# Metal Mixing in Primordial Minihaloes


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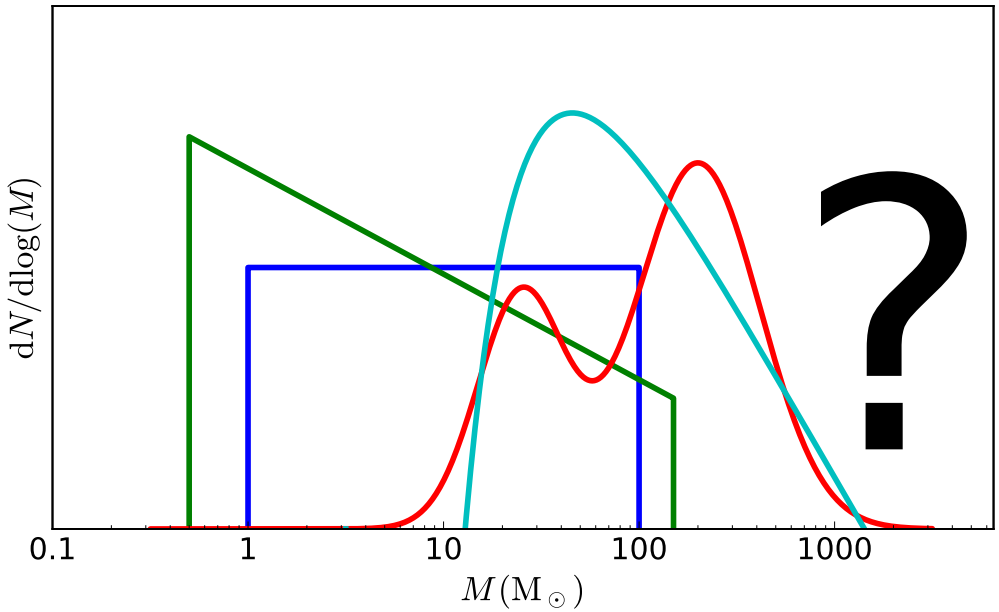
# Background: What is the Pop III IMF?

Question:

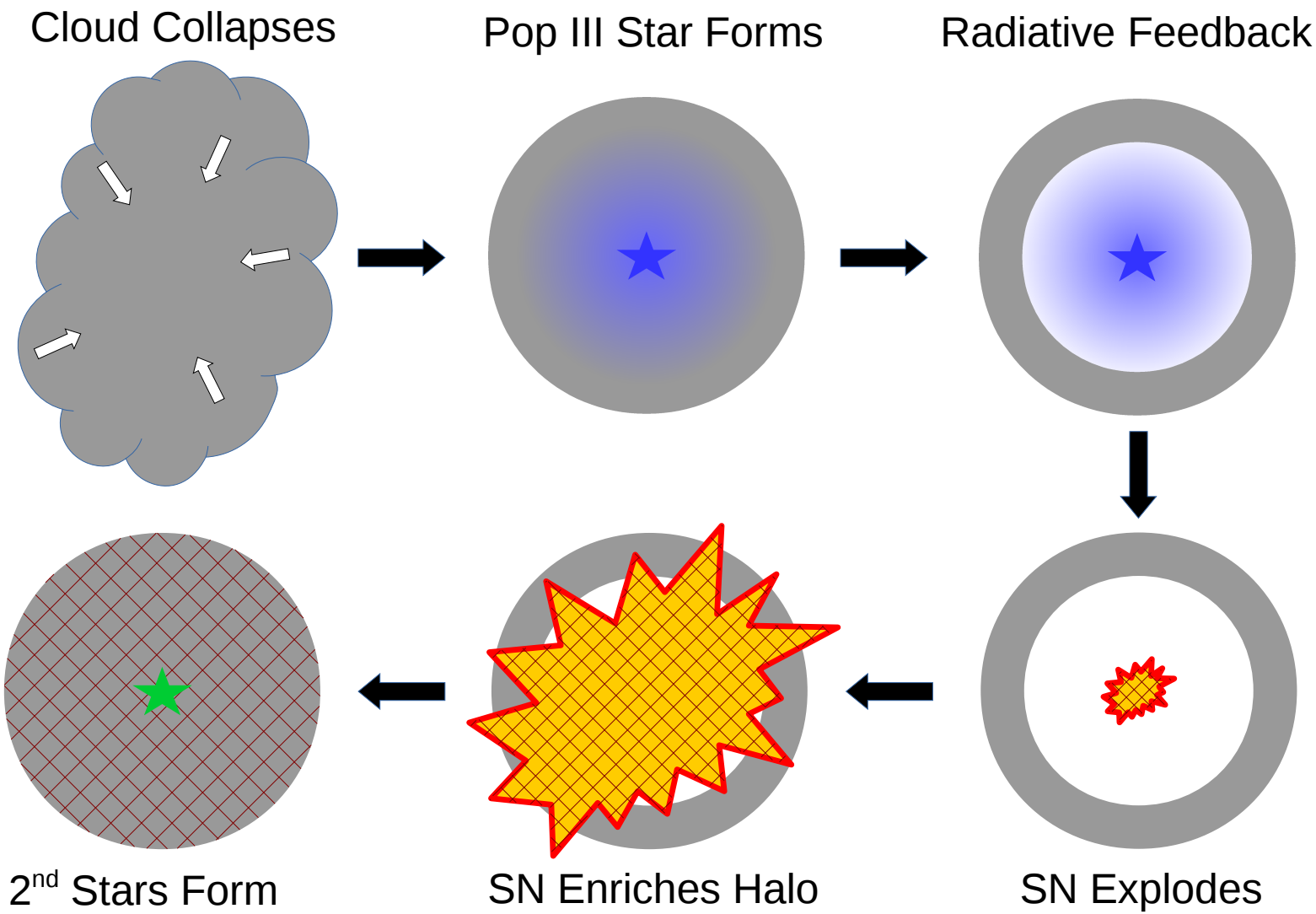



- Only observations: abundance patterns
- Assumes: $M_*$ $\Leftrightarrow$ SN $\Leftrightarrow$ abundance patterns

