Triggered star formation by Pop III supernovae

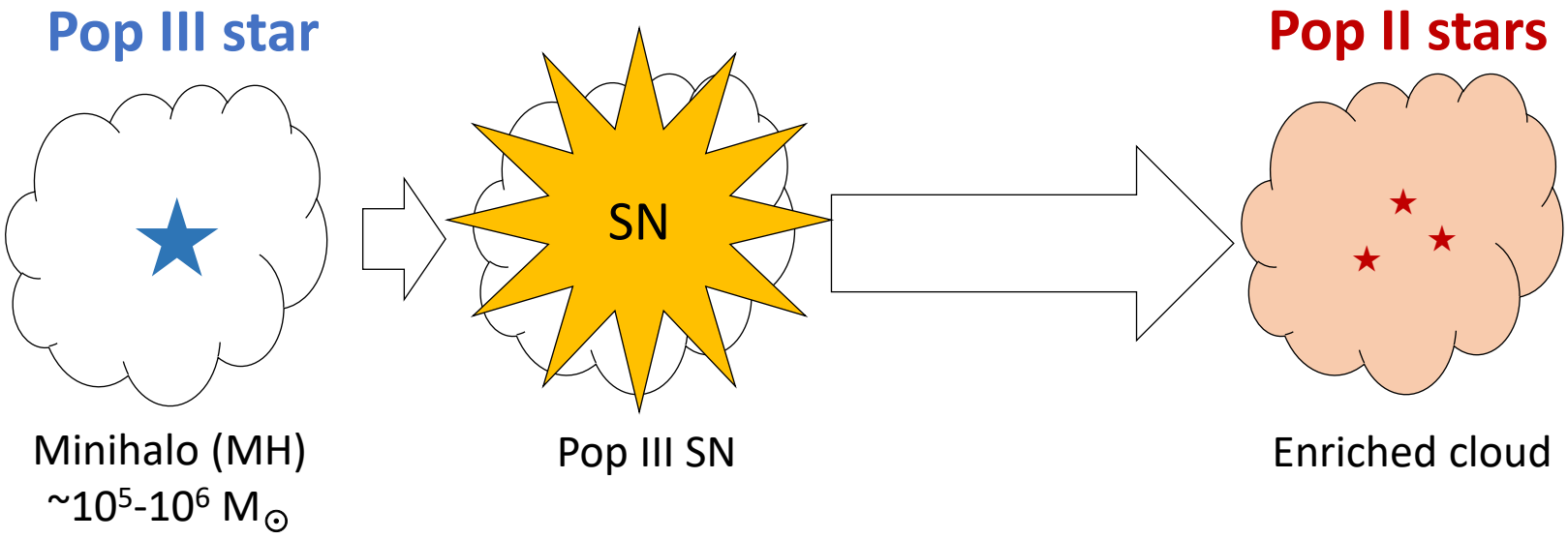
Gen Chiaki (Georgia Tech)

Collaborators:
John Wise, Corey Brummel-Smith (Georgia Tech)
Stefania Marassi, Raffaella Schneider (Sapienza University)
Marco Limongi (INAF/OAR), Alessandro Chieffi (INFN)

The First Stars, October 23, 2020

Research Interest: Transition from Population III to II stars

Safranek-Schrader et al. (2014, 2016); Ritter et al. (2012, 2015, 2016); Sluder et al. (2015); Chen et al. (2014, 2017)
Smith et al. (2015); Hicks et al. (2020)



Past researches: Single enrichment event

- Gen Chiaki & John Wise (2019, MNRAS, 482, 3933)
- Gen Chiaki, John Wise, et al. (2020, MNRAS, 497, 3149)

Cosmological sim.

Enzo

Box size: 300 comoving kpc

Top grid: 64^3

DM mass: $53\ \mathrm{M}_\odot$

Jeans factor: 64

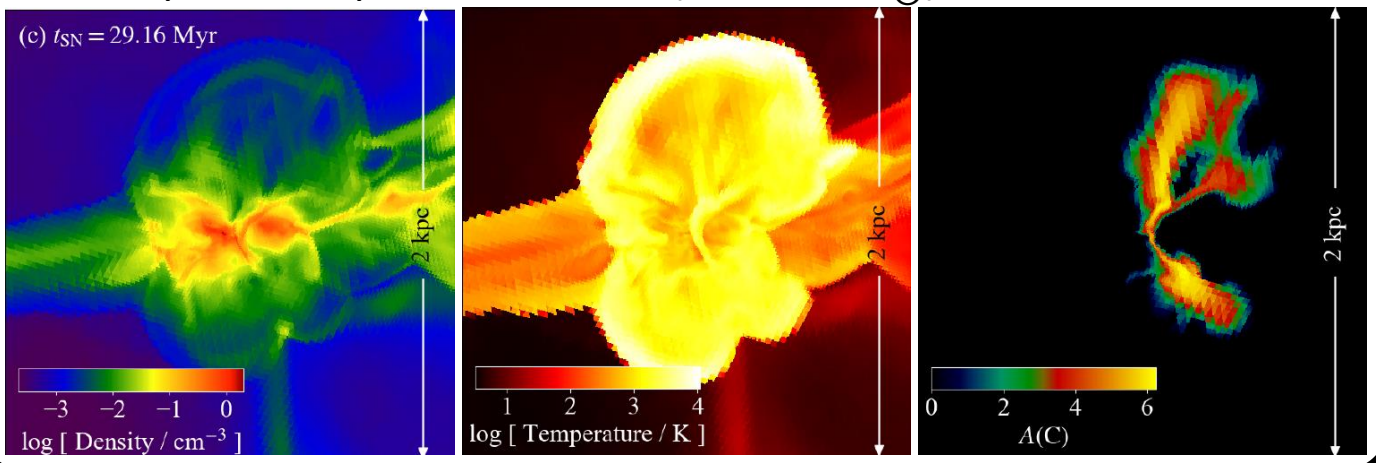
33 AMR levels

Grackle

48 chemical species

100 chemical reactions

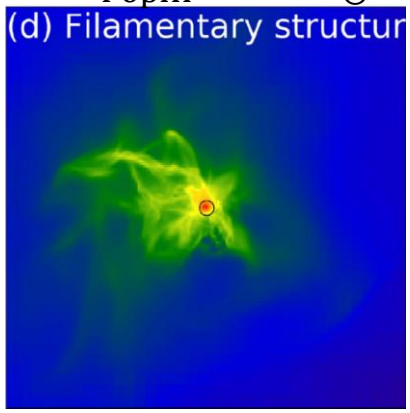
Pop III SN explosion in a MH ($3 \times 10^6\ \mathrm{M}_\odot$) at redshift 12



Pop II star formation in the enriched clouds

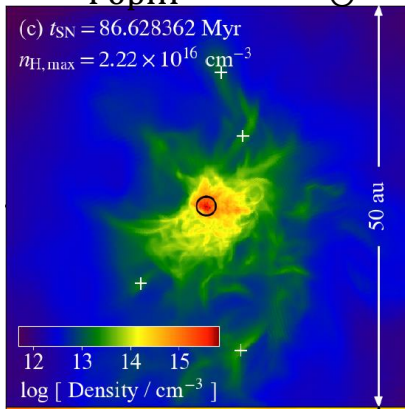
Normal CCSN

$M_{\mathrm{PopIII}} = 13\ \mathrm{M}_\odot$

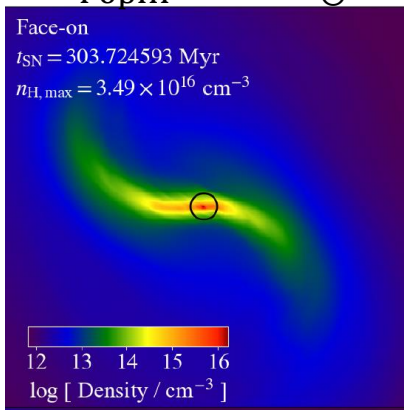


Faint SNe

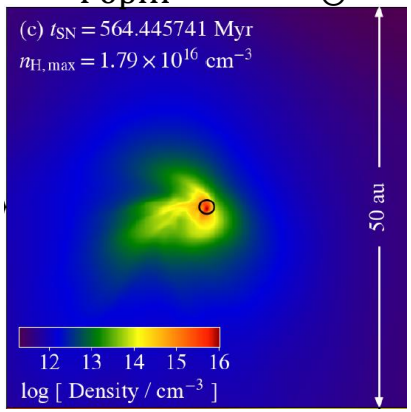
$M_{\mathrm{PopIII}} = 13\ \mathrm{M}_\odot$



