

# *Dust Evolution In Galaxy Simulations*

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# Topics

1. Current Problems in Galaxy Dust
2. Implementing Dust Evolution in SPH
3. Results
4. Future Prospects
5. Summary

# **1. Current Problems In Galaxy Dust**

# Dust in Galaxies

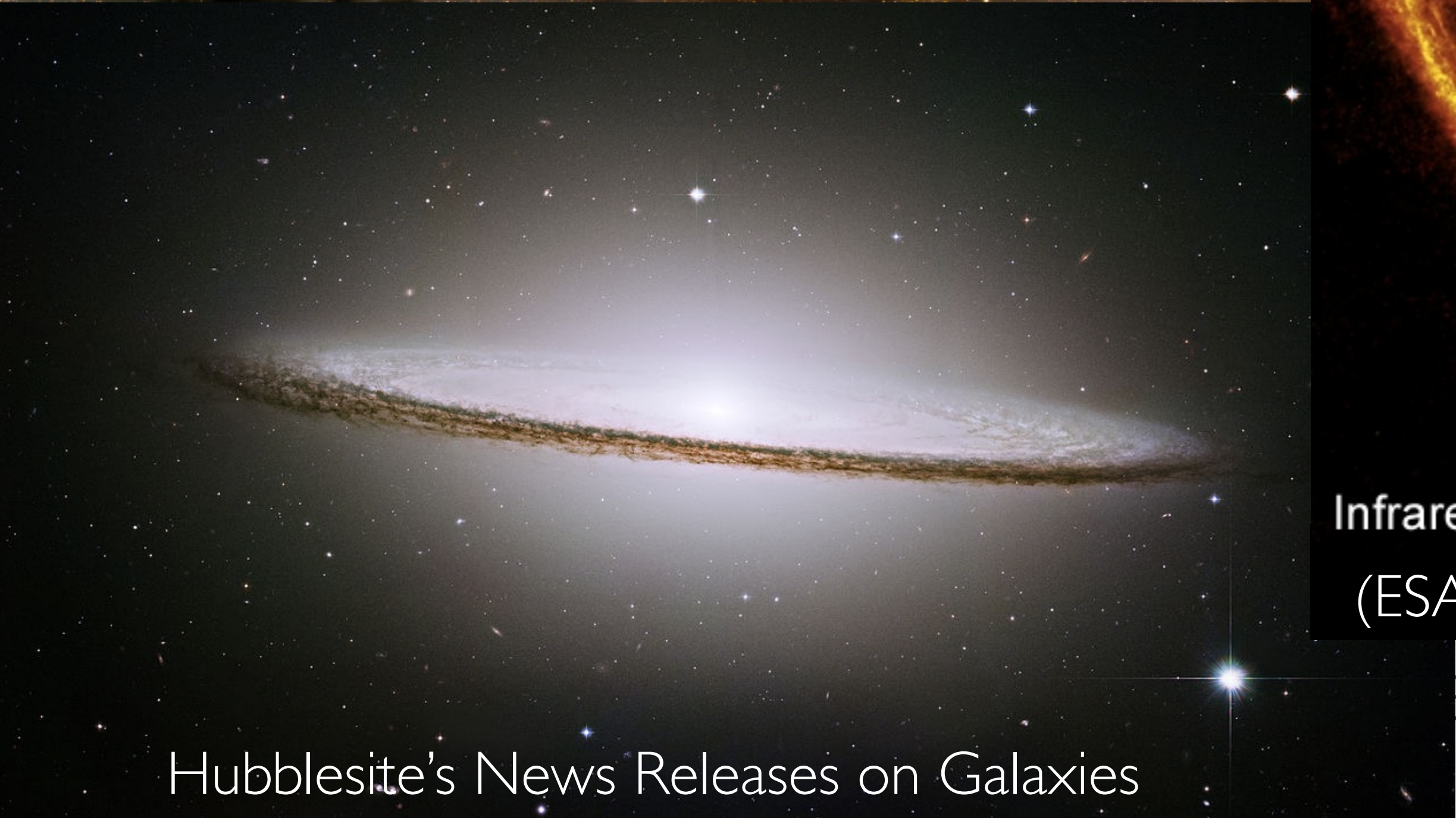
- Small solid particles ( $0.001 \sim 1 \mu\text{m}$ )
- An important aspect for understanding the galaxies evolution
  - ➔ Obscuration of the starlight (optical) & Re-emit IR
    - ★ Shaping the spectral energy distributions of galaxies.
    - ★ Correction for dust extinction is important in estimating star formation rate.
  - ➔ Formation of  $\text{H}_2$  on dust surface



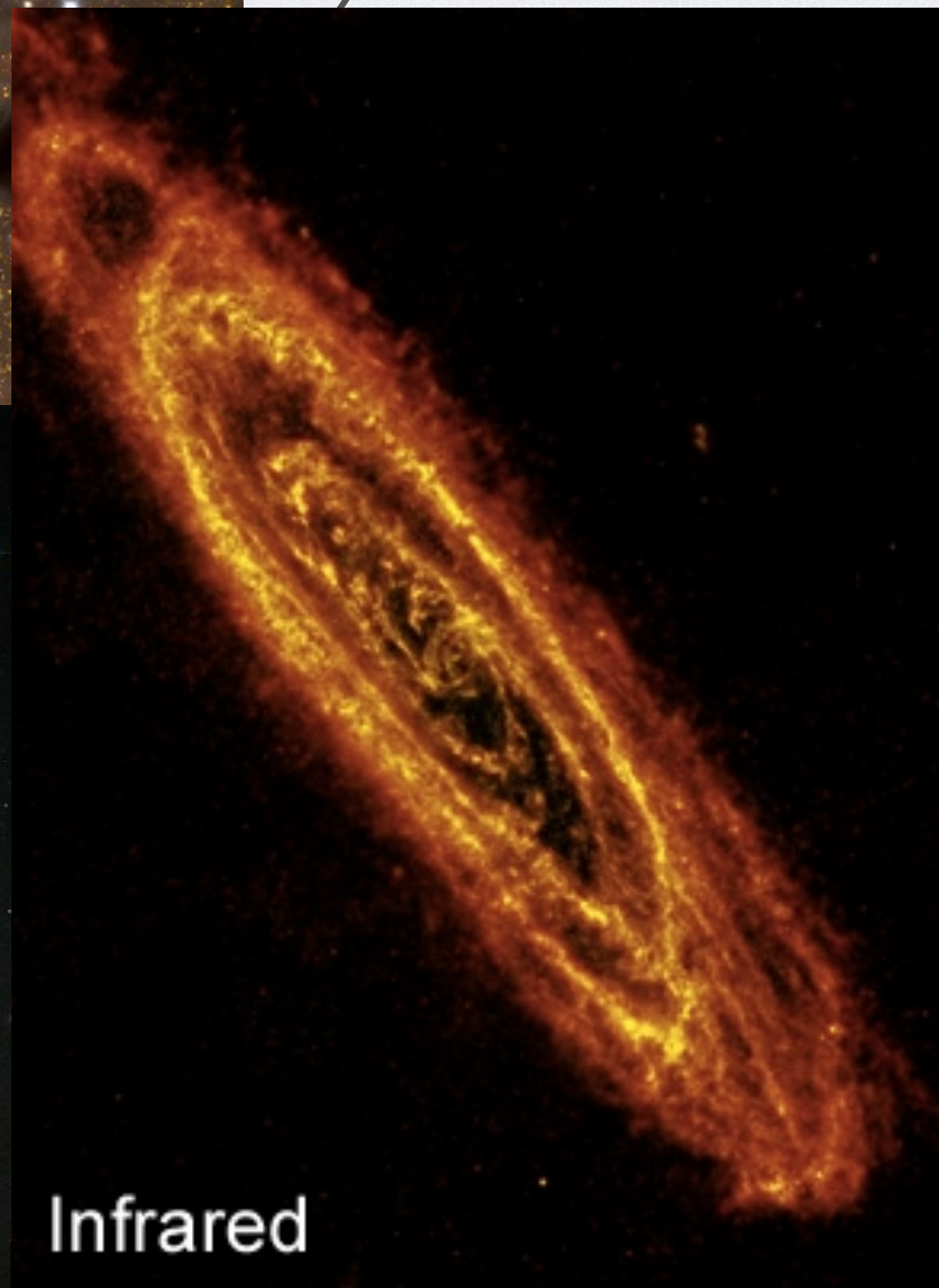
Adam Block/Mount Lemmon SkyCenter/University of Arizona

# Galaxies

m)



Hubblesite's News Releases on Galaxies



Infrared



Visible & Infrared



Visible

(ESA/HERSCHEL/PACS & SPIRE CONSORTIUM, O. KRAUSE, HSC, H.

ace

# Dust in Galaxies

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# Current Problems

- Lack of understandings on **spatial distribution of dust & grain size distribution**

- ★ Grain size distribution changes optical properties of dust

- ➔ Extinction curves & grain-surface chemical reaction rates

- ★ Spatial distribution

- ➔ Correction for dust extinction & FIR SED

# Goal

- Implement all relevant processes driving dust evolution in a galaxy evolution simulation
- Understand the spatial distribution of dust in a galaxy using simulations
- Trace grain size evolution as well

