Star Formation and Chemical enrichment in protoclusters

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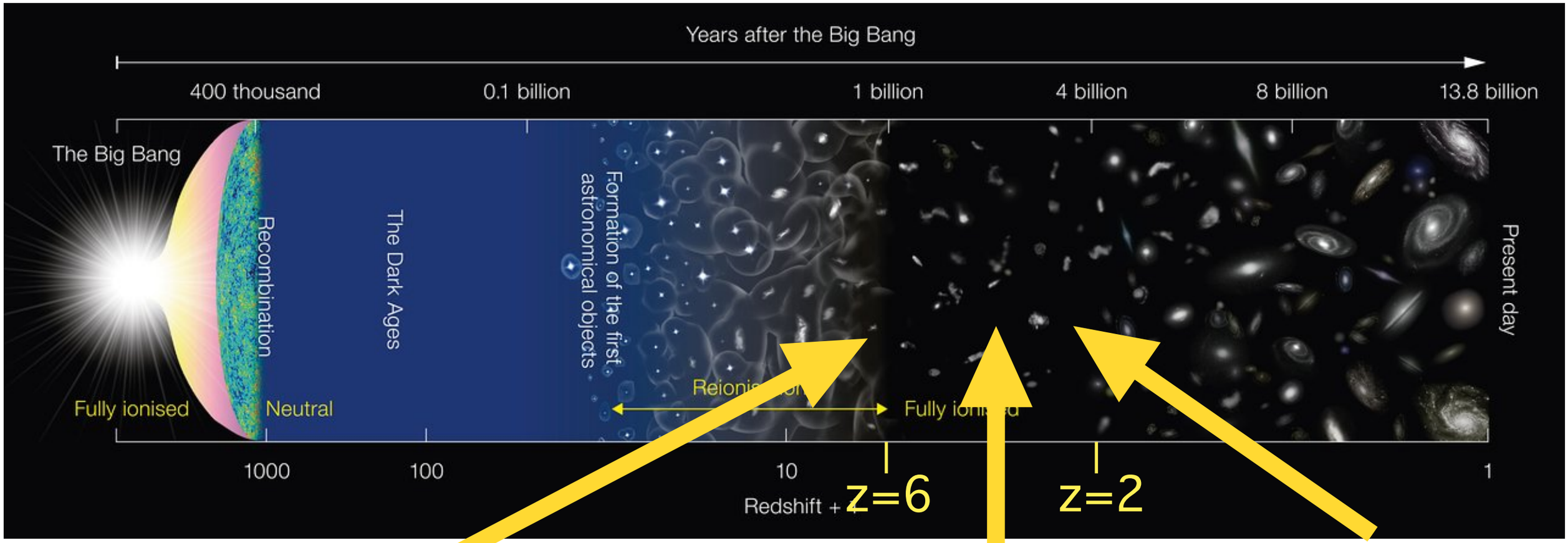
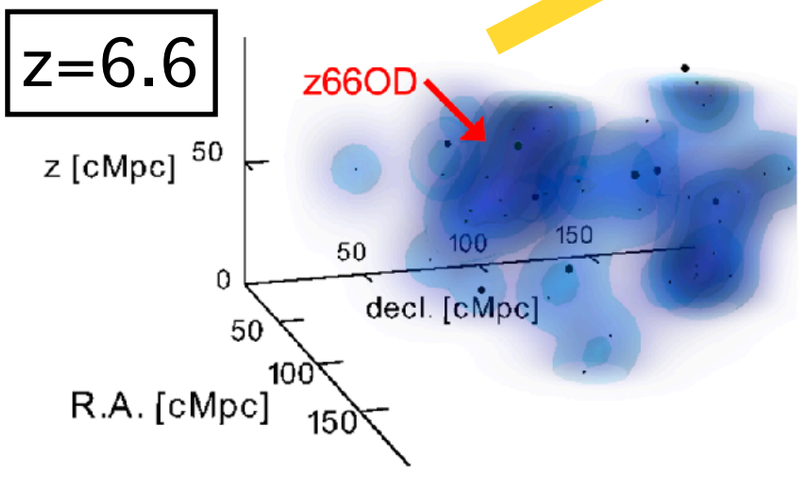
Galaxy-IGM workshop, Aug 5, 2020

