# *Effects of supernova feedback and dust processing on circum-galactic dust*

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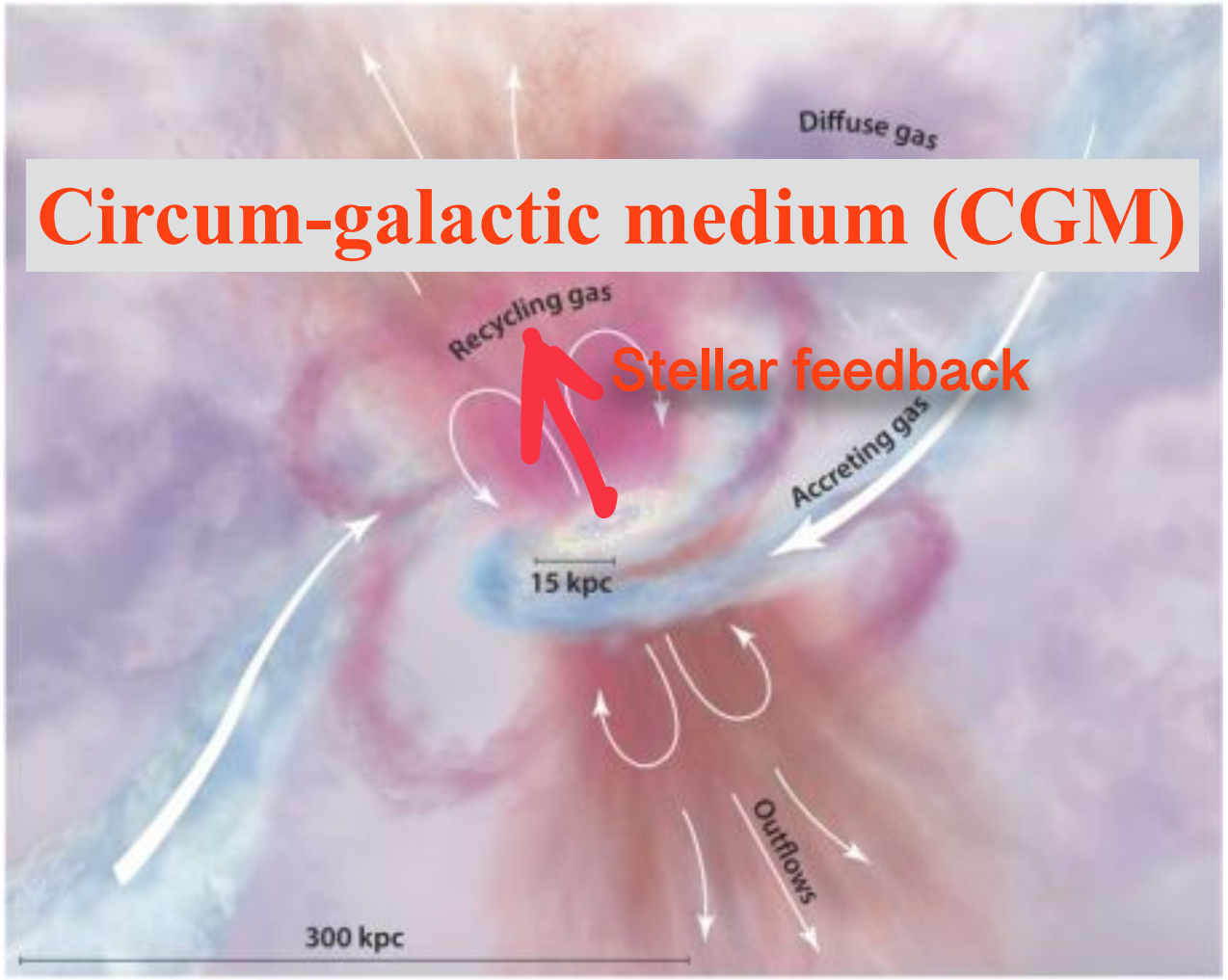
# Outline

1. Dust around Galaxies (in the CGM)
2. CGM Dust in Galaxy Simulations
3. Dust Processing in the CGM
4. Summary

# 1. Dust around Galaxies

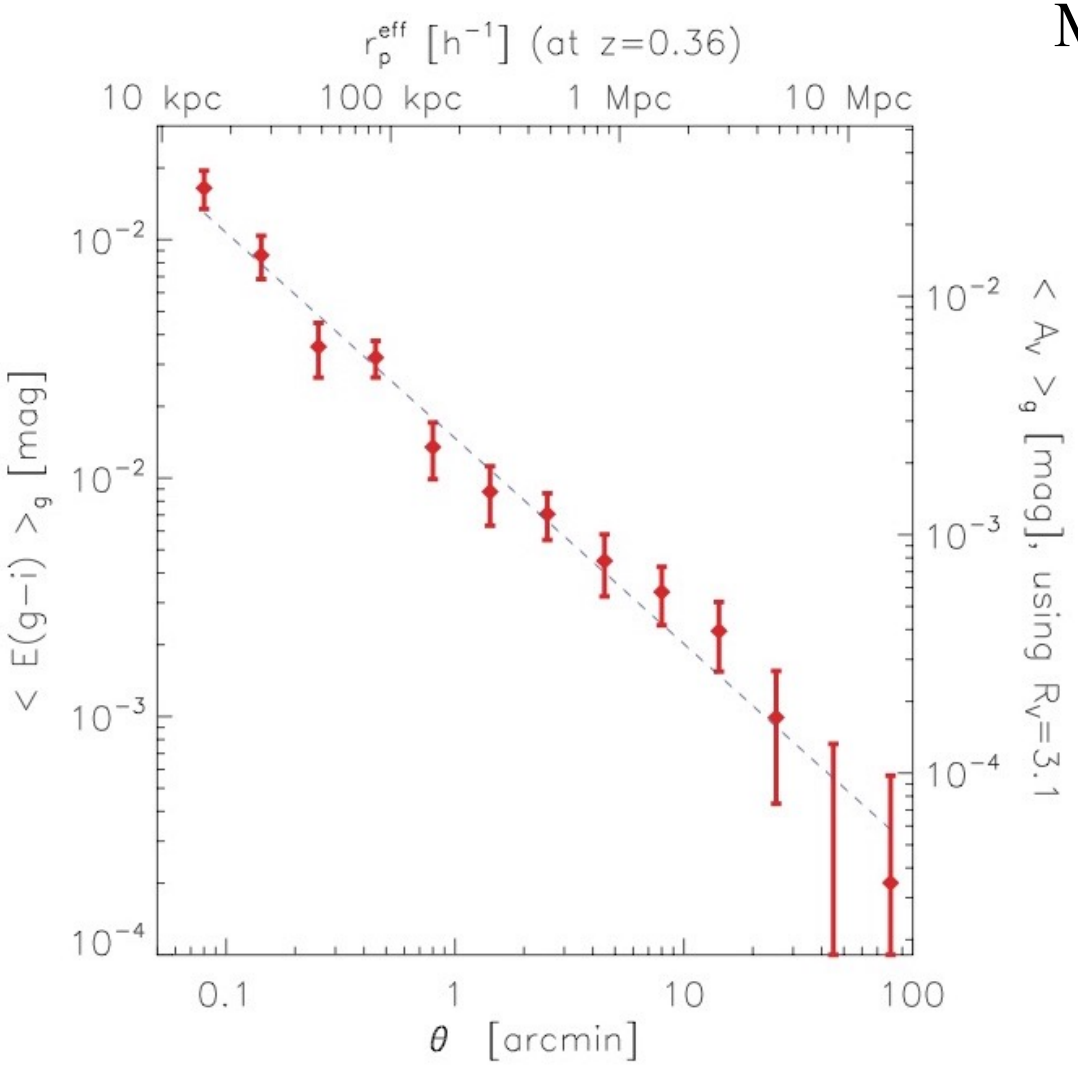



Tumlinson et al. (2017)

