New Dust Evolution Model in Galaxies with Gas Infall

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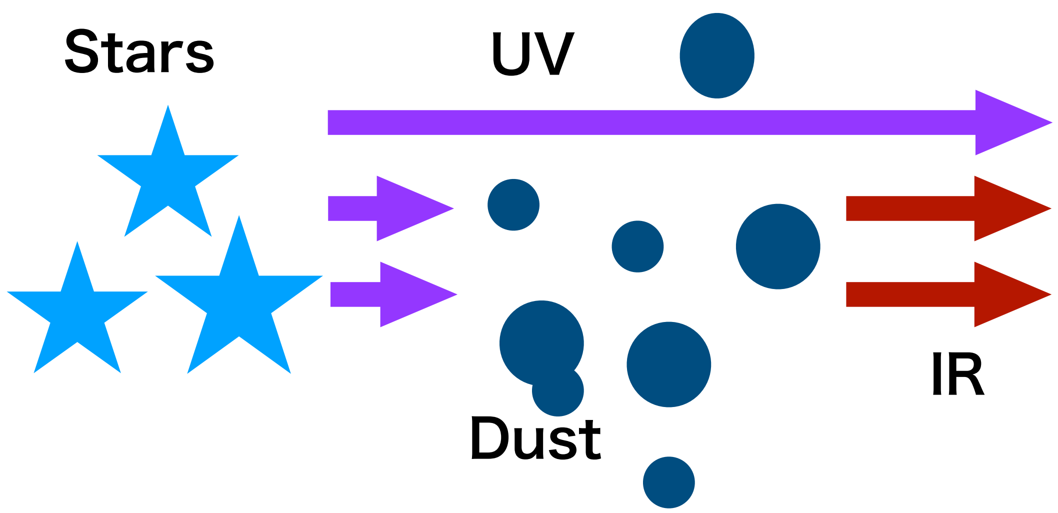
Introduction

- Dust is small particles which influence the various physical properties of galaxies

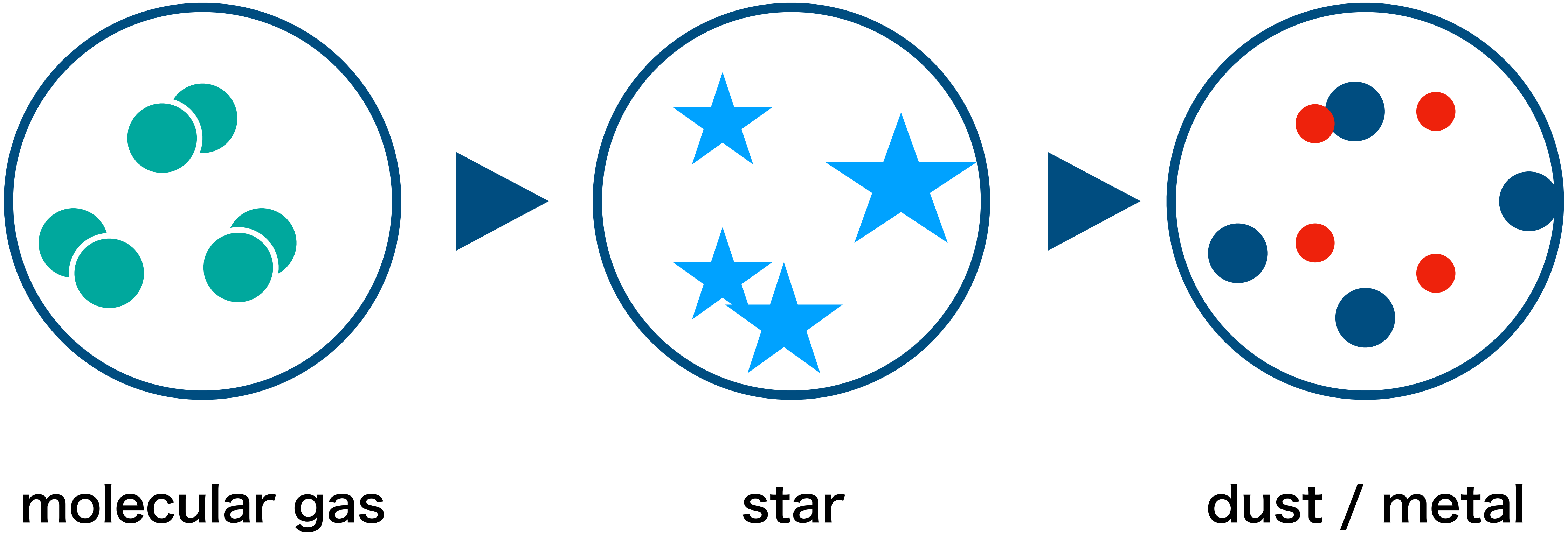
- Emission from stars in galaxies is affected by dust absorption and re-emission



- The amount of stellar light that dust absorbs and re-emits depend on the **quantity** and **size distribution** of dust