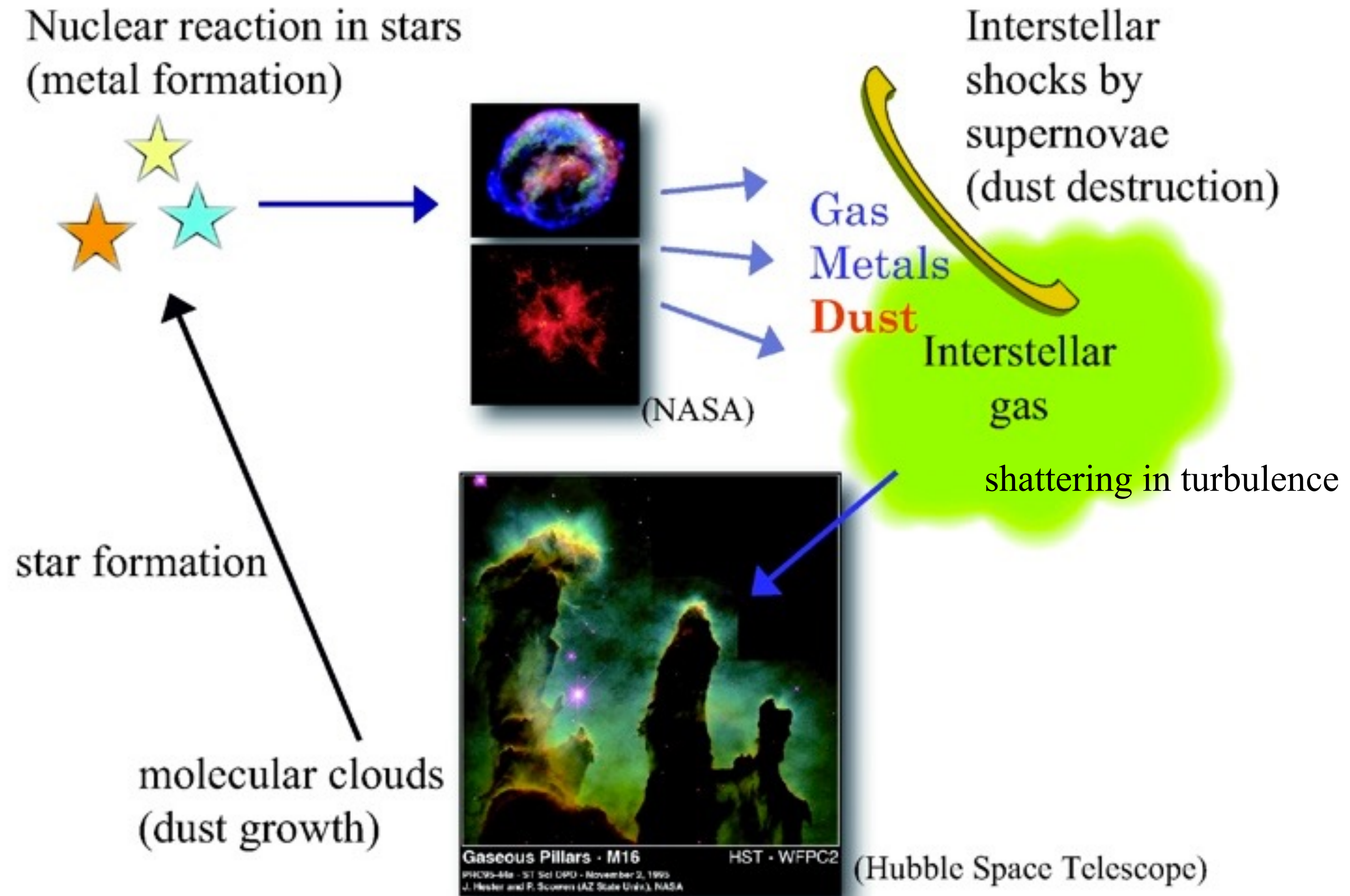


# Technical Problem

- **Full grain size distribution** calculation is **time consuming** (Asano et al. 2013: one-zone calculations)
- Two-size approximation (Hirashita 2015):
  - ➔ Simply divide the grains into **Small** and **Large** populations around  $\sim 0.03$  micron
  - ➔ The same evolutionary behavior of grain sizes and extinction curves as Asano et al. (2013)
  - ➔ **Computationally light**: suitable for already heavy galaxy simulations

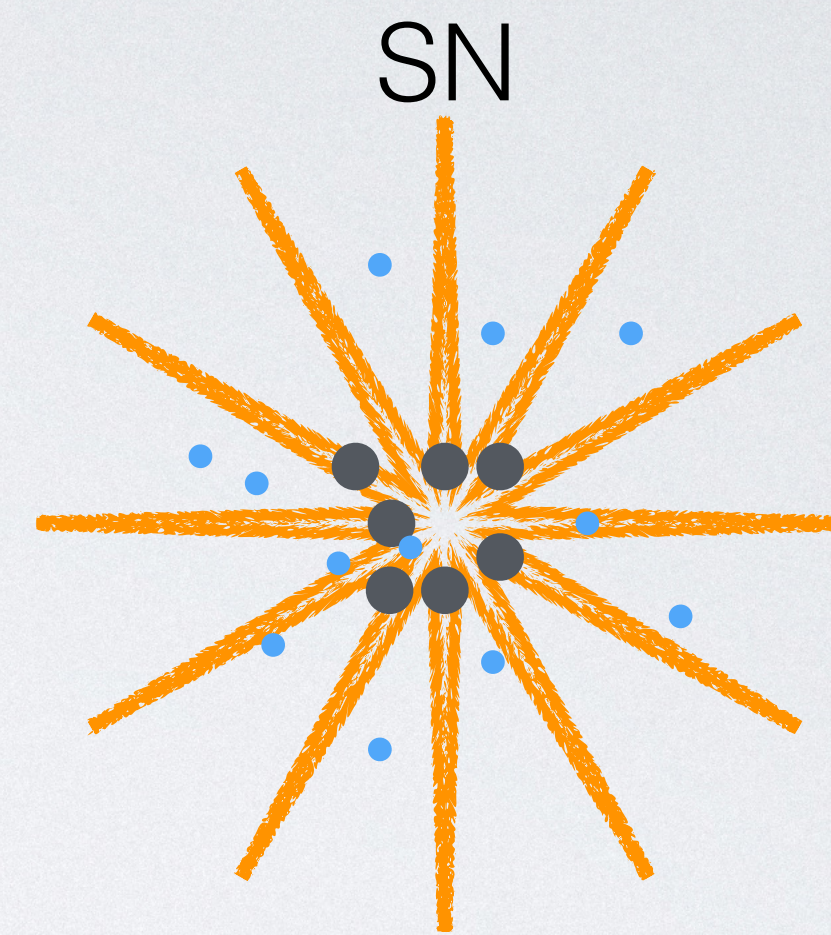
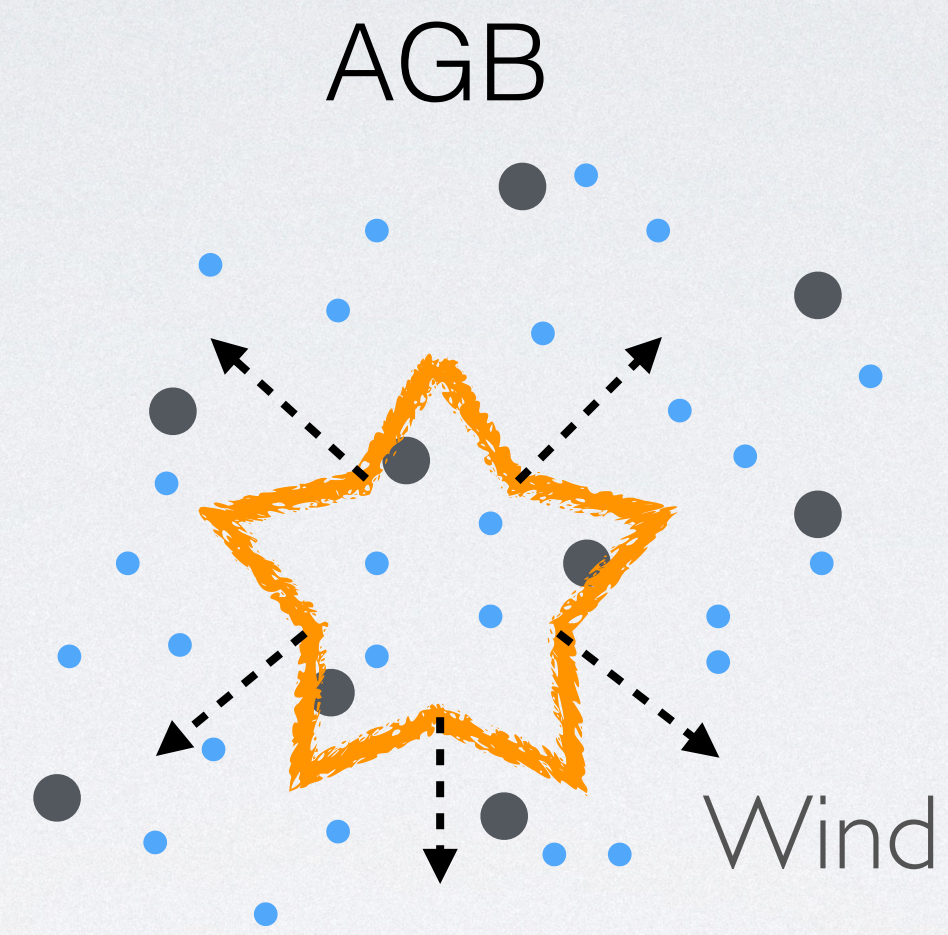
## **2. Implementing Dust Evolution In Sph**