Protocluster: the densest regions of the early universe

Credit: NAOJ

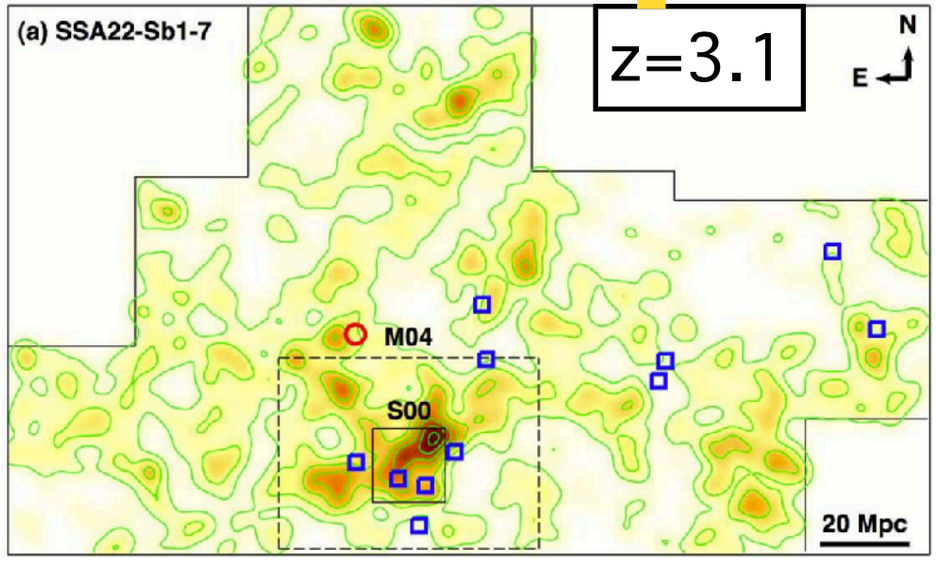


z=6.6



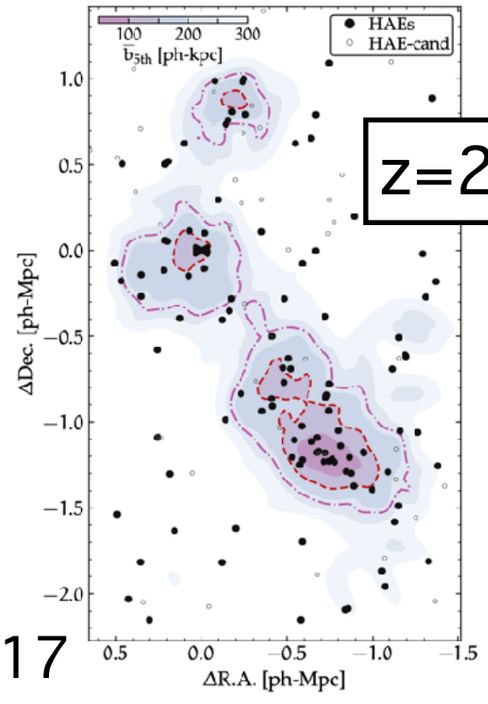
Harikane+'19

z=3.1



Matsuda+'10

z=2.5



Shimakawa+'17

Protocluster: the densest regions of the early universe

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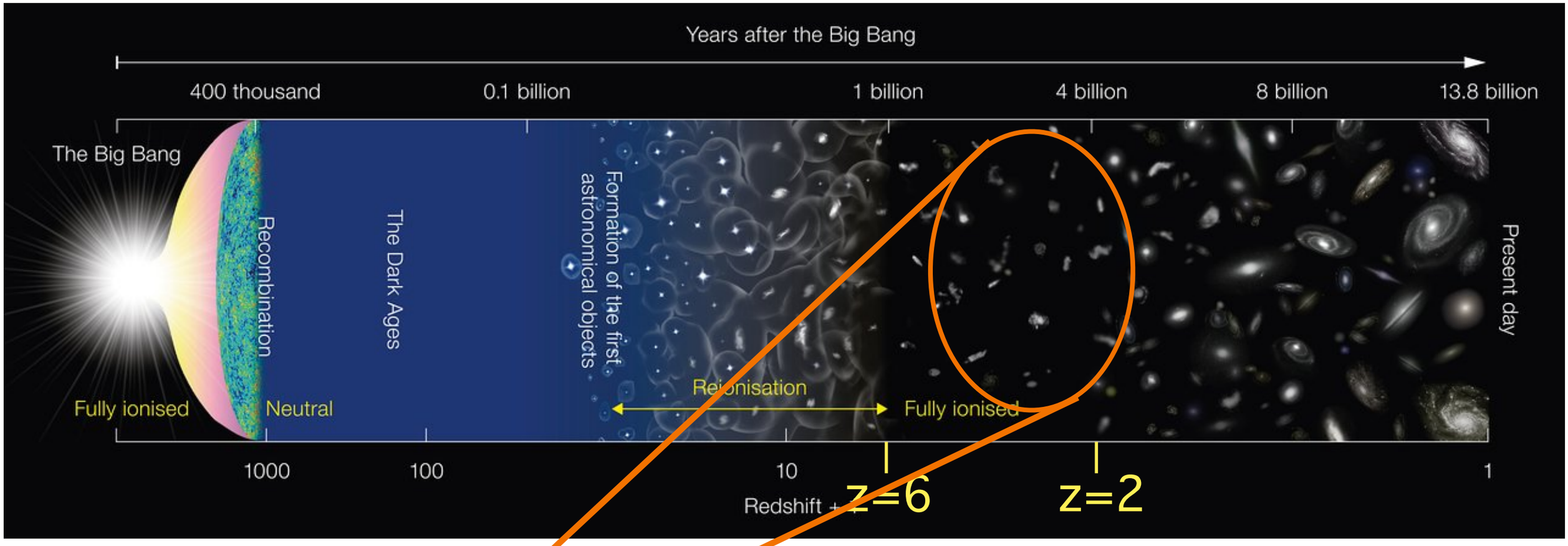
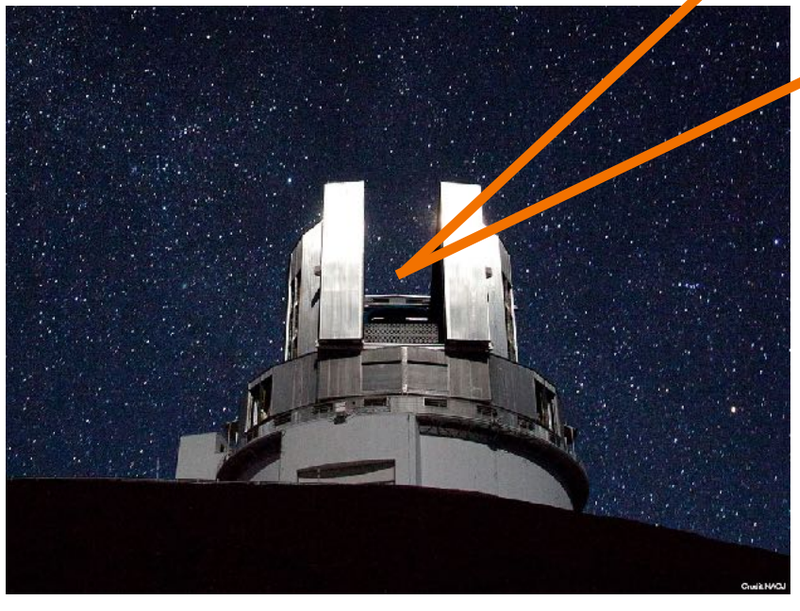
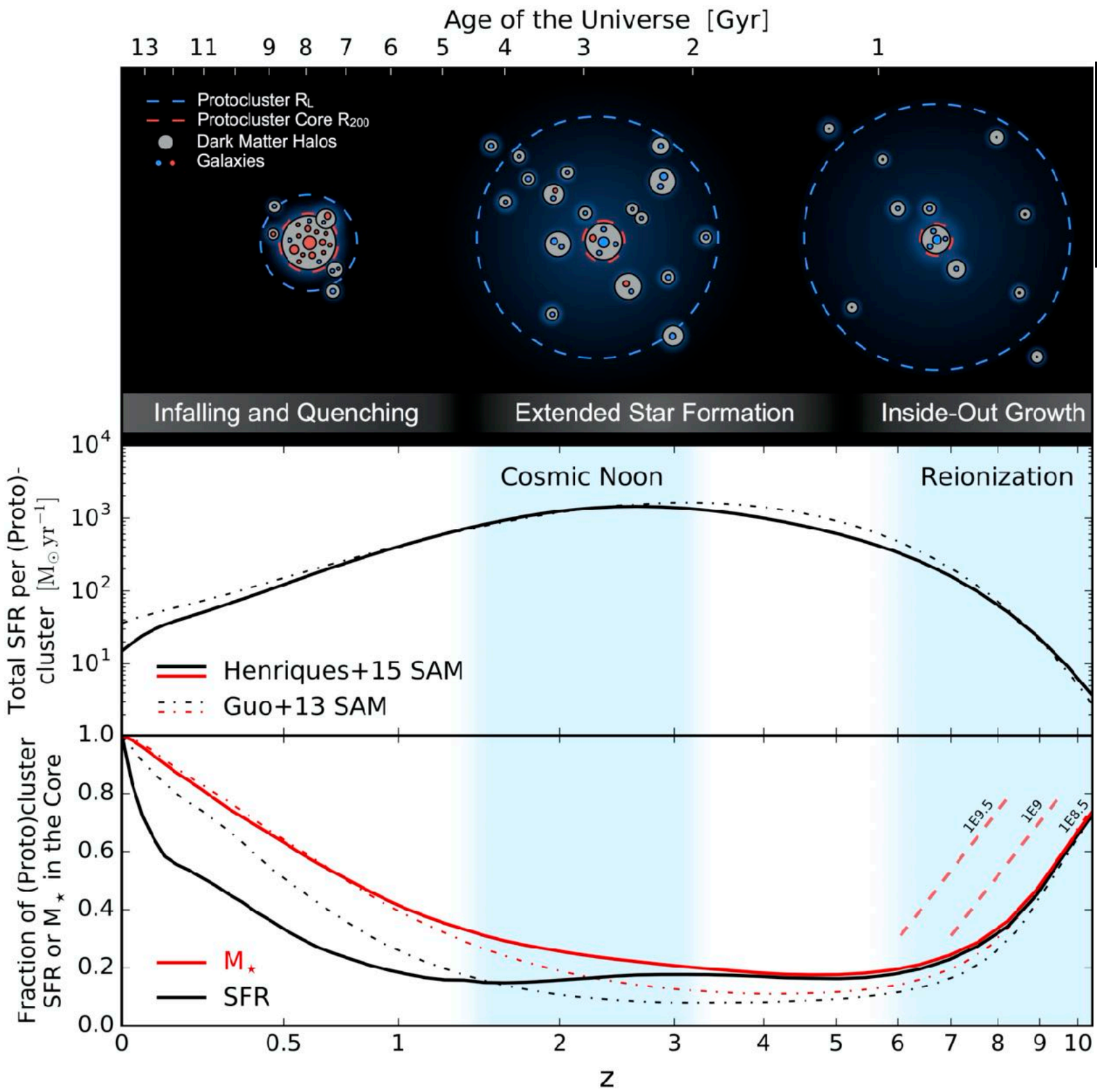


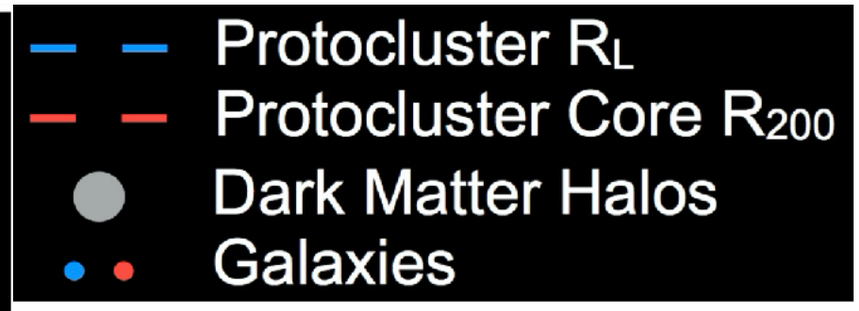


Credit: NAOJ

Subaru Prime Focus Spectrograph (PFS) coming soon !!

Protocluster(PC)'s Star Formation





PC have high Star Formation Rate(SFR).

20% of the PC's SF has become the core. (SF is more active in the core than in the PC.)

Metal enrichment proceeds quickly at the core

Chiang+'17

Metal enrichment in PC

Each element is created by various processes.

→ Over time, their proportions change.