$M_{\mathrm{PopIII}} = 50\ \mathrm{M}_\odot$



$M_{\mathrm{PopIII}} = 80\ \mathrm{M}_\odot$



Press release on

TACC TEXAS ADVANCED COMPUTING CENTER
Powering Discoveries That Change The World

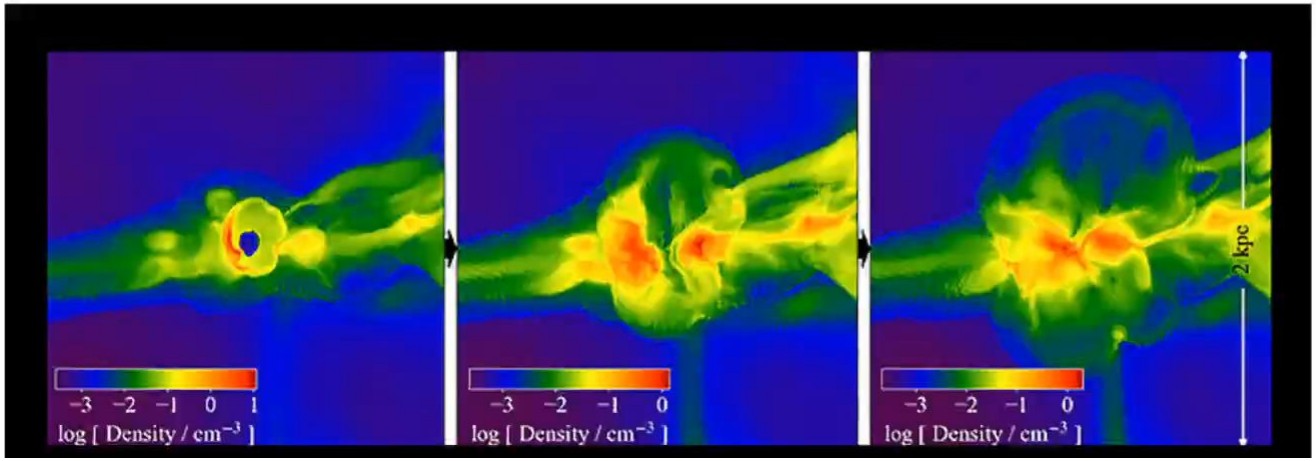
- Gen Chiaki, John Wise, et al. (2020, MNRAS, 497, 3149)

GALACTIC ARCHAEOLOGY

Supercomputers dig into first star fossils

Published on October 22, 2020 by Jorge Salazar

Facebook Twitter LinkedIn Email



NEWS CATEGORIES

- User News
- Press Releases
- Feature Stories
- Podcasts
- Multimedia
- TACC In The News

STORY HIGHLIGHTS

Computational astrophysics study modeled fo
faint supernovae of metal-free first stars, yield

https://www.tacc.utexas.edu/-/galactic-archaeology

Past researches: Single enrichment event

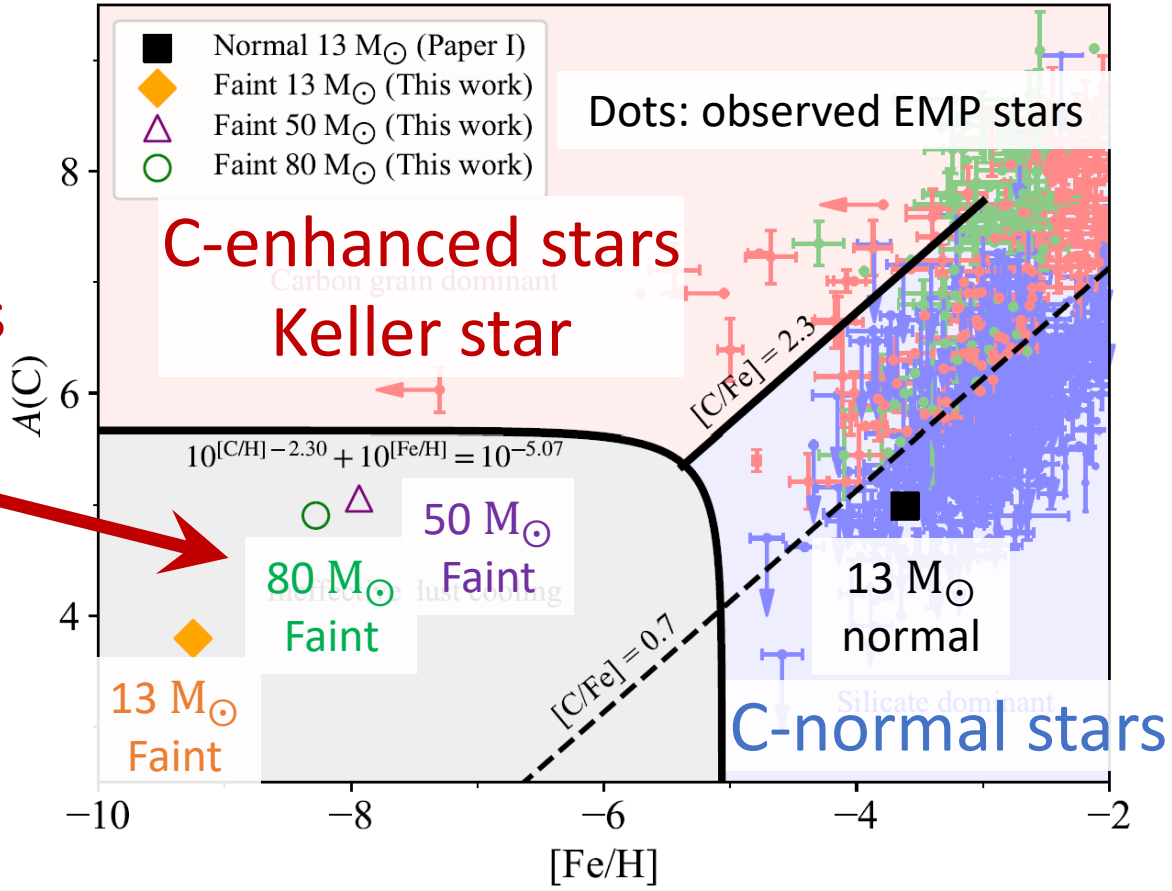
- Gen Chiaki & John Wise (2019, MNRAS, 482, 3933)
- Gen Chiaki, John Wise, et al. (2020, MNRAS, 497, 3149)

