Feedback in dusty elliptical galaxies

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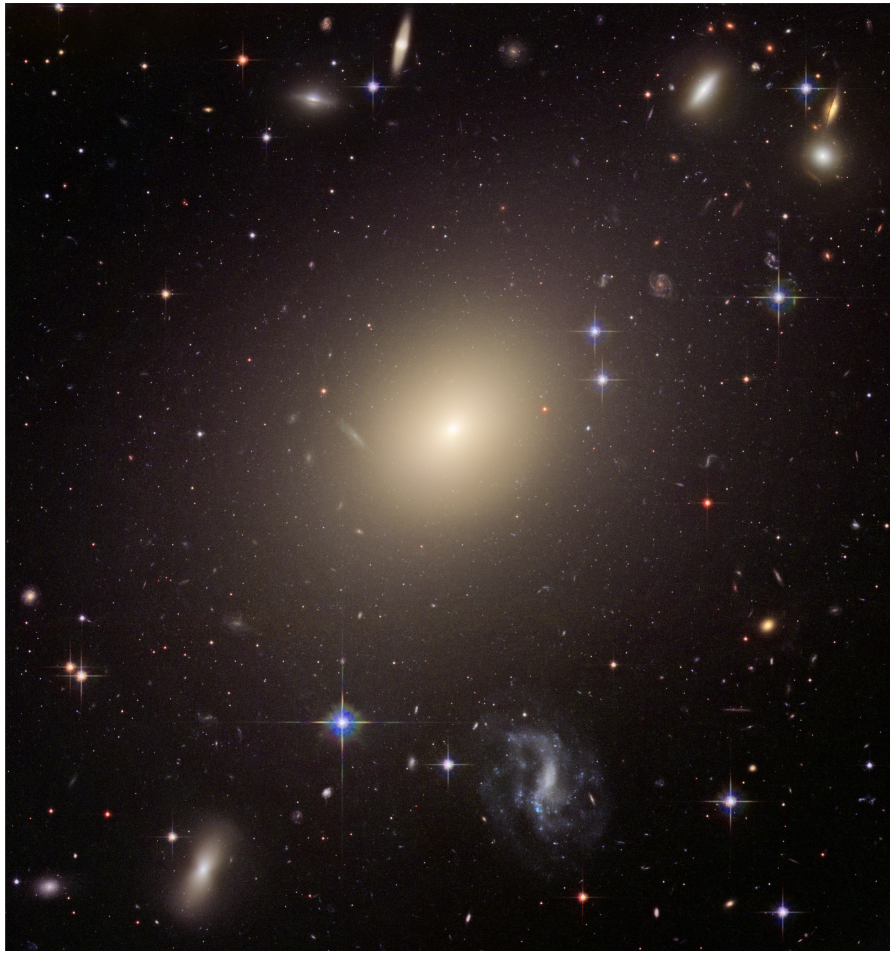
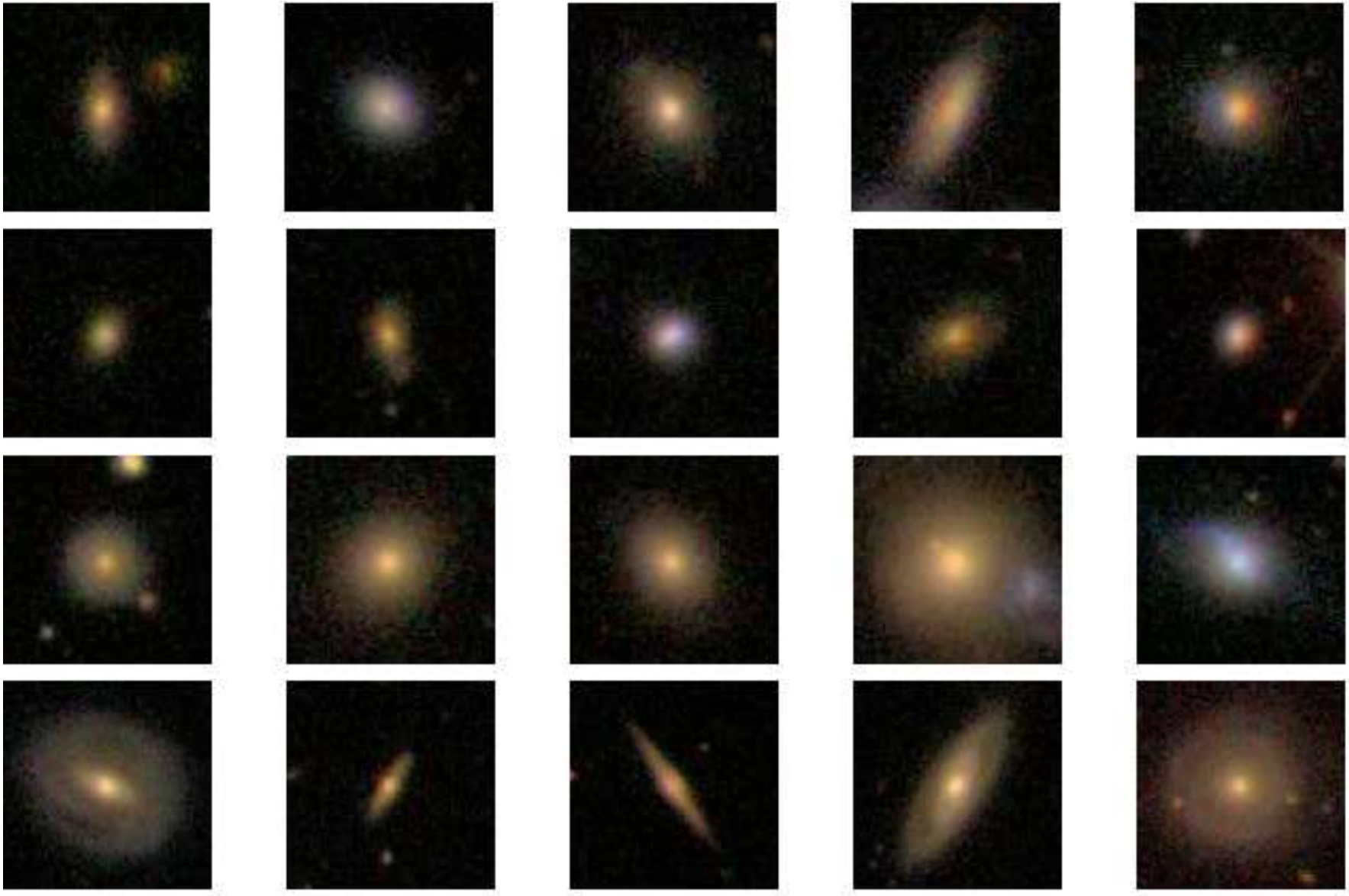
Motivation: how to explain galaxy bimodality?



How to study dust removal?