The origin of dust

These components of galaxies are linked each other

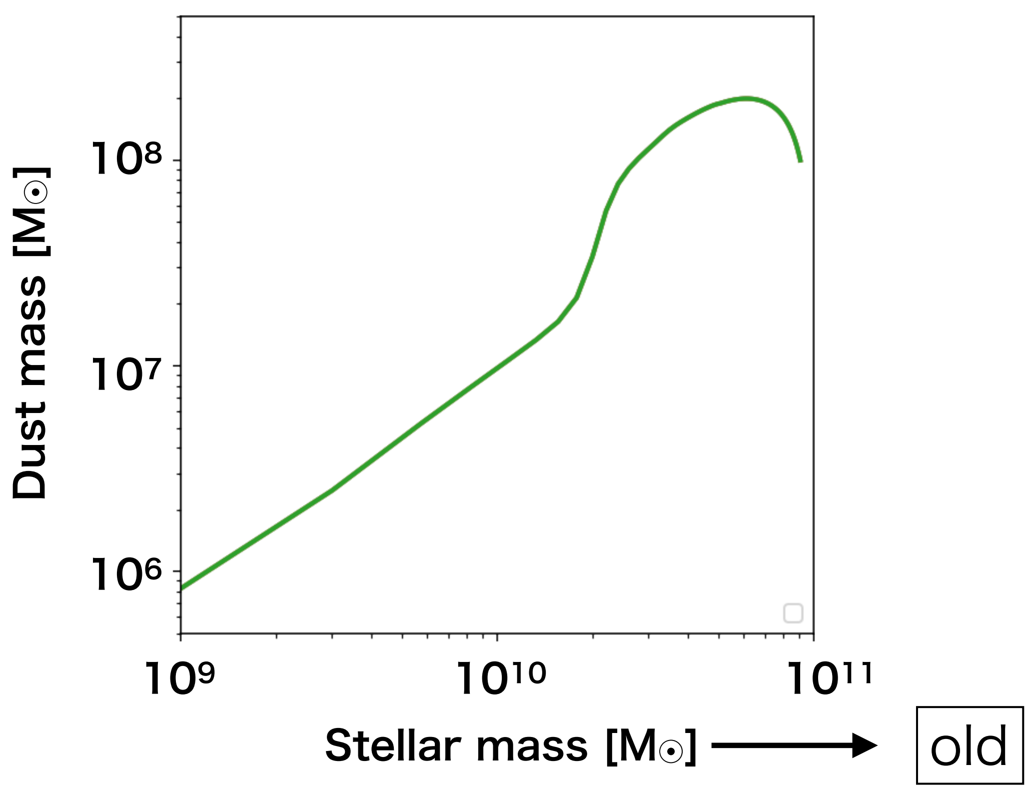


Composition evolution of galaxies

→ **Chemical evolution**

Chemical evolution of dust

Asano et al. (2013) have developed the model to explain the dust evolution (Asano model)



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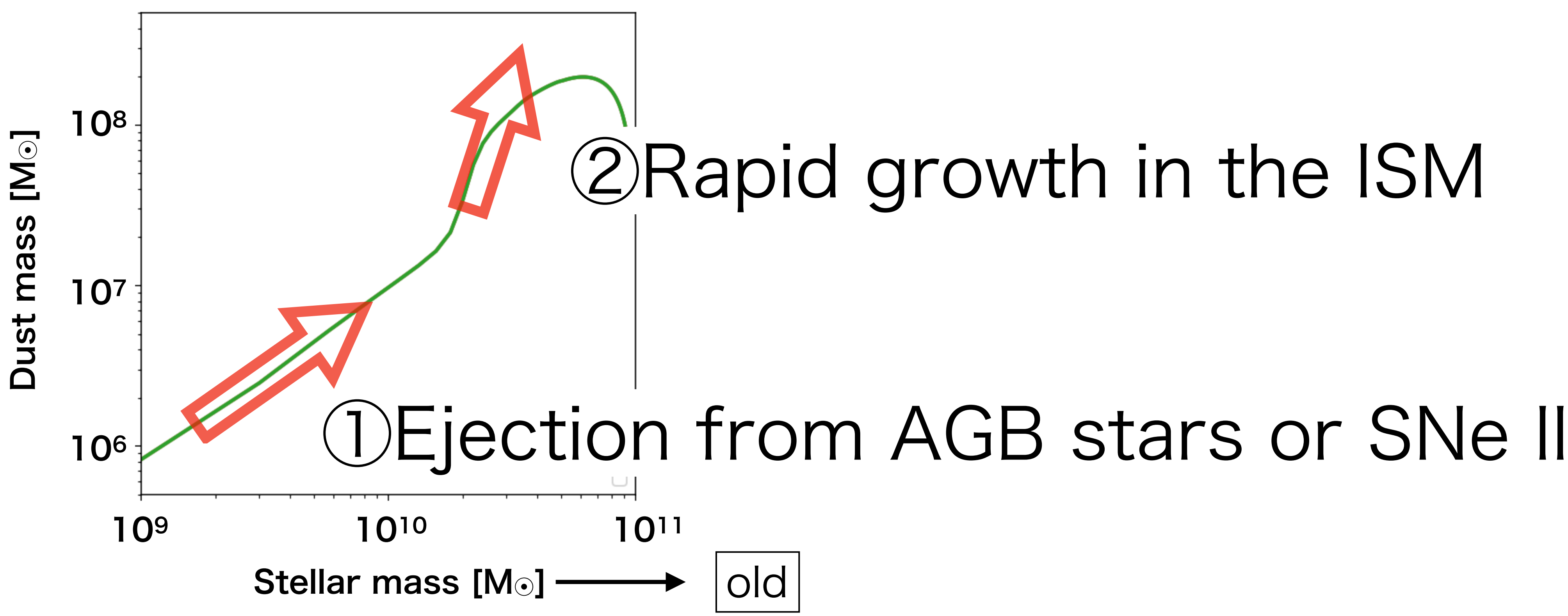


