Star formation quenching and dissipation of cold flow

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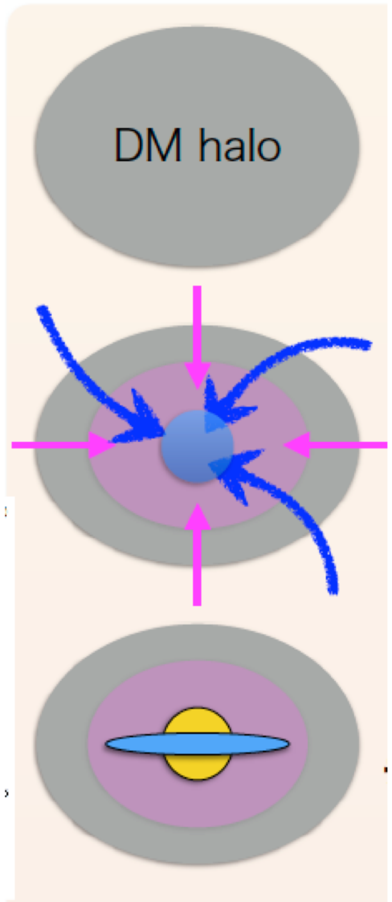
銀河・銀河間ガス研究会 (2020/8/4)

A schematic picture of galaxy formation

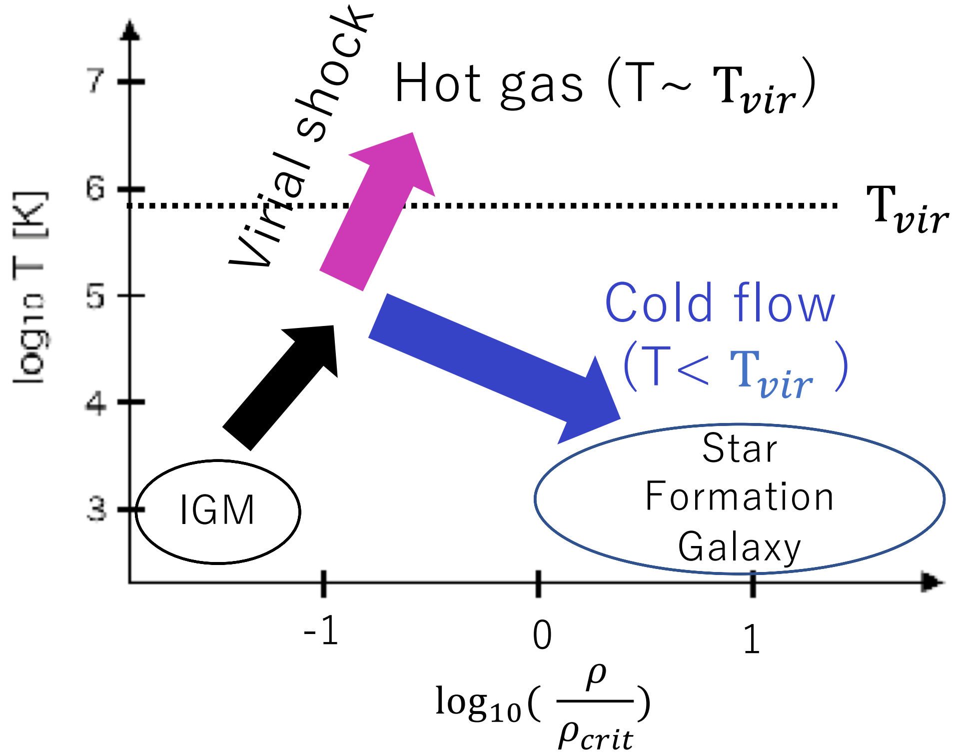
(Dekel et al. 2006, Keres et al. 2005)



1. DM Halo forms

2. Almost spherically accretion
&
Filamentary accretion (Cold flow)

- Gas Phase Diagram



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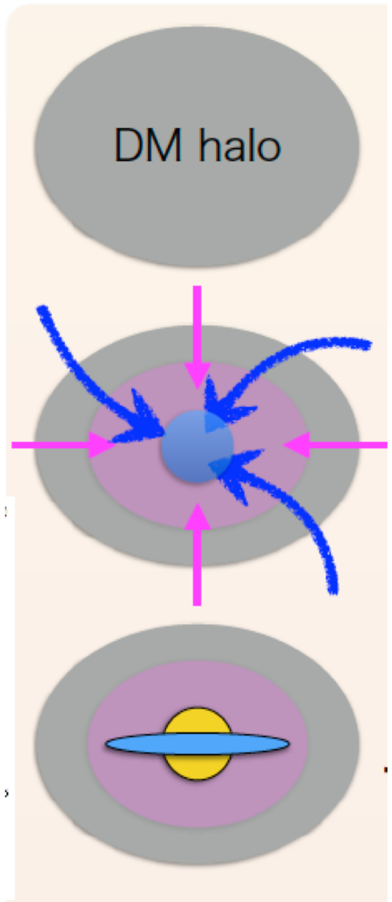

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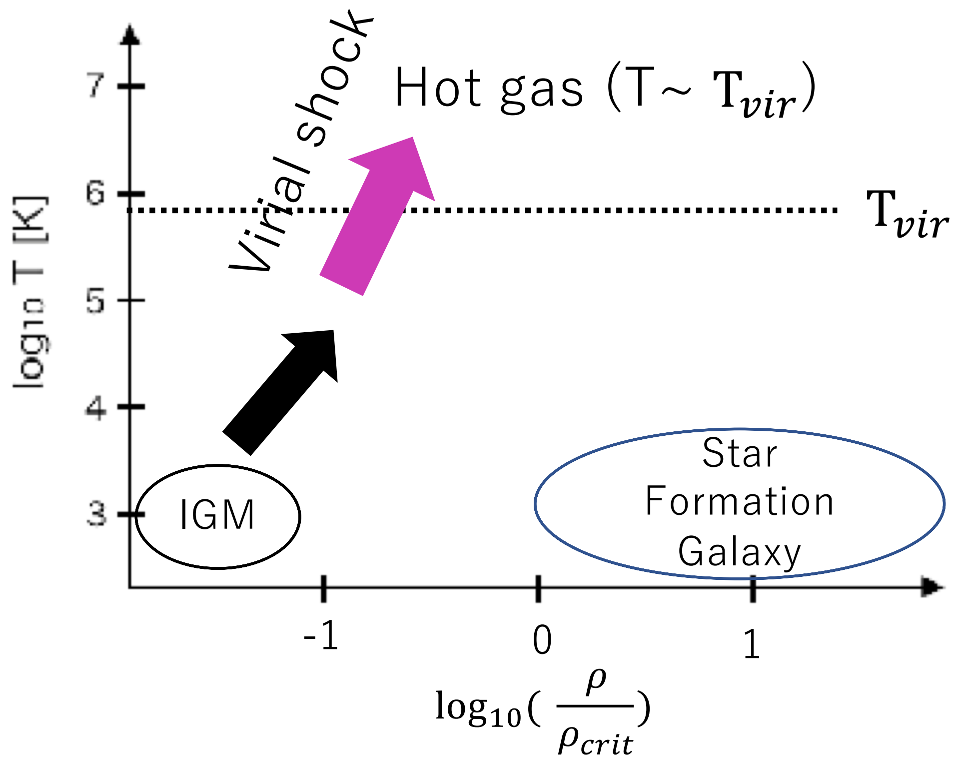

