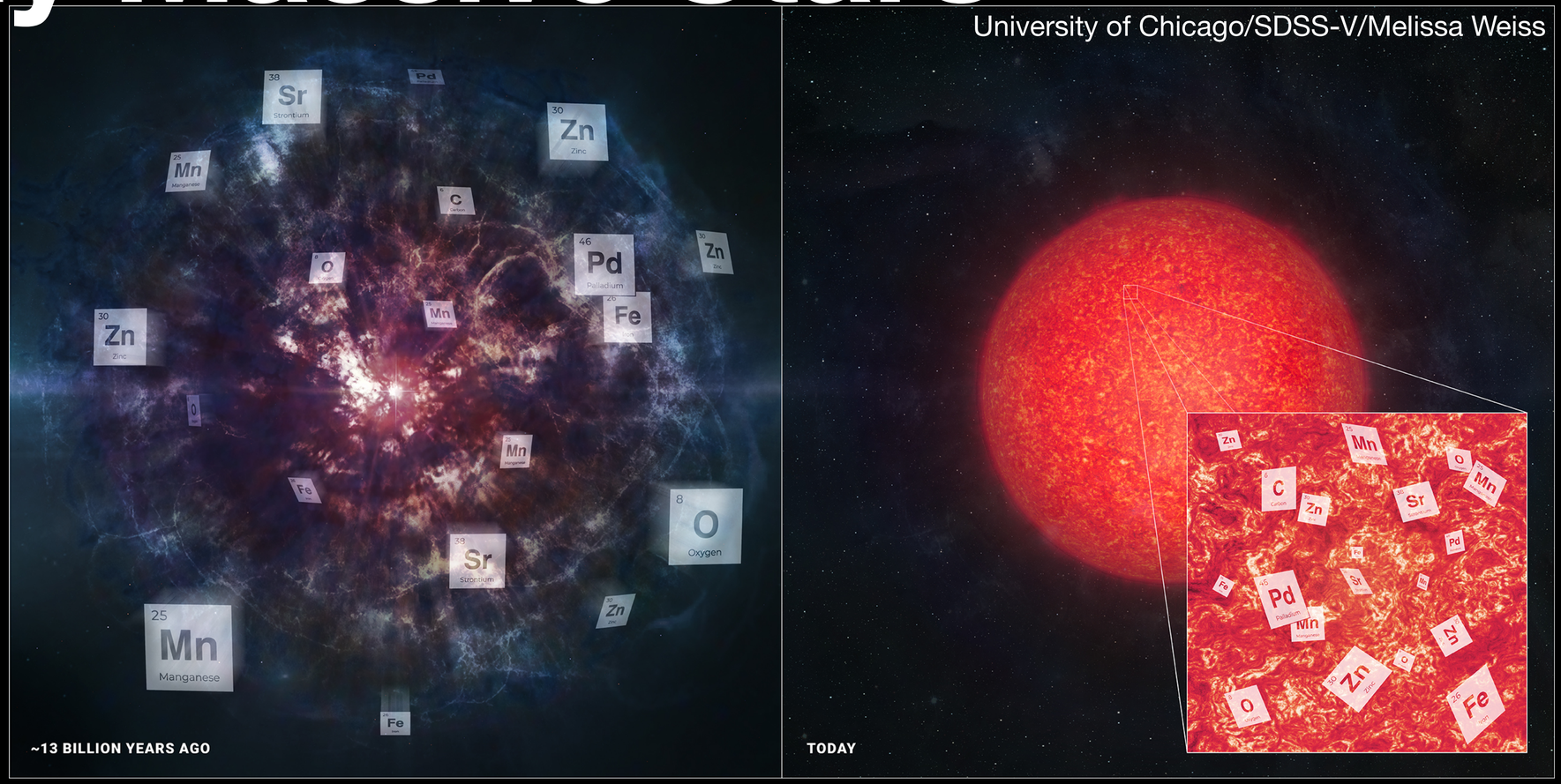
Spectacular Nucleosynthesis in Early Massive Stars