Problem

- The mechanism of dust supply at high redshift is still unknown !!

Dusty galaxies at high redshift

For example,

we cannot explain the observation completely

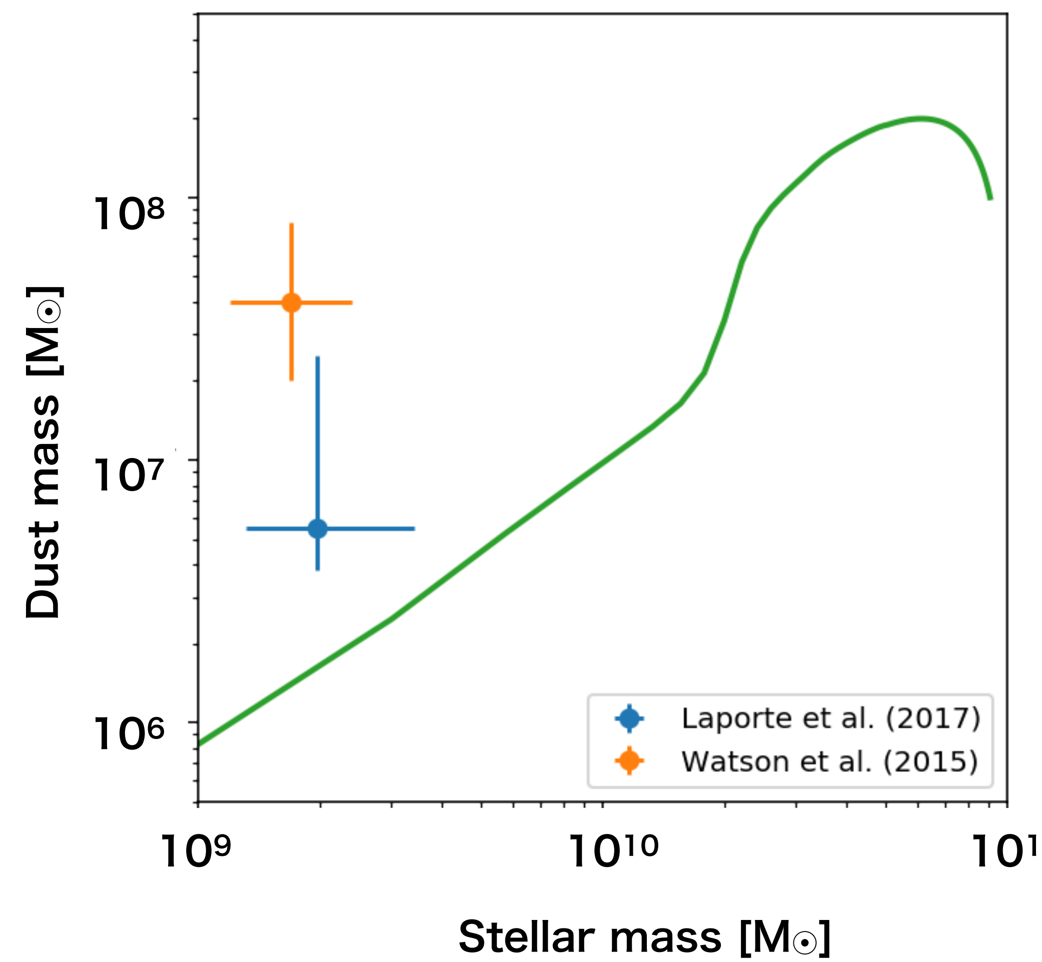
- Lensed galaxy A1689-zD1 (Watson et al. 2015)

$$z = 7.5$$
$$M_* = 1.7 \times 10^9 \ M_\odot$$
$$M_{dust} = 4 \times 10^7 \ M_\odot$$