Elemental abundances in the enriched clouds

vs

observed extremely metal-poor (EMP) stars

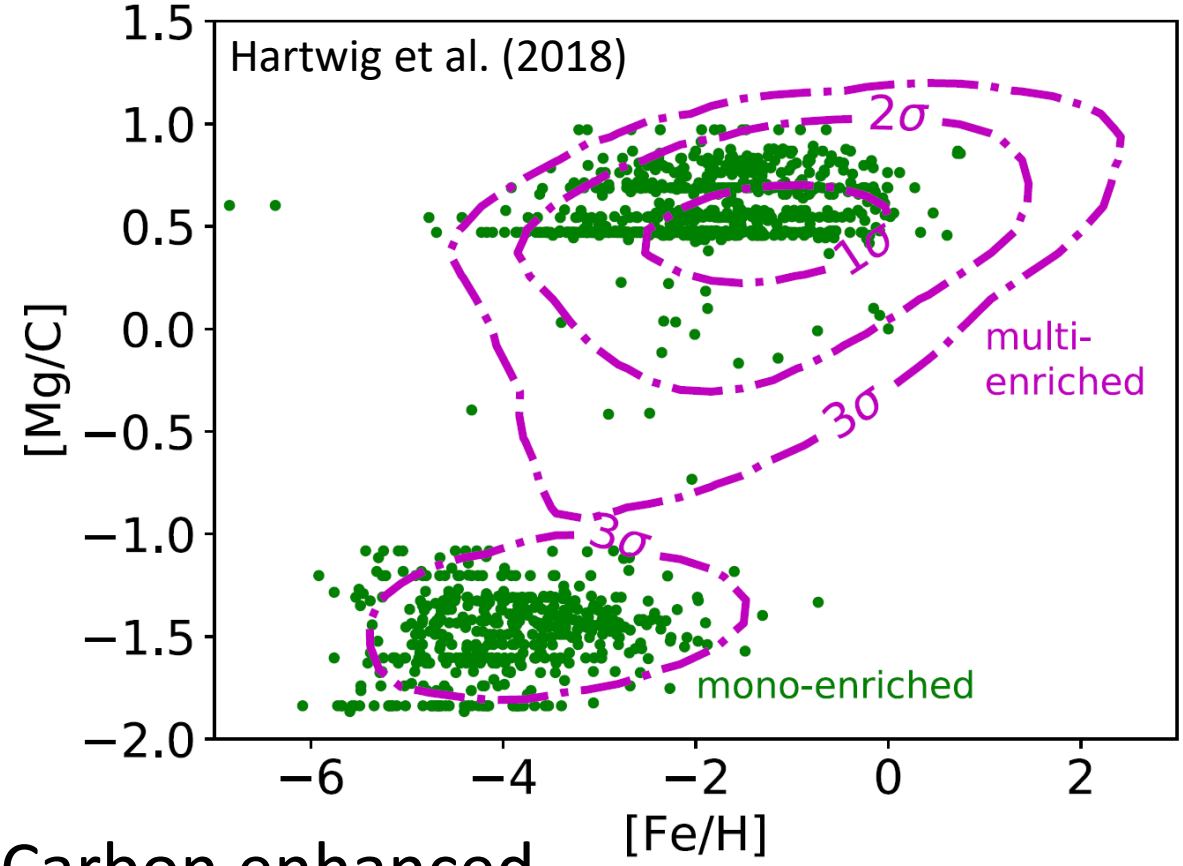
Multi-enrichment is required to explain the formation of C-enhanced stars.



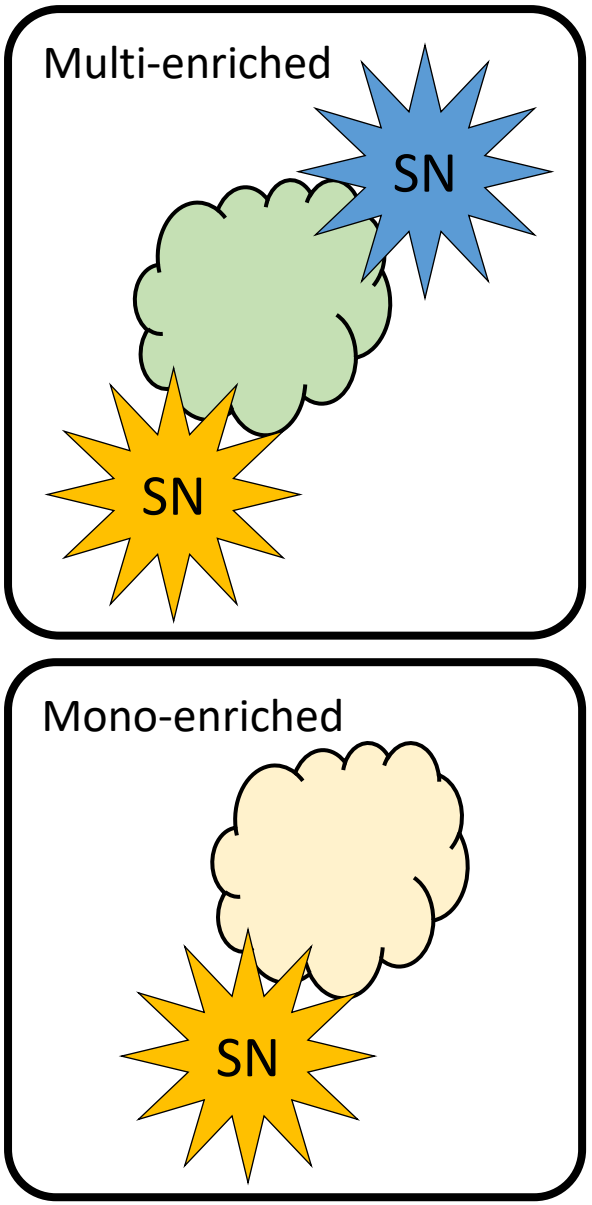
Result of semi-analytic calculations

e.g., Ritter et al. (2016); Hartwig et al. (2018); Skinner & Wise (2020)

Carbon normal



Carbon enhanced



Larger-box simulation
→Multi-enrichment events
→Larger samples of EMP stars

Cosmological sim.

