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大阪大学(南部陽一郎ホール)

ダストのサイズ分布を考慮した宇宙論的ダスト形成シミュレーション

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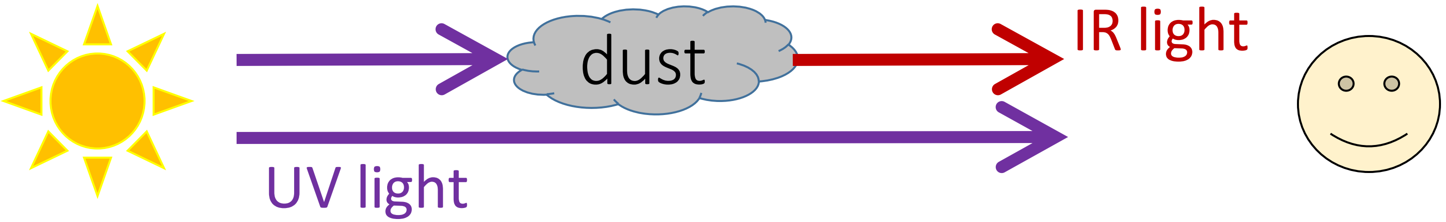
Introduction: cosmic dust (dust)

- Dust consists of heavy elements such as carbon and silicate, floating in the interstellar medium.
- It is generated in the nucleosynthesis of heavy elements on stars.

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

- 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).
   → The size distribution and abundance of dust grains is essential.



Introduction: previous works

Total dust

$$\langle \mathcal{D}_{\rm dust} \rangle = \frac{\boxed{\langle \rho_{\rm dust}^{\rm tot} \rangle}}{\langle \rho_{\rm gas} \rangle} = \mathcal{O}(10^{-2})$$

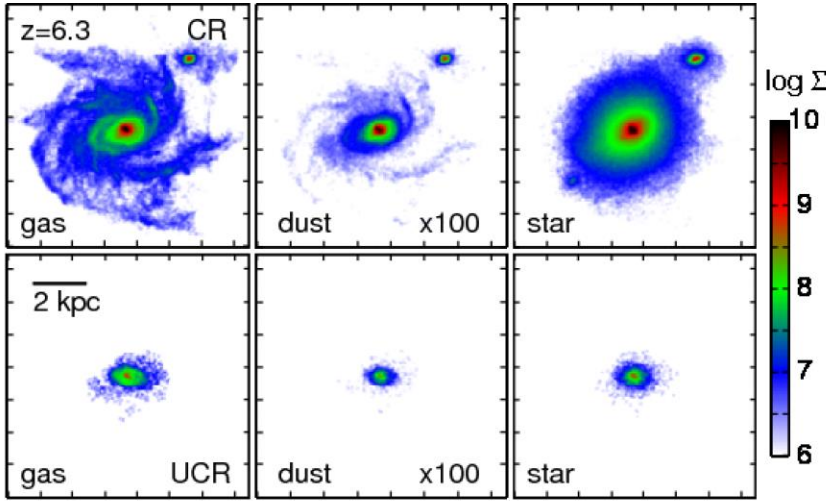
Estimated by extinction

e.g., Spitzer (1978)

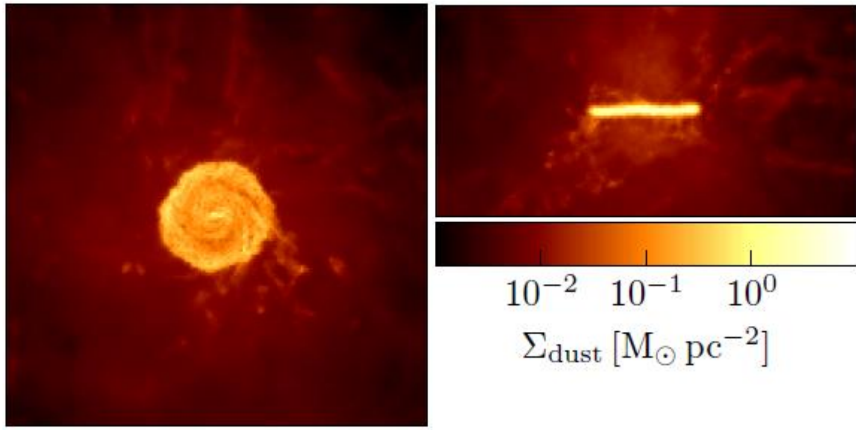
One-zone Timeline **Simulation**

- Hirashita & Kuo(2011)
  Grain growth by the accretion in interstellar clouds
- Asano et al.(2013b, 14)
  Entire distribution function with all ISM processes was derived.

- Yajima et al.(2015)
  Radiation transfer is calculated with dust.
  D∝Z
- Bekki (2015)
  Dust is included in another component of ptcls.
- McKinnon et al. (2016, 17)
  Dust is included in a component of SPH ptcls.



Yajima et al (2015) [1411.2626]

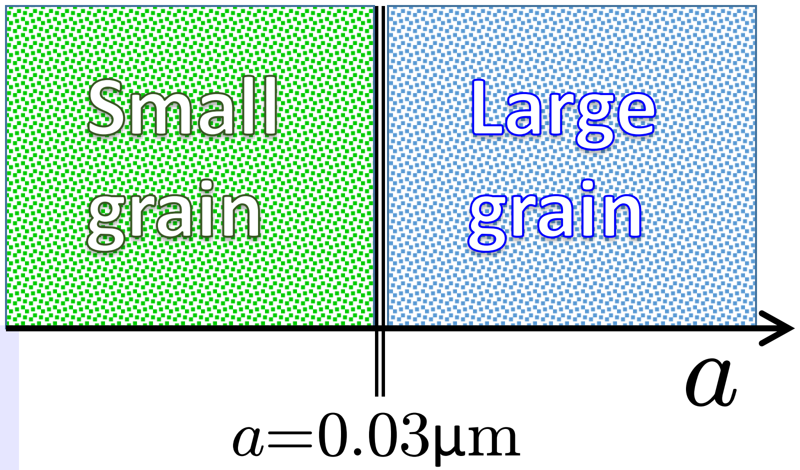


McKinnon et al. (2016) [1505.04792]

We implement detailed dust growth/destruction in ISM into SPH simulation.