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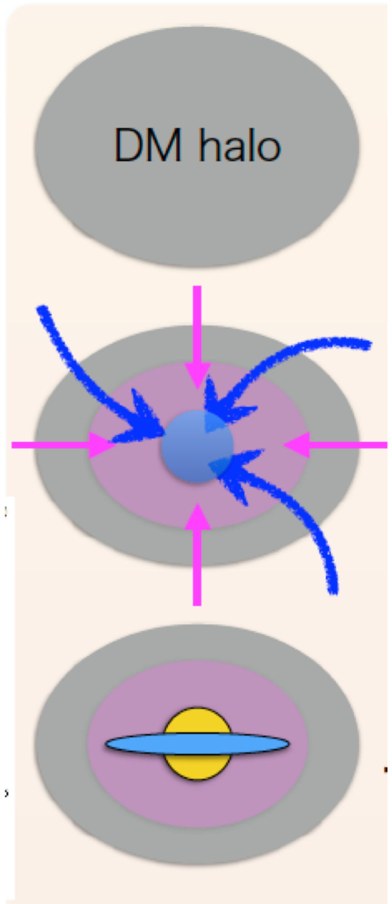

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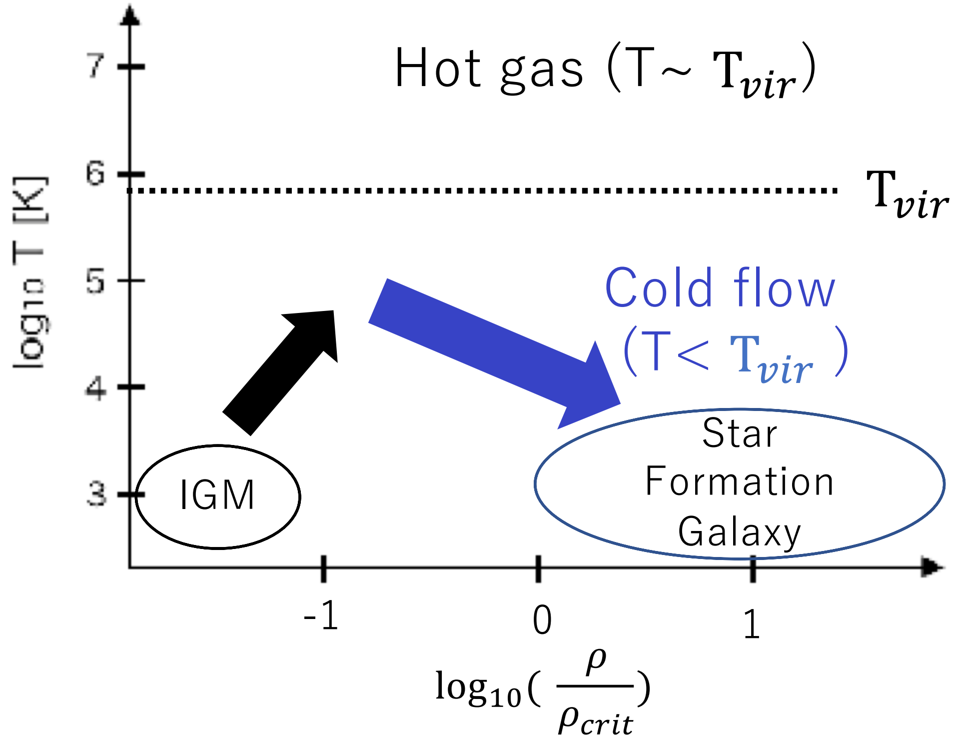

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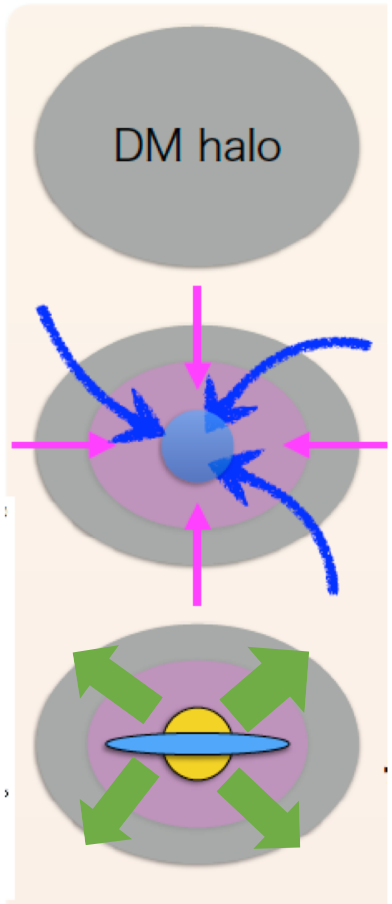

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2. Almost spherically accretion
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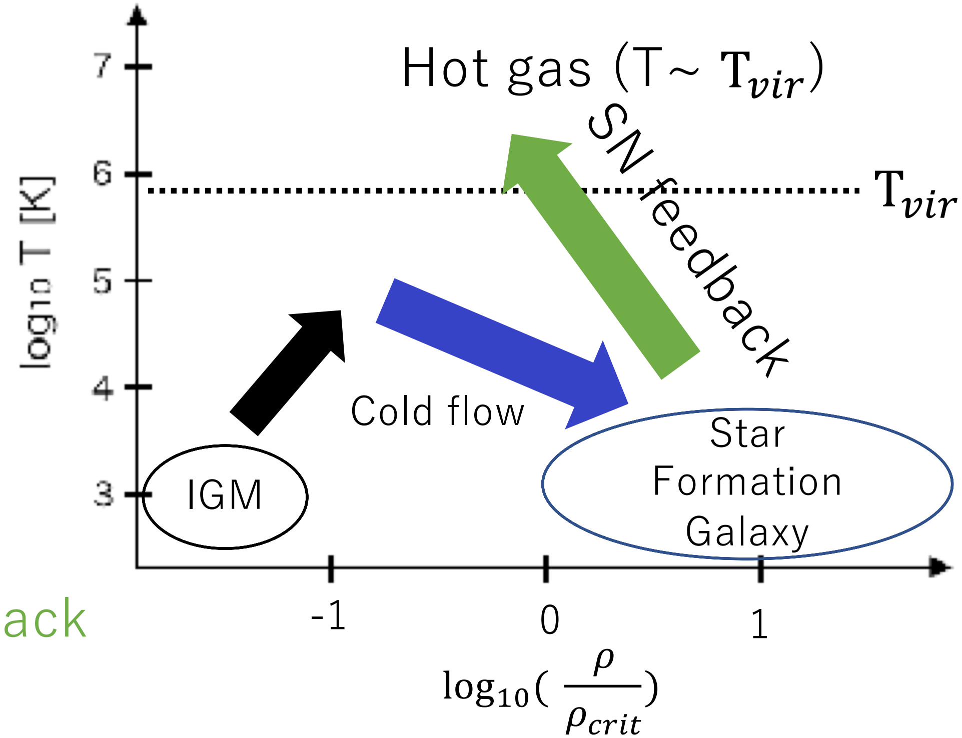
Filamentary accretion (Cold flow)