# Dust in the CGM

Ménard et al. (2010)

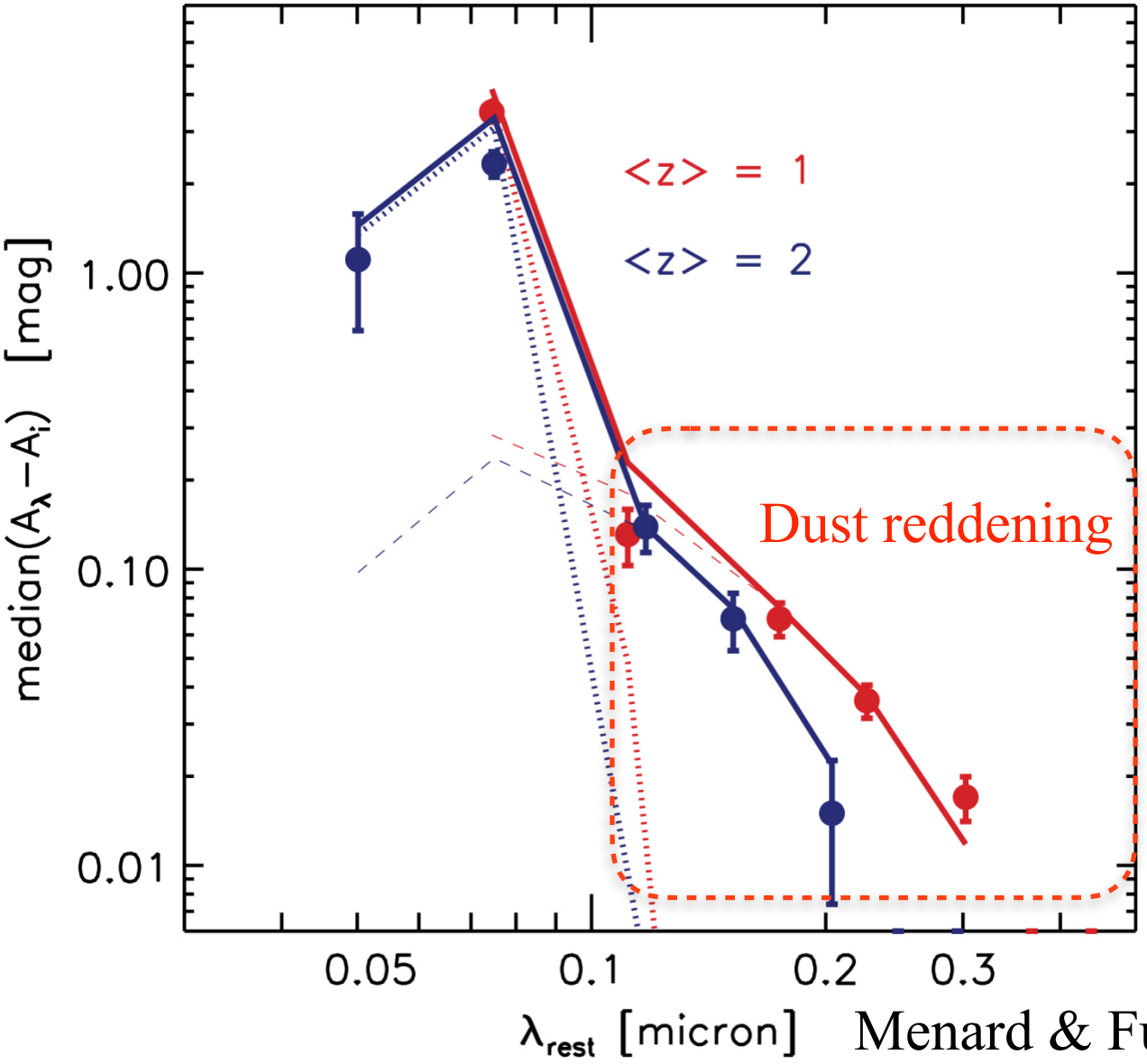
Reddening (indicator of dust)




Distance from the galaxy center

Measured the correlation between galaxies and reddening of background quasars.

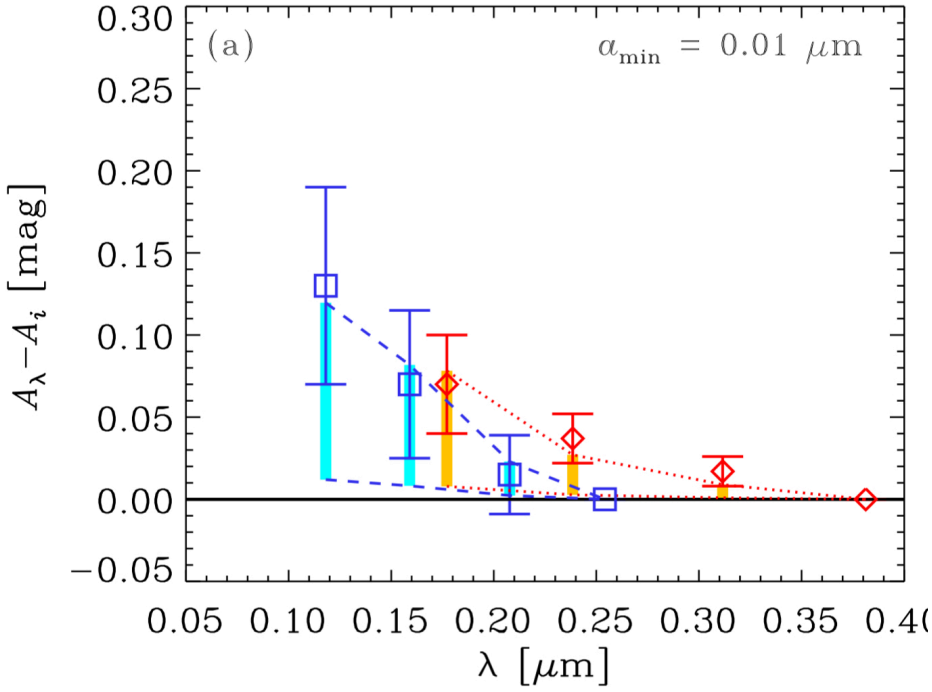
# Reddening in Mg II Absorbers

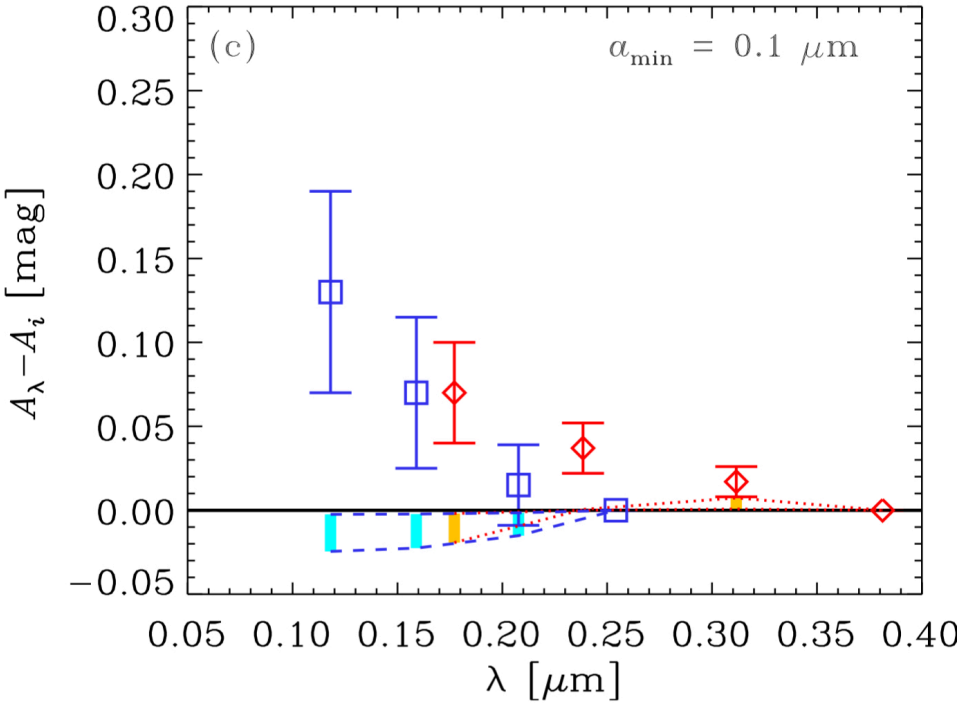



Menard & Fukugita (2012)

# Small Grains in the IGM

Hirashita & Lin (2020)




Observed reddening indicates the existence of small (< 0.03 μm) grains.