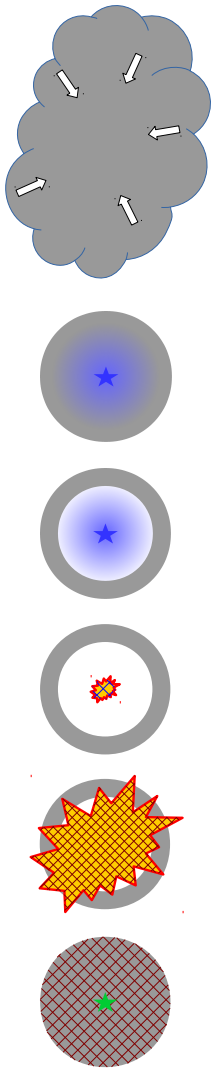
However:

Mixing between SN and $2^{\mathrm{nd}}$ generation stars?
(e.g. Ritter+15, Hartwig+18 (+MM))

# From First to Second Stars



# Simulations: Toolbox



- AREPO (Springel 2010) simulations
- Resolve minihaloes (Schauer et al. 2017)
- Primordial chemistry (Glover 2015)
- Sink particles (Paul Clark)
- SPRAI Radiative transfer (Jaura et al. 2018)
- Supernovae (Treß et al. in prep.)
- Monte-Carlo tracer (Genel et al. 2013)
- SN yields (Nomoto+ 2013 or Ishigaki+ 2018)

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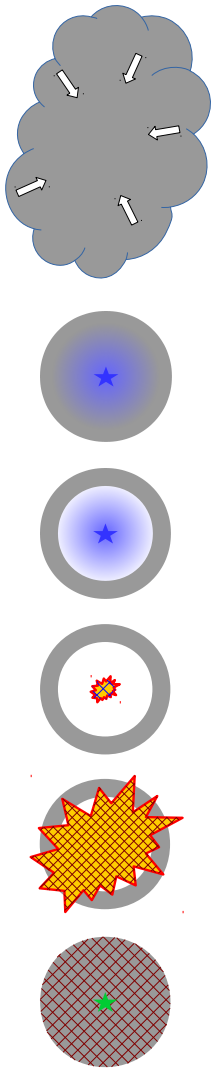


## Sprai / Simplex

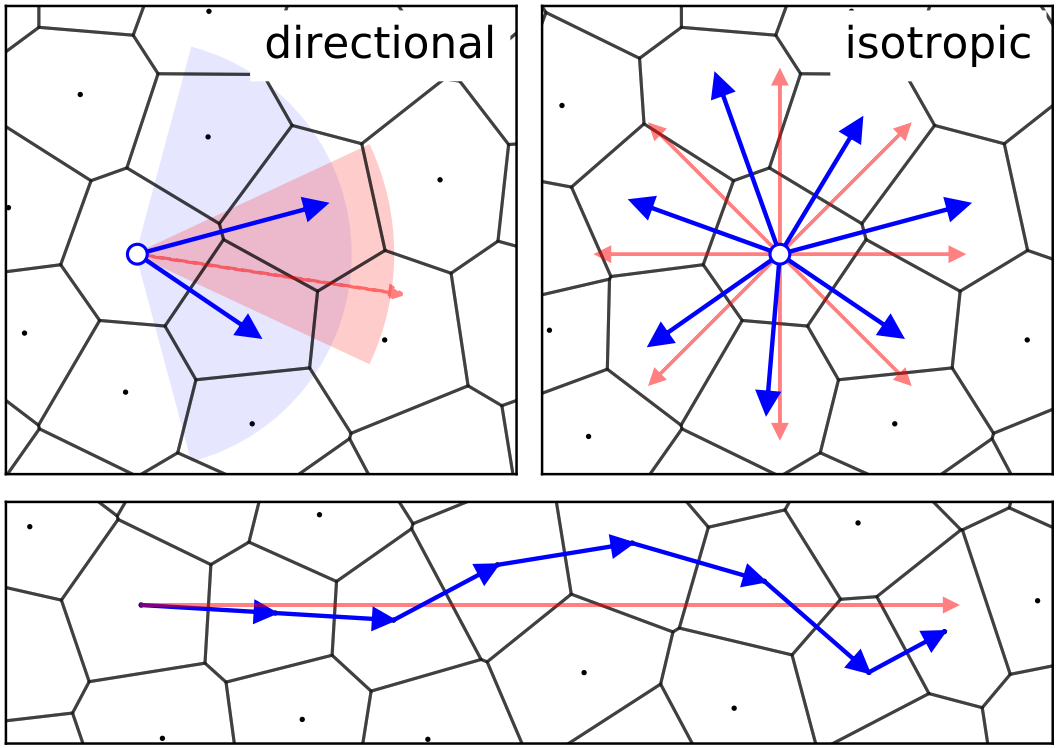
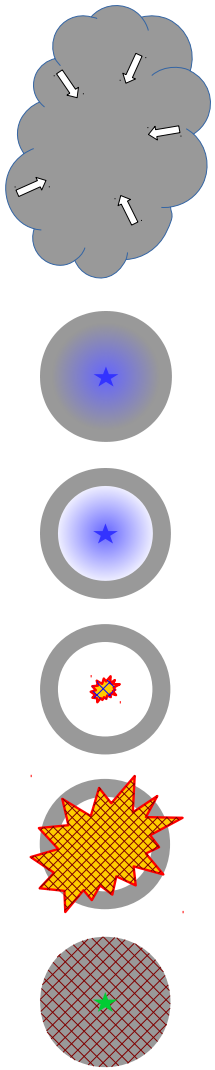