Alex Ji (UChicago), Sanjana Curtis (UC Berkeley), Nicholas Storm (MPIA), Vedant Chandra (Harvard), Kevin Schlaufman (JHU), Kevin Stassun (Vanderbilt), Alexander Heger (Monash), Marco Pignatari (Konkoly), Adrian Price-Whelan (Flatiron), and the SDSS-V Collaboration; ApJL Accepted, arXiv:2401.02484

Spectacular Nucleosynthesis in Early Massive Stars

- SDSS-V discovered a star with spectacular composition
- Records a unique ancient supernova explosion
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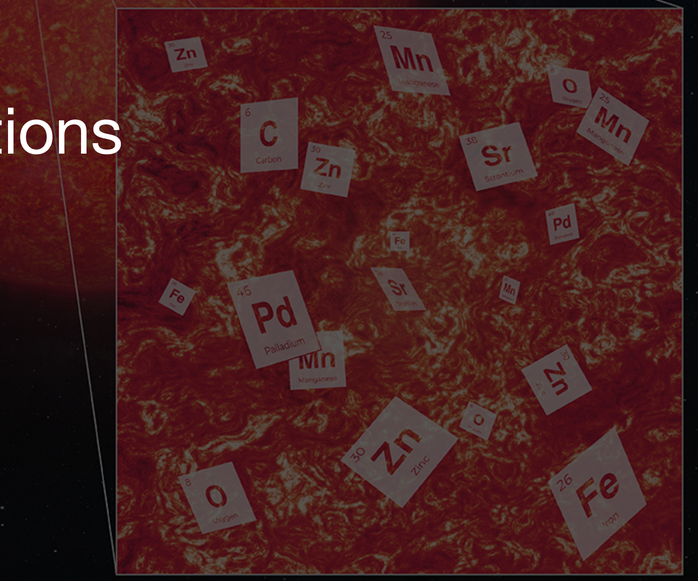
  Should have turned directly into a black hole
- But don’t know for sure: at the limits of theoretical predictions



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~13 BILLION YEARS AGO

TODAY

Illustrations: University of Chicago/SDSS-V/Melissa Weiss

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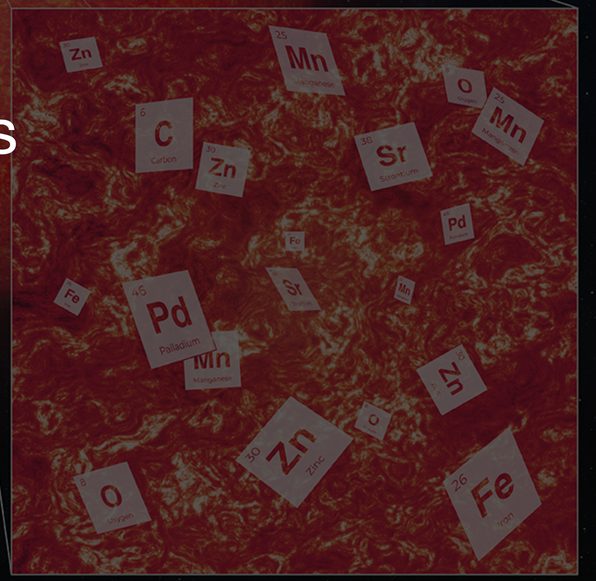
a.k.a. the Barbenheimer Star



