The Effect of Dust Evolution on the Multi-phase Interstellar Medium

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Introduction

The interstellar medium (ISM) plays a crucial role in galaxy evolution, while dust act as a key component in regulating various reactions. However, the processes governing dust evolution affected by stellar feedback remains poorly understood. Among these, photoionization feedback from massive stars is known to shape the ISM structure and chemistry. While supernova-driven shocks have been extensively studied as a major source of dust destruction, the role of photoionization in regulating dust evolution remains largely unexplored. Understanding how photoionization feedback from massive stars influences dust evolution in the ISM is crucial for studying the early universe. Using the GIZMO hydrodynamics code, we model six simulations that selectively include photoionization, dust growth, and dust sputtering, allowing us to isolate the physical effects of photoionizing radiation on dust and gas dynamics.

Methodology & Initial Condition Setup

- **Simulation Setup**
  - GIZMO: combining the advantages of SPH and non-moving mesh[1]
  - Non-equilibrium cooling and H_2 chemistry network
  - Star-by-star stochastic star formation with the star formation efficiency of 50%
- **Initial conditions**
  - Isolated dwarf galaxy embedded in a dark matter halo
  - Initial gas mass $= 7 \times 10^7 \mathrm{M}_\odot$; dark matter mass $= 10^{10} \mathrm{M}_\odot$
  - Simulation time: 800 Myr
  - Stellar feedback: photoionization and supernovae
  - Dust evolution with dust sputtering and dust growth
- **Erosion Rate:** thermal sputtering vs. gas temperature[2]

