Dust removal timescale in galaxies across cosmic time

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Introduction

Cosmic dust

- Dust regulates star formation, cooling, and metal retention
- Removal mechanisms control the dust budget of galaxies

Supernova shocks
Jones et al. 1994
Bocchio, Jones & Slavin 2014

AGN-outflows
Fabian 2012
Piotrowska et al. 2022

Astration
Schawinski et al. 2014
Peng et al. 2015

Mergers
McGee et al. 2011
Davies et al. 2015, 2019

Stellar-winds
Walter et al. 2017

How fast is dust removed, and how does this evolve with time?

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Act I: Directly Measured Dust Removal Timescale

Michałowski et al. 2019

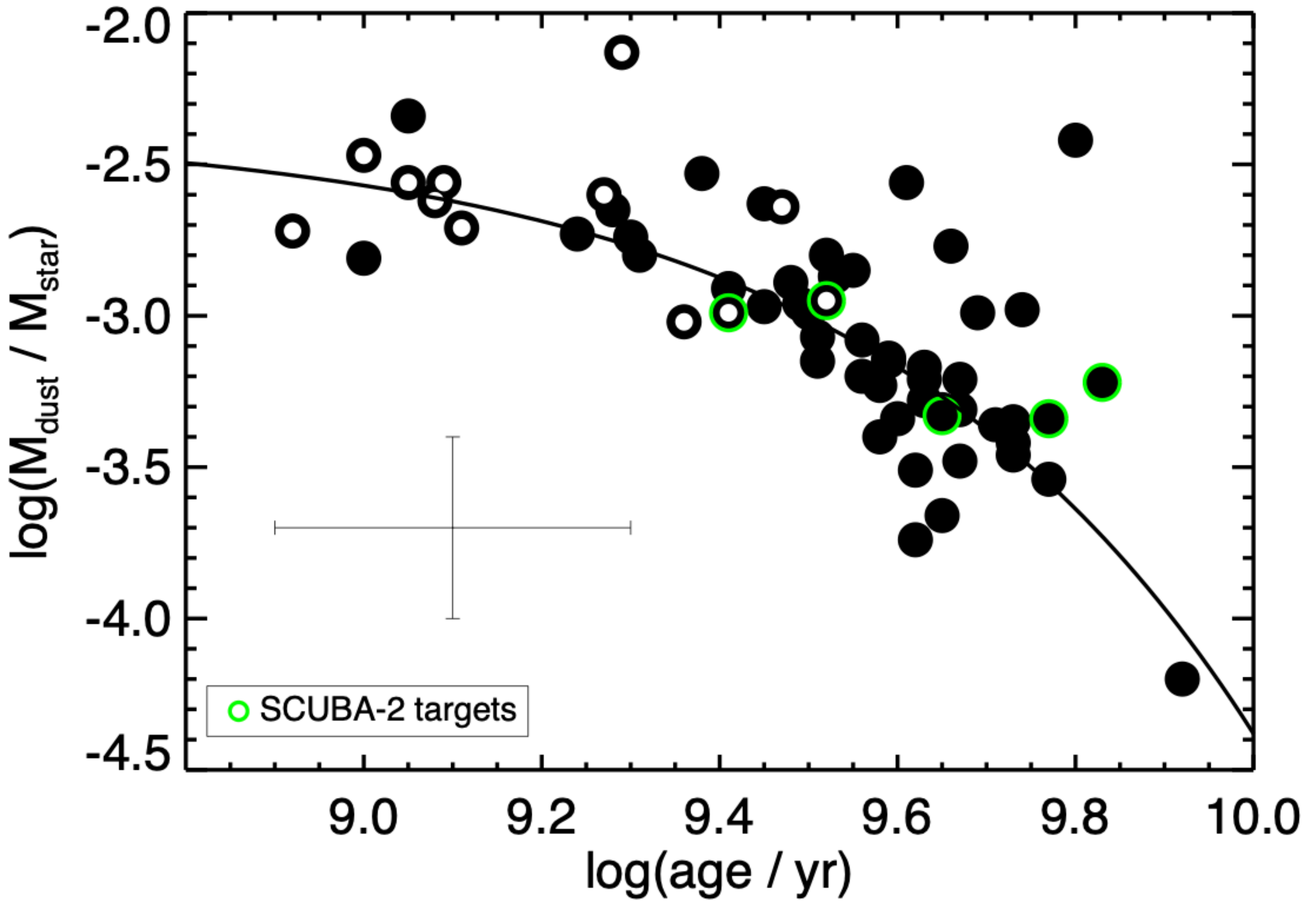
- 61 dusty early-type galaxies
  Herschel dust detection
  $z < 0.32$

