Modeling Dust in Galaxies Across Cosmic Time

Qi Li[1], Desika Narayanan[1] and Romeel Davé[2],
[1]Department of Astronomy, University of Florida; [2]Institute for Astronomy, University of Edinburgh
Email: pg3552@ufl.edu

Introduction

Dust plays a critical role in the physics of galaxy evolution. For example, the ejection of dust from galaxies contribute to metals in the intergalactic medium and provides an additional cooling channel. Absorption of far ultraviolet and optical photons can shape the temperature structure of interstellar medium.

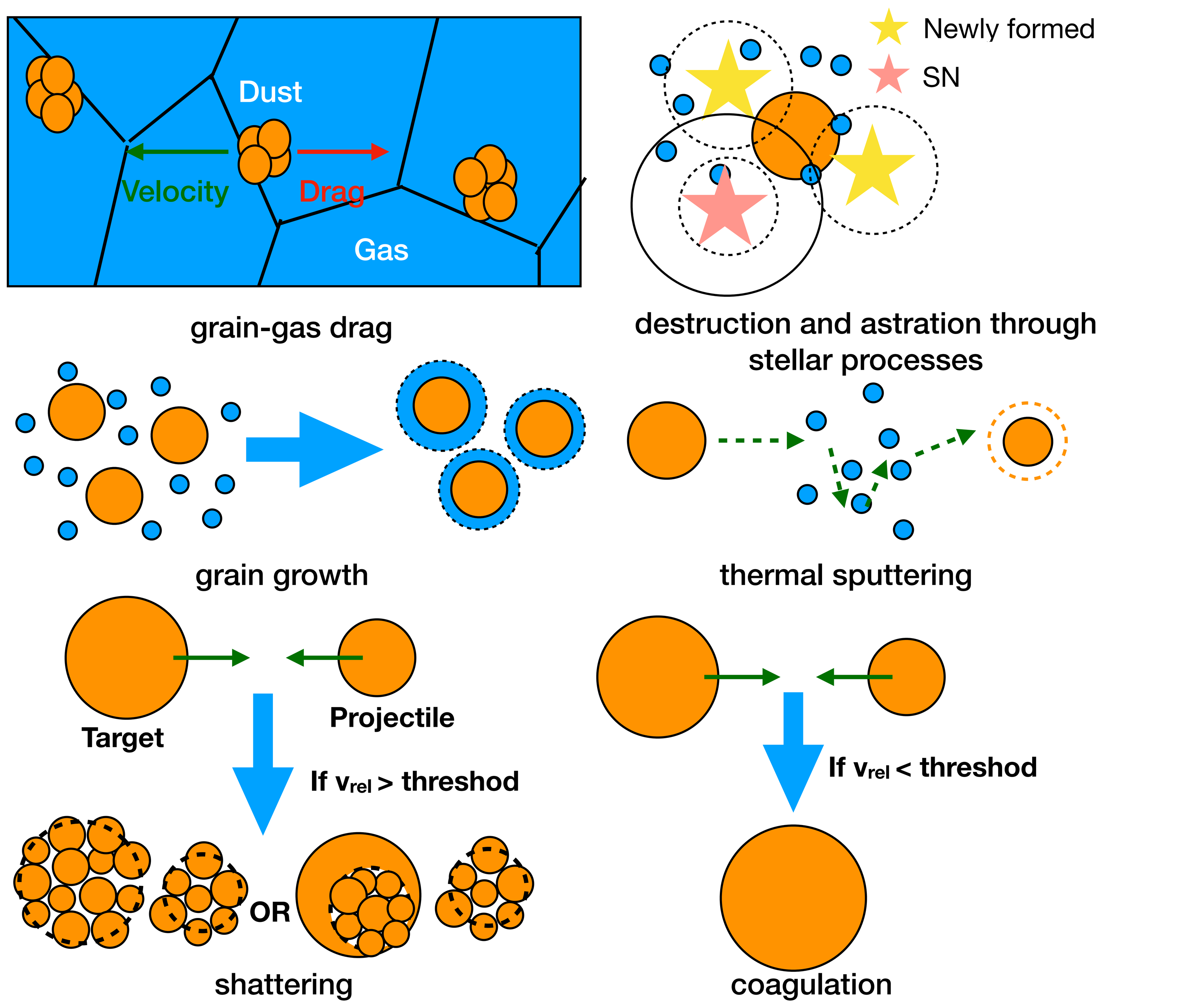
Nevertheless, a self-consistent model for dust content has usually been missing in the galaxy evolution models. In this work, we aim to enhance the predicting power of galaxy evolution models by incorporate self-consistent dust physics into state-of-the-art cosmological hydrodynamic simulations.