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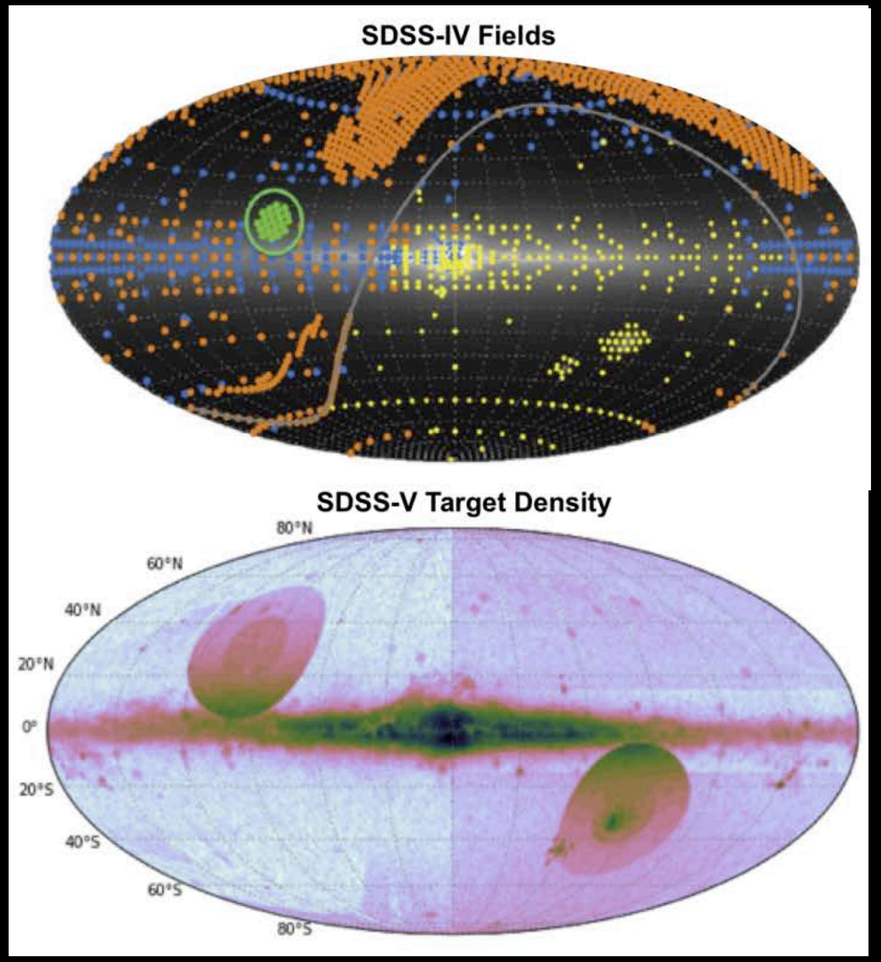
Sloan Digital Sky Survey V - Milky Way Mapper

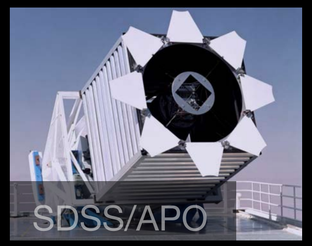
Finding rare stars while surveying the Galaxy

- Mapping whole sky with robots
  - Apache Point Observatory (North)
  - Las Campanas Observatory (South)
- Milky Way Mapper Halo:
  looking through the oldest stars
  for rare gems

