The 7th of January, 2017
「銀河進化と遠方宇宙」2017
アーデンホテル阿蘇

ダスト形成を考慮した銀河形成シミュレーションと観測量との比較

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Introduction: cosmic dust (dust)

- Dust consists of heavy elements such as carbon and silicate, floating in the interstellar medium.

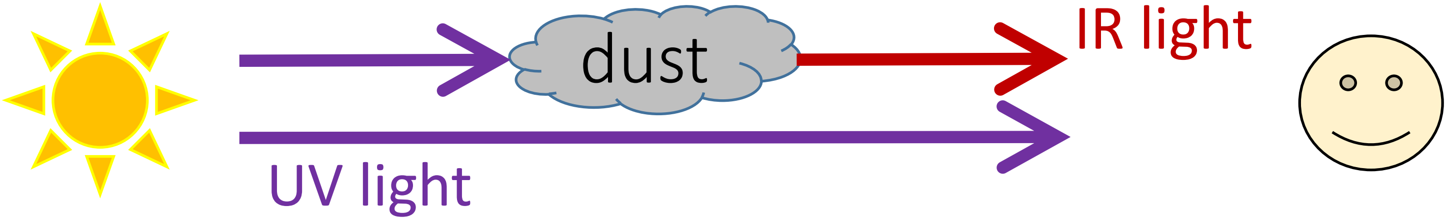
http://www.drcom.co.jp/blog/wp-content/uploads/2013/12/zz3.png

- It is generated in the nucleosynthesis of heavy elements at the end of the massive stars.

- Dust plays important role in ISM as follows:

1. Highly efficient catalyst of H_2 formation, necessary for star formation.

2. Absorption of the UV light and reemitting in the infrared (IR).



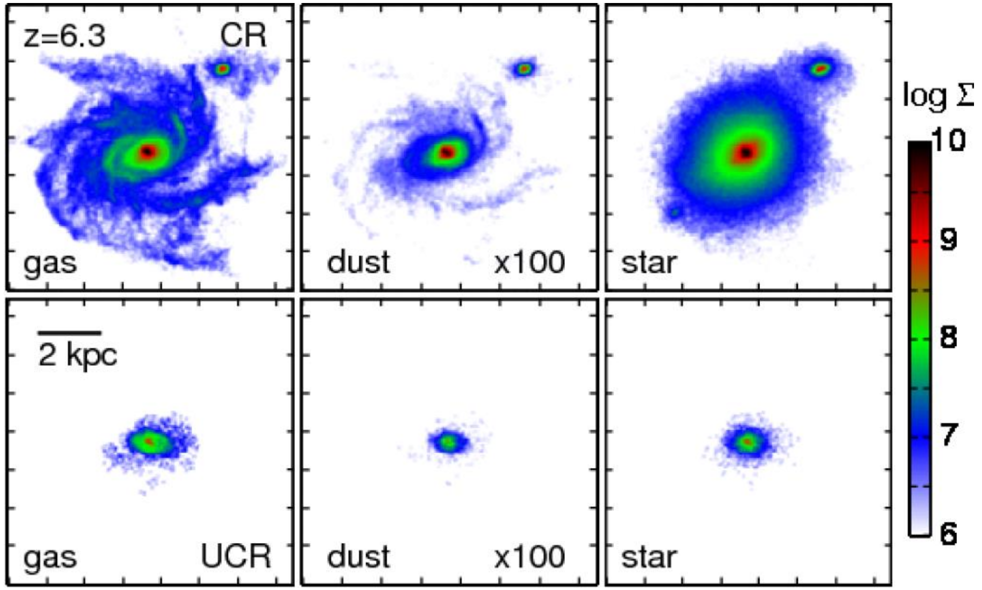
Introduction: previous works

- Yajima et al.(2015) *MNRAS*, **451**, 418

Cosmological zoom-in simulation(z=199→6)

Radiation transfer is calculated with dust.

Constant dust-to-metal mass ratio.

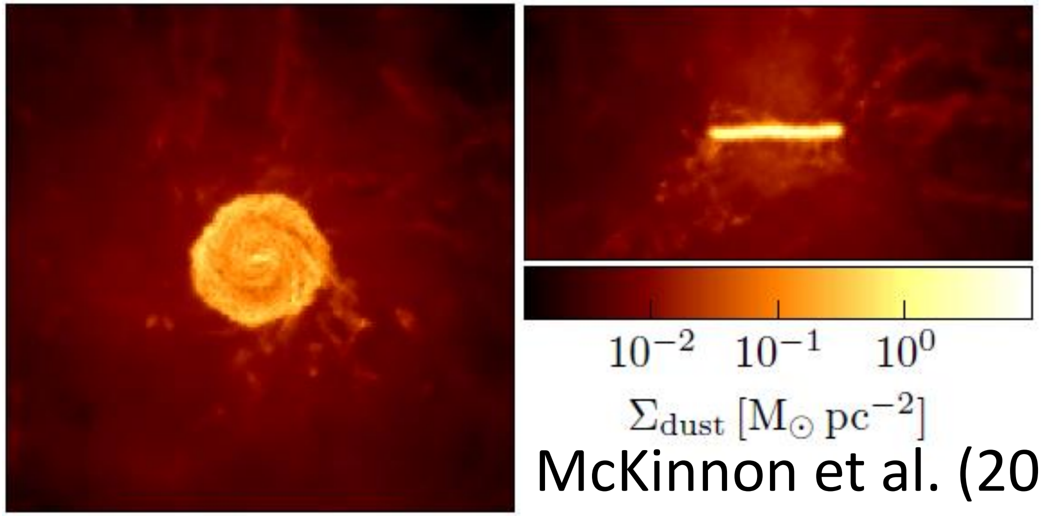


Yajima et al (2015) [1411.2626]

- McKinnon et al. (2016) *MNRAS*, **457**, 3775

Dust is included in a component of SPH ptcls.