Model

We conduct cosmological simulations with hydrodynamics and gravity solver GIZMO in Mesh-less Finite Mass mode (Hopkins 2015). Dust is treated as super-particles, representing grains with different radii and interacting with other particles via gravity and grain-gas drag (modified from Lee & Hopkins 2016).

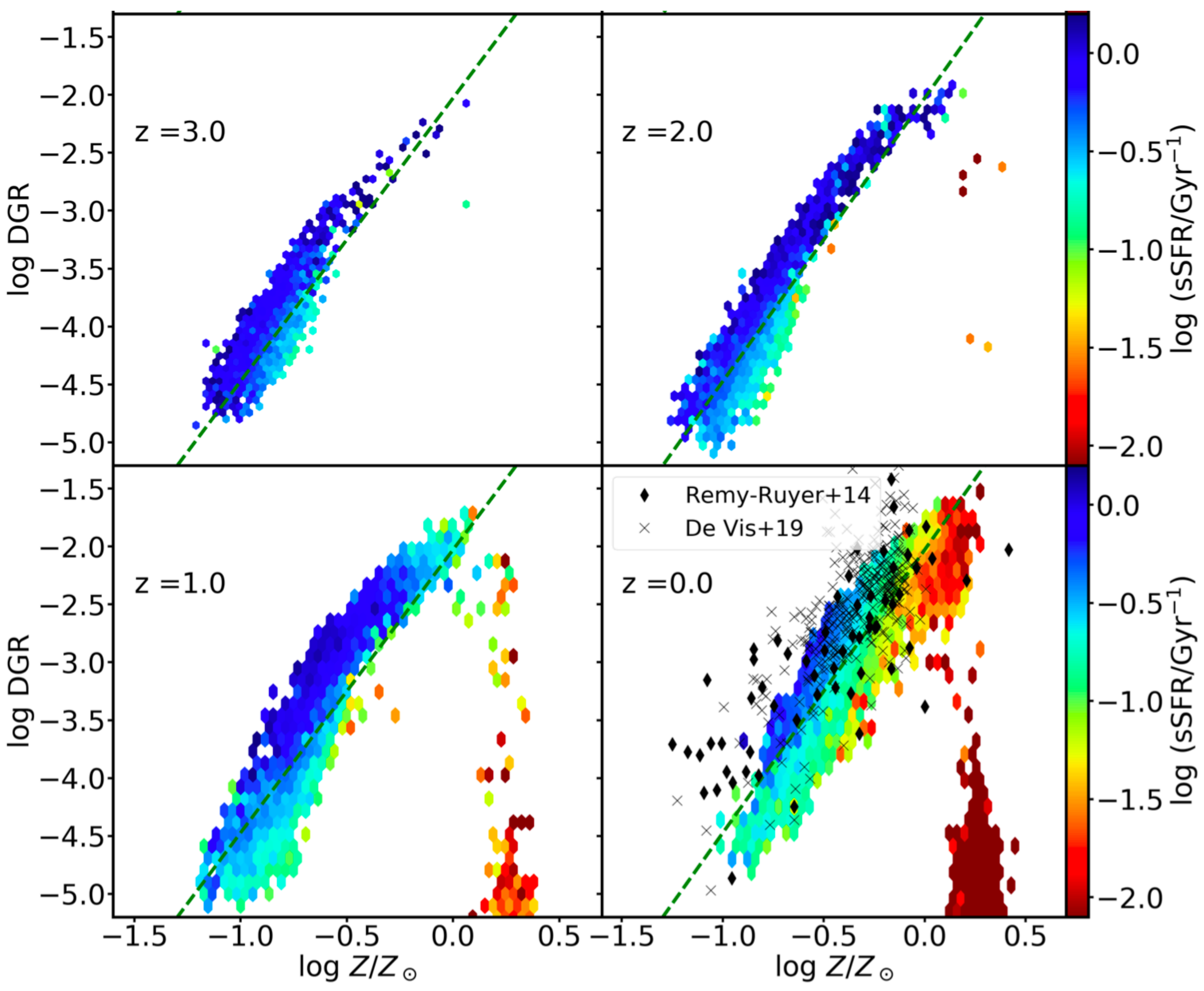
The dust model implements on-the-fly dust seeding via condensation of stellar ejecta, grain growth via accreting gas-phase metals, astration through star formation, grain destruction via supernova shocks and thermal sputtering, grain-grain collisional processes including shattering (high-velocity collision) and coagulation (low-velocity collision). We refer readers to Li et al. (2019) and McKinnon et al. (2018) for details.