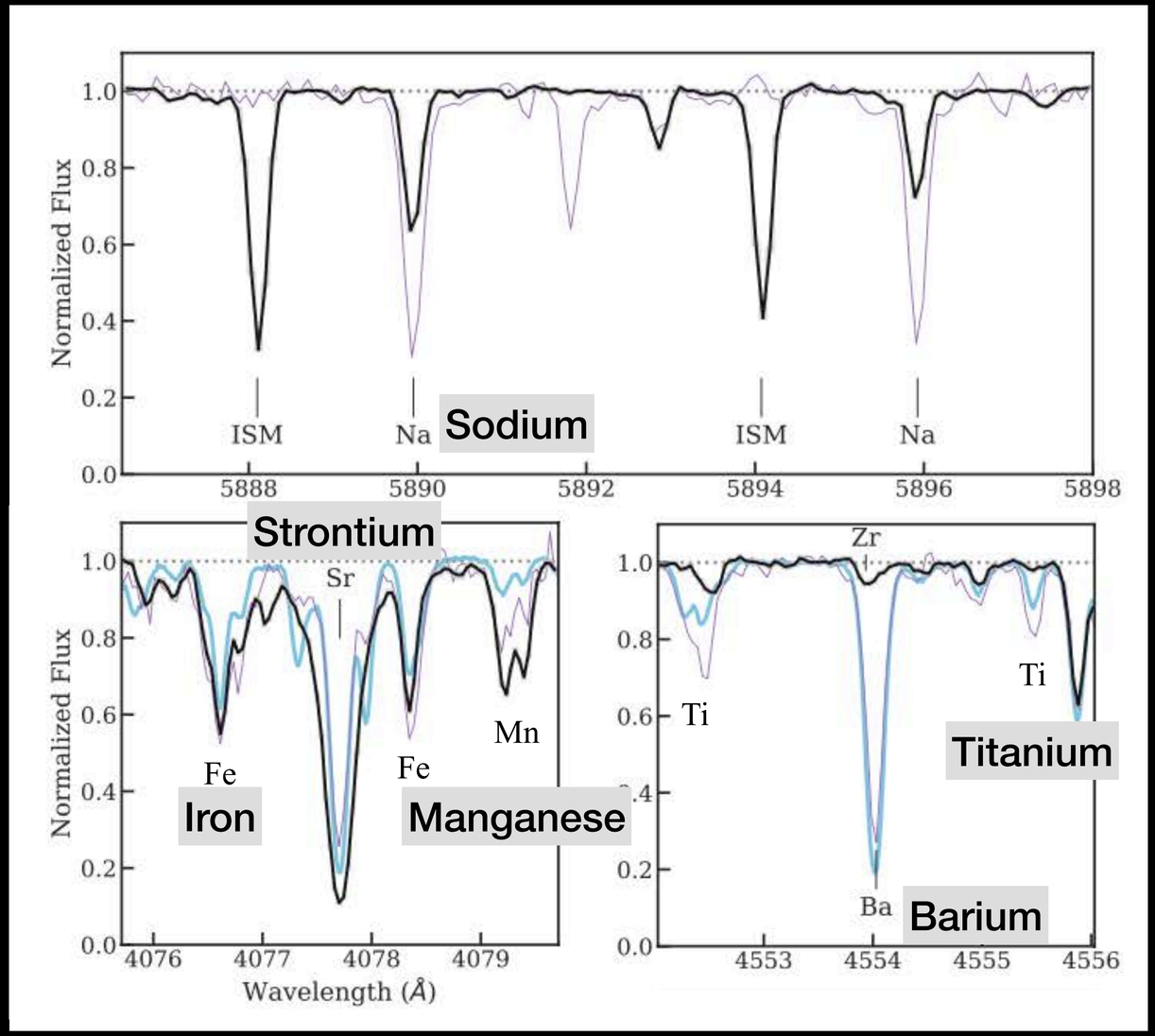


A Spectacular Star!

- SDSS-V flagged J0931+0038: old star, unusually low magnesium