3. Star formation
&
SN (super nova) feedback

- Gas Phase Diagram



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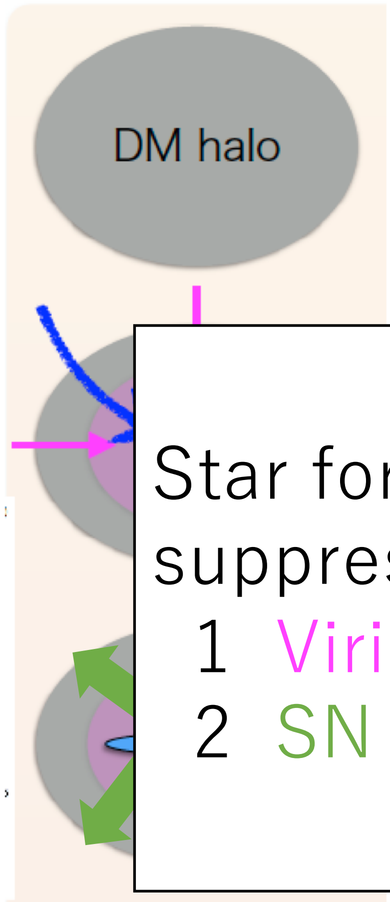


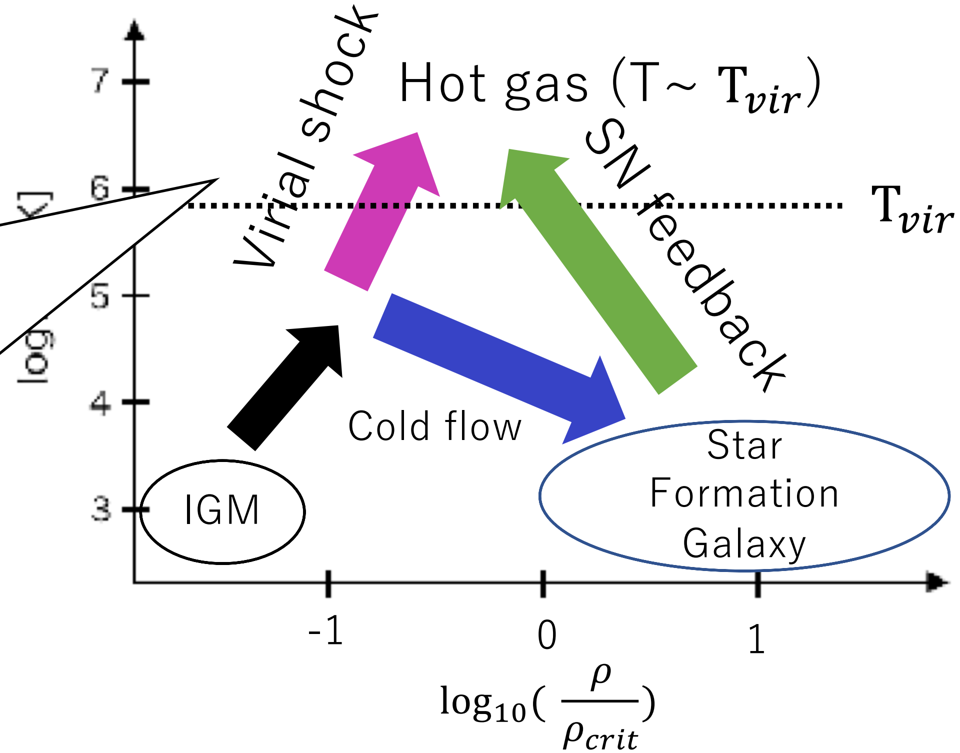
1. DM Halo forms

Star formation can be suppressed by

1 Virial shock

2 SN feedback

- Gas Phase Diagram



Two Classes of galaxies from Observations

- Blue galaxy

  Star formation is active

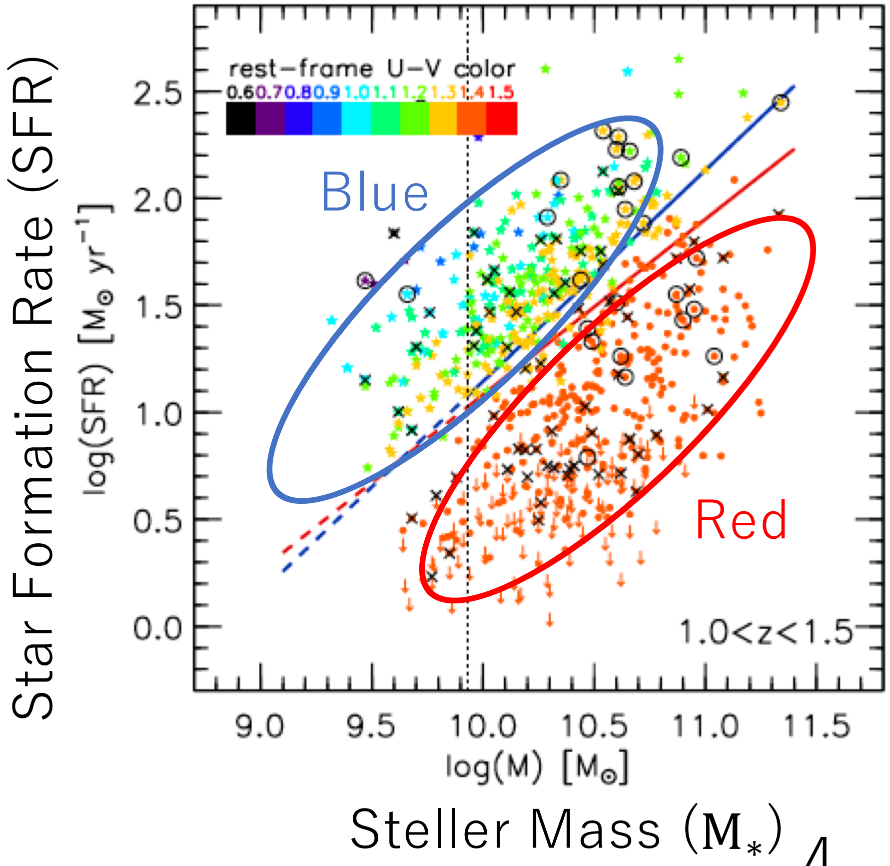
  Young galaxies