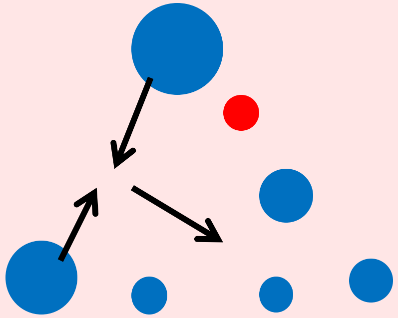
Hirashita (2015) 2-component model [*MNRAS*, **447**, 2937]

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

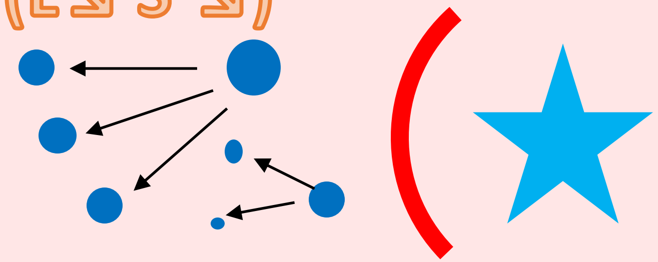


- Shattering (L↘ S↗)

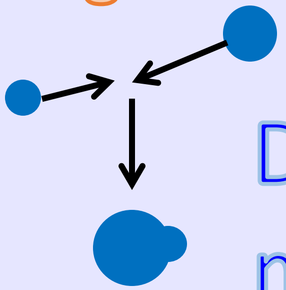
Diffuse medium



- Shock waves from SNe (L↘ S ↘)

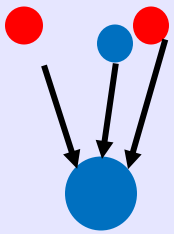


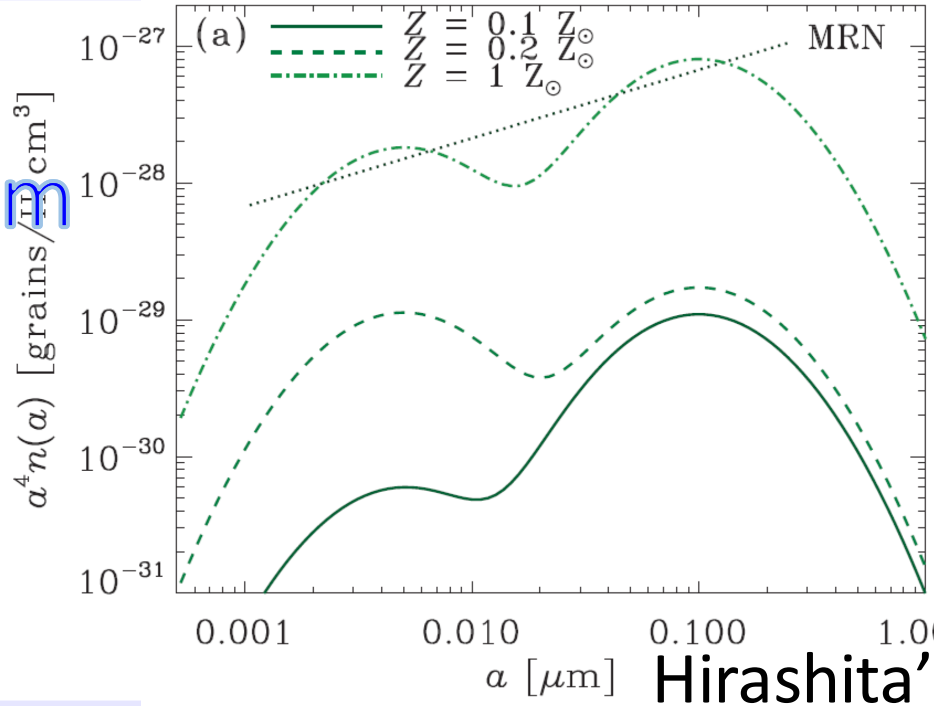
- Coagulation (L↗ S↘)



Dense medium

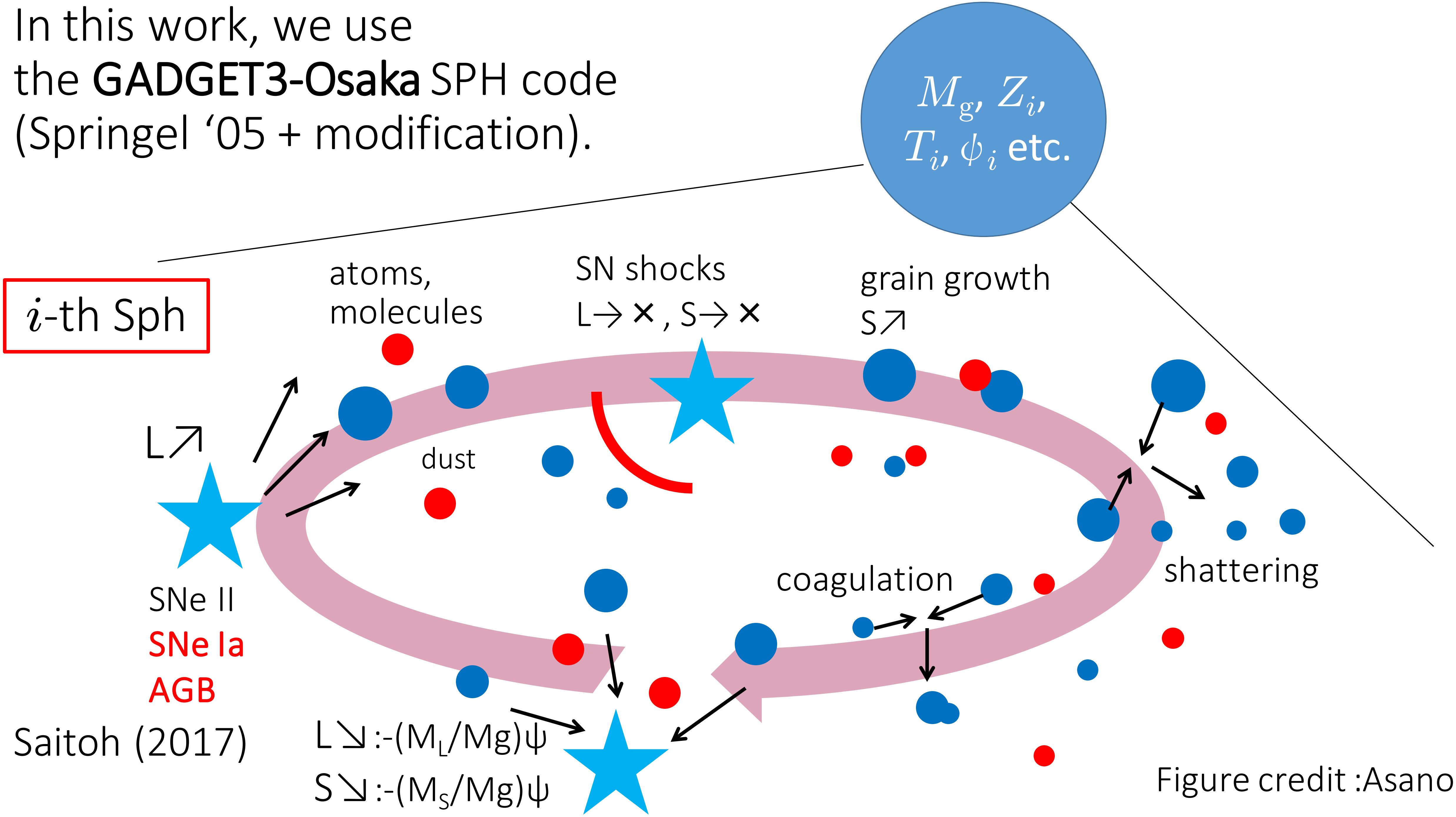
- Accretion (S↗)





