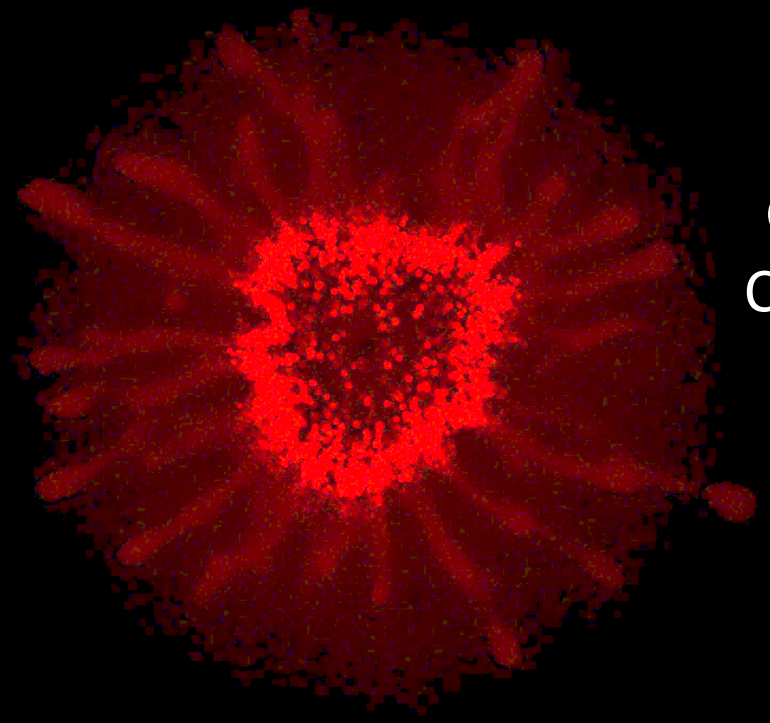
Asymmetric Supernovae and the Elements They Create



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SESE Colloquium
March 3, 2021

ASU School of Earth & Space Exploration
ARIZONA STATE UNIVERSITY

Los Alamos NATIONAL LABORATORY
EST. 1943

Talk Outline

1. Introduction to core-collapse supernovae (and motivation)
2. Our work on asymmetric supernova simulations
3. Explanation of our models
4. Preliminary results and visualizations
5. Wrap up and summary

Stellar Evolution and Mass

- Mass is the most important factor in stellar evolution

- Affects all of these:
  - Temperature
  - Absolute brightness
  - Color
  - Lifetime
  - Radius
  - **Fate**