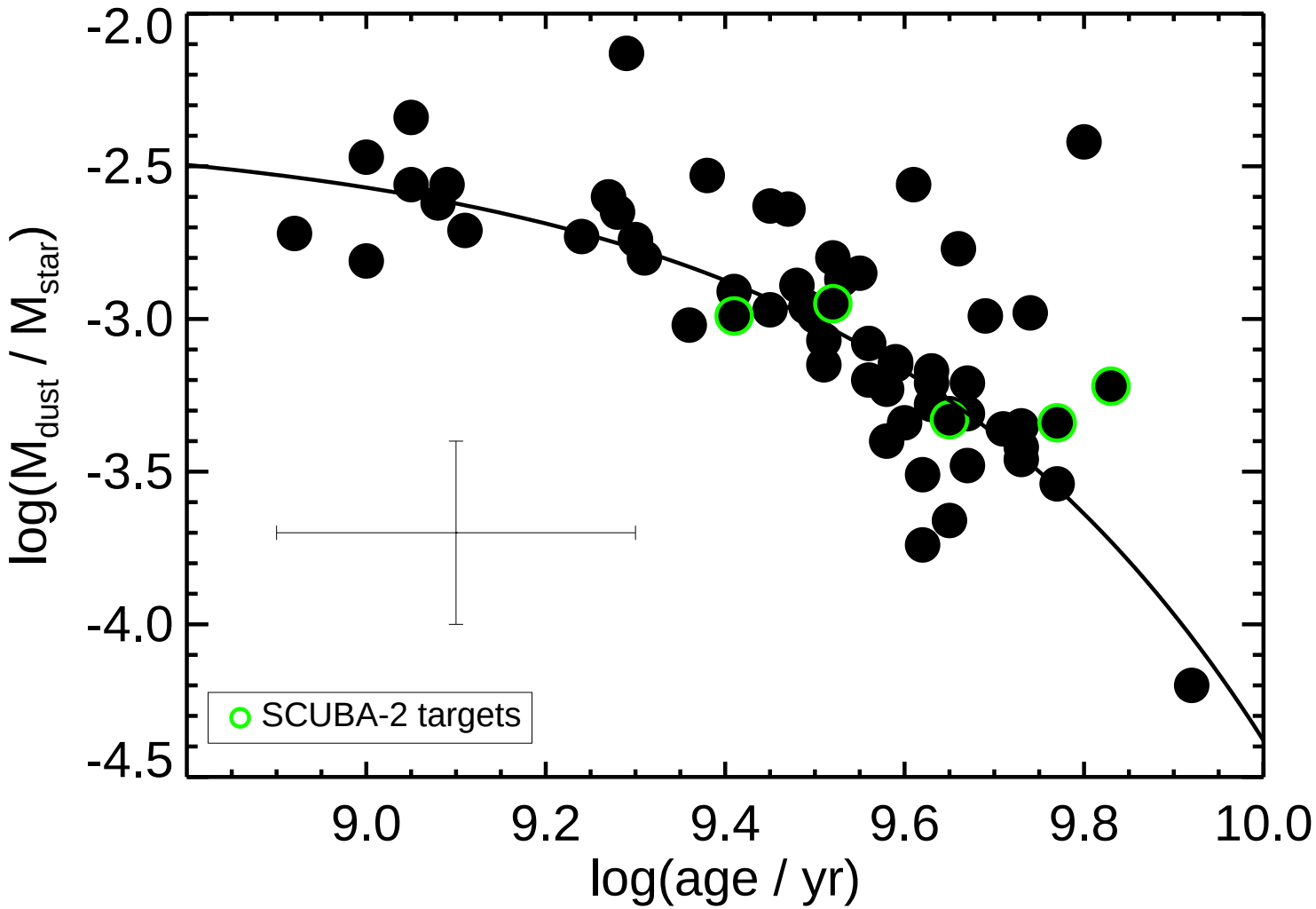
- Difficult to disentangle dust removal and production
- Solution: galaxies with dust but with limited dust production
- Dusty early-type galaxies (ETGs)
  - dust detection with *Herschel* 250 μm
  - $0.01 < z < 0.32$
  - Visually classified as an ETG over 14 deg^2: 61 galaxies (Rowlands et al. 2012)
  - Sersic index $n > 4$ over 162 deg^2: 2050 galaxies (Leśniewska et al., 2023, ApJ, 953, 27)



Rowlands et al. (2012, MNRAS, 419, 2545)

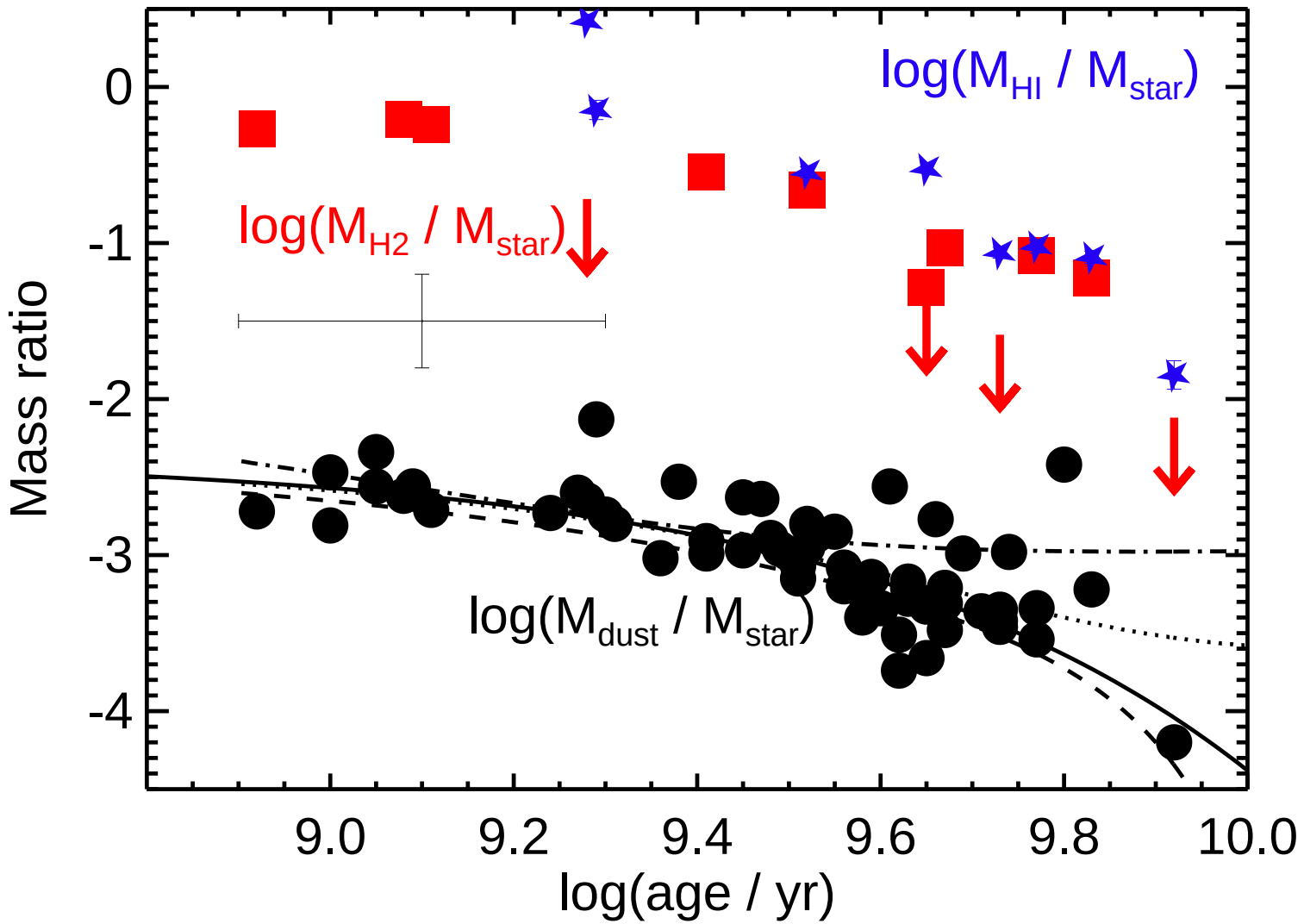
First direct measurement of the dust removal timescale

Exponential lifetime $\tau = 2.2\,\mathrm{Gyr}$; Half-lifetime $\sim 1.5\,\mathrm{Gyr}$



Michałowski et al. (2019, A&A, 632, A43)

Gas decline



Michałowski et al. (2024, ApJ, 964, 129)

What is the mechanism of the ISM removal?