- $$\frac{M_{\rm dust}}{M_*} = A \times e^{-{\rm age}/\tau}$$

- Dust removal timescale

$$\tau = (2.5 \pm 0.4)\,{\rm Gyr}$$

~ quenching timescale
strangulation, *Peng et al. 2015, Trussler et al. 2018*



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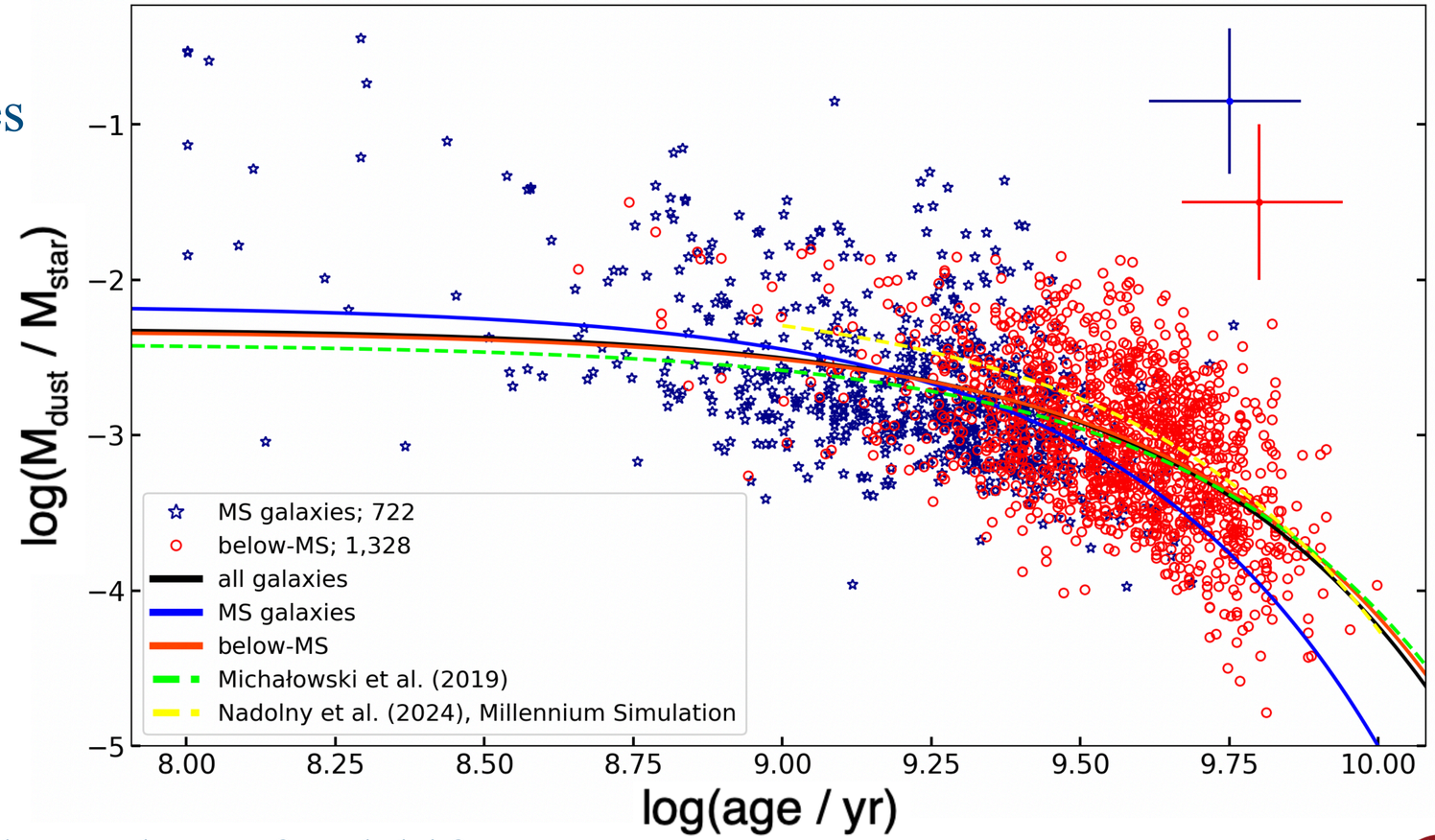
Act II: Expanded Sample