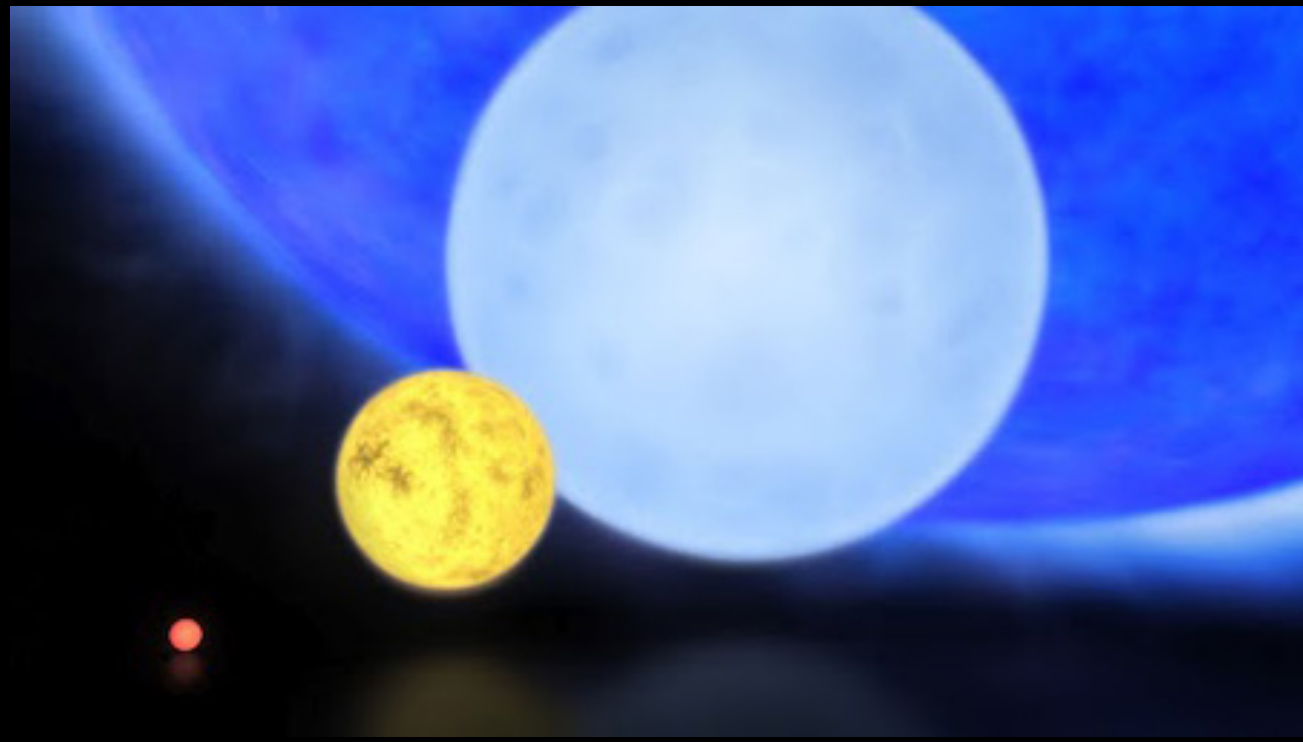


Image: ESO / M. Kornmesser

Core-Collapse Supernovae