Formation, growth, and destruction
by AGB stars, supernovae (SNe) and ISM
Dust growth by the accretion is important.

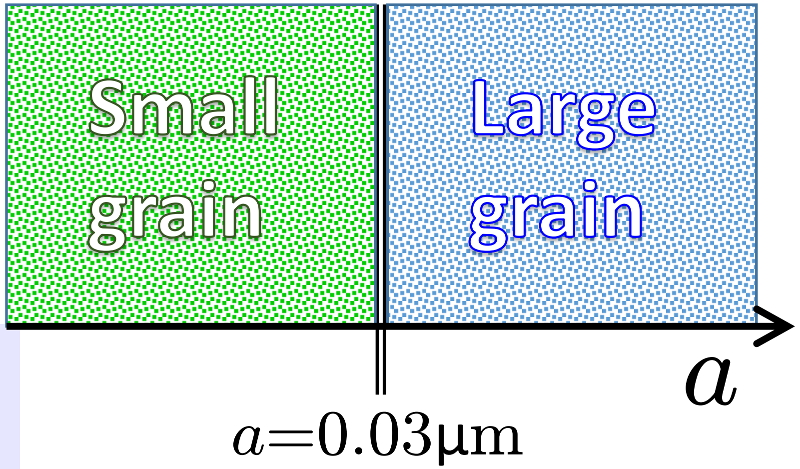


McKinnon et al. (2016) [1505.04792]

Some of interactions of dust (coagulation, shattering) has not been included yet.

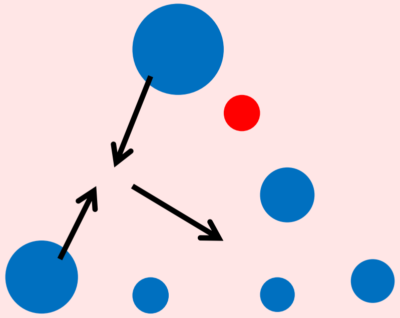
Hirashita (2015) 2-component model [*MNRAS*, **447**, 2937]

Hirashita categorizes dusts into two sizes:
large / small dusts
(a > 0.03μm , a < 0.03μm).

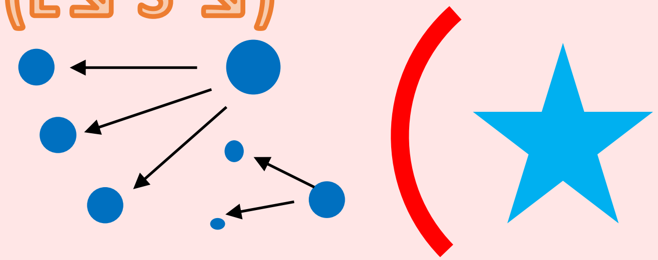


Diffuse medium

- Shattering (L↘ S↗)

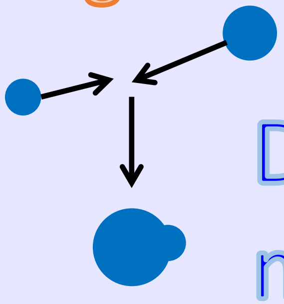


- Shock waves from SNe (L↘ S ↘)

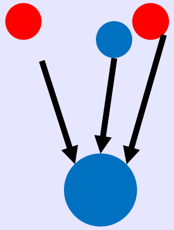


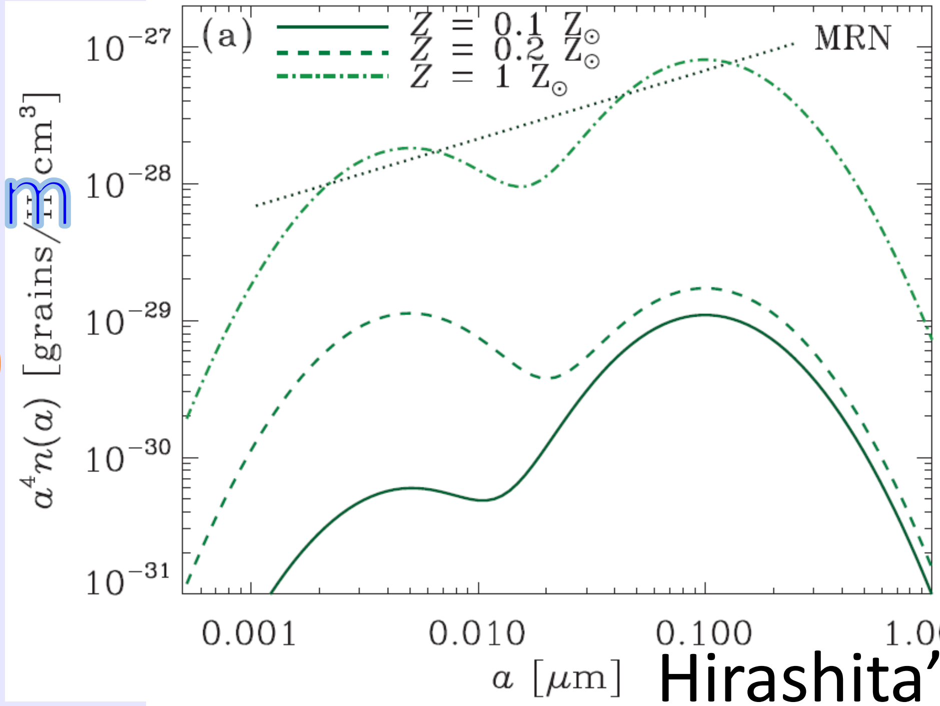
Dense medium

- Coagulation (L↗ S↘)



