



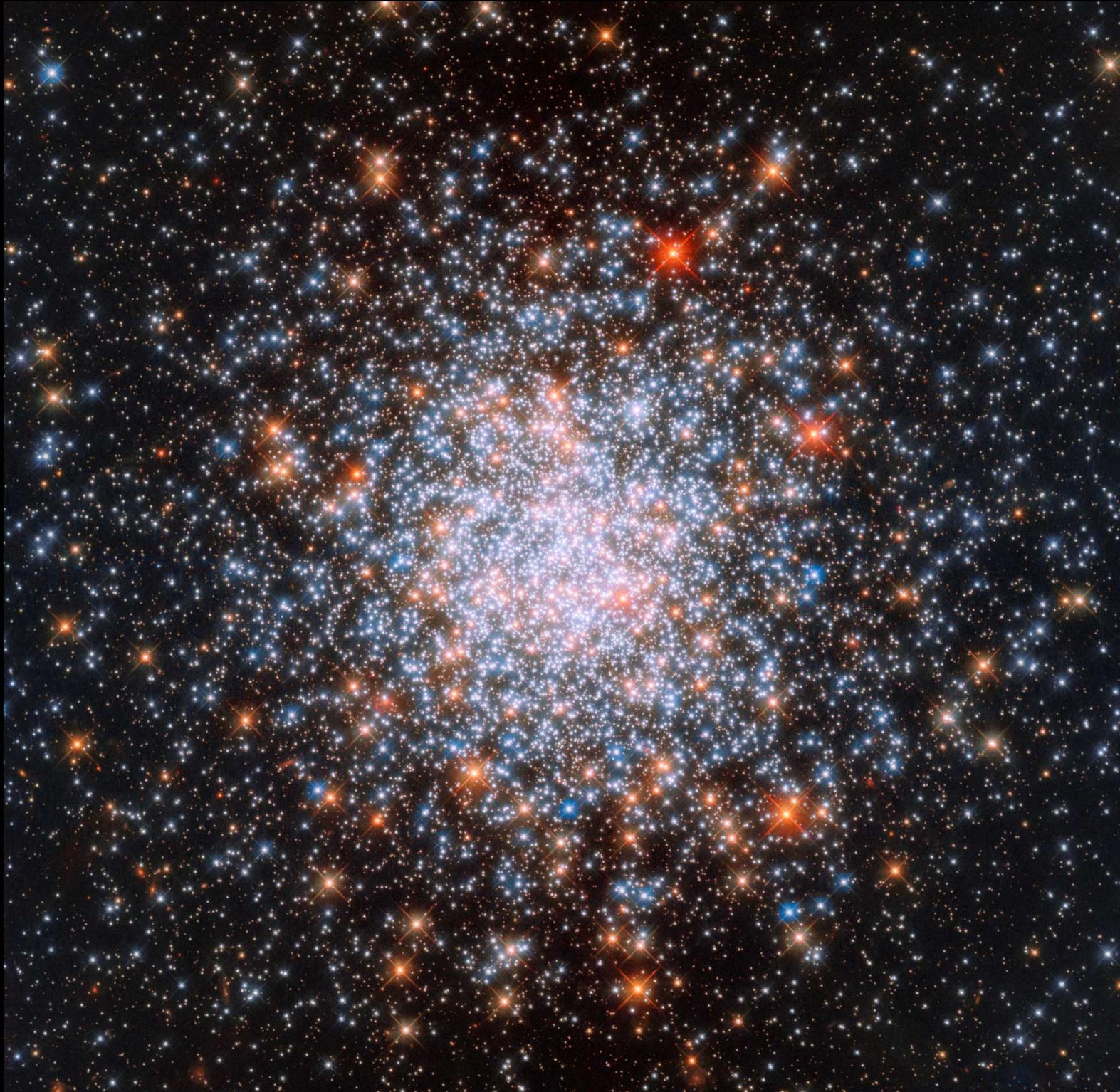
The role of Type Ia supernova feedback on the second generation formation in globular clusters

Elena Lacchin

In collaboration with: F. Calura, E. Vesperini

RUM 2021 - 27 September 2021

Globular clusters



- ▶ old: $\sim 10\text{-}12$ Gyr
- ▶ compact: $R_h \sim$ a few pc
- ▶ most of them host metal-poor stars
- ▶ almost mono-metallic $\sigma_{[\text{Fe}/\text{H}]} < 0.10$ dex
- ▶ show anti-correlations among light elements abundances

NGC 1866

Credit: NASA / ESA / Hubble

AGB scenario

Second generation (SG) stars form from the AGB ejecta of the first generation (FG)

BUT

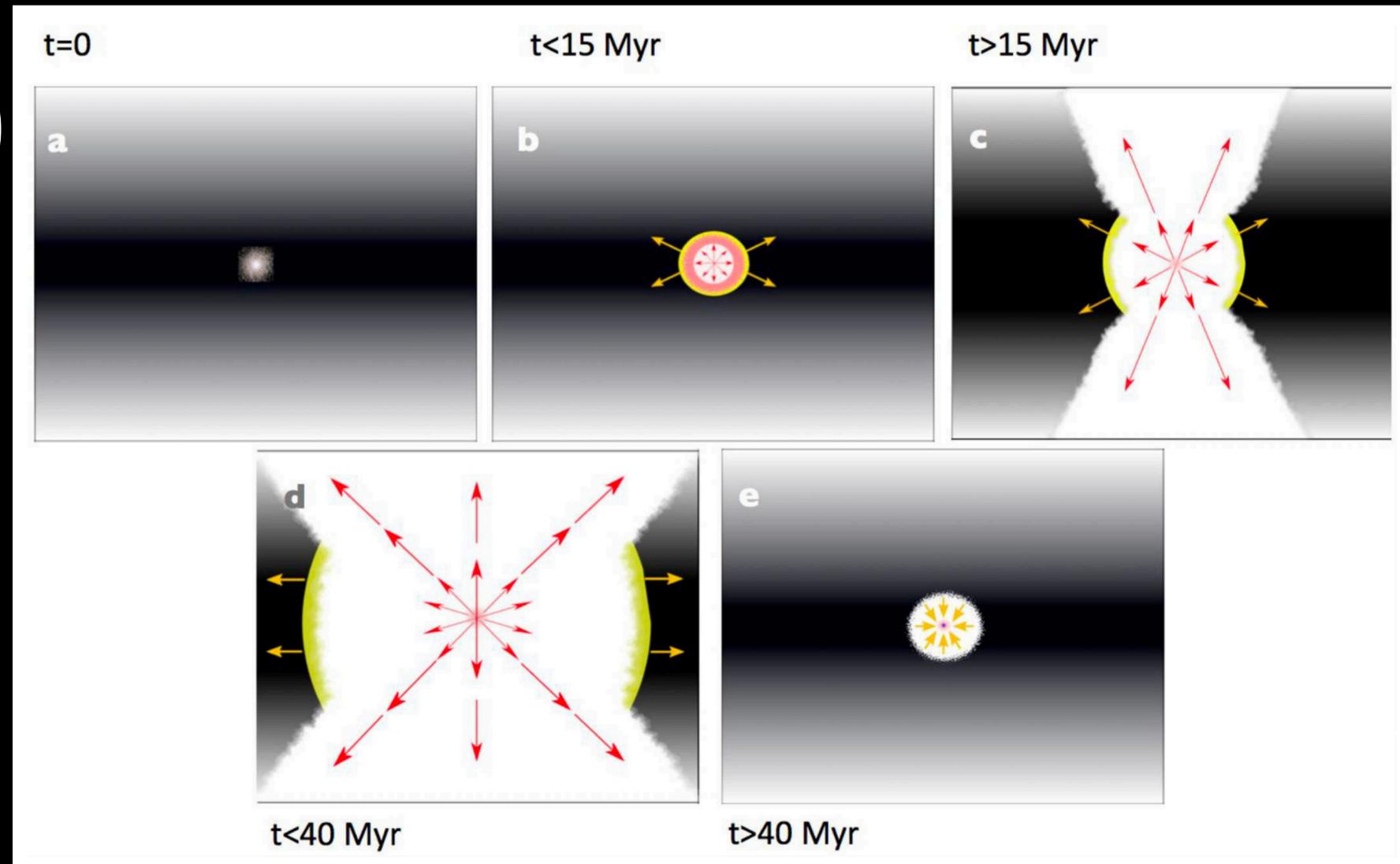
With AGB ejecta only,
SG abundance patterns are not reproduced