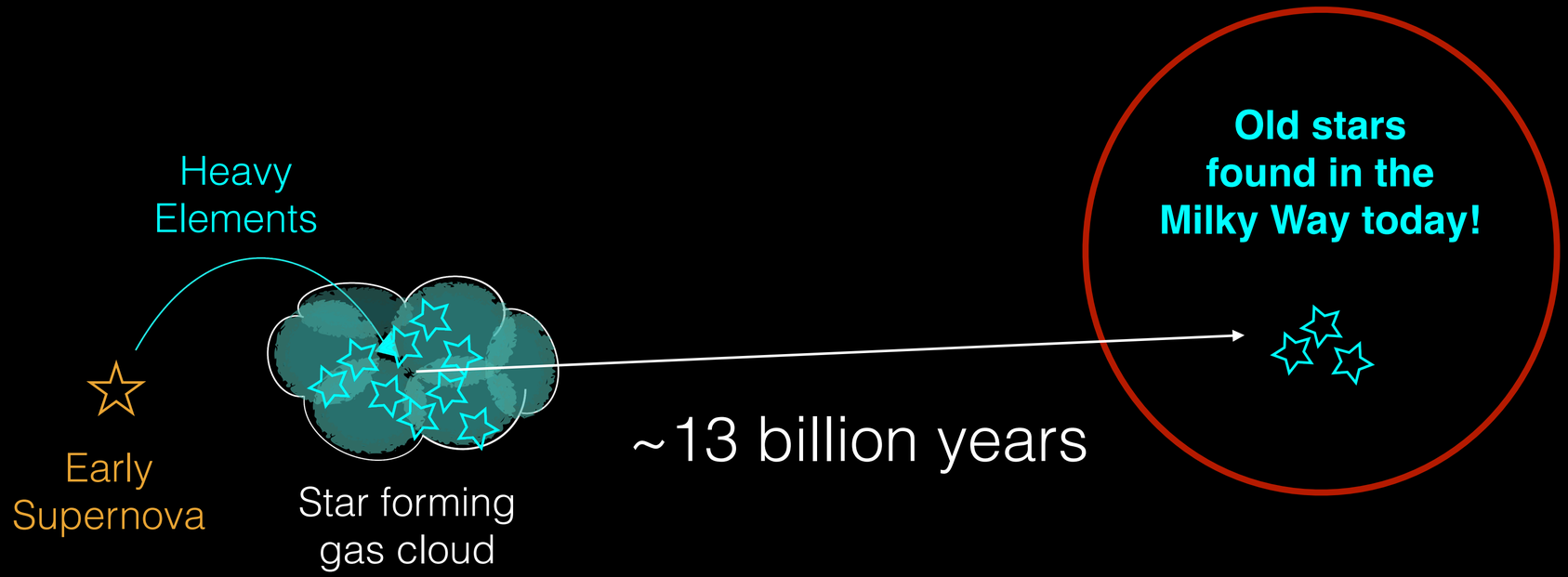
- Followup with Magellan Telescope at Las Campanas Observatory: never-before-seen composition!