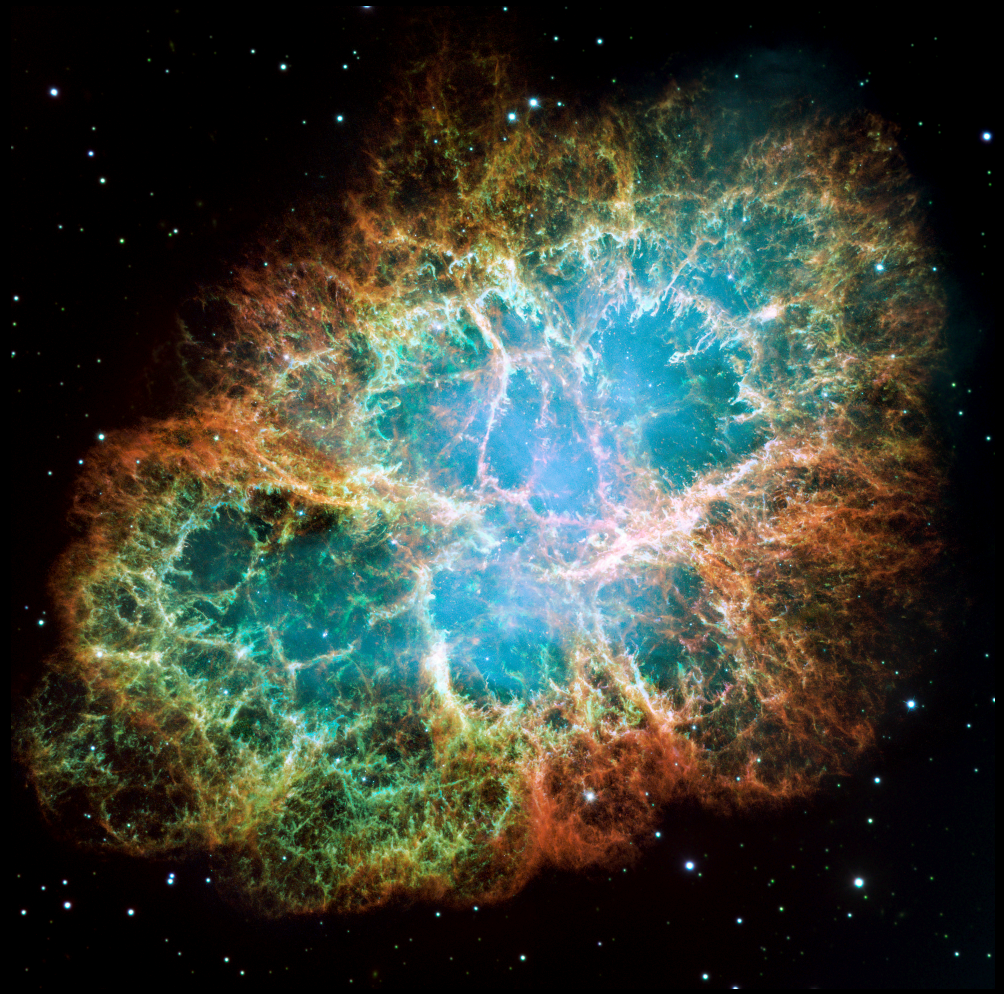
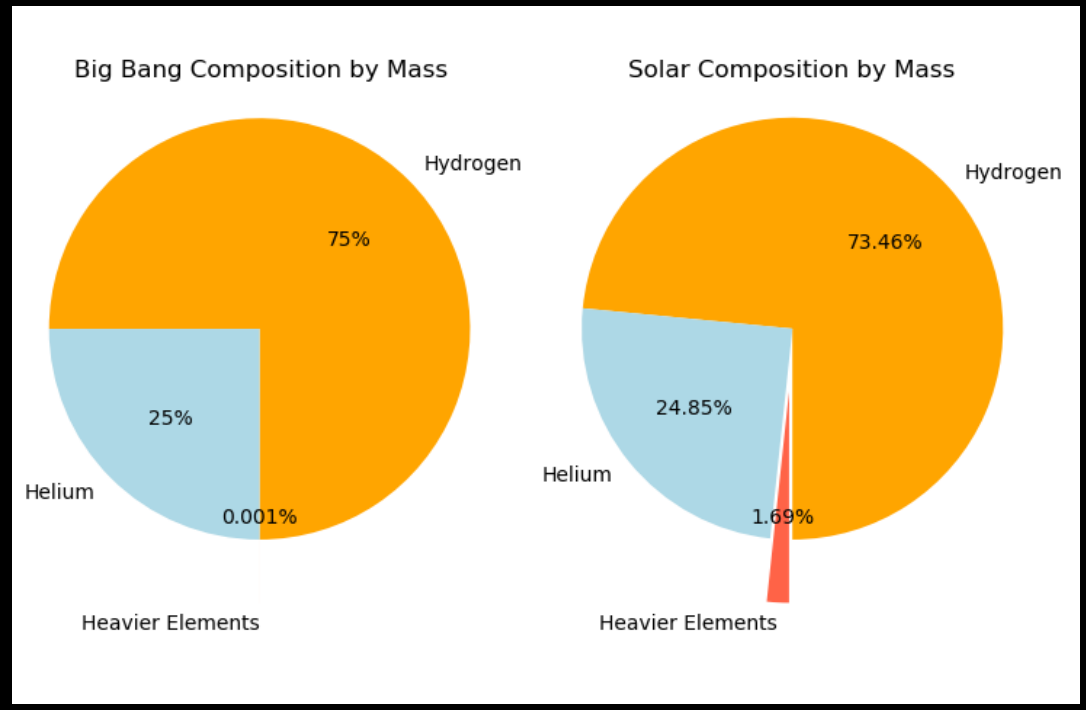