Enzo

Box size: 1 h^{-1}Mpc

Top grid: 64^3

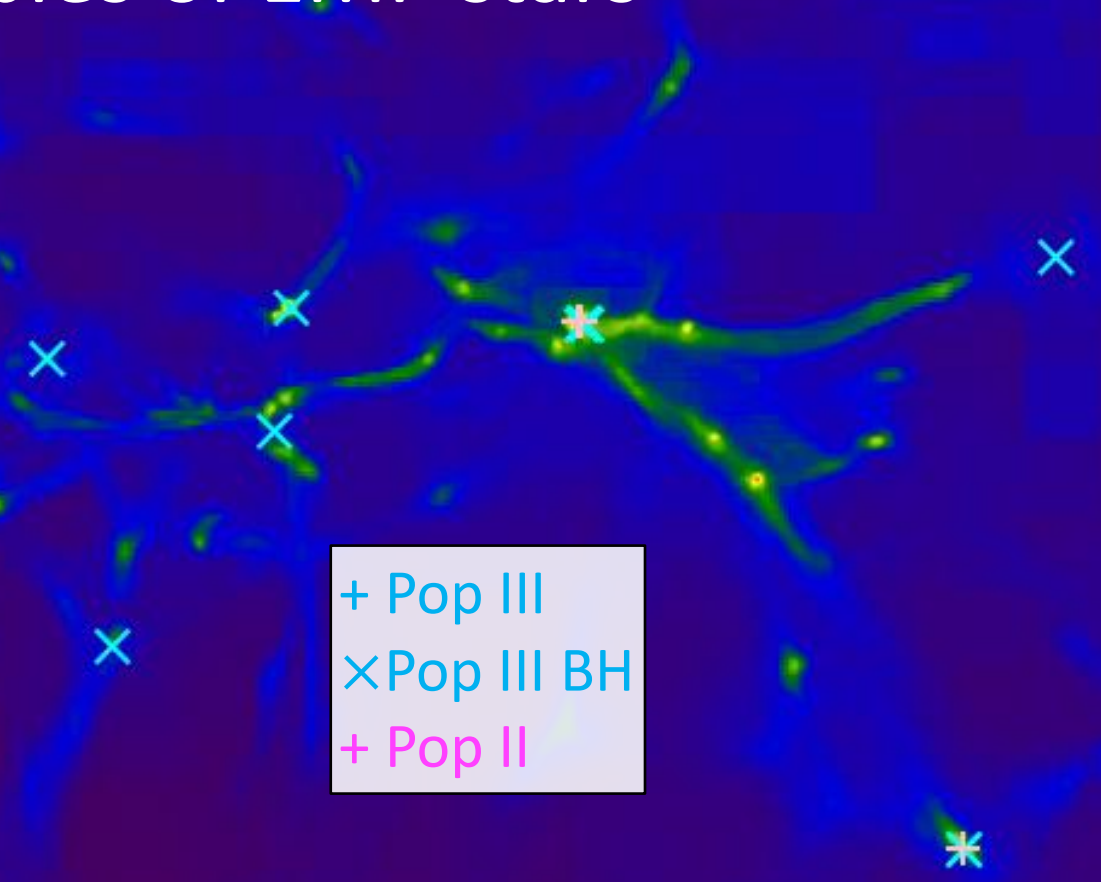
DM mass: 6×10^3 $M_\odot$

Jeans factor: 4

Grackle

48 chemical species

100 chemical reactions

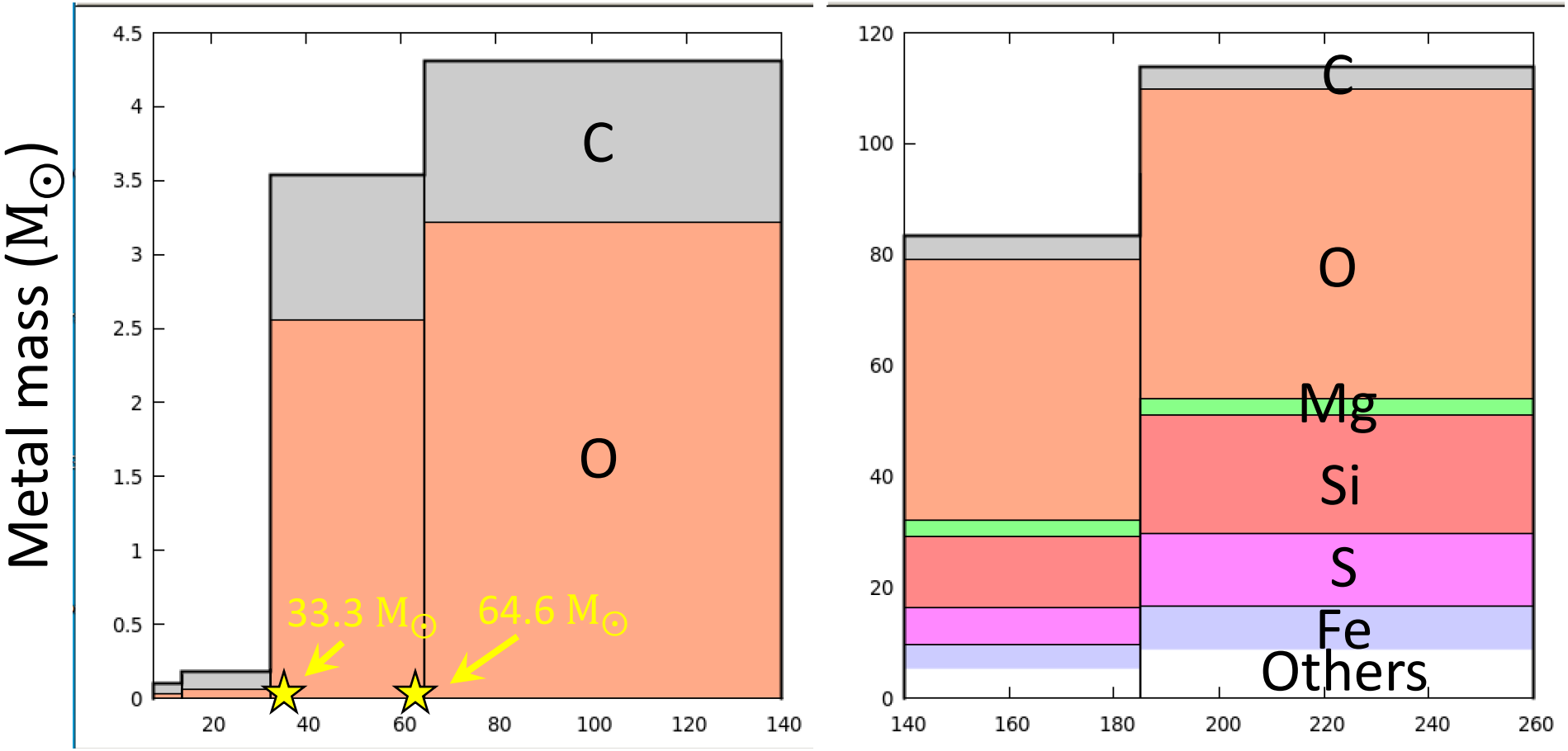


Note: Low-resolution test simulation

Enrichment from Pop III stars

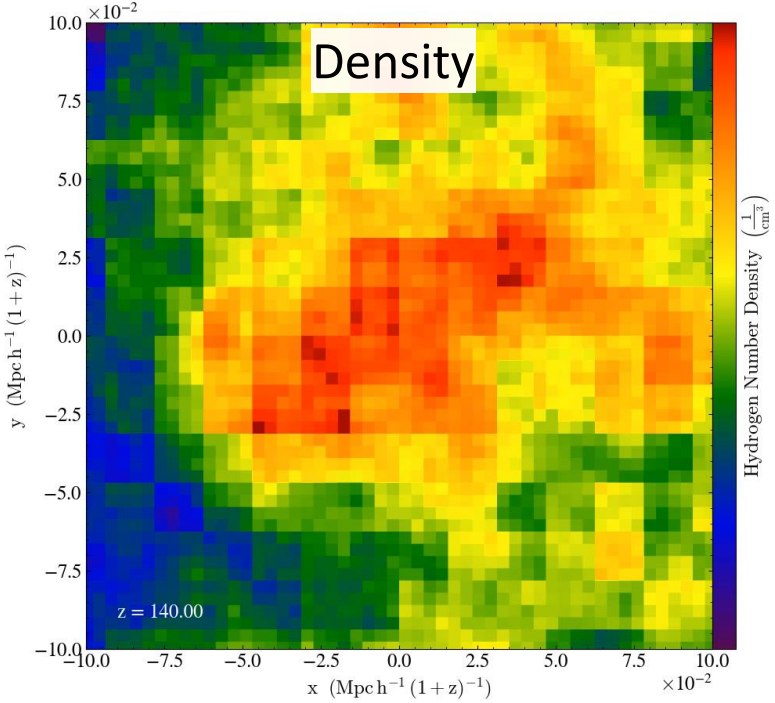
Faint SN ($< 140\ M_\odot$)

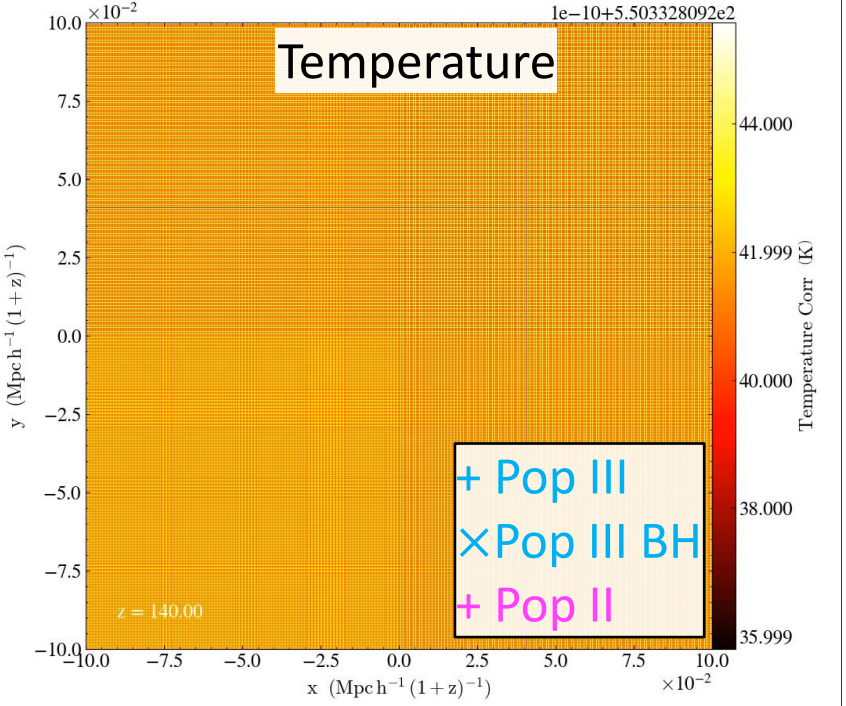
Pair-Instability SN ($> 140\ M_\odot$)



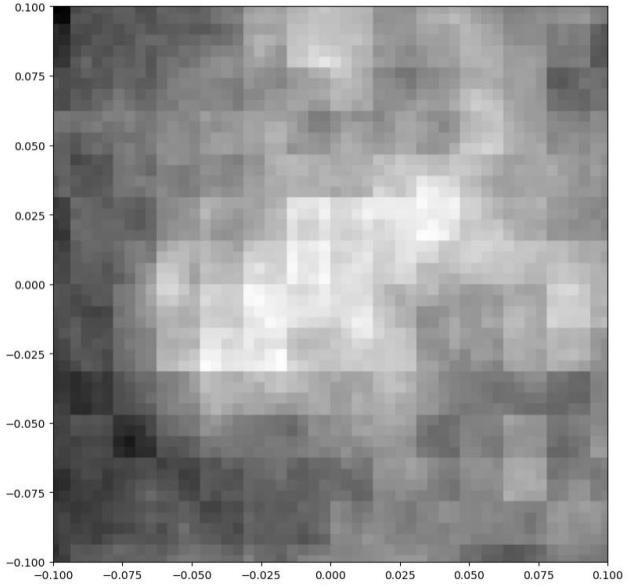
Marassi, GC et al. (2014)