- Red galaxy

  Star formation is not active

  Old galaxies

Whitaker et al. 2012



Two Classes of galaxies from Observations

- Blue galaxy

  Star formation is active

  Young galaxies

  ⬇ Quenching

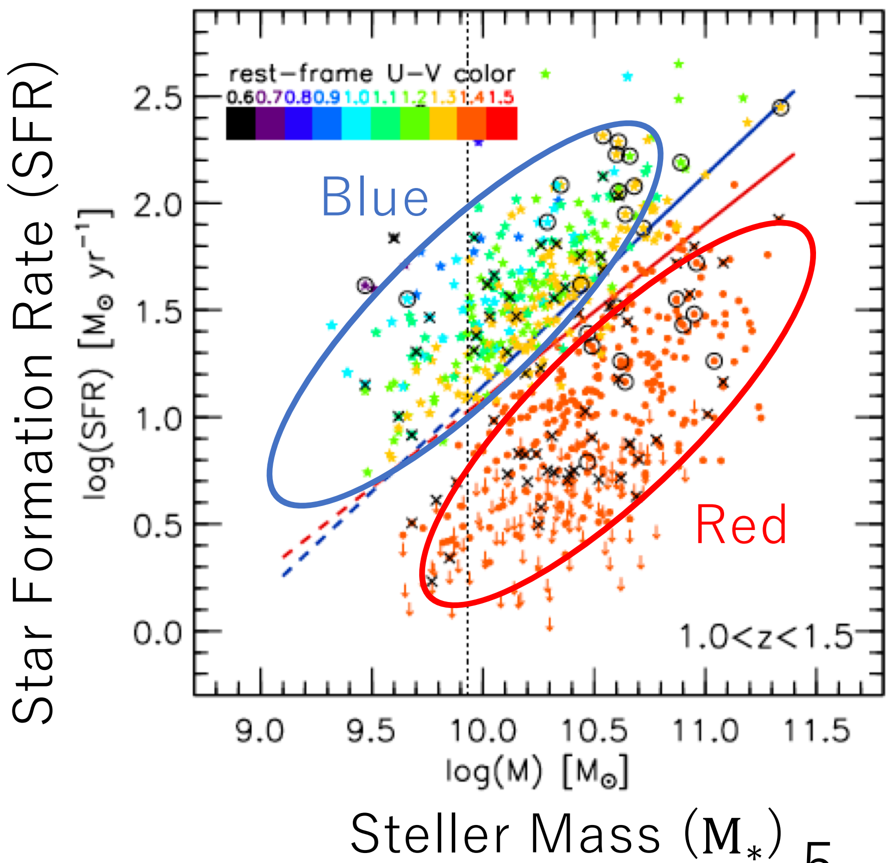
- Red galaxy

  Star formation is not active

  Old galaxies

When and how quenching of star formation happen in galaxies.

Whitaker et al. 2012



Method

GADGET3-Osaka Simulation

(Shimizu et al. 2019, Aoyama et al. 2018)