Hirashita'15

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



Saitoh (2017)

Figure credit :Asano

Treatments for collisional processes

- Accretion (significant only in dense medium)

  $T_{Sph} < 10^4$ K & $n_{Sph} > 1$ cc^{-1} : $\tau = 2\ \tau_{acc}$ (50 K, 10^3 cc^{-1})
  Others: $\tau = \infty$ [No reaction]

Hirashita (2015)
Hirashita&Kuo(2011)

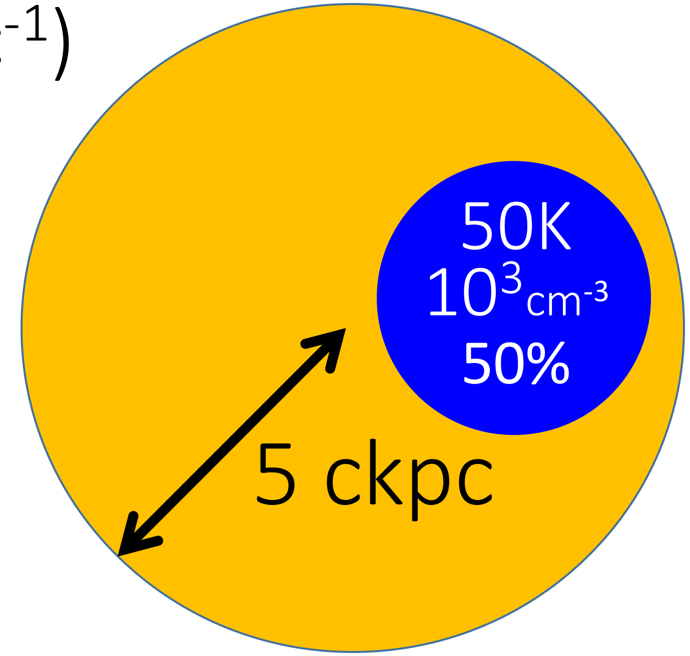
- Coagulation (significant only in dense medium)

  $T_{Sph} < 10^4$ K & $n_{Sph} > 1$ cc^{-1} : $\tau = 2\ \tau_{coll(S)}$ (50 K, 10^3 cc^{-1})
  Others: $\tau = \infty$ [No reaction]

- Shattering (significant only in diffuse gas)

  $n_{Sph} < 0.1$ cc^{-1} : $\tau = \tau_{coll(L)}$
  $n_{Sph} > 0.1$ cc^{-1} : $\tau = \infty$ [No reaction]

Cosmological simulation



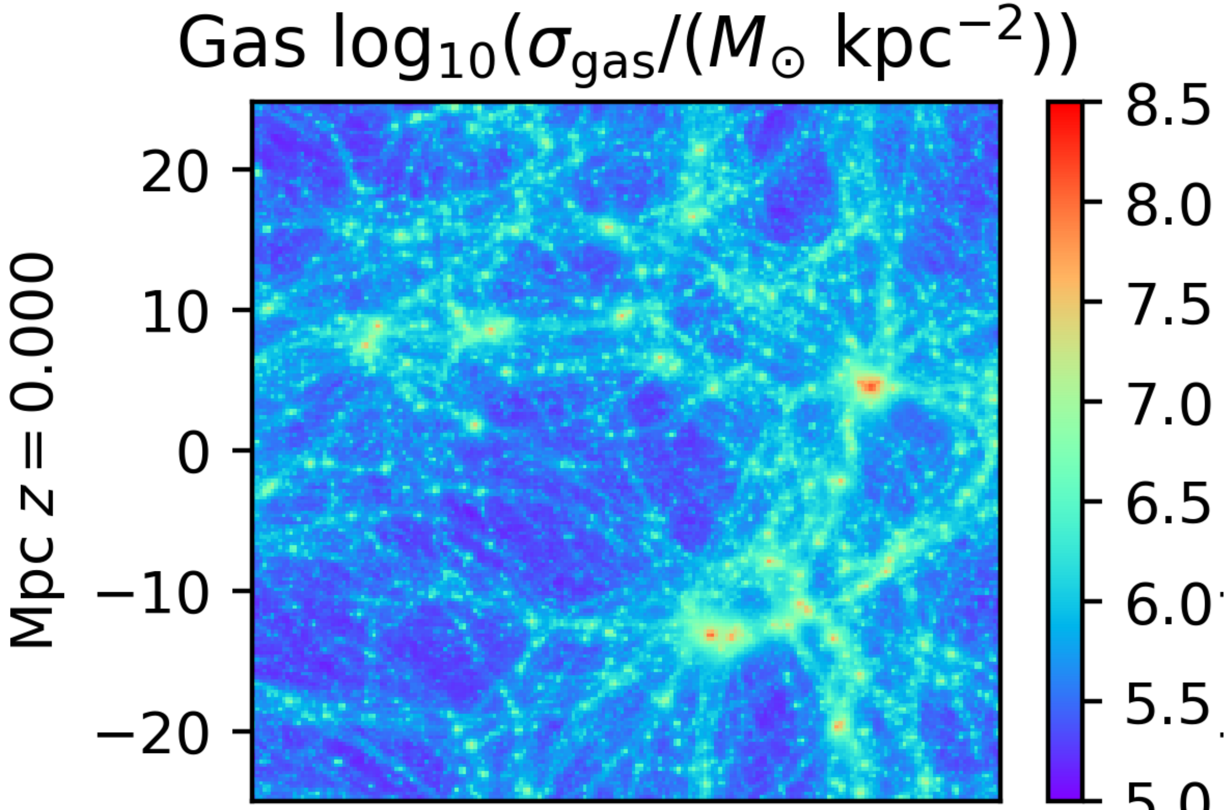
孤立系なら
80 pcくらい

Cosmological simulation

- L=50 cMpc/h, N=2 × 256^3
- Resolution : 9.8 comoving kpc (gravity)
  Baryon : ~ 1 comoving kpc

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

- Galaxies are identified with `P-Star` groupfinder (Springel+2003; Nagamine+2004).