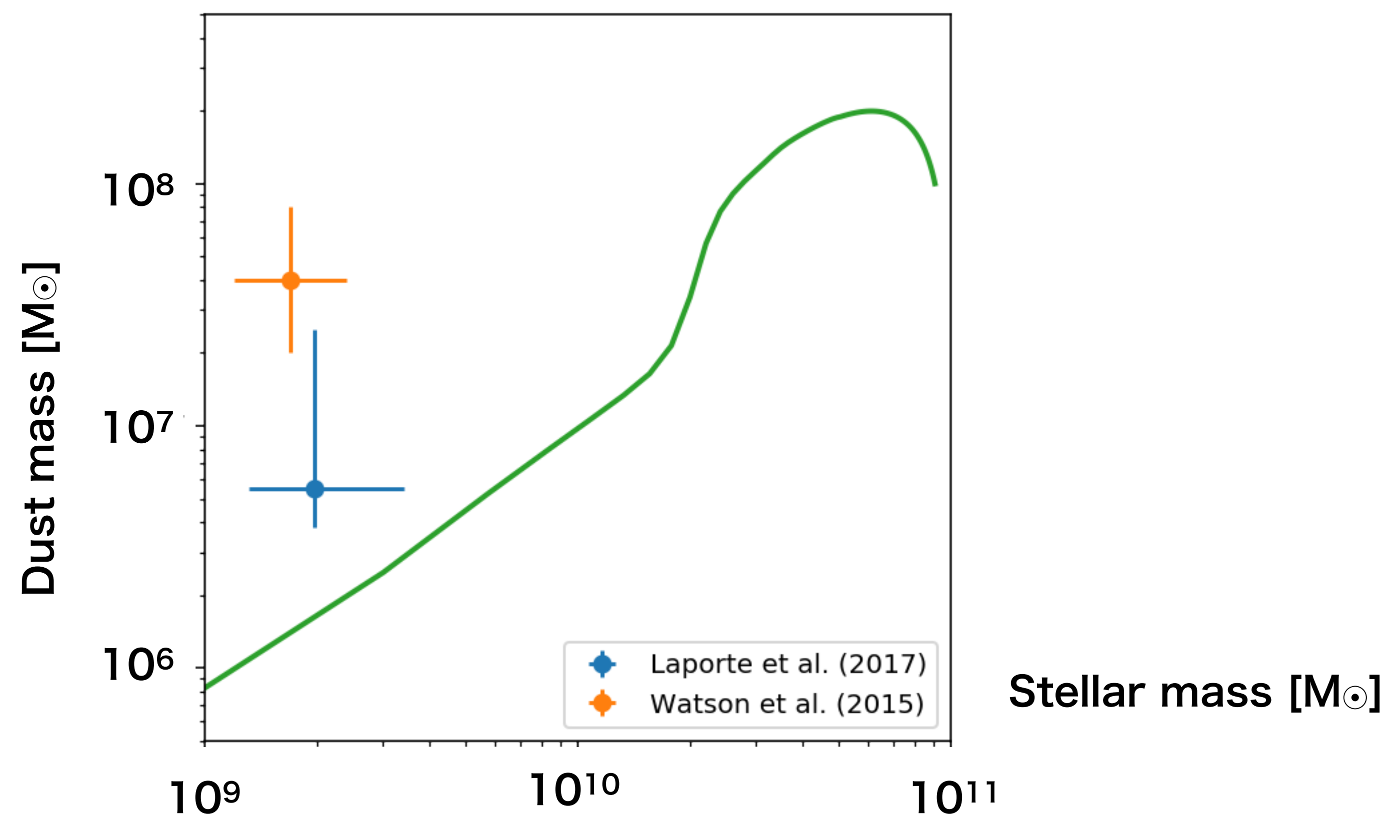
- Lensed galaxy A2744-YD4.

  (Laporte et al. 2017)

$$z = 8.38$$
$$M_* = 1.97 \times 10^9 \ M_\odot$$
$$M_{dust} = 5.5 \times 10^6 \ M_\odot$$



Infall model



- When we discuss the early stage of galaxies, we have to consider how galaxies formed and evolved in their first phase
- Therefore, we introduced the gas infall to construct more realistic evolution model for dust in galaxies

Infall model

We adopted the following scenario (Inoue 2011)

① Small galaxies are formed

② The galaxies become larger and larger as they merge with each other

③ Galaxies also obtain mass by an accretion process

We simply assume a **smooth exponential gas-infall rate**

$$I(t) = \frac{M_{\mathrm{infall}}}{\tau_{in}} \exp(-\frac{t}{\tau_{in}})$$

τ_{in} : infall time-scale

M_{infall}: total infall mass

Method

- We calculated the masses of these 4 components

ISM

$$\frac{\mathrm{d}M_{\mathrm{ISM}}(t)}{\mathrm{d}t} = -\,\mathrm{SFR}(t) + R(t) + I(t)$$

Infall rate

$$\frac{M_{\mathrm{infall}}}{\tau_{in}} \exp\left(-\frac{t}{\tau_{in}}\right)$$

Stars

$$\frac{\mathrm{d}M_{*}(t)}{\mathrm{d}t} = \mathrm{SFR}(t) - R(t)$$

Metal

$$\frac{\mathrm{d}M_{z}(t)}{\mathrm{d}t} = -\,\mathrm{Z}(t)\mathrm{SFR}(t) + Y_Z(t) + R_Z(t)$$