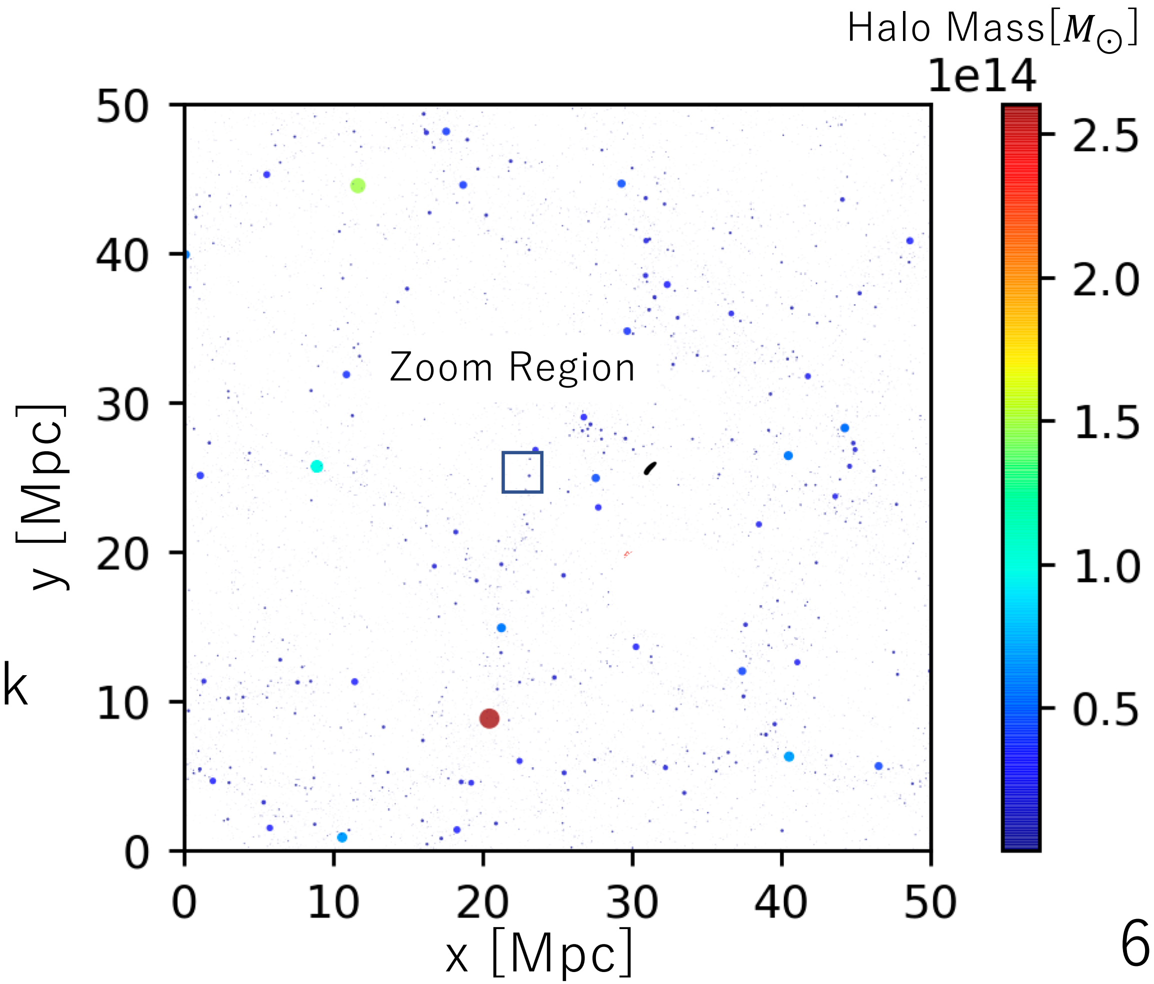
- Zoom in simulation

  $\mathrm{M_{halo}} \sim 10^{12} M_{\odot}$ @z=0

  $(2.7 \times 0.38 \times 5\ [\mathrm{Mpc}^3])$
- Softening length $\varepsilon = 814$ pc
- $\mathrm{m}_{DM} = 1.05\times10^{6}\ [\mathrm{M}_{\odot}/h]$
- $\mathrm{m}_{gas} = 1.96\times10^{5}\ [\mathrm{M}_{\odot}/h]$
- Feedback Model

  SN II, SN Ia (including Wind), AGB Star, Early stellar Feedback

- ISM $(\mathrm{R} \leqq 0.2\ \mathrm{R}_{vir})$
- Cold flow $(\mathrm{T} < \mathrm{T}_{vir})$



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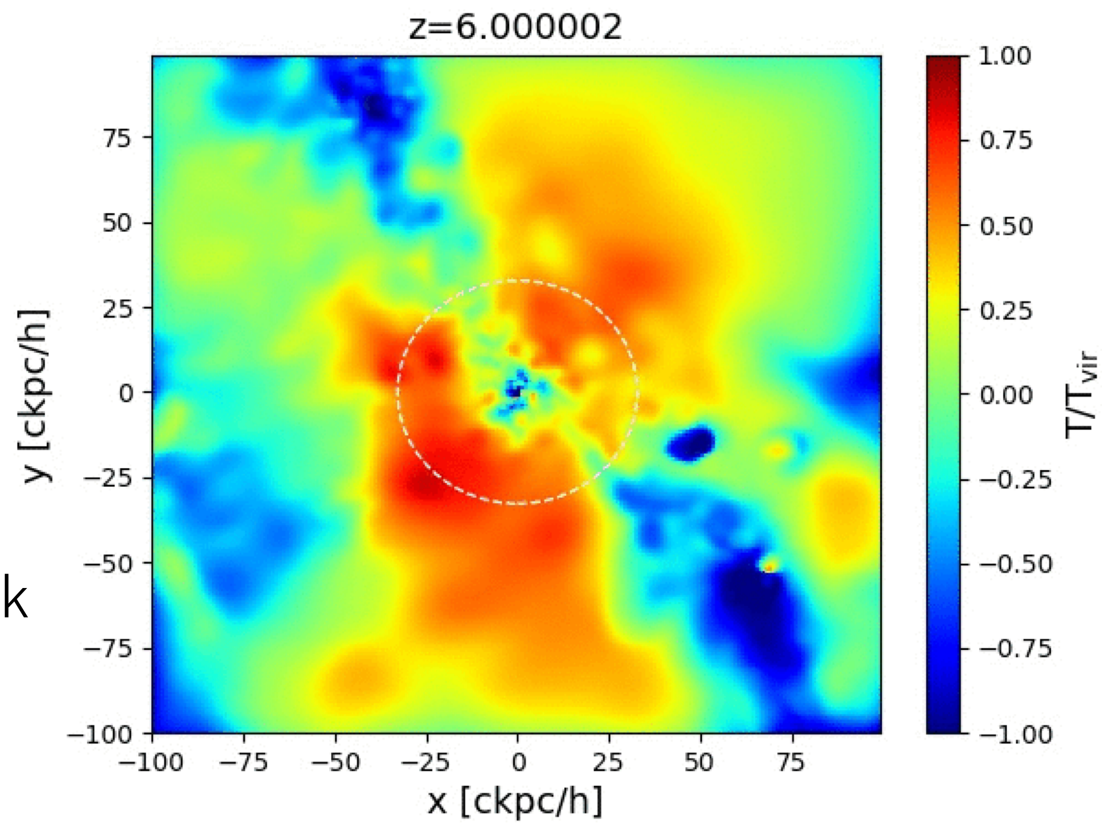
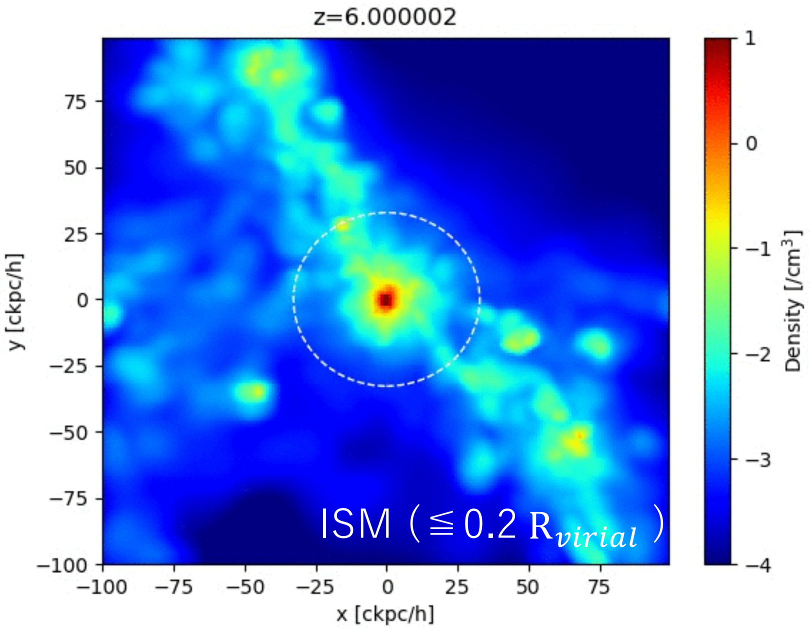


