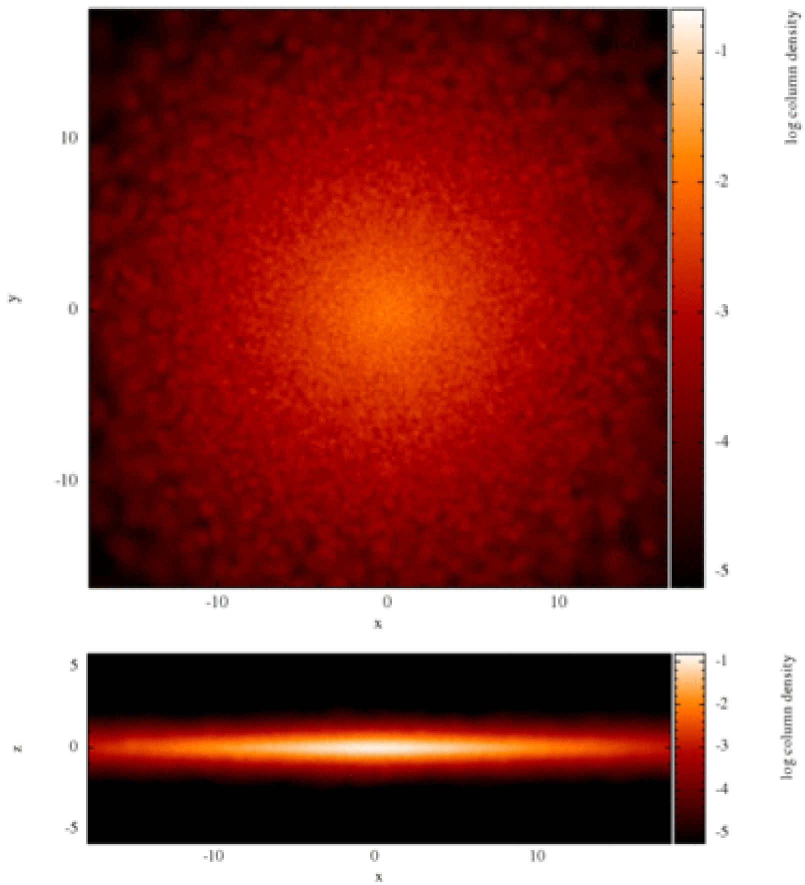
Development for New SNII Feedback Treatment



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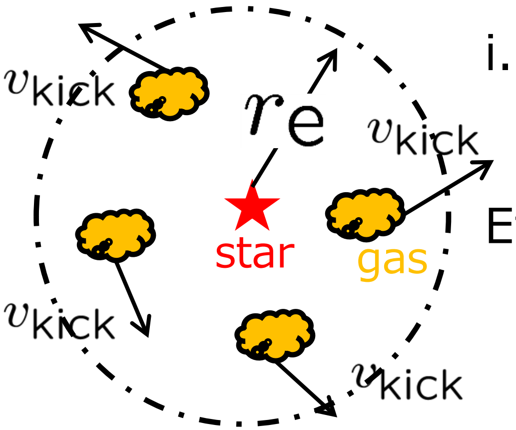
Traditional SNII model

Traditional SNII scheme



i. Kick velocity ($v_{\rm kick}$) assignment to nearest particles

← momentum or energy conservation

← constant kick velocity of all kick particles

Effective SNII radius depends on the simulation resolution

$$v_w \propto v_{vir}$$

Global value (not local value)

ii. Cooling and hydro-interaction turns off if the below conditions satisfies

$$n_{\rm esc} > 0.1 n_{\rm SF}$$

or

$$t_{\rm esc} < l_{\rm esc}/v_{\rm wind} : l_{\rm esc} \sim 10{\rm kpc}$$

根拠？

iii. Cooling and hydro-interaction turns on again if below conditions satisfies

$$n_{\rm esc} < 0.1 n_{\rm SF}$$

or

$$t_{\rm esc} > l_{\rm esc}/v_{\rm wind} : l_{\rm esc} \sim 10{\rm kpc}$$

Beyond the traditional model

- Traditional model
  - ✓ Wind velocity is proportional to virial velocity of host halo
    ⇒ using global value (halo information) not local value
$$v_w \propto v_{vir}$$
  - ✓ Non physical motivated value of effective radius of SNII is not
  - ✓ Non physical motivated value of no cooling and hydro-interaction time

In far future, each Star (not assumption IMFs) may be resolved.
Moreover, SNII bubble of each star particle may be resolved.
We need to develop beyond the traditional model for such future.