R : returned mass rate from dying stars

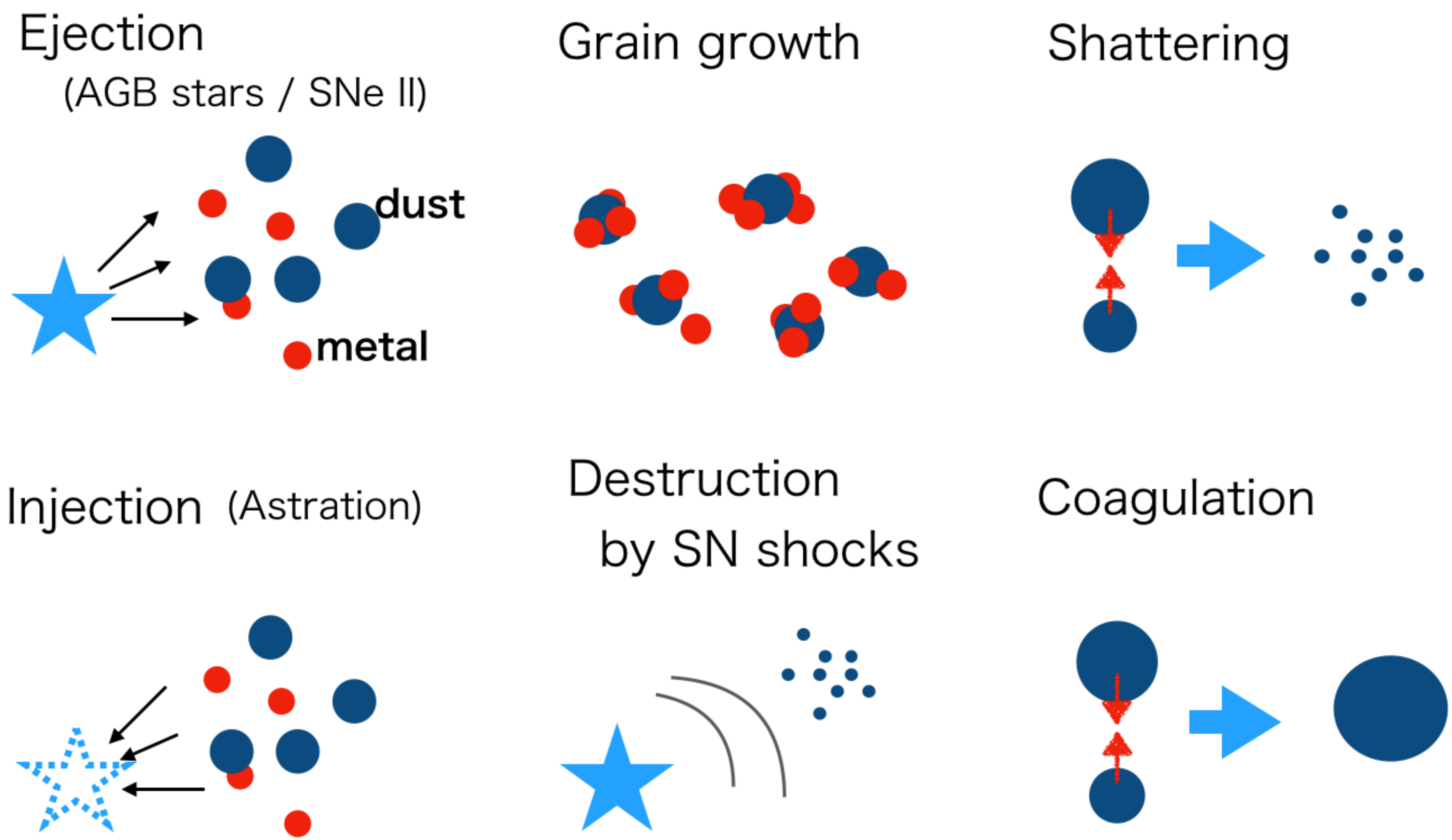
$\mathrm{Z}(t) \equiv M_{\mathrm{metal}}/M_{\mathrm{ISM}}$: metallicity

Y_Z : metal supplying rate by dying stars

Dust equation is slightly complicated . . .