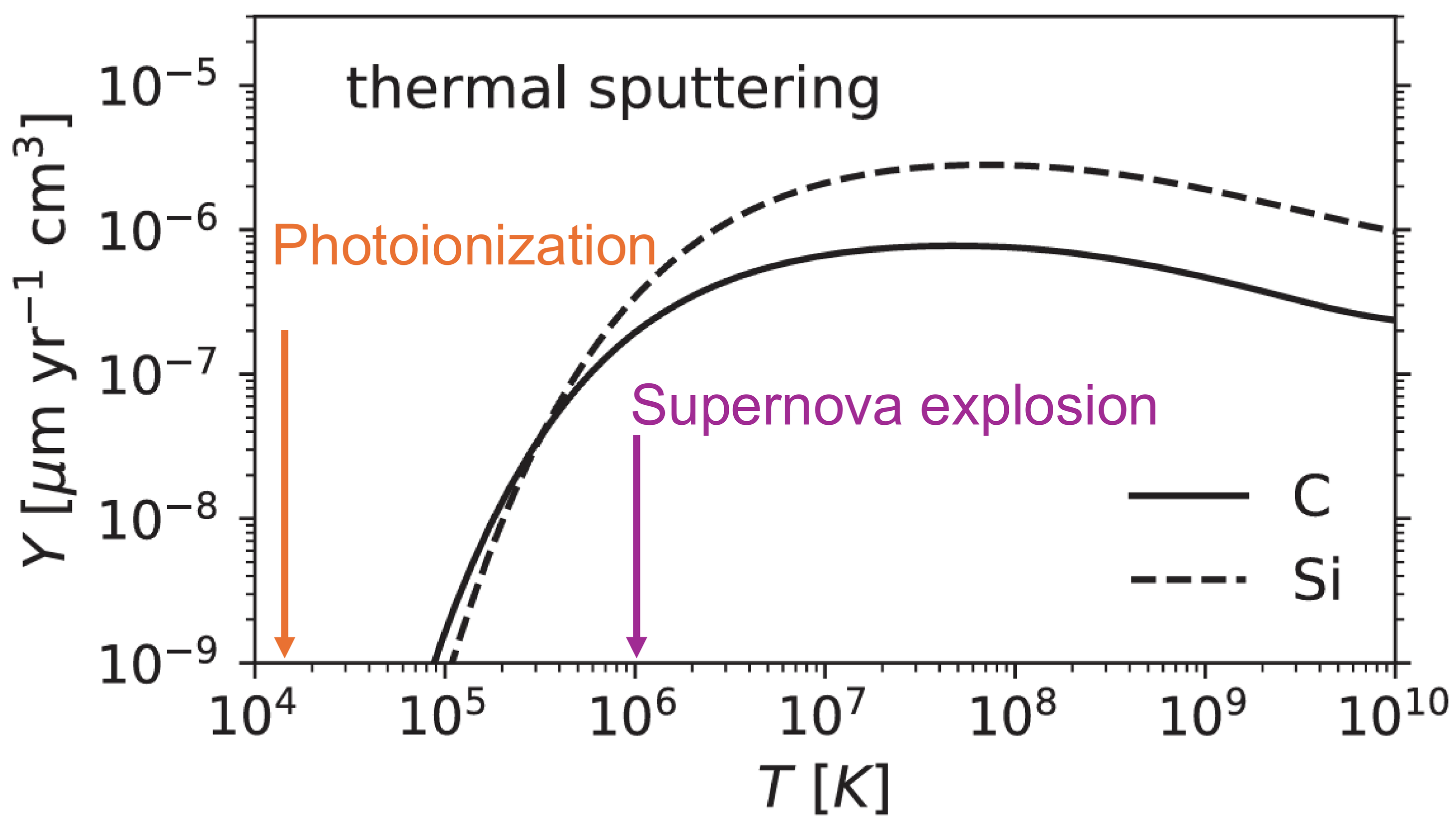

Figure 1. thermal sputtering of C and Si vs. temperature

Results & Discussion

1. Total Gas Phase Diagram

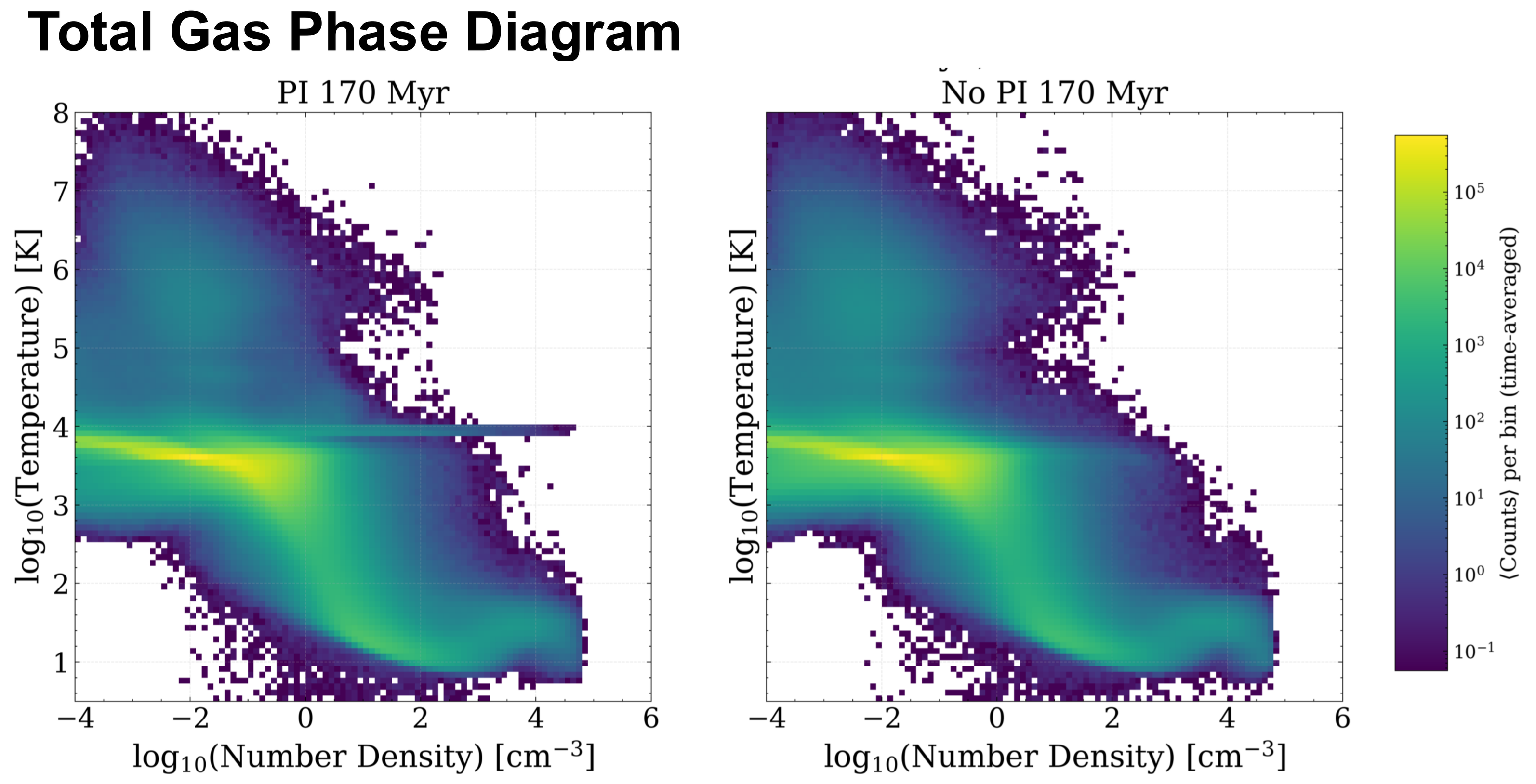

Figure 2. The Total Gas Phase Diagram at 170Myr shows a prominent peak at $10^4 K$ due to photoionization compare to the no-PI run, other runs exhibit no significant differences (with/without sputtering and with/without dust growth).