Simulate the metal enrichment

Observe the chemical abundance using PFS

How chemical evolution of the universe has progressed

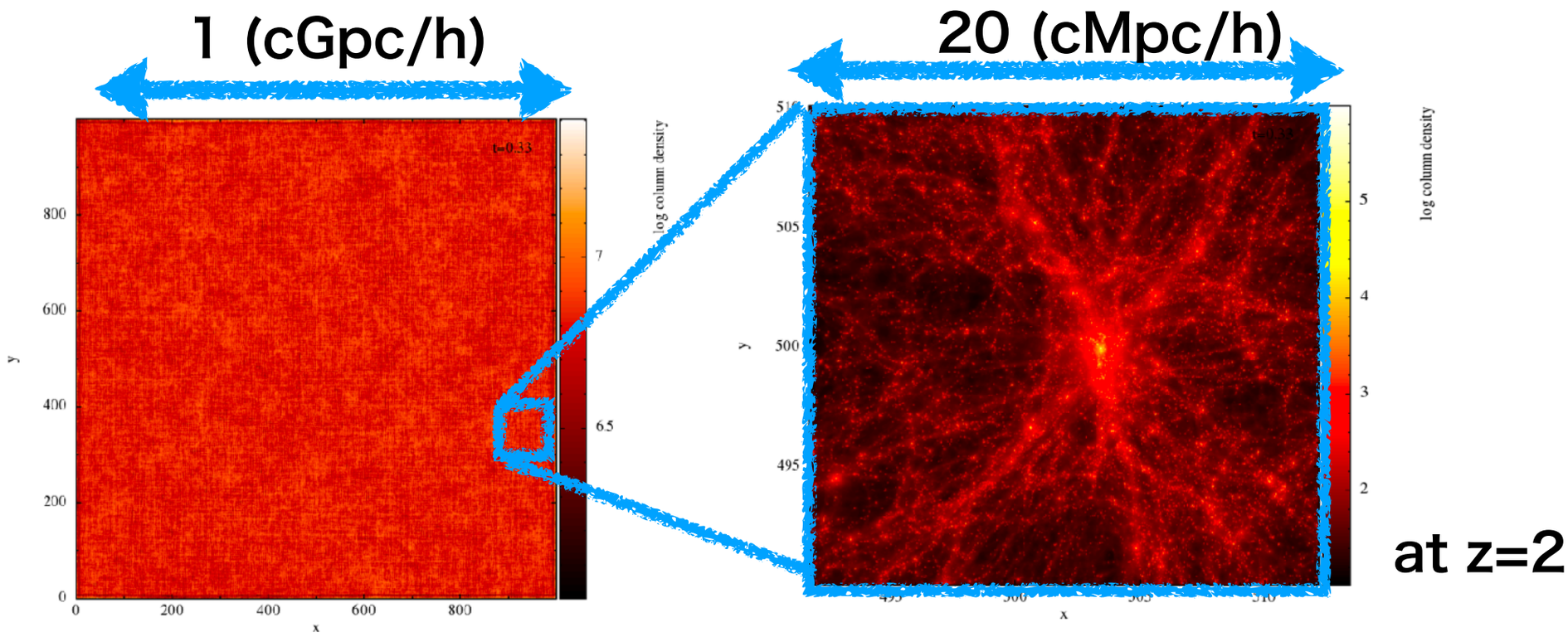
SN feedback model's limitations

Simulation setup

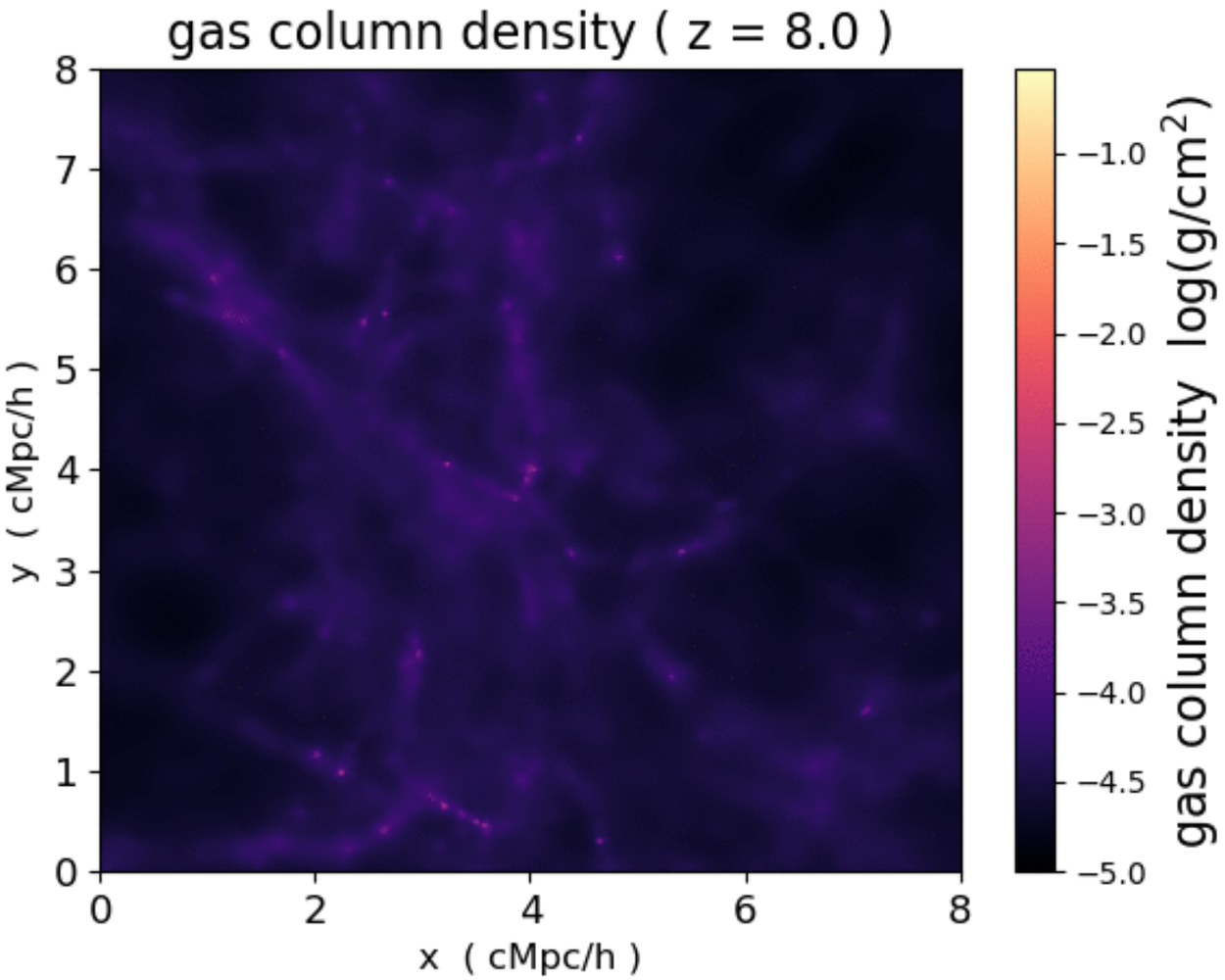
Cosmological SPH simulation code: GADGET3-Osaka

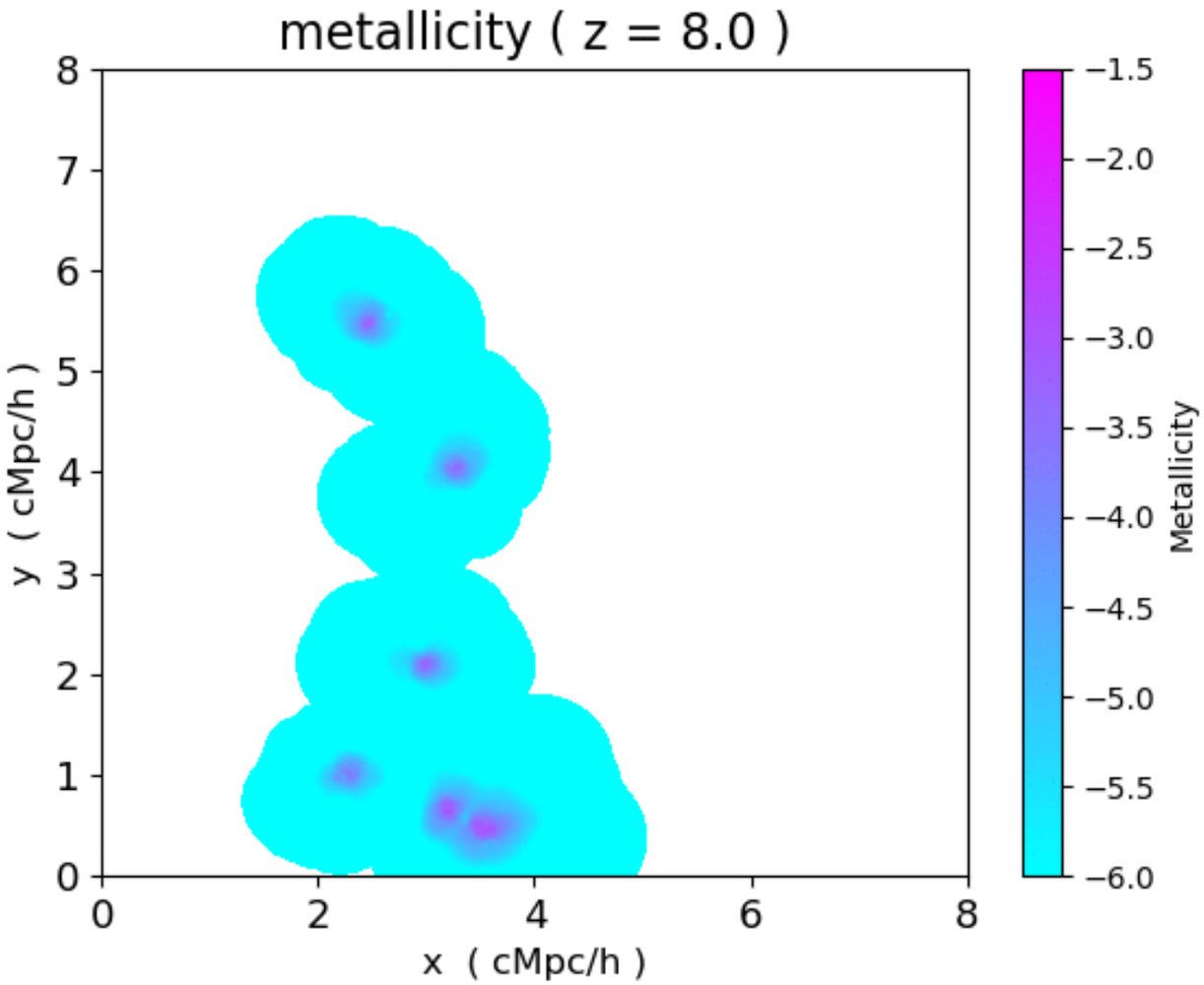
Aoyama+'17, Shimizu+'19

- Models: Star Formation
  Energy & Momentum driven feedback from the SNe
  CELib Chemical Evolution library (Type II SNe, Type Ia SNe, AGB)
  Saitoh (2017)
- Zoom-in method: (DM particle mass; $10^9 M_\odot/h$, DM softening length; 8kpc/h)