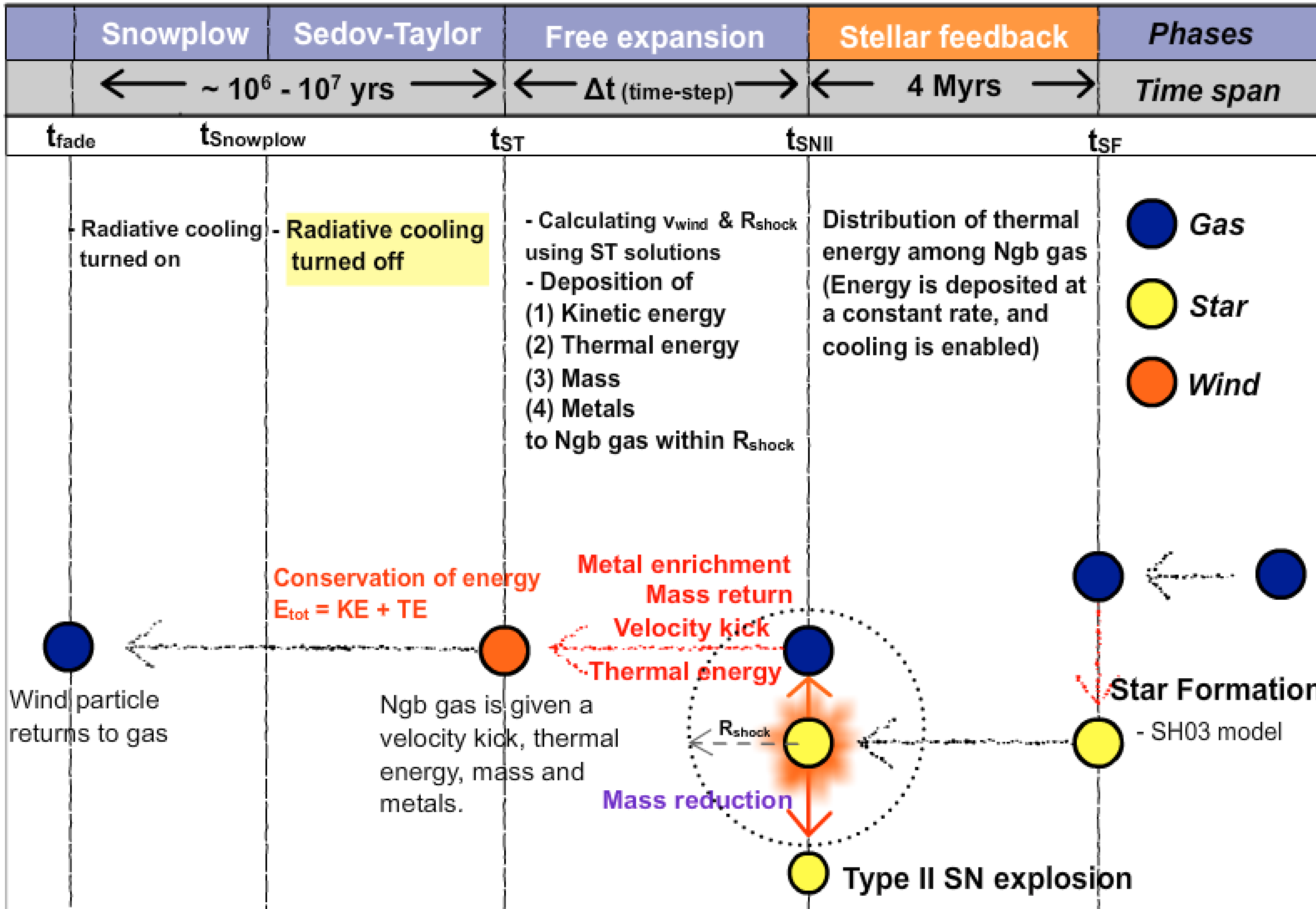
- New model
  - ✓ Using physical motivated values for SN feedback
    - ・Effective SNII radius, wind velocity, no-cooling time
      ⇒ Analytic solution (Sedov-Taylor solution)
      ⇒ Using local value not using halo information

New SNII feedback treatment

New SNII feedback treatment

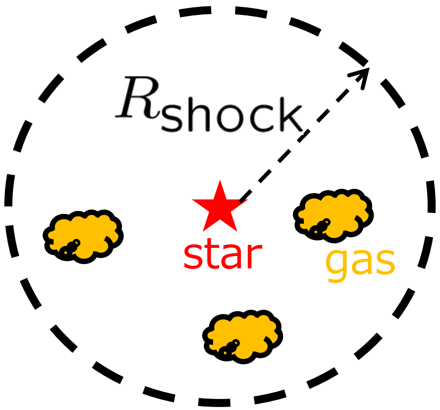
Schematic picture

Based on master thesis of Todoroki 2014



New SNII feedback treatment

Based on analytic solution of SN bubble evolution



1. Calculation shock radius (R_{shock})
(Estimation density and pressure around star particles using gas particle around them)

$$R_{\rm shock} = 10^{1.74} E_{51}^{0.32} n^{-0.16} P_{04}^{-0.20} \rm pc$$

$$E_{51} = E_{\rm SN}/10^{51} \rm erg/s$$

$$P_{04} = 10^{-4} P k^{-1}$$

Chevalier 1974, Stinson et al.2006

2. Assignment SNII energy (kinetic, thermal) to gas particles in R_{shock}
(fiducial model : E_K=0.3, E_T=0.7)

$$\Delta A_i = \frac{A m_i W(|r_s - r_i|, h_s)}{\sum_{j=1}^{N} m_j W(|r_s - r_j|, h_s)}$$

I assign gas and Metal mass by SNII in the same manner

New SNII feedback treatment

3.Estimation Kick velocity (v_{shock}) based on energy conservation

$$v_{\rm shock} = \sqrt{\frac{2E_K}{m}}$$

Analytic solution of shock velocity in Sedov-Taylor phase

$$v_{\rm shock}^{\rm ana} = 188\left(\frac{E_K}{10^{51}}\right)^{0.07} n^{0.14} {\rm km/s}$$

Resolution of our simulation is not enough to resolve SN bubble.
This method does not satisfy energy conservation if all kick particles have this analytic velocities.