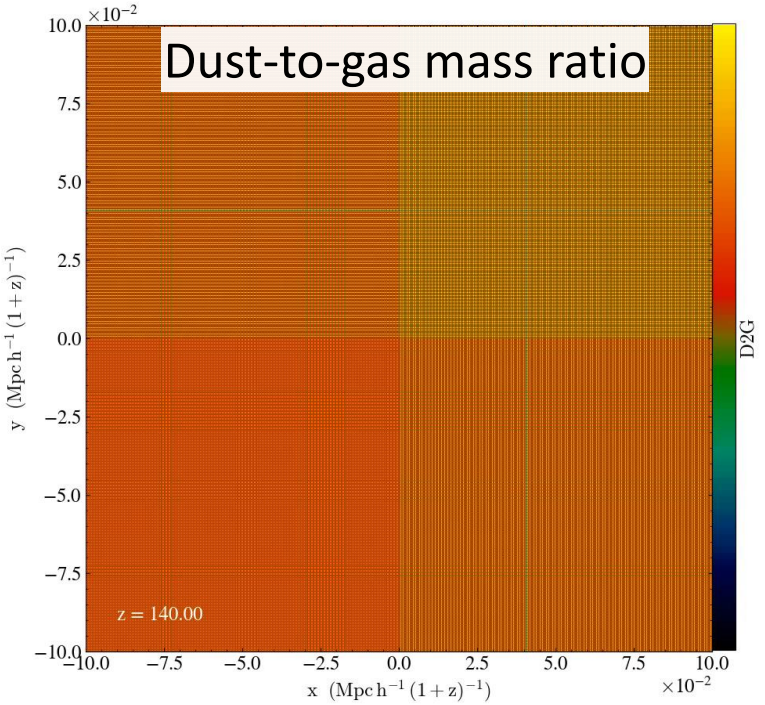
Umeda & Nomoto (2002)