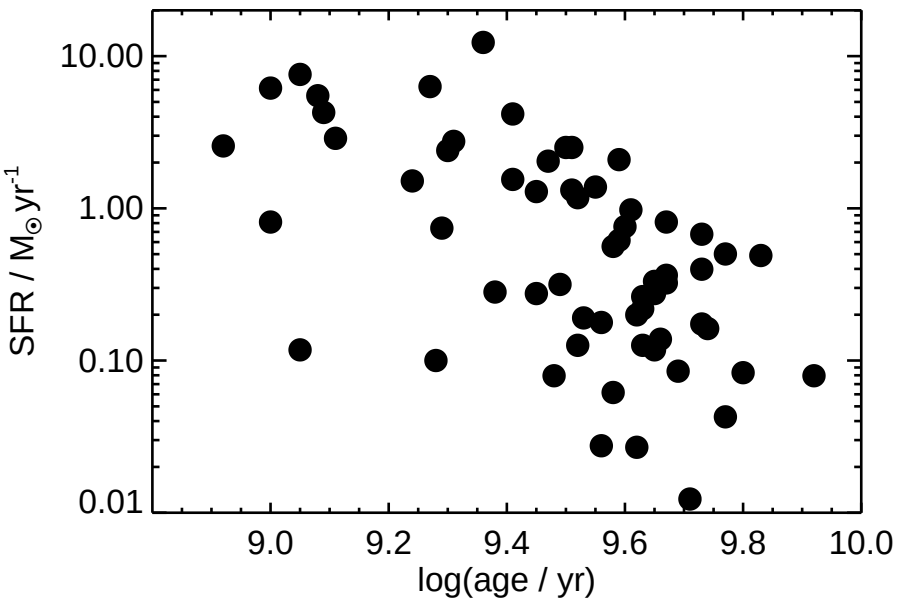
- Decreasing number of AGB stars? NO
- Astration / starvation (strangulation)? NO
- Outflows? NO
- Environment? NO
- Age-stellar mass correlation? NO
- Destruction of the entire cold ISM? Yes?

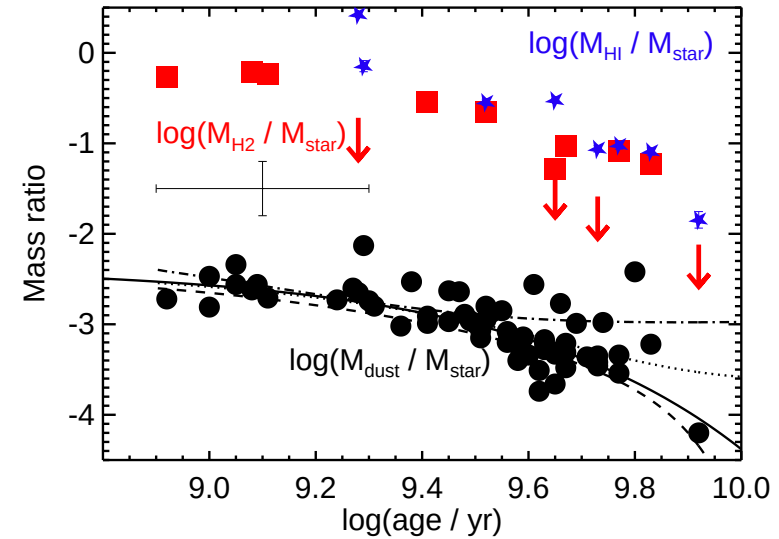
Decreasing number of AGB stars? NO

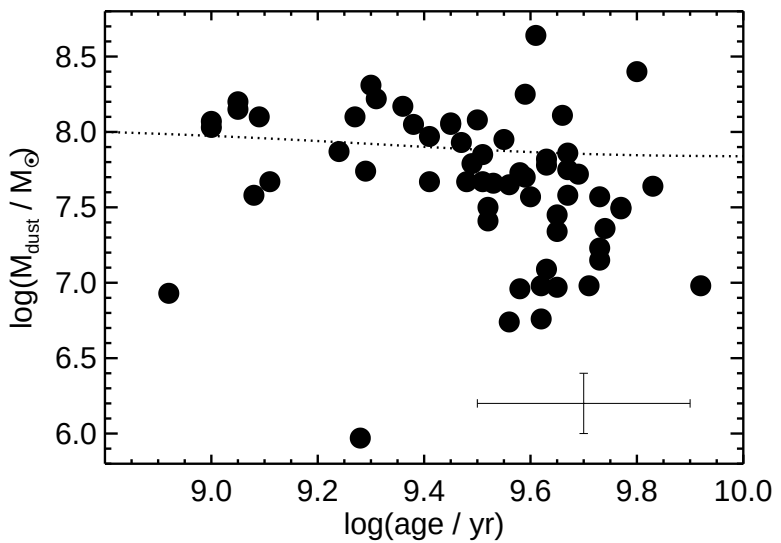
Given the stellar and dust masses of these galaxies, AGB stars did not dominate the dust production, so this is not relevant