4.Cooling turns off during Sedov-Taylor phase (adiabatic phase).
But, hydro-interaction always turns on.

$$T_{\rm ST} = 8.31\times 10^5 E_{51}^{0.31} n^{0.27} P_{04}^{-0.64} {\rm yr}$$

Chevalier 1974, Stinson et al.2006

Simulation Results

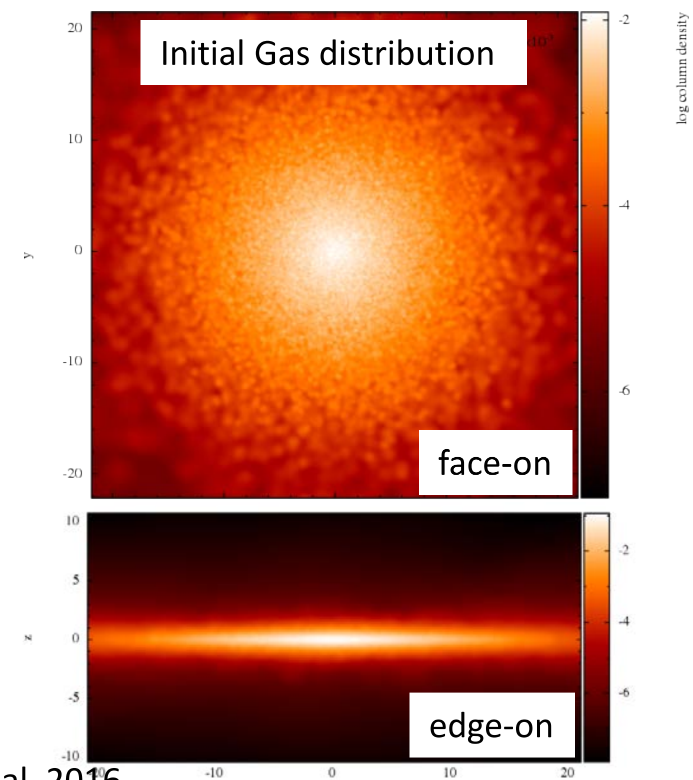
Test for Isolated disk galaxy

Simulation code: Gadget3-Osaka

radiative cooling (grackle package)/heating, Star formation,
time dependence feedback (early stellar feedback, SNII, SNIa),
Time dependence metal yield (SNII, SNIa, AGB: CELib package, Saitoh 2016),
DISPH method (Saitoh & Makino '13, Hopkins'13)

Isolated disk galaxy initial condition (AGORA project)

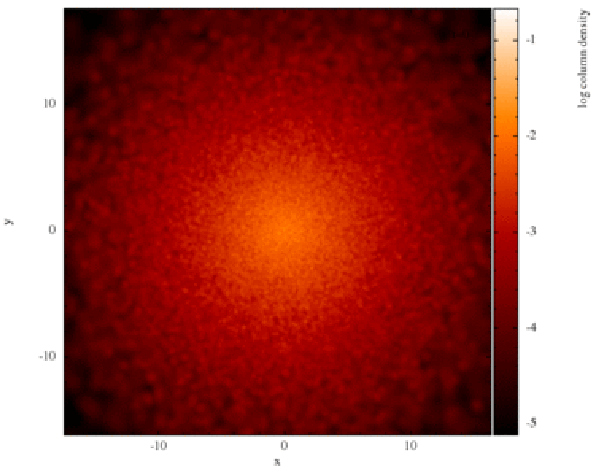
Parameter	Value
Gas mass	$8.59 \times 10^{10} M_\odot$
Dark matter mass	$1.25 \times 10^{12} M_\odot$
Disk mass	$4.30 \times 10^{9} M_\odot$
Bulge mass	$3.44 \times 10^{10} M_\odot$
Total mass	$1.3 \times 10^{12} M_\odot$
Number of gas particle	1.00×10^{5}
Number of dark matter	1.00×10^{5}
Number of disk particle	1.00×10^{5}
Number of bulge particle	1.25×10^{4}
Gas particle mass	$8.59 \times 10^{4} M_\odot$
Dark matter particle mass	$1.25 \times 10^{7} M_\odot$
Disk particle mass	$3.44 \times 10^{5} M_\odot$
Bulge particle mass	$3.44 \times 10^{5} M_\odot$
Softening length	80 pc