# Lifecycle Of Dust In A Galaxy

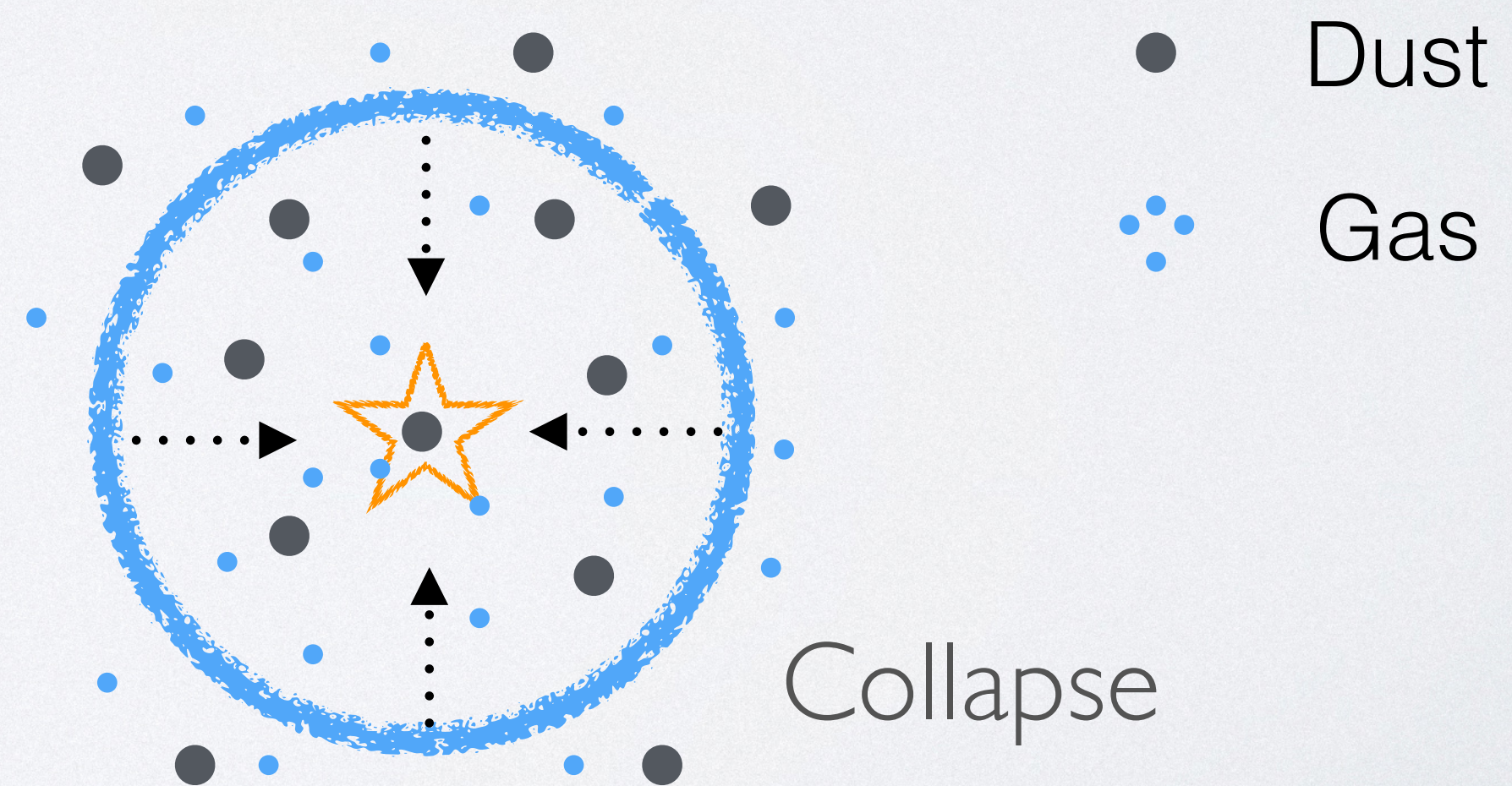


# Processes For Dust Evolution

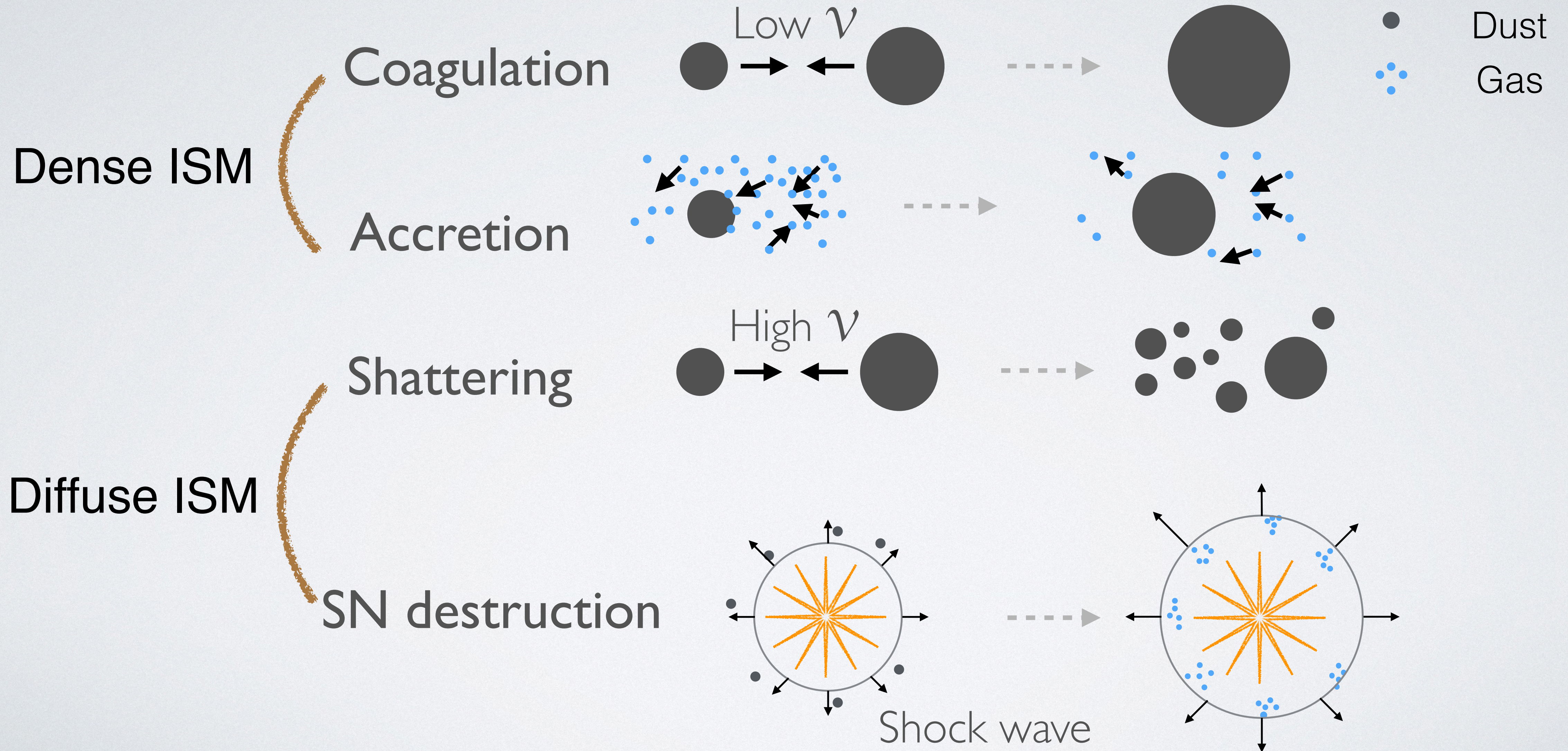
Dust condensation in stellar ejecta



Astration



# Processes For Dust Evolution

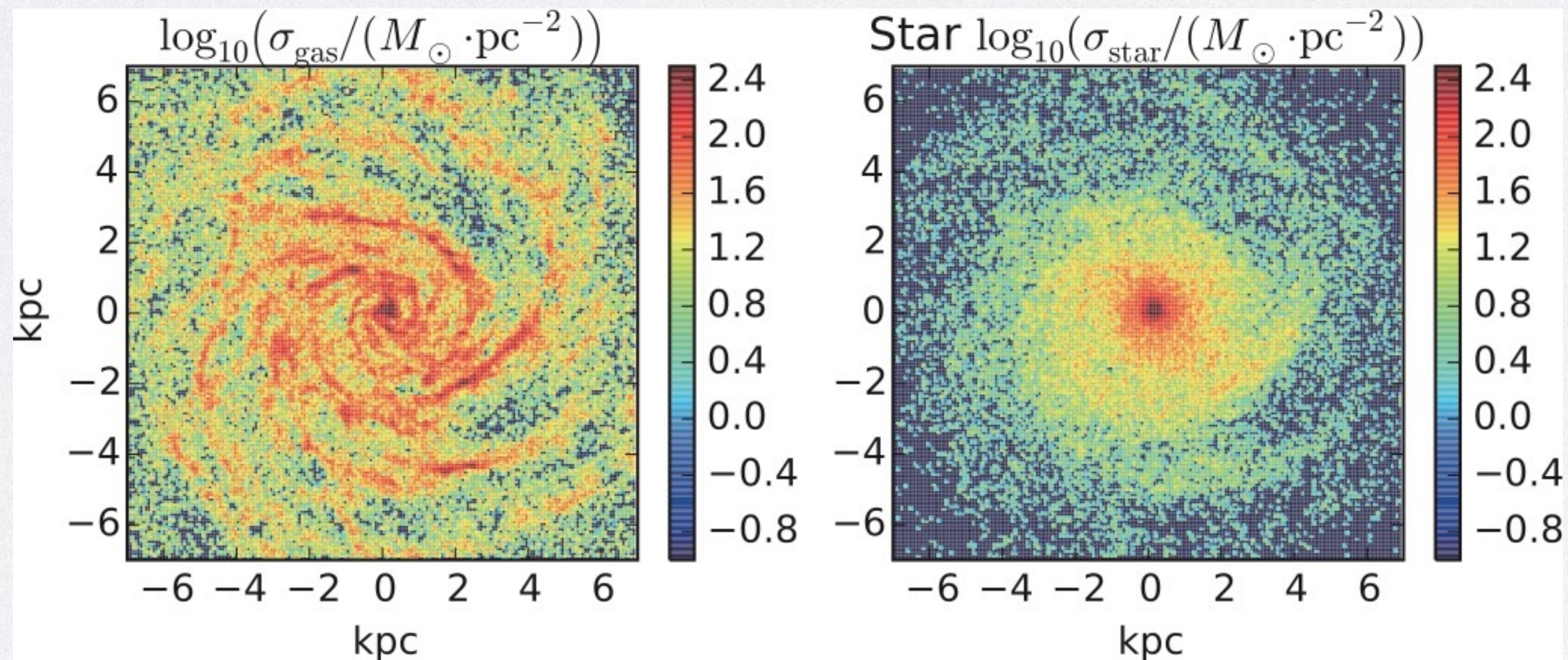


# Simulation

- **SPH** simulation (smoothed particle hydrodynamic simulation) using **Gadget 3** (Springel 2005)
- **Isolated spiral galaxy** for the first step

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Aoyama et al. (2016, in preparation)

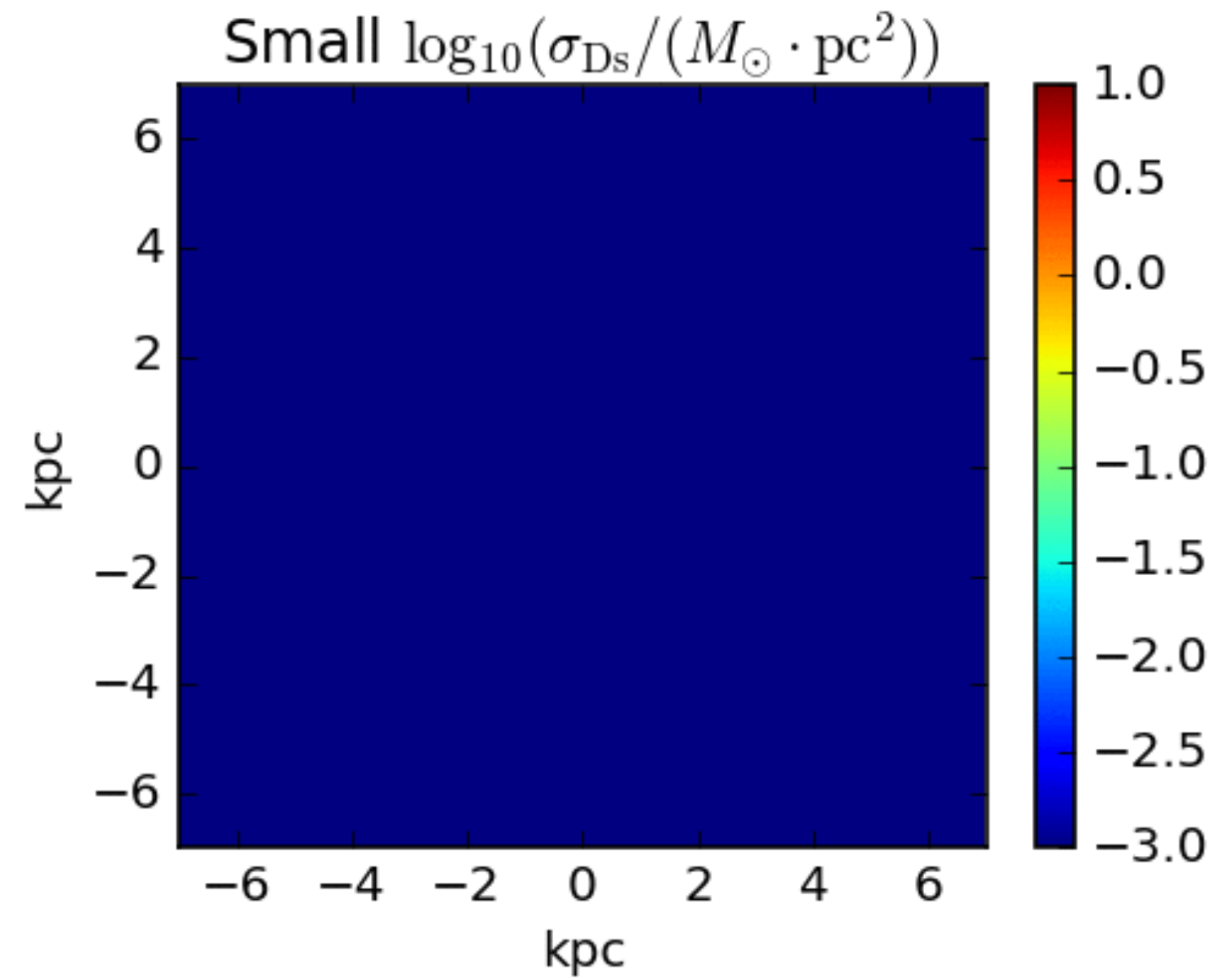
# Dust Model + Simulation

- **Shattering** and **Coagulation** time-scales are based on the **Collision time-scale** between dust grains
- **Accretion** time-scale is based on the **Collision time-scale** of a grain with gas-phase metals
  - \* Density & Temperature dependence
- **Shattering** occurs in the **diffused medium**
- **Coagulation & accretion** occurs in the **dense medium**
  - \* Resolution is not enough ➡ **sub-grid model**
- **SN destruction** is estimated by **swept mass** of SN (efficiency is 0.4)
  - \* Resolution is not enough ➡ sub-grid treatment based on Sedov-Taylor argument