dilution with pristine gas

SG stars abundances range from those of FG ones to pure AGB yields

D'Ercole+16



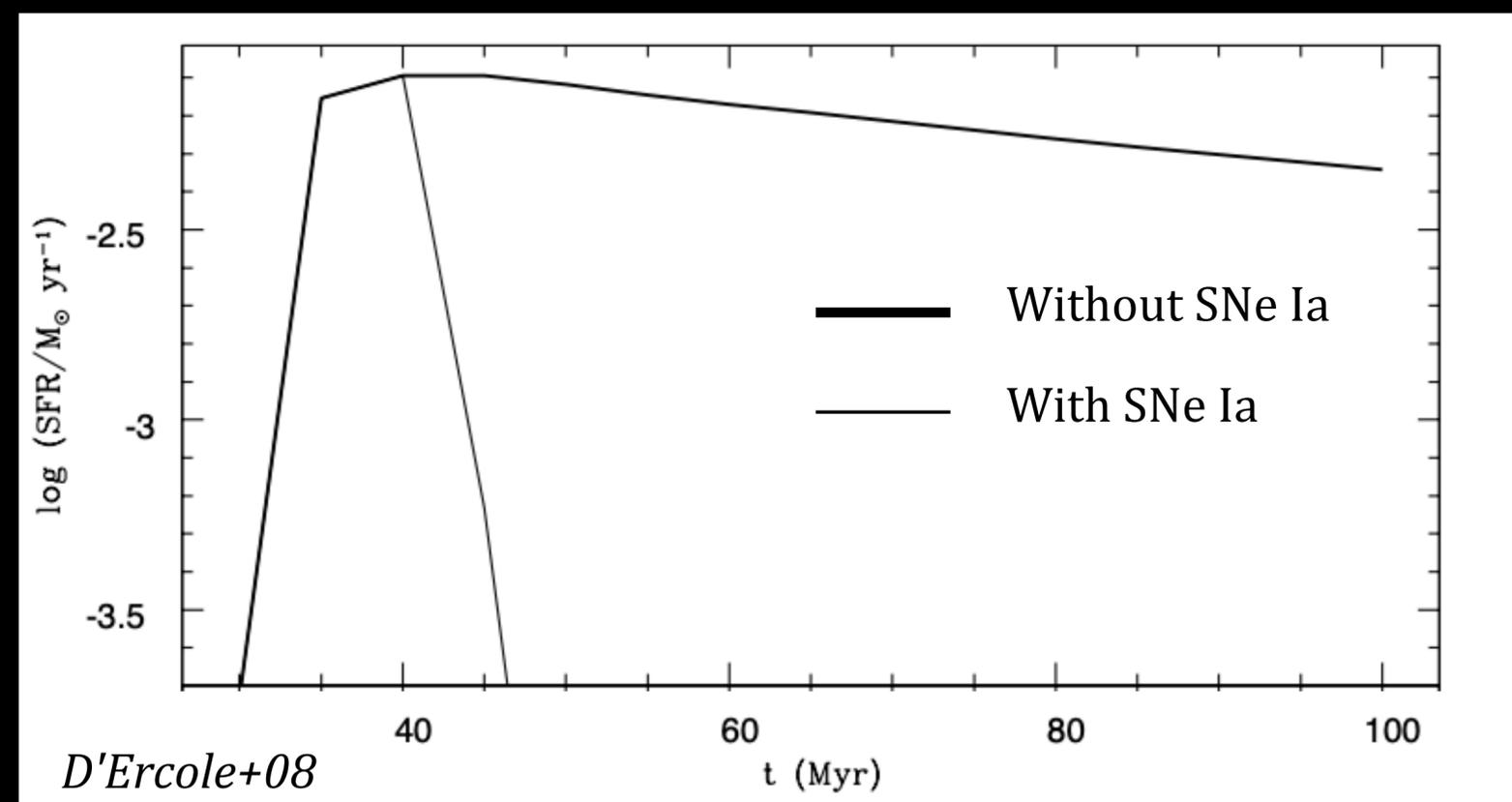
What is halting the SG formation?

In the AGB scenario, it is assumed that **Type Ia SNe** halt the SG formation after some hundreds Myr

Is it really so?

Which are the side effects?

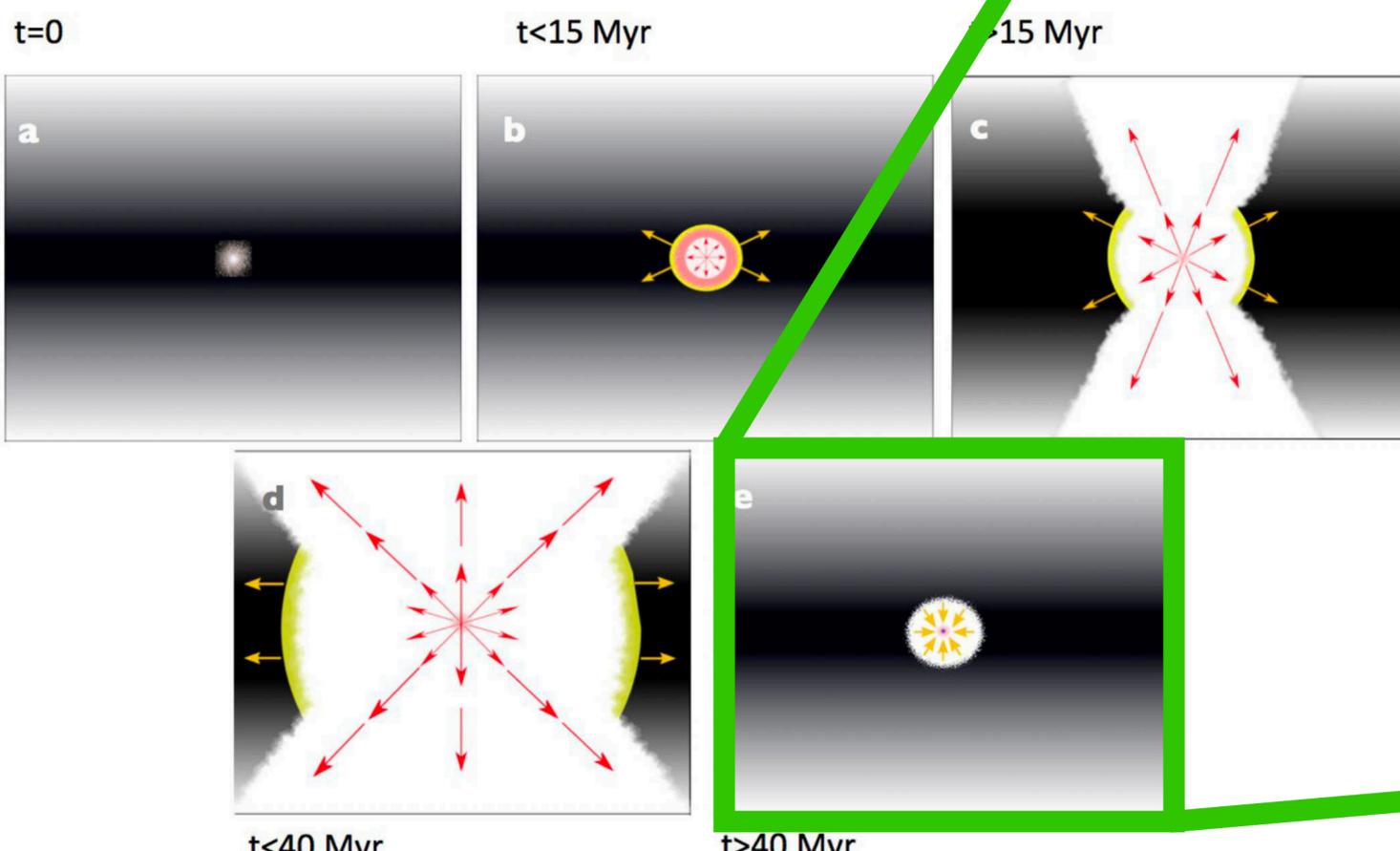
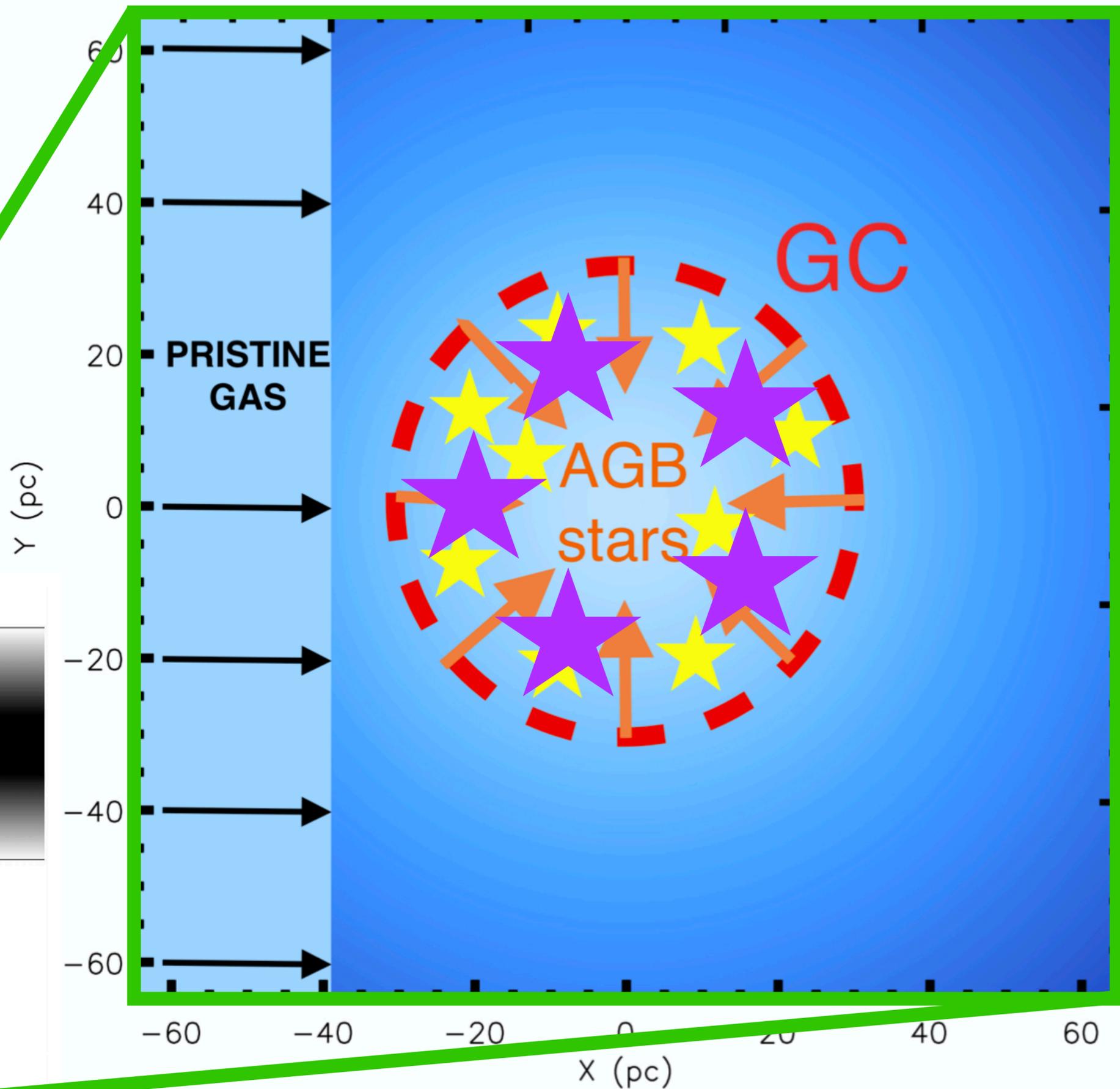
SFR evolution in **1D** simulations