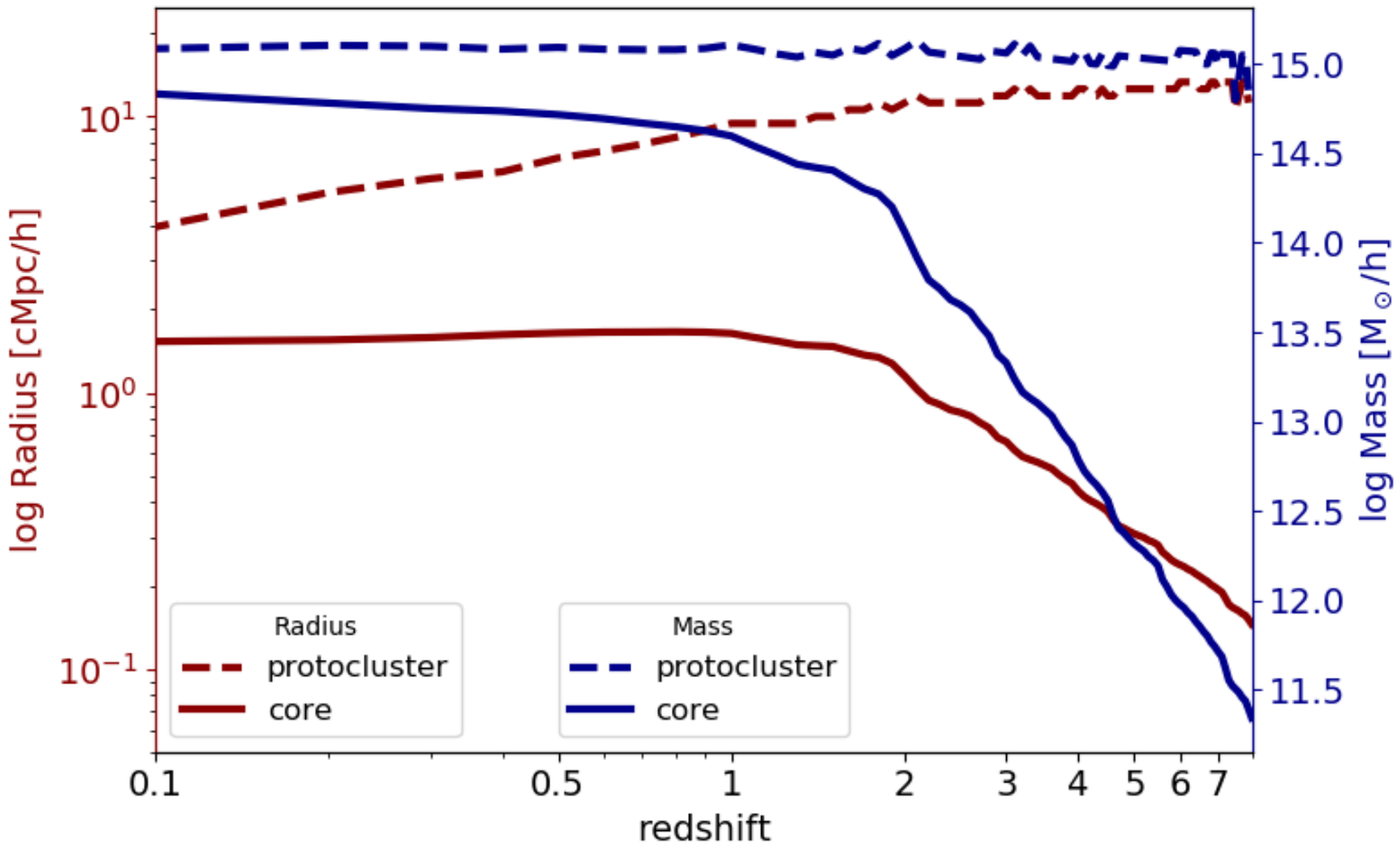
Density, metallicity distribution

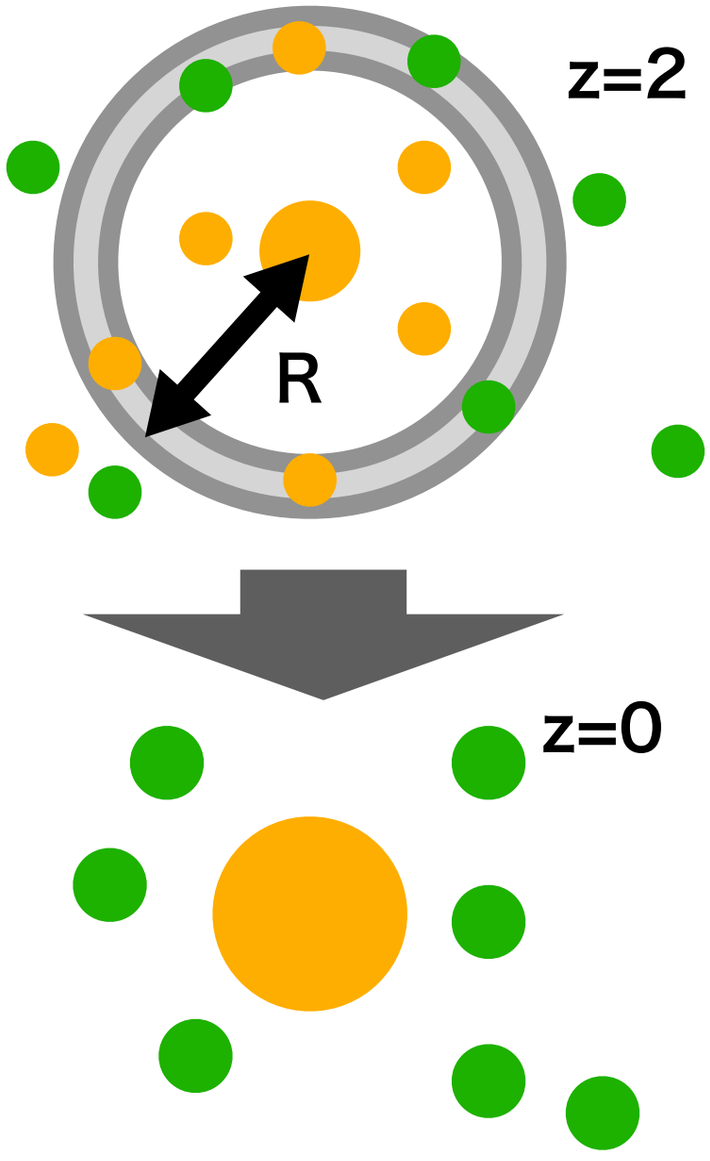




Metal enrichment proceeds from the high density region.

Evolution of Mass and Radius in Protocluster(PC), core region

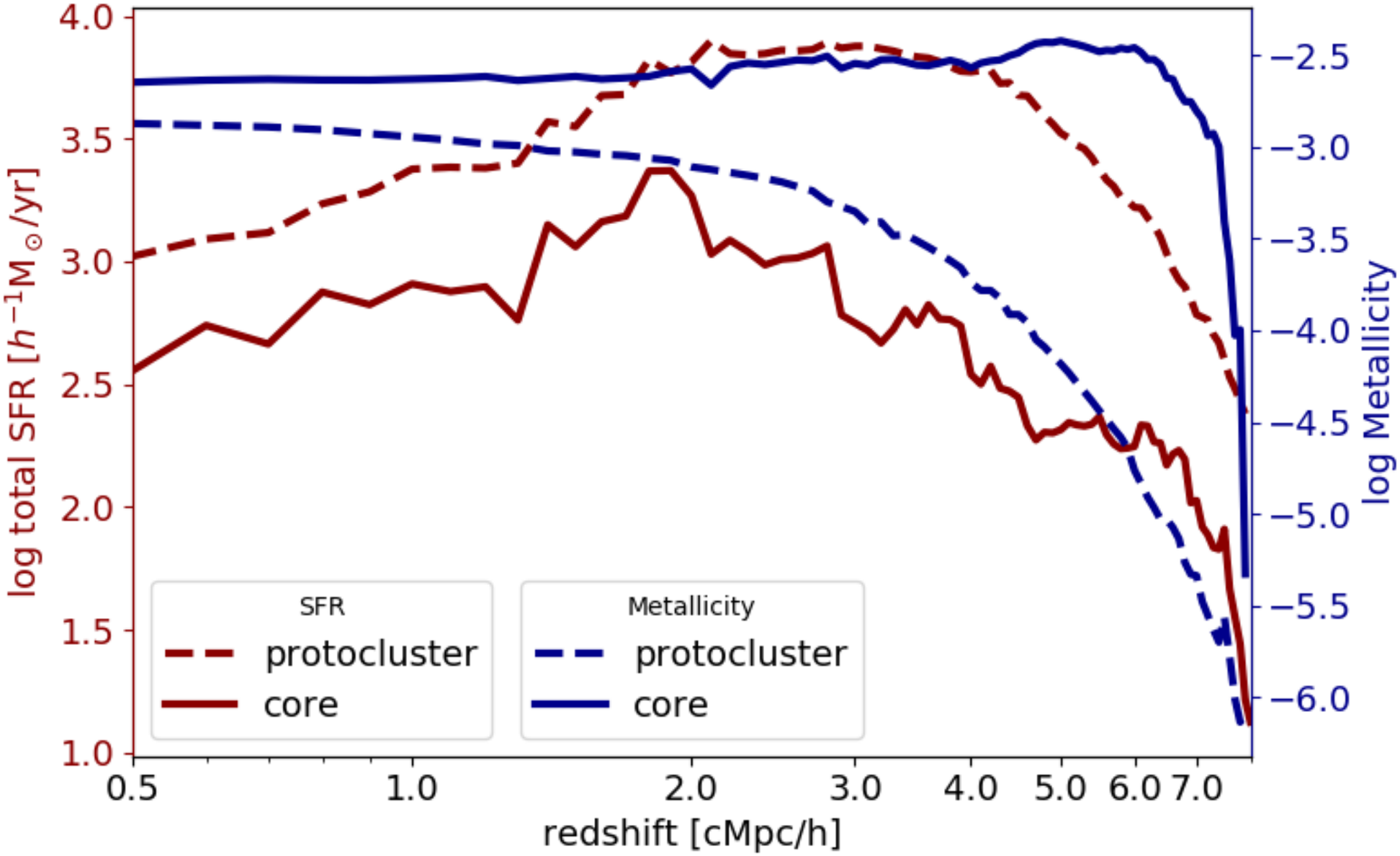




Our PC's mass reaches $10^{15}\,M_\odot$ at z=0 and core mass reaches $10^{14}\,M_\odot$ at z=2.

Core's R is 10 times smaller than PC's R at z=2.

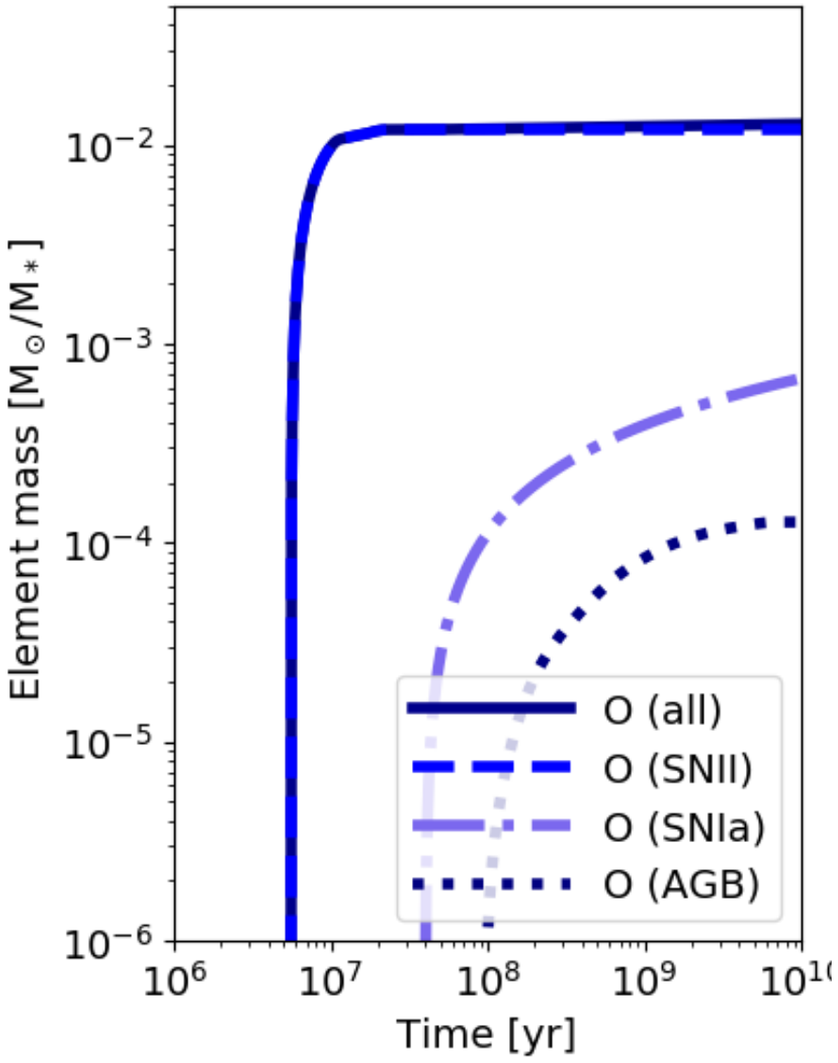
Evolution of SFR and Metallicity in Protocluster(PC), core region