Black spectrum = J0931+0038
Blue + Purple spectrum = “normal” stars

Stellar Archaeology

Old Stars are Time Capsules of Supernova Ashes



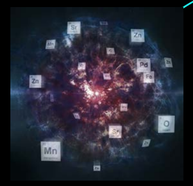
Measure stars today -> properties of ancient supernovae

Illustrations: University of Chicago/SDSS-V/Melissa Weiss

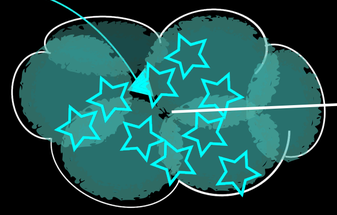
Stellar Archaeology

Old Stars are Time Capsules of Supernova Ashes

Heavy Elements



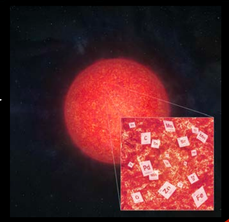
Early Supernova



Star forming gas cloud

~13 billion years

Old stars found in the Milky Way today!



Measure stars today -> properties of ancient supernovae

Barbenheimer Star Explodes

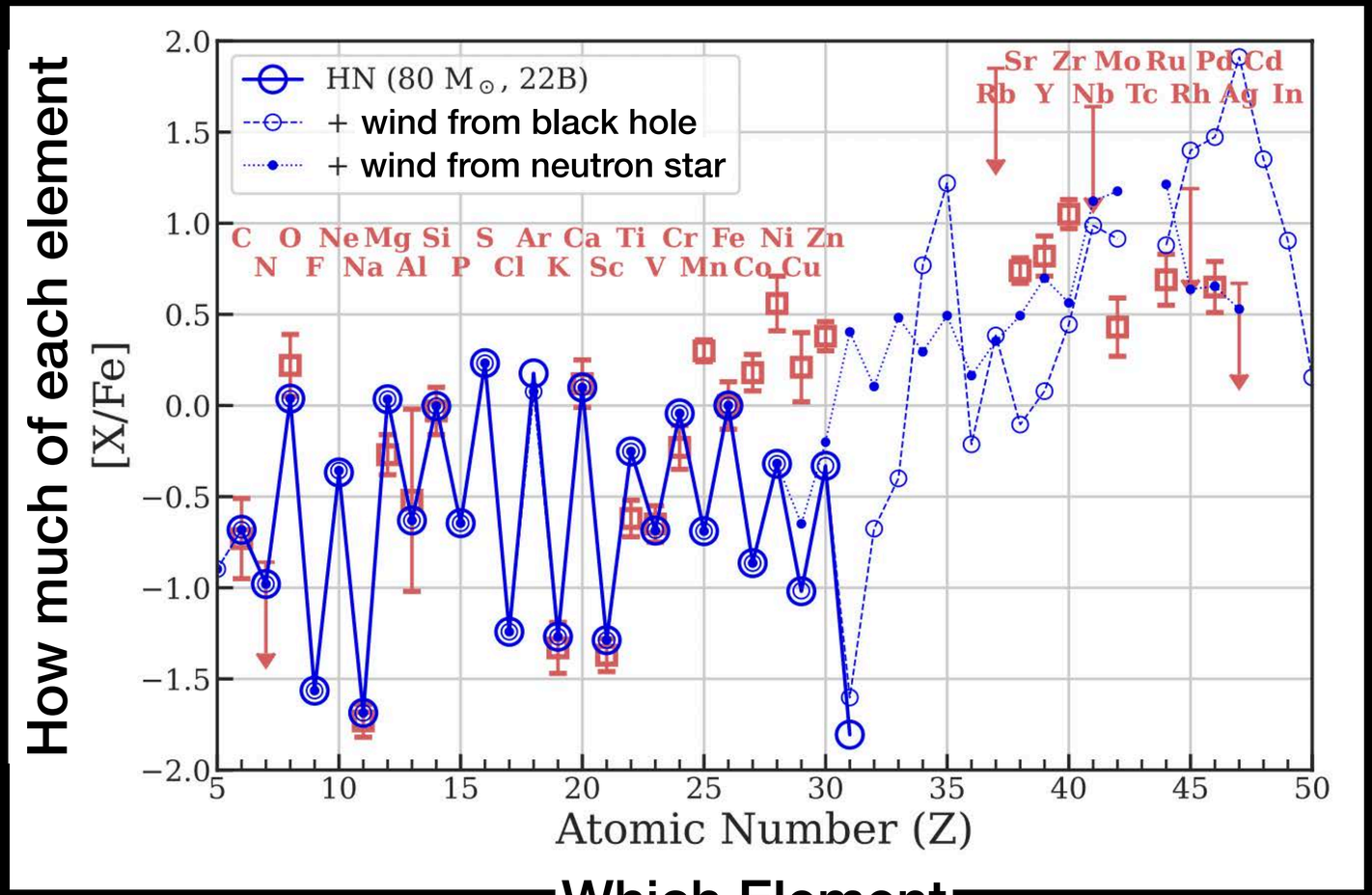
Evidence from J0931+0038 Today

Illustrations: University of Chicago/SDSS-V/Melissa Weiss

Alex Ji (University of Chicago and SDSS-V), Spectacular Nucleosynthesis in Early Massive Stars

Massive (>50 M_{sun}) Supernova Progenitor

Best fit: 80 M_{sun} Hypernova (High Energy Supernova)



No model fits all elements: existing supernova models are too simple!

80 solar mass stars should not explode

But now we think they might!