# Questions

Can we explain the dust abundance in the CGM by the stellar feedback scenario?

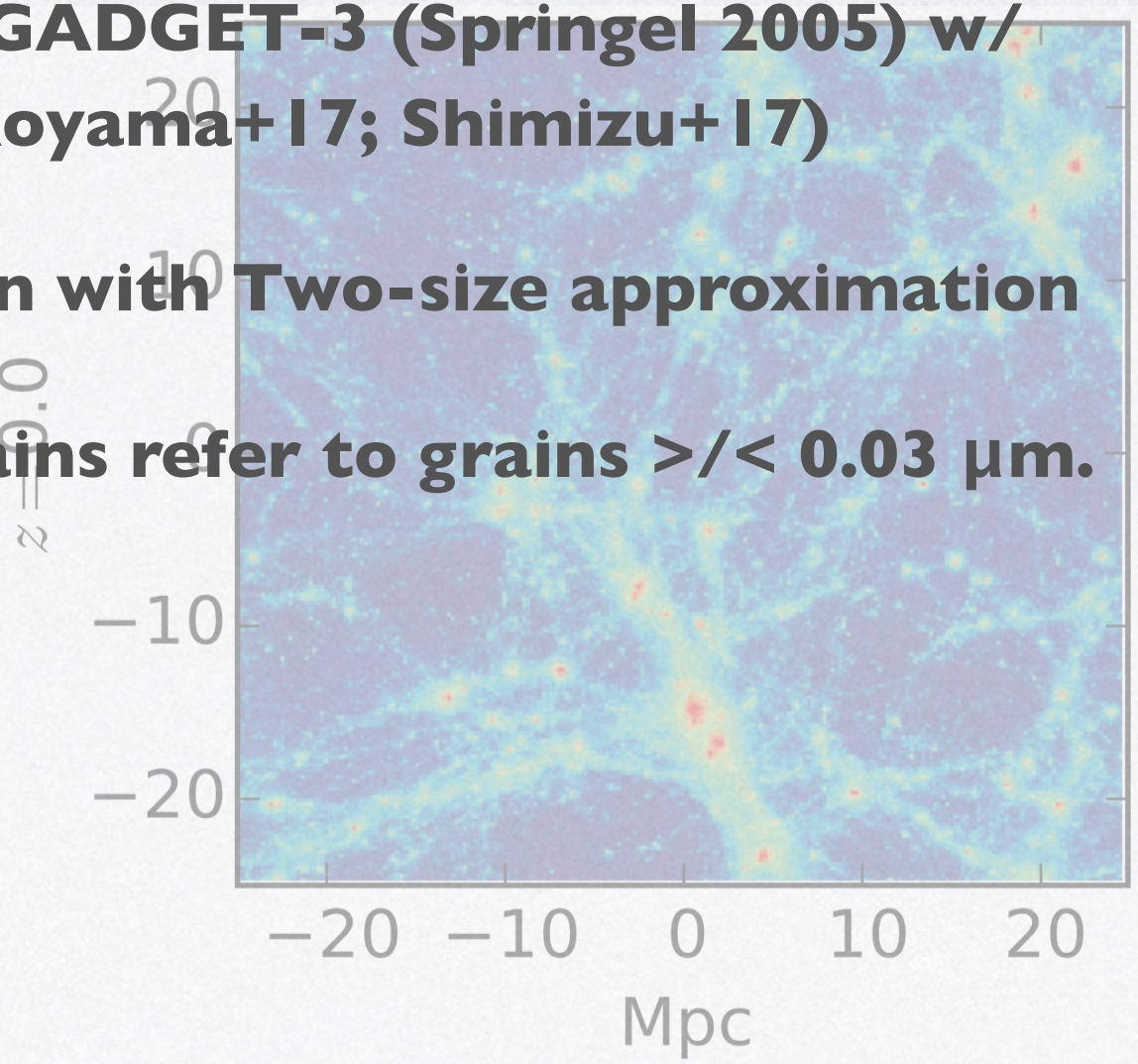
Can we explain the dust properties (reddening curves) in the CGM by the stellar feedback scenario?

# 2. CGM Dust in Galaxy Simulations

with
Shohei Aoyama
Kuan-Chou Hou
Kentaro Nagamine
Ikkoh Shimizu
(GADGET3-Osaka team)

# Cosmological Hydrodynamical Simulation

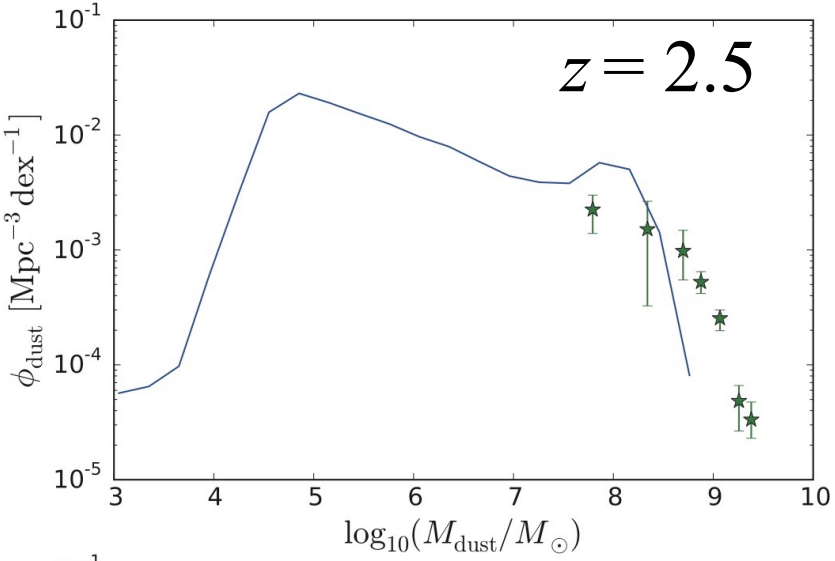
- **SPH (smoothed particle hydrodynamic) simulation using modified GADGET-3 (Springel 2005) w/ SF+feedback (Aoyama+17; Shimizu+17)**
- **+ Dust evolution with Two-size approximation**
- **Large/Small grains refer to grains >/< 0.03 μm.**