- Accretion (S↗)





Hirashita’15

One zone

$$\frac{\mathrm{d}m_{\mathrm{S}}}{\mathrm{d}t} = -\mathcal{D}_{\mathrm{S}}\psi - \frac{m_{\mathrm{S}}}{\tau_{\mathrm{SN}}} + \frac{m_{\mathrm{L}}}{\tau_{\mathrm{sh}}} - \frac{m_{\mathrm{S}}}{\tau_{\mathrm{co}}} + \frac{m_{\mathrm{S}}}{\tau_{\mathrm{acc}}}, \tag{11}$$

$$\frac{\mathrm{d}m_{\mathrm{L}}}{\mathrm{d}t} = -\mathcal{D}_{\mathrm{L}}\psi + f_{\mathrm{in}}E_Z - \frac{m_{\mathrm{L}}}{\tau_{\mathrm{SN}}} - \frac{m_{\mathrm{L}}}{\tau_{\mathrm{sh}}} + \frac{m_{\mathrm{S}}}{\tau_{\mathrm{co}}}, \tag{12}$$

Our work

$$\begin{aligned}\mathcal{D}_{\mathrm{L}(i)}(t+\Delta t) &= \mathcal{D}_{\mathrm{L}(i)}(t) - \Delta\mathcal{D}_{(\mathrm{SNe/L})(i)} \\ &\quad - \left(\frac{\mathcal{D}_{\mathrm{L}(i)}(t)}{\tau_{\mathrm{sh}}} - \frac{\mathcal{D}_{\mathrm{S}(i)}(t)}{\tau_{\mathrm{co}}}\right)\Delta t \\ &\quad + f_{\mathrm{in}}\frac{\Delta\tilde{m}_{\mathrm{Z}}}{m_{\mathrm{g}}}(1-\delta)\,, \end{aligned} \tag{13}$$

$$\begin{aligned}\mathcal{D}_{\mathrm{S}(i)}(t+\Delta t) &= \mathcal{D}_{\mathrm{S}(i)}(t) - \Delta\mathcal{D}_{(\mathrm{SNe/S})(i)} \\ &\quad + \left(\frac{\mathcal{D}_{\mathrm{L}(i)}(t)}{\tau_{\mathrm{sh}}} - \frac{\mathcal{D}_{\mathrm{S}(i)}(t)}{\tau_{\mathrm{co}}} + \frac{\mathcal{D}_{\mathrm{S}(i)}(t)}{\tau_{\mathrm{acc}}}\right)\Delta t\,, \end{aligned} \tag{14}$$

In this work, we use the **GADGET3-Osaka** SPH code (Springel '05 + modification).