140-260 solar masses
supernova, no remnant

40-140 solar masses
black hole
without supernova

~10-40 solar masses
supernova with black hole

~8-10 solar masses
supernova with neutron star

1-8 solar masses
white dwarf

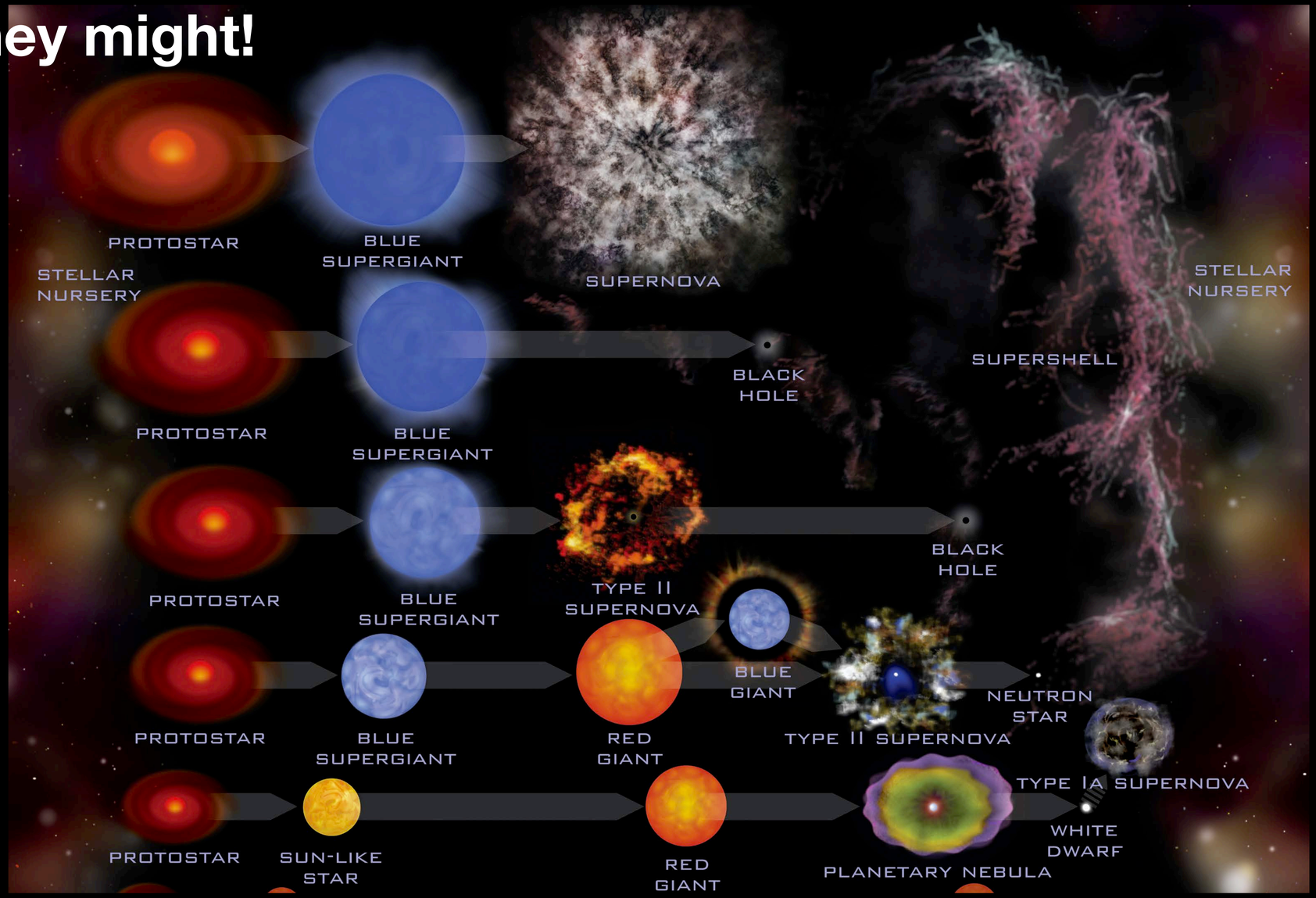


Illustration: NASA/CXC/Melissa Weiss; theoretical mass ranges are for the oldest (metal-poor) stars

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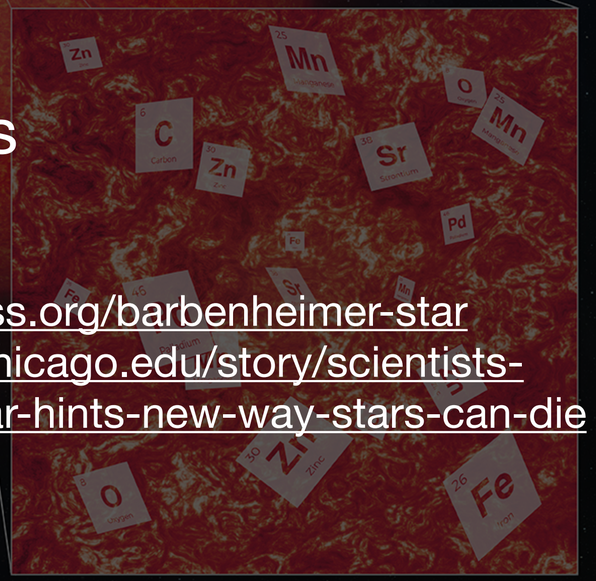

Press Releases
https://www.sdss.org/barbenheimer-star
https://news.uchicago.edu/story/scientists-find-unusual-star-hints-new-way-stars-can-die

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