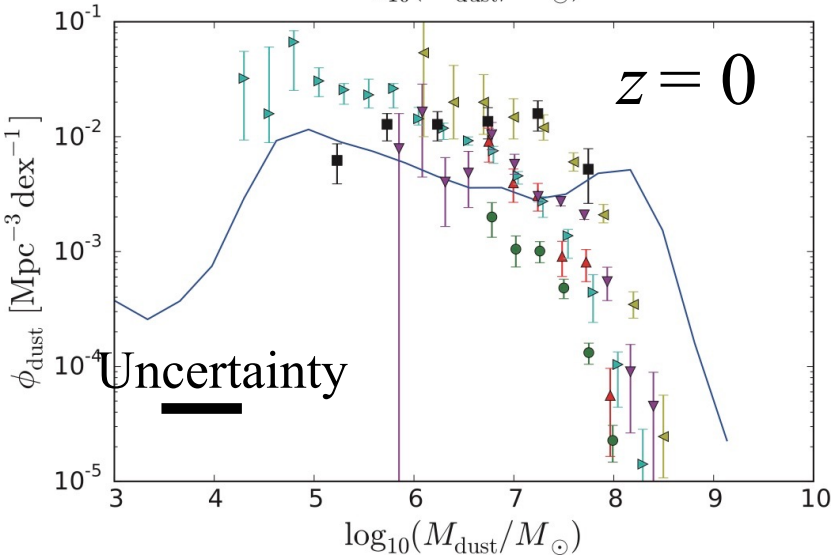


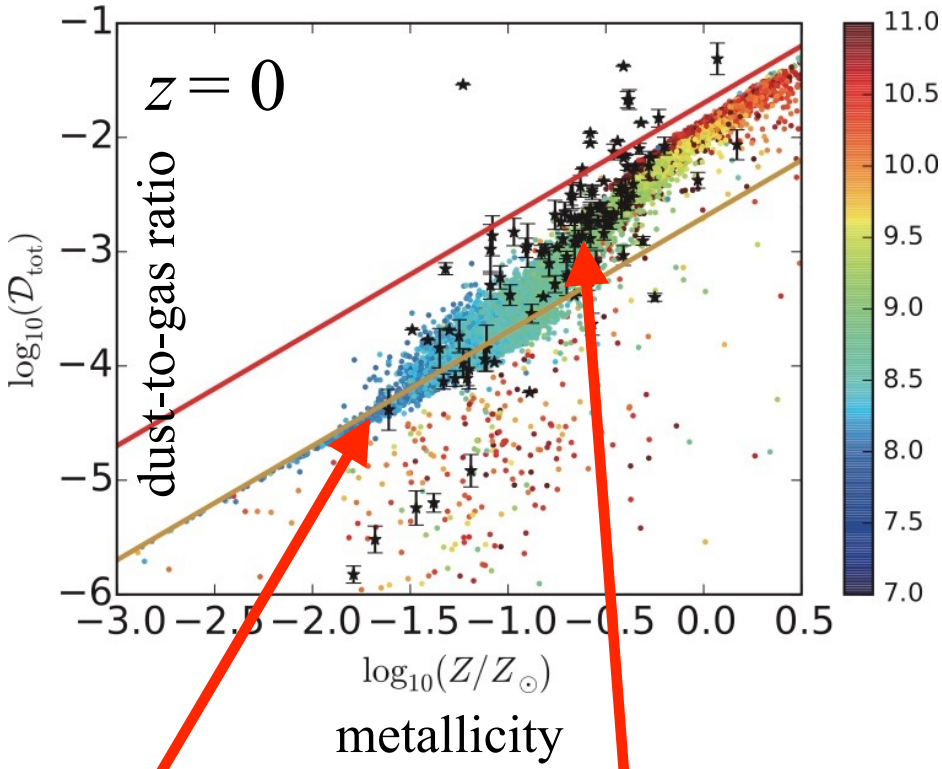
# Dust Abundances

Dust mass function

Statistics of dust mass



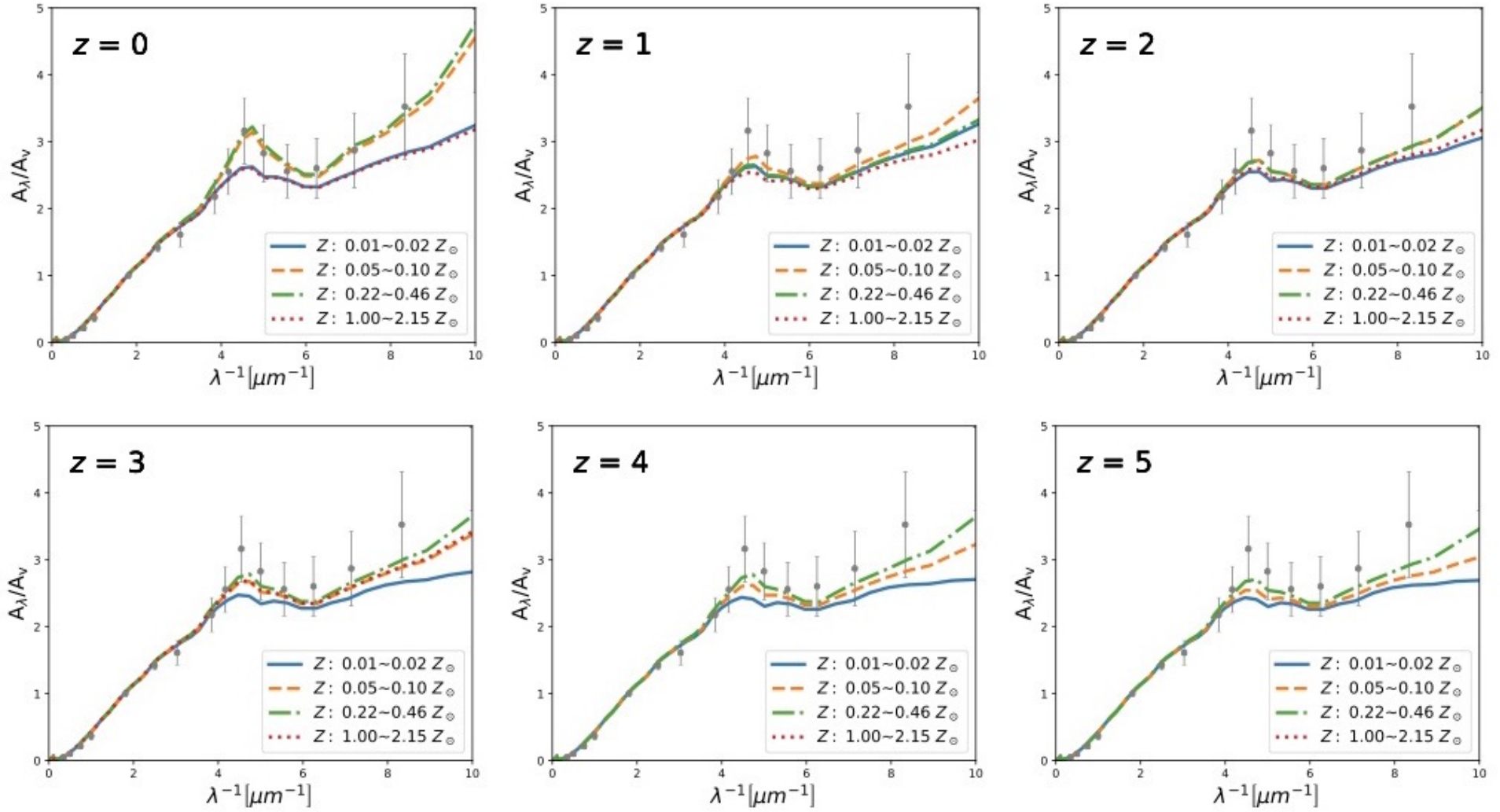

Stellar dust production

Dust growth by accretion

Aoyama et al. (2018)

Hou et al. (2019)

# Extinction Curves




- Flatter at higher *z*.
- Steepest at intermediate metallicity

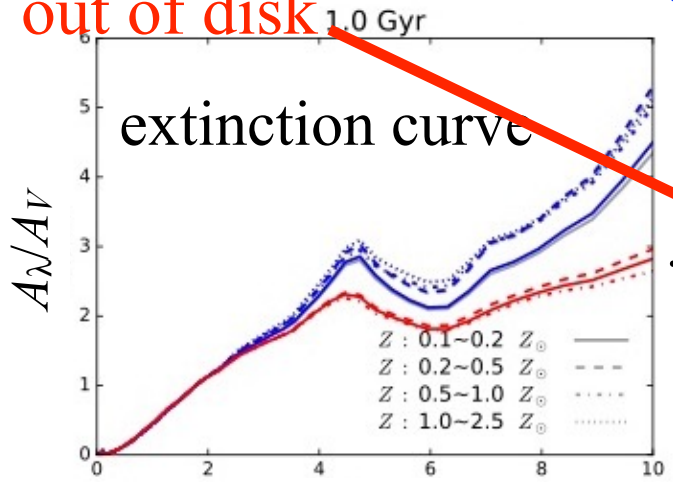
Hou et al. (2019)