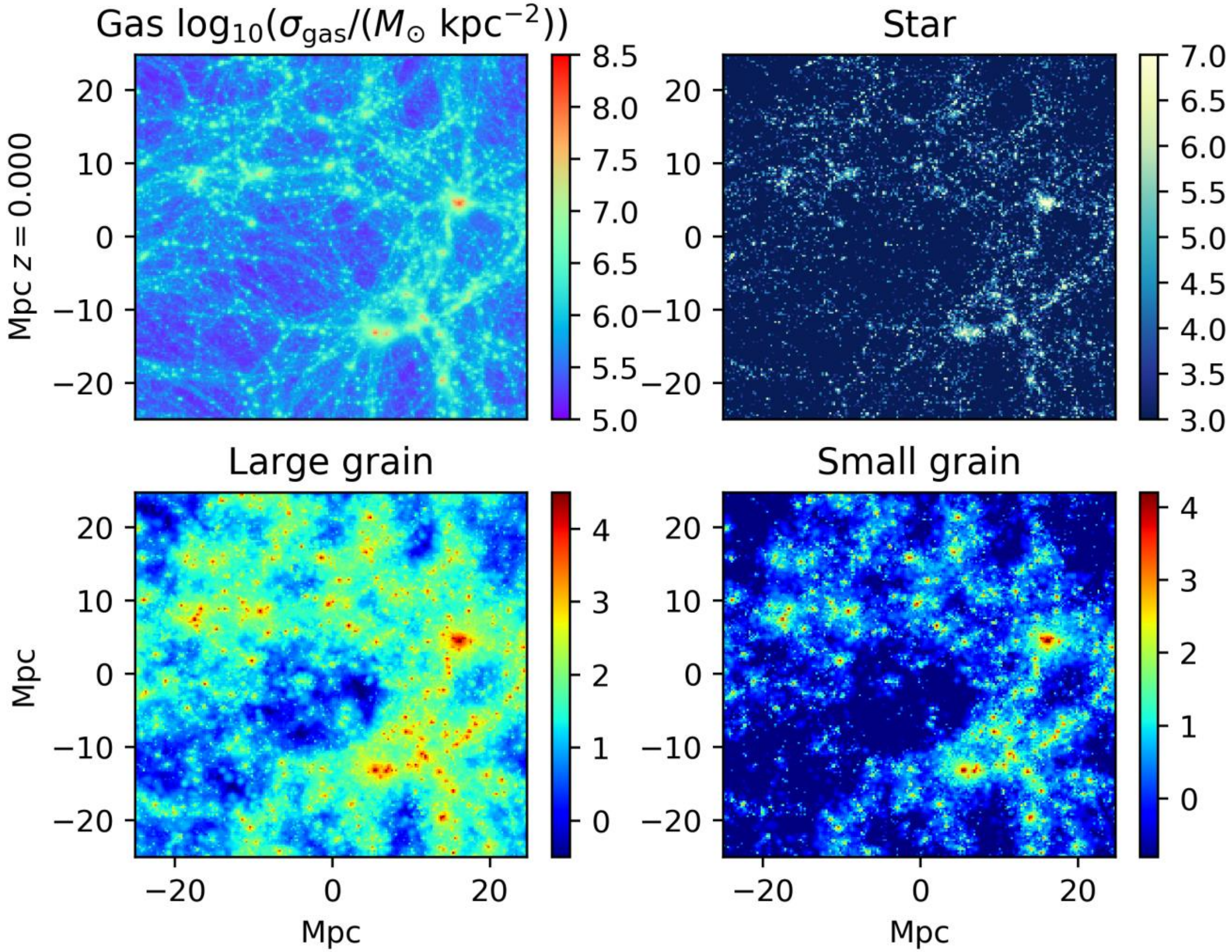


Dust abundance (space distribution)

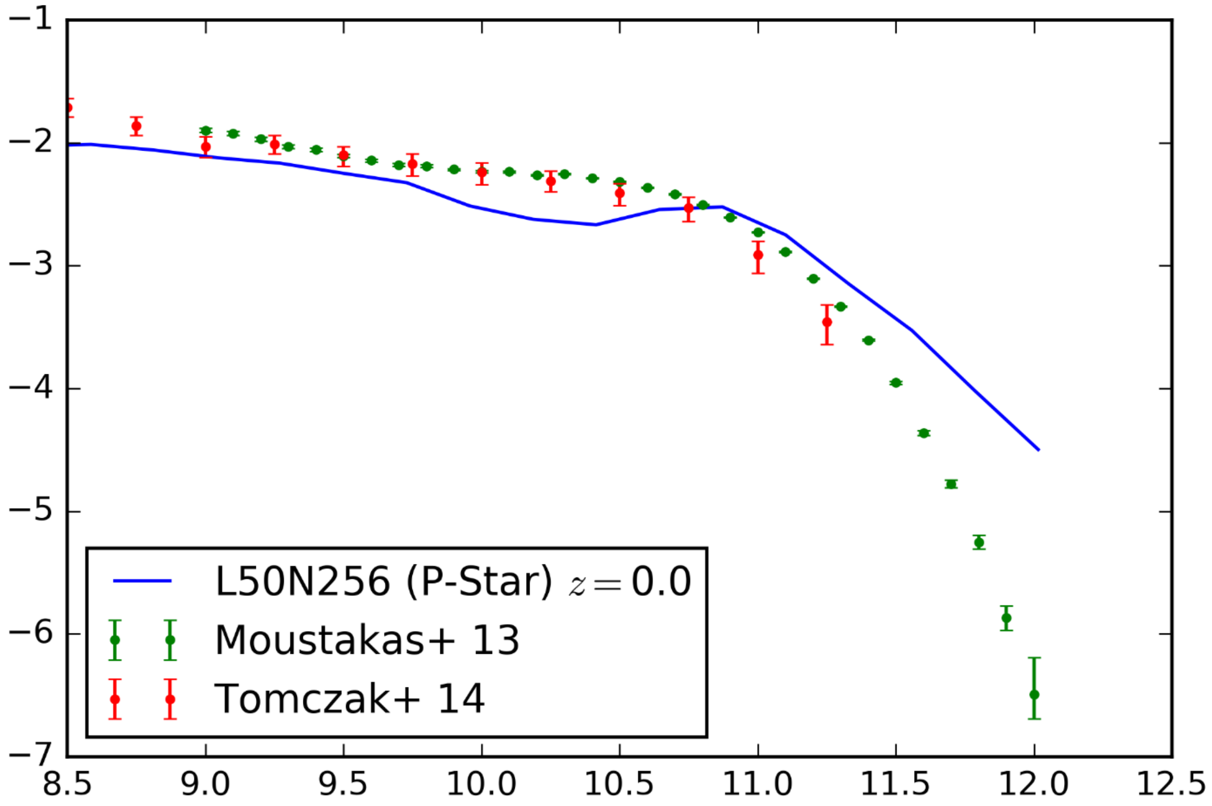
50 cMpc Box
(0<z<99)