Leśniewska et al. 2023

- 2,050 dusty early-type galaxies
  GAMA survey
  Herschel dust detection
  $z < 0.32$

- Dust removal timescale

$$\tau = 2.26 \pm 0.18\ \mathrm{Gyr}$$



- The decline in dust mass is independent of redshift, environment, stellar mass, and central surface luminosity.

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Act II: Morphological quenching

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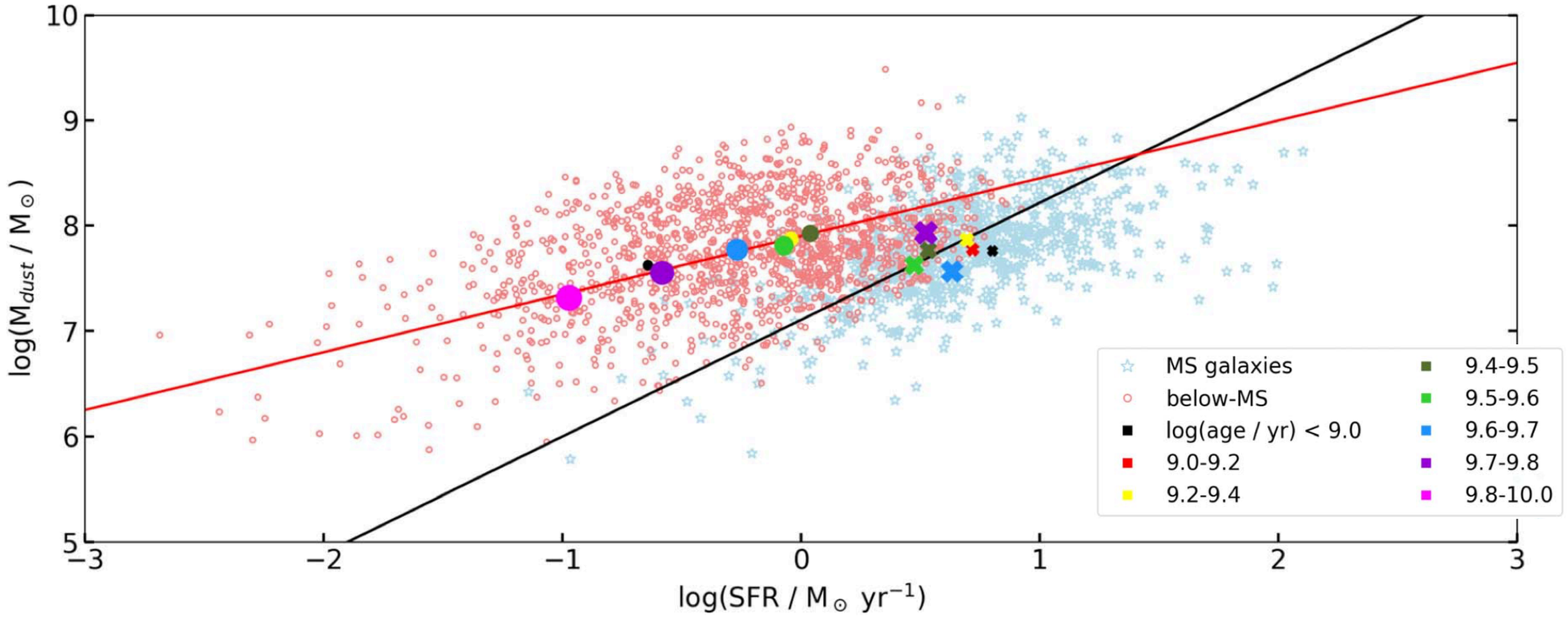
- Morphological quenching is a potential mechanism for departing from the da Cunha et al. 2010 relation (black line)