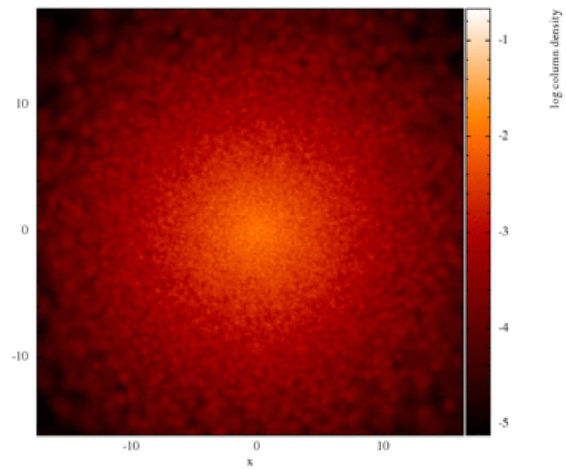
Kim et al. 2016

Galaxy evolution of each model

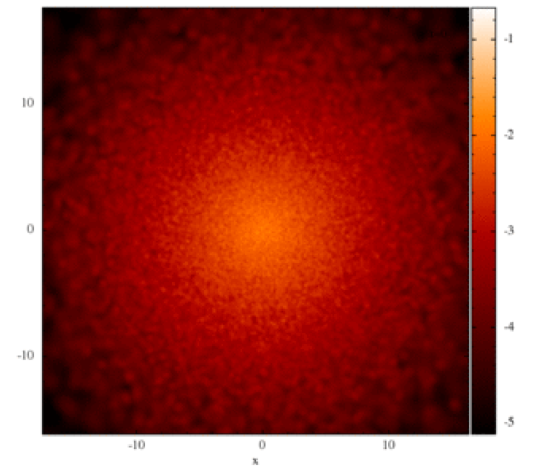
ESFB+SNII+SNIa



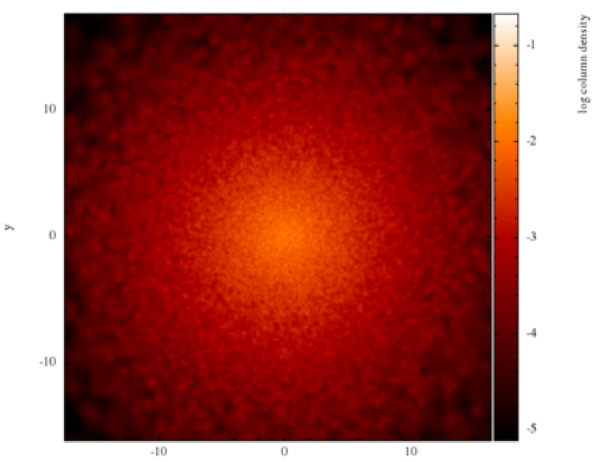
No FB



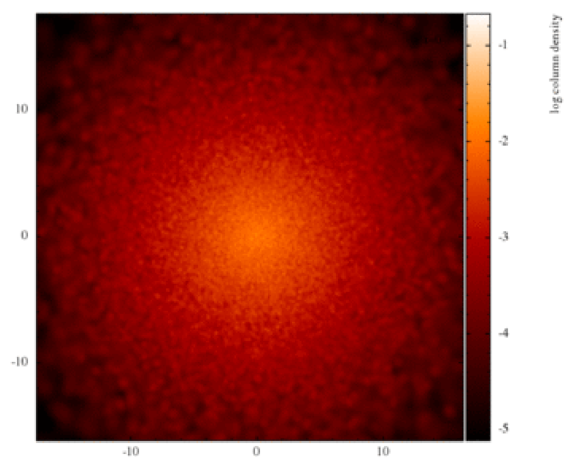
ESFB only