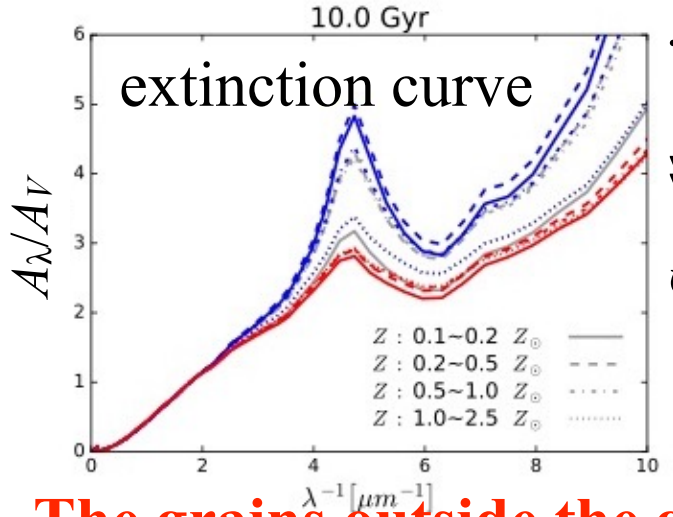
# Isolated-Galaxy Simulation

in disk: $R < 15$ kpc, $|z| < 2$ kpc

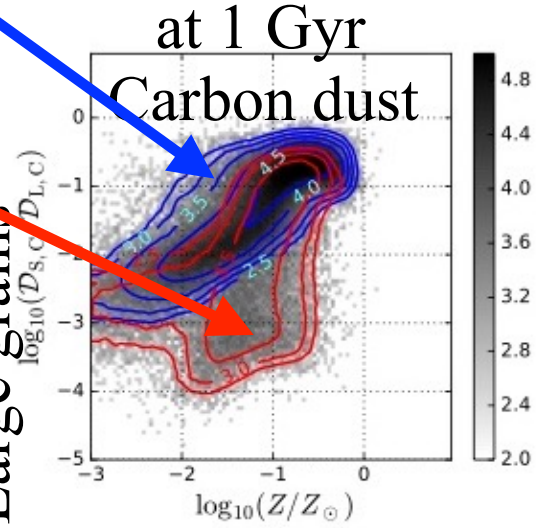
out of disk

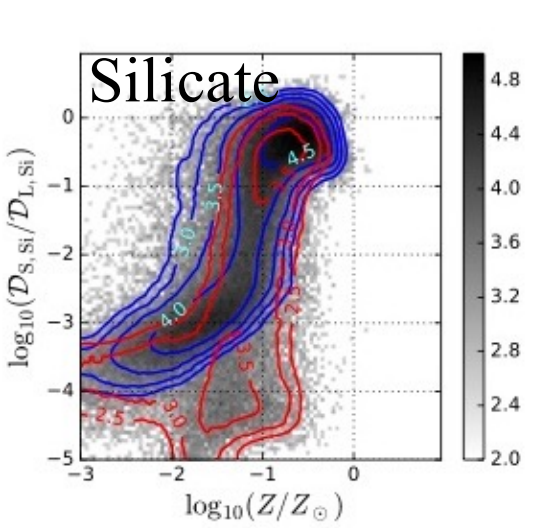
Hou, Hirashita, et al. (2017)