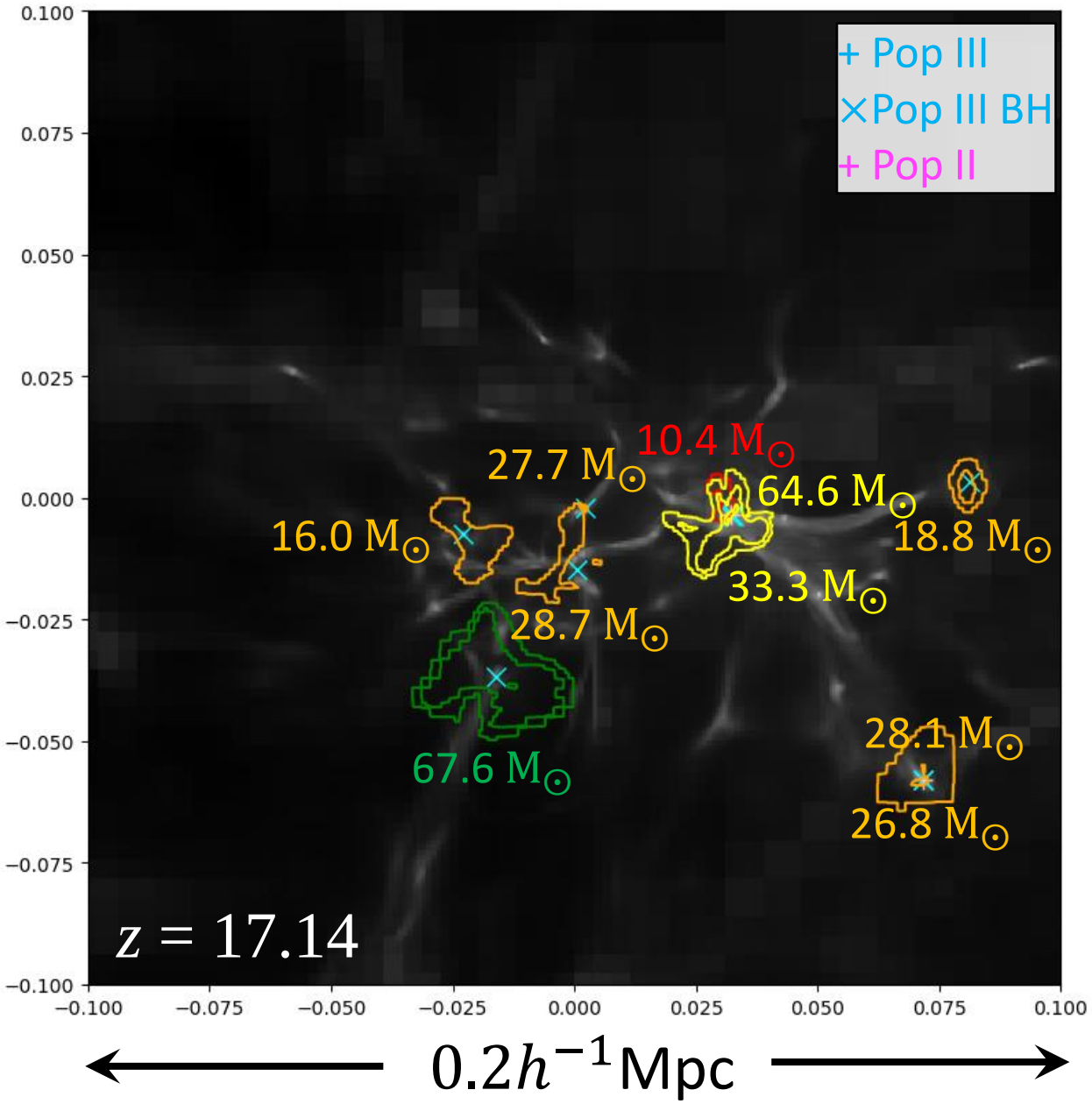


Metallicity

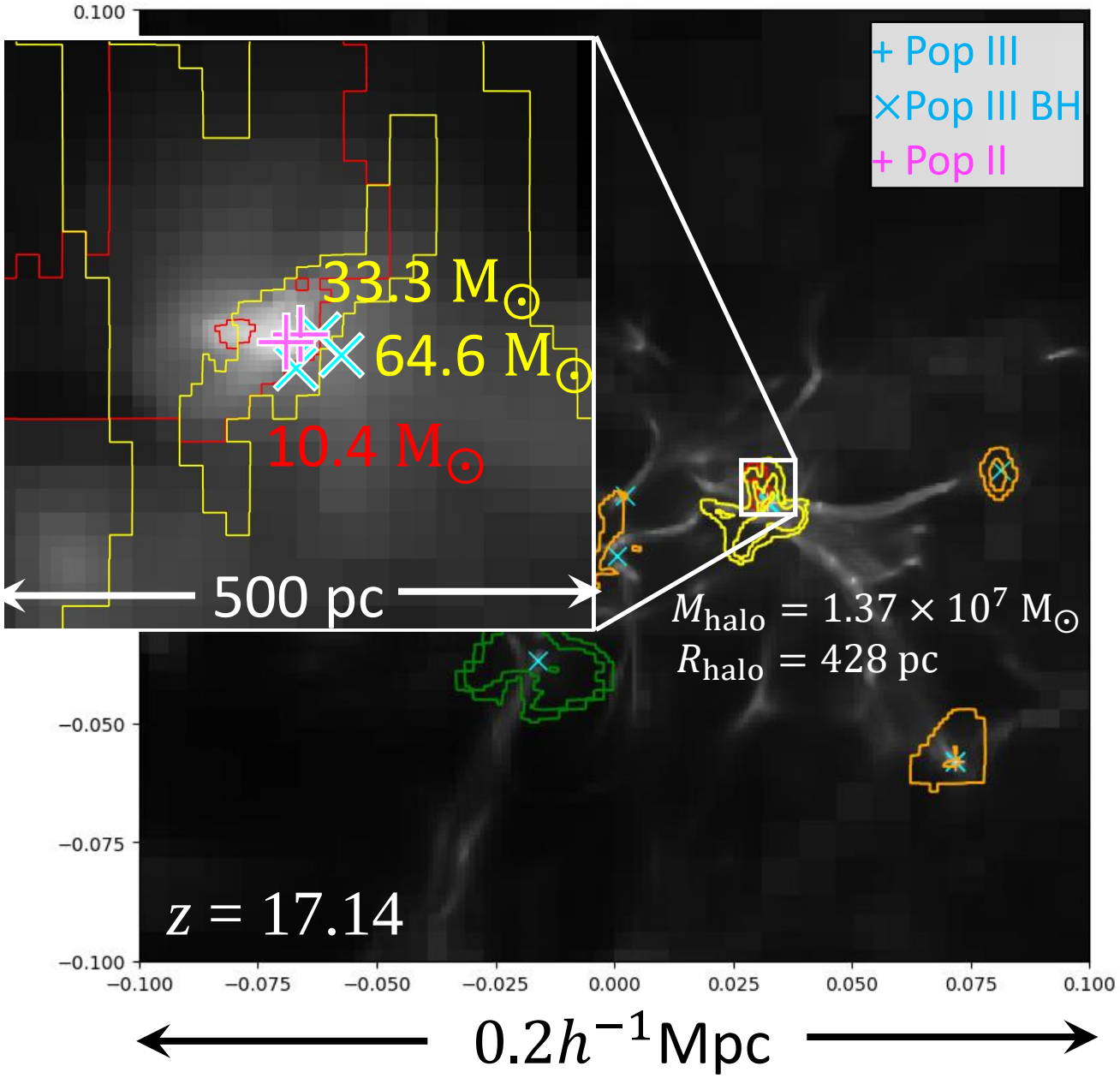


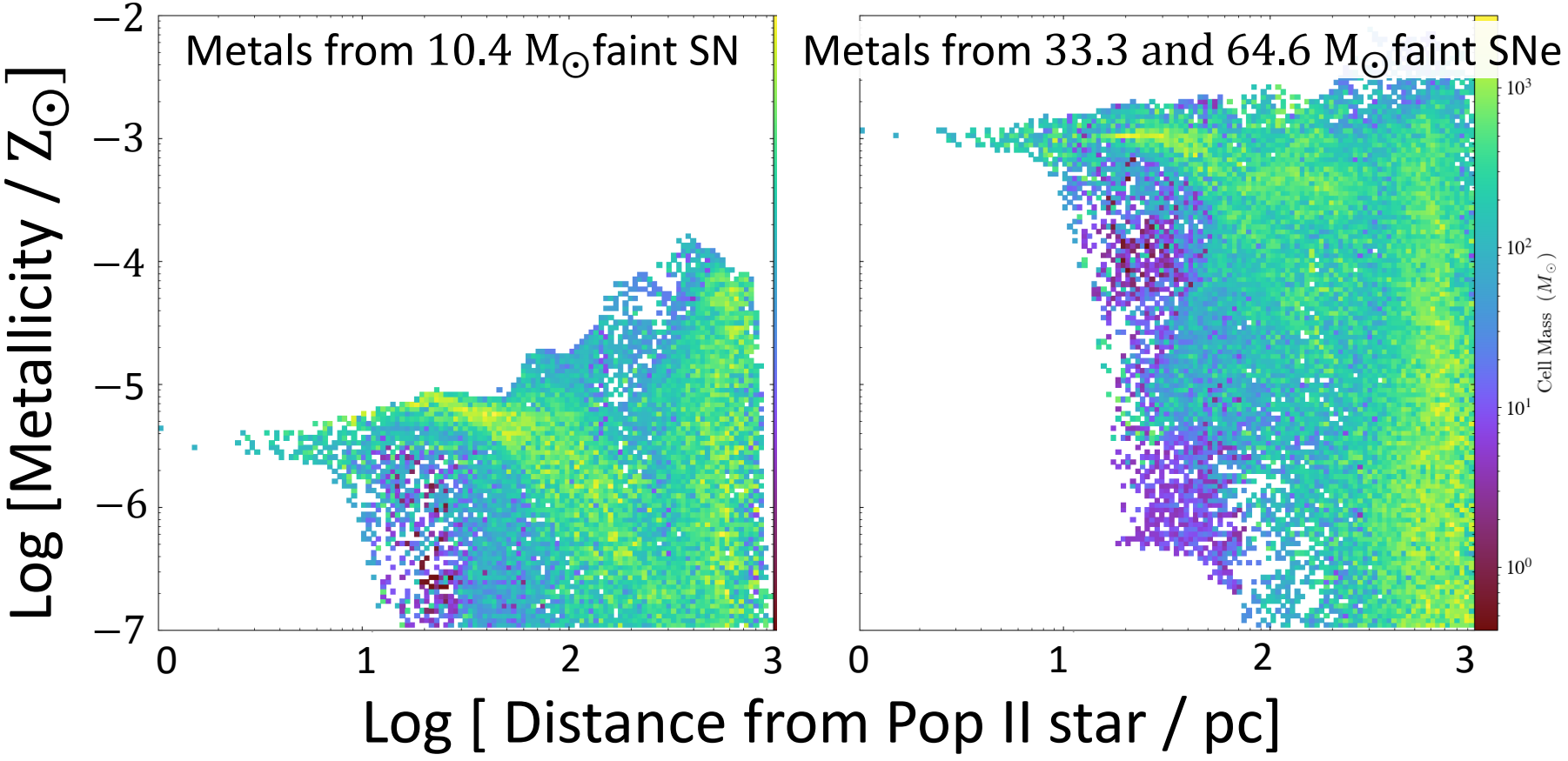


Metals from Pop III SNe with various masses



Pop II stars form in multi-enriched region!