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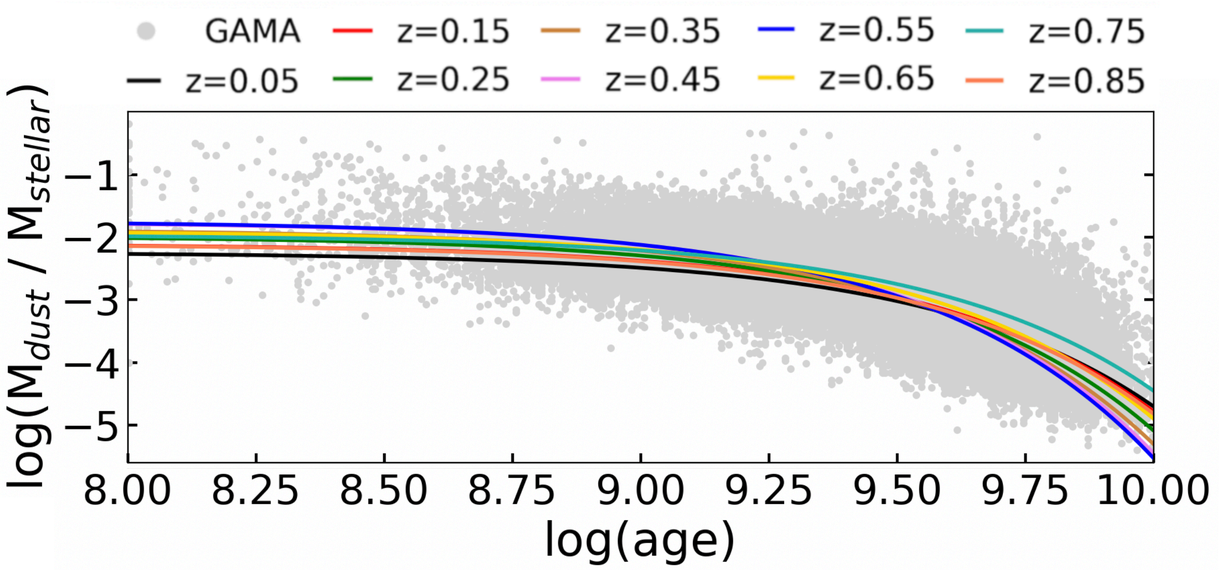
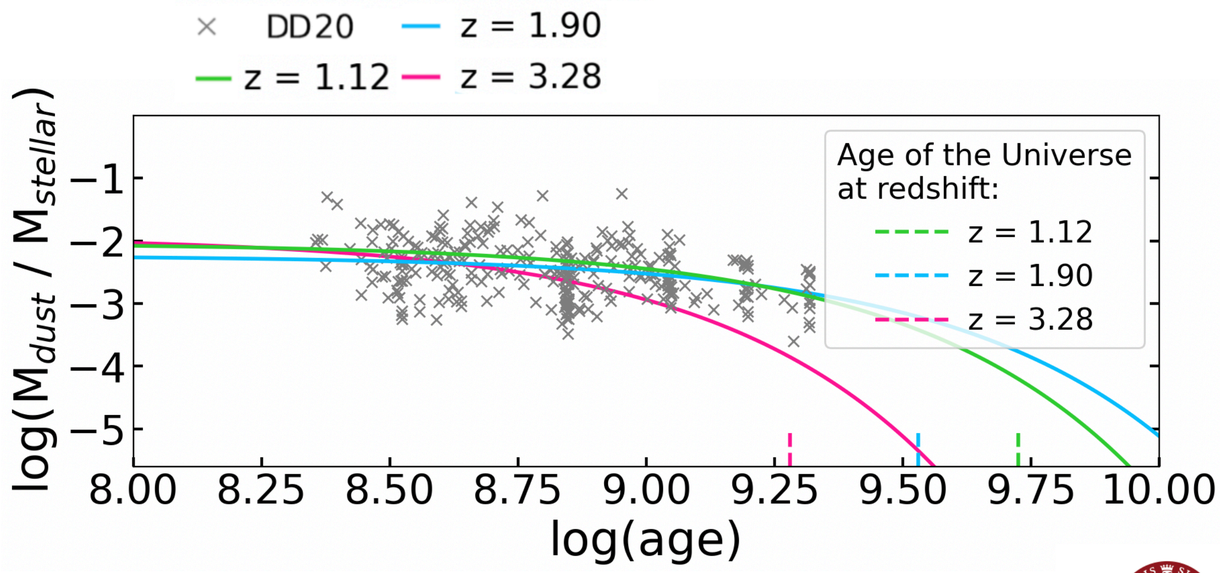
Act III: Dust removal timescale across cosmic time