Image: NASA, ESA, J. Hester and A. Loll

- Above 10 solar masses, stars die with a core-collapse supernova
- Core collapses under its own weight to form a compact object
- Outer layers of star are blasted off in a violent explosion

Supernova Nucleosynthesis

- Matter in today's universe looks different than it did immediately after the Big Bang
- Cosmic chemical evolution
- Stars and supernovae create heavy elements, supernovae disperse them into the ISM



Using Simulations to Study Supernovae

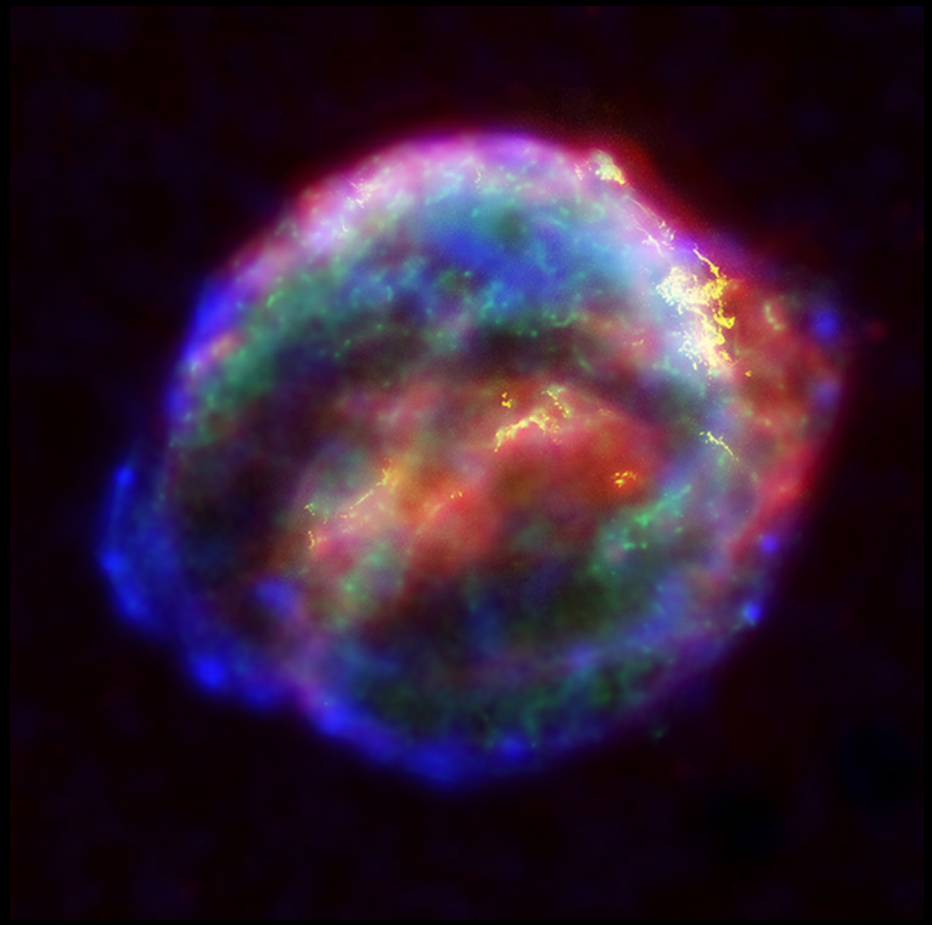
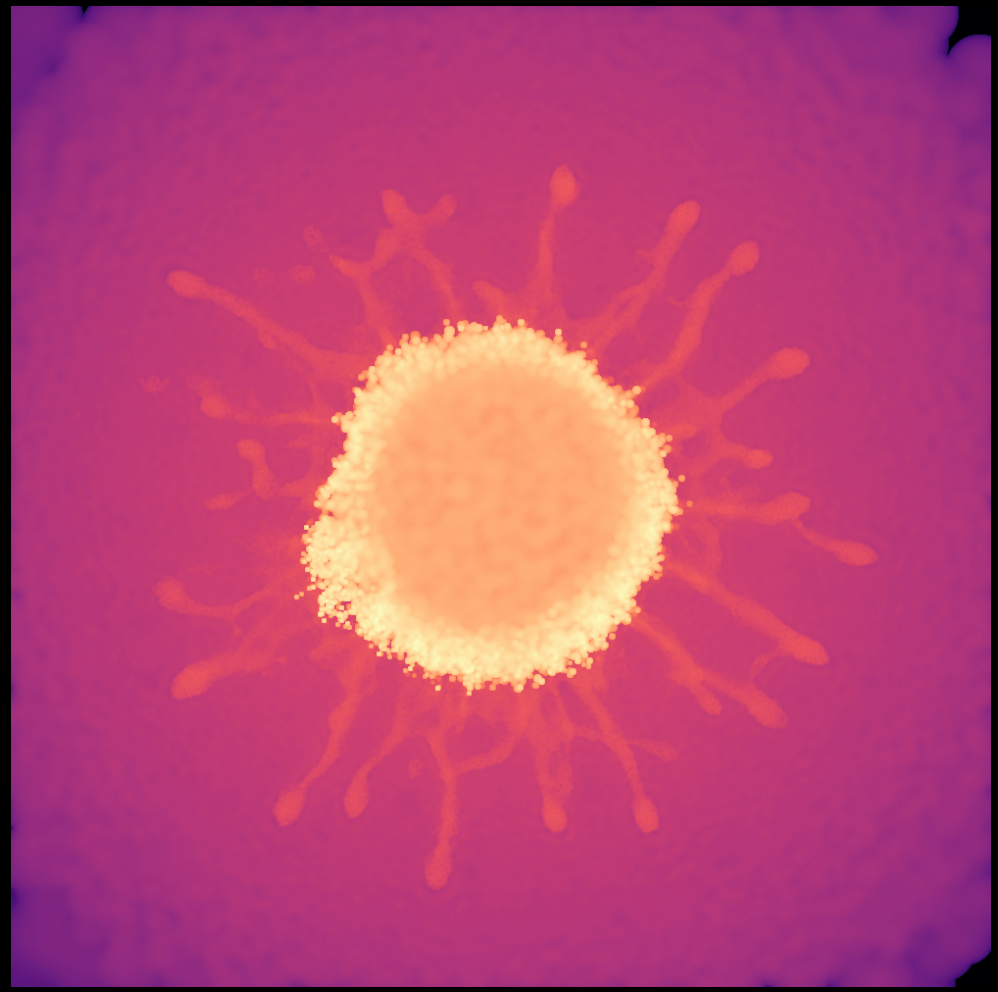