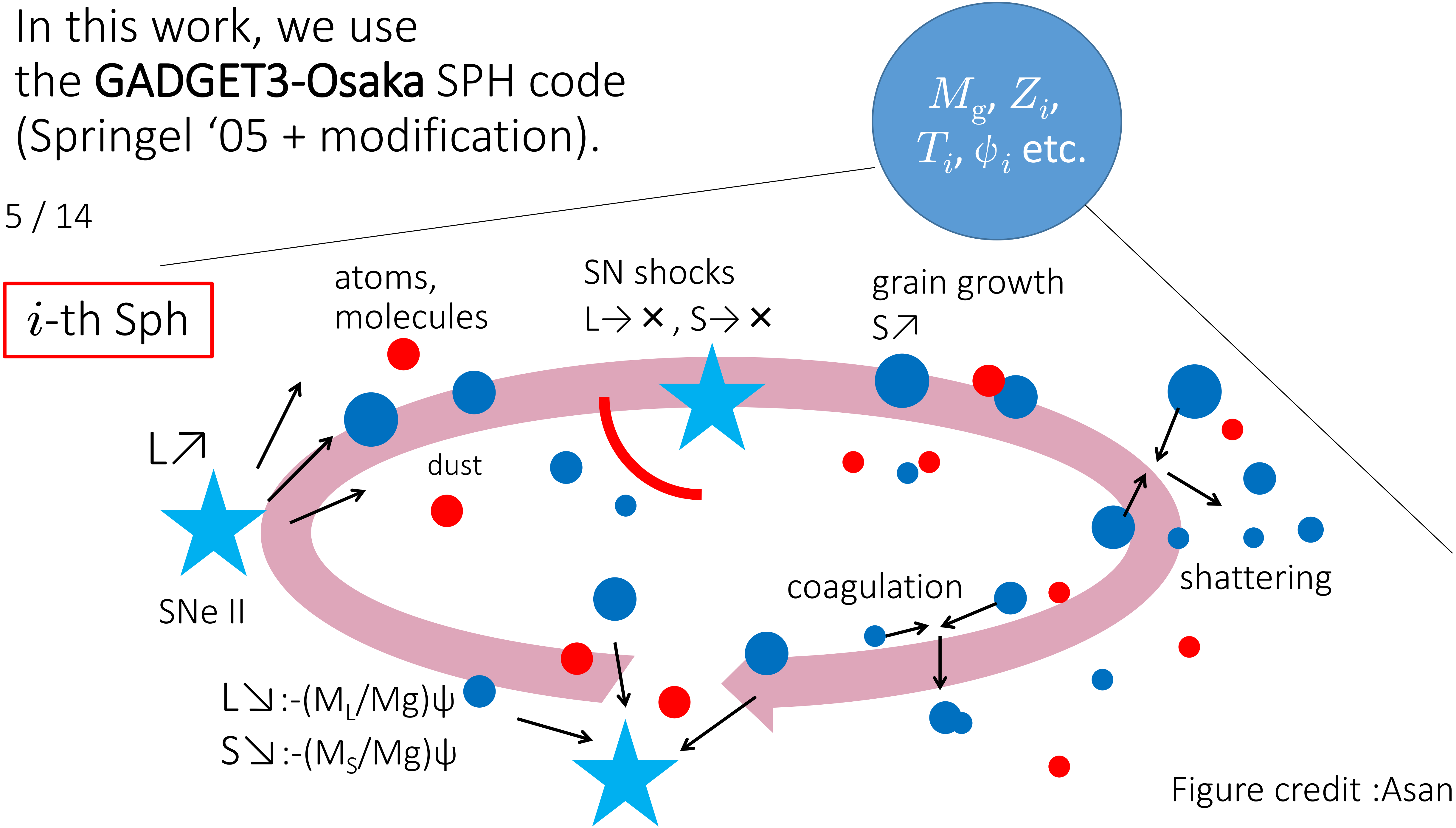


Figure credit :Asano

Sub-grid model for collisional processes

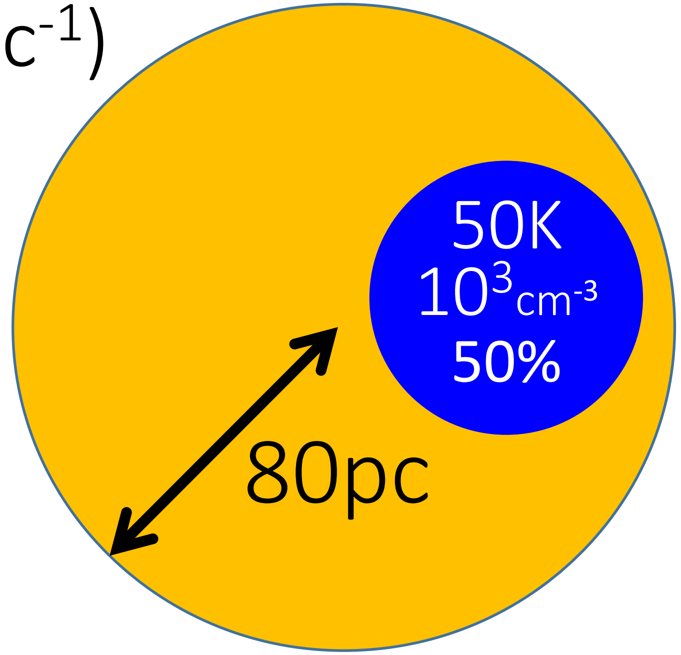
SA+ (2017) [1609.07547]

- Accretion (significant only in dense medium)
  $T_{Sph} < 10^{3.5}$ K & $n_{Sph} > 5$ cc^{-1} : $\tau = 2\,\tau_{acc}$ (50 K, 10^3 cc^{-1})
  Others: $\tau = \infty$ [No reaction]

Hirashita (2015) [1412.3866]
Hirashita&Kuo(2011) [1105.4930]

- Coagulation (significant only in dense medium)
  $T_{Sph} < 10^{3.5}$ K & $n_{Sph} > 5$ cc^{-1} : $\tau = 2\,\tau_{coll(S)}$ (50 K, 10^3 cc^{-1})
  Others: $\tau = \infty$ [No reaction]

- Shattering (significant only in diffuse gas)
  $n_{Sph} < 1$ cc^{-1} : $\tau = \tau_{coll(L)}$
  $n_{Sph} > 1$ cc^{-1} : $\tau = \infty$ [No reaction]