Initial setup



Type Ia SNe



Initial setup

- $M_{\text{FG}} = 10^7 M_{\odot}$ distributed following a Plummer profile with $a = 23 \text{pc}$
- AGBs continuous sources of mass and energy modelled as an external potential
- 10^3 Type Ia SNe modelled as instantaneous sources *Greggio+05 + Salpeter IMF*
- Pristine gas will infall in the system depending on the initial gas density

$$\rho_{\text{pg}} = (10^{-23}, 10^{-24}) \text{g/cm}^3$$

- Star formation follows: $\dot{\rho}_{\star} = \frac{\rho}{t_{\star}}$ (Schmidt - Kennicutt law)

Type Ia SNe - feedback

Each SN injects:

- $1.44 M_{\odot}$ of ejecta, all metal
- $0.5 M_{\odot}$ of Fe *Scalzo+14*
- 10^{51} erg of thermal energy

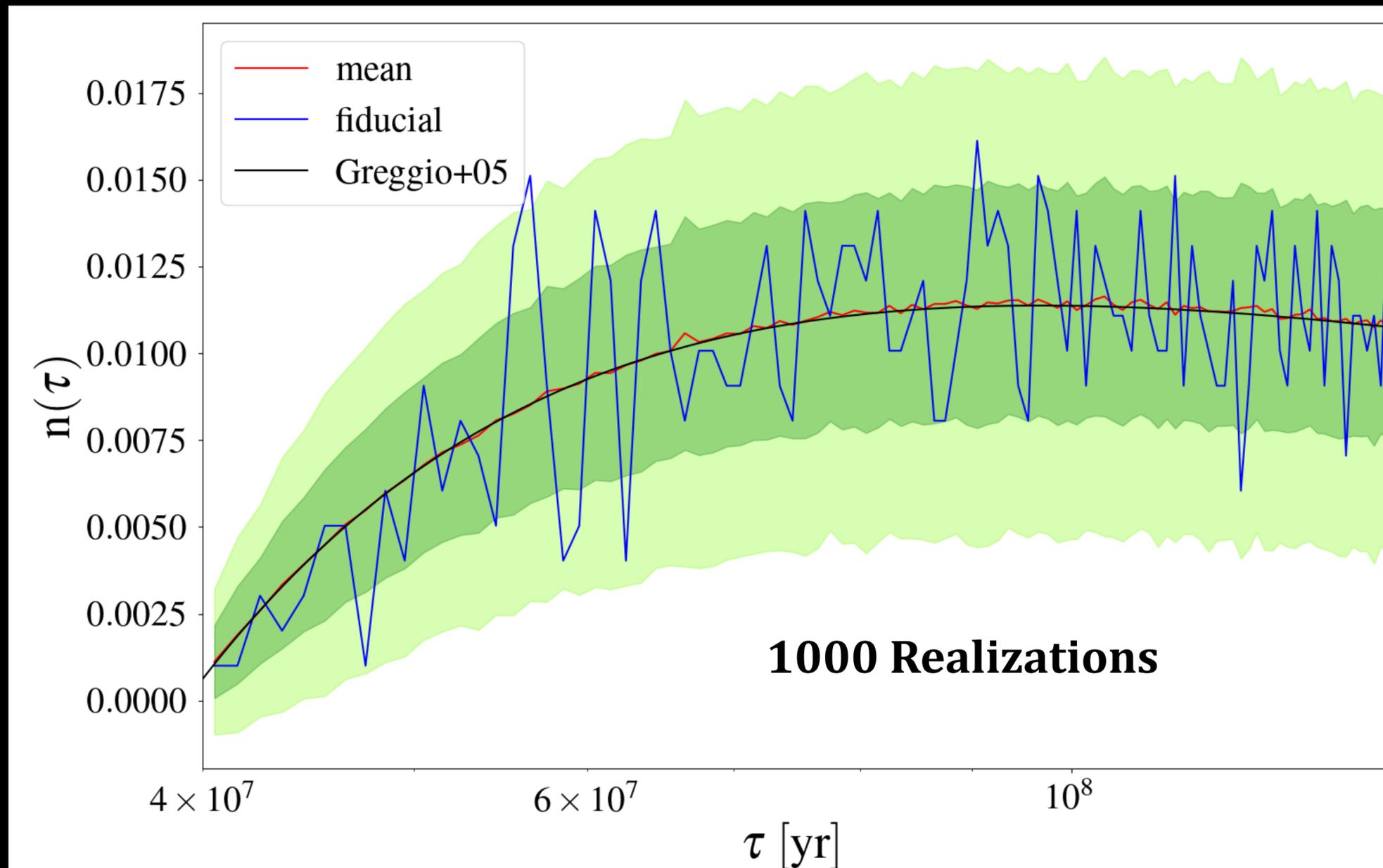
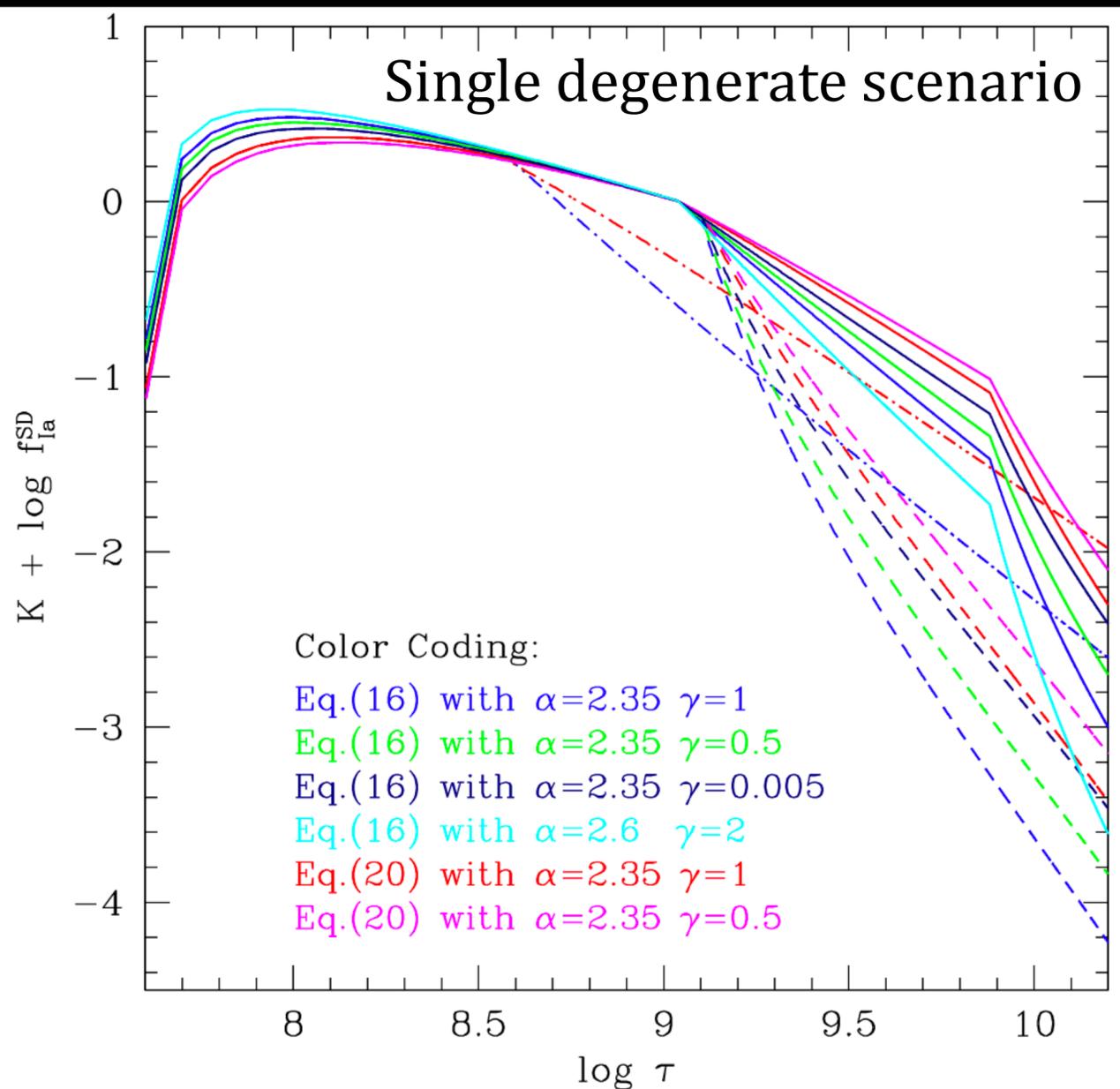