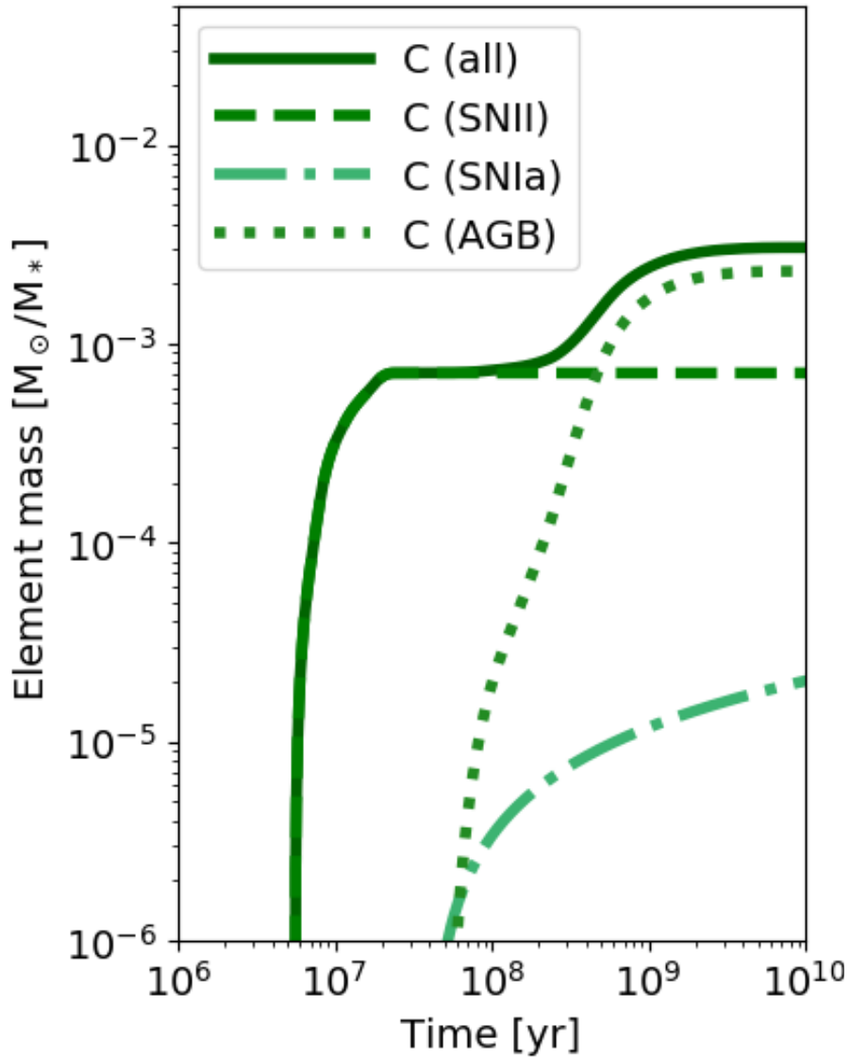
SF is more active in the core than in the PC.
Core's metallicity reach > 10^{-3} at z=7.