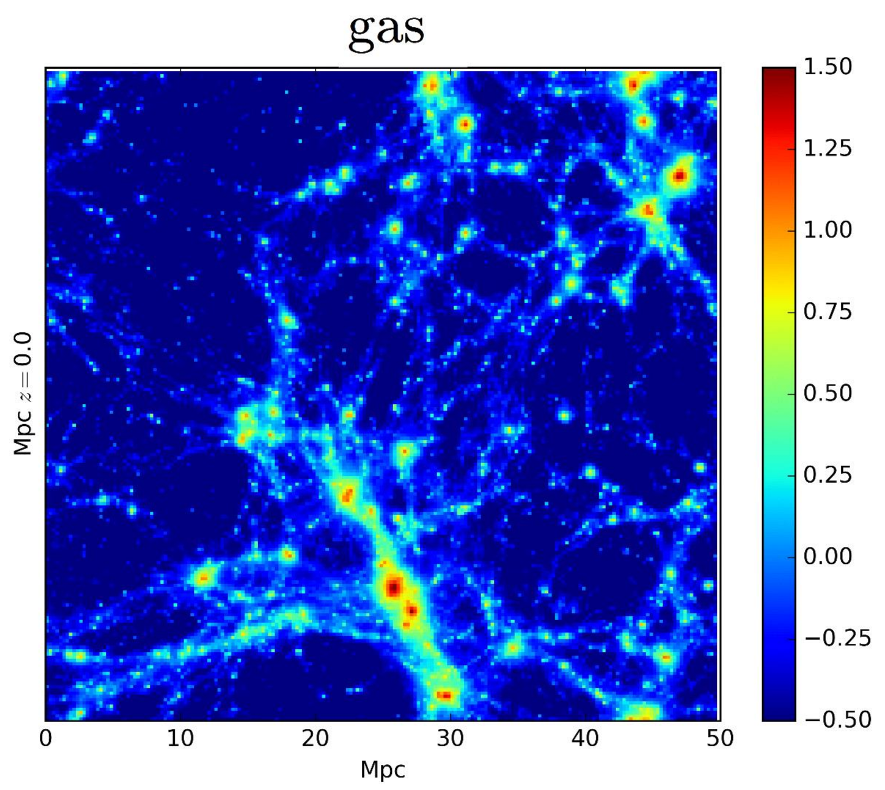


Cosmological simulation

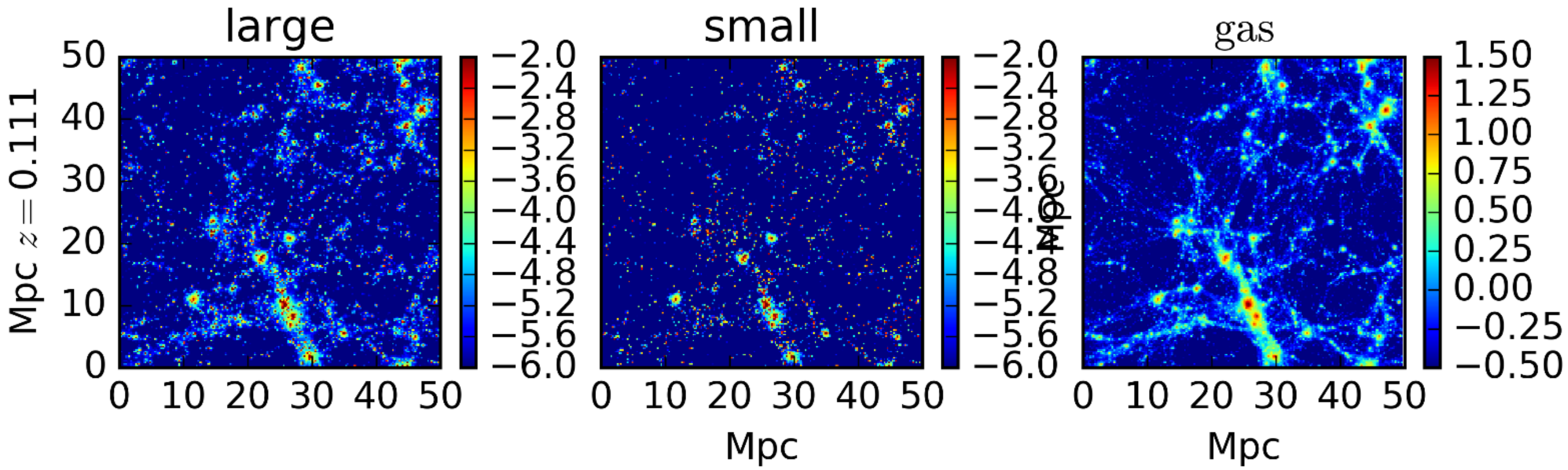
- L=50 cMpc/h, N=2 $\times$ 256^3
- Resolution : 9.8 kpc

- Initial condition is given at z=99 with MUSIC (Hahn & Abel 2011 [1103.6031]).

- Galaxies are identified with SKID (Weinberg et al. 1997 [astro-ph/9604175] Goetz et al. 1998 [astro-ph/9811393]).



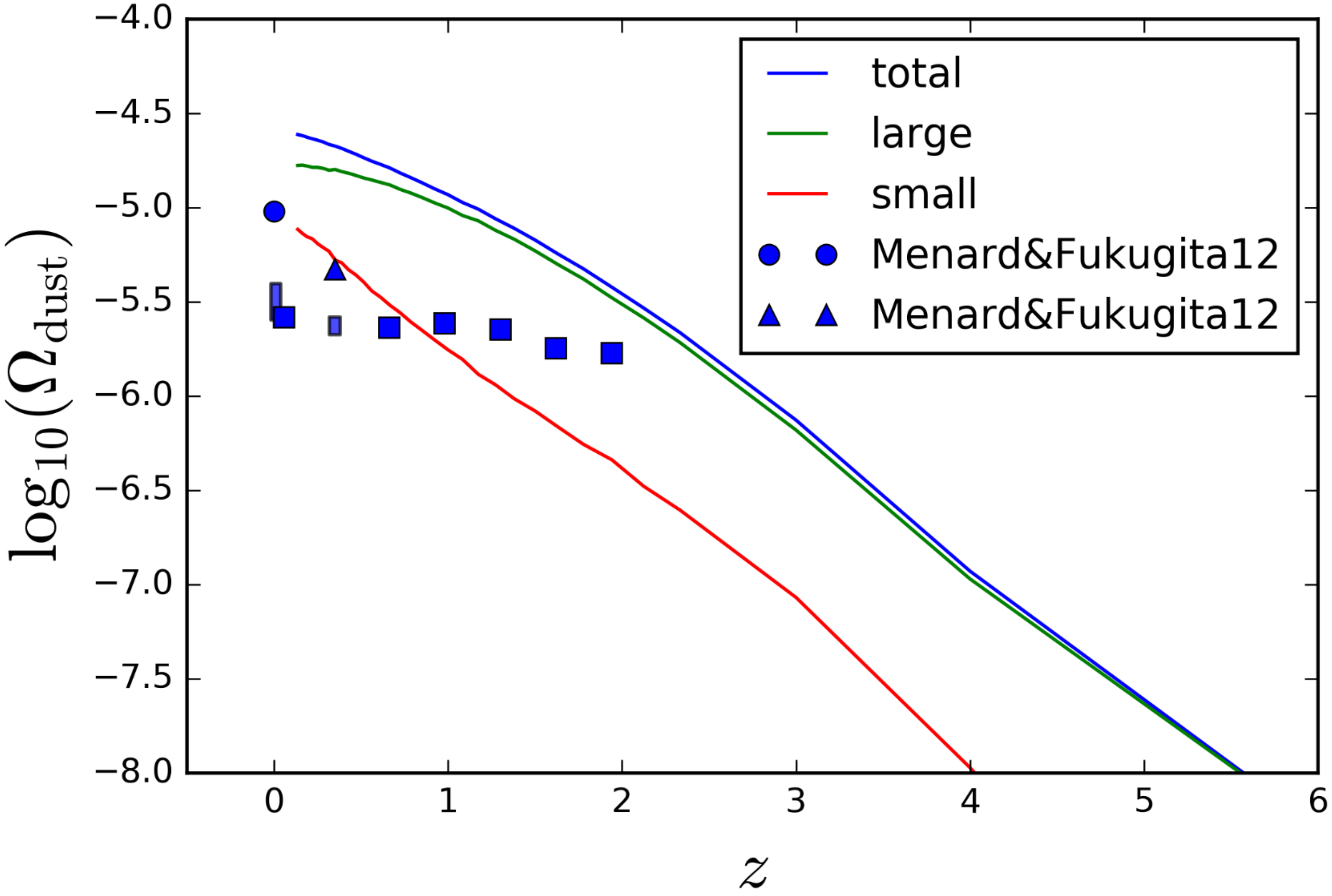
Dust abundance (space distribution)