Leśniewska et al. 2025

- 120,000 GAMA galaxies
  Driver et al. 2011, 2016; Baldry et al. 2018; Smith et al. 2011
  Herschel, MAGPHYS
  $z < 0.9$

300 massive dusty star-forming galaxies
Donevski et al. 2020
Herschel, CIGALE
$0.9 < z < 5.3$





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Act III: Dust removal timescale across cosmic time

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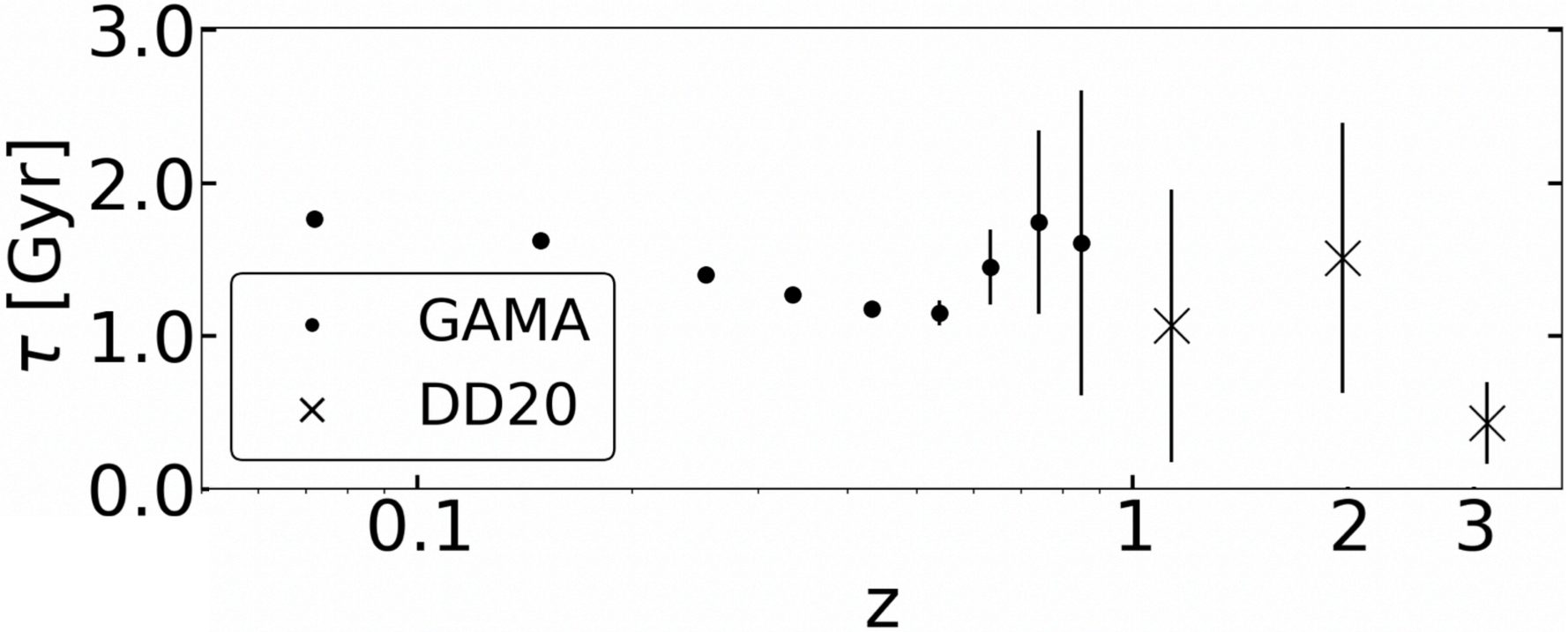
- Dust removal timescale decreases with increasing redshift