Metal formation by Type II SN, Type Ia SN, AGB

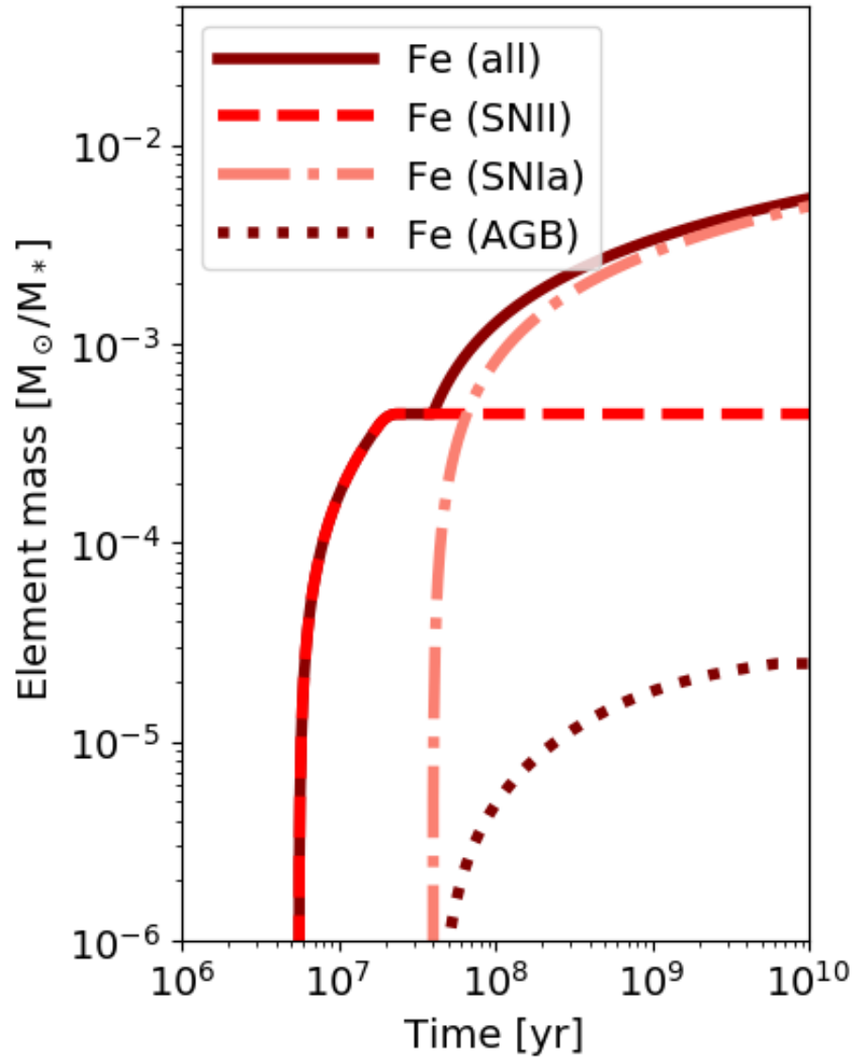
CELib result at Z=0.001



Oxygen made by Type II SNe

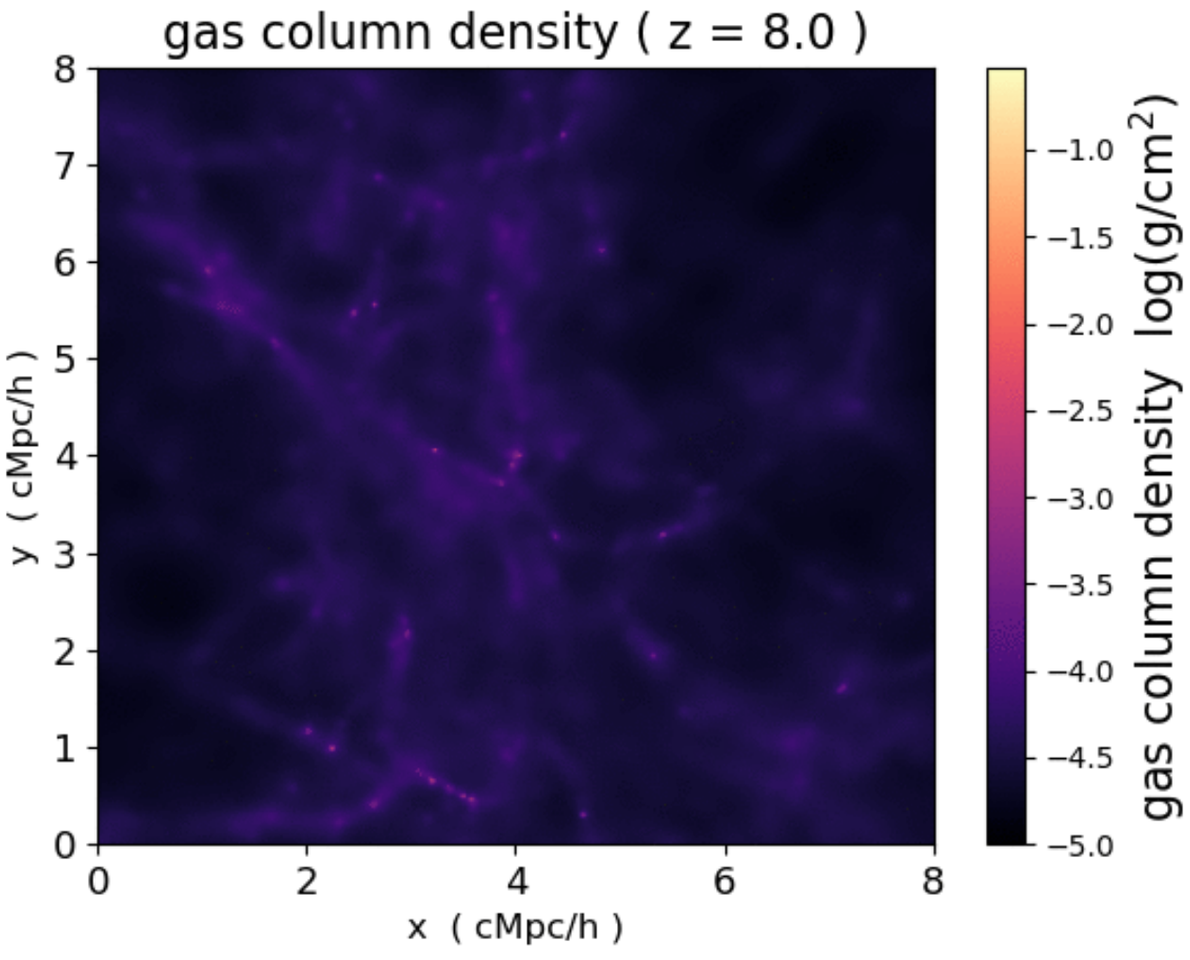


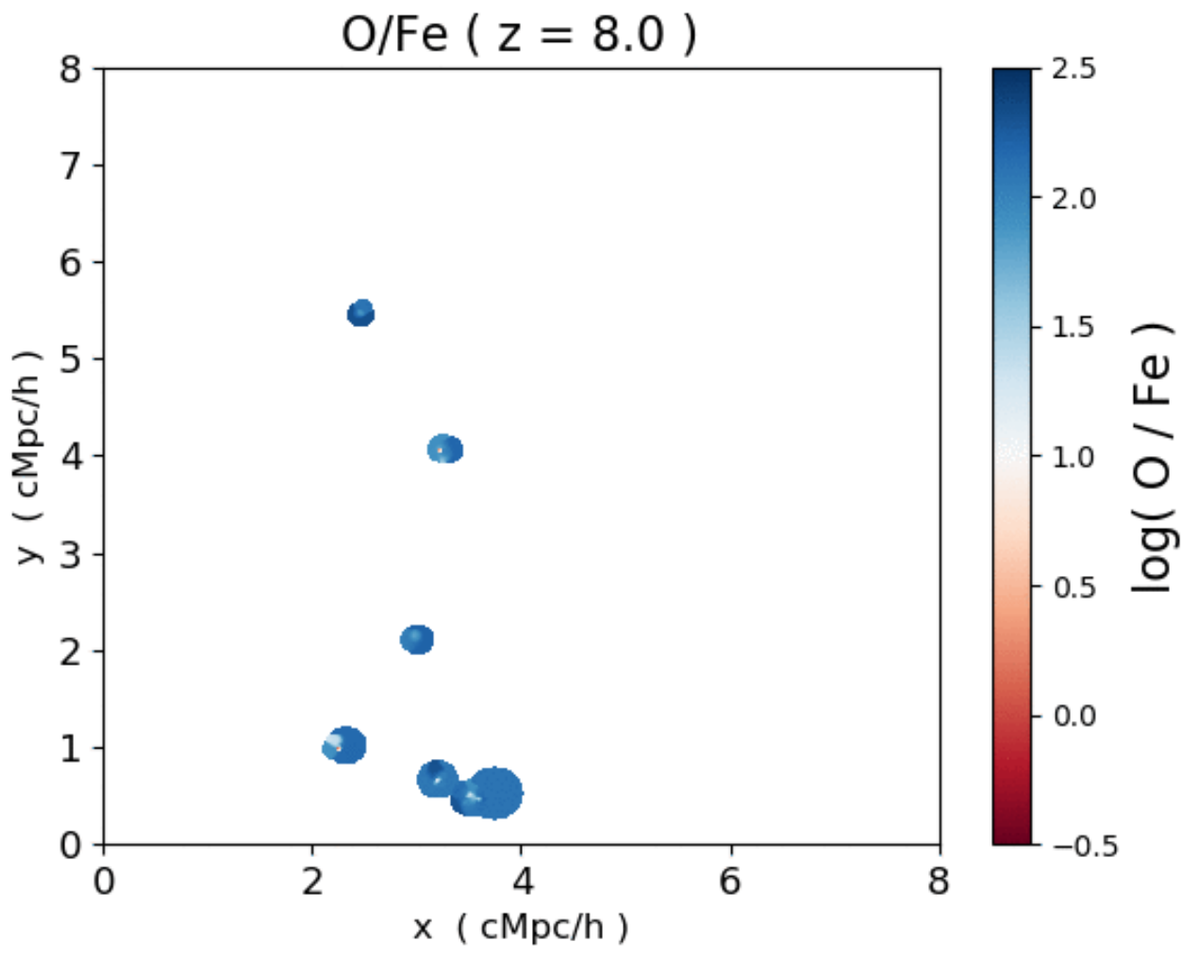
Carbon made by AGB



Iron made by Type Ia SNe

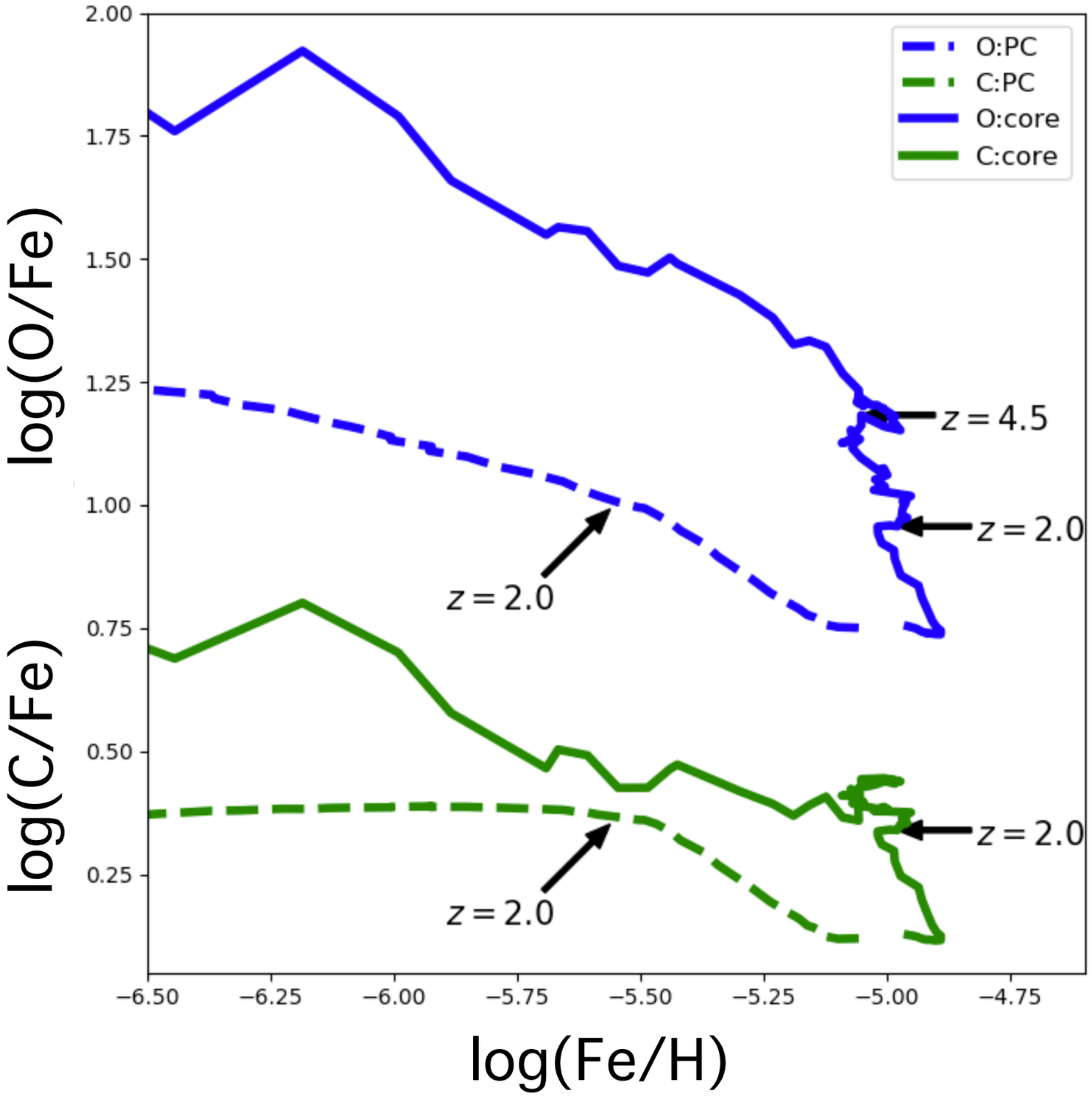
Chemical enrichment of O and Fe





At high redshift, there’s more O than Fe.(Type II SNe)
With time, Fe increases at high density region.(Type Ia SNe)

Chemical abundance in Protocluster region(PC), core region



Chemical abundance changes significantly around z=2 in PC.

Type Ia SNe affect core region by z=4.5.

Star Formation starts early (z=7-10) in the core region.

Summary

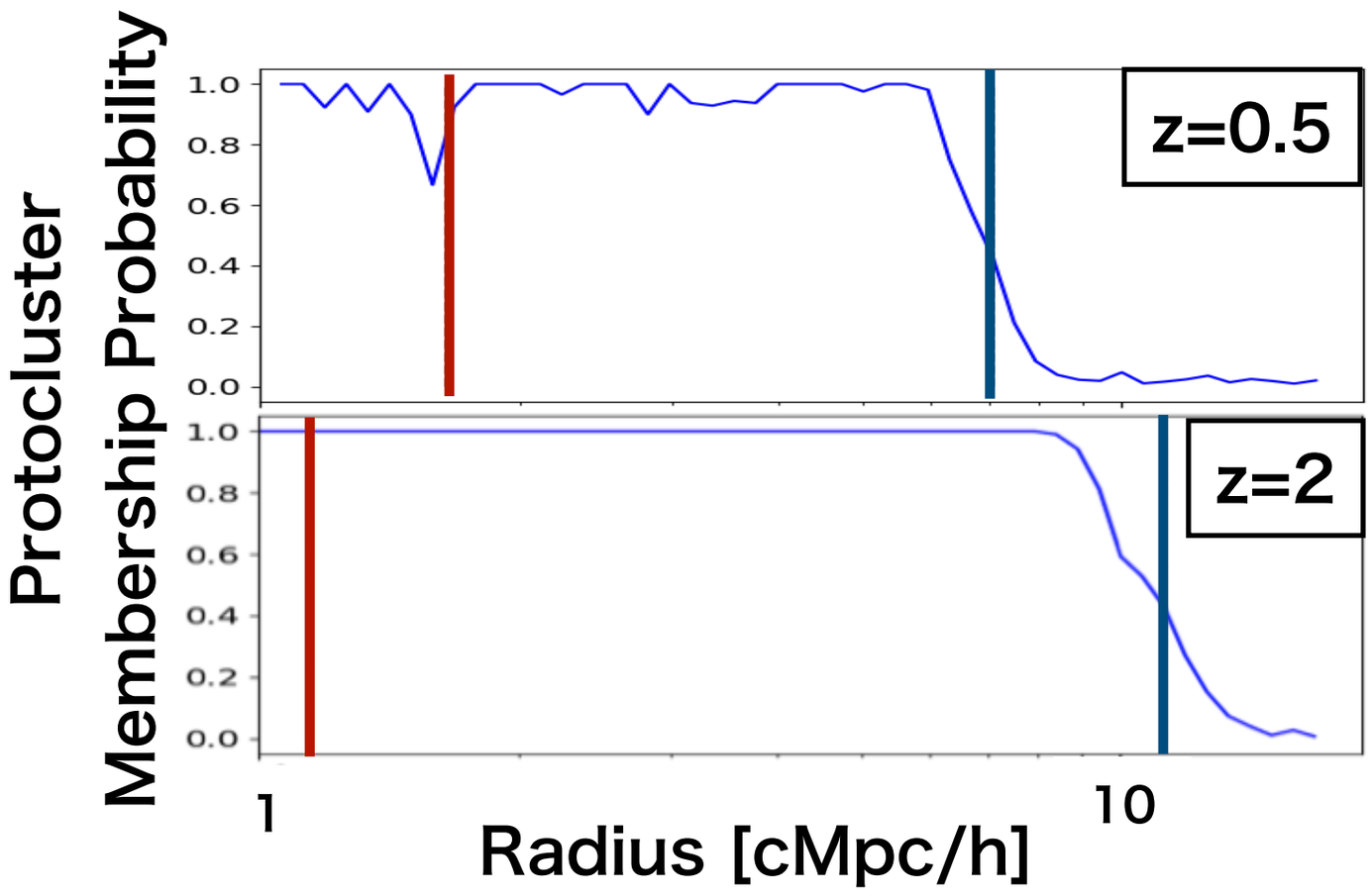
Using Gadget3-Osaka simulation, we study the evolution of protocluster and it's chemical abundance evolution.