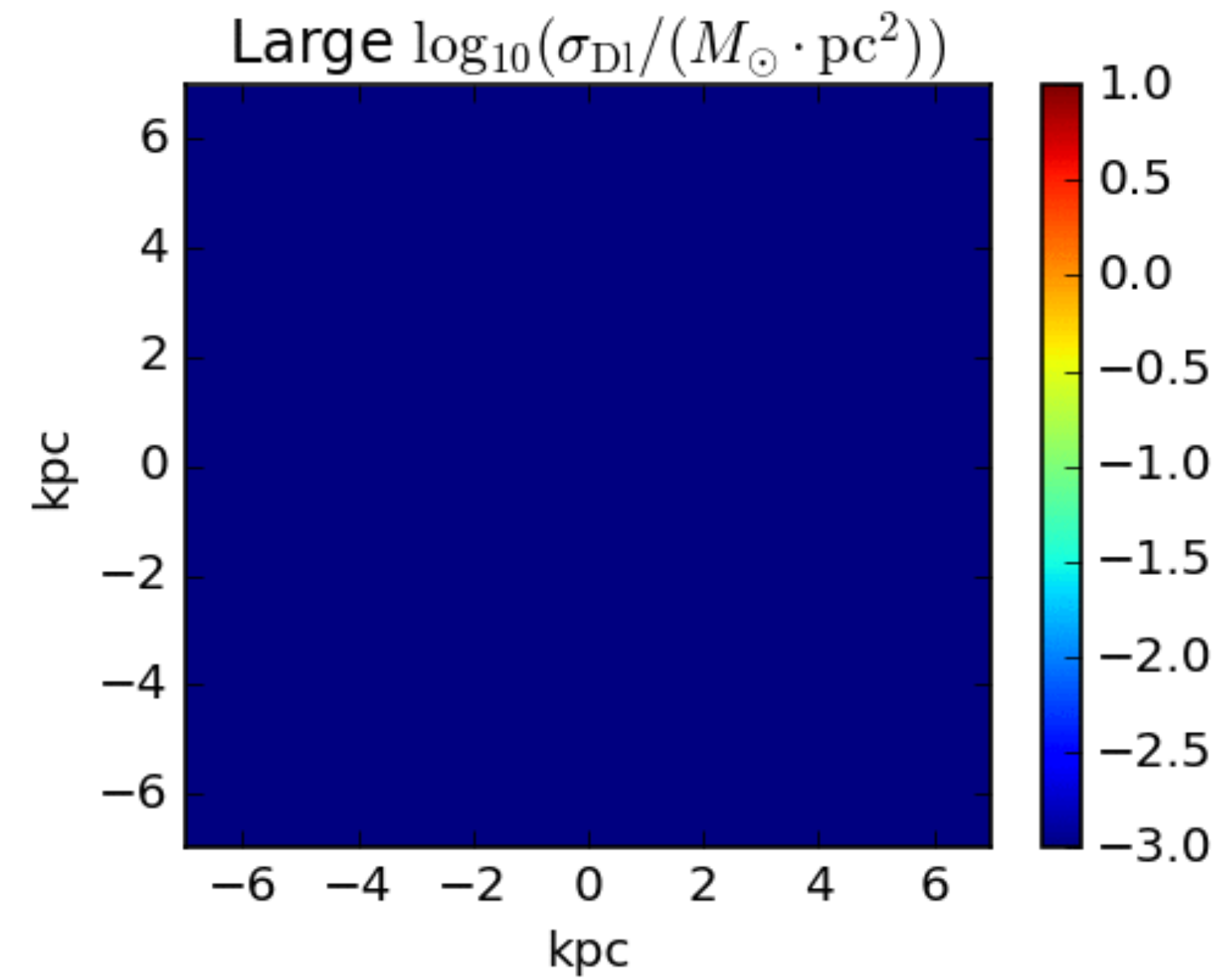


# 3. Results

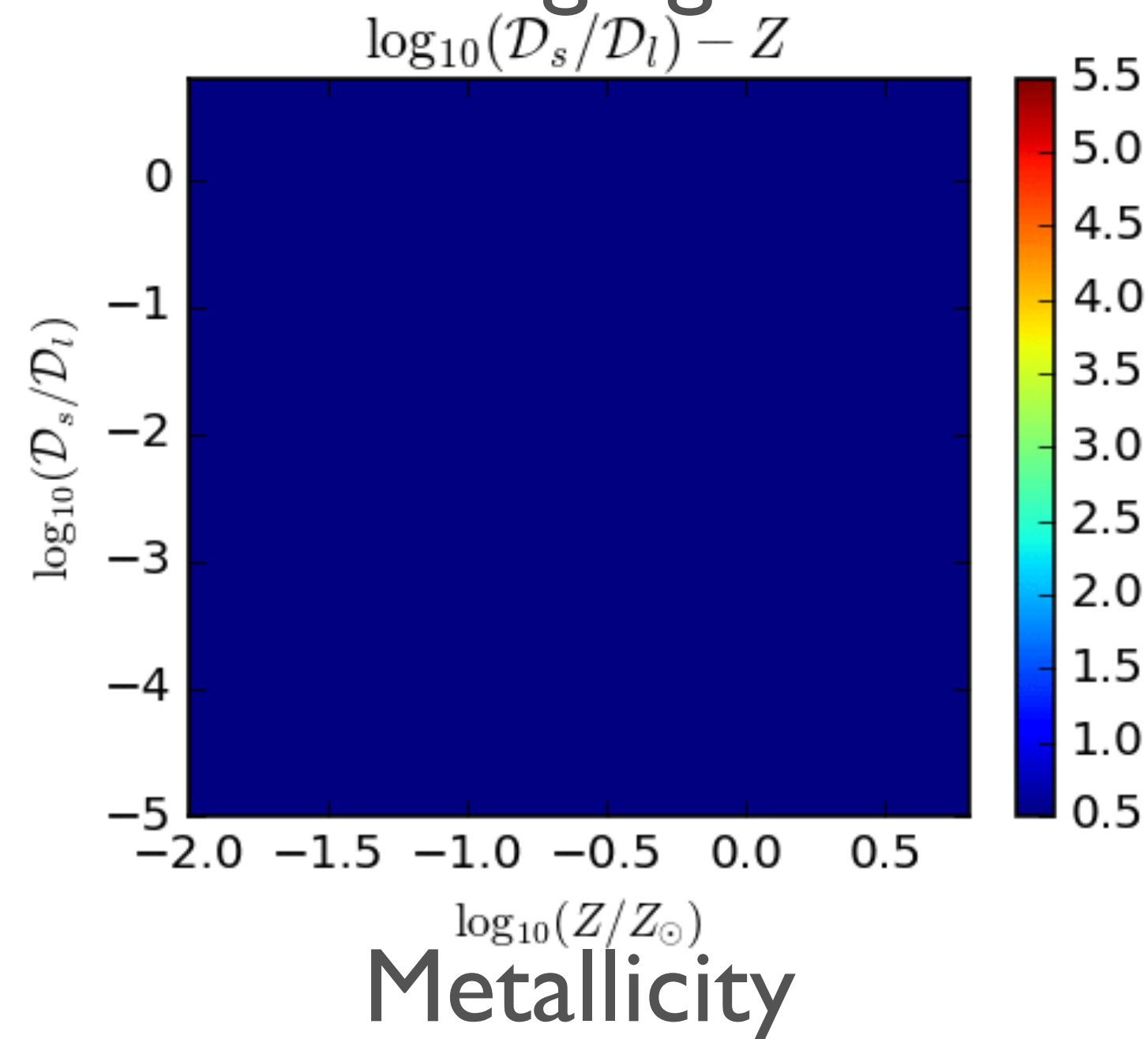
## Small grain



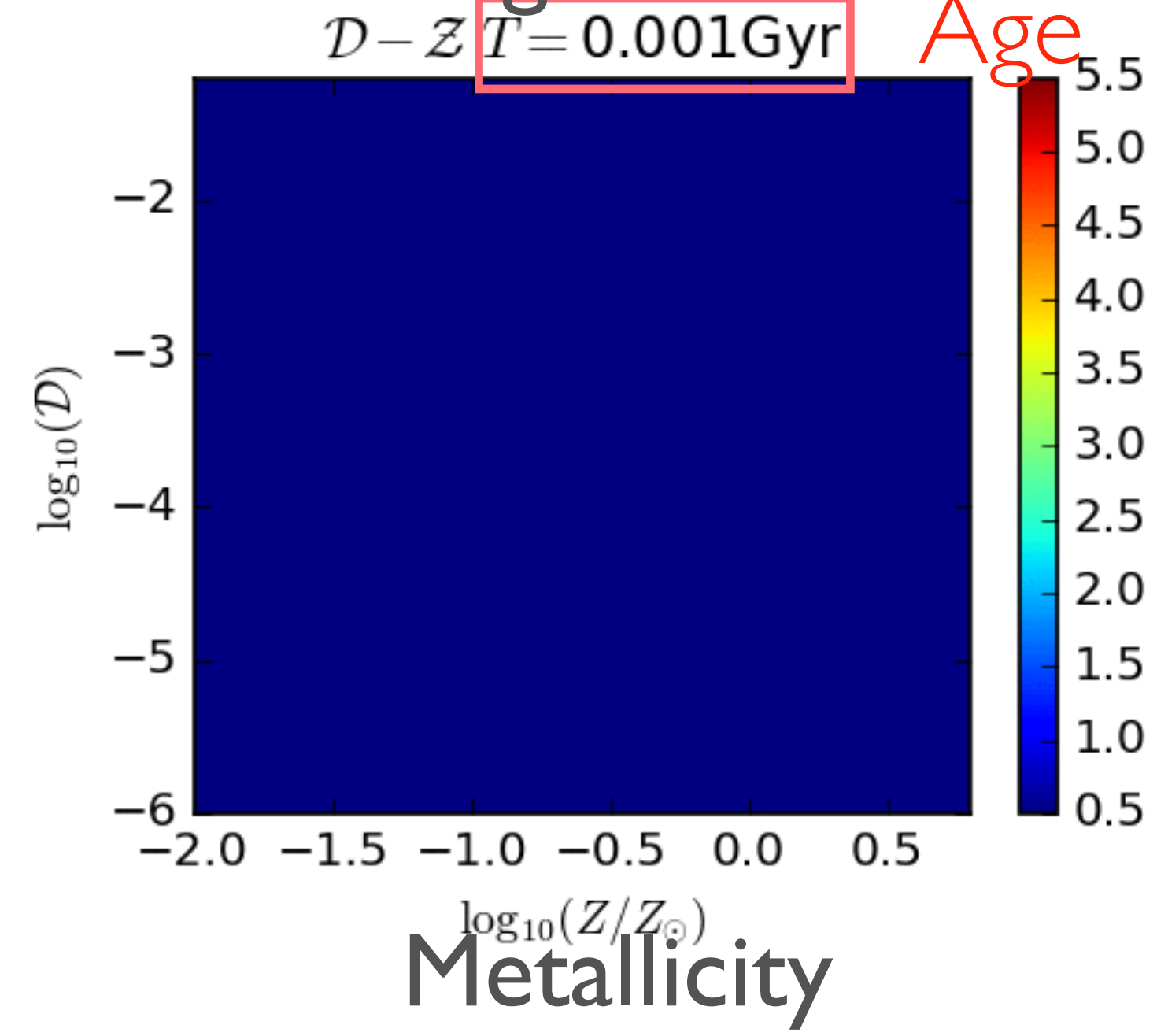
## Large grain



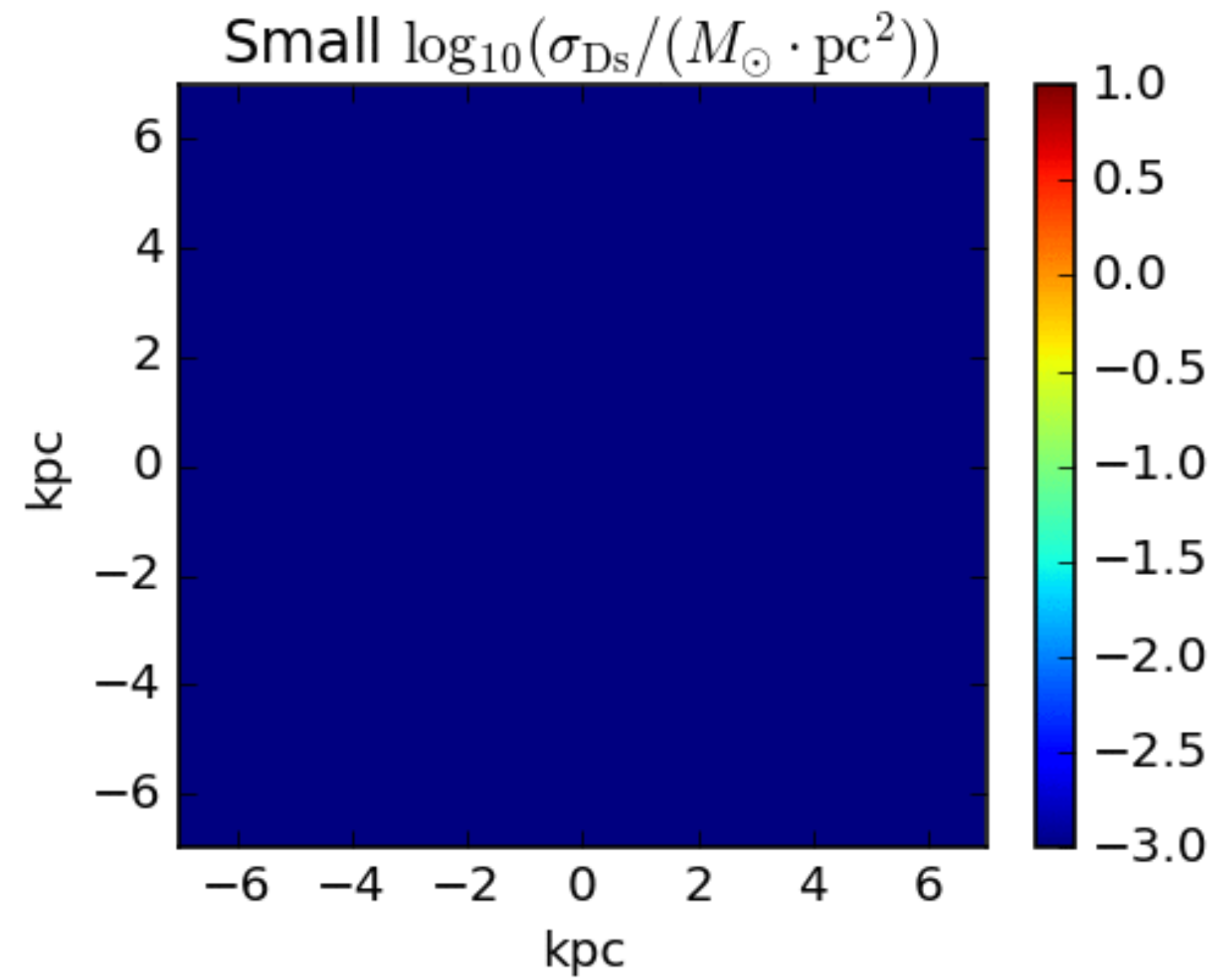