A surface density of gas, large and small grains at current Universe are shown.

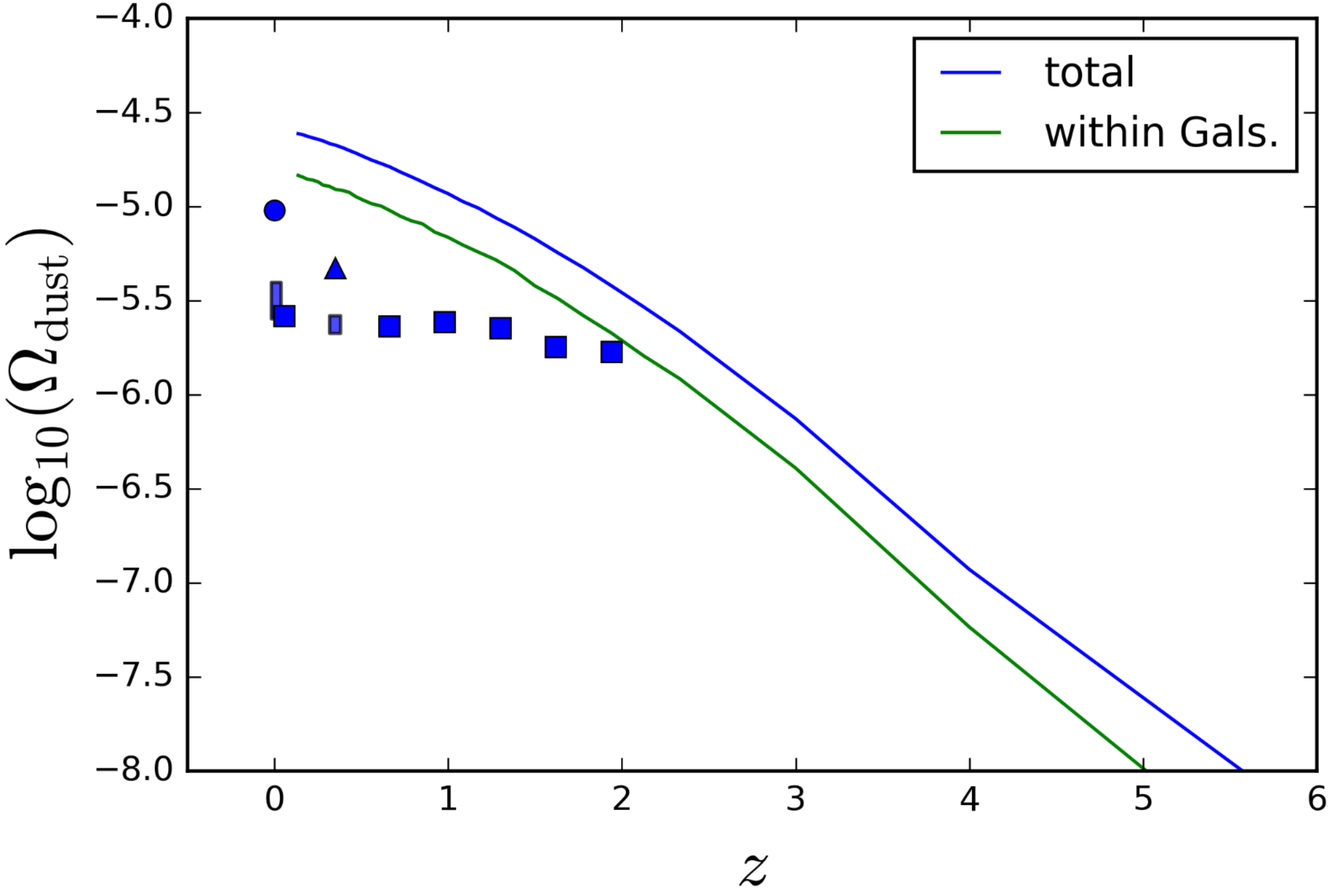
Distribution of both of dust grains is similar to that of gas.
Because of the production and distribution processes are different between L and S, the distribution in IGM/ICM is different between large (L) and small (S) grains.