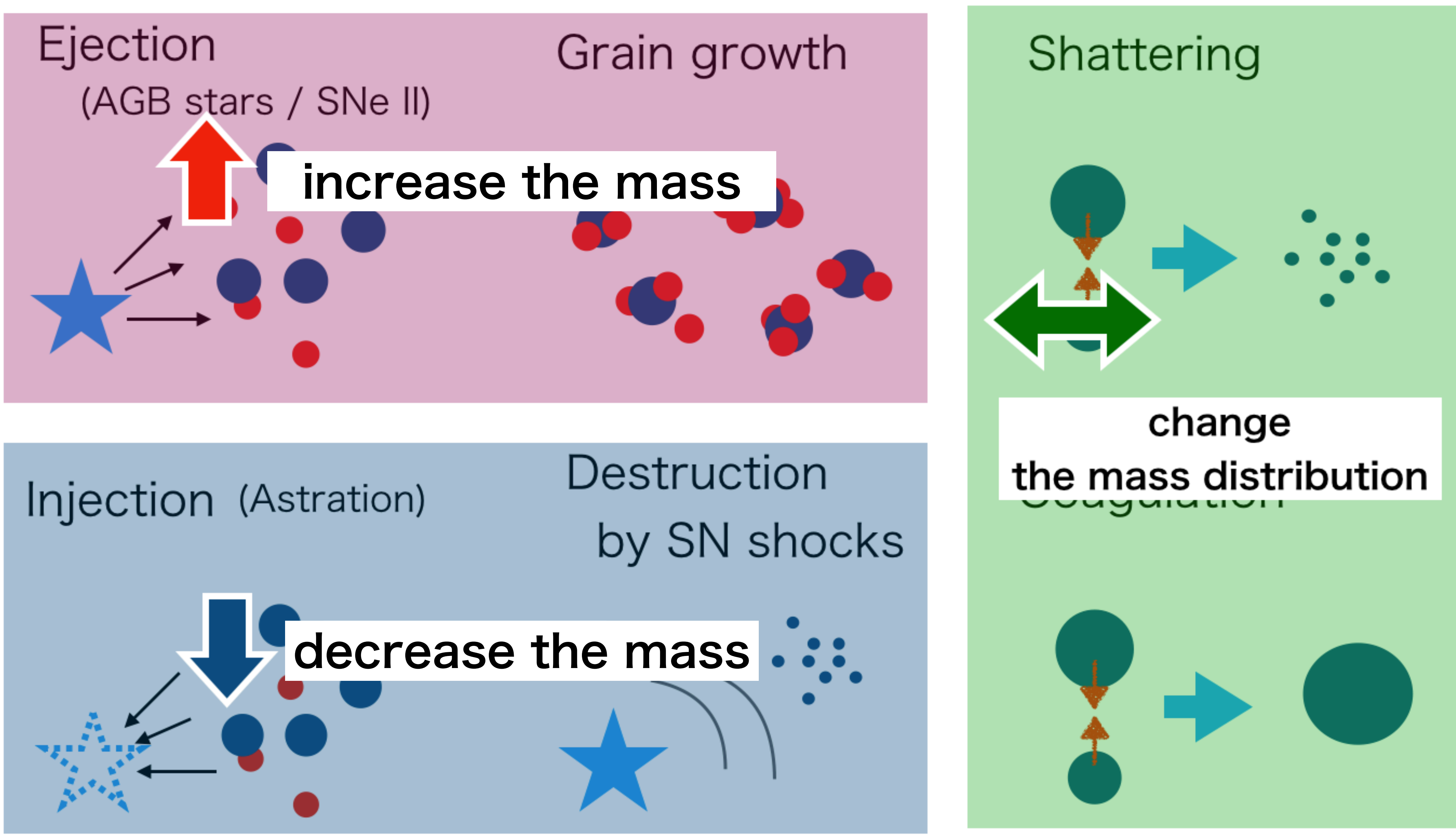
Method

Dust evolution processes



Method

Dust evolution processes



Method

Model assumption

- ISM contains 2 phases
  - Warm neutral medium (**WNM**): 6000K, 0.3 cm^{-3}
  - Cold neutral medium (**CNM**): 100K, 30 cm^{-3}