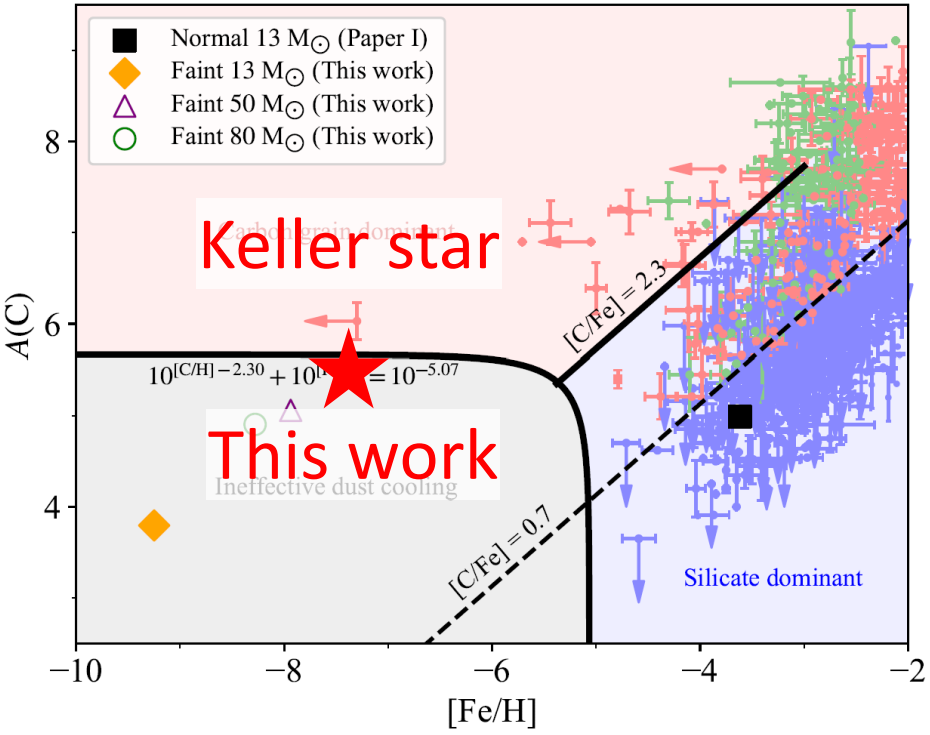




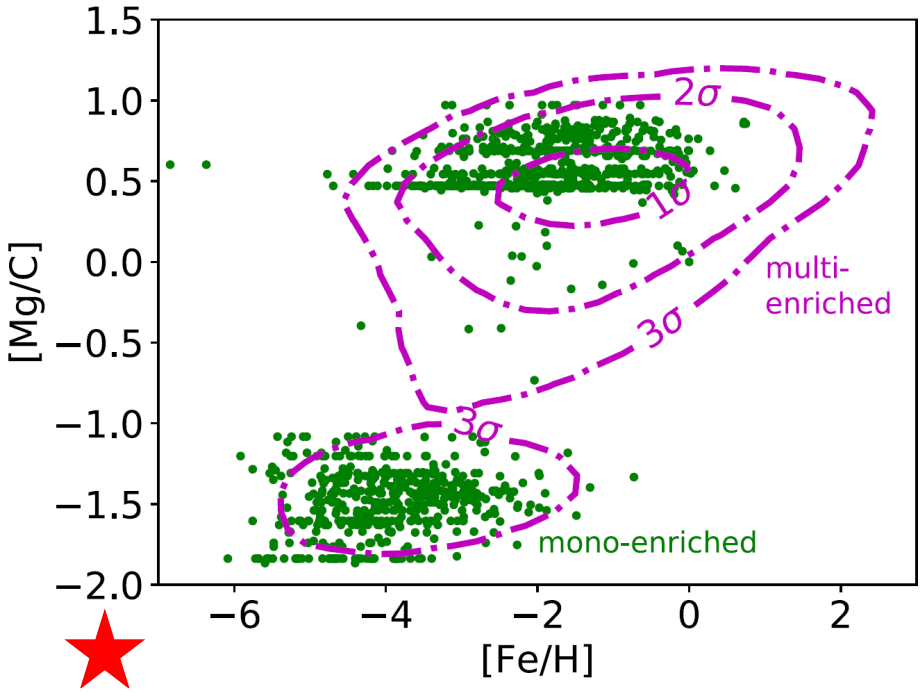
Metallicity within 5 pc

M_{PopIII} ($\mathrm{M}_\odot$)	Z_{met} ($\mathrm{Z}_\odot$)	A(C)	[Mg/C]	[Fe/H]
10.4	4.61×10^{-6}	3.49	-3.03	-9.55
33.3 + 64.6	8.51×10^{-4}	5.59	-2.52	-7.41
Total	8.56×10^{-4}	5.59	-2.52	-7.41

Discussion



Hartwig et al. (2018)



This work

- Similar abundances to Keller star (Keller et al. 2014)!
- Plotted in the mono-enriched region (Hartwig et al. 2018)?

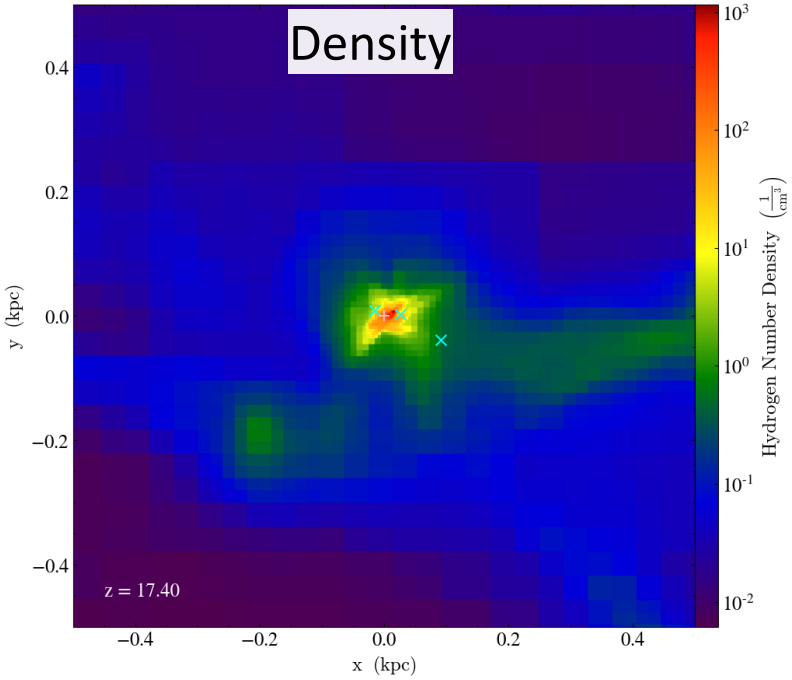
Summary

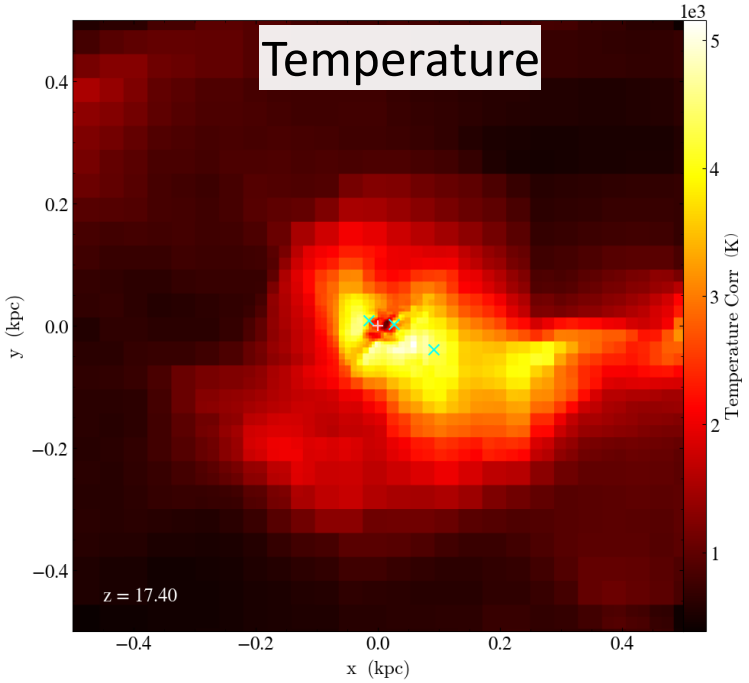
- Large volume cosmological simulation
- Pop II star formation in multi-enriched system
  - ✓ Its elemental abundance is similar to the one of Keller star
  - ✓ Plotted in the “mono-enriched” region of Hartwig et al. (2018)