Figure from Jaura et al. 2018 MNRAS, 475, 2822

# Simulations: Toolbox



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# Simulations: Setup

- $125\,\mathrm{kpc}\,h^{-1}$, $\sigma_8 = 1.4$
  $250\,\mathrm{kpc}\,h^{-1}$, $\sigma_8 = 1.2$
- Resolution: $\sim 160\,\mathrm{M}_\odot$ gas + refinement
- Test: different stars and combinations of stars ($25\,\mathrm{M}_\odot$, $30\,\mathrm{M}_\odot$, $40\,\mathrm{M}_\odot$, $100\,\mathrm{M}_\odot$, $160\,\mathrm{M}_\odot$, $30{+}15\,\mathrm{M}_\odot$)

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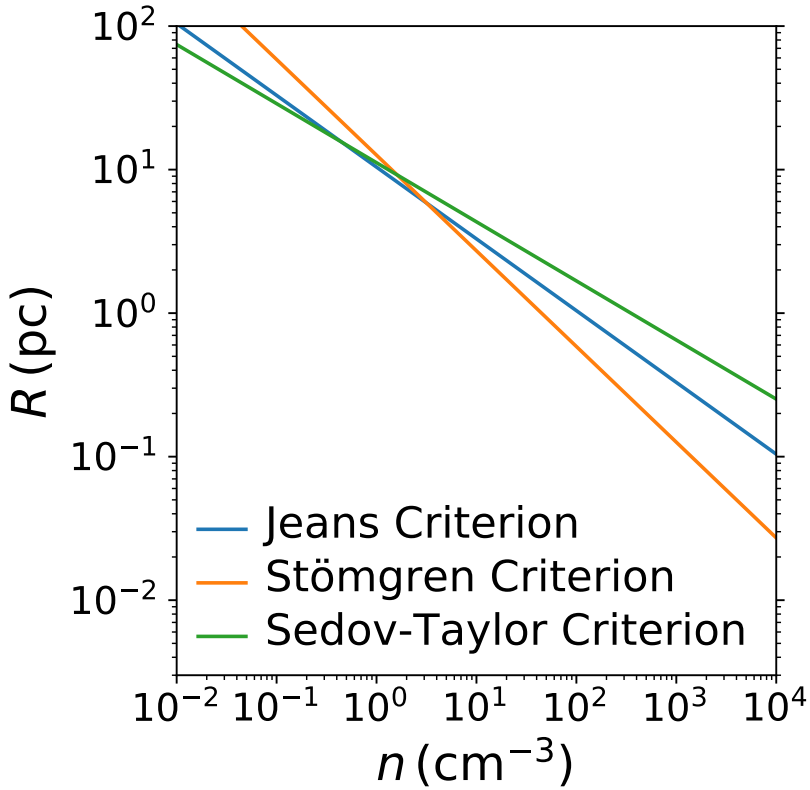