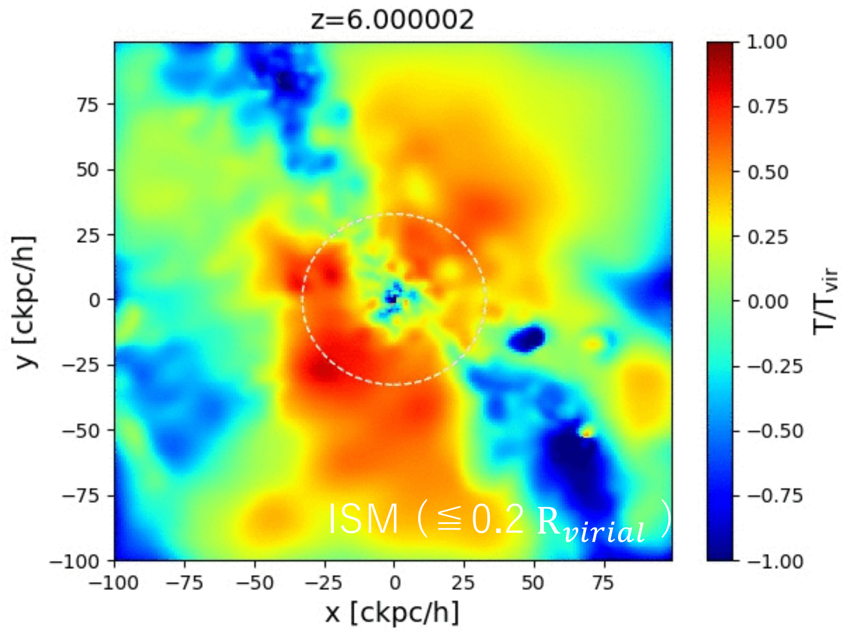
Results & Discussion

Movies of The Simulation

- Gas density (200 × 200 kpc)



- Tempertature (200 × 200 kpc)



- Cold gas accretes to the center clearly at high z
- Hot gas is dominant around the galaxy after z~3

Star Formation History of ISM

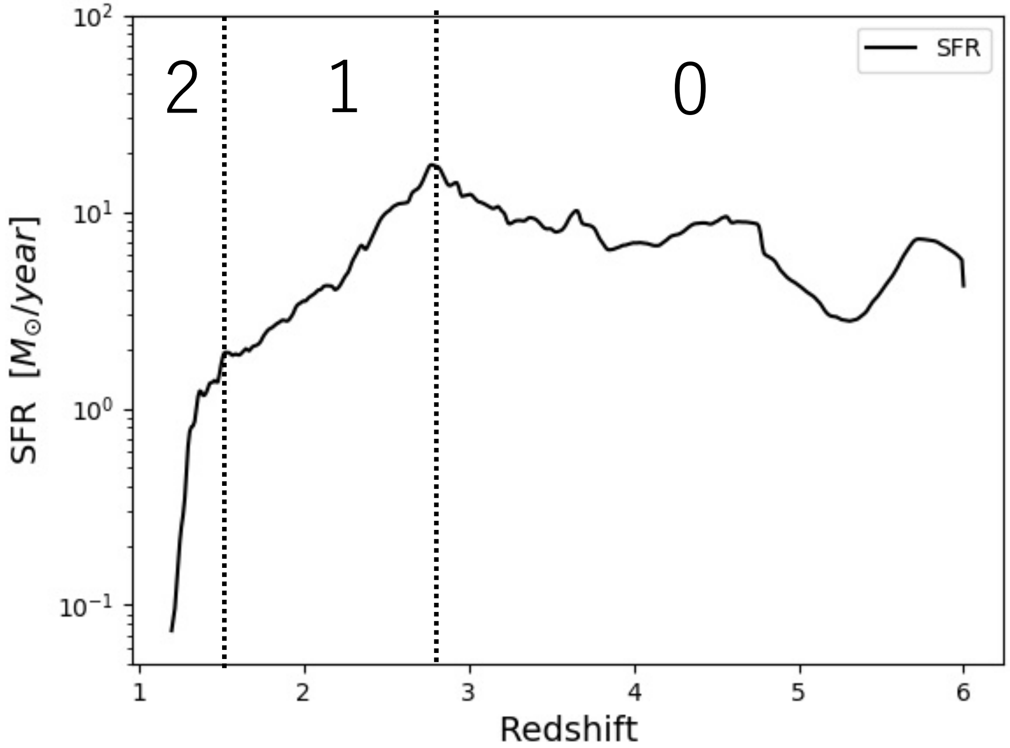
0. Star forming epoch

1. Slow quenching epoch
   Time scale ~ 2 Gyr

2. Fast quenching epoch
   Time scale ~ 300Myr

What causes each star formation quenching ?

Star Formation history in ISM ($\leqq 0.2\ R_{vir}$)

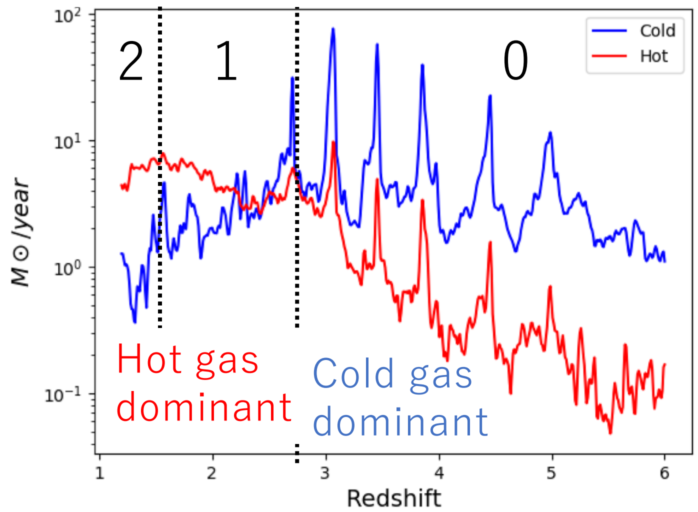


1.Slow quenching - gas accretion

Lack of cold gas inflow

⇨ SFR decreases

Inflow Rate (Cold vs Hot) @ 0.2 R_{vir}



1.Slow quenching
- gas accretion

Lack of cold gas inflow

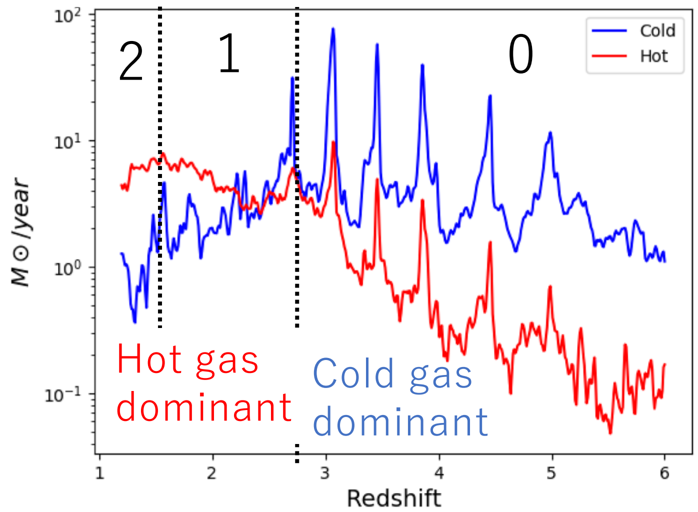
⇨ SFR decreases

2.Fast quenching
-gas flow (Out/In)