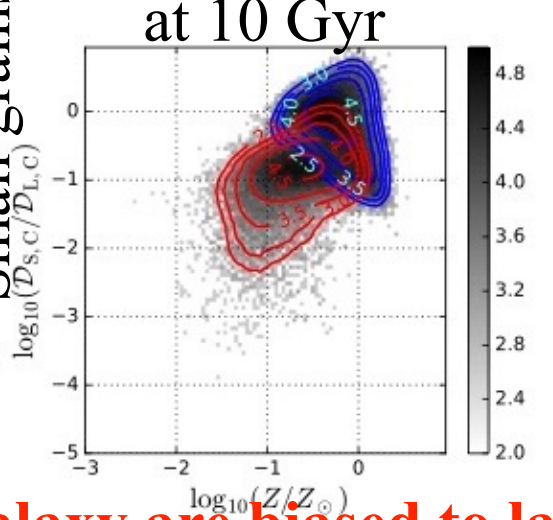


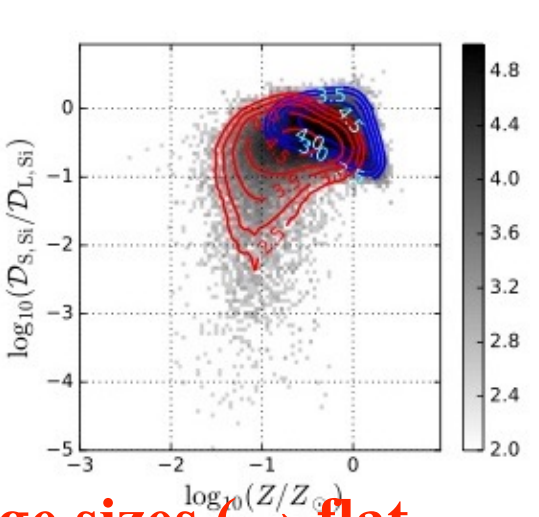




Small grains/Large grains



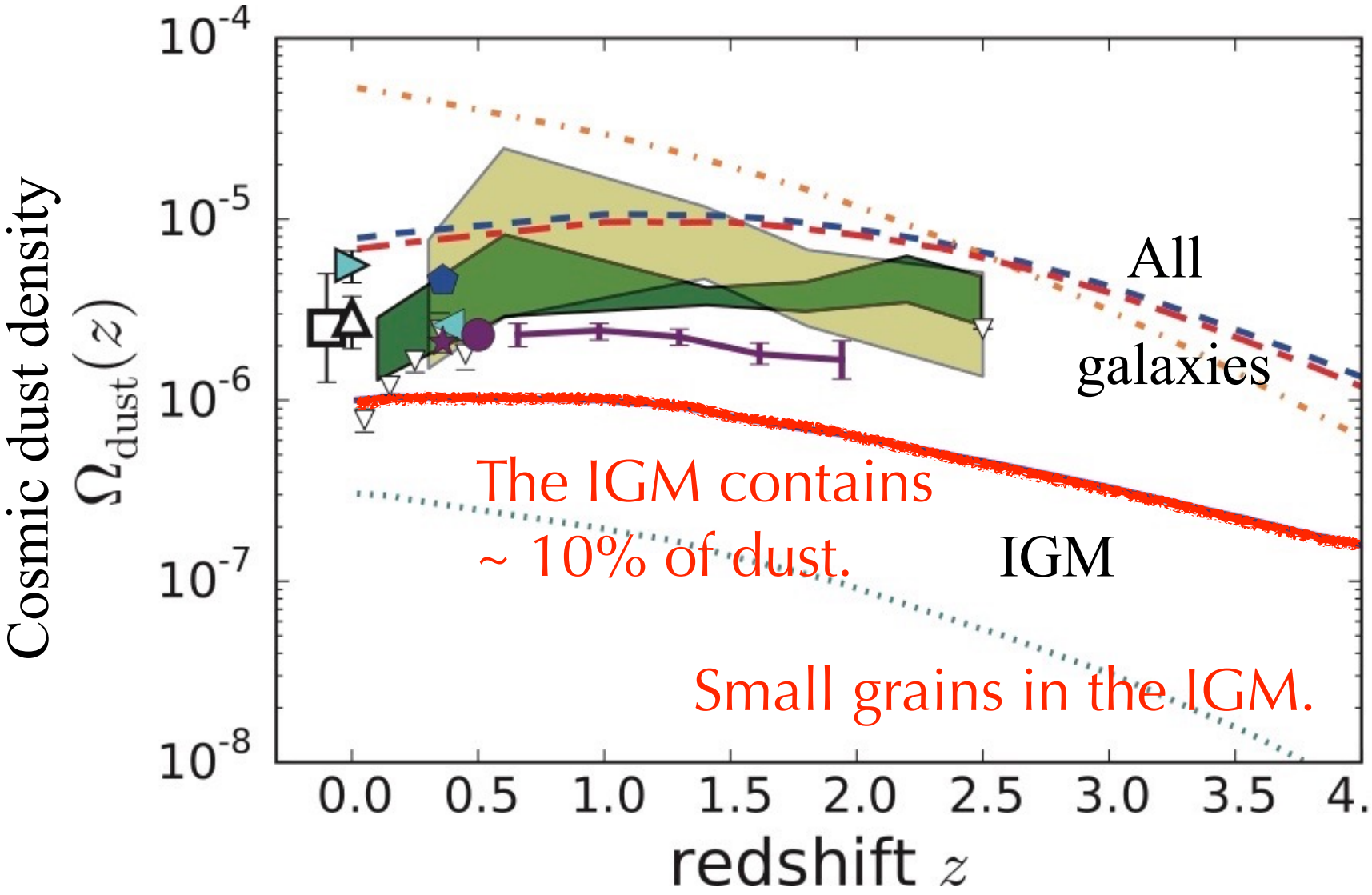

**The grains outside the galaxy are biased to large sizes (→ flat extinction curves).**

# Why Large Grains out of Galaxies?

(1) Stars produce large grains.
(2) Small grains are produced by interstellar processing (shattering + accretion).

Dust is transported out of the galaxy before being processed in the ISM.

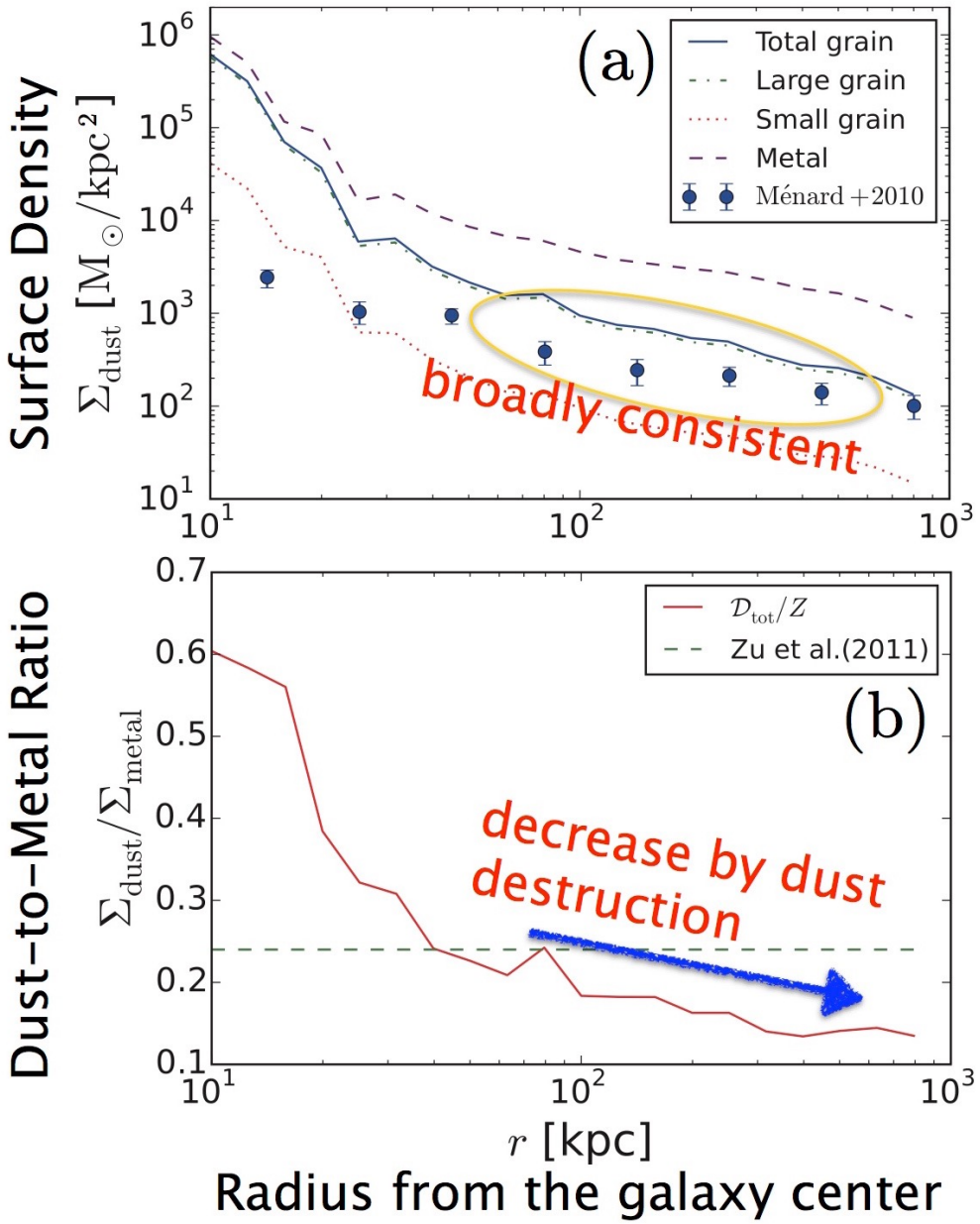
# Cosmological Simulation




Aoyama, Hirashita et al. (2018)

# Our Theoretical Prediction

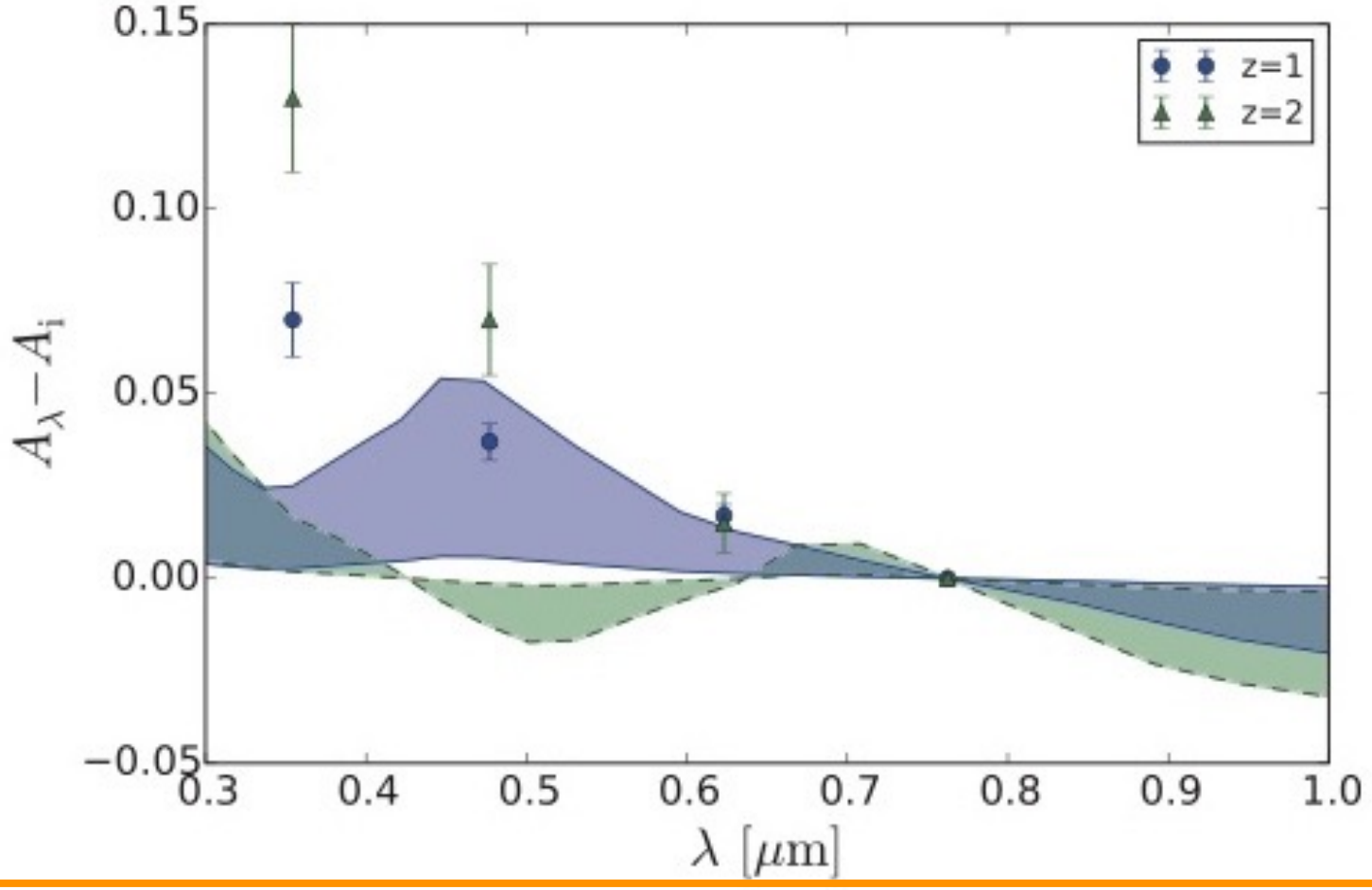
Aoyama et al. (2018)



