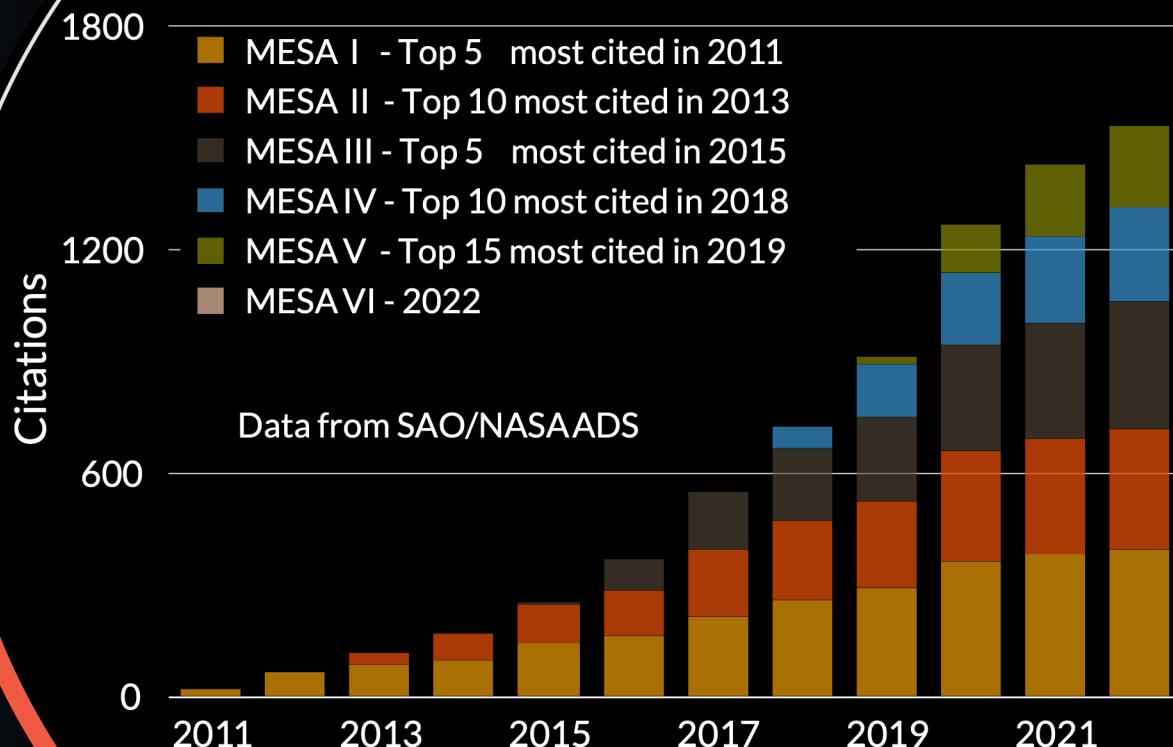
4. **~(MESA): Convective Boundaries, Element Diffusion, and Massive Star Explosions**

Paxton, Bill; Schwab, Josiah; Bauer, Evan B. (2018) ApJS..234...34P

5. **~(MESA): Pulsating Variable Stars, Rotation, Convective Boundaries, and Energy Conservation**