Astration / starvation (strangulation)? NO

ISM removal flattening at higher ages due to low SFRs: NO

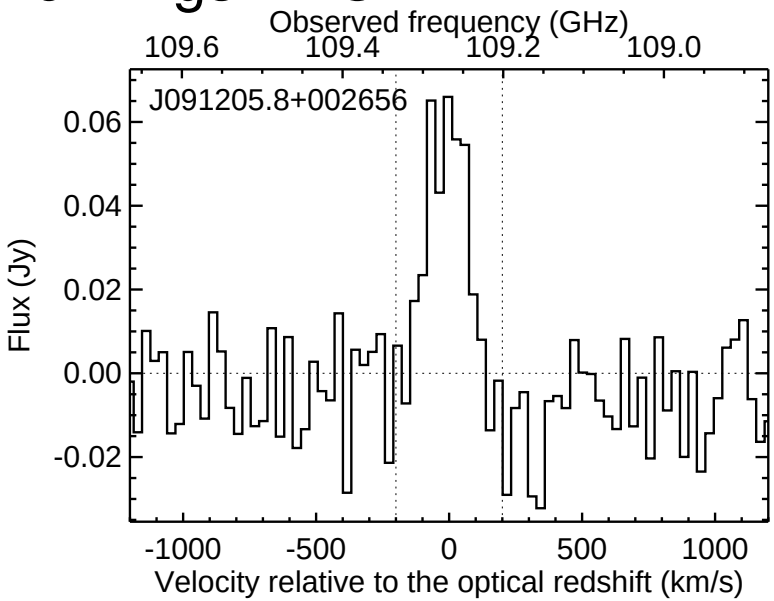




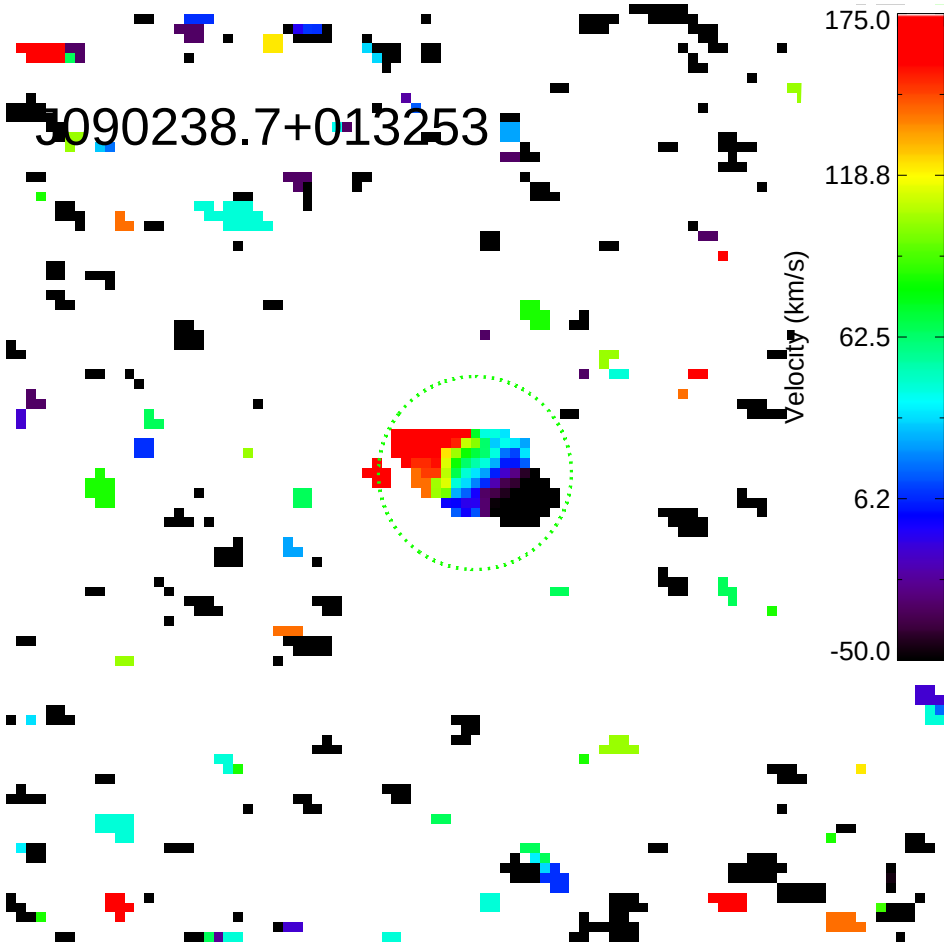


Outflows? NO

Multiple velocity peaks or broad line wings : NO

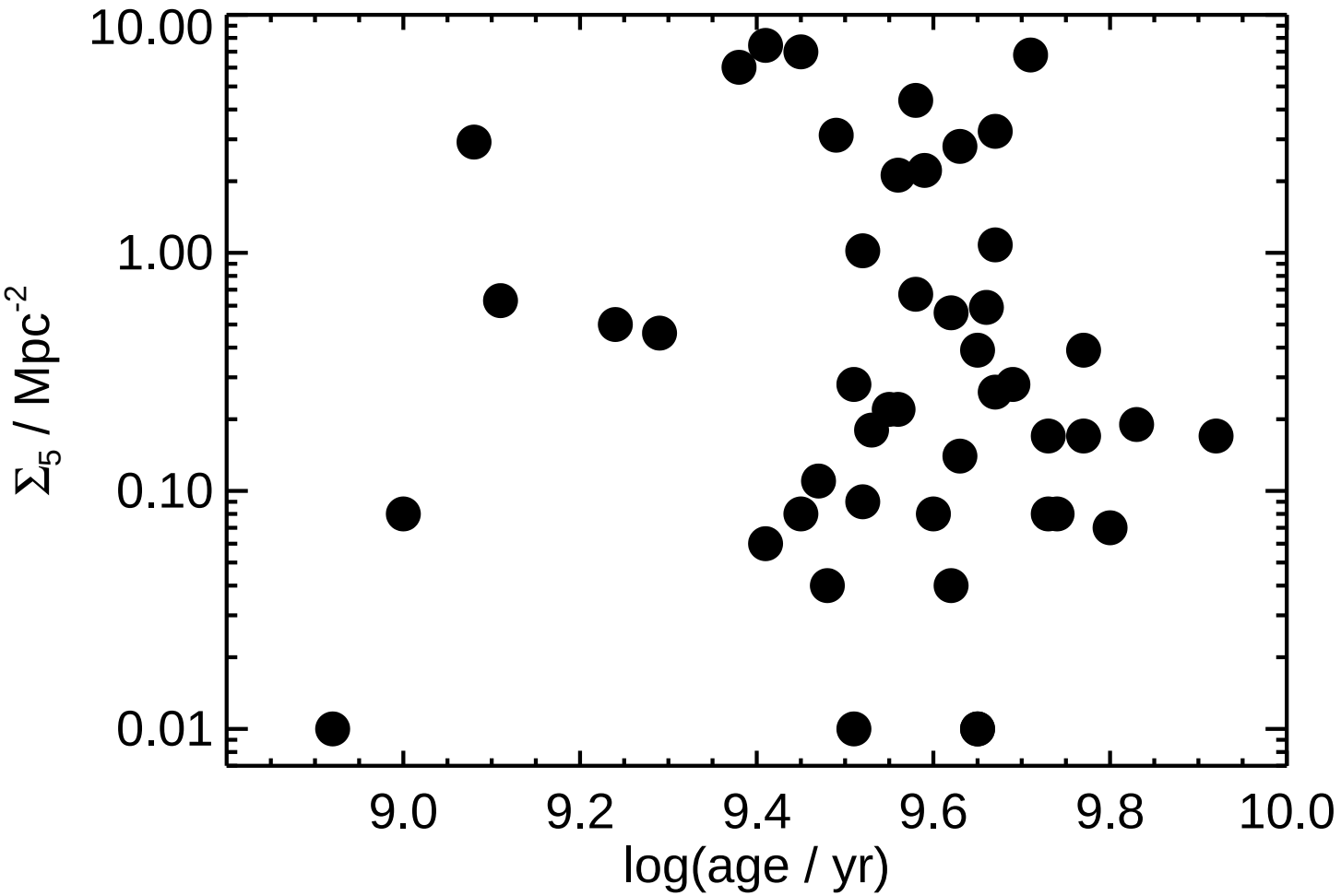


Off-centre filamentary or plume-like gas structures: NO



Environment? NO

Dependence on environment: NO



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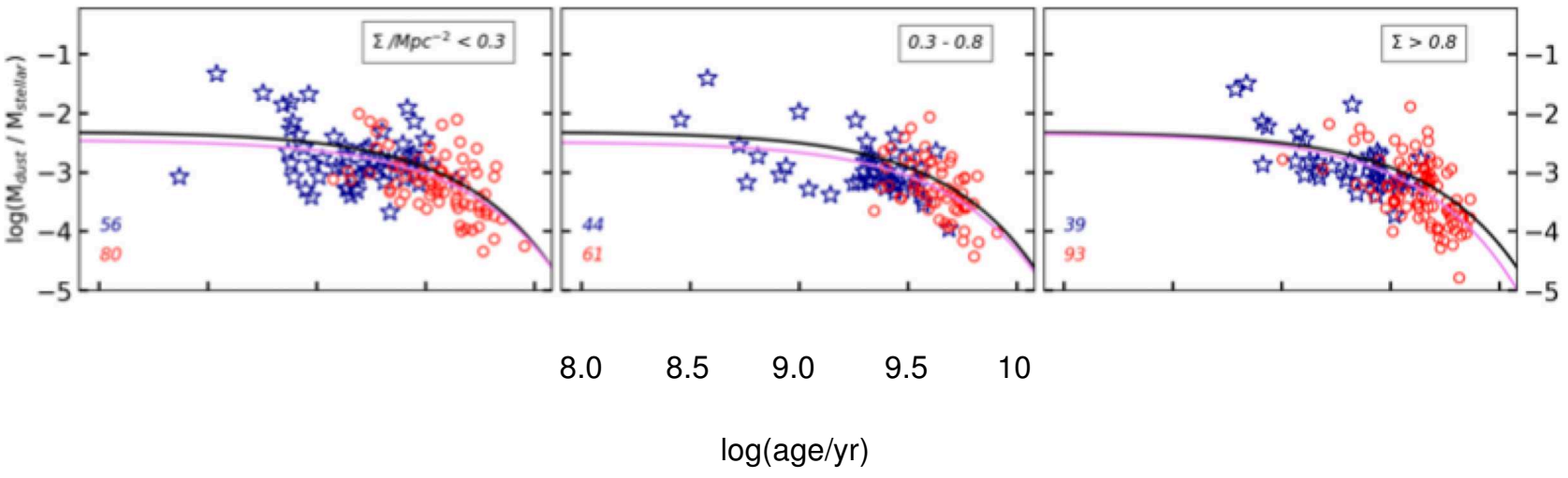
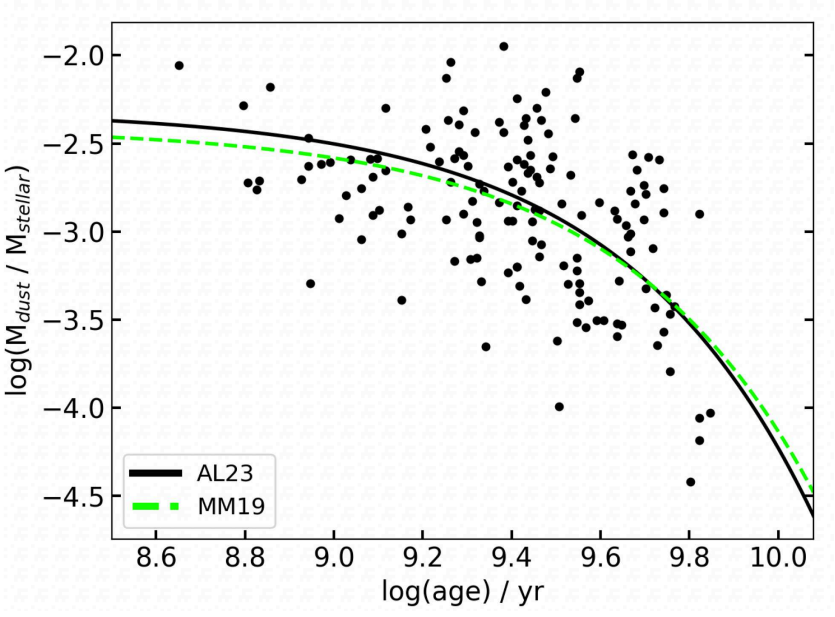


Leśniewska et al., (2023, ApJ, 953, 27)

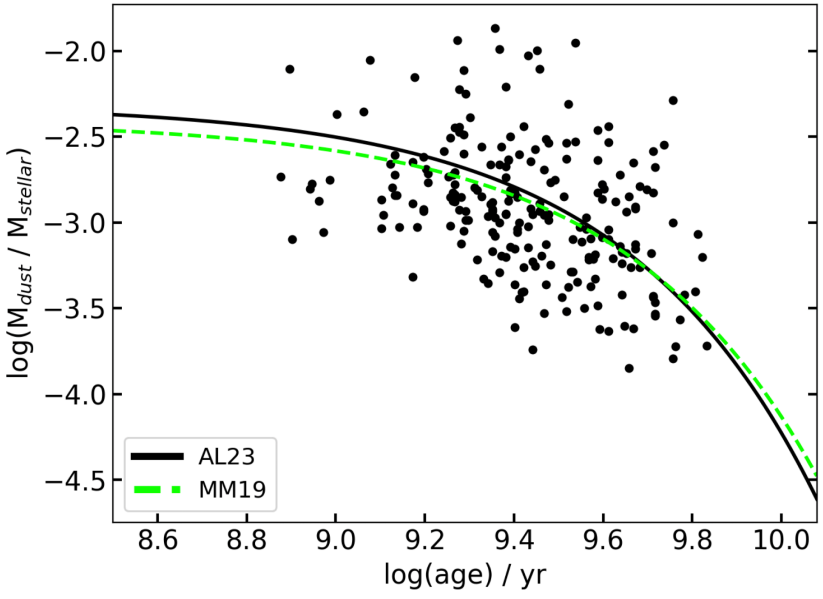