Image: NASA/ESA/JHU/R. Sankrit & W. Blair

- Most observed supernovae are bright spots in distant galaxies
- Supernovae near enough to Earth to be observed in detail are a once-in-a-lifetime event
- Computer simulations are essential to studying them

Supernova Nucleosynthesis Simulations

- Core-collapse supernova simulations in full 3D using the SNSPH hydrodynamics code
- Nucleosynthetic calculations to get yields for 500+ isotopes
- We are exploring the effects of asymmetric explosions



Asymmetric Supernova Morphology

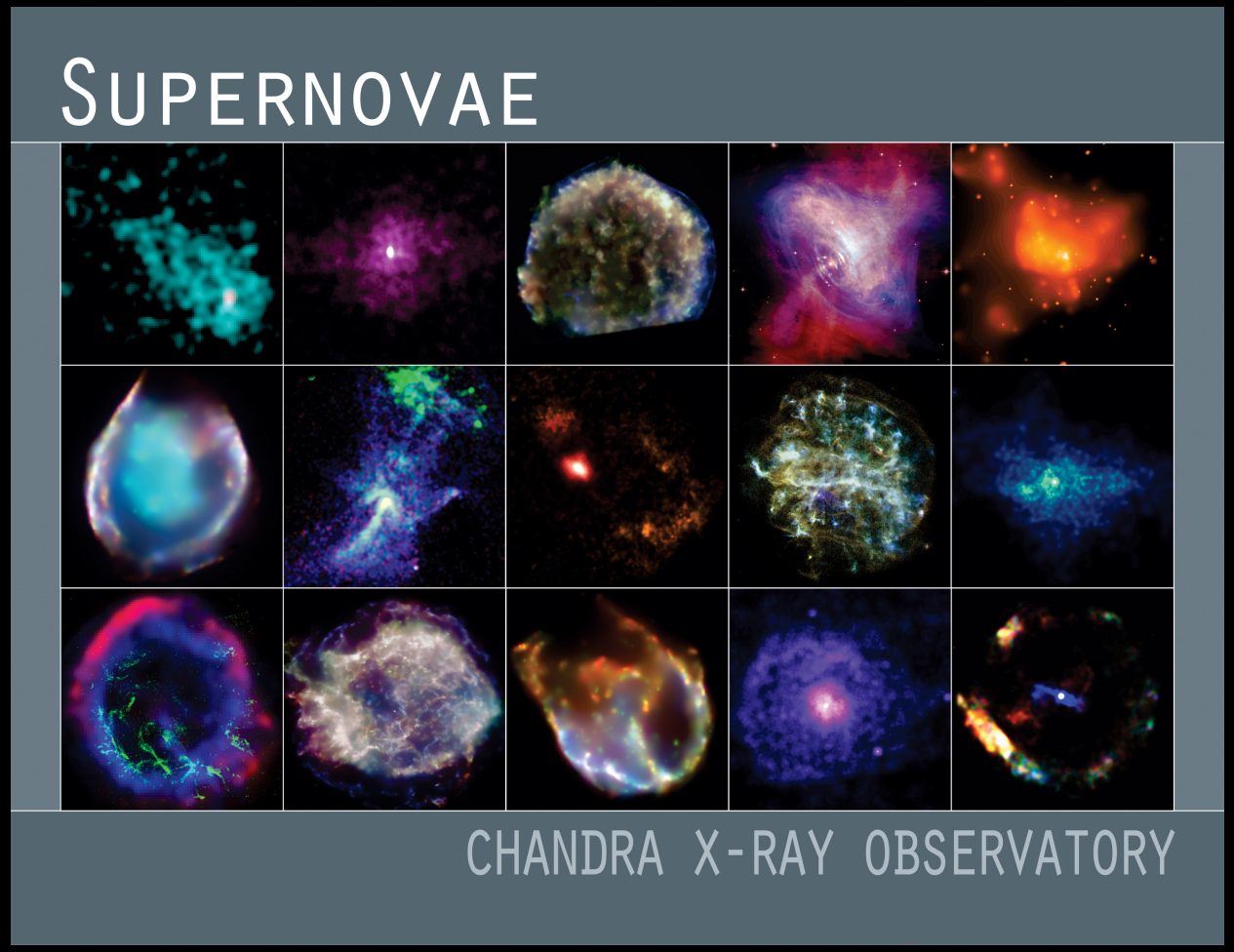


Image: NASA/CXC

- Real supernovae are a varied bunch and are rarely spherical
- Scientific models give insights when they emulate reality
- Not much work has been done to quantify the effects morphology has on yields

Four Simulation Models

- One progenitor star model
  - TYCHO stellar evolution code
  - 15 solar masses
  - Solar metallicity
  - Non-rotating
- Asymmetries are artificially imposed at the moment when core collapse occurs

Model Name	Asymmetry Notes
15M_sym	Spherically symmetric (control)
15M_bip	Bipolar (2:1 velocity ratio)
15M_dco	Dynamic compact object (1.35 solar masses)
15M_con	Realistic 3D convection (newest model!)