Evolution of surface density of gas, stars large and small grains 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.

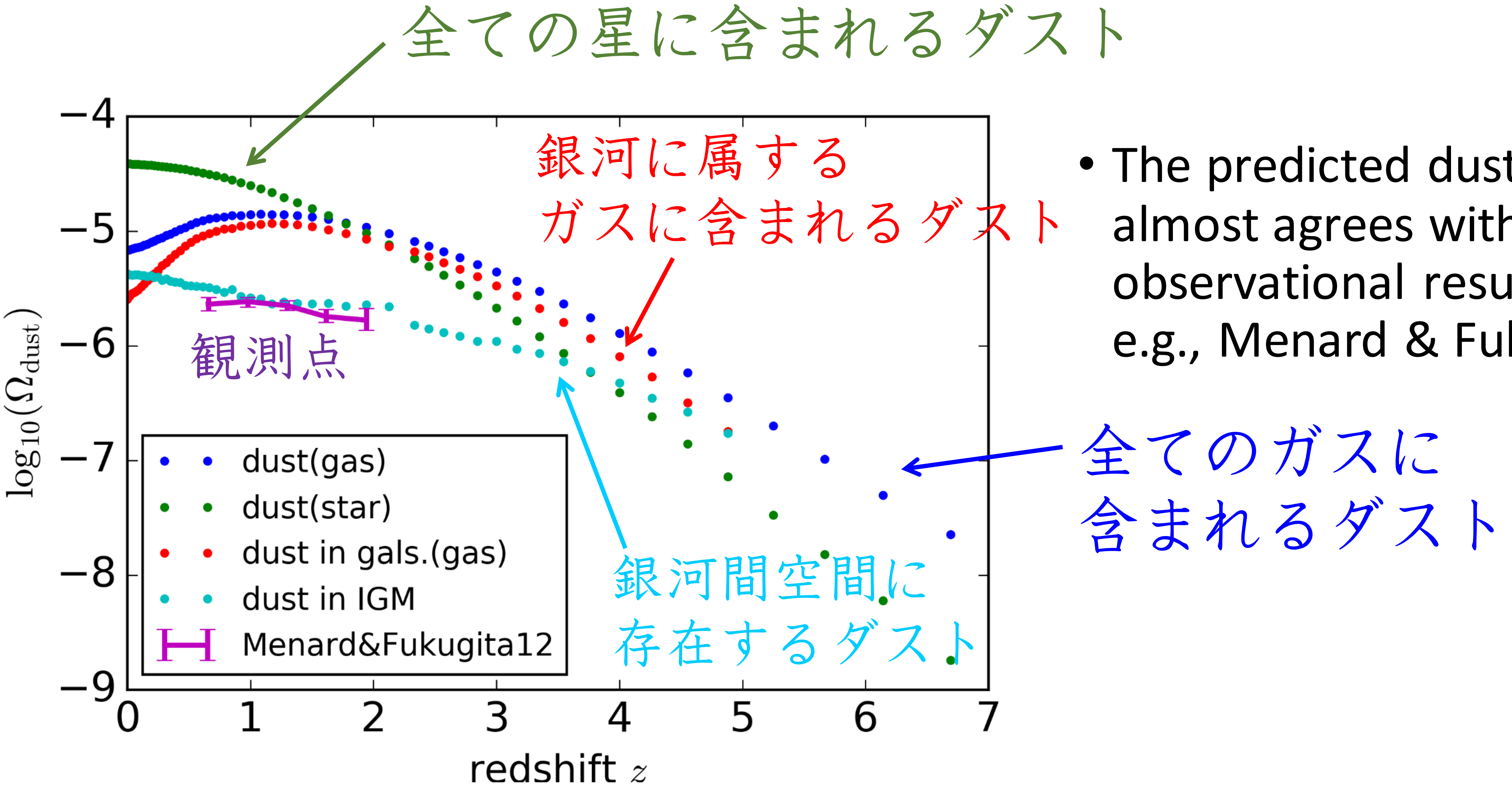


Galaxy stellar mass function @ z= 0



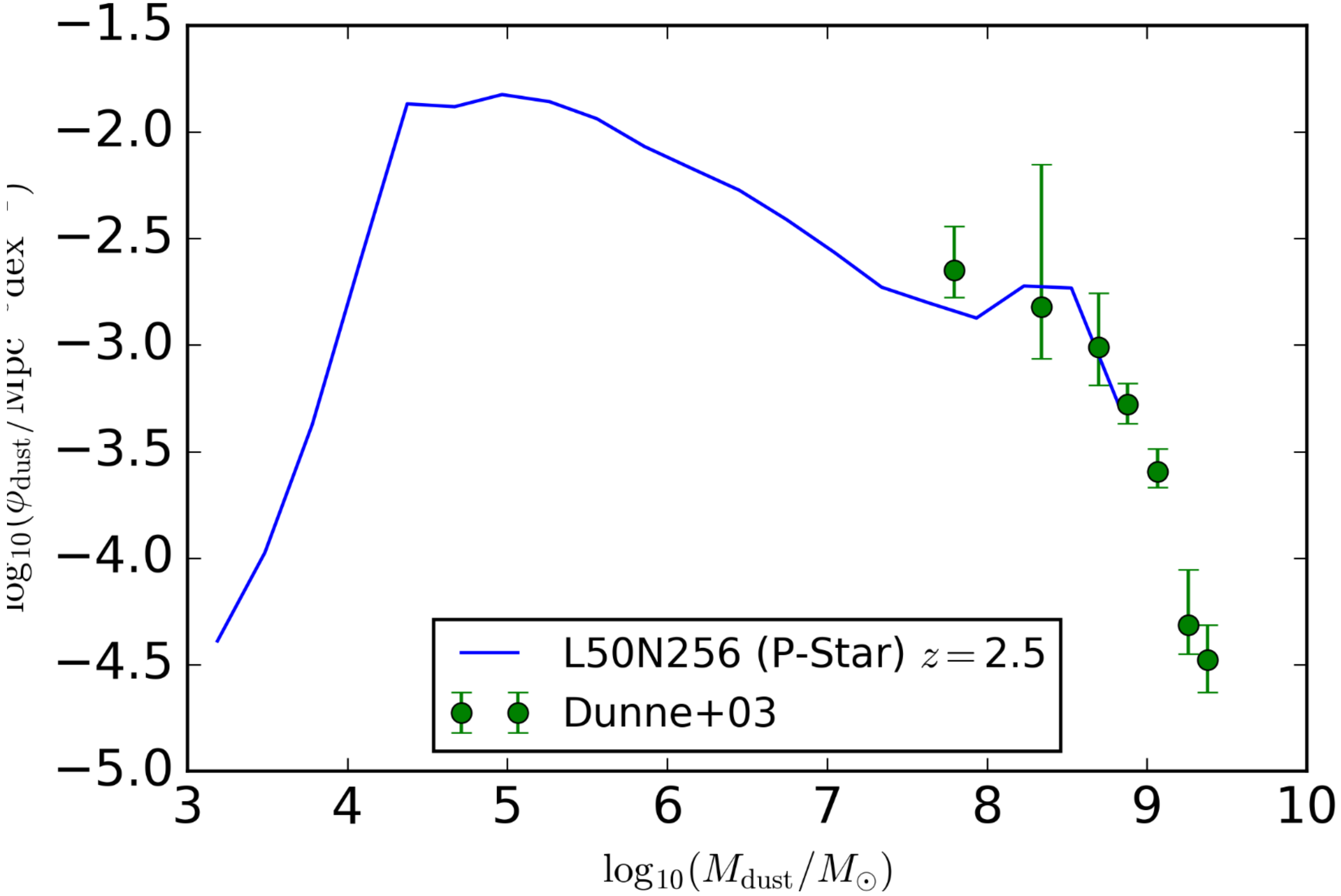
Our feedback model can produce the galaxy stellar mass function down to $M=10^{8.5}\ M_{\odot}$