2. Face-on map of the gas surface density at 170Myr

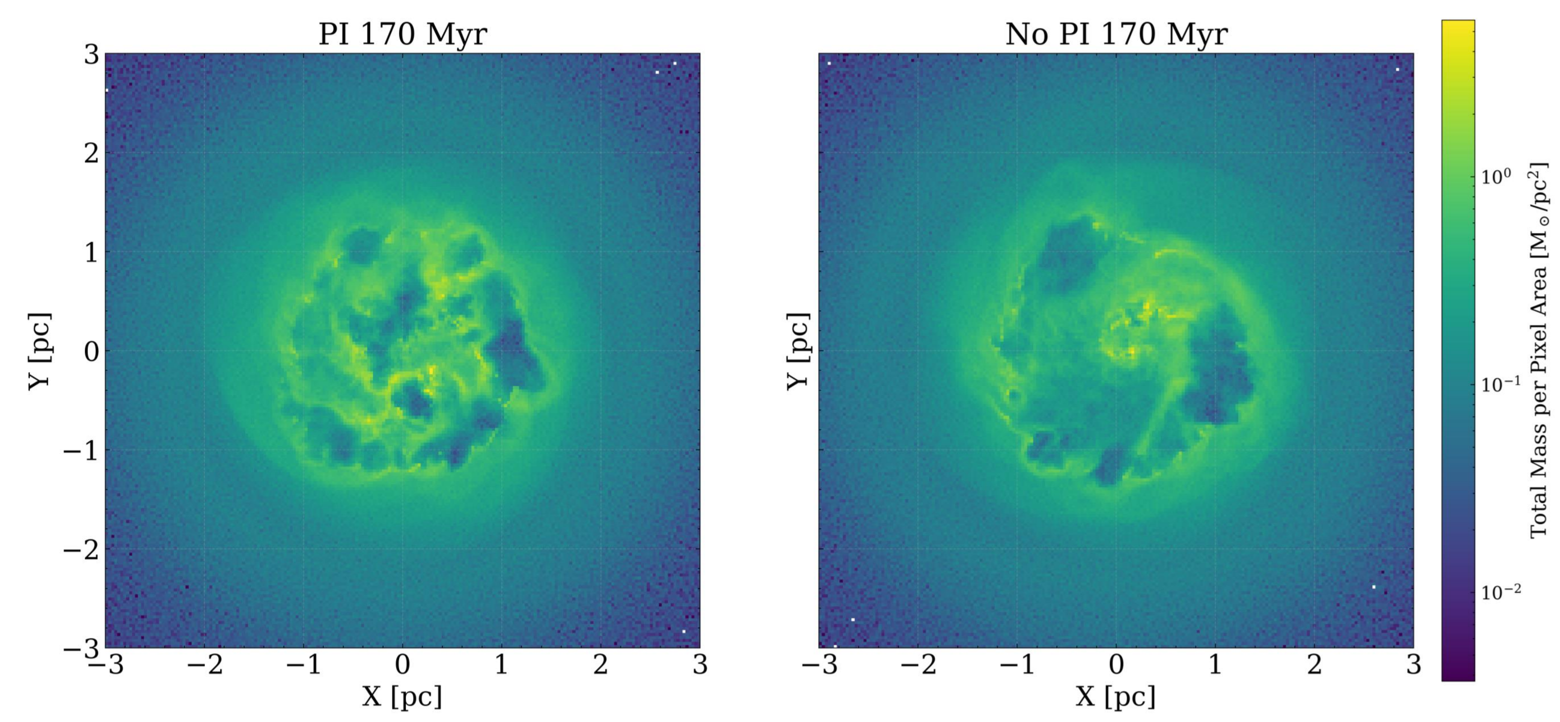

Figure 3. Gas surface density at 170 Myr, comparing PI vs. no-PI run. In the no-PI run the dense gas remains strongly clustered around SNe sites, leading to more efficient thermal sputtering and hence greater dust destruction rate.