New Convective Velocity Model

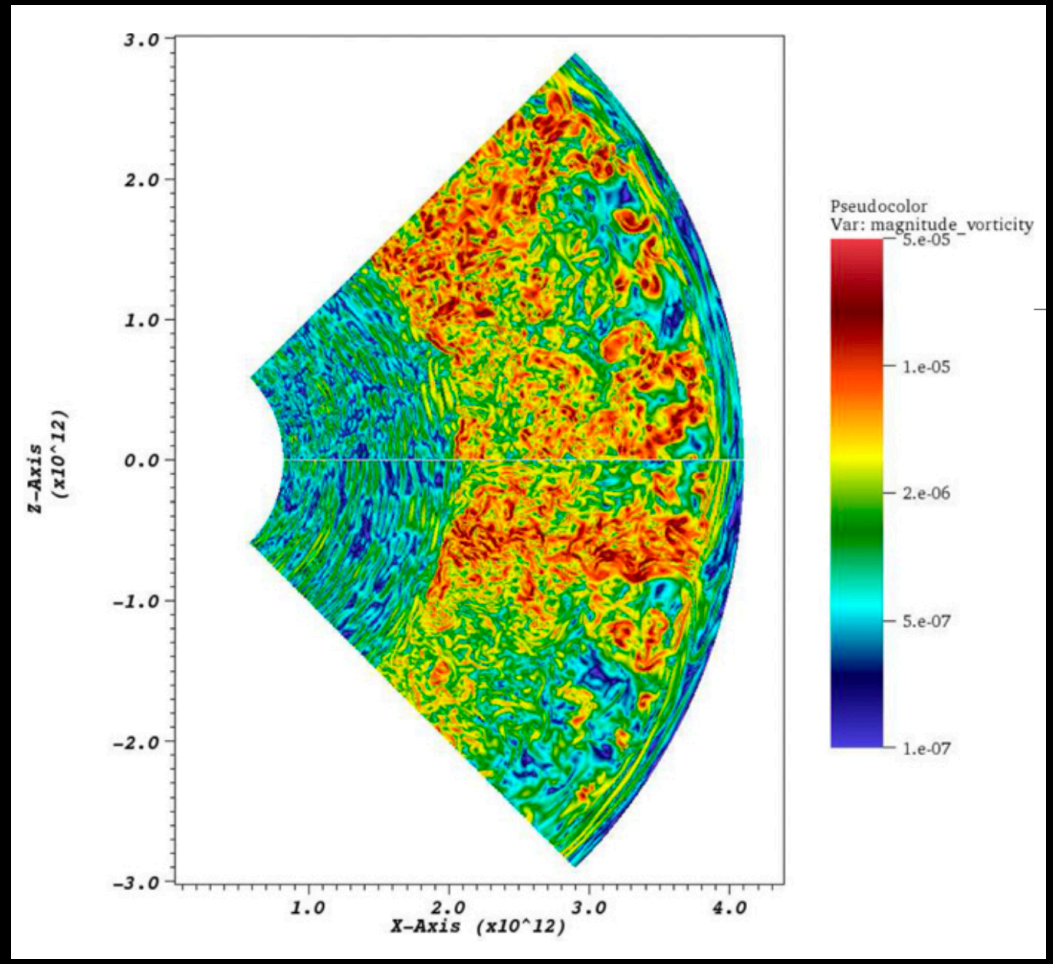
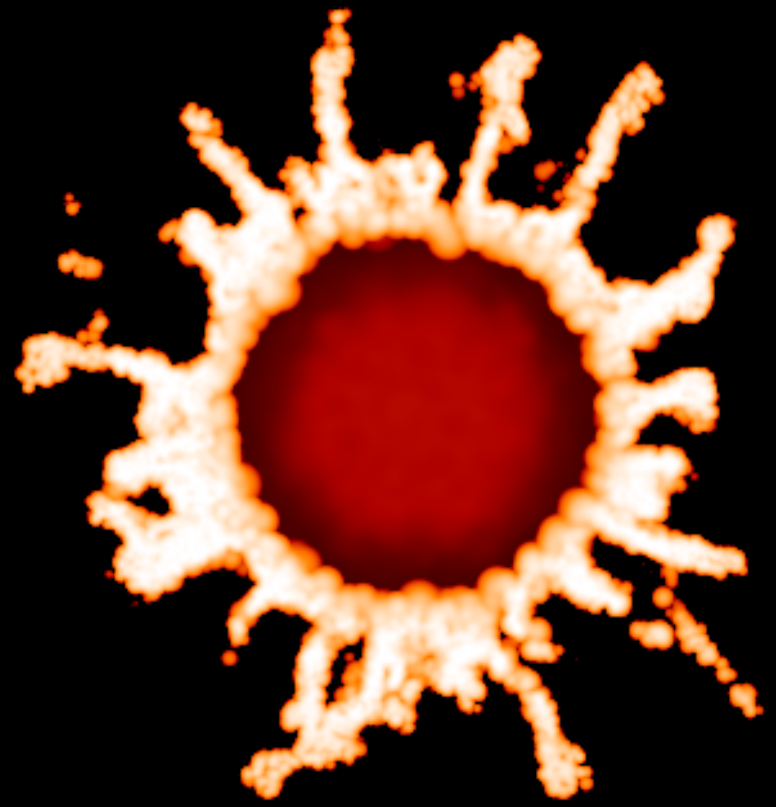