# Lack of Small Grains in Simulation

Aoyama, Hirashita, et al. (2018)

$A_\lambda$: Magnitude of dust extinction

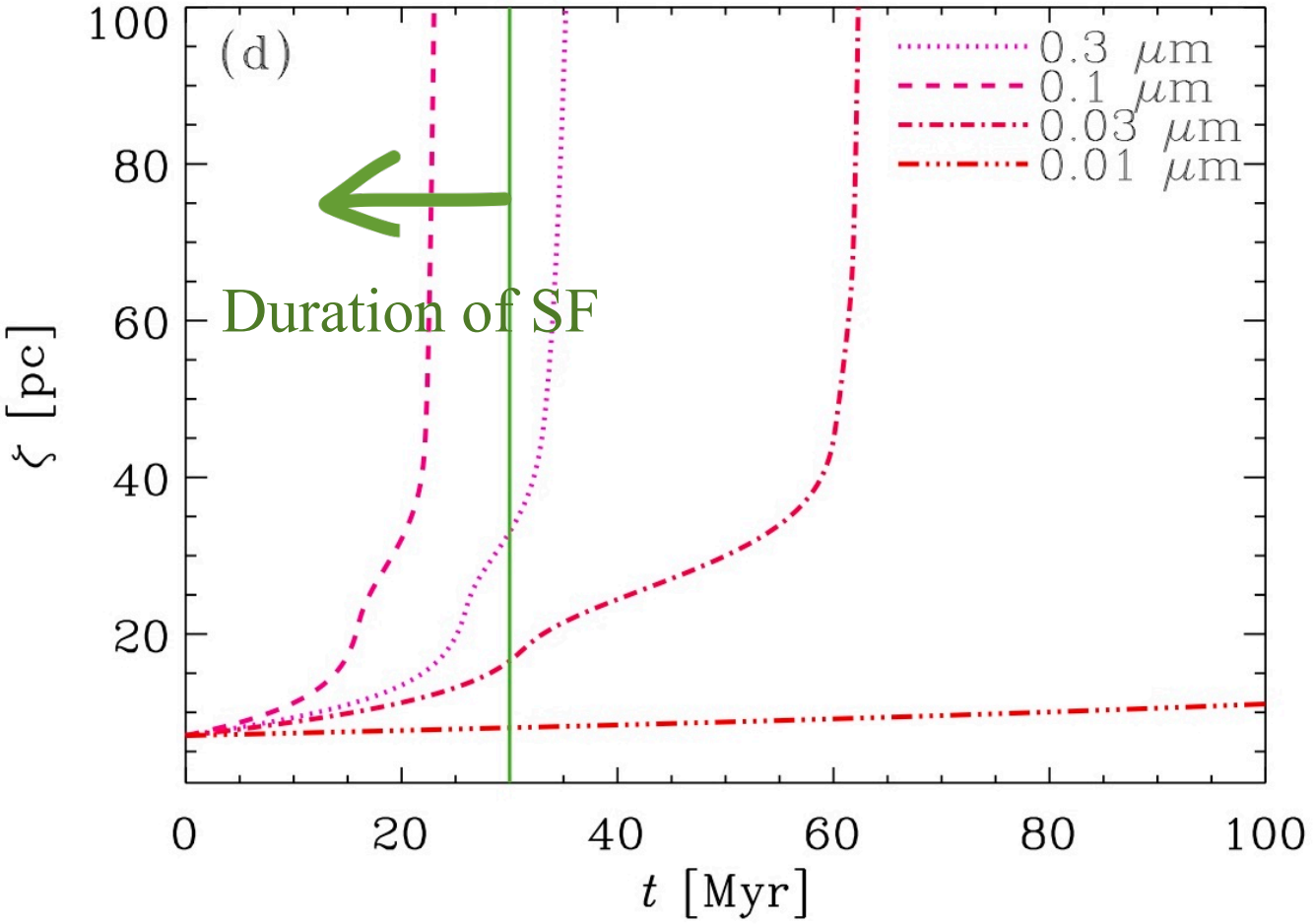



Simulation fails to explain the reddening in the CGM.

# Radiation Pressure

Hirashita & Inoue (2019)

Height from the galaxy disk




Optimum grain radius for escape: $a \sim 0.1$ μm

See also Ferrara et al. (1991), Bianchi & Ferrara (2005), etc.

**Lack of Small Grains**
**(<~ 0.03 μm)**
**→ What is the Origin of Reddening?**

# 3. Dust Processing in the CGM

Hirashita & Lan (2021)

(1) Shattering is a unique mechanism of small grain production (but is inefficient in the mean density of the CGM).

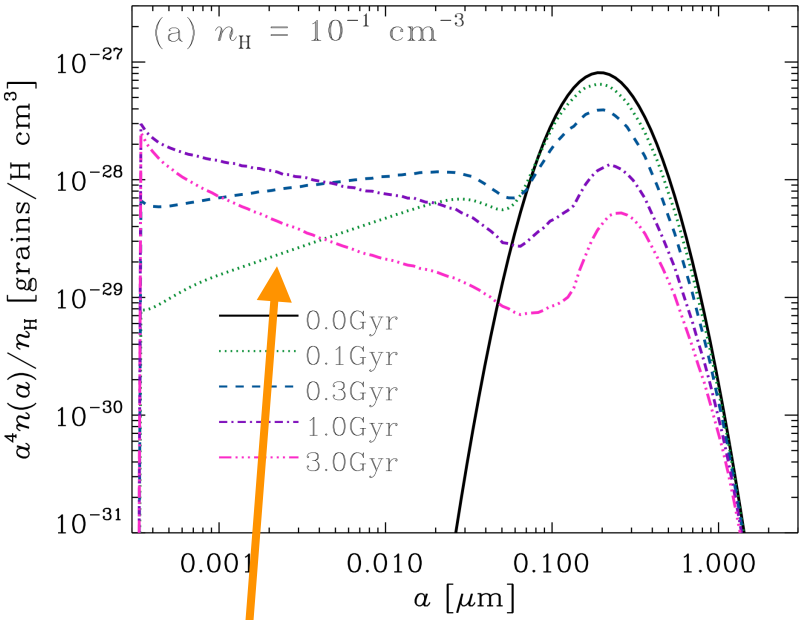
(2) Small clumps (~ 30 pc, ~ 0.3 $cm^{-3}$) exist from the observations of Mg II absorbers (Lan & Fukugita 2017).