Credit: NASA/JPL-Caltech

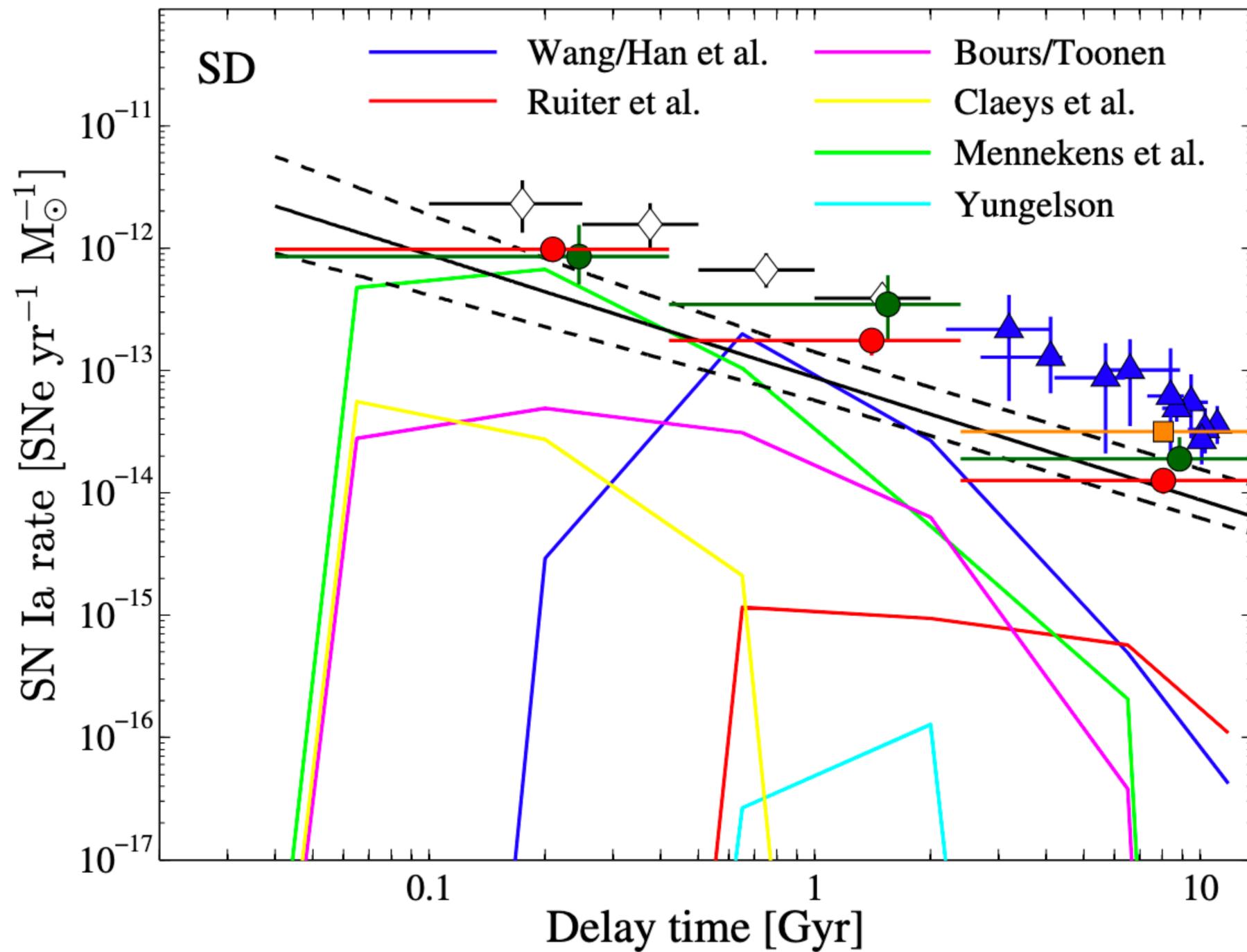
SNR 0509-67.5

Image: NASA, ESA, CXC, SAO, the Hubble Heritage Team

Type Ia SNe - explosion time

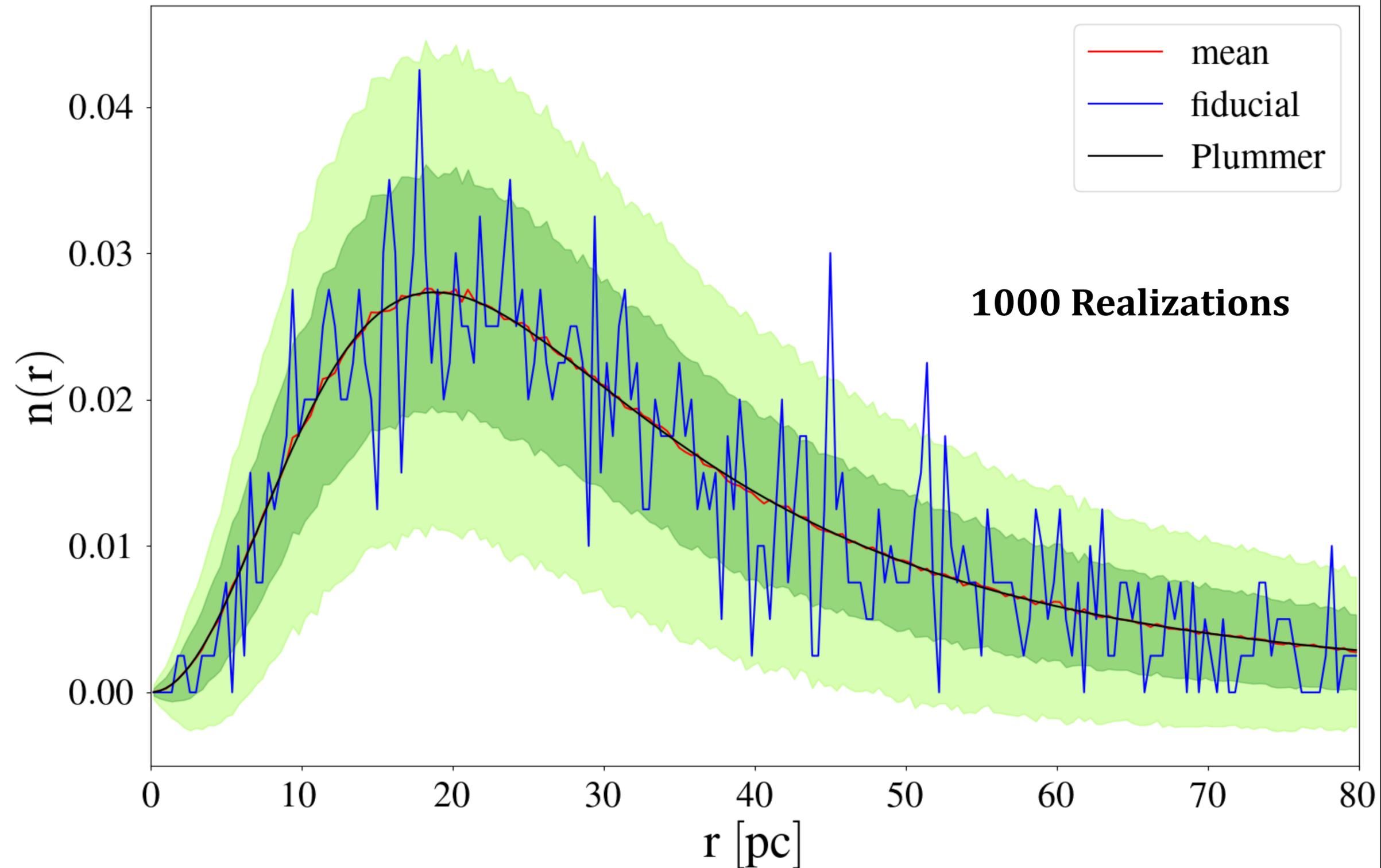


Delayed Type Ia SNe



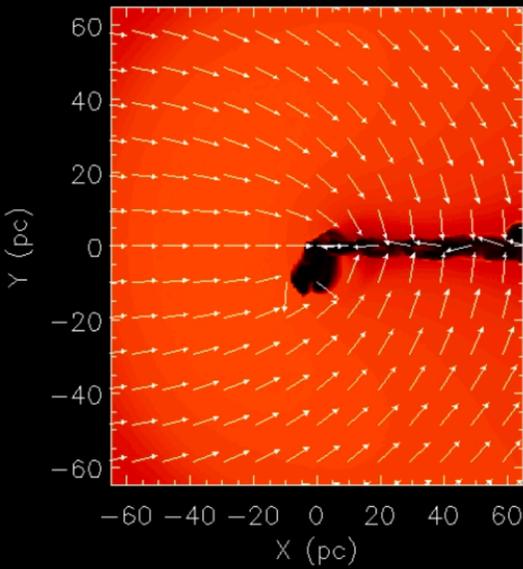
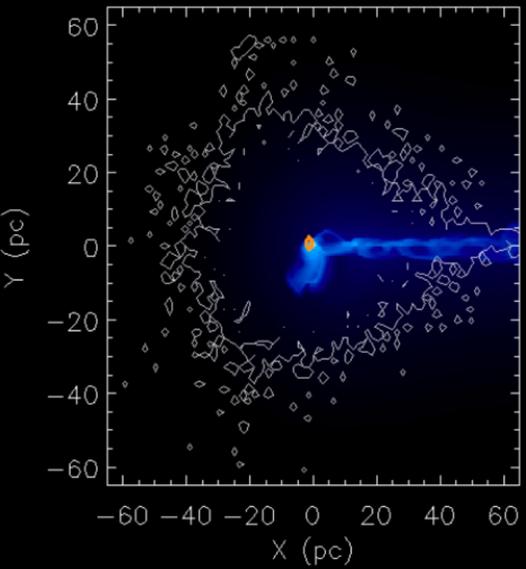
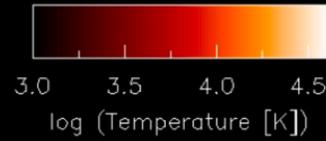
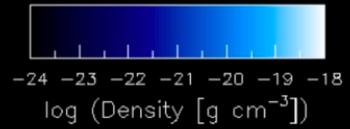
test a case in which Type Ia SN are delayed of ~ 25 Myr