Paxton, Bill; Smolec, R.; Schwab, Josiah (2019) ApJS..243...10P

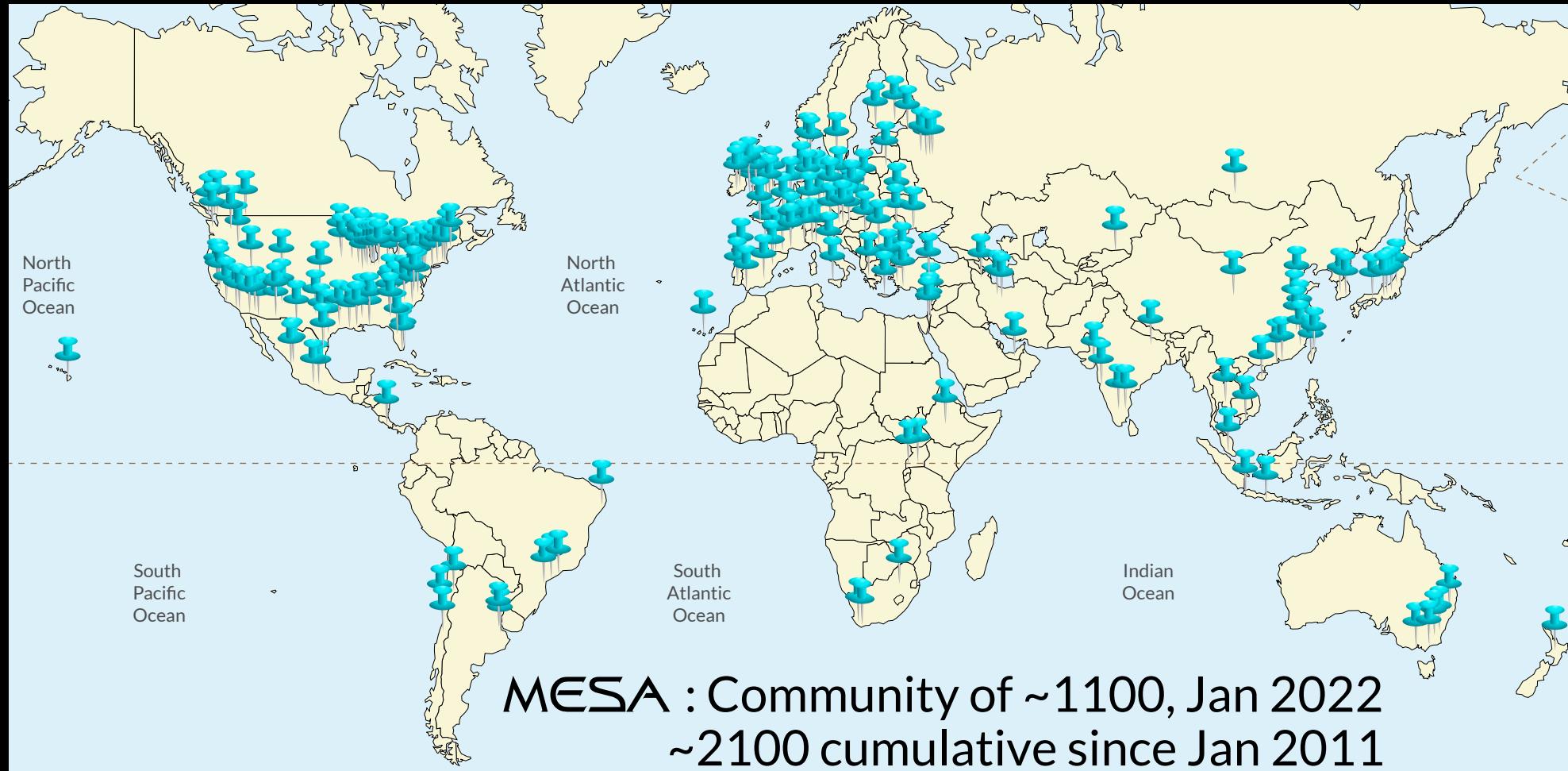
MESA



Citations: 7,401

Slide by Frank Timmes
VAST 18Jan202

The MESA community



MESA = open source

Useful links

https://cococubed.com/rsa/mesa_market/

.php?ref=mesasdk

1/star/defaults/*.list ; *.defaults

.1/

s.html

APPENDIX A 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.

Annual MESA summer school!

To dive deeper into the subject!