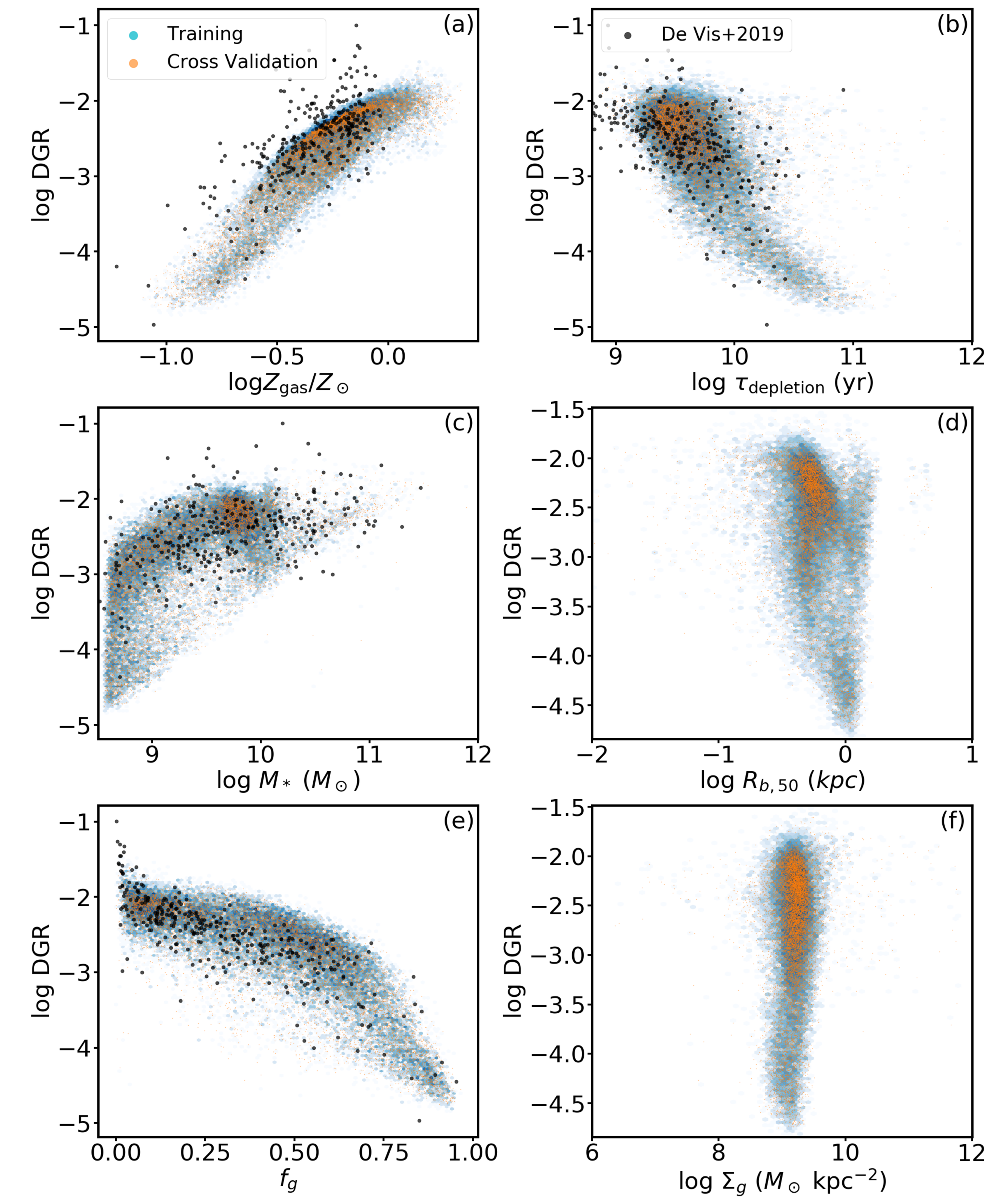
Other baryonic physics are described in Davé et al. (2019) for the SIMBA simulation.