Image: Viallet et al. 2013, ApJ, 769, 1

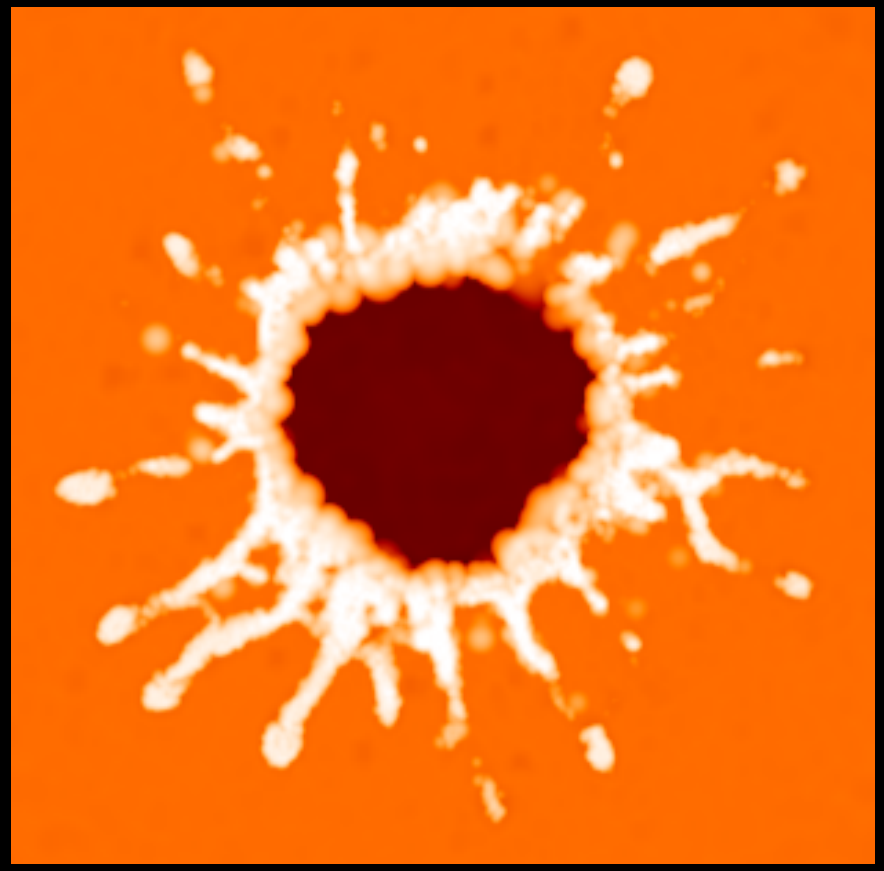
- Realistic treatment of supernova shock moving through turbulent stellar interior
- Using late-stage convection data from a 3D stellar evolution code
- The first supernova simulation of its kind