Total abundance of dust (Ω_{dust})



- Dust abundance (asterisks) is overproduced compared with observations by factor 3. (magenta bars)

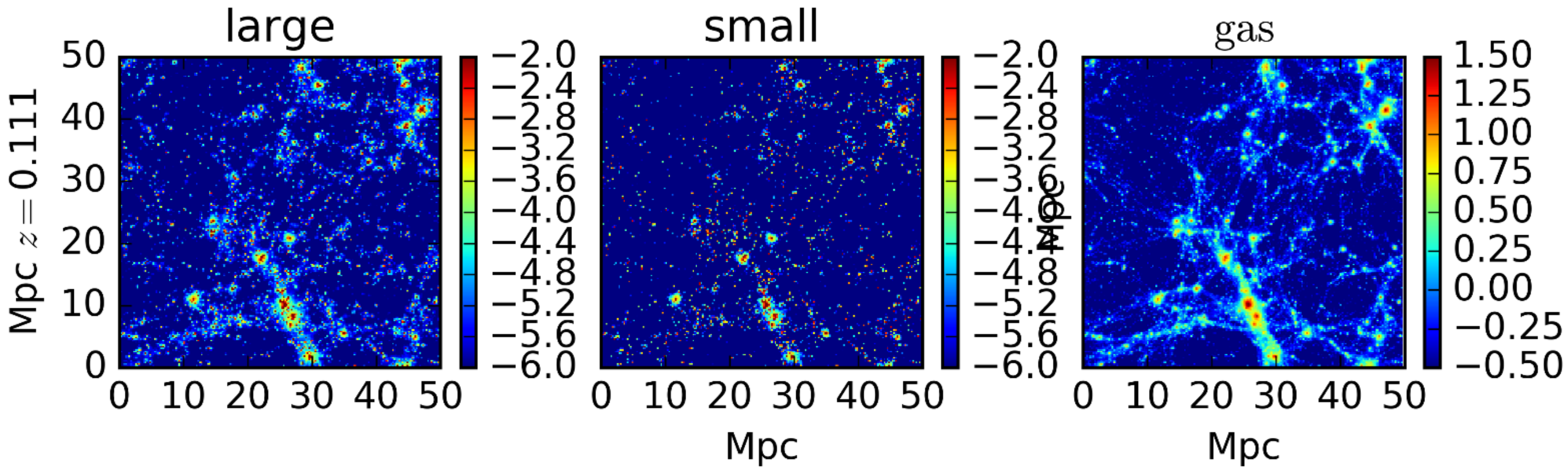
Total abundance of dust (Ω_{dust})



- When we picked up the dense and cold particles ($n > 10^{-2}$ cm^{-3} & $T < 10^4$ K), we find that a half (0.3 dex) of dust exists in IGM.

- This difference is consistent with the estimation on Fukugita (2011) and Menard & Fukugita (2012).

Dust abundance (space distribution)



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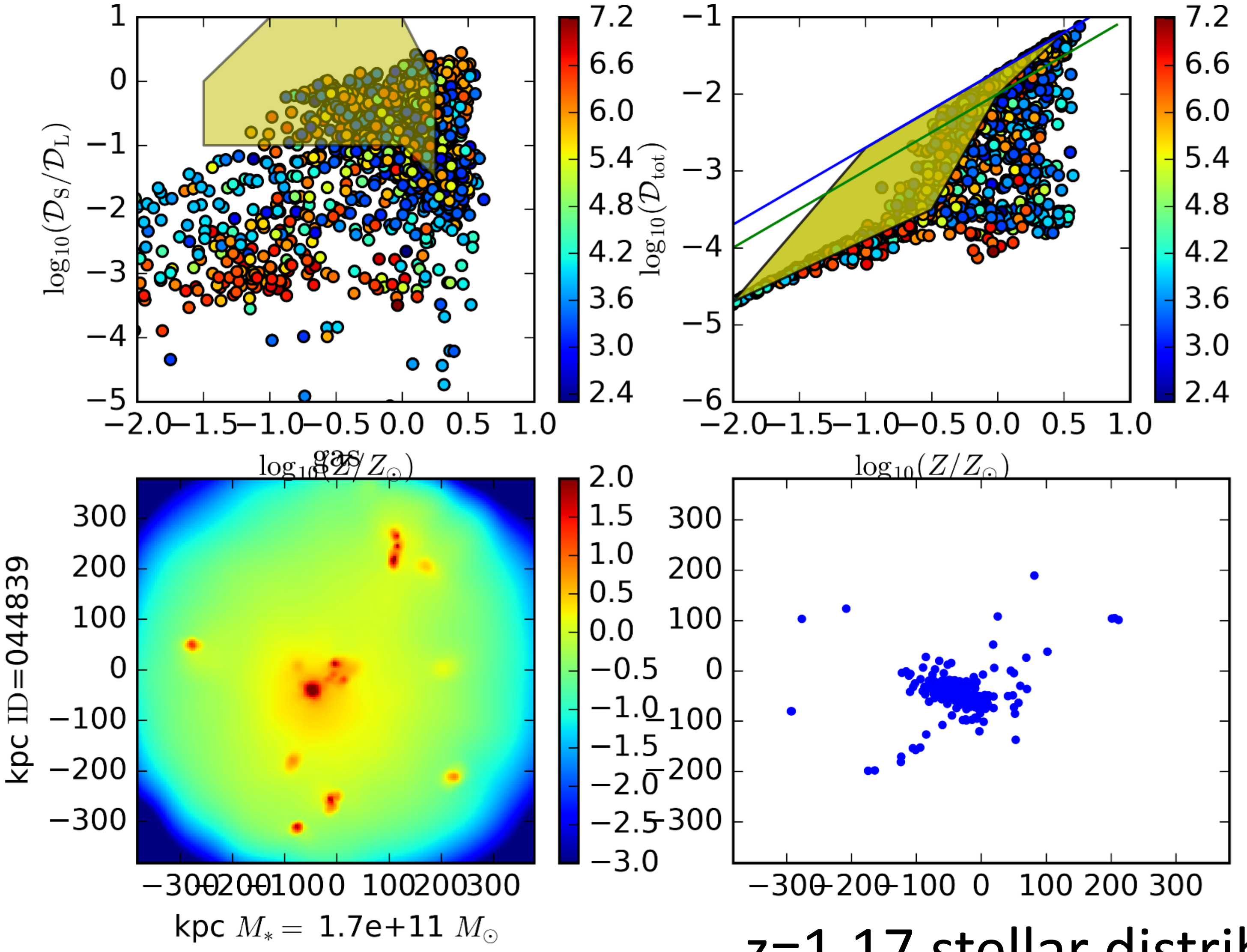
Dust abundance (D_{tot}-Z)