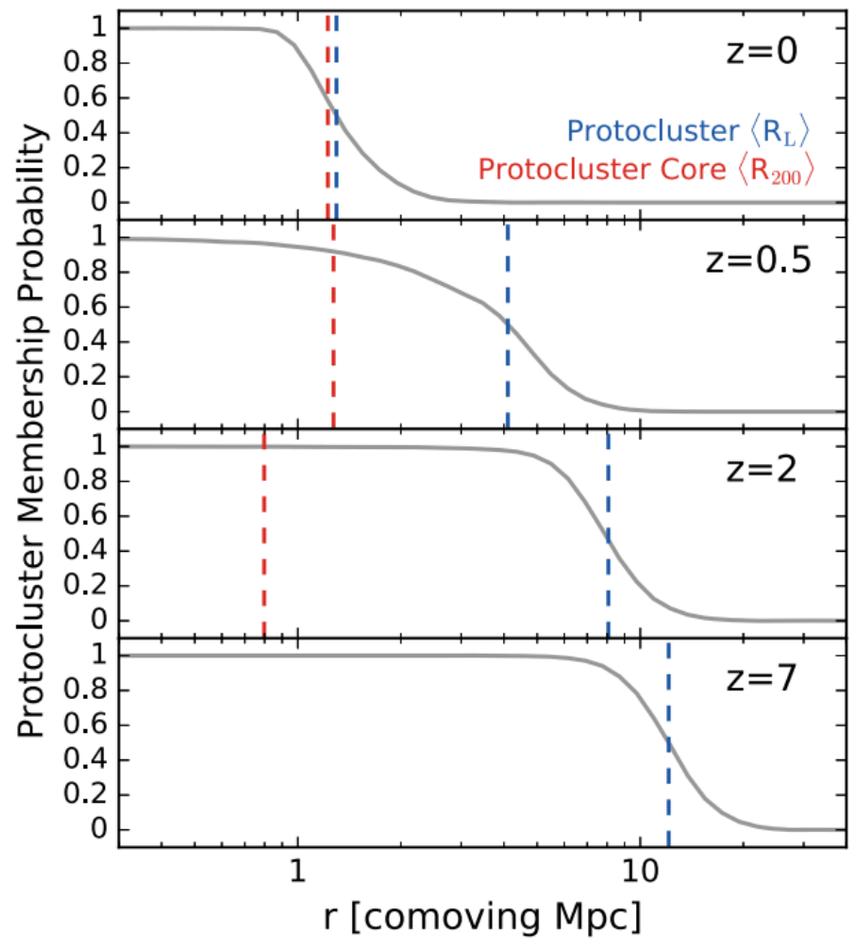
- Protocluster core's mass reaches $10^{14}\,M_\odot$ at z=2. And it grows to $10^{15}\,M_\odot$ at z=0.
- PC has a high SFR, but core is a special region that has a particularly high SFR.
- Core's metallicity reach > 10^{-3} at z=6.
- Type Ia SNe affect the core region by z=4.5. Star formation begins at z=7-10 in the core region.
- In the protocluster region, chemical abundance changes significantly around z=2.

How to decide the PC's radius

Membership probability represents the probability that a test halo at that radius belongs to a cluster of galaxies with z=0.

We trace all DM particle in the galaxy cluster at z=0 and define the protocluster radius when membership probability = 0.5.

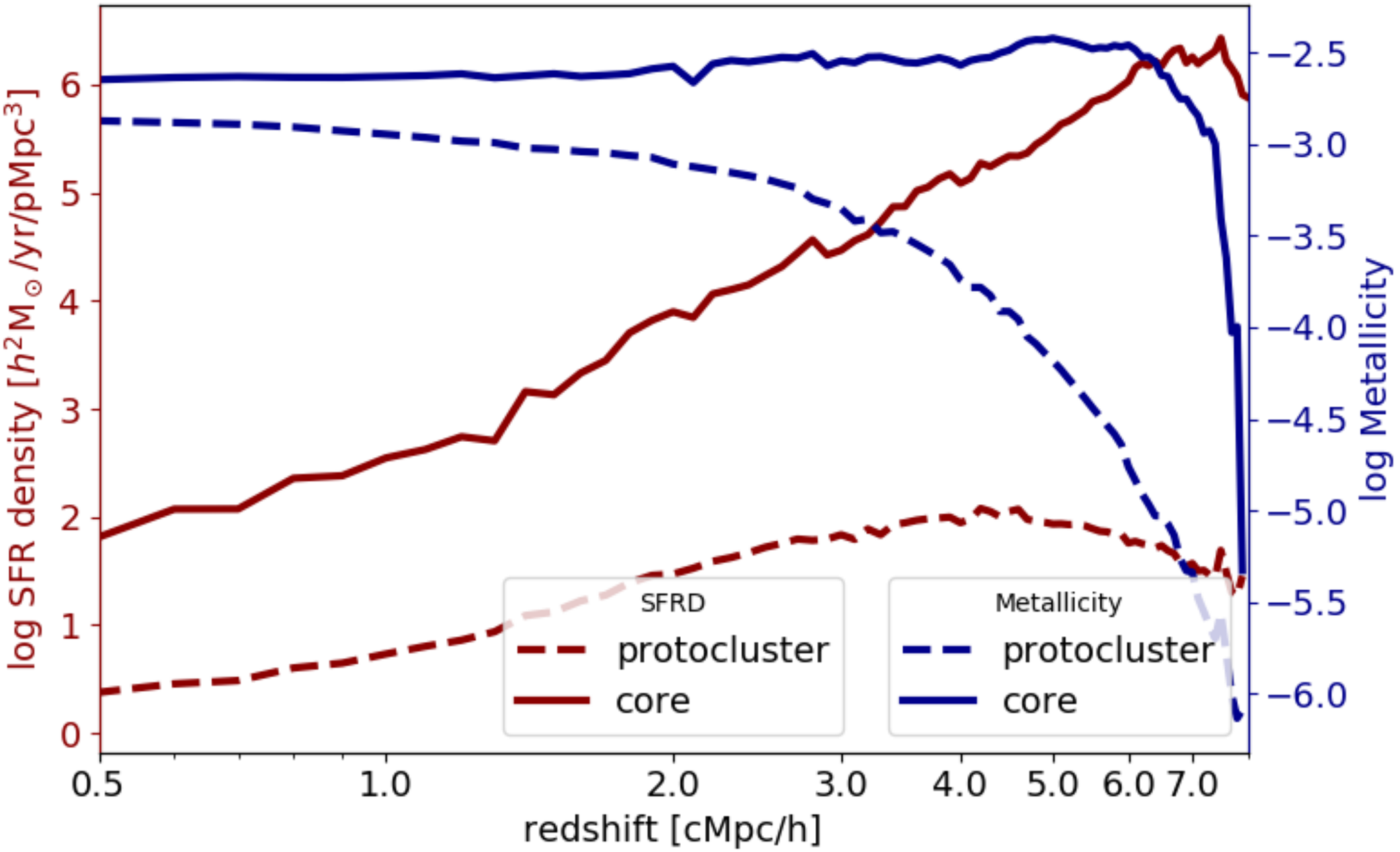




— Protocluster Core R_{200}
— Protocluster R

Chiang et al. 2017

Evolution of SFRD and Metallicity in Protocluster(PC), core region

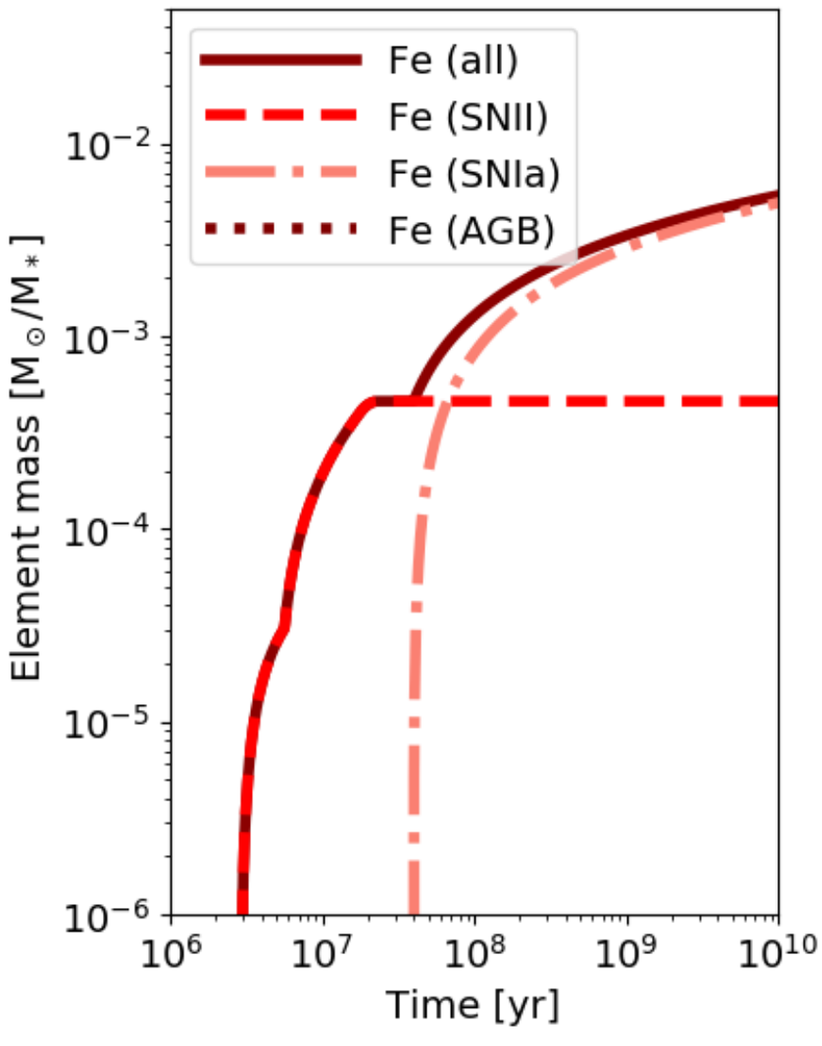


Star formation in the Core is active in the PC.