Type Ia SNe - position

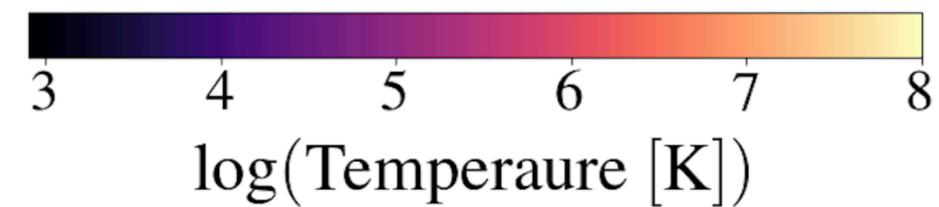
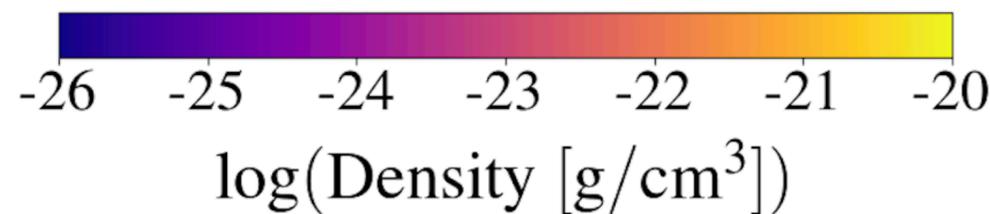
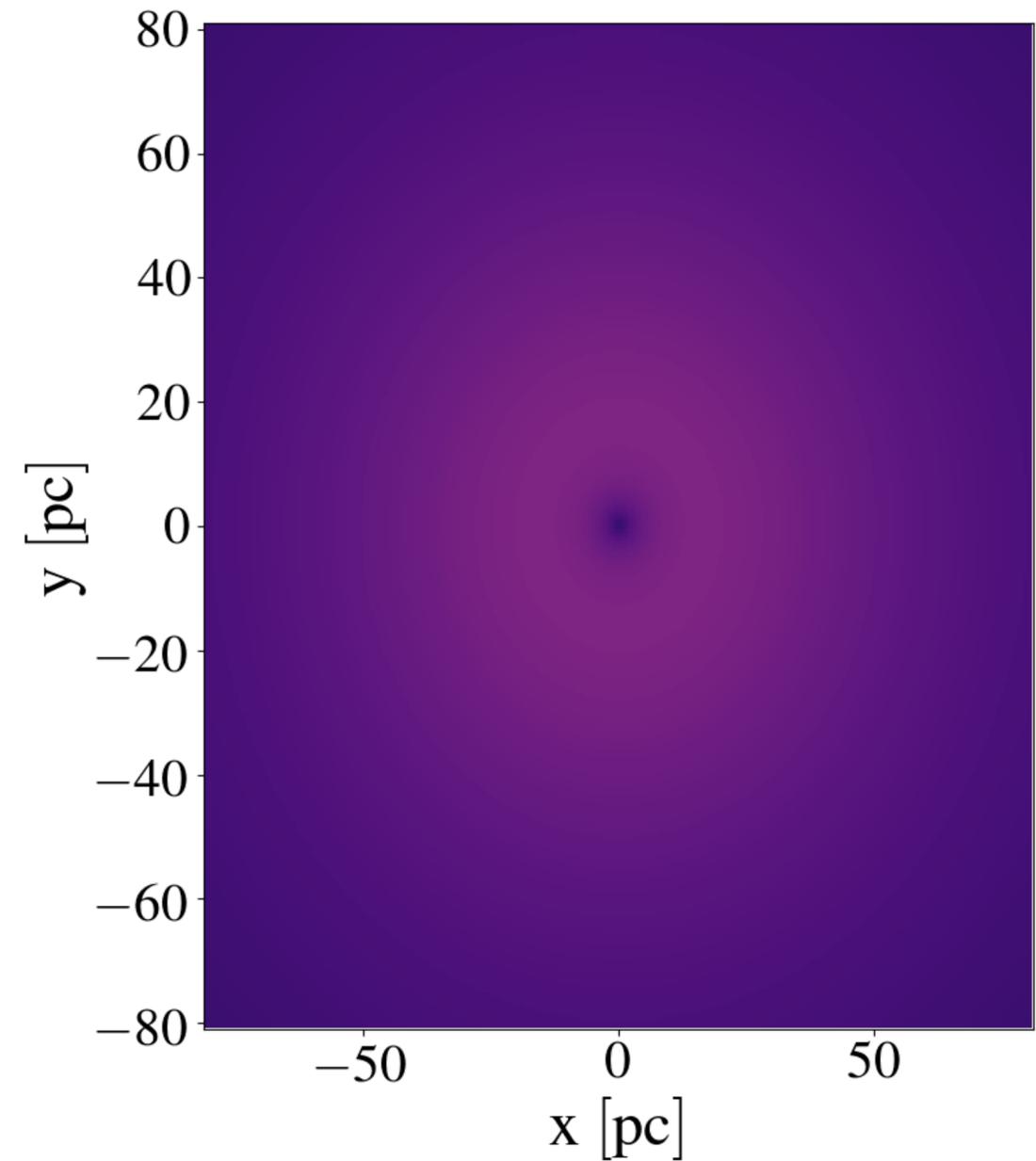
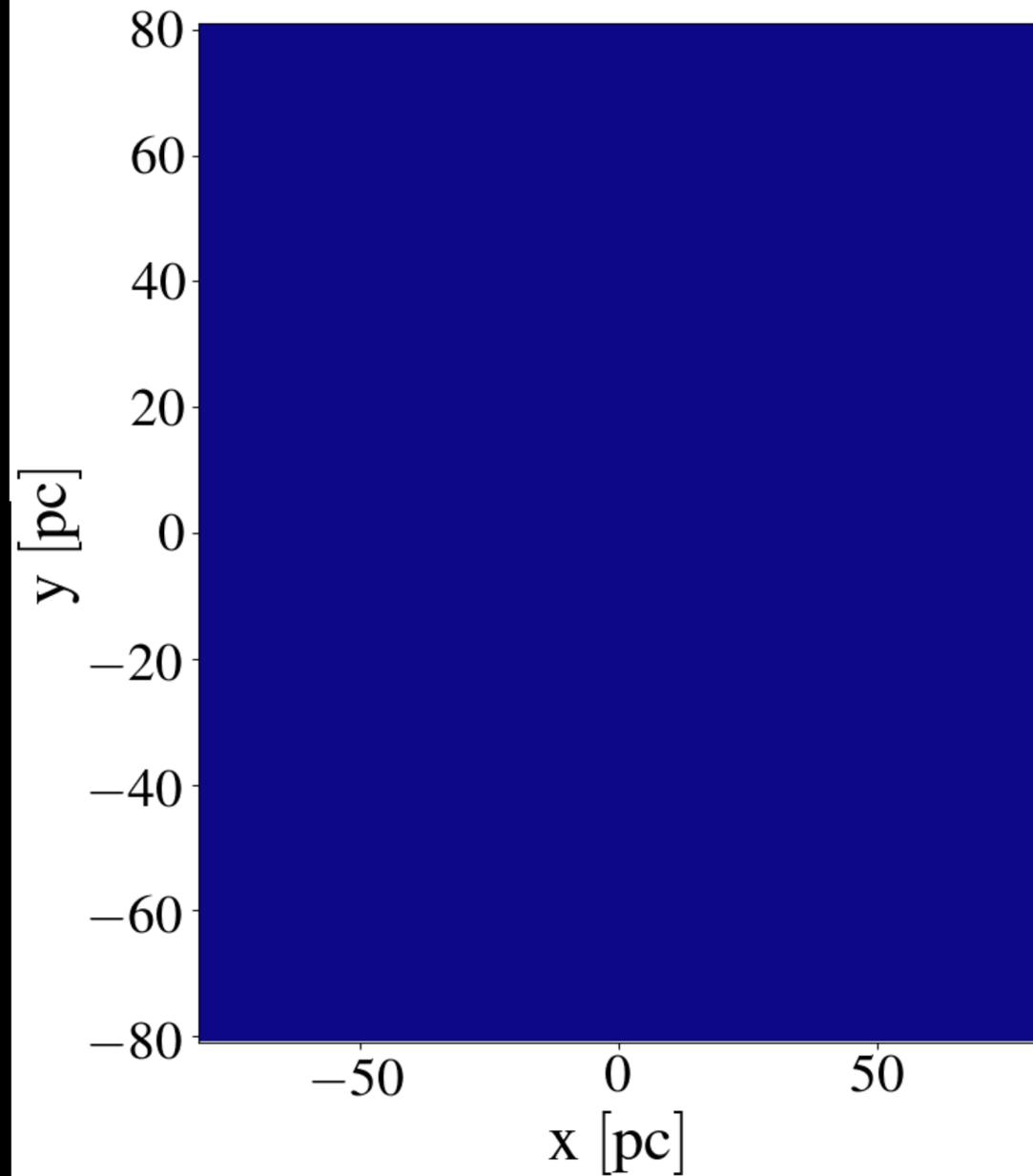


Low density

$$\rho_{\text{pg}} = 10^{-24} \text{g/cm}^3 - t_{\text{inf}} = 21 \text{Myr}$$



Time : 0.00Myr

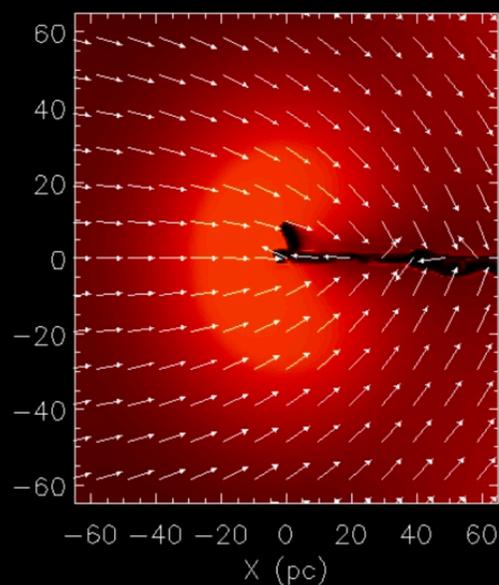
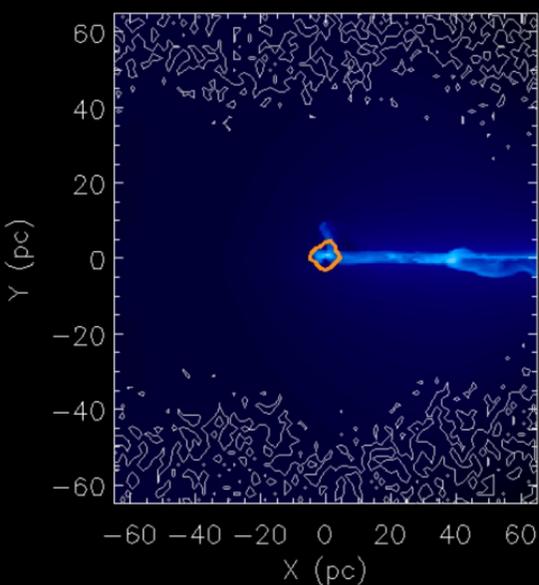
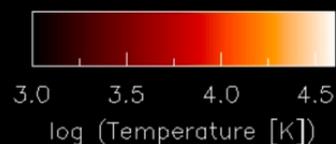
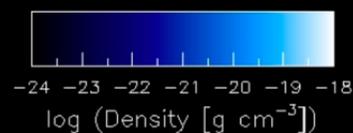