3. Star Formation Rate

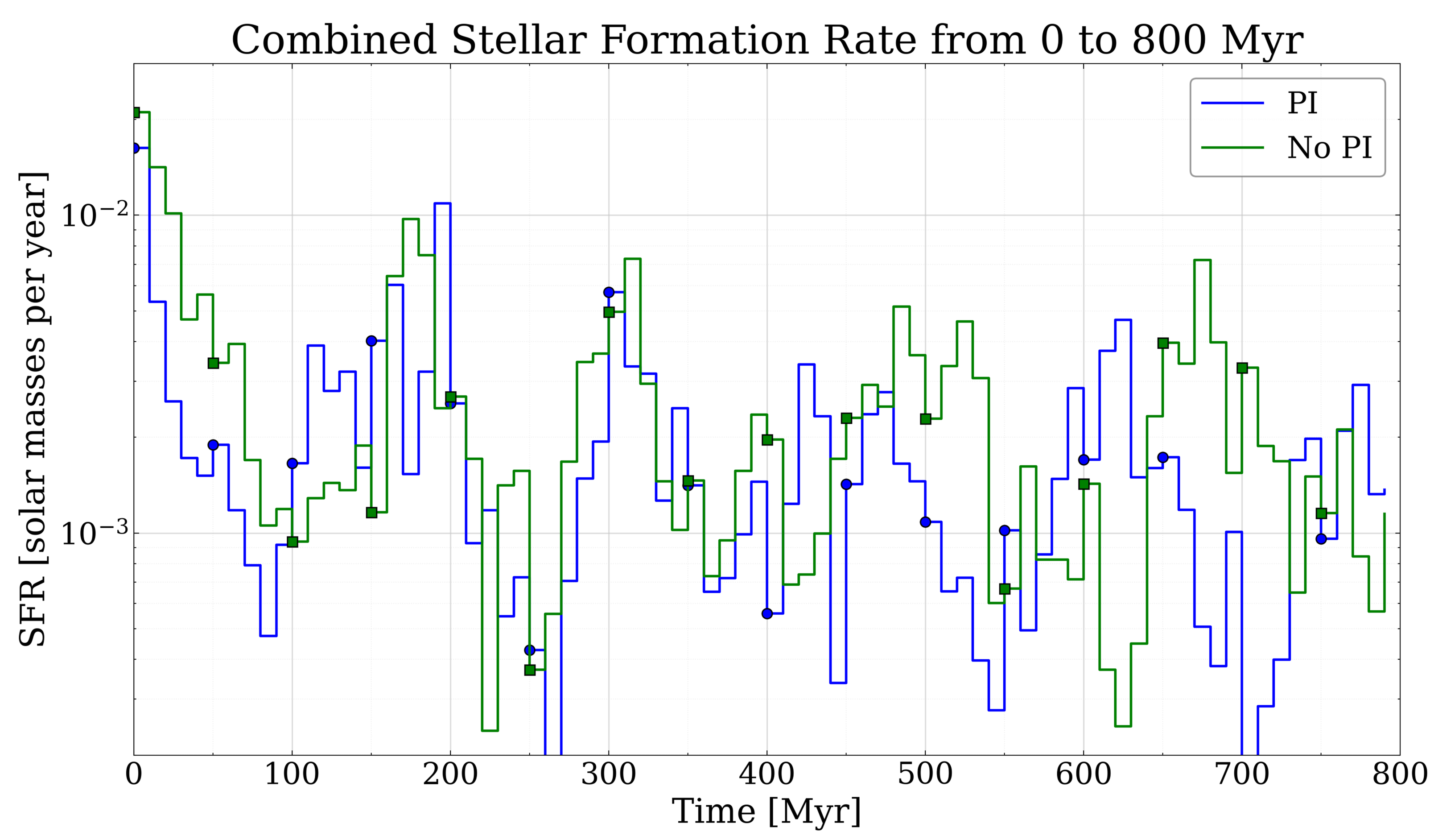

Figure 4. Star formation histories. Before 100 Myr, the no-PI run exhibits a burstier SFR. After ~100 Myr both runs settle into comparable low-amplitude oscillations shows no significant difference.