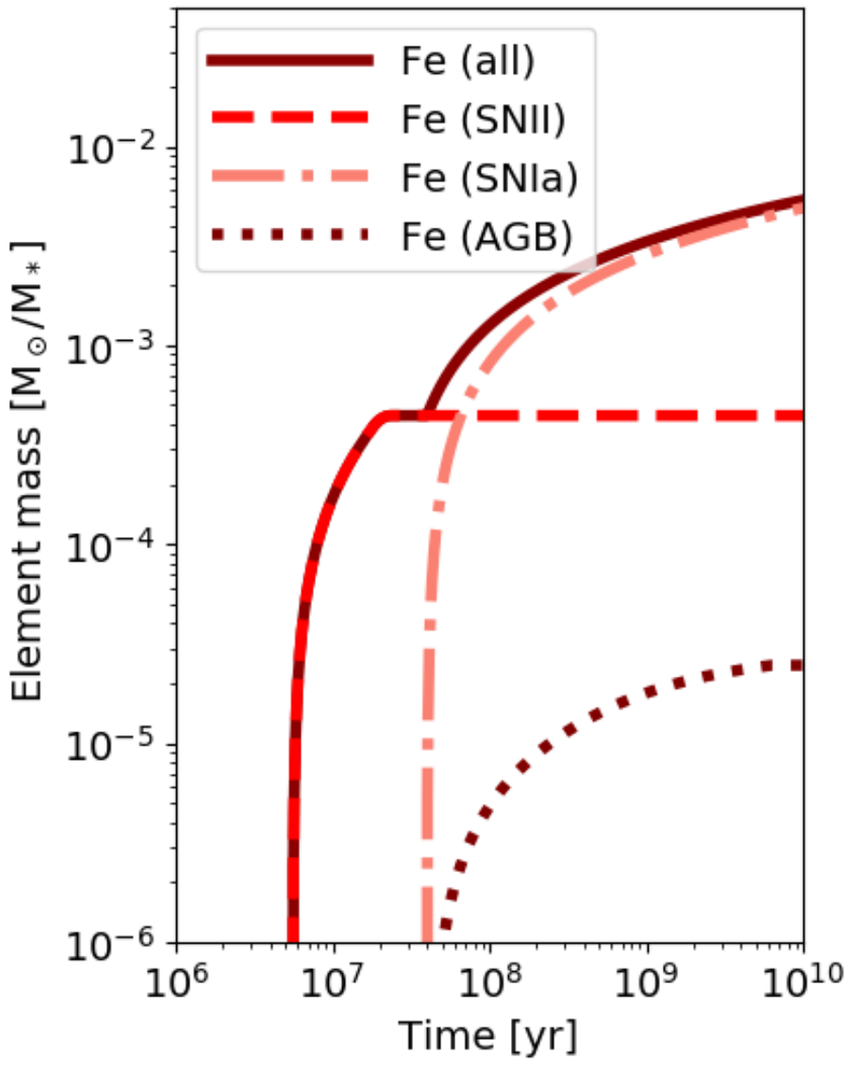
Metal formation by Type II SN, Type Ia SN, AGB

CELib metallicity dependence (Saitoh 2017)

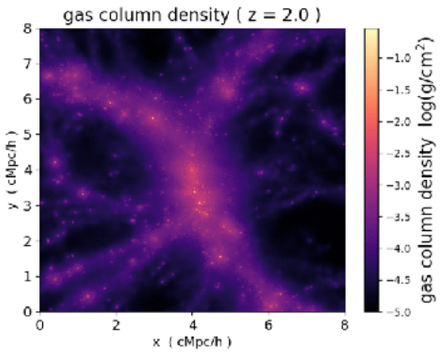
$Z = 10^{-6}$



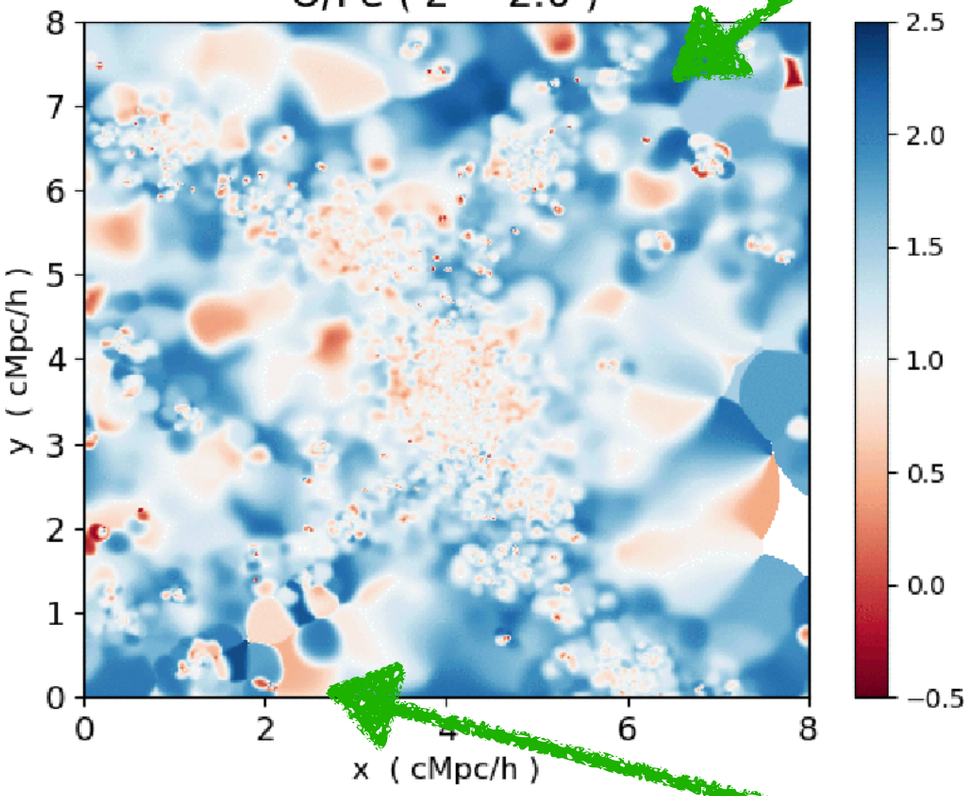
$Z = 10^{-3}$

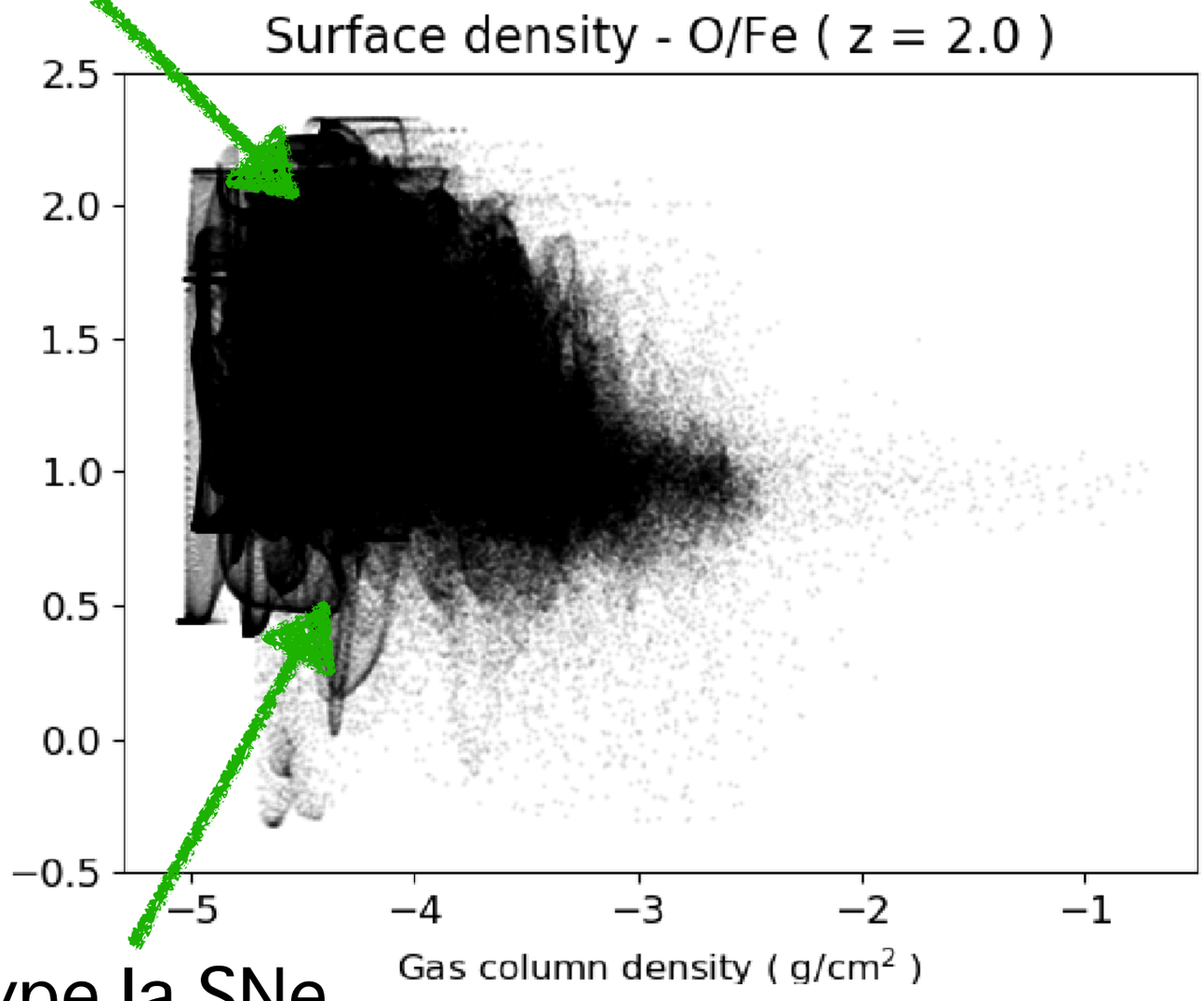


Surface density - O/Fe @ z=2



Here is not yet contaminated with iron.





Iron spreads by Type Ia SNe.

The high column density region have low O/Fe .
The low column density region have the large dispersion.