Calura+19

Lacchin+21

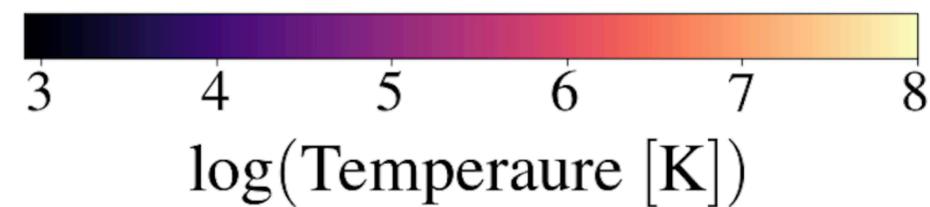
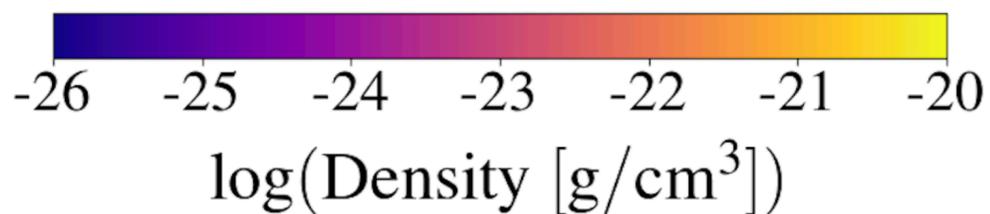
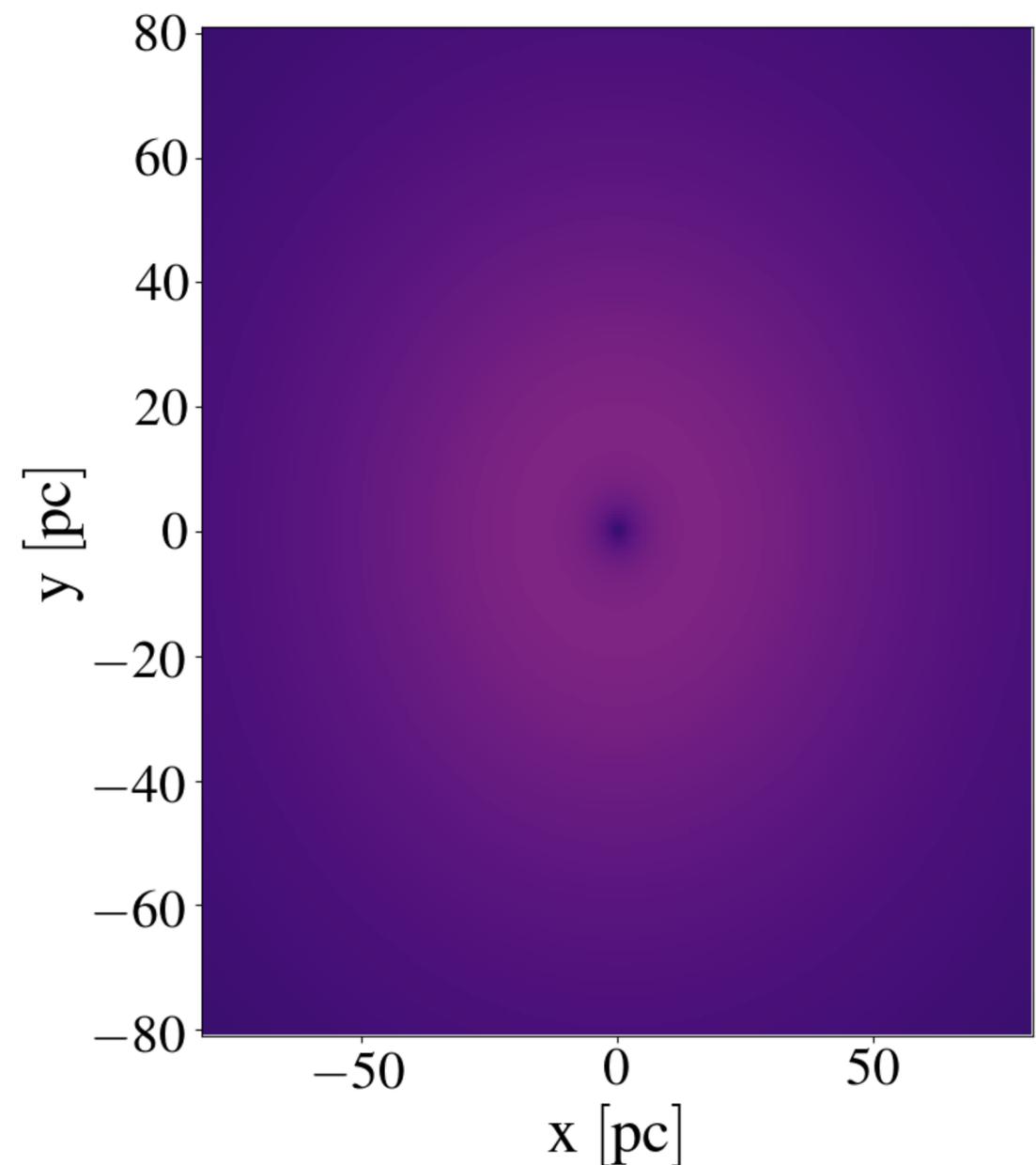
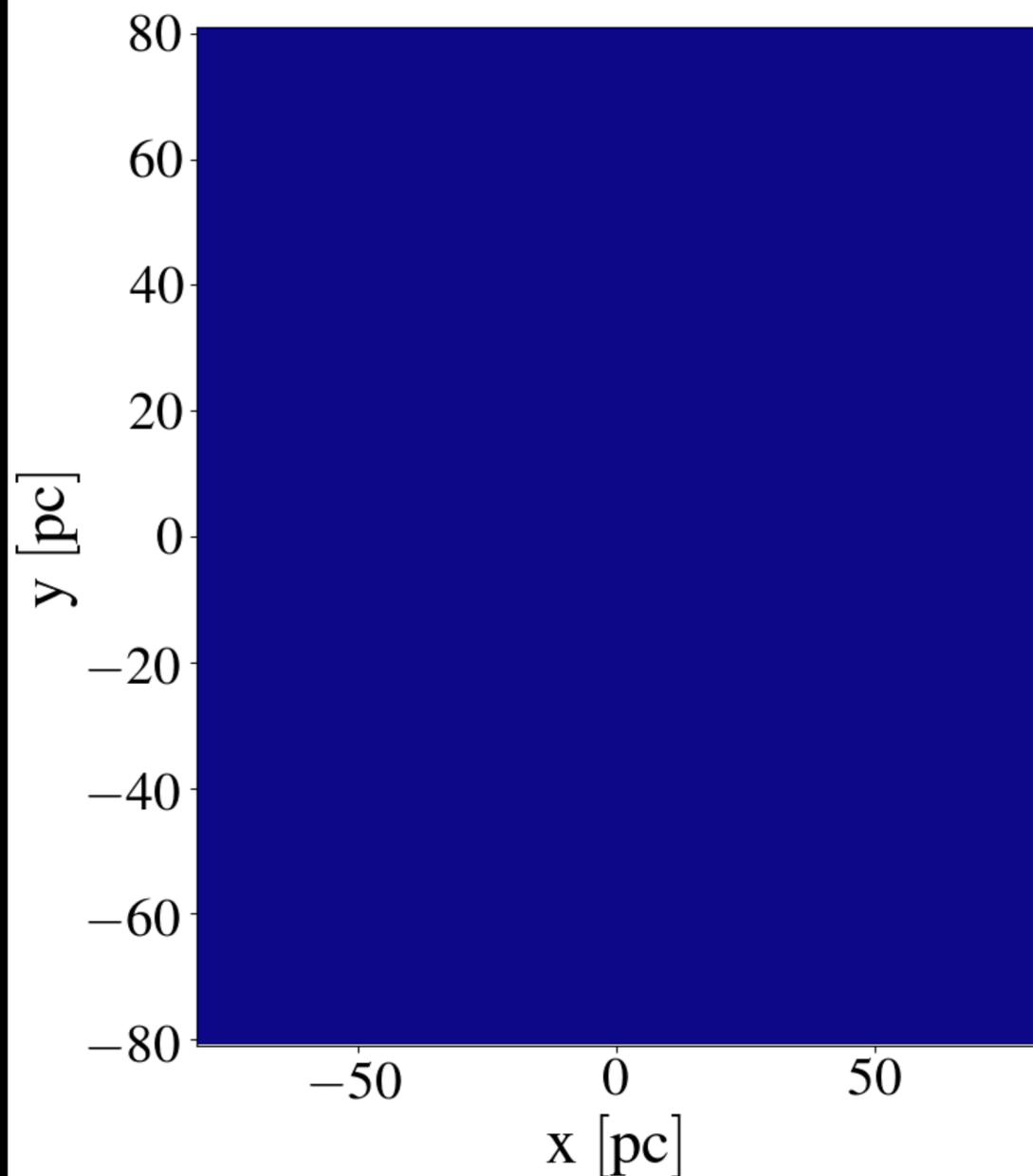
High density