1.77 ±0.04 Gyr at z~0.05

0.43 ±0.33 Gyr at z~3.28
~ quenching timescale of 0.3 Gyr
COS-z5-Q1 @ z = 5.11
Baker et al. submitted to A&A

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Act III: Dust removal timescale across cosmic time

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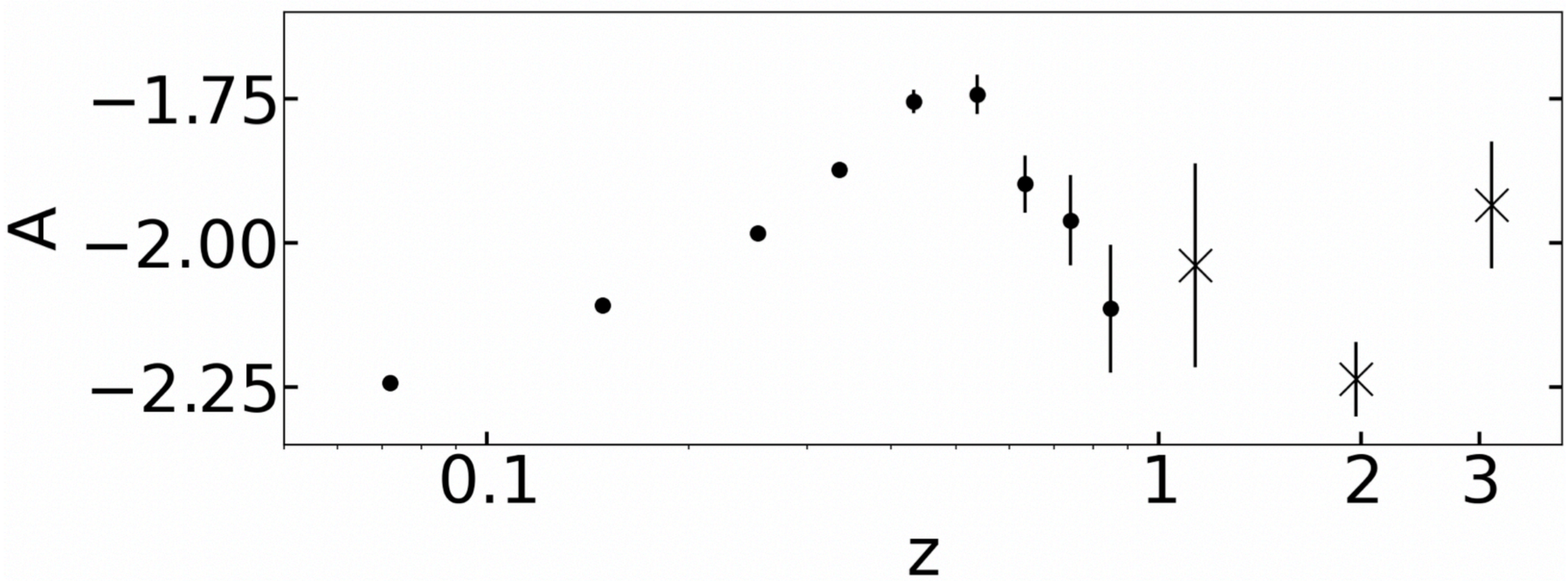
- Normalisation constant (A, maximum dustiness of galaxies) changes with redshift