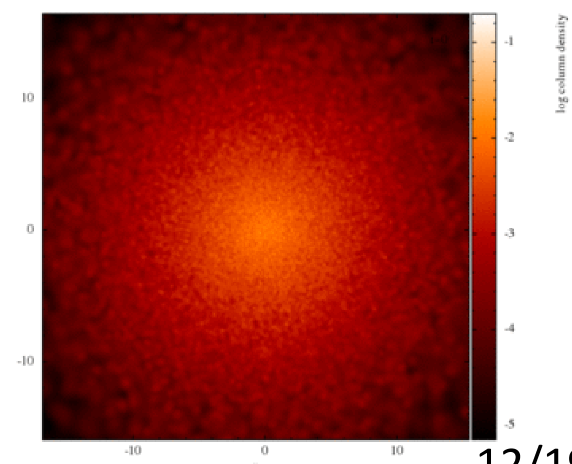
SNII only



SNIa only

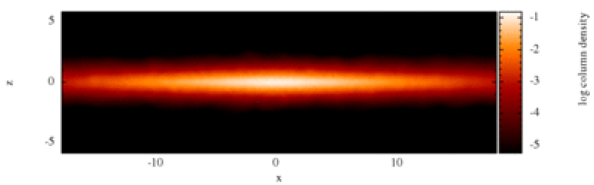


Const wind

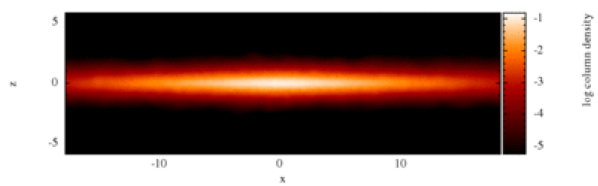


Galaxy evolution of each model

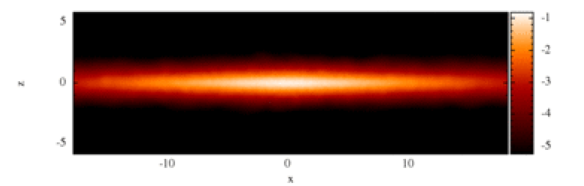
ESFB+SNII+SNIa



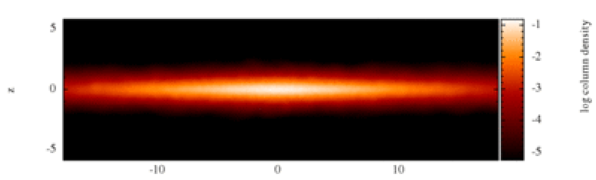