## Small-to-large grain ratio



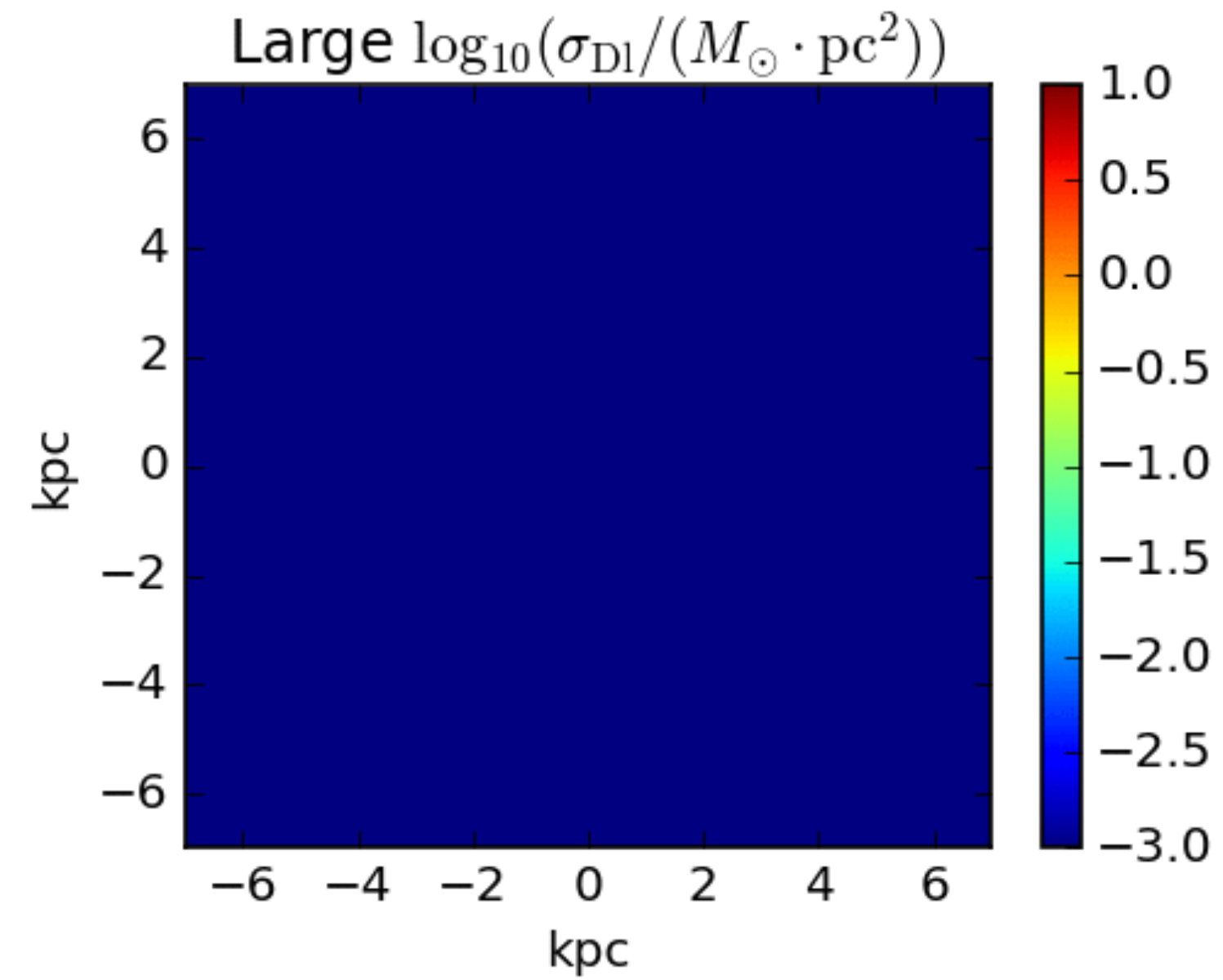
## Dust-to-gas mass ratio



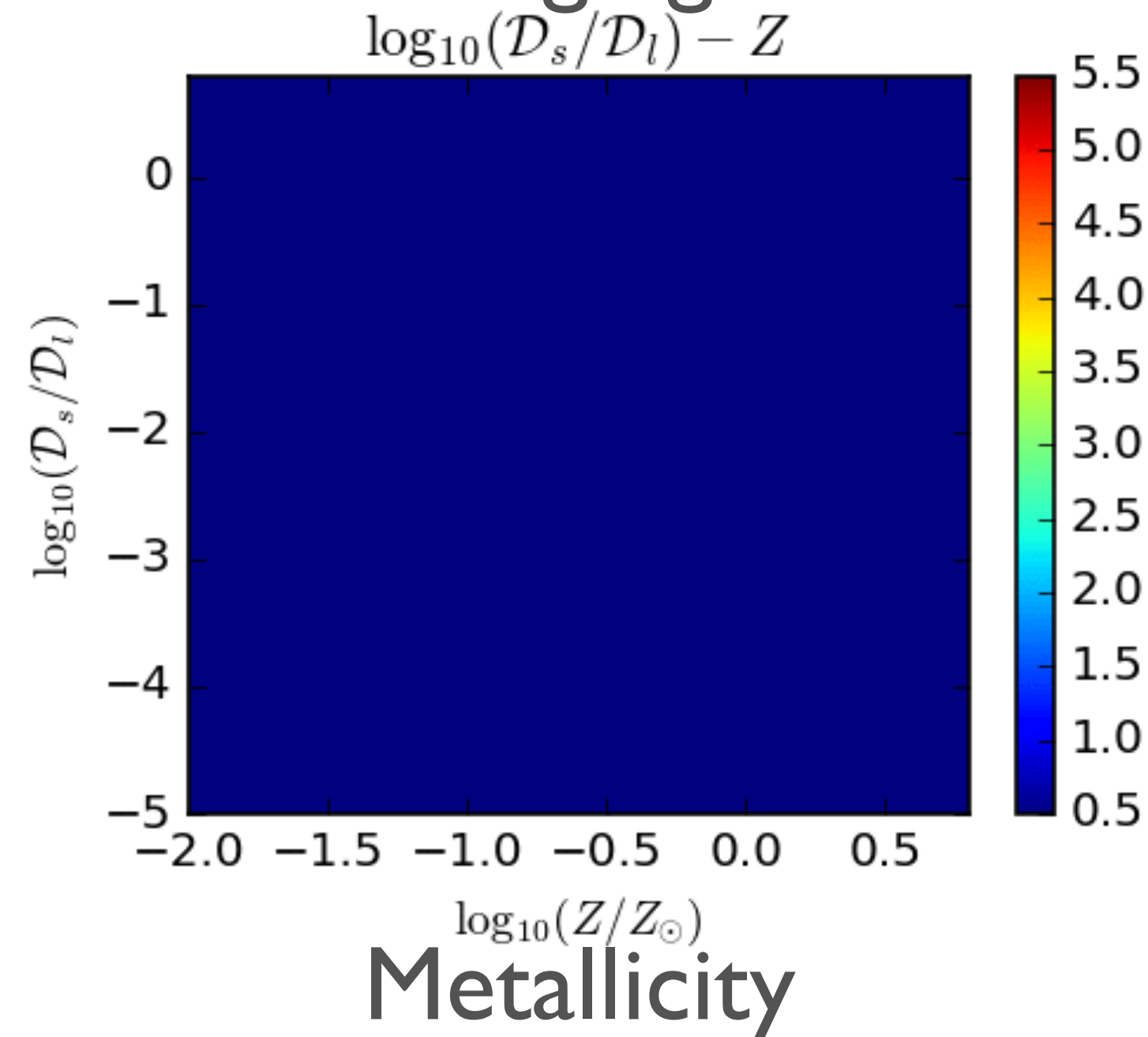
## Small grain



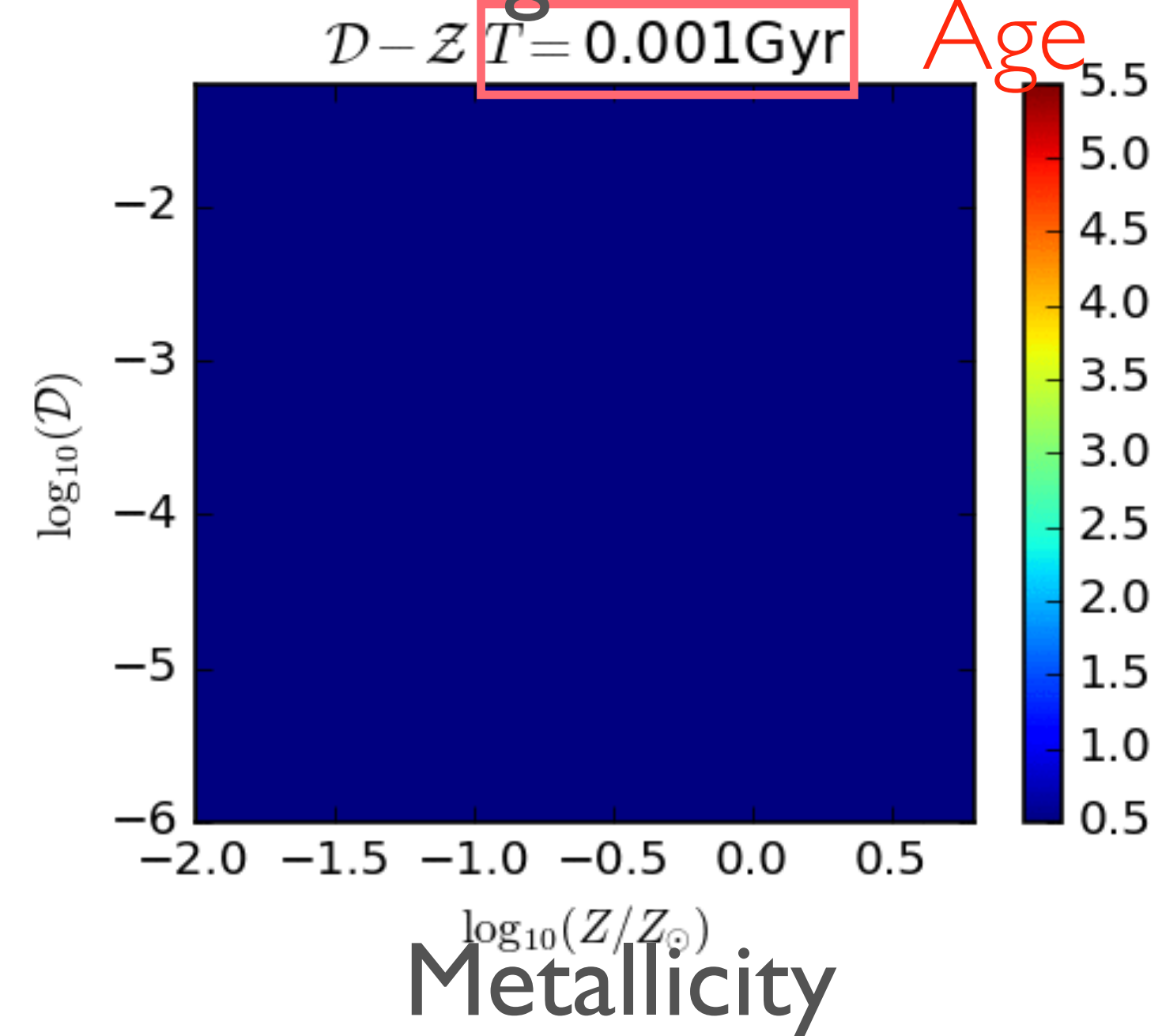