$M_{dust}/M_{stellar} = 10^{-2.24}$ at $z \sim 0.05$

$M_{dust}/M_{stellar} = 10^{-1.93}$ at $z > 3$

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Act III: Dust removal timescale across cosmic time

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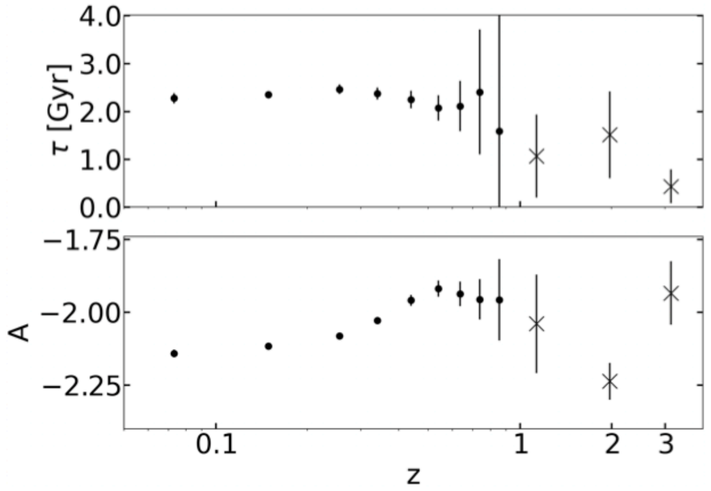
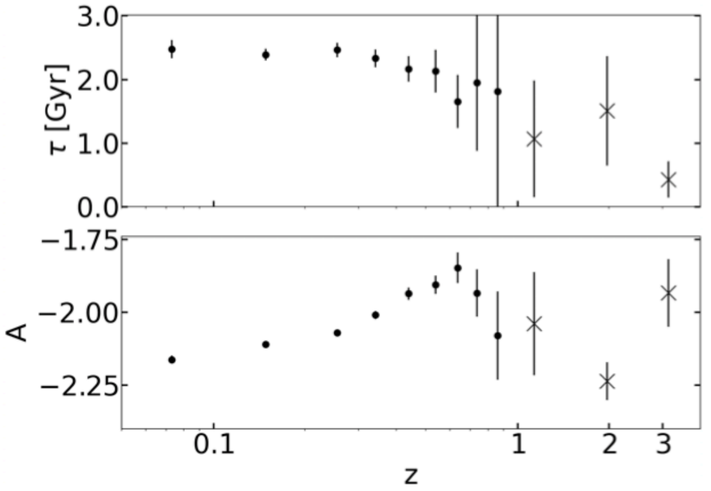
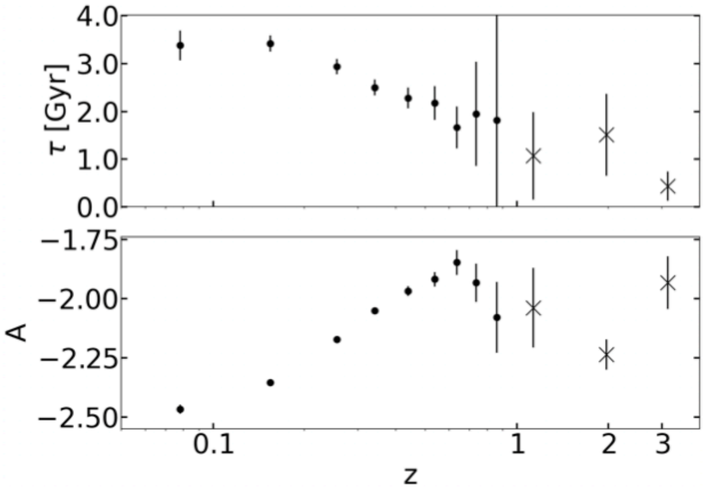