Dust-to-Gas Mass Ratio

We are able to predict dust-to-gas mass ratios across cosmic time. Our dust model reproduces the dust-to-gas mass ratio (DGR) vs. gas-phase metallicity (Z) relation observed in the local universe, and predict a weak evolution of DGR-Z relation from z=3 to z=0.

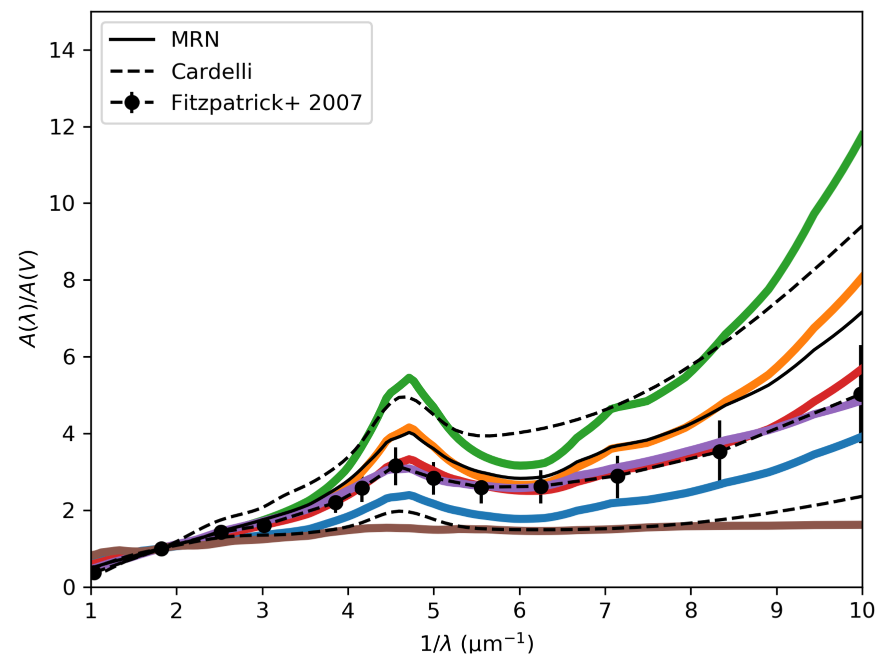




The simulated dataset facilitate the study of relations between DGR and other properties of galaxies. We train extremely randomized trees (ERT) with 70% of simulated galaxies and fit the map from DGR to (gas-phase metallicity, gas depletion time scale, stellar mass, gas-to-baryon mass ratio, etc.). The map can be applied to improve the modeling of dust effect on SEDs where oversimplified assumptions on DGR are widely adopted.