$\Omega_{dust}(z)$



- The predicted dust abundance almost agrees with some observational results e.g., Menard & Fukugita2012.

Dust mass function @ z= 2.5

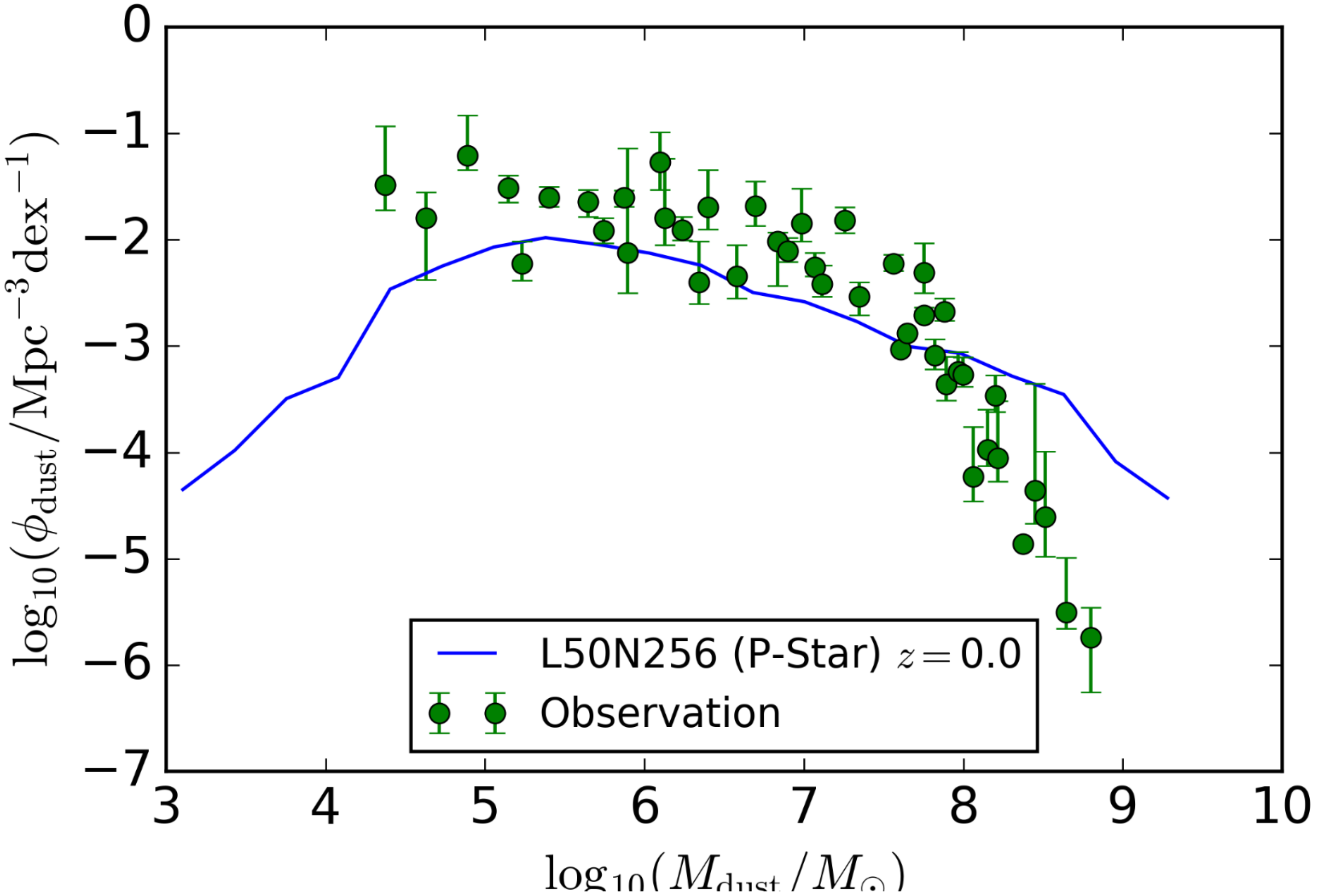


The dust mass function was observationally reported by Dunne+03 .