4. Dust mass vs. Time

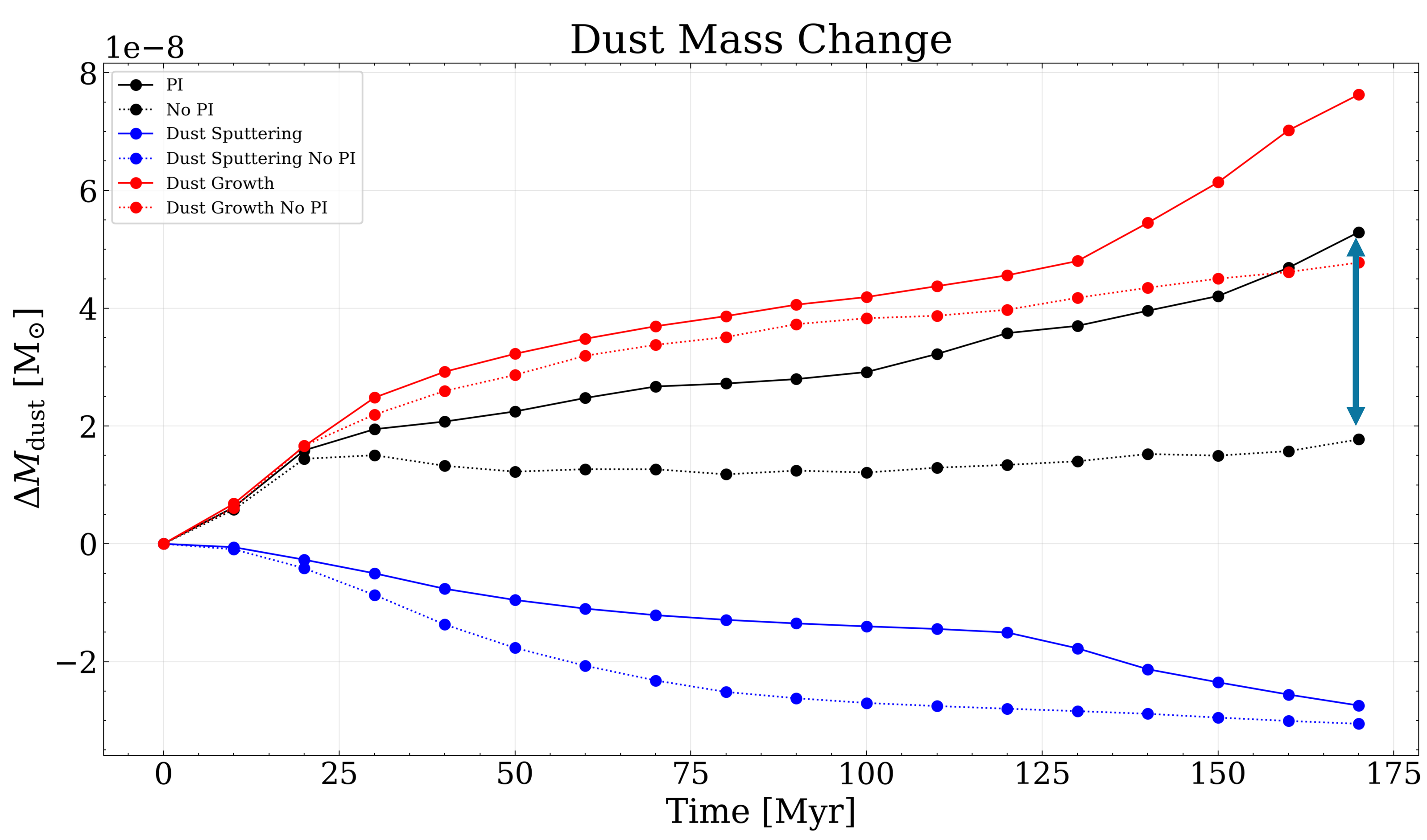

Figure 5. Evolution of total dust mass over 0–170 Myr. The PI run accumulates about 2 times more dust than the no-PI run. With dust sputtering only, PI effect is more moderate, highlighting the non-linear interplay between grain growth and destruction.

Summary & Future Work

- **Photoionization Reduces Dust Destruction.** Early UV heating in the PI runs evacuates gas around young stars, lowering the density into which the first supernovae explode and thereby **suppressing thermal sputtering**.
- **Higher Net Dust Mass with PI.** Over 0–170 Myr, simulations with photoionization show about 2 times larger increase in total dust mass than those without PI, whereas disabling dust growth reverses the trend (net dust loss).
- **Next Steps:**
  - Analyze the local environmental densities where SNe occur.
  - Select individual SNe bubbles, examine their time evolution to confirm our physical interpretation.

Reference:
[1]: Hopkins, P. F. (2016). A constrained-gradient method to control divergence errors in numerical MHD. *Monthly Notices of the Royal Astronomical Society*, *462*(1), 576-587.
[2]: Hu, C. Y., Zhukovska, S., Somerville, R. S., & Naab, T. (2019). Thermal and non-thermal dust sputtering in hydrodynamical simulations of the multiphase interstellar medium. *Monthly Notices of the Royal Astronomical Society*, *487*(3), 3252-3269.