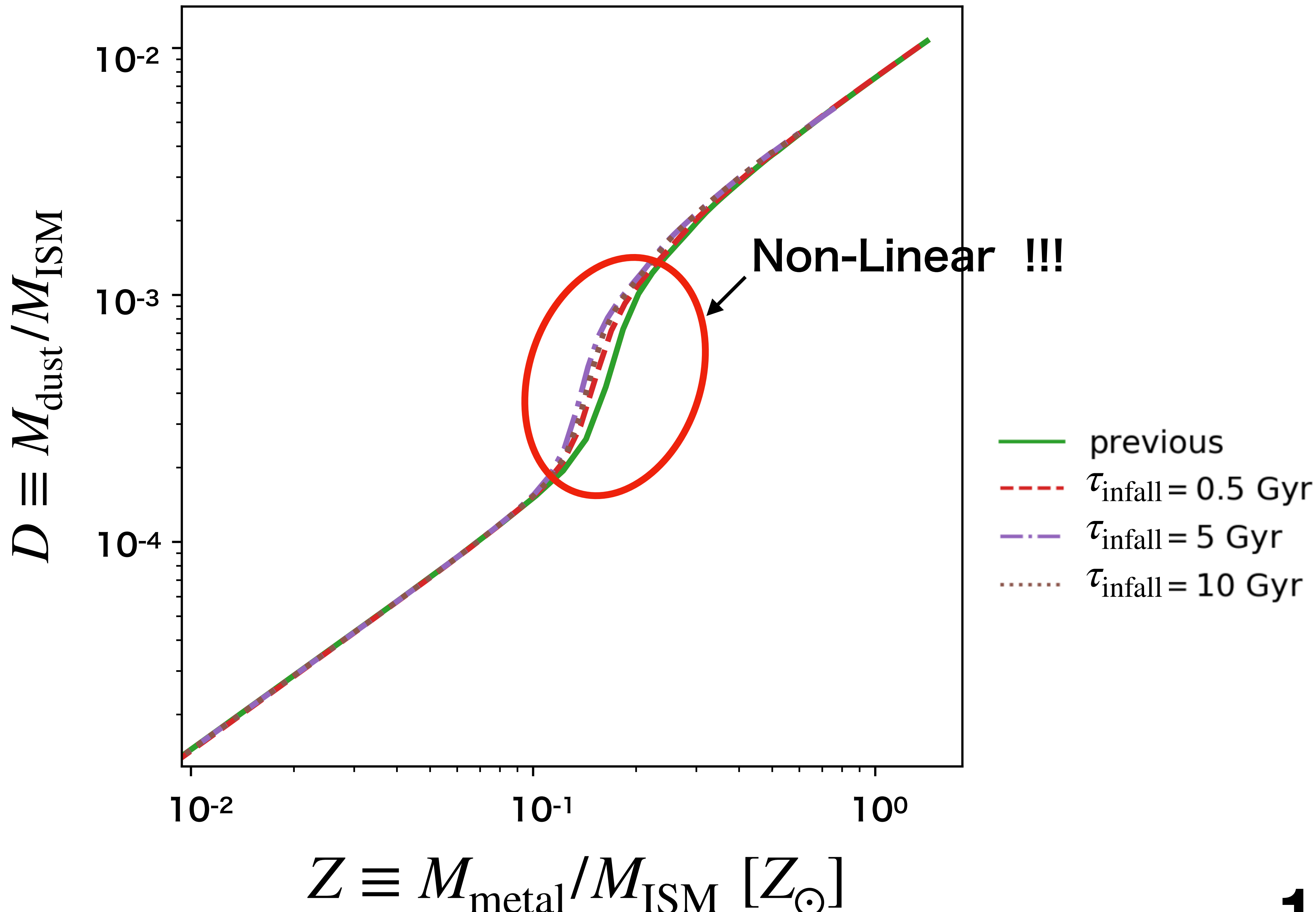
- We adopted Schmidt law for the SFR

$$\Sigma_{\rm SFR} \propto \Sigma_{\rm ISM}^{n} \quad \xrightarrow{\text{for } n=1} \quad {\rm SFR}(t) = \frac{M_{\rm ISM}(t)}{\tau_{\rm SF}}$$