The predicted mass function agrees with massive end.

Larger box size is needed to reproduce massive systems.

Dust mass function @ z= 0

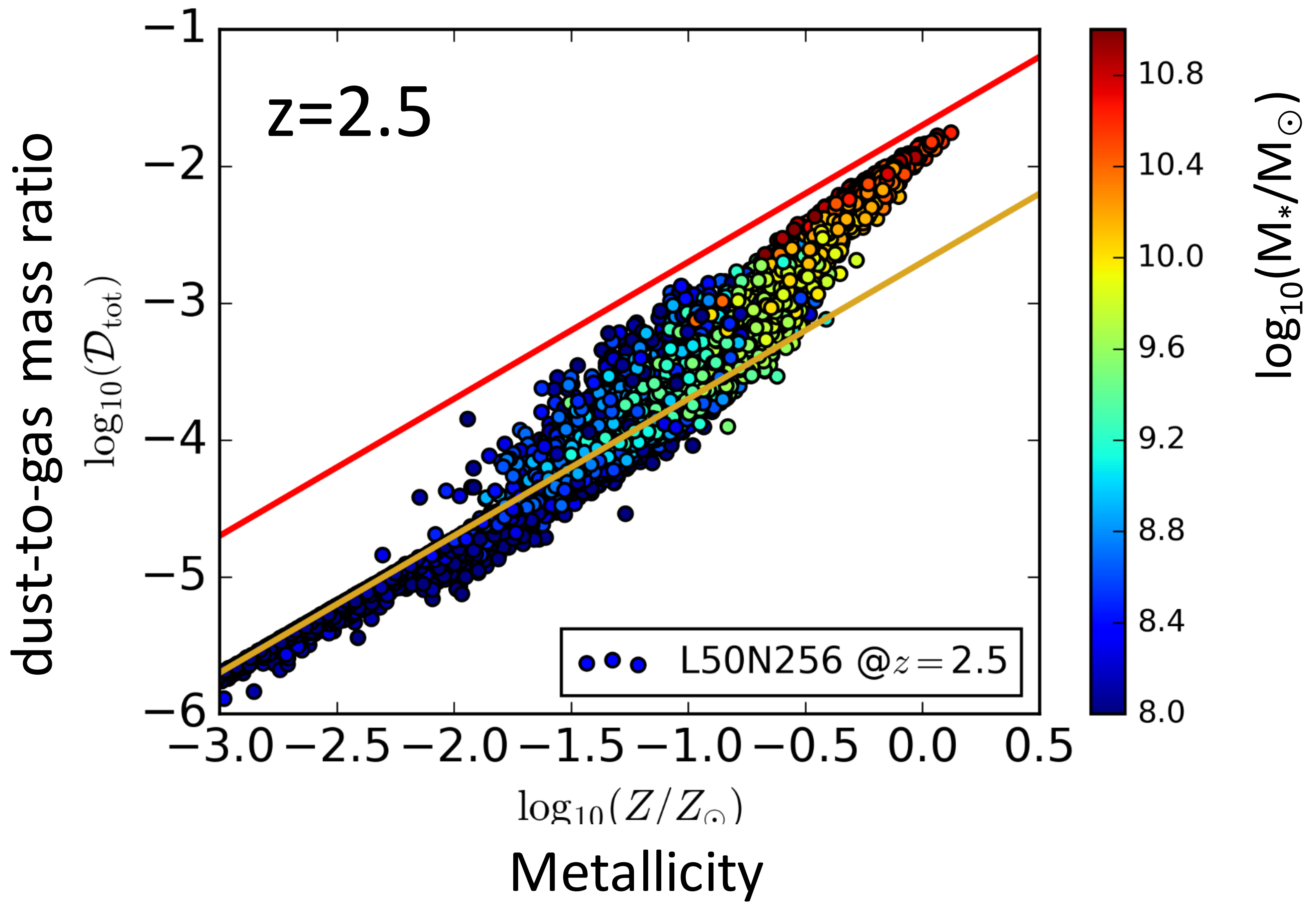


The dust mass function was observationally by many authors.

The predicted mass function agrees with observational data.

Lacking of AGN Feedback, we overestimate it at the massive end.