## Large grain



## Small-to-large grain ratio

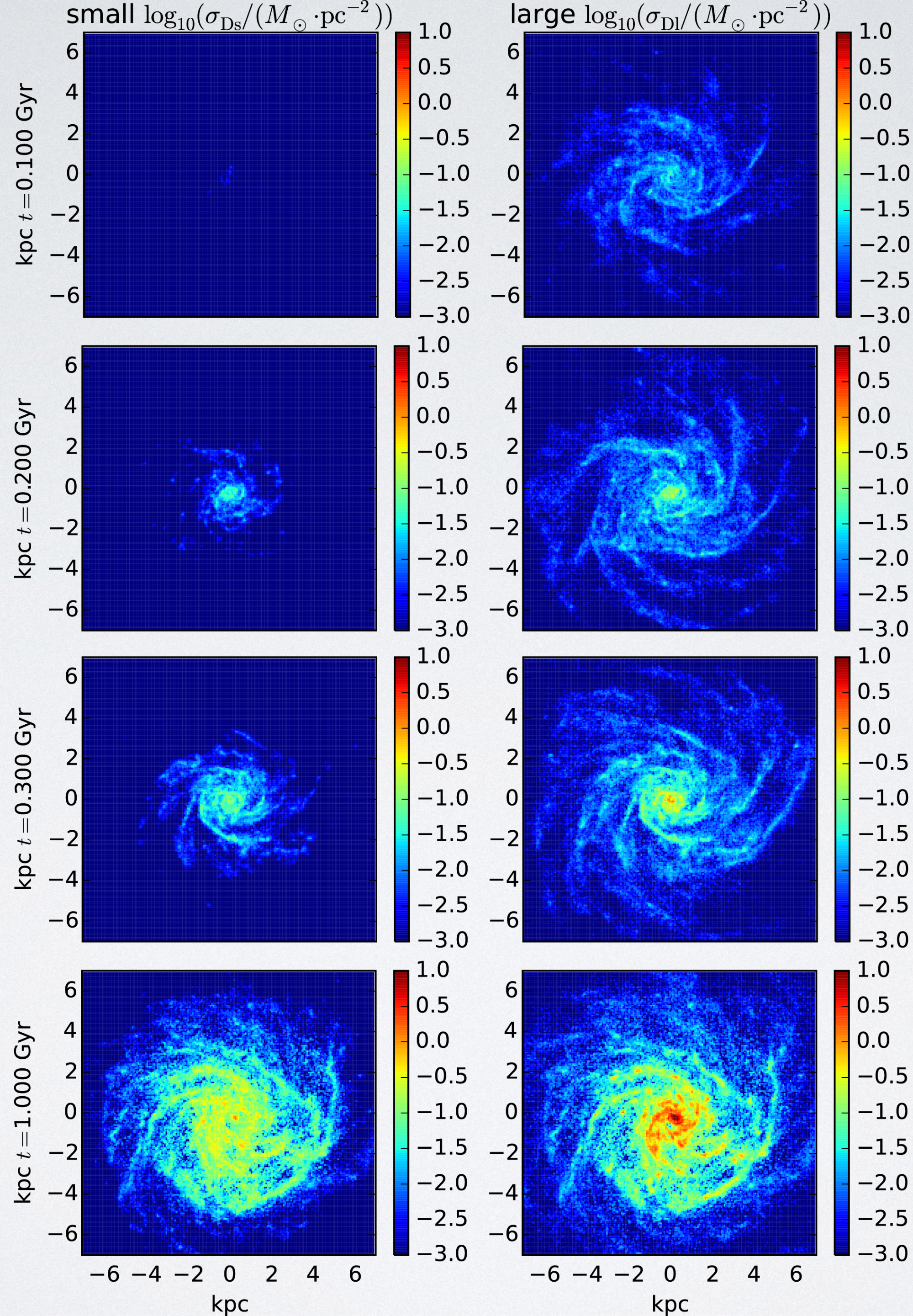


## Dust-to-gas mass ratio



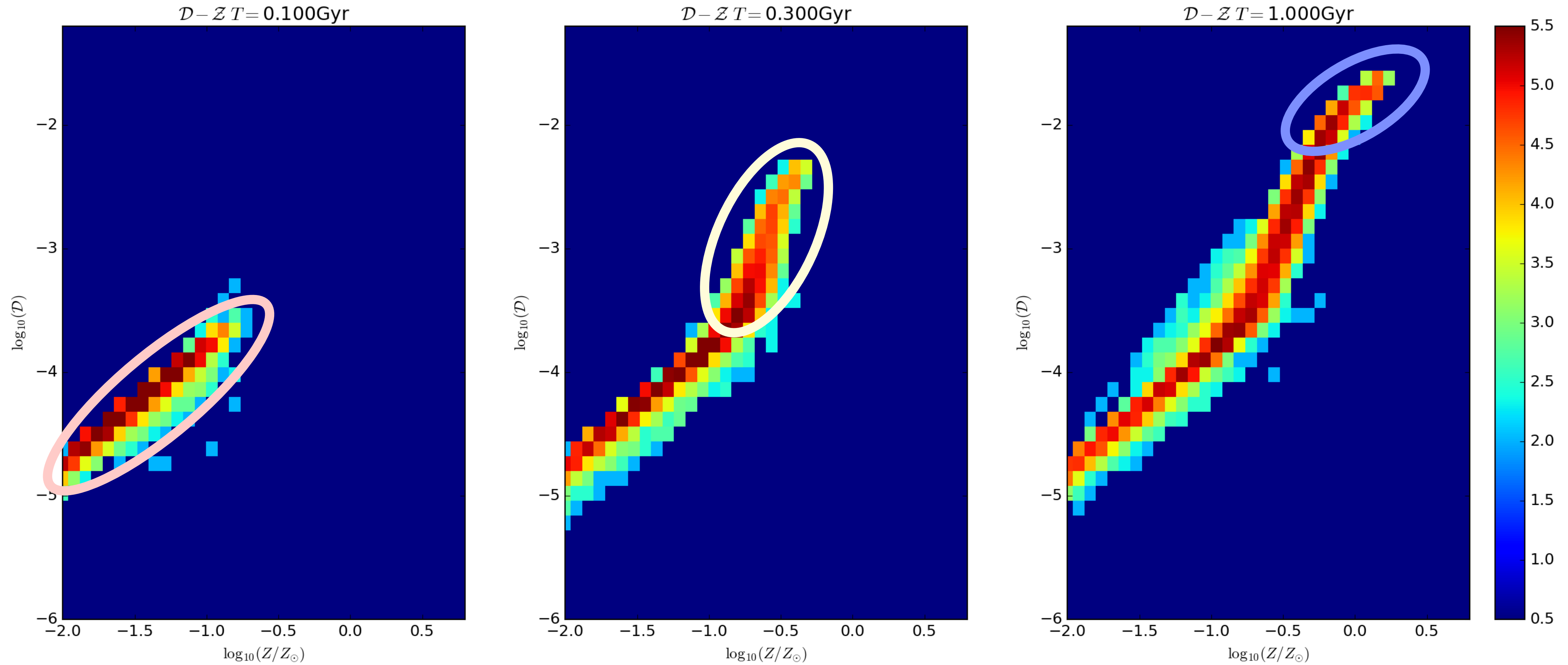
# Dust abundance

Small grain