$\tau_{\rm SF}$: star formation timescale

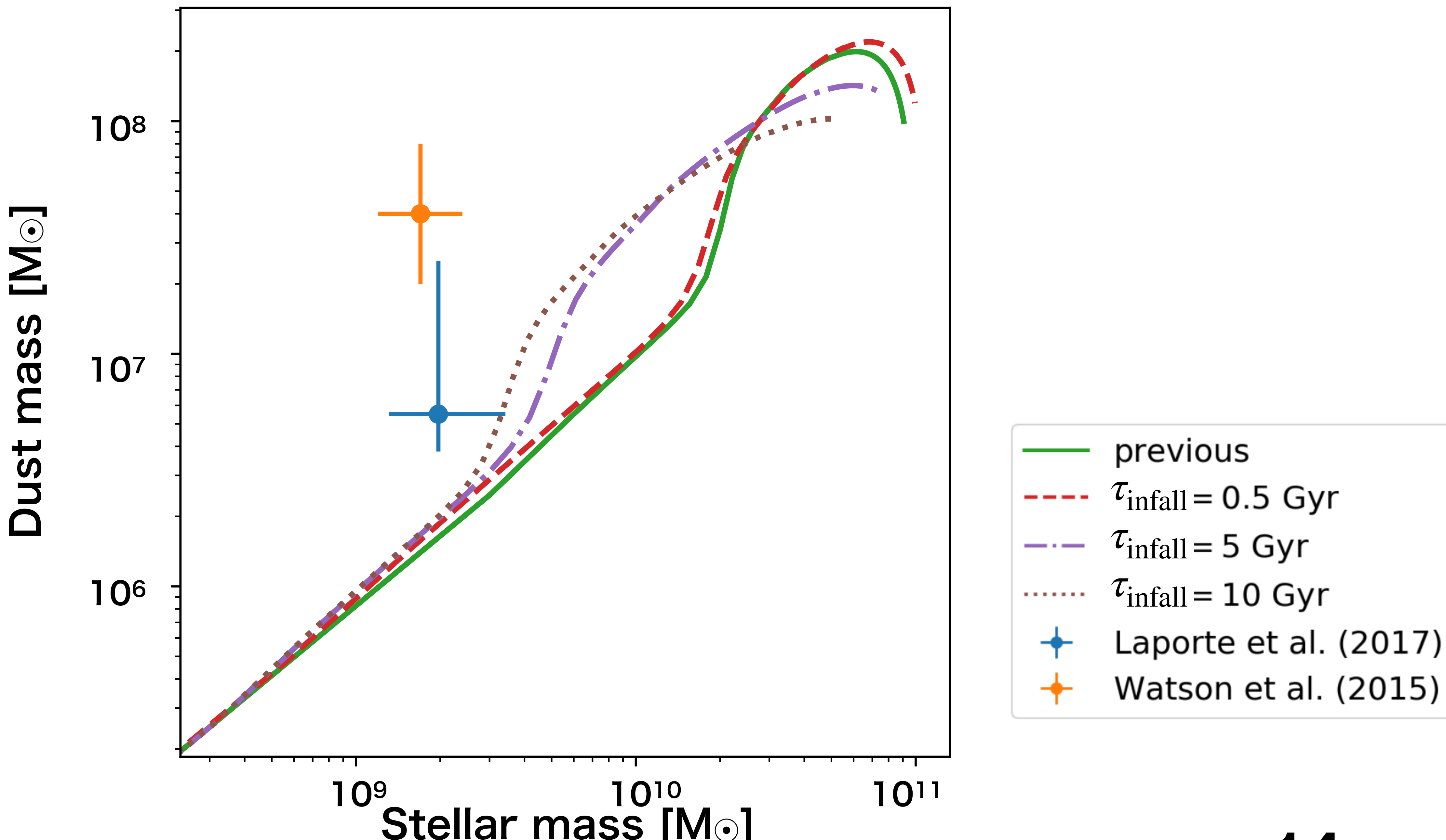
Result : Z-D relation

Z-D relation is consistent with previous research



Result : M_{star}-M_{dust} ratio

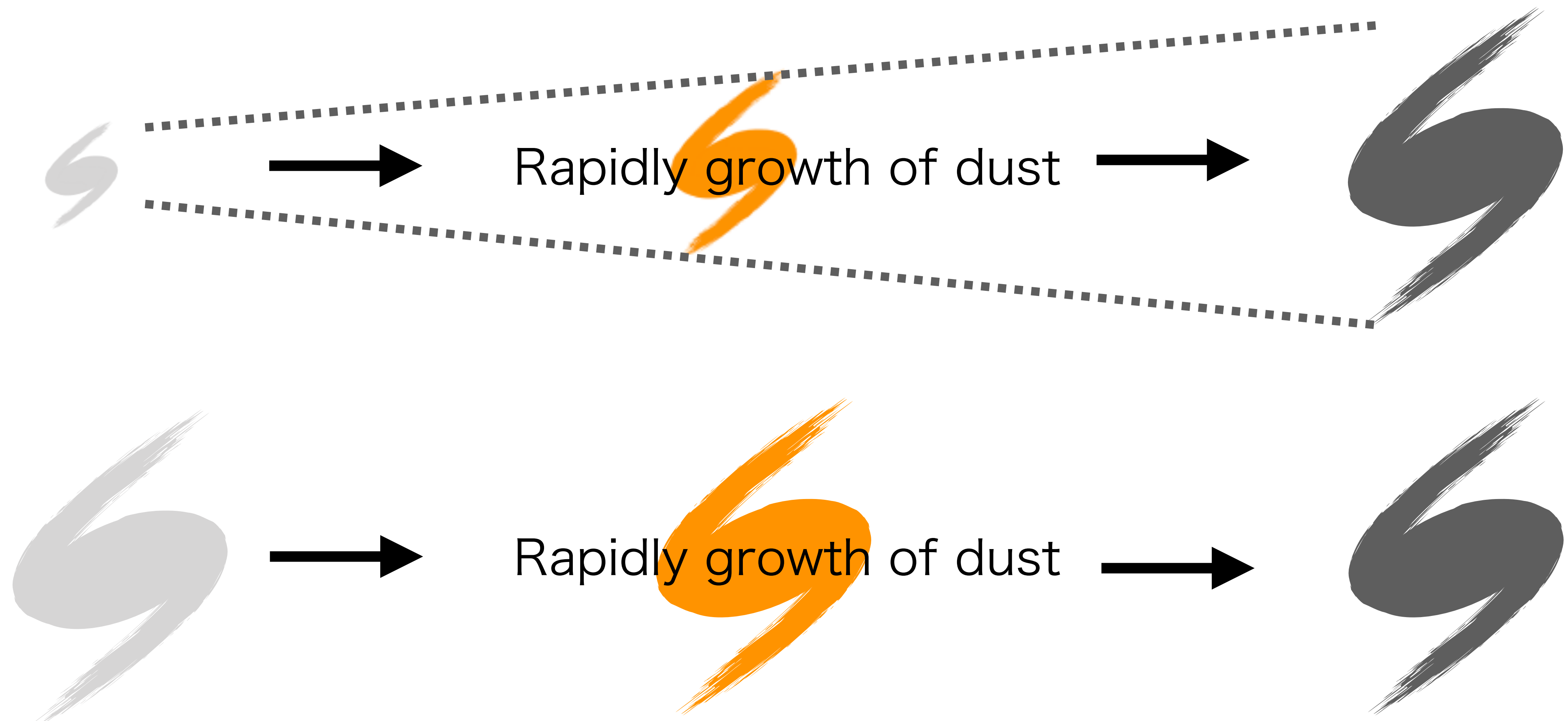
Gas infall model seems to be better model compared with than the previous model



Discussion: M_{star}-M_{dust} ratio

Infall model

Previous model



- If we consider the galaxy evolution due to gas infall, the size of galaxies become larger as dust evolve
- Dust can experience the rapid growth at lower stellar masses

Summary

- Infall model can explain the formation of galaxy more accurately
- The Z-D relation remains unchanged even if we introduced a gas infall, and it is found to be consistent with previous results
- Dust can experience the rapidly growth at lower stellar masses