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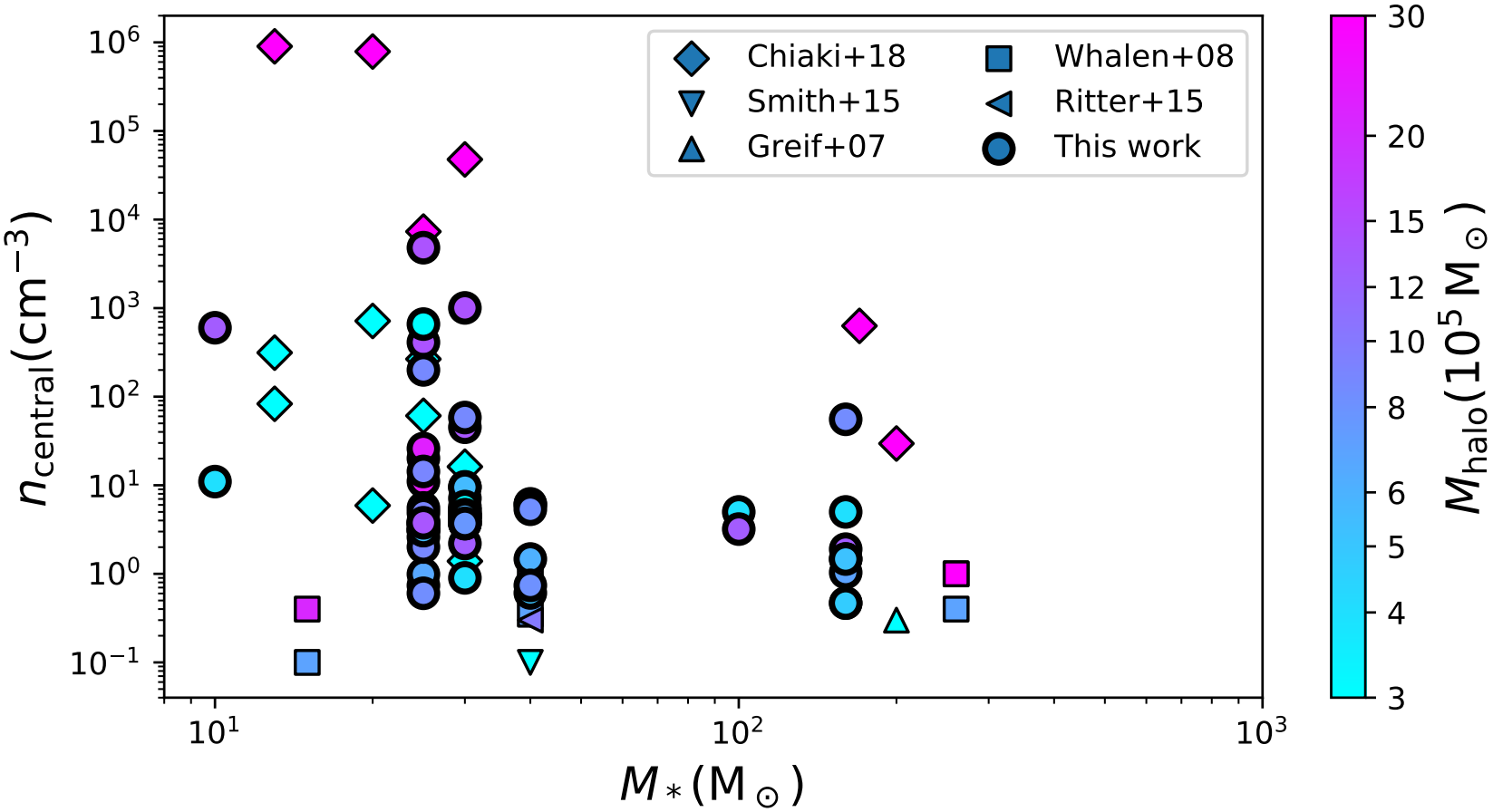
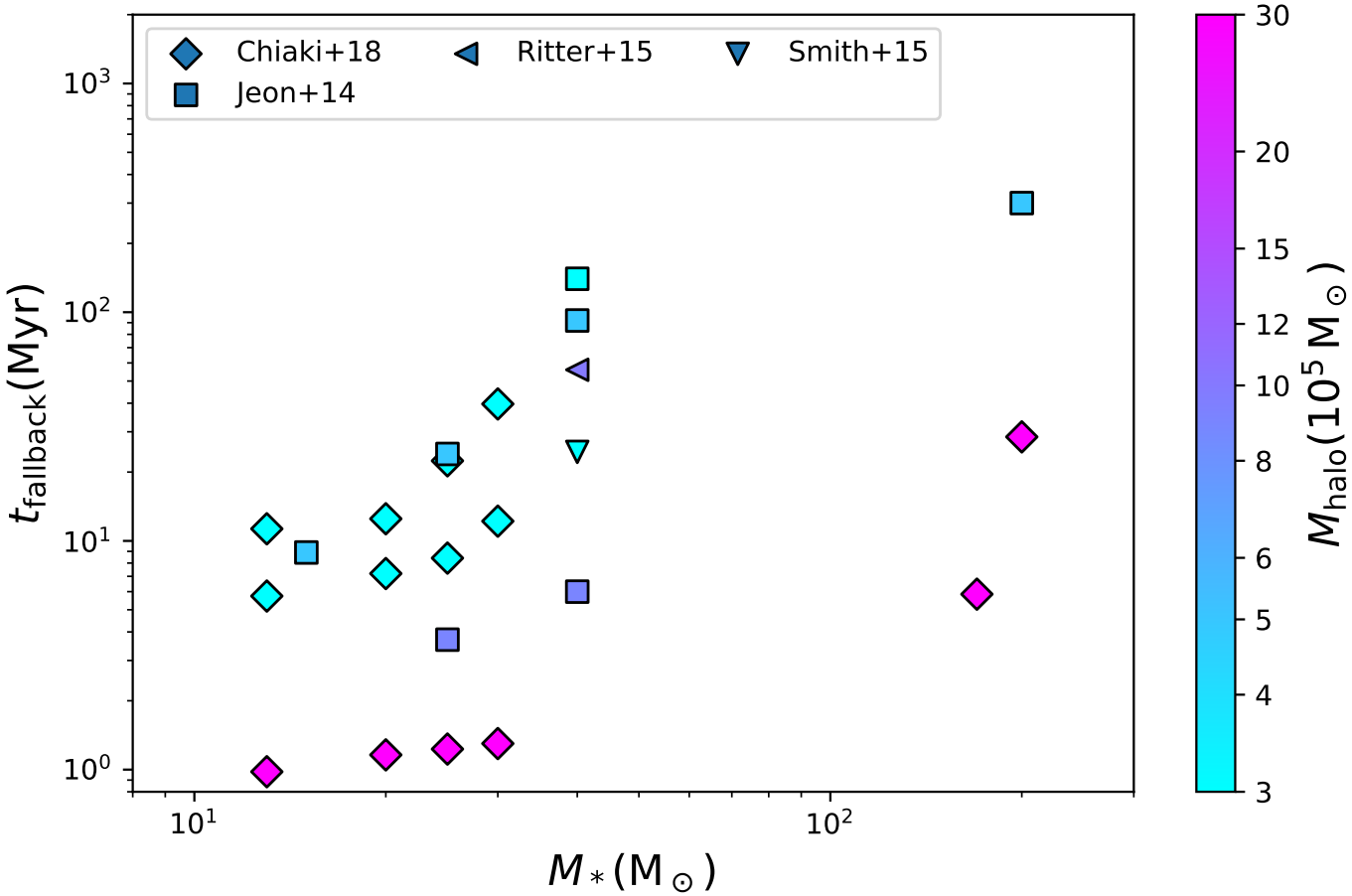
- Resolution: $\sim$160 $\mathrm{M}_\odot$ gas + refinement
- Test: different stars and combinations of stars (25 $\mathrm{M}_\odot$, 30 $\mathrm{M}_\odot$, 40 $\mathrm{M}_\odot$, 100 $\mathrm{M}_\odot$, 160 $\mathrm{M}_\odot$, 30+15 $\mathrm{M}_\odot$)