Outflow rate is more than inflow rate

⇨ Outflow gas carries cold gas out of ISM & Cold gas is not supplied to galaxy

Inflow Rate (Cold vs Hot) @ 0.2 R_{vir}



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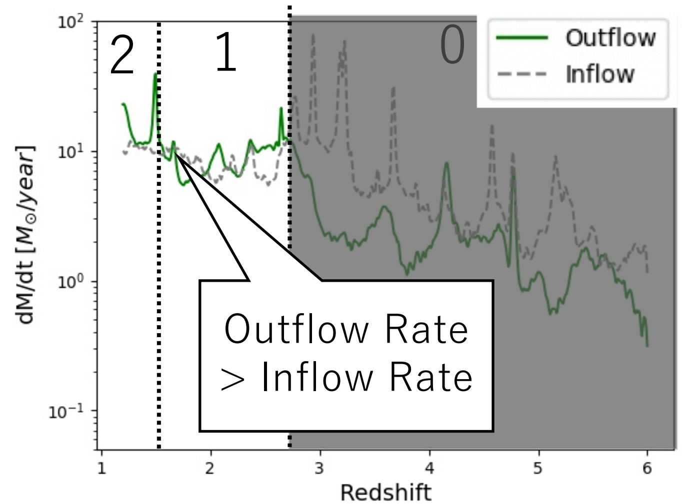
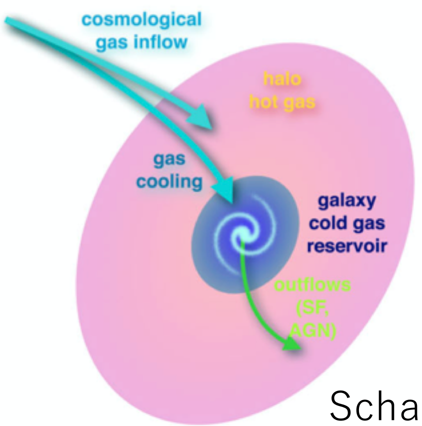
Inflow rate vs Outflow rate @ 0.2 R_{vir}



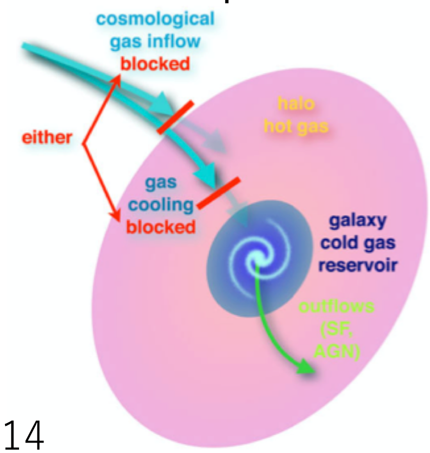
A schematic picture of Star formation quenching of this simulation

0. Star forming

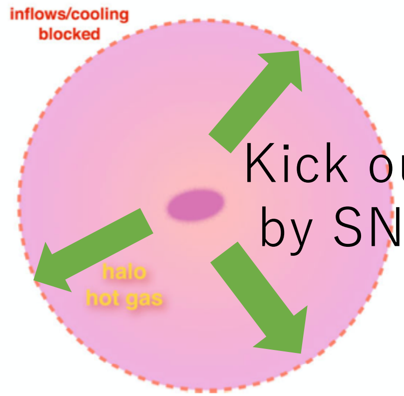


Schawinski et al.2014

1. Slow quenching



2. Fast quenching



Kick out cold gas
by SN feedback

Cold gas is supplied to ISM

Cold gas inflow dissipates by virial shock or heating of SNe

Cold gas in ISM is kicked out by SNe

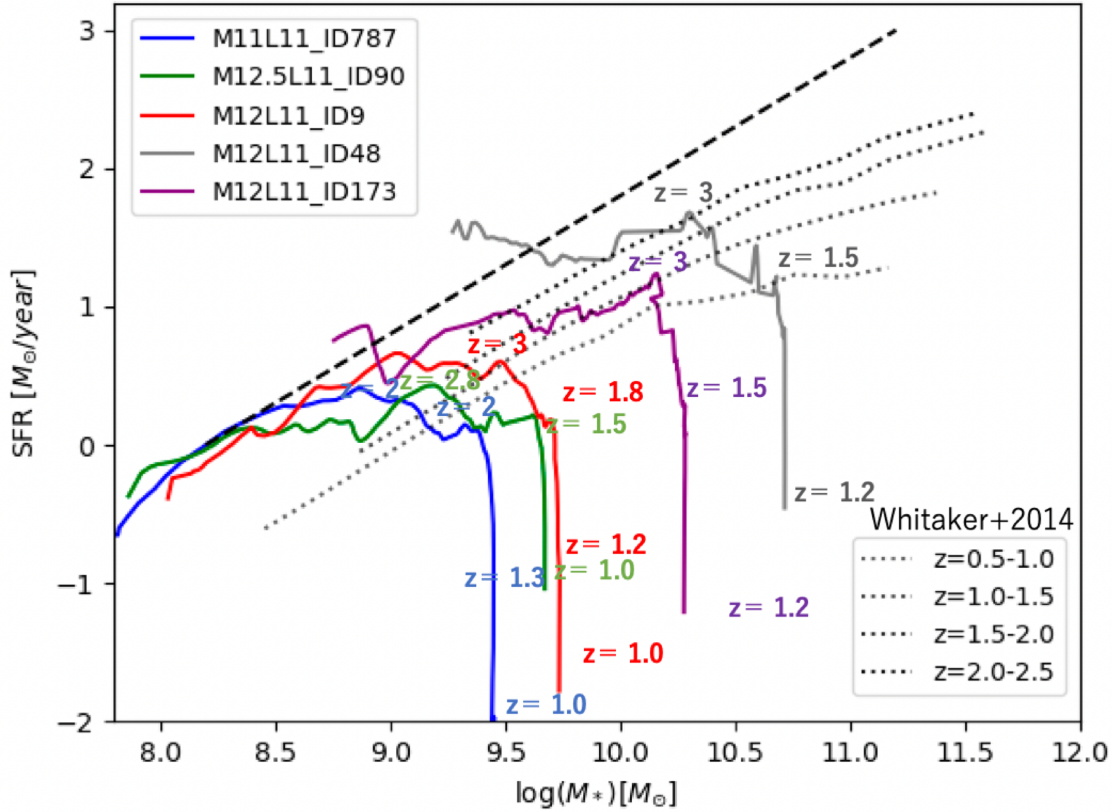
Star formation quenching of various galaxies