Large grain

# Dust-to-gas mass ratio

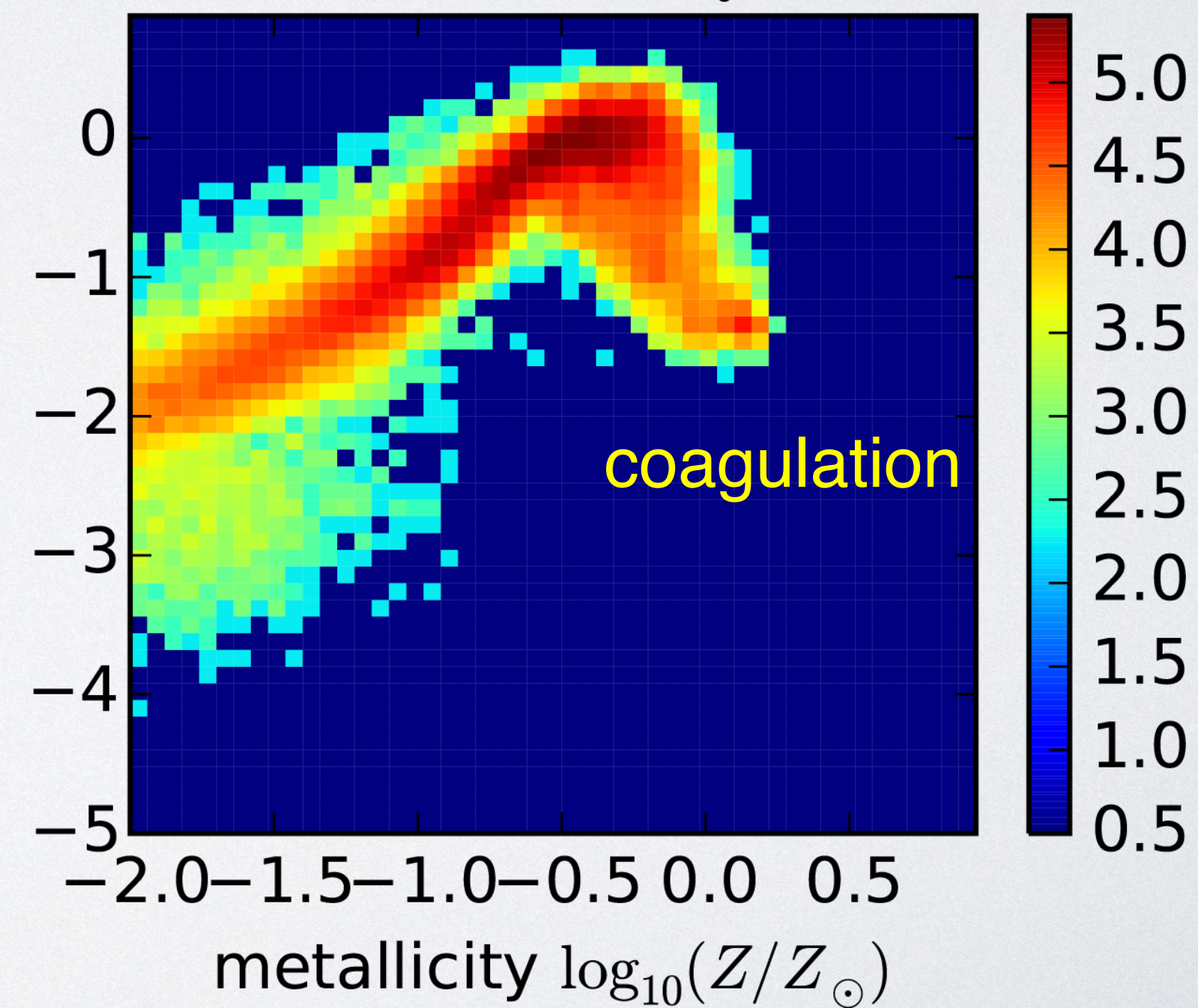
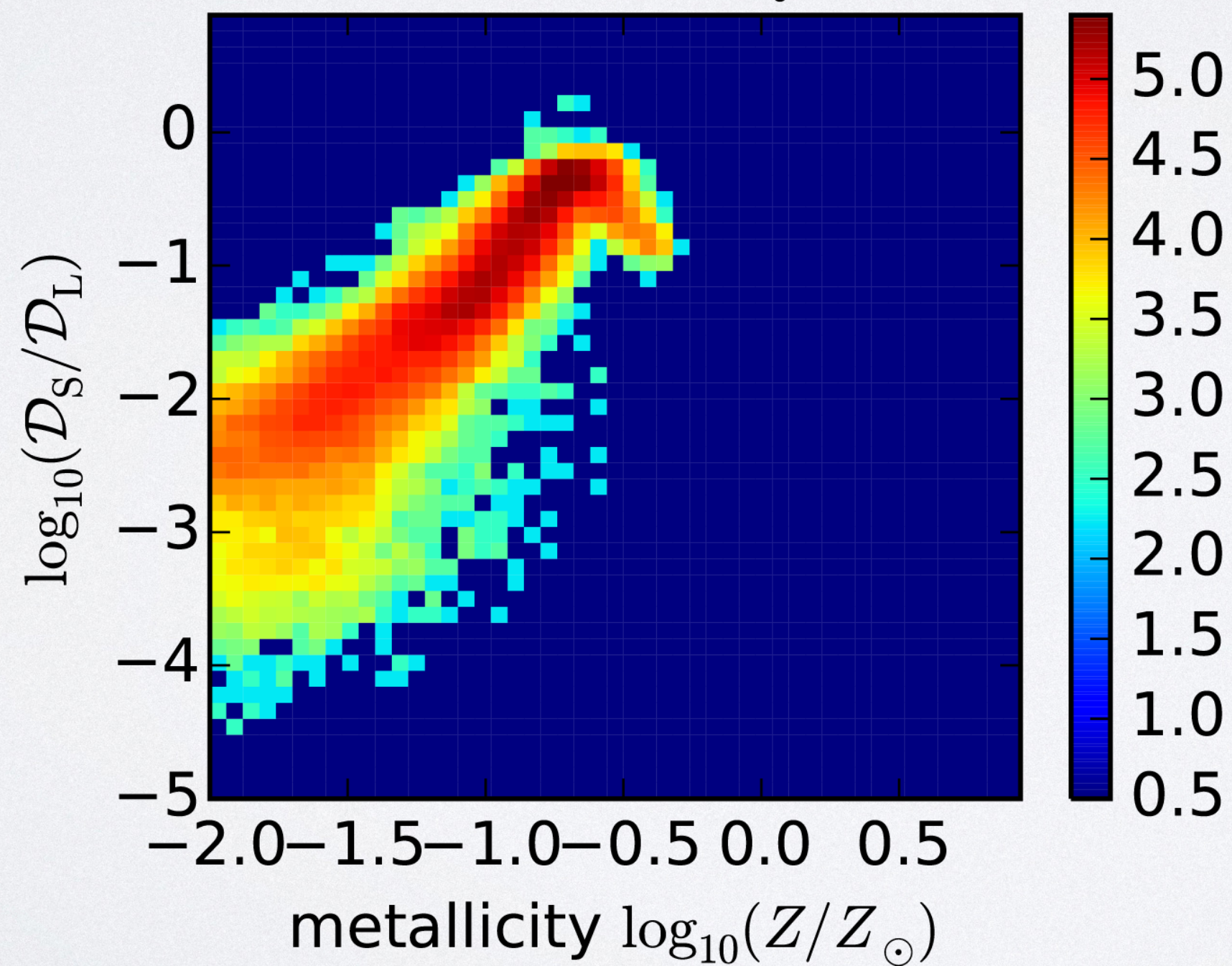
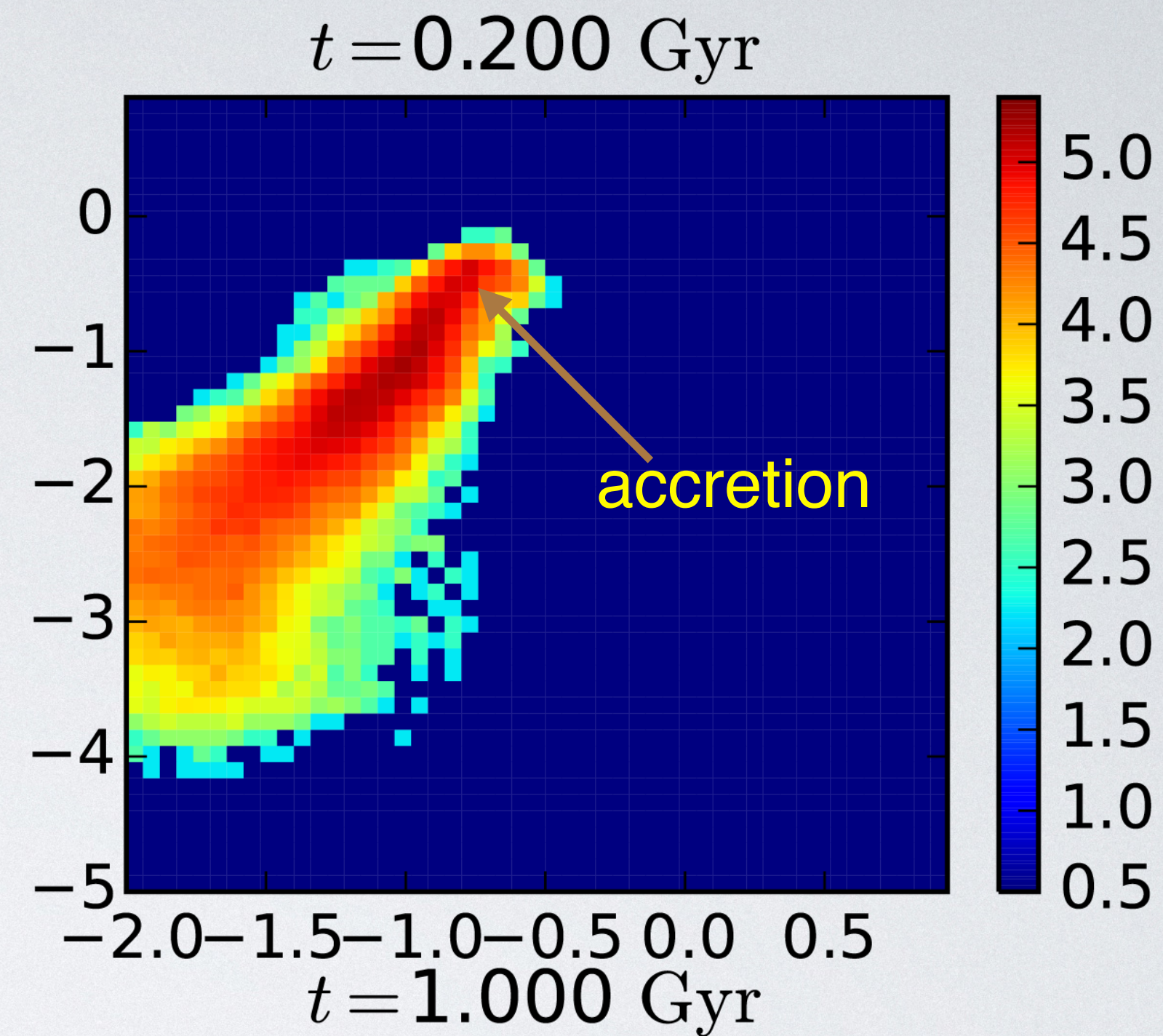
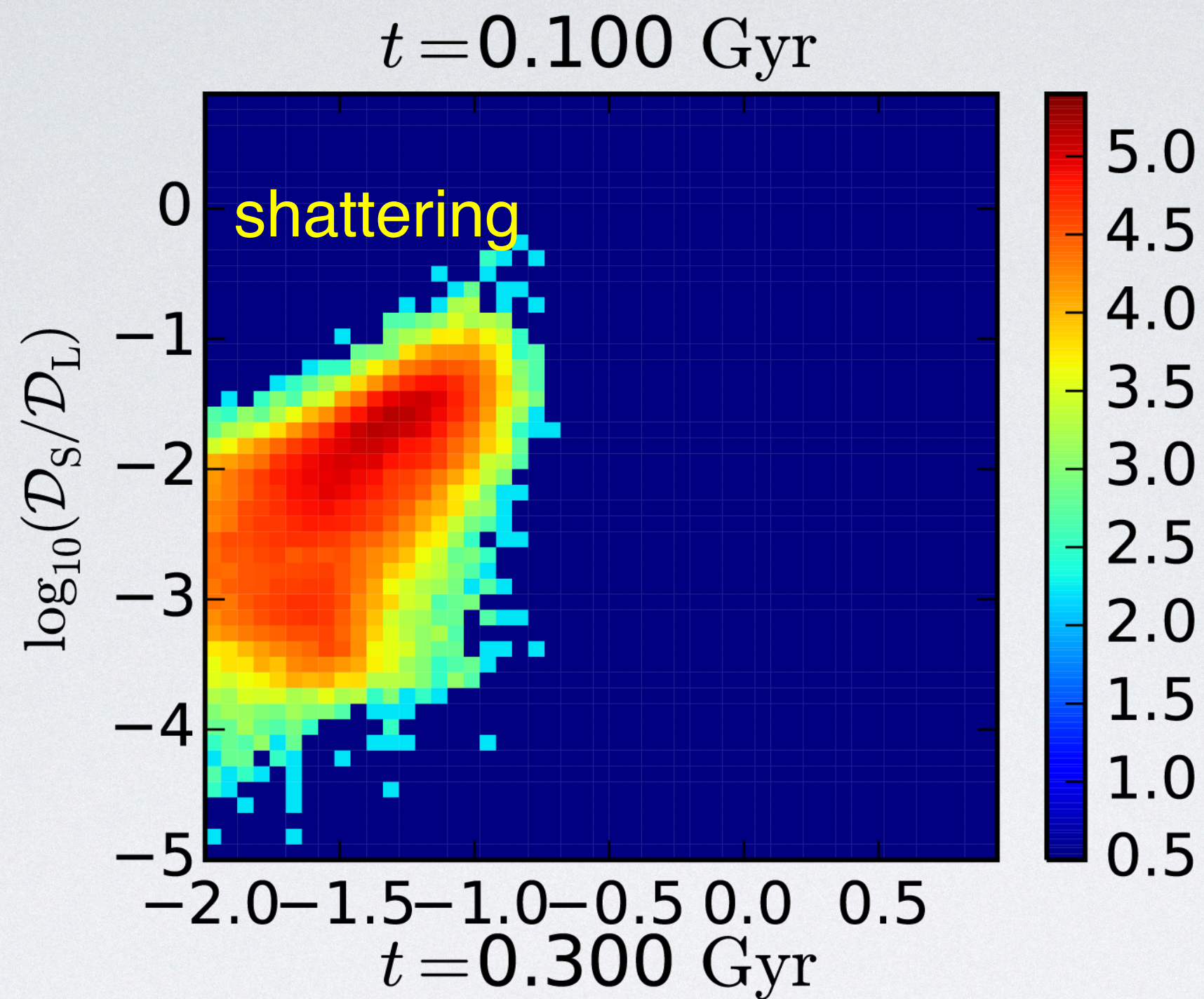