$$\rho_{\text{pg}} = 10^{-23} \text{g/cm}^3 - t_{\text{inf}} = 1 \text{Myr}$$



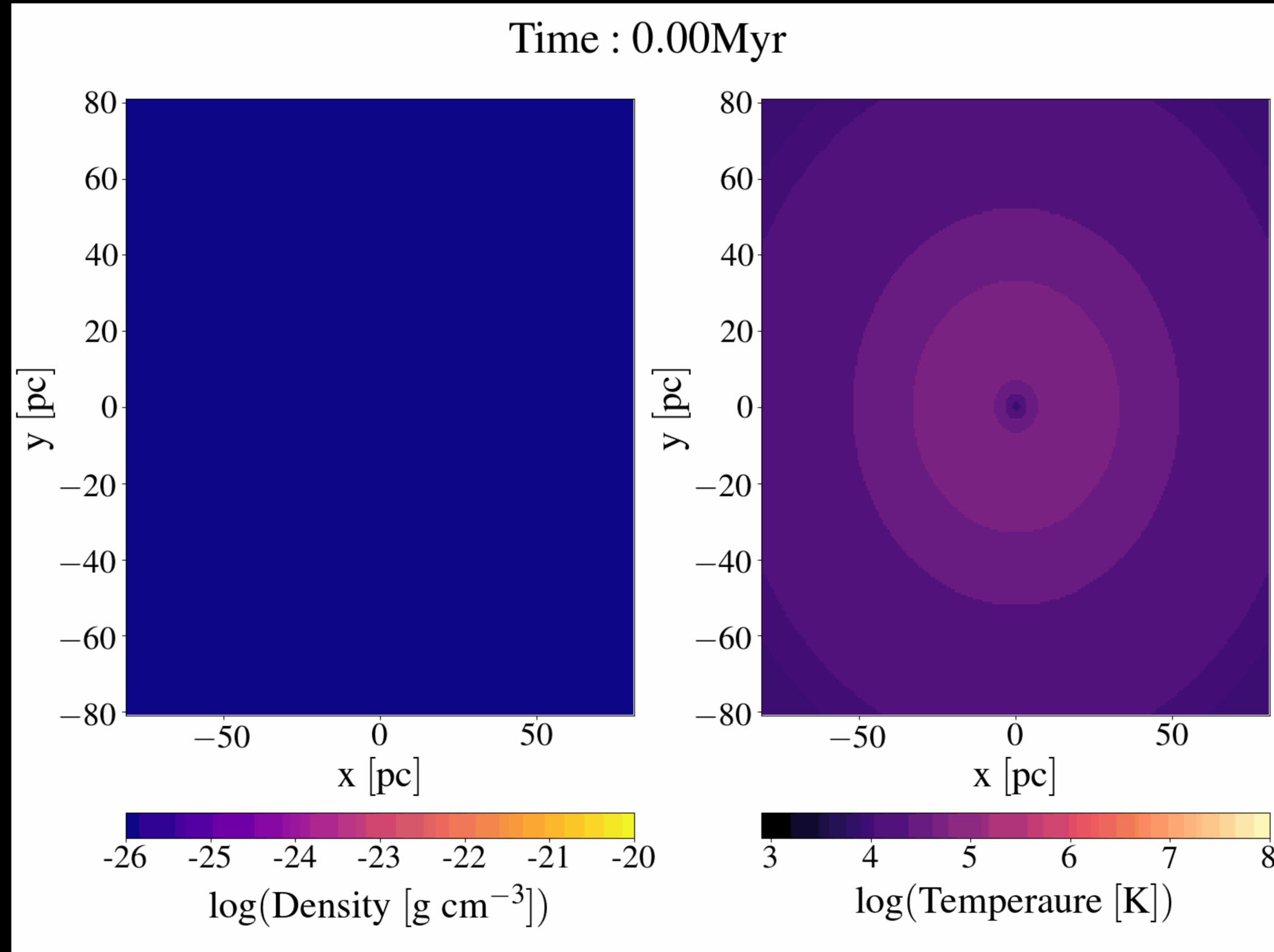
Calura+19

Time : 0.00Myr

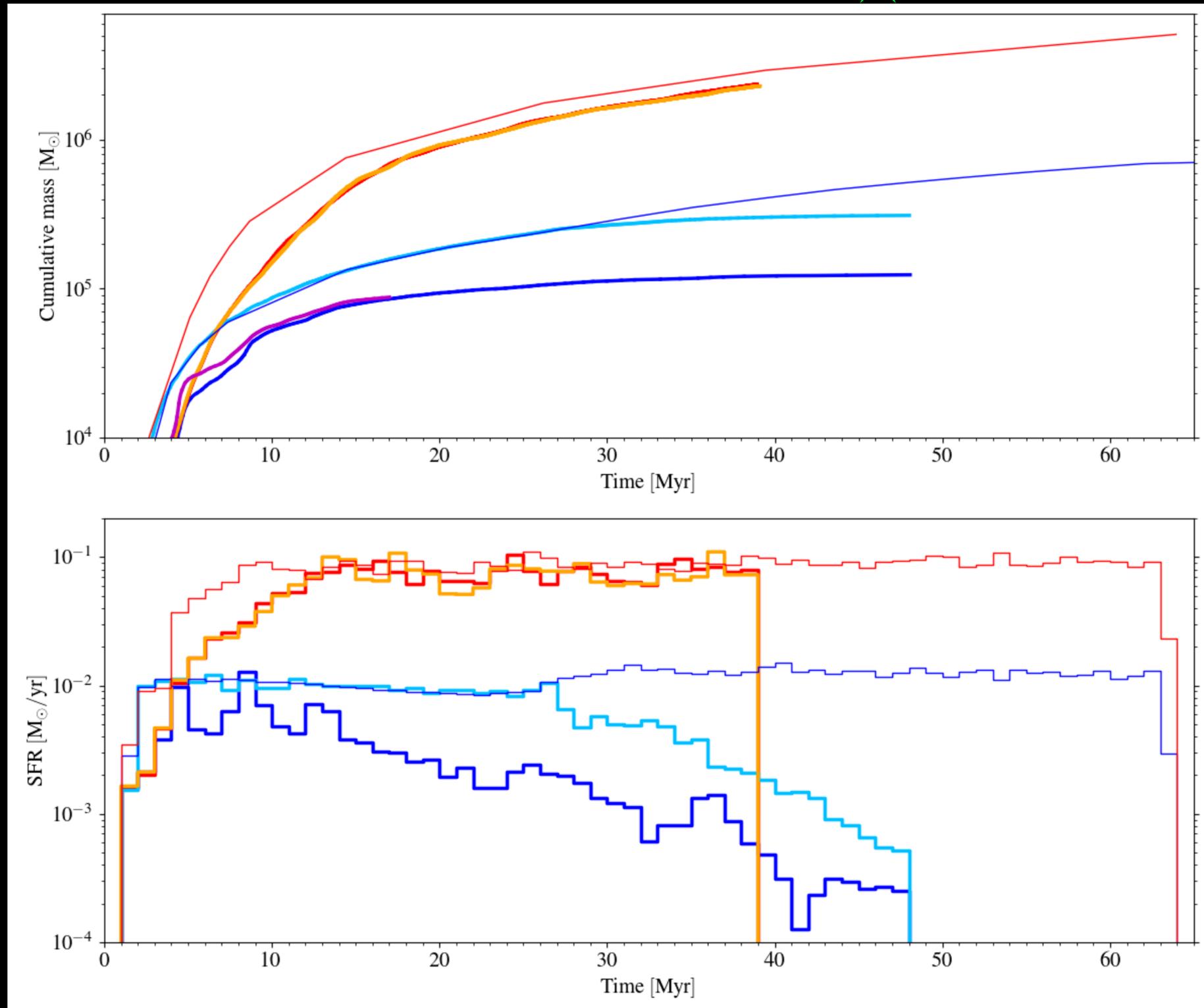


Lacchin+21

Low density with delayed SNe Ia



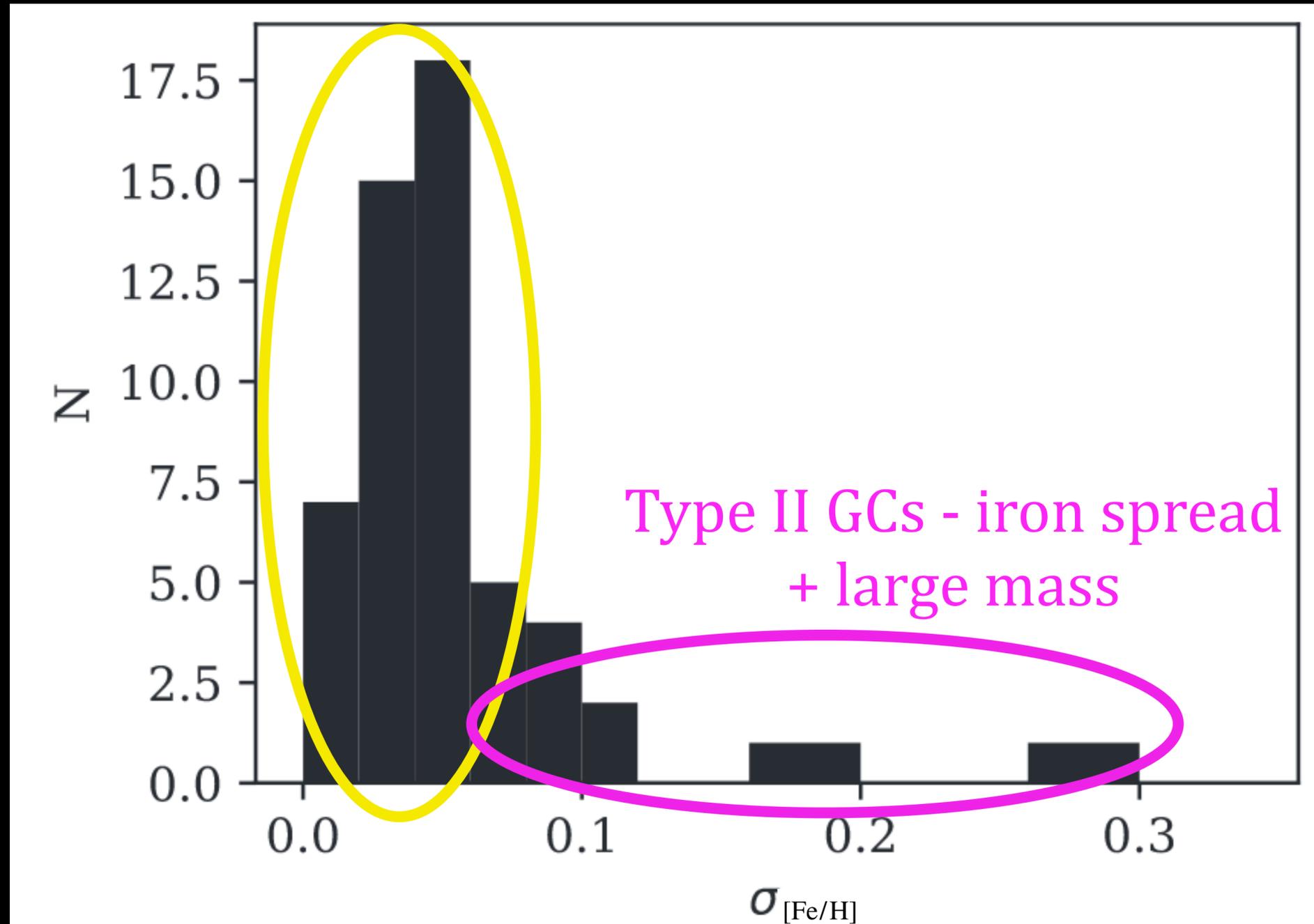
SFR vs time & M_{\star} vs time



- Without SNe Ia
- With SNe Ia
- High density
- Low density

Distribution of iron

Type I GCs - monometallic

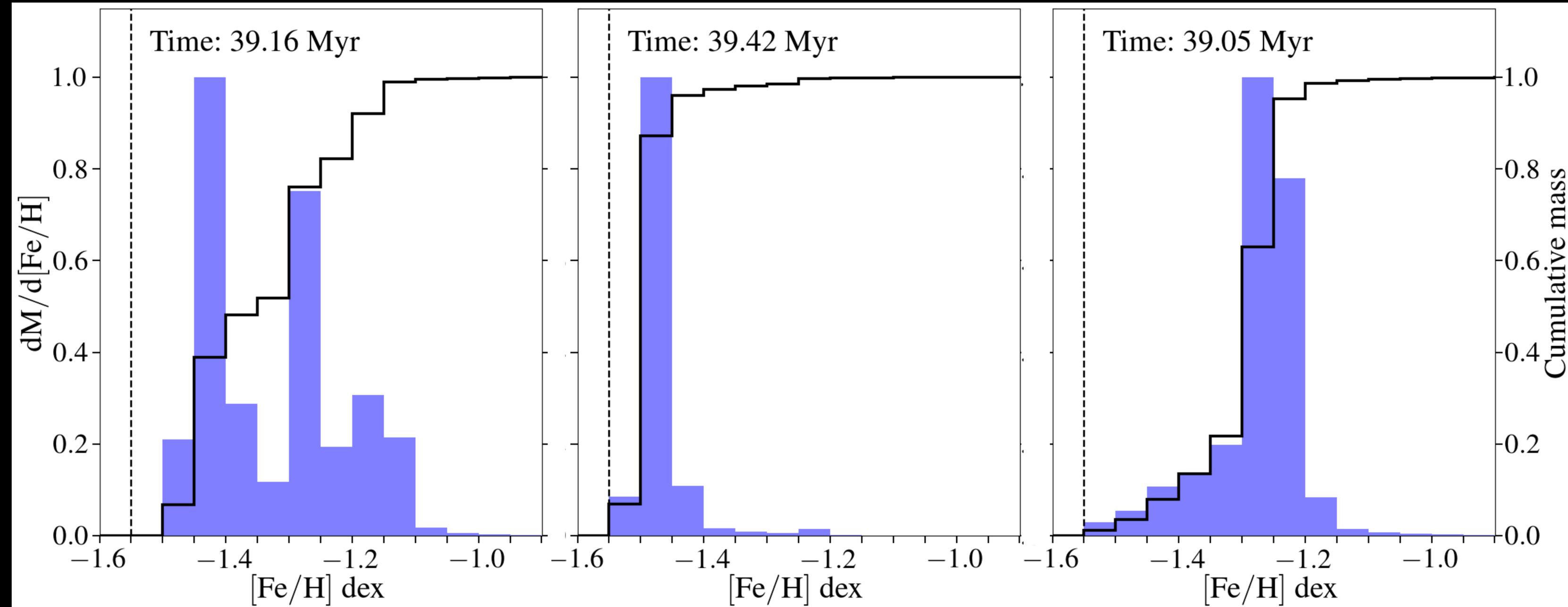


Distribution of iron

Low Density

Low Density with delayed SNe

High Density



$$\sigma_{[Fe/H]} = 0.14 \text{ dex}$$

$$\sigma_{[Fe/H]} = 0.07 \text{ dex}$$

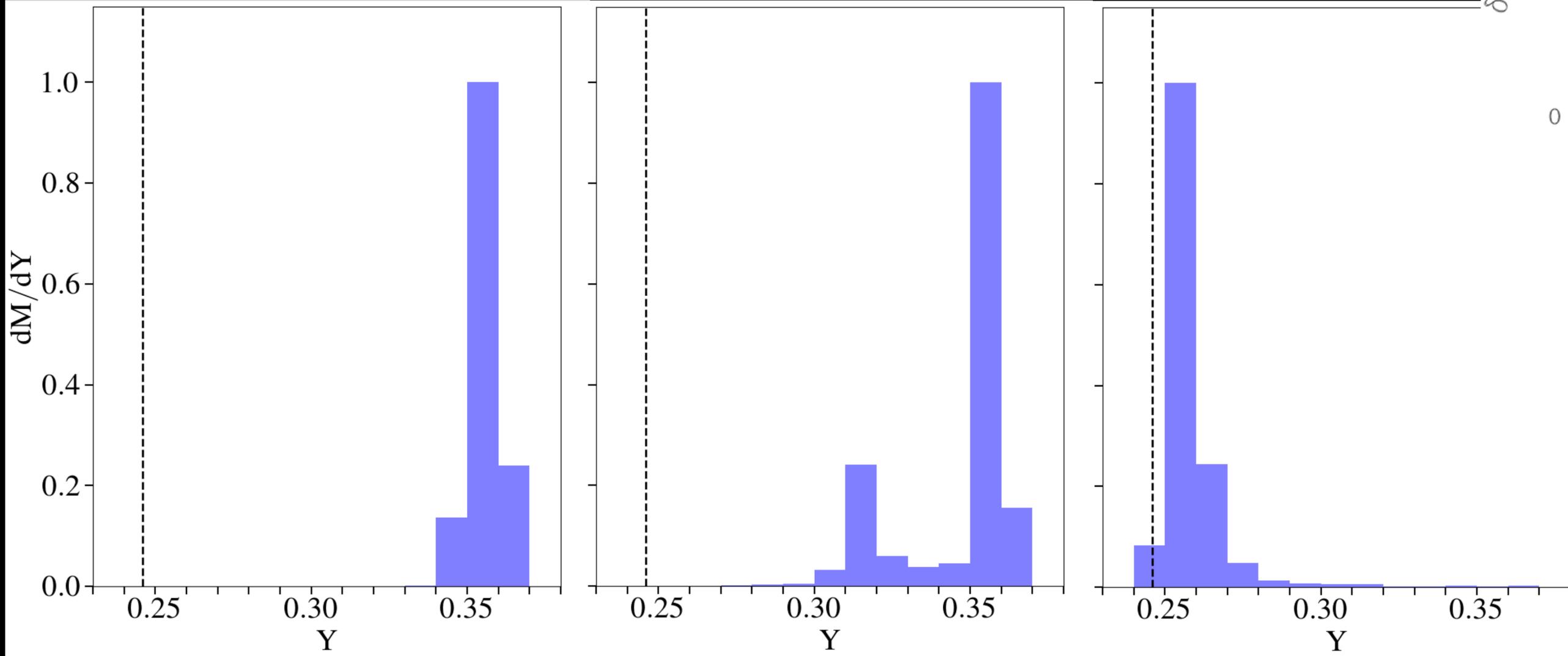
$$\sigma_{[Fe/H]} = 0.14 \text{ dex}$$

Distribution of helium