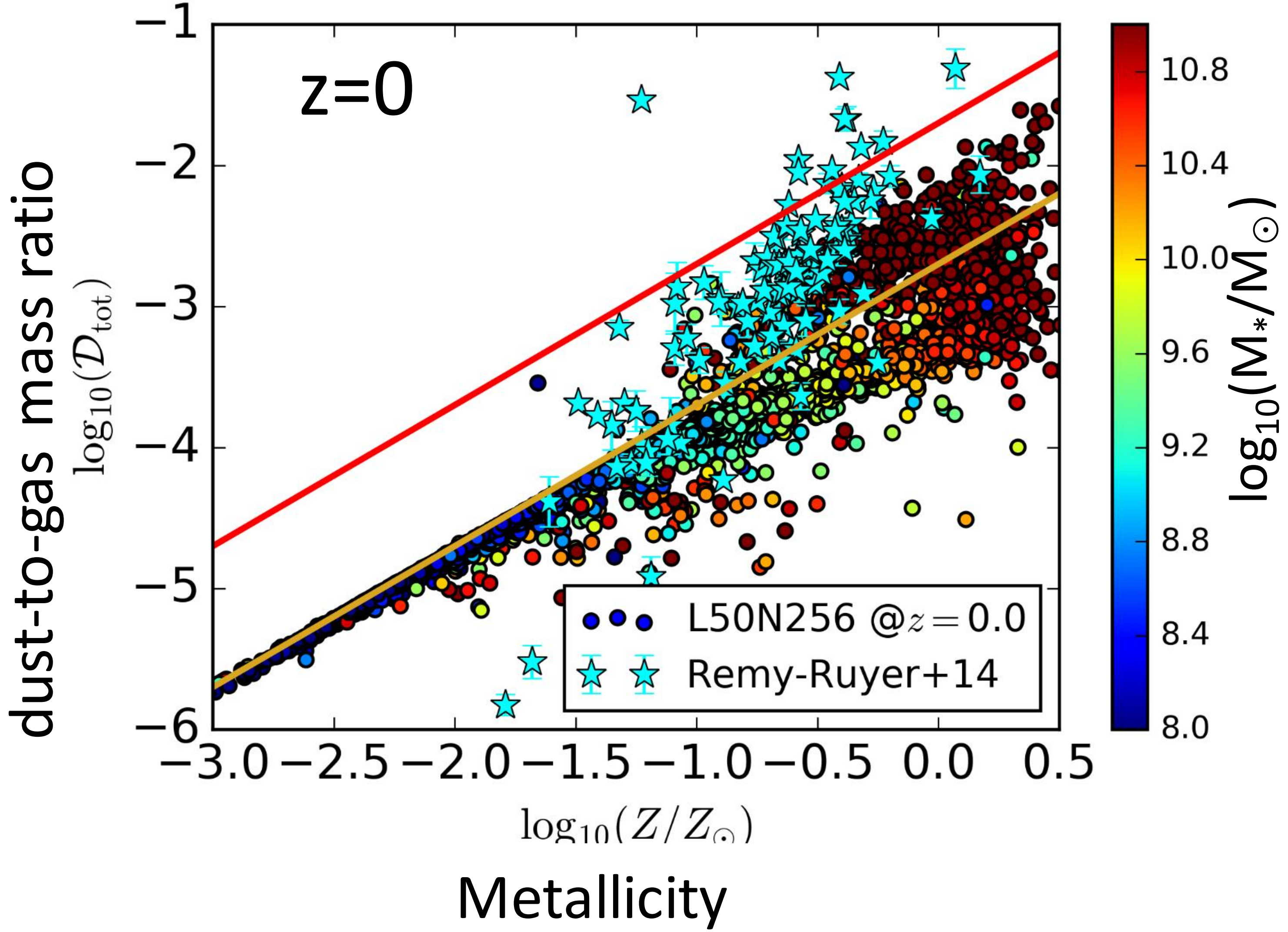
Dust abundance (D_{tot}-Z)



The accretion occurs in massive galaxies as they form stars.

Dust growth is not so enhanced in low mass ones.

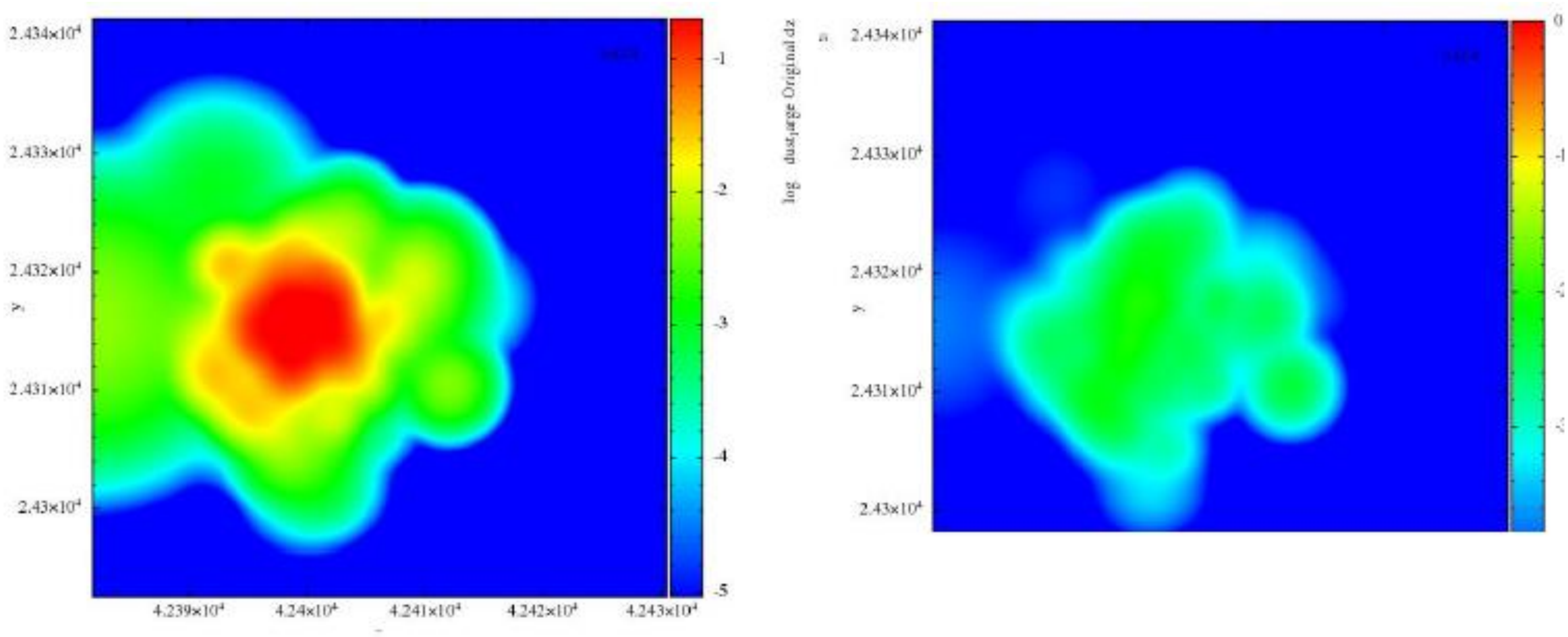
Dust abundance (D_{tot}-Z)



Our results roughly agree with Observational results, reported by Remy-Ruyer et al. (2014) A&A, 563, A31

The difference between the prediction and observation might be caused by resolution of simulation.

Dust abundance around massive galaxy.



A surface density of gas, large and small grains at current galaxy are shown.
Simulations with high resolution are required.

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** with sub-grid models for coagulation, shattering and accretion.

- Our simulation can roughly reproduce observational results such as total dust abundance $\Omega_{dust}(z)$, D_{tot}-Z relation and dust/stellar mass function.

- Accretion and coagulation occur in a cosmological simulation and small grains whish originate them are important even at z ~ 2 .

- Simulations with larger boxes and high resolutions are required.