Stellar dust production is dominated

Accretion

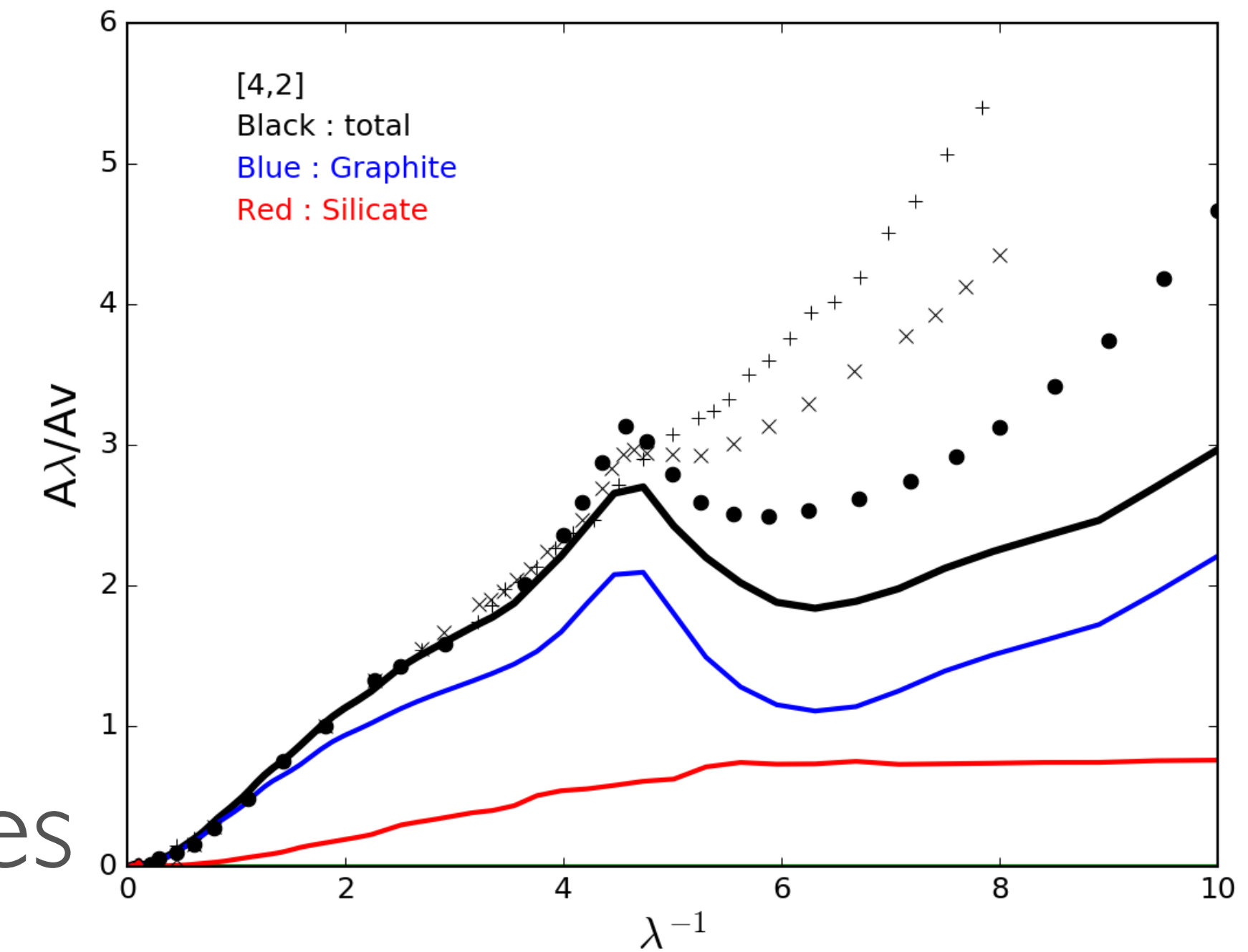
Accretion is saturated

# Small-to-large grain mass ratio



# 4. Future Prospects

- Prediction of observational properties
- For example, extinction curves
- Separate predictions for individual dust species



# 5. Summary

- Dust enrichment model + SPH Simulation: Framework completed.
- Simulated dust abundance and grain size distribution (two sizes) consistently in an isolated galaxy
- Spatially resolved grain properties (e.g., extinction curves) are ready to predict



**Thank You.**