# Environment of SNe



# Time Delay for the Second Generation Stars



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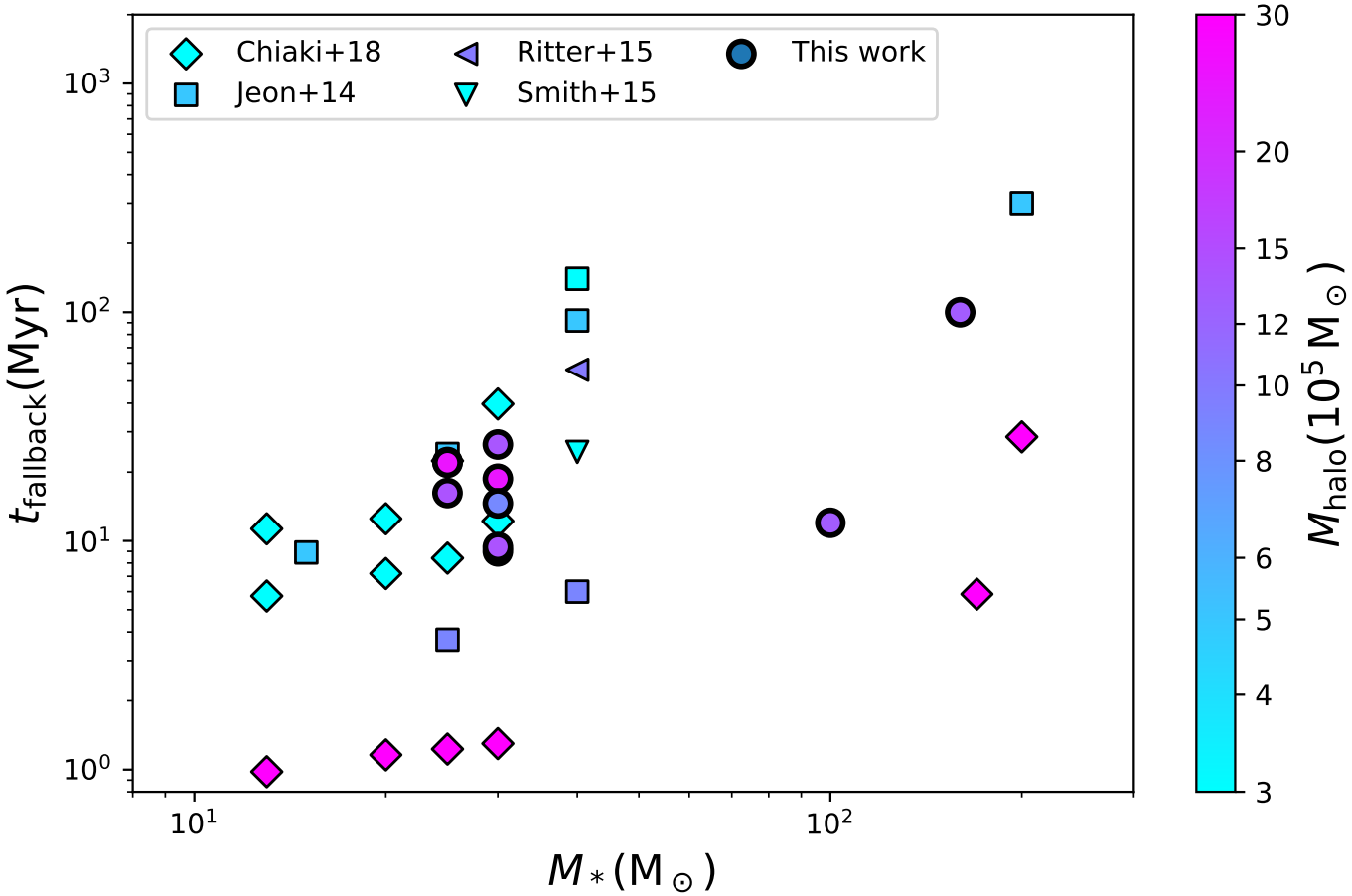