Age-stellar mass correlation? NO

ISM trend disappears for narrow ranges in stellar mass: NO

$\log(M_* / M_\odot) = 10.5$–$10.6$



$\log(M_* / M_\odot) = 10.6$–$10.7$

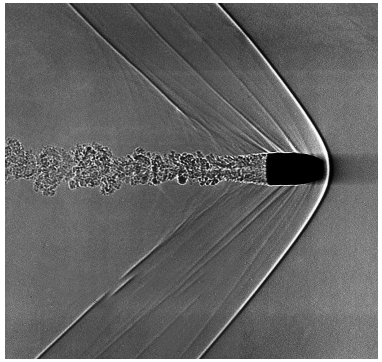


From the sample of Leśniewska et al. (2023, ApJ, 953, 27)

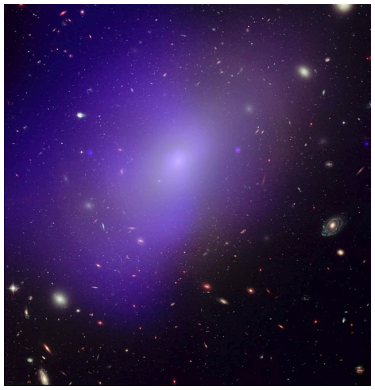
Destruction of the entire cold ISM? Yes?

Heating by planetary nebulae

Cosmic rays



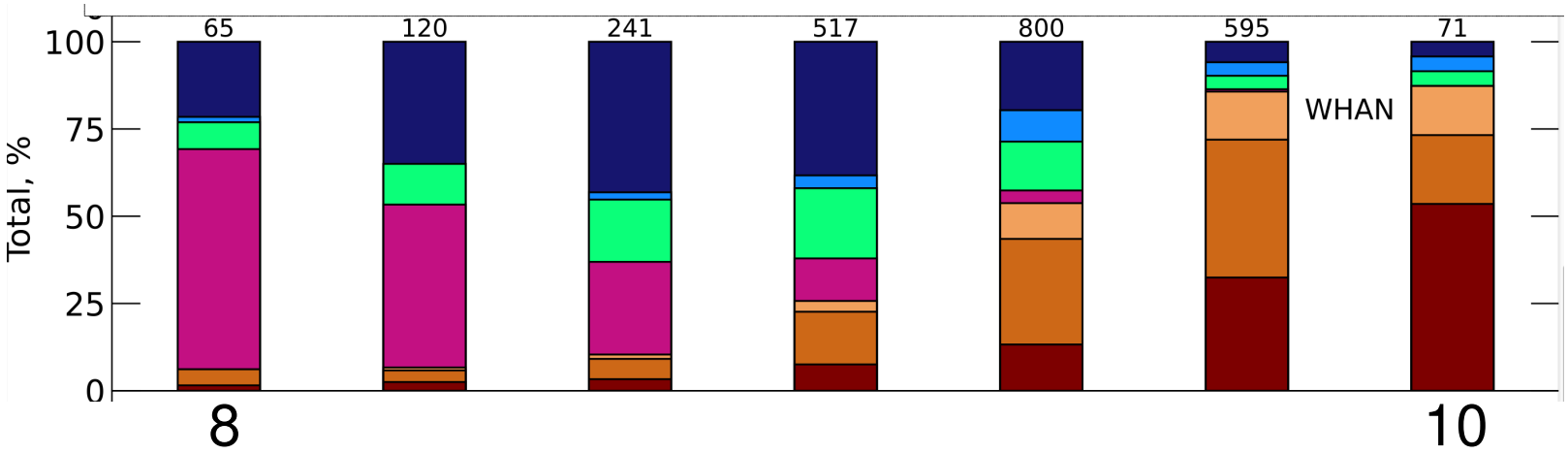
Shocks



Hot halo gas

AGN

AGN do not dominate at high ages when the decline is the fastest



Blue - AGN; Green - unclear; pink - SF; brown - passive

Ryzhov et al. (2025, ApJS, 276, 55)

What have we learnt?