No FB



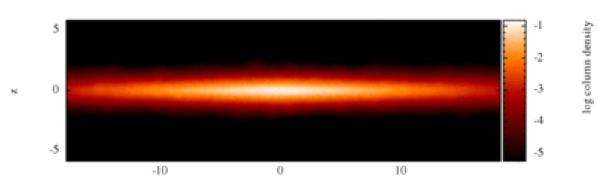
ESFB only



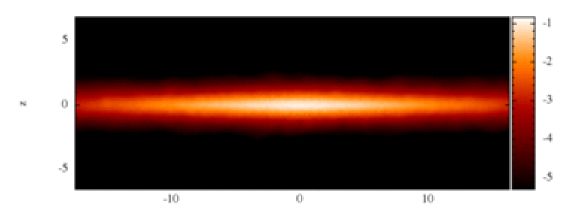
SNII only



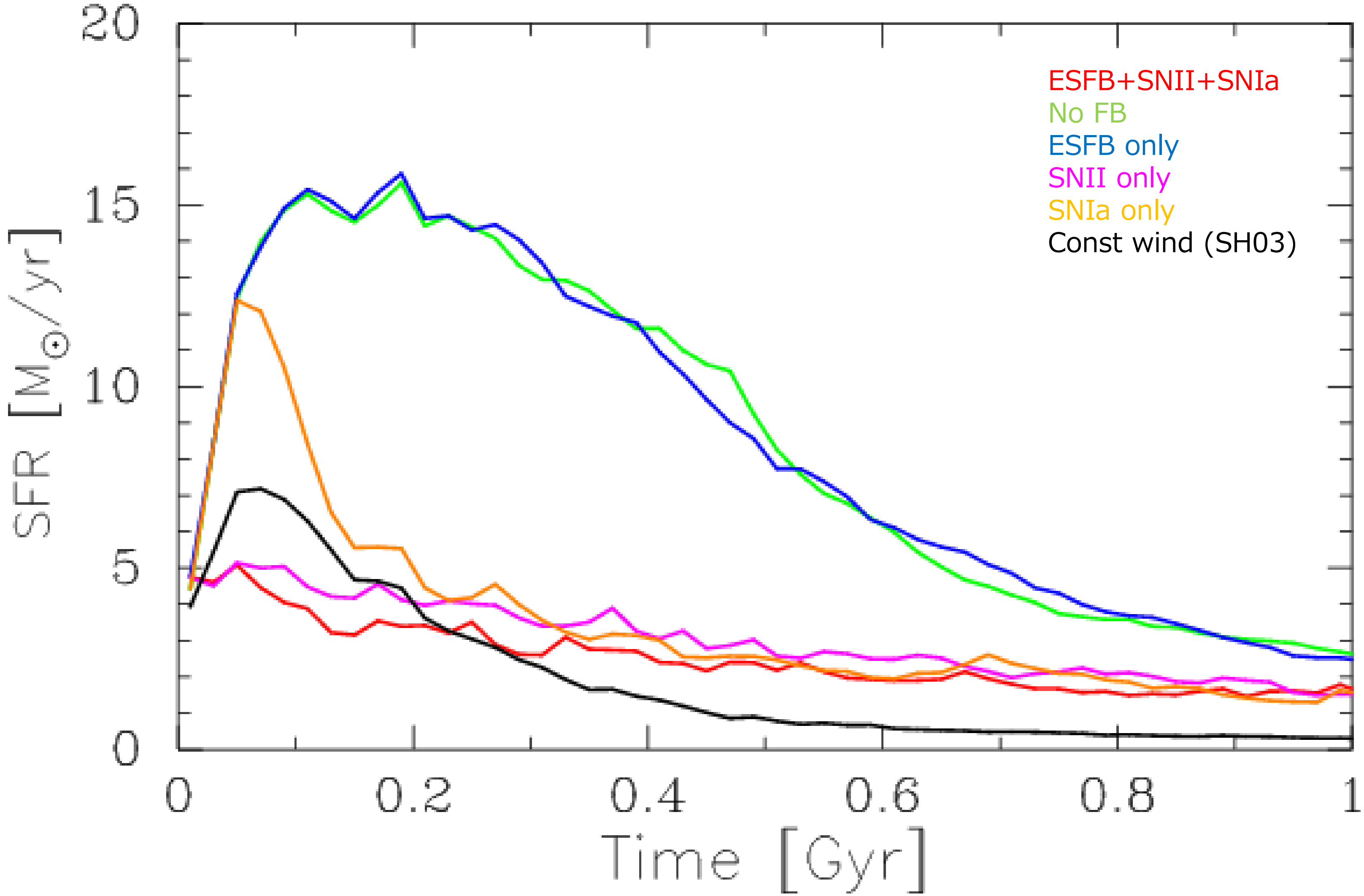
SNIa only



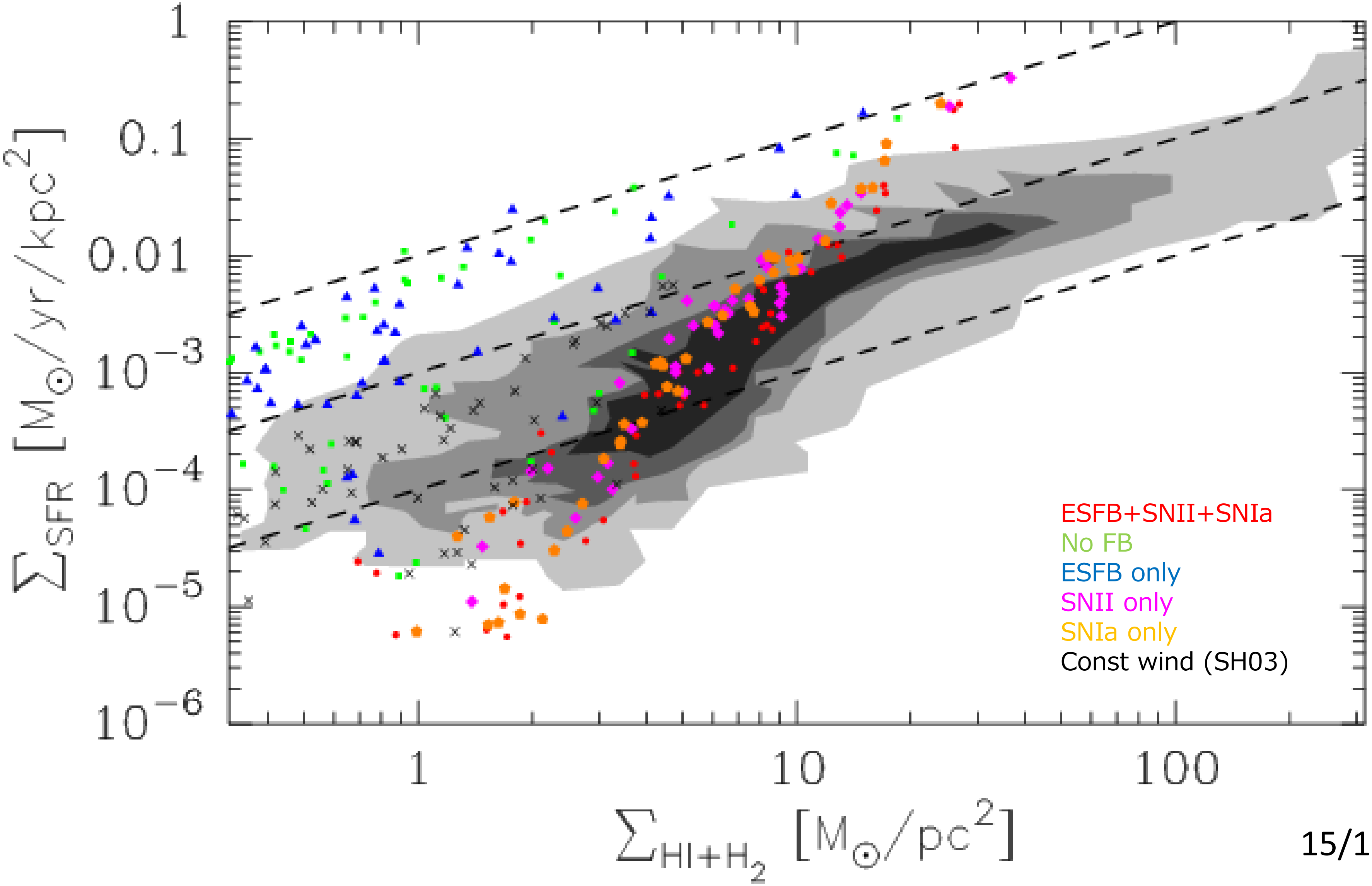
Const wind



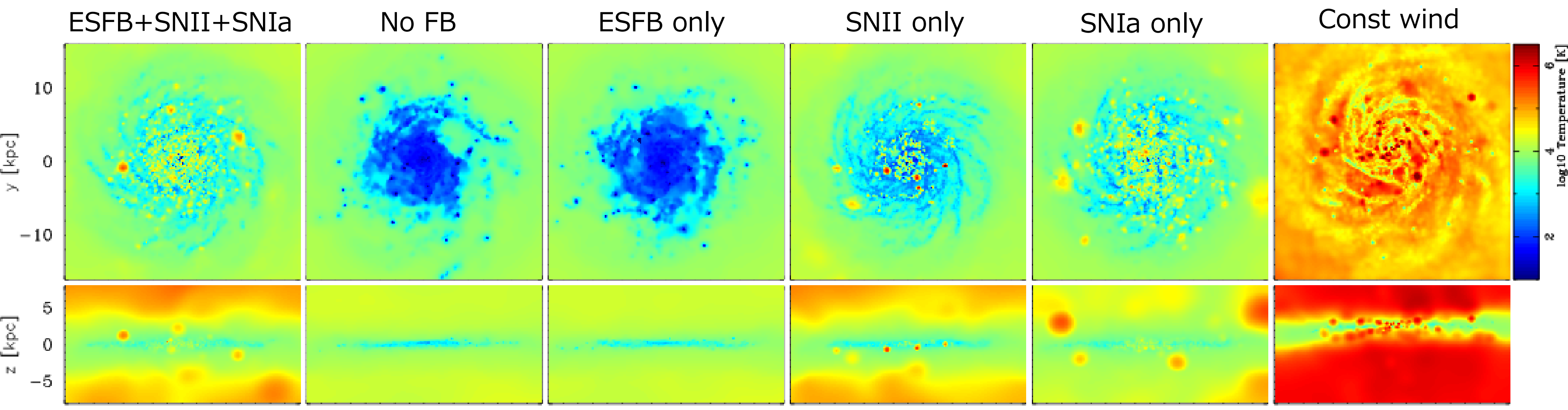