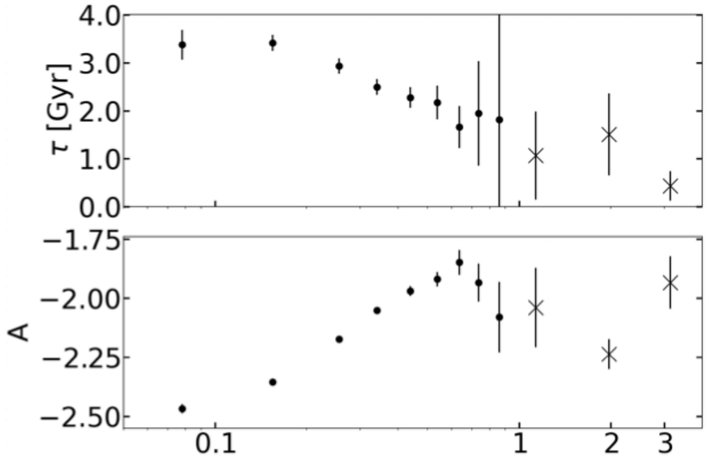
(a) **GAMA dusty galaxies**



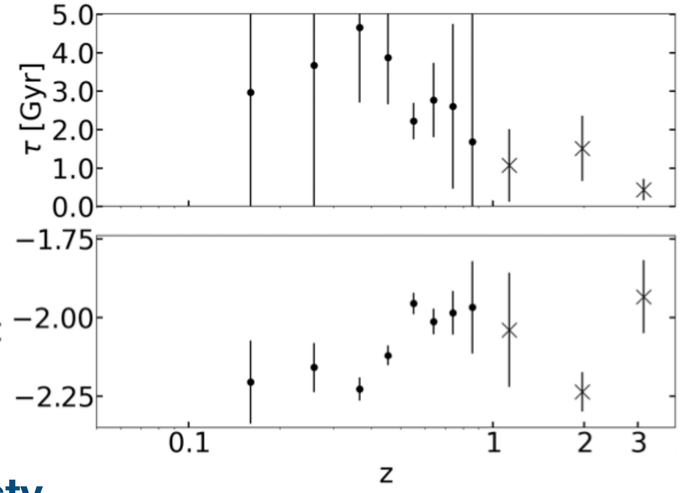
(b) **GAMA dusty spirals**



(c) **GAMA massive dusty spirals**



(d) **GAMA massive dusty star-forming galaxies**



(e) **GAMA massive dusty ETGs**

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Act III: Dust removal timescale across cosmic time

Dust removal mechanisms:

- Astration - galaxies @ $z > 0.9$, likely contributes substantially
  - elevated SFRs at high-z have been observed

(e.g. Reeves & Hudson 2024; Yuan et al. 2024).

- Supernova shocks - linked to the star formation activity of a galaxy, IMF

- AGN feedback - outflows operating on timescales of a few hundred million years

(Hardcastle 2018)

  - dust removal timescales of 0.2–0.7 Gyr in quiescent galaxies at $z = 3–4$, mainly driven by AGN activity

(Sato et al. 2024)

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Summary

- Dust removal timescale decreases with redshift
  Matches the rapid quenching observed in early galaxies
  (Singh et al. (2024); Baker et al. submitted to A&A)

- The normalisation (dustiness peak) increases with redshift
  $M_{dust}/M_{stellar}$ @ z ~ 3 suggests efficient early dust buildup,
  possibly from a high-mass-biased IMF.
  (Gall et al. 2011)

- More efficient dust removal and higher dust content in early galaxies

- Dust removal is closely linked to star-formation quenching and feedback efficiency

- Dust removal and quenching are closely connected at all epochs

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THANK YOU