- ISM removal is slow in (some) early-type galaxies
- The measured timescale may be applied to models in which it must be assumed a priori and cannot be derived
- Quenching in these galaxies is not due to running out of gas

Conclusions

- Alternative and unique method of studying ISM removal and quenching
- First direct measurement of the timescale of ISM removal
- Understanding of the ISM removal mechanism: internal (i.e. feedback from old stellar population)
- *The Fate of the Interstellar Medium in Early-type Galaxies*

dust decline	Michałowski et al. (2019, A&A, 632, A43)
morphological quenching	Leśniewska et al. (2023, ApJ, 953, 27)
gas decline	Michałowski et al. (2024, ApJ, 964, 129)
simulations	Nadolny et al. (2024, A&A, 689, A210)
AGN, BPT	Ryzhov et al. (2025, ApJS, 276, 55)

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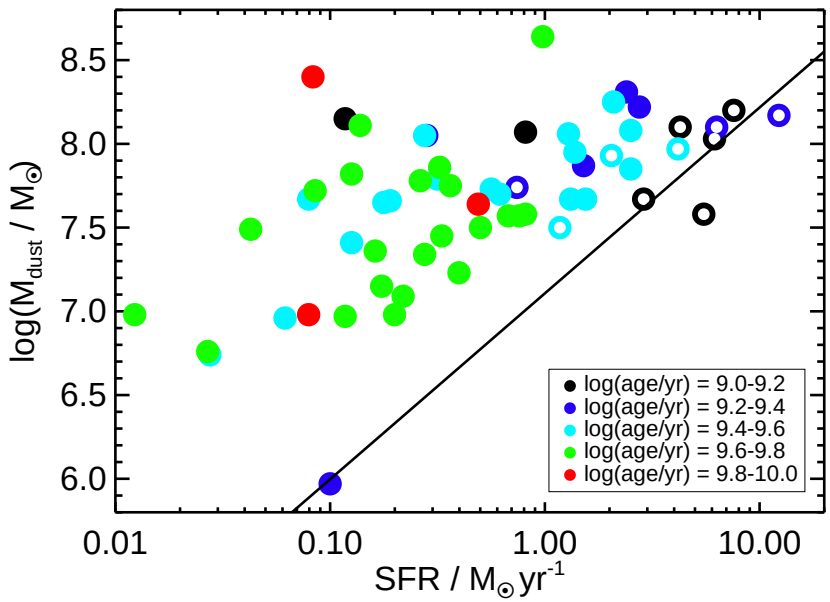
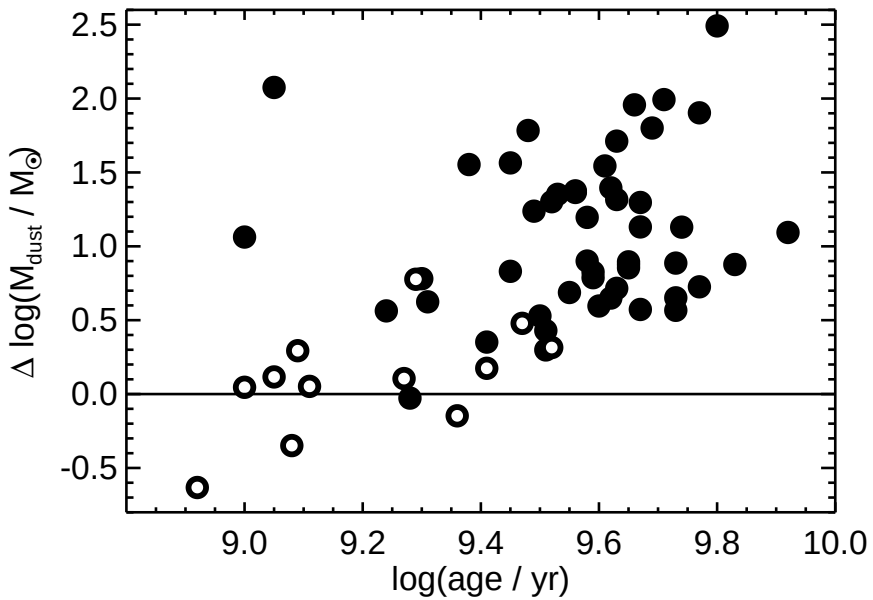
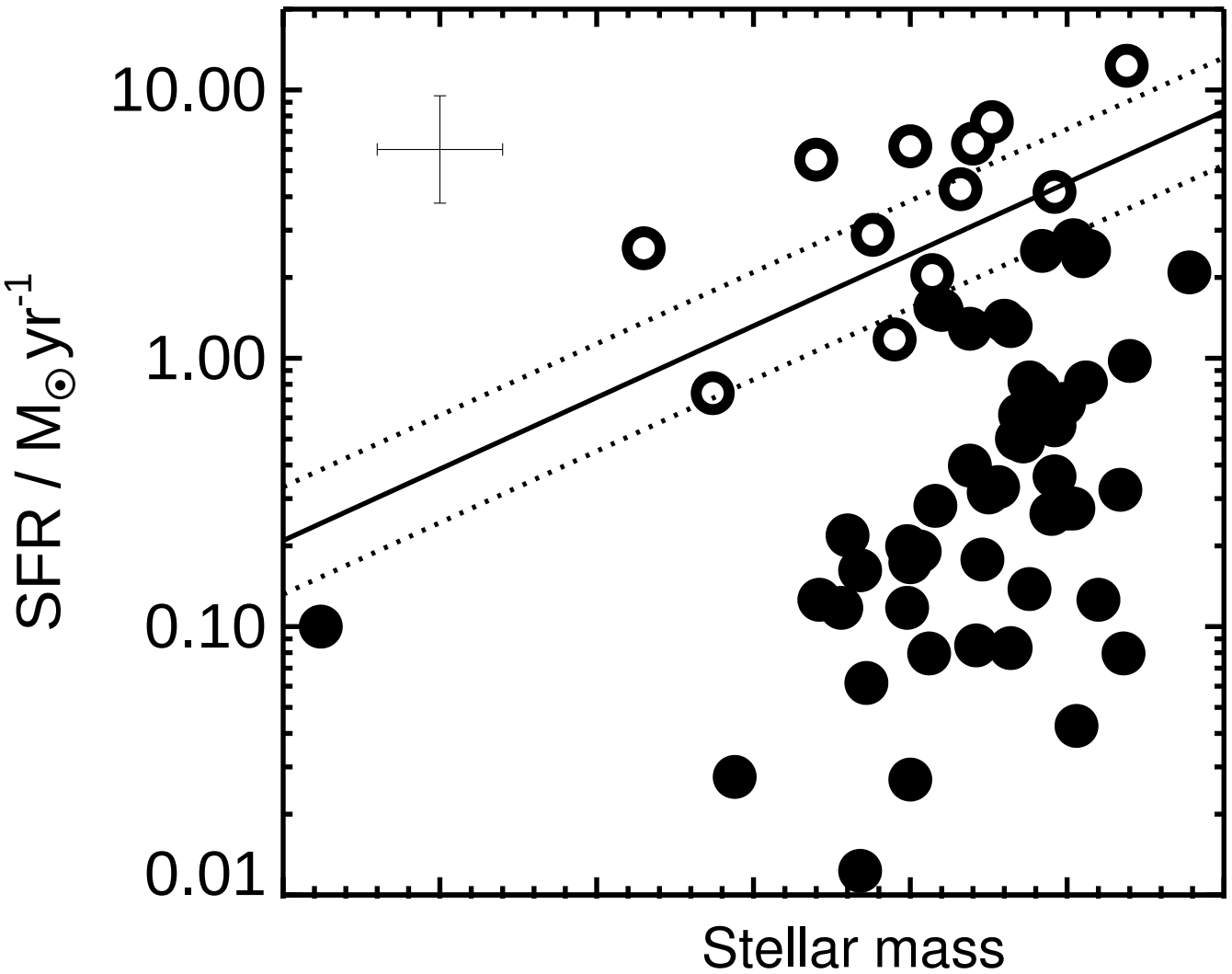
Evolution on the $M_{\rm dust}$-SFR diagram