**More than 10 year of MESA Summer School lectures & labs
(including solutions):**

https://cococubed.com/mesa_market/education.html



MESA Summer School at Konkoly
2023



2024

MESA Down Under School

17th-21st of June 2024 at University of Sydney



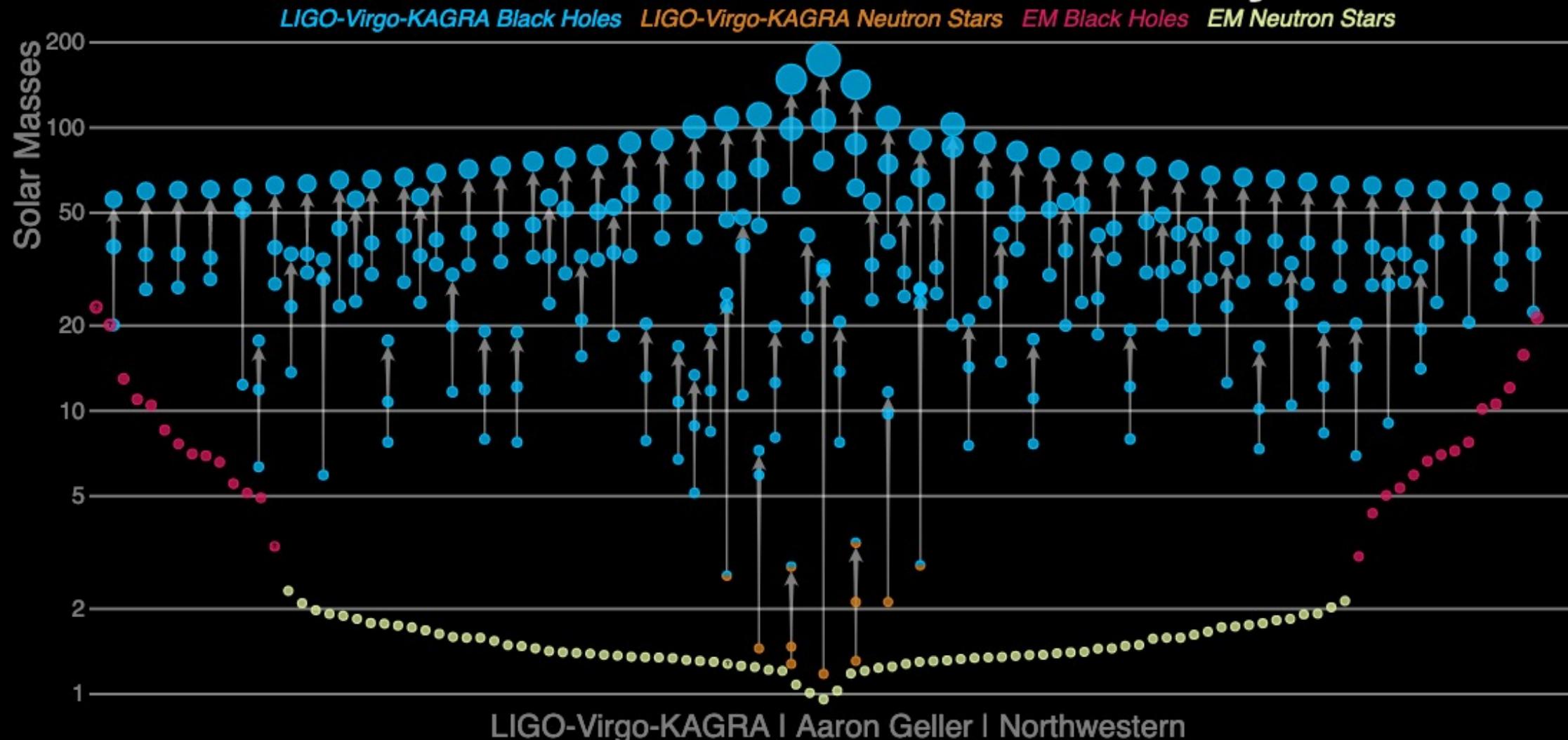
This Hackathon:

Rotating stars and black holes

This MESA hackathon

MESA hack	Sunday 4th August	Monday 5th August
9:00-10:00		Part 2.0 continued
10:00-10:30	Welcome/Guidelines/intro/Icebreaker	Birth rotation
10:30-11:00	Tea Break	Birth rotation
11:00-11:30	Lecture: Introduction to MESA	Tea Break
11:30-12:00	Getting started / Running MESA	AM transport
12:00-13:00	Running MESA	AM transport
13:00-14:00	Lunch	Lunch
14:00-15:00	MESA output	Winds
15:00-15:30	MESA output	Winds
15:30-16:00	Tea Break	Tea Break
16:00-17:00	Start on part 2.0	Final proj. / begin preparing presentations
17:00-18:00	Team updates and questions	Final Presentations