Star formation history



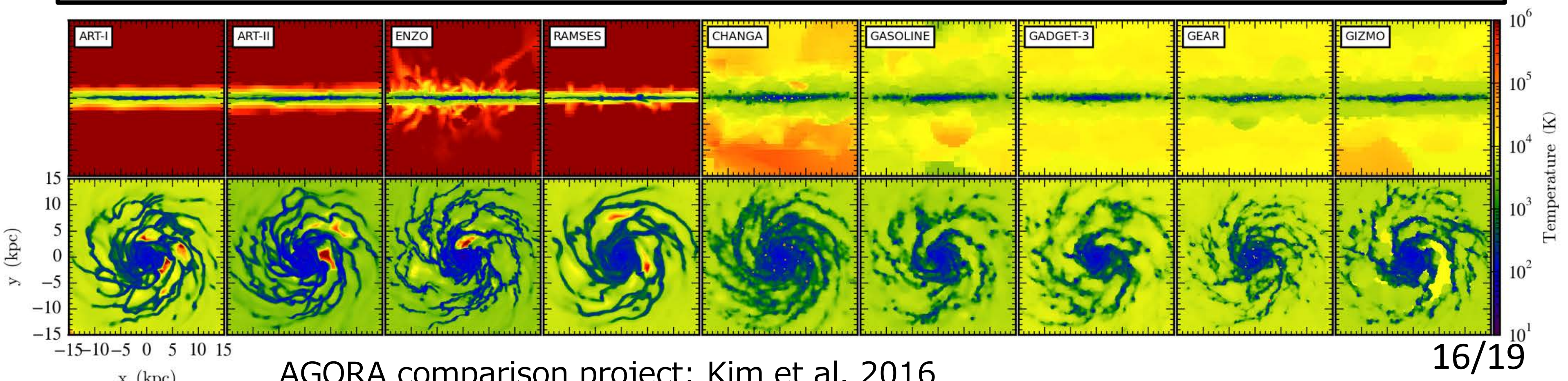
Kennicutt–Schmidt Law (1Gyr)



Projected temperature map (1Gyr)

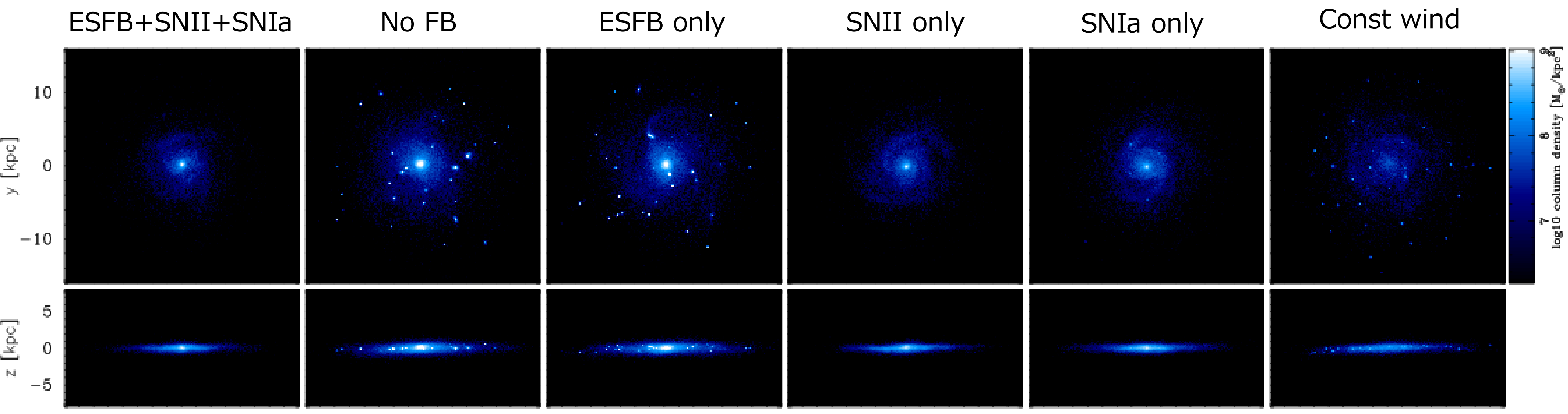


Hot bubble structure can be seen in our model!
This is the specific feature of our model