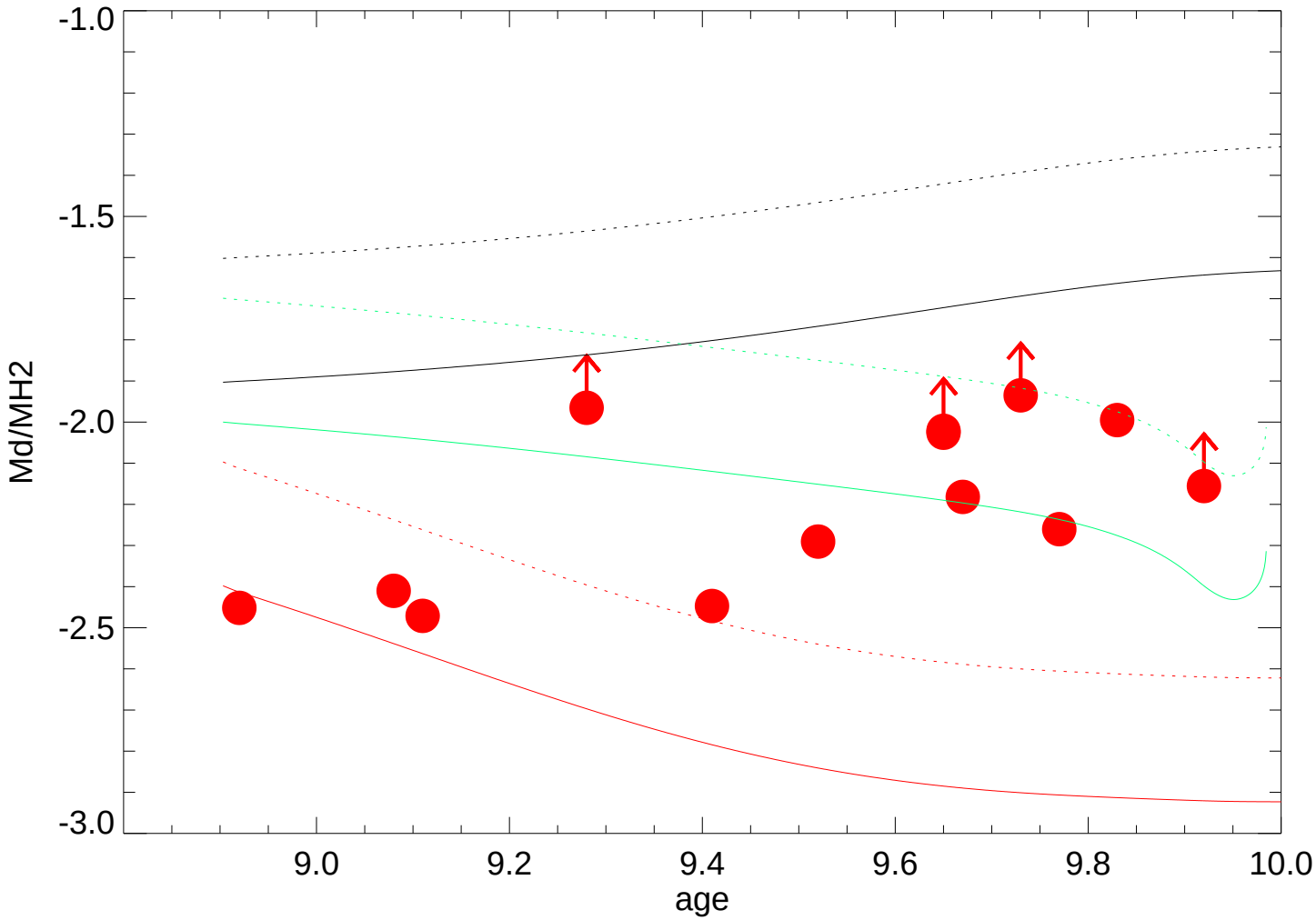


Relation to the star-formation main sequence



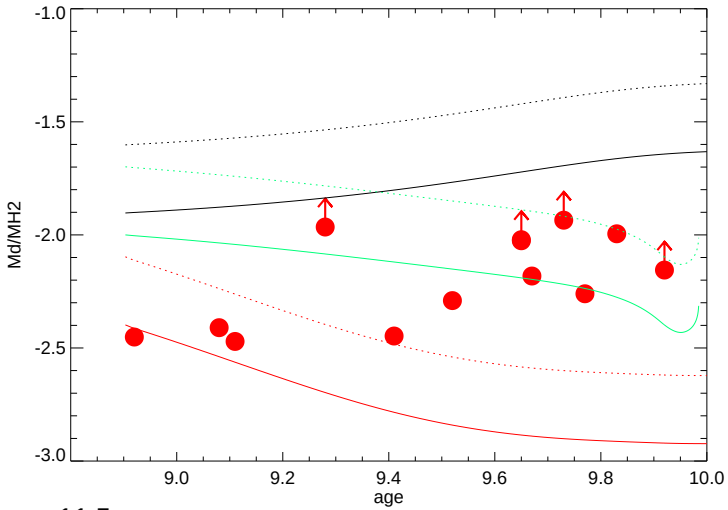
Dust grain destruction? NO

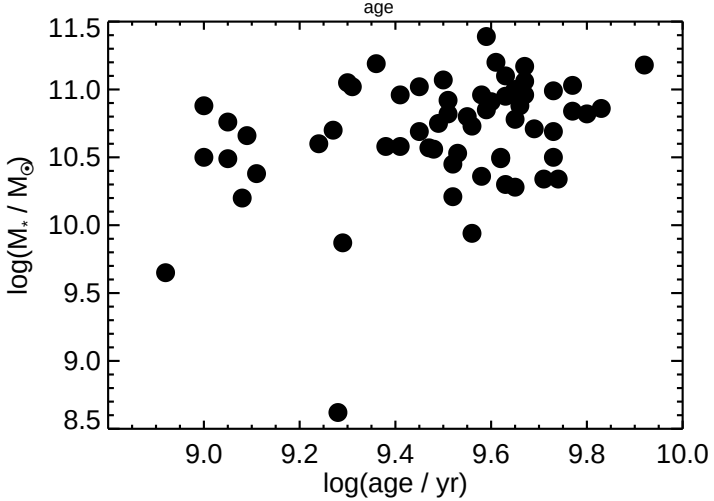
$M_{\rm dust}/M_{\rm gas}$ decreasing with age: NO