- Fallback takes long enough for subsequent SNe

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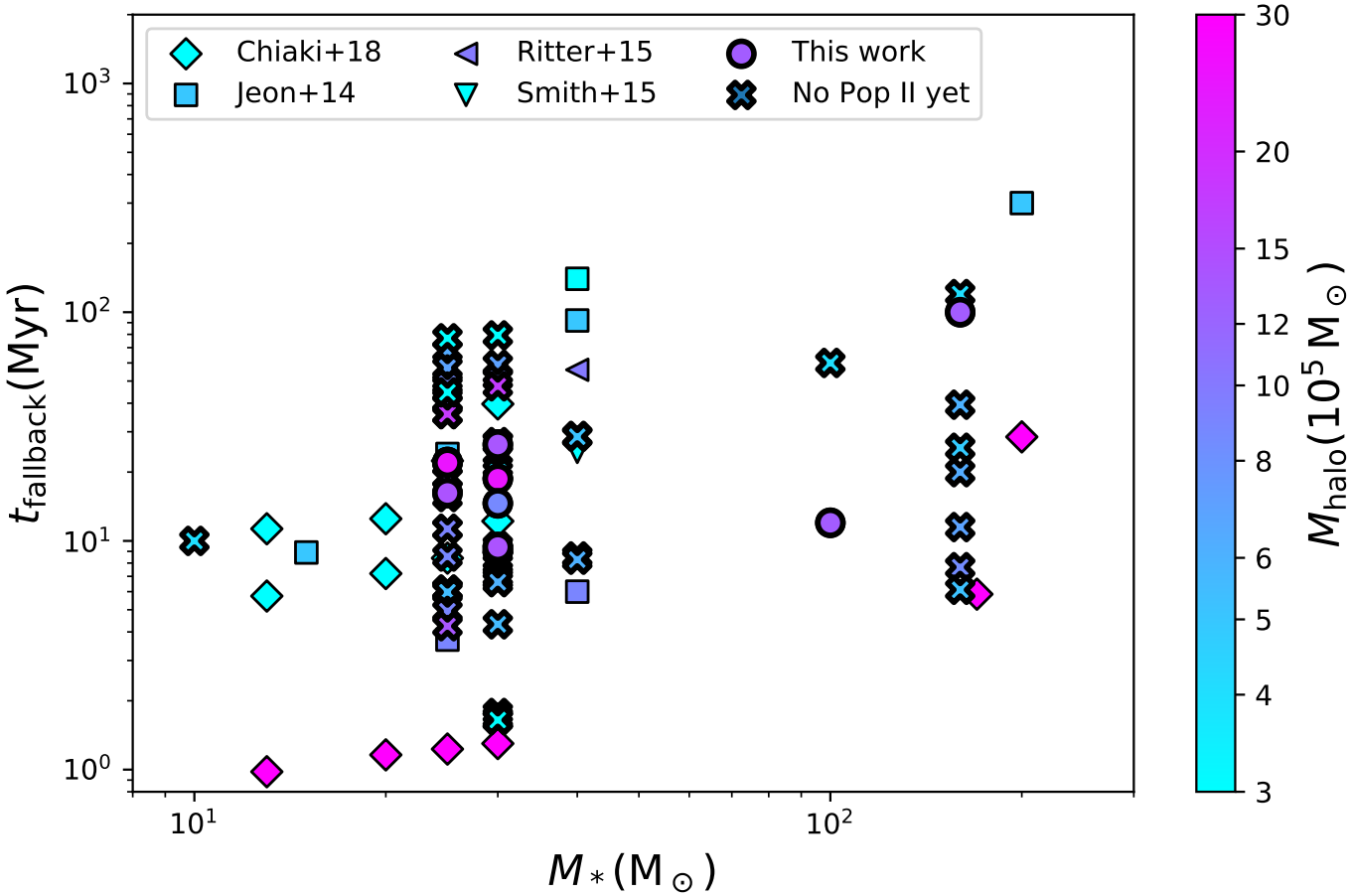
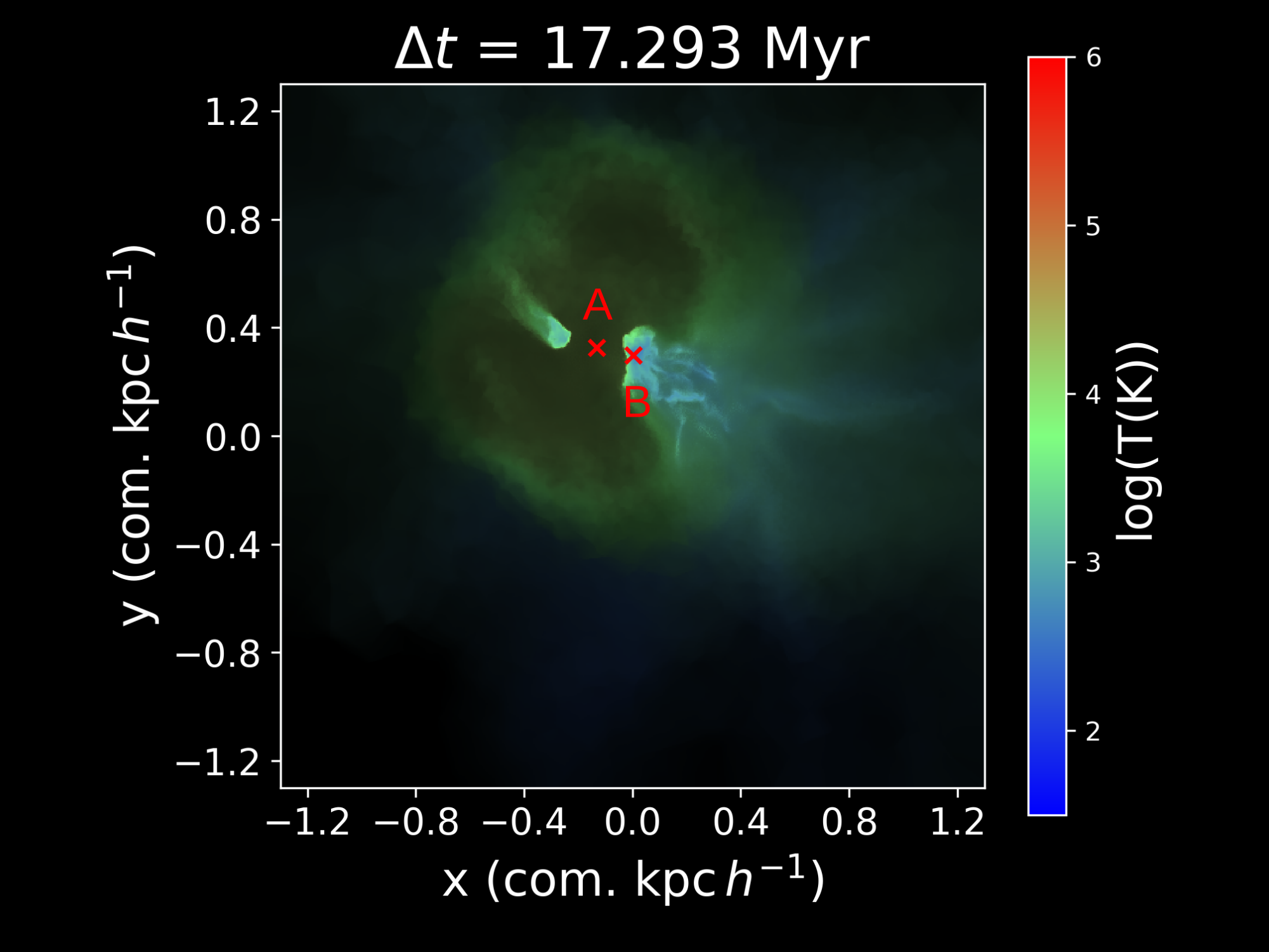
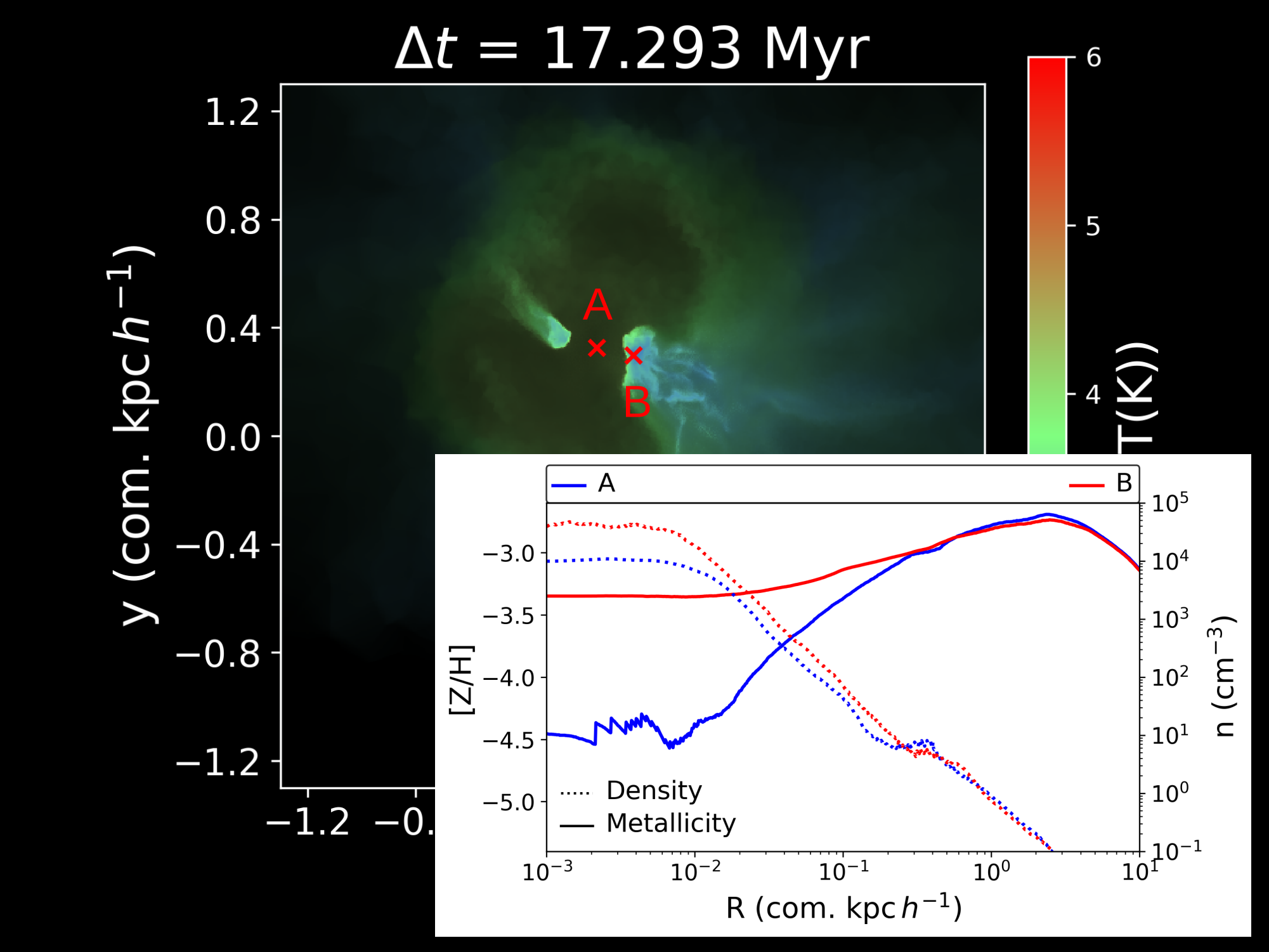