Consider **shattering** occurring in the cool clumps.
Assumptions: Grain motion is driven by the turbulence with the maximum size and the density comparable to those in small clumps.

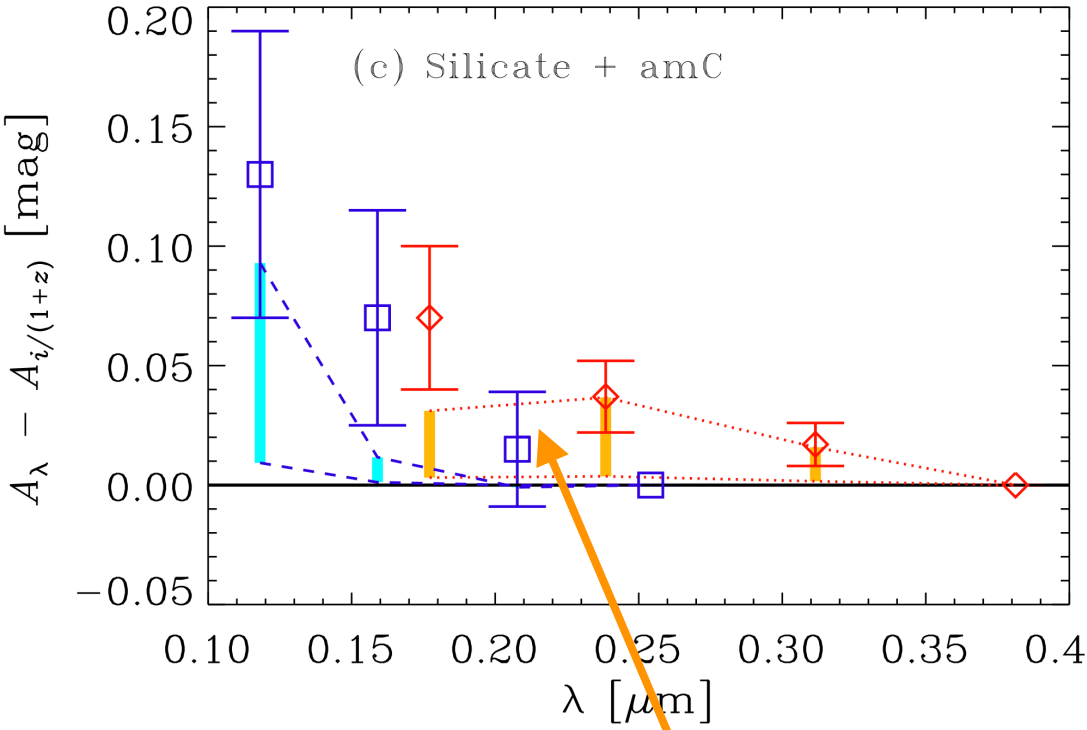
# Shattering in the CGM

Hirashita & Lan (2021)

Grain size distribution




Reddening curves




Small grain production in ~ 0.3 Gyr
(<~ lifetime of clumps)

Significant reddening

# 4. Summary

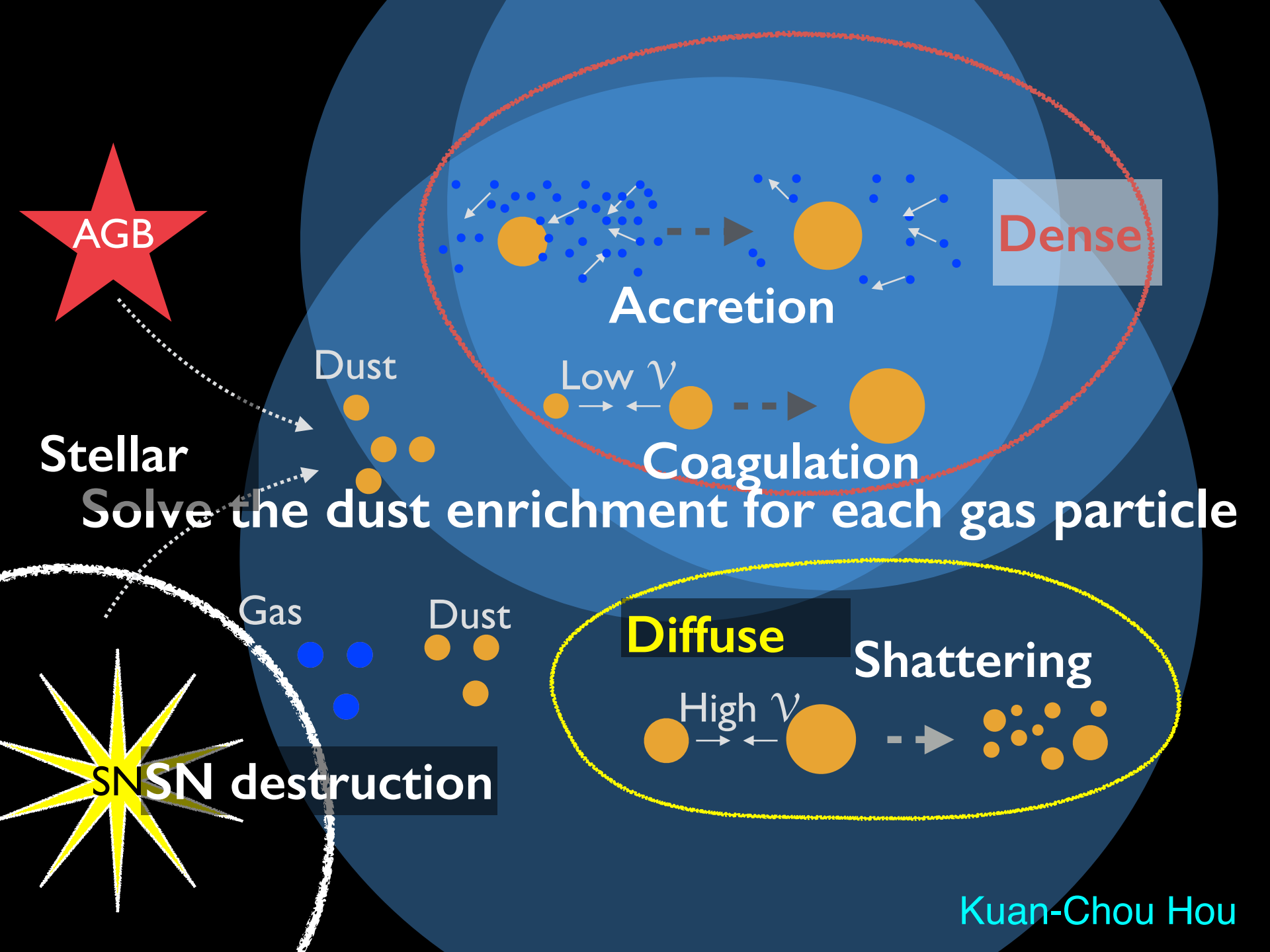
(1) **Stellar feedback (cosmological simulations)**

a. The IGM (including CGM) contains ~ 10% of dust.
b. The radial profile of dust is consistent with our simulation up to ~ 1 Mpc from the galaxy center.
c. Stellar feedback scenarios produces too few small grains in the IGM.

(2) **Dust processing in the CGM**

a. Shattering is efficient enough in cold clumps.
b. Reddening occurs in a few $\times 10^8$ yr (comparable to the lifetimes of the clumps).

# Thank you.


AGB
Dense
Accretion
Dust
Low $\mathcal{V}$
Coagulation
Stellar
Solve the dust enrichment for each gas particle
Gas
Dust
Diffuse
Shattering
High $\mathcal{V}$
SNSN destruction
Kuan-Chou Hou