Preliminary Oxygen Cross Sections

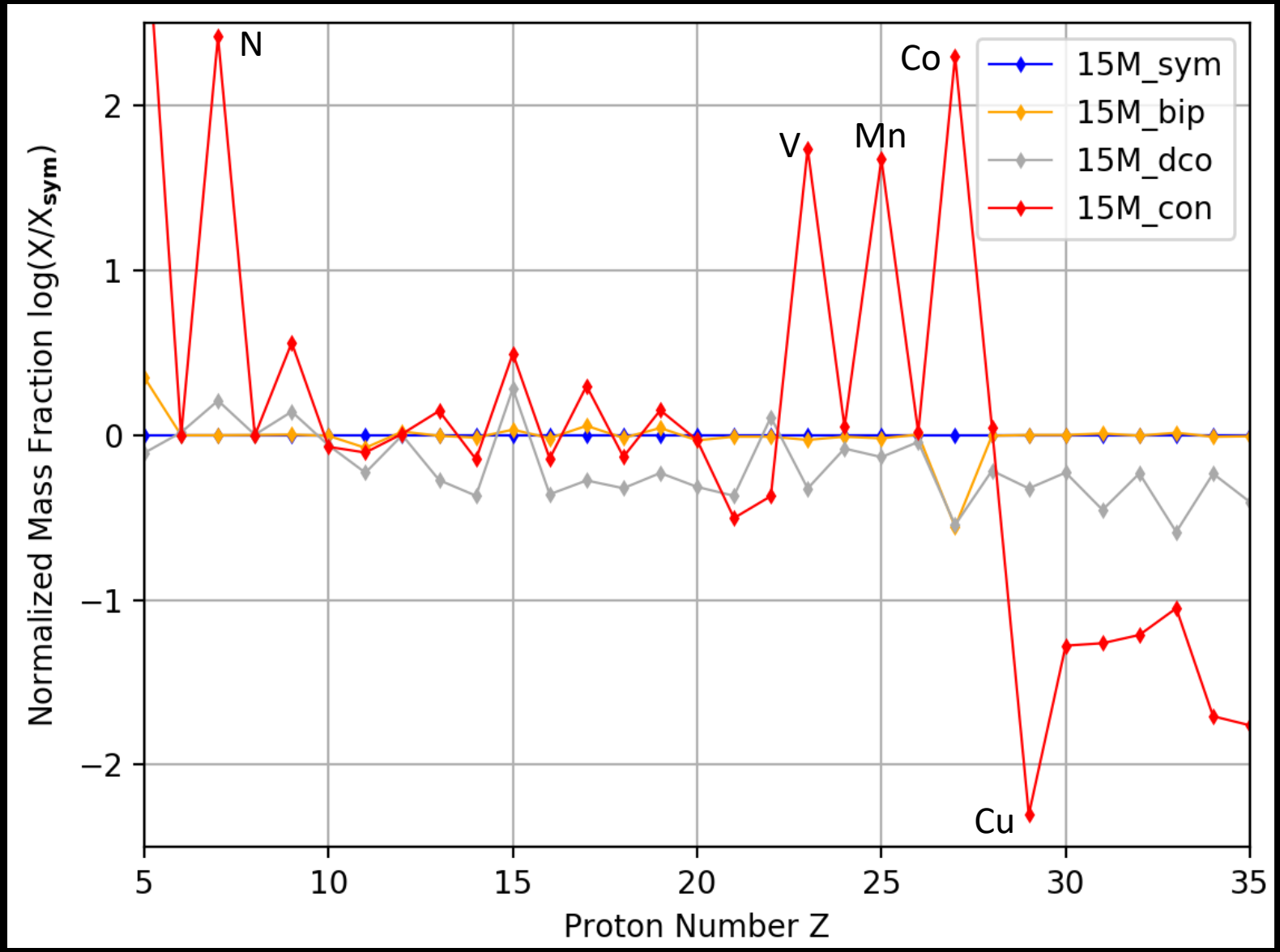
Symmetric Model



Convective Velocity Model



Preliminary Comparative Yields



Future Analysis

- Simulation models run and produce 10s of GB of output for analysis
- Models will be published this year with detailed comparative analysis
- Deep exploration of radioisotopes ^{44}Ti and ^{56}Ni
  - Probes of supernova mechanism
- Preliminary results suggest that natural convective asymmetries can strongly influence supernova yields

Summary

- Supernova nucleosynthesis created many of the atoms that make up Earth and its biosphere
- Asymmetries play an essential role in that cosmic process
- We are excited to be publishing our set of models this year

Image: NASA, ESA, M. Robberto (Space Telescope Science Institute/ESA) and the Hubble Space Telescope Orion Treasury Project Team