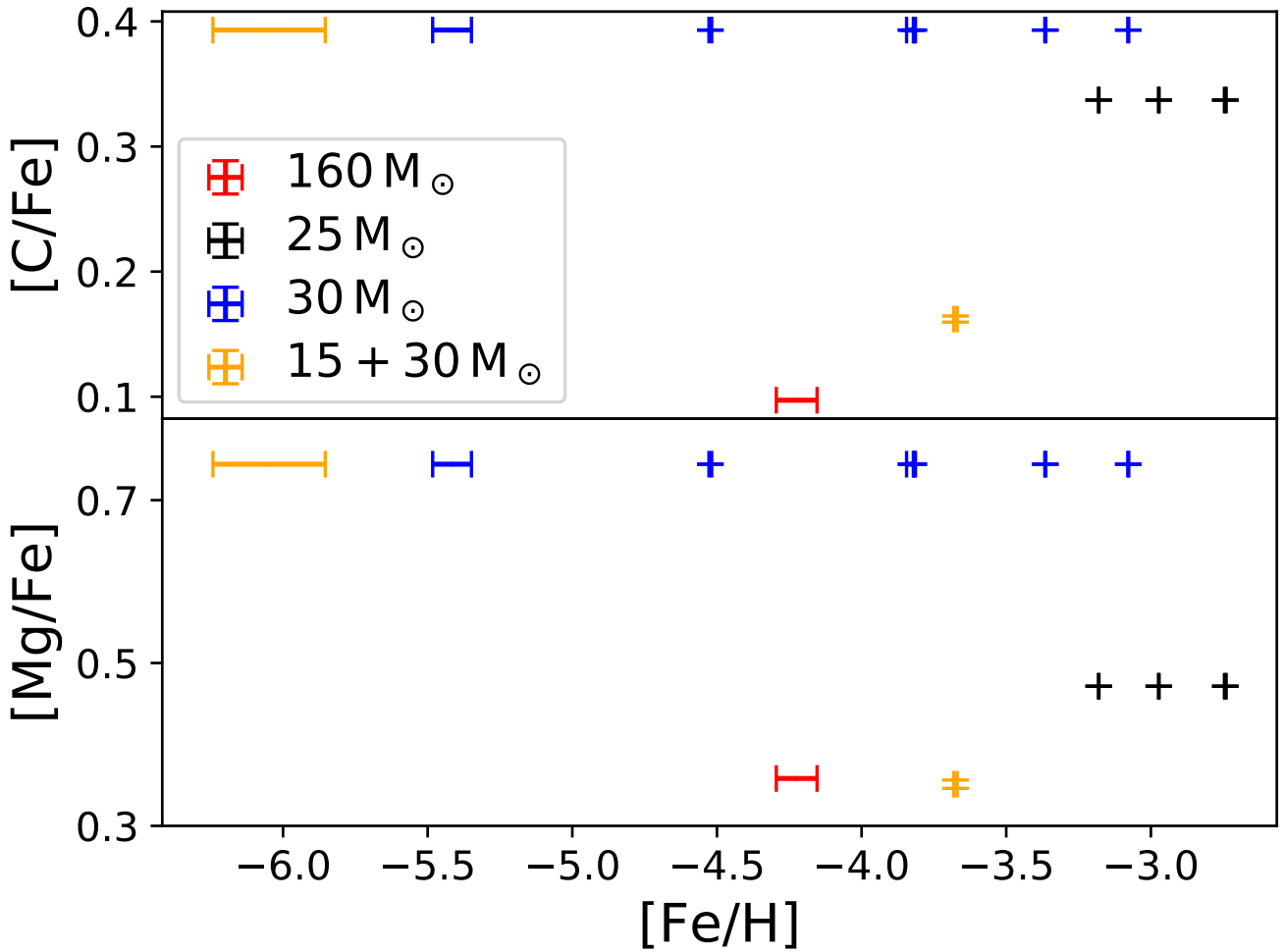

- Fallback takes long enough for subsequent SNe

A movie of first and second generation star formation was shown here. It is available on request.


Δt = 17.293 Myr
A
B
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
y (com. kpc h^−1)
−1.2 −0.8 −0.4 0.0 0.4 0.8 1.2
x (com. kpc h^−1)
6
5
4
3
2
log(T(K))


Δt = 17.293 Myr
A
B
y (com. kpc h⁻¹)
T(K))
6
5
4
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.2 −0.
A
B
[Z/H]
n (cm⁻³)
−3.0
−3.5
−4.0
−4.5
−5.0
10⁵
10⁴
10³
10²
10¹
10⁰
10⁻¹
Density
Metallicity
10⁻³
10⁻²
10⁻¹
10⁰
10¹
R (com. kpc h⁻¹)

# Modelled Abundances




with yields from Nomoto+ 2013

# Summary

1. Toolbox for studying formation of $2^{\mathrm{nd}}$ generation stars
2. Metal mixing is inhomogeneous
3. Scatter: halo-to-halo, explosion energies
4. Two distinct modes of internal enrichment?

   (See also: Chiaki + 2018)