Low Density

Low Density + delayed SNe

High Density



$$\bar{Y}_{\text{SG}} = 0.355$$

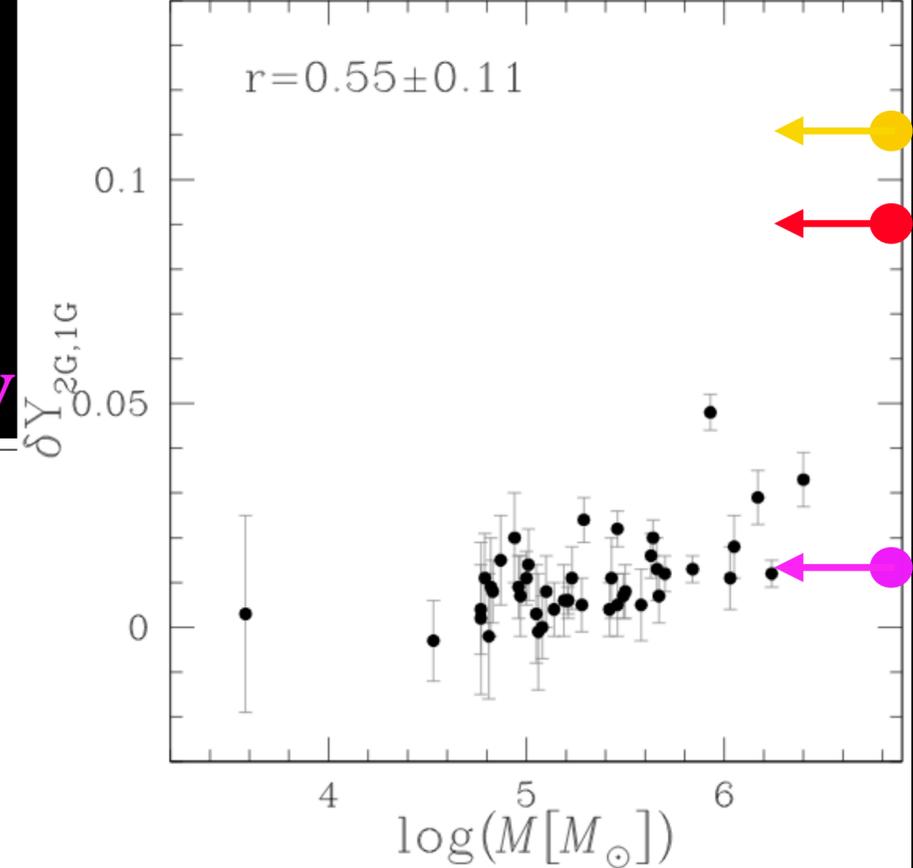
$$\bar{Y}_{\text{SG}} = 0.336$$

$$\bar{Y}_{\text{SG}} = 0.258$$

$$\Delta Y_{\text{FG-SG}} = 0.11$$

$$\Delta Y_{\text{FG-SG}} = 0.09$$

$$\Delta Y_{\text{FG-SG}} = 0.012$$



Milone+18

Conclusions

- Type Ia SNe do **not halt immediately the star formation** as in the 1D simulation
- **Low density** case:
 - ▶ the SF is considerably reduced by Type Ia SNe
 - ▶ infall has a weak effect on the evolution
 - ▶ unobserved helium 1G-2G spread
- **High density** case:
 - ▶ negligible effect of Type Ia SNe on the SF
 - ▶ large $\sigma_{[\text{Fe}/\text{H}]}$ in agreement with Type II GCs