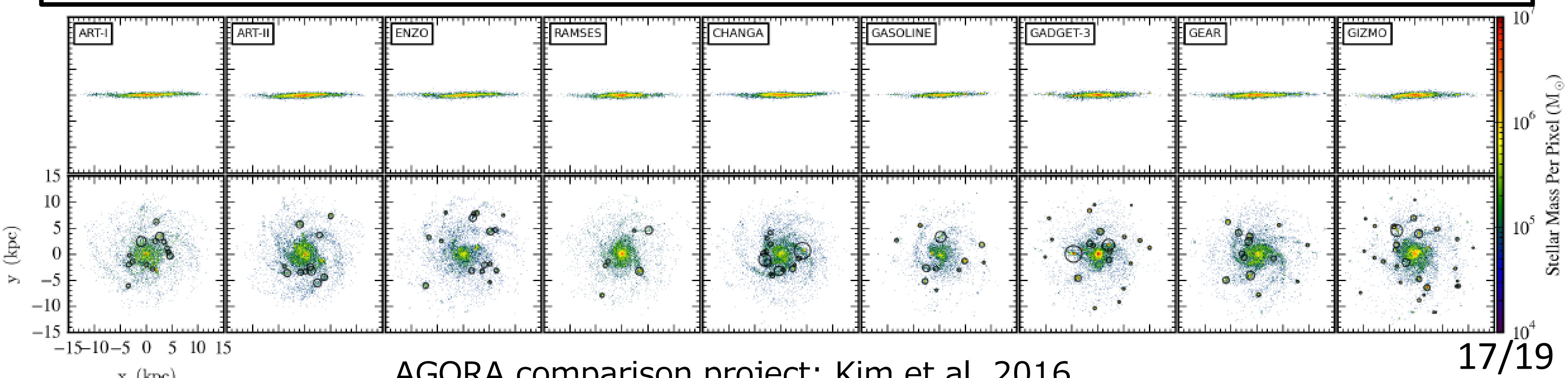


AGORA comparison project: Kim et al. 2016

Projected stellar density (1Gyr)

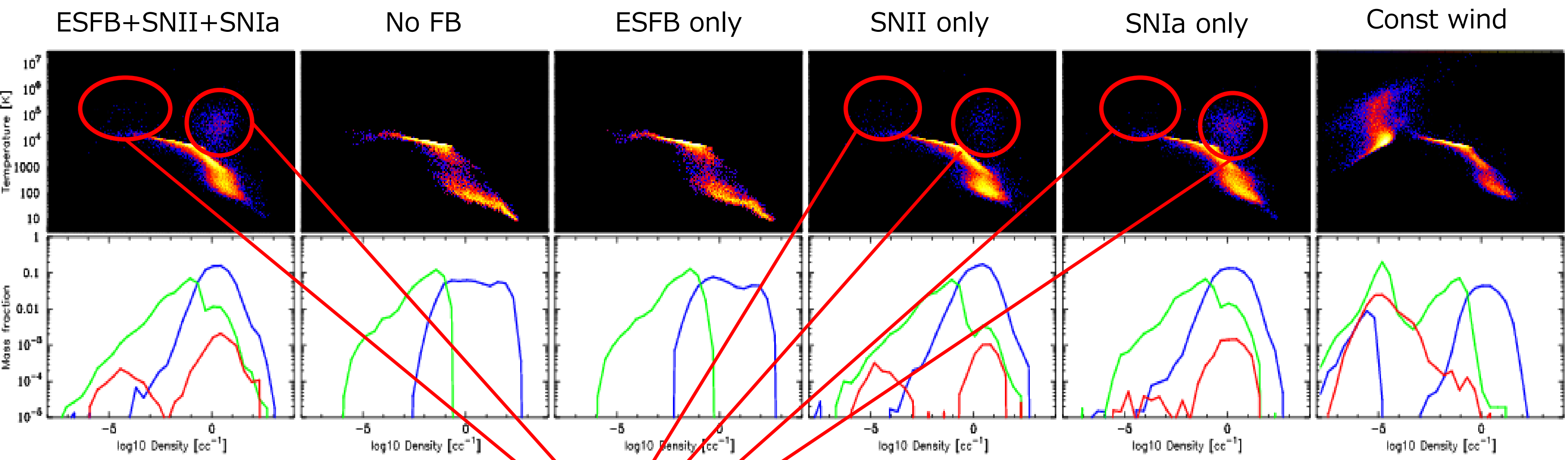


The number of sub-clump is very small!
Smooth distribution of stars can be seen.



AGORA comparison project: Kim et al. 2016

ρ-T plane (1Gyr)



Cold (< 5000 K)
Warm (5000 K < T < 10^5 K)
Hot (> 10^5 K)

Hot gas due to SN feedback

SN feedback makes high-dense, high-temperature gas particles.

Summary (Isolated galaxy)

We develop new SNII feedback treatment

- ✓ Physical motivated SNII bubble evolution (Analytic solution)
- ✓ Using physical motivated value
  - ⇒ shock radius, wind velocity, no-cooling time
- ✓ Using local values not global values (halo information)

⬇

- Strong suppression of fragmentation and star formation activity
- Gas heating in dense gas is dominant effect
  (Gas eject to outside of galaxy by wind is not so strong)
- Compact stellar structure
- Success to reproduce kennicutt-schmidt law