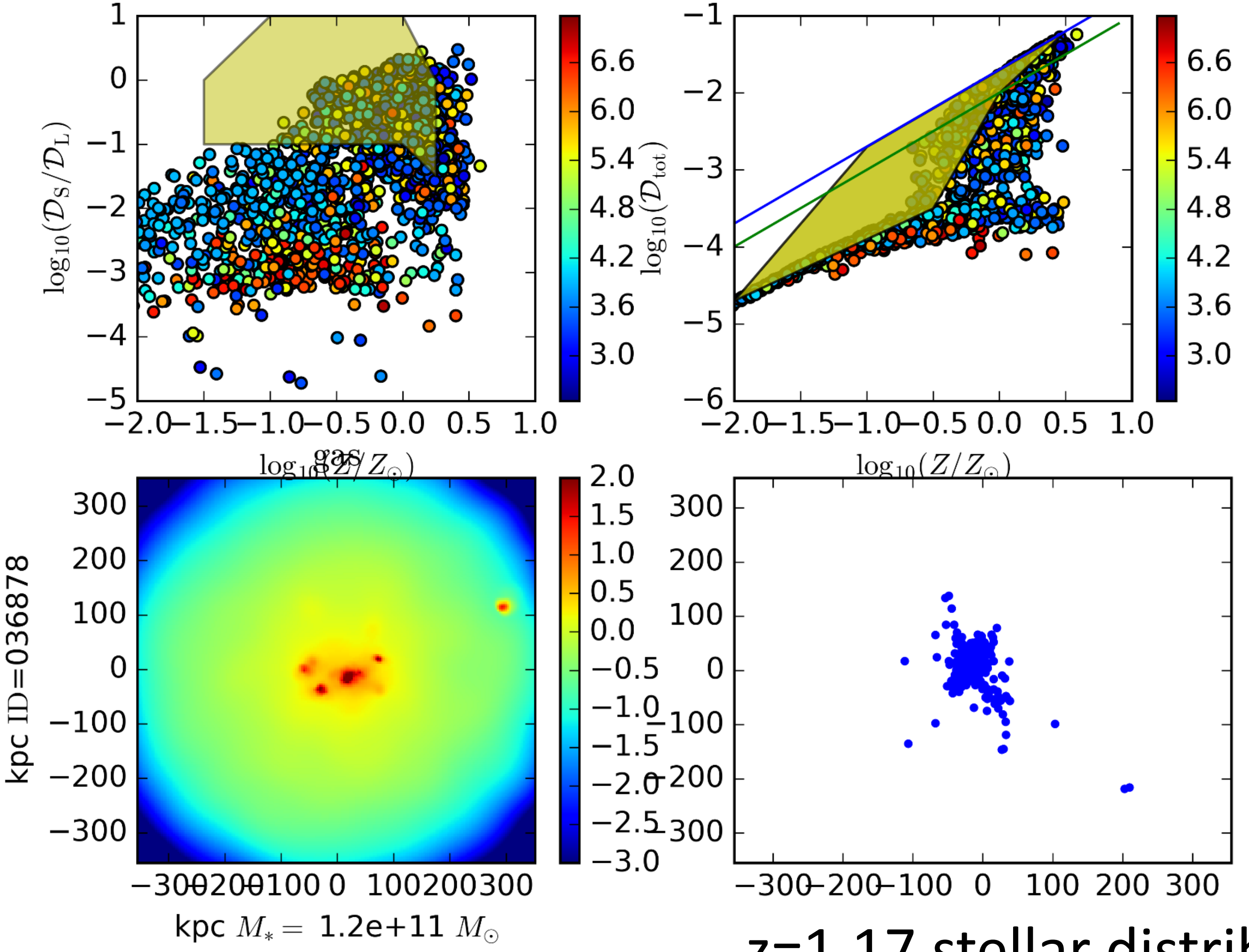


z=1.17 stellar distribution

- Accretion and coagulation can be seen in galaxy whose stellar mass is $1.7 \times 10^{11}\ M_\odot$.

  The metallicity at which the accretion becomes significant moves to high metallicity.

Dust abundance (D_{tot}-Z)



z=1.17 stellar distribution

- Accretion and coagulation can be seen in galaxy whose stellar mass is 1.2×10^{11} $M_\odot$.

  The metallicity at which the accretion becomes significant moves to high metallicity.

Conclusions

- We investigate the time evolution and spatial distribution of large and small dust grain in an isolated galaxy based on Hirashita (2015) 2-component dust model using **GADGET3-Osaka**.
- We have implemented sub-grid models for coagulation, shattering and accretion.
- Accretion and coagulation occur in a cosmological simulation.
- The metallicity at which the accretion becomes significant moves to high metallicity compared with low-z galaxies.
- Some issues remain (e.g., calibration of the parameters of subgrid model).