- Object

3天体 $\mathrm{M_{halo}} \sim 10^{12} M_{\odot}$ @z=0

1天体 $\mathrm{M_{halo}} \sim 10^{13} M_{\odot}$ @z=0

1天体 $\mathrm{M_{halo}} \sim 10^{11} M_{\odot}$ @z=0



Those galaxy evolves along main sequence

⇨ quenching

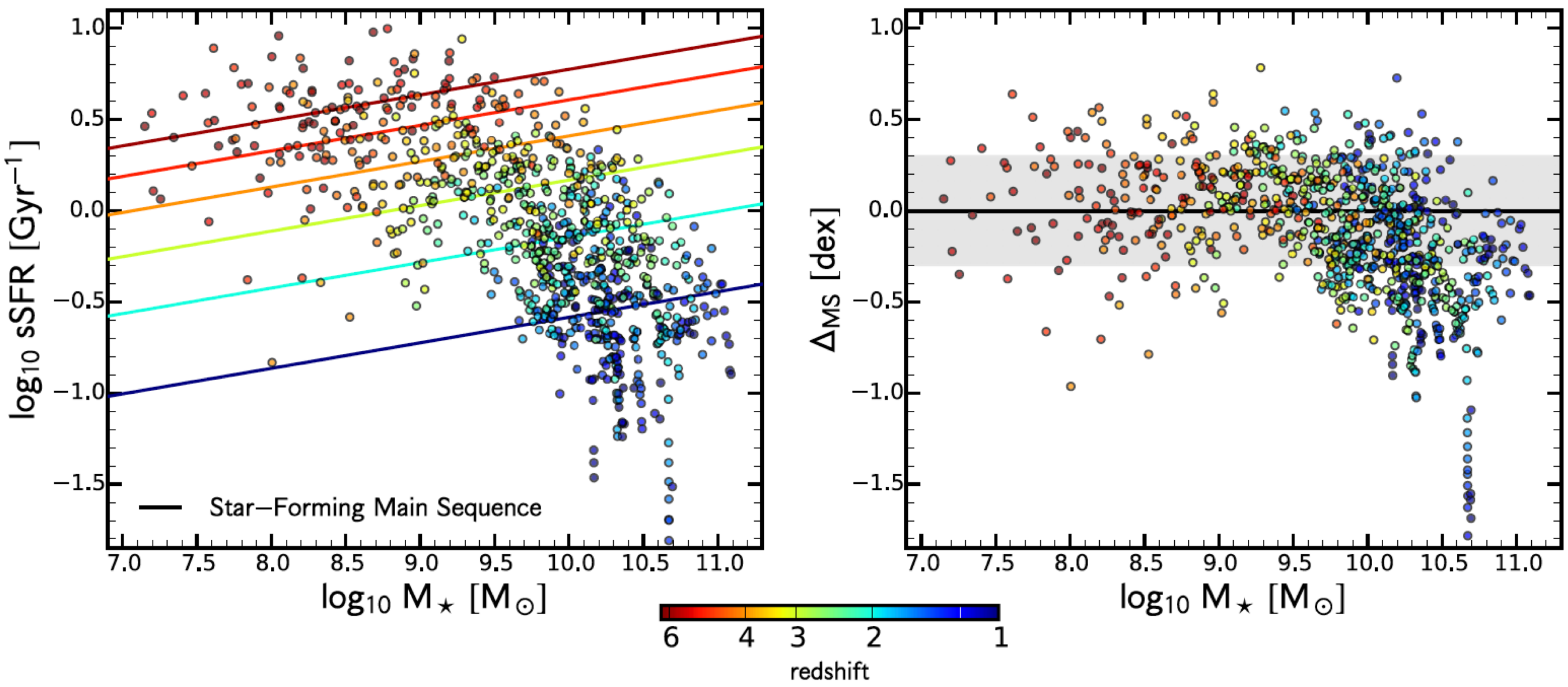
Summary

- Simulate a halo ($\mathbf{M_{halo}} \sim \mathbf{10^{12}} M_{\odot}$ @z=0)
- Two type of Star formation quenching in the galaxy
  1. Slow quenching (~ 2 Gyr) ← Cold gas inflow rate decrease
  2. Fast quenching (~ 300 Myr) ← No cold gas in ISM
- SN feedback is crucial for star formation quenching($\mathbf{M_{halo}} < \mathbf{10^{13}} M_{\odot}$)

Future work

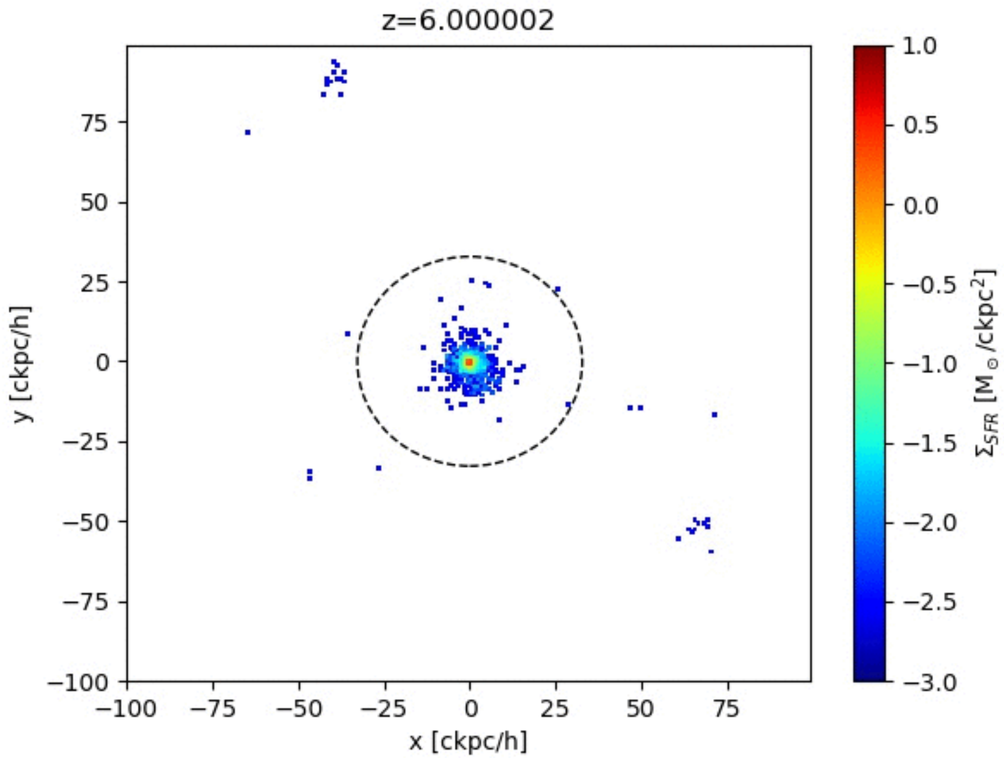
- Investigate how much heating of SN feedback contributes to cold flow dissipation
- Investigate star formation quenching of another galaxies

tacchella2016



SFR MAP & Stellar distribution

SFR



Stellar mass distribution