Masses in the Stellar Graveyard



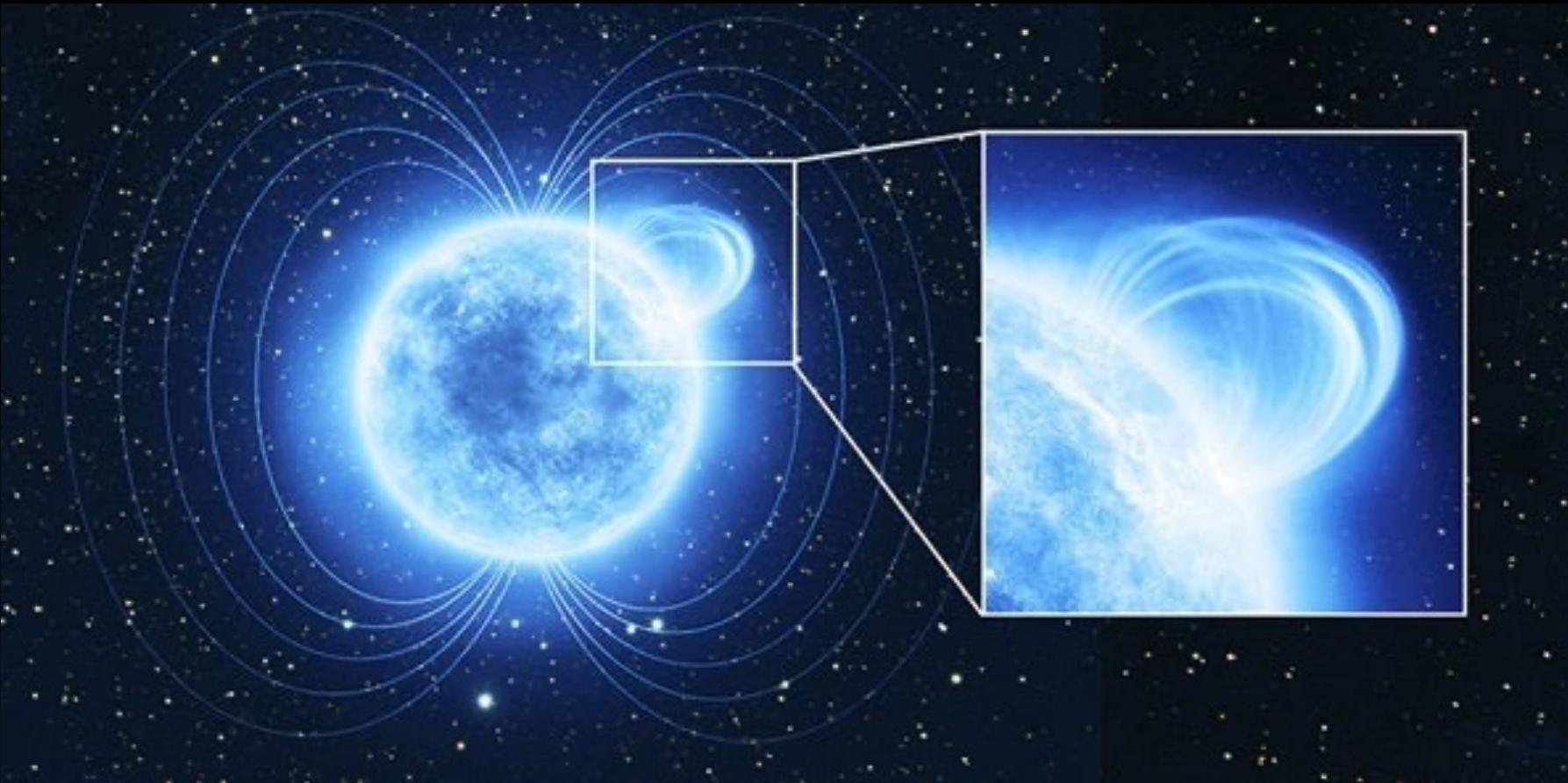


Birth rotation



Protostar forming in L1527
JWST NIR Cam

Magnetic fields



Magnetic loop on magnetar SGR 0418. // ESA

Stellar Winds

The 'bubble nebula'
Credit: NASA, Hubble Space Telescope



Rotating stars and black holes



Questions?

Getting started

go to:

<https://liekevanson.github.io/IAUhackathon/home.html>