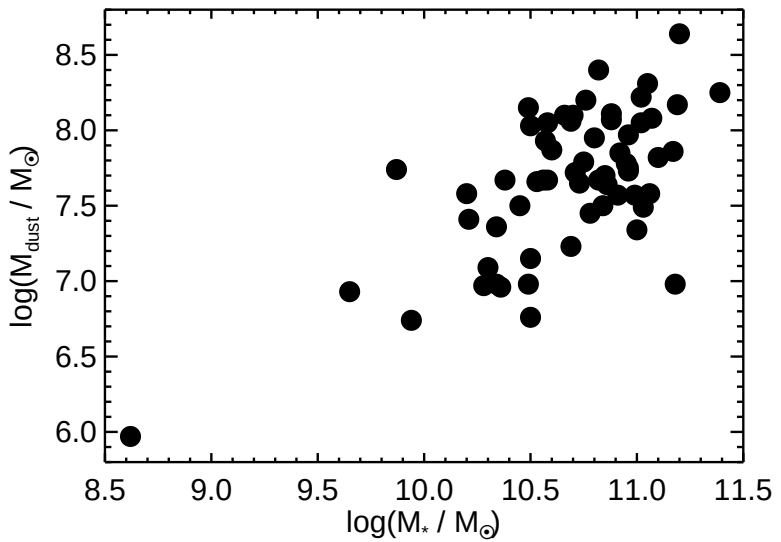
Mergers with gas-rich galaxies? NO

$M_{\rm dust}/M_{\rm gas}$ and M_* decreasing with the derived age: NO



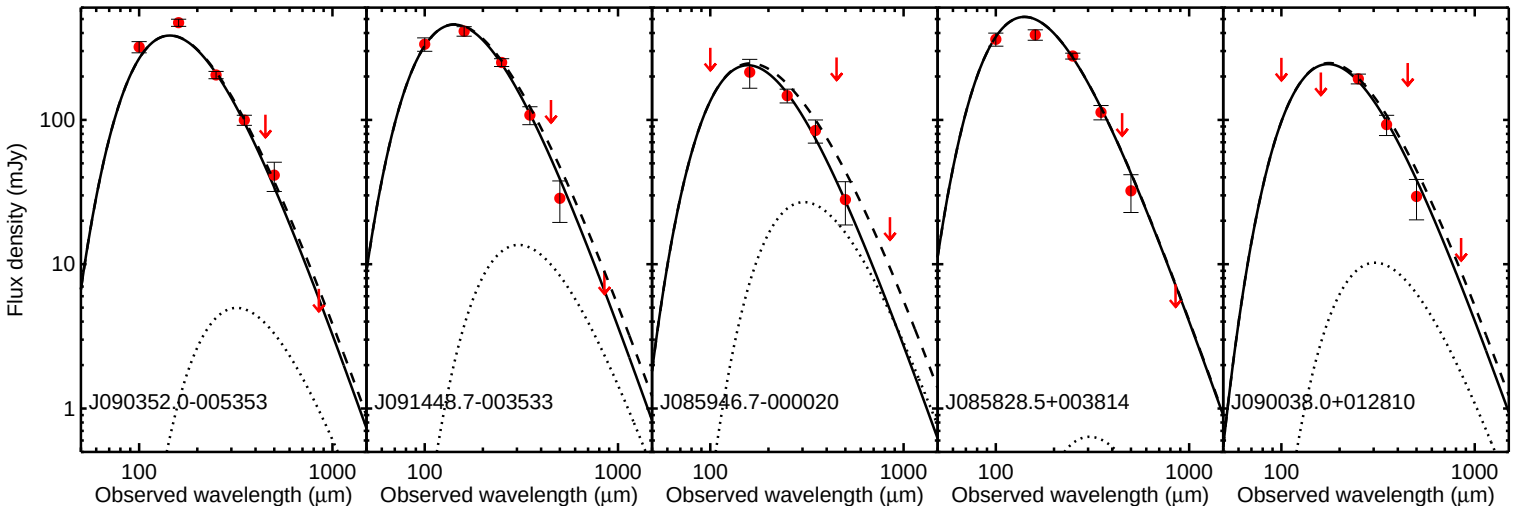


$M_{\rm dust}$ only weakly correlated with M_*: NO

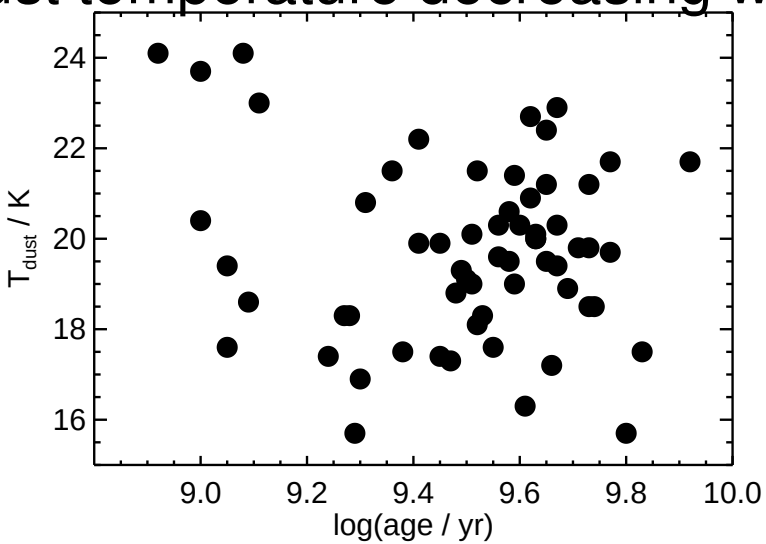


Dust cooling? NO

Submm excess (very cold gas): NO

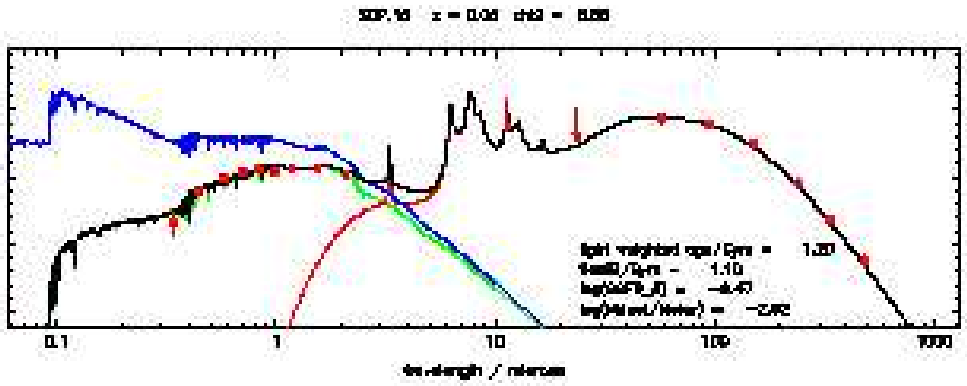


Dust temperature decreasing with age: NO

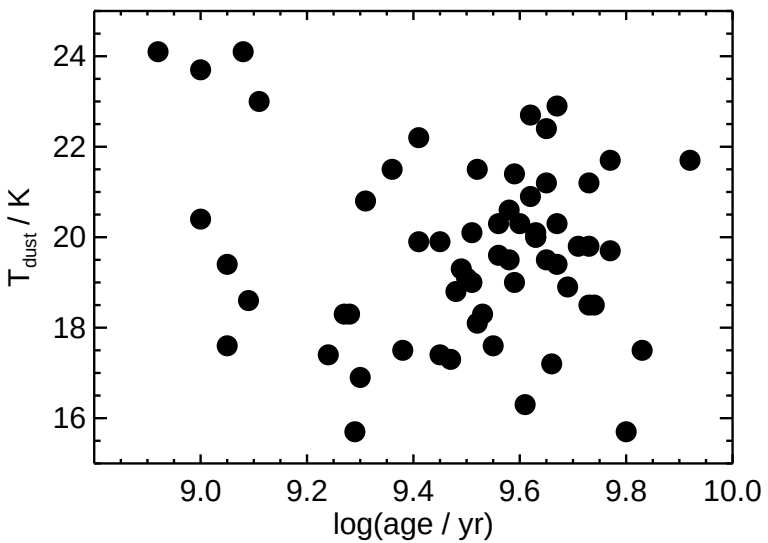


Dust heating? NO