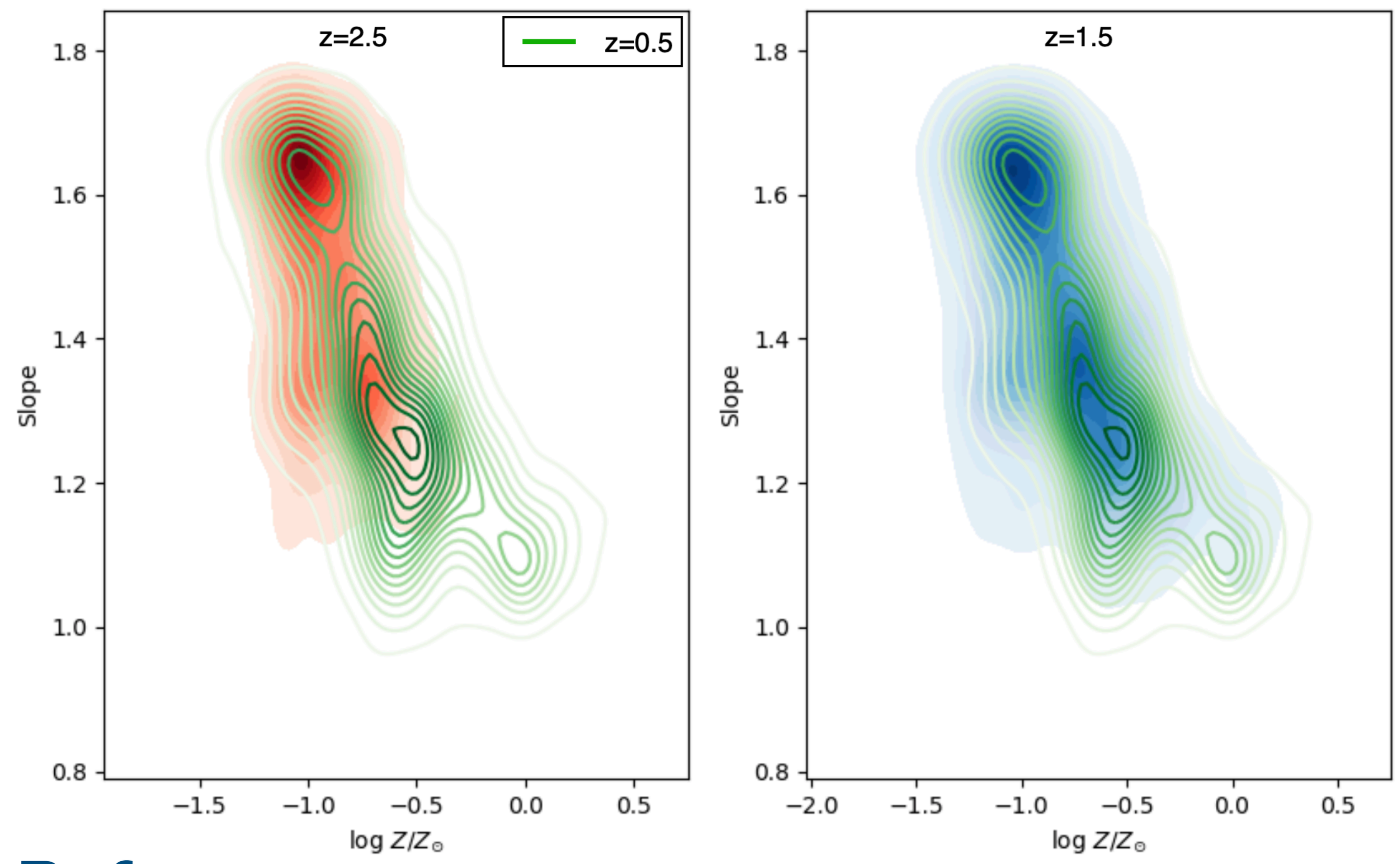
Extinction Curves

The extinction curves are obtained for galaxies with a variety of physical properties and evolutionary histories via post-processing grain size distributions from the simulations (Li, Narayanan, Davé et al., in prep.).



The simulation broadly matches the observed range of extinction curves for Milky-way like galaxies.

An anti-correlation between optical slopes of extinction curves and metallicities is predicted for all simulated galaxies, indicating that dust growth with short timescales dominates.



References

Davé R., Anglés-Alcázar D., Narayanan D., Li Q., Rafieferantsoa M. H., Appleby S., 2019, MNRAS, 486, 2827
Hopkins P. F., 2015, MNRAS, 450, 53
Lee H., Hopkins P. F., Squire J., 2017, MNRAS, 469, 3532
Li, Q., Narayanan D., Davé R., 2019, MNRAS, 490, 1425
McKinnon R., Vogelsberger M., Torrey P., Marinacci F., Kannan R., 2018, MNRAS, 478, 2851