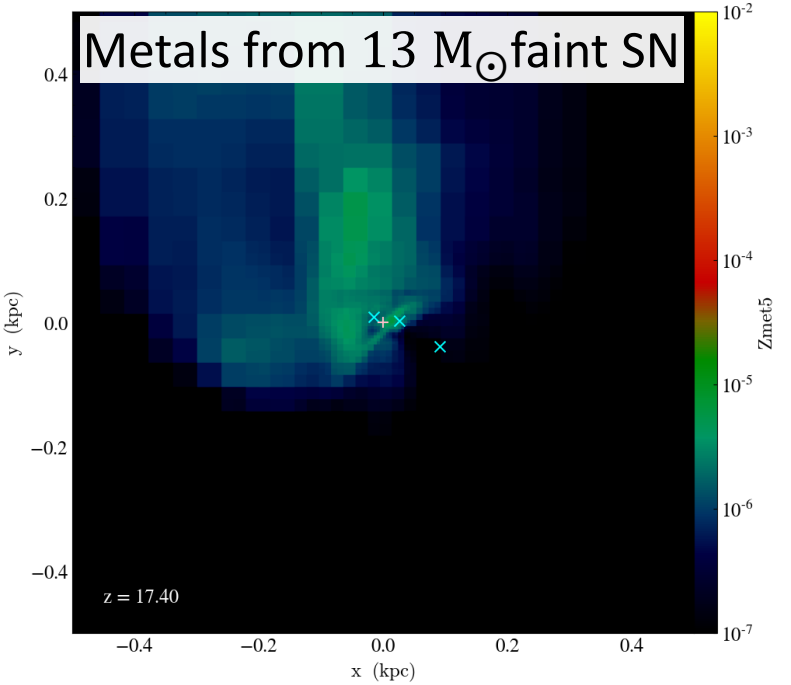
Next step

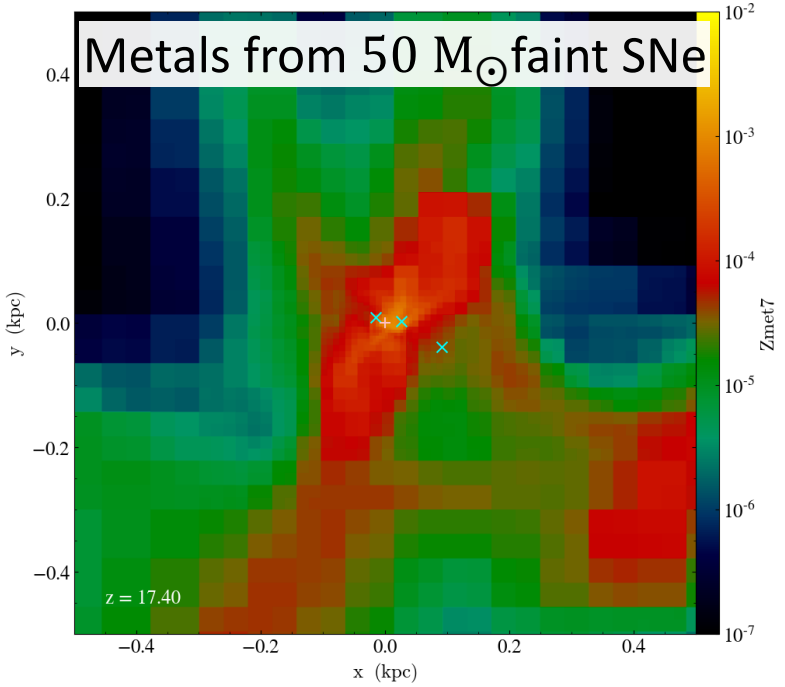
- Higher-resolution simulation
  - ✓ Top grid 512^3
  - ✓ Jeans criterion 64
- Statistical samples of Pop II stars

Thank you!


Density
z = 17.40
x (kpc)
y (kpc)
Hydrogen Number Density $\left(\frac{1}{cm^3}\right)$

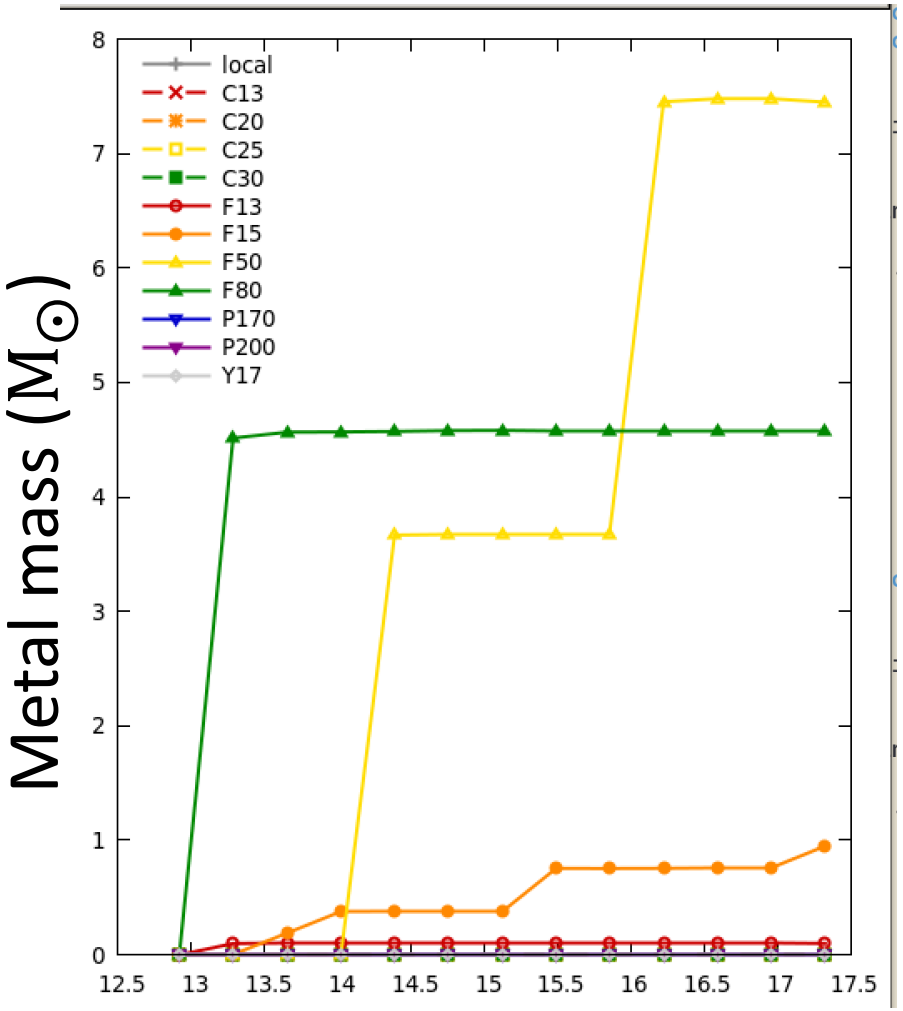

Temperature
1e3
z = 17.40
x (kpc)
y (kpc)
Temperature Corr (K)


Metals from 13 $M_\odot$ faint SN
z = 17.40
x (kpc)
y (kpc)
Zmet5

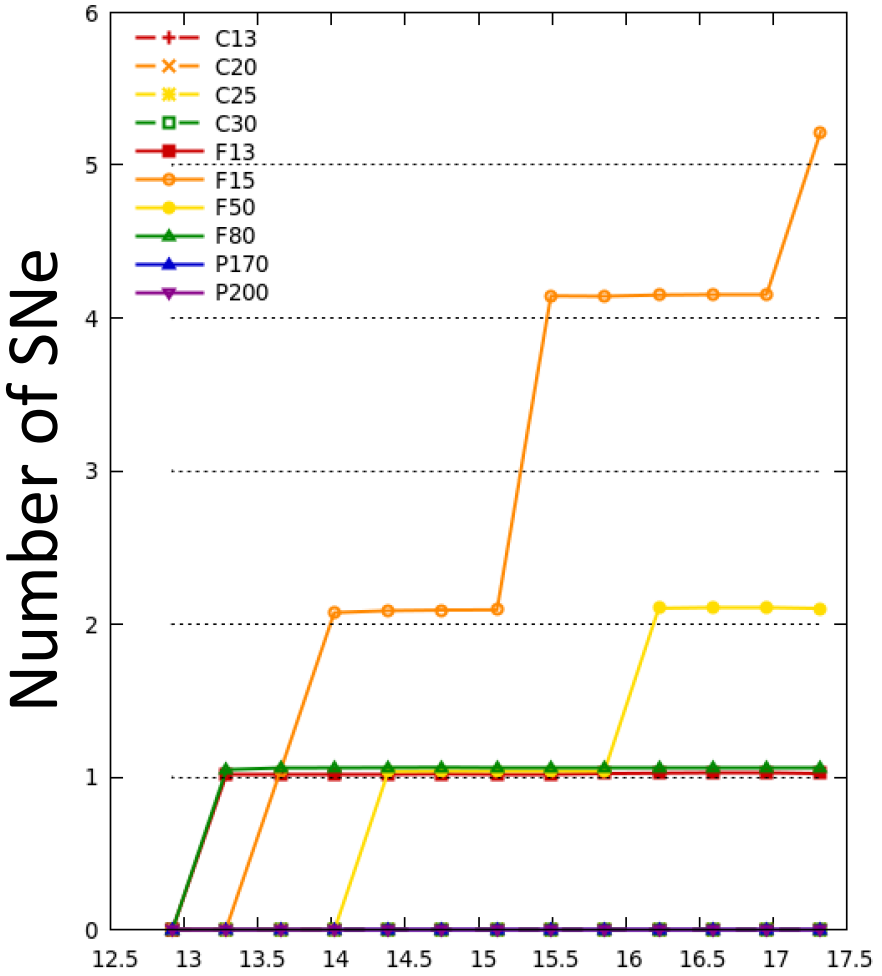

Metals from 50 $M_\odot$ faint SNe
z = 17.40
x (kpc)
y (kpc)
Zmet7

Metals from Pop III SNe with various masses

Ejected metal mass



Metal mass /
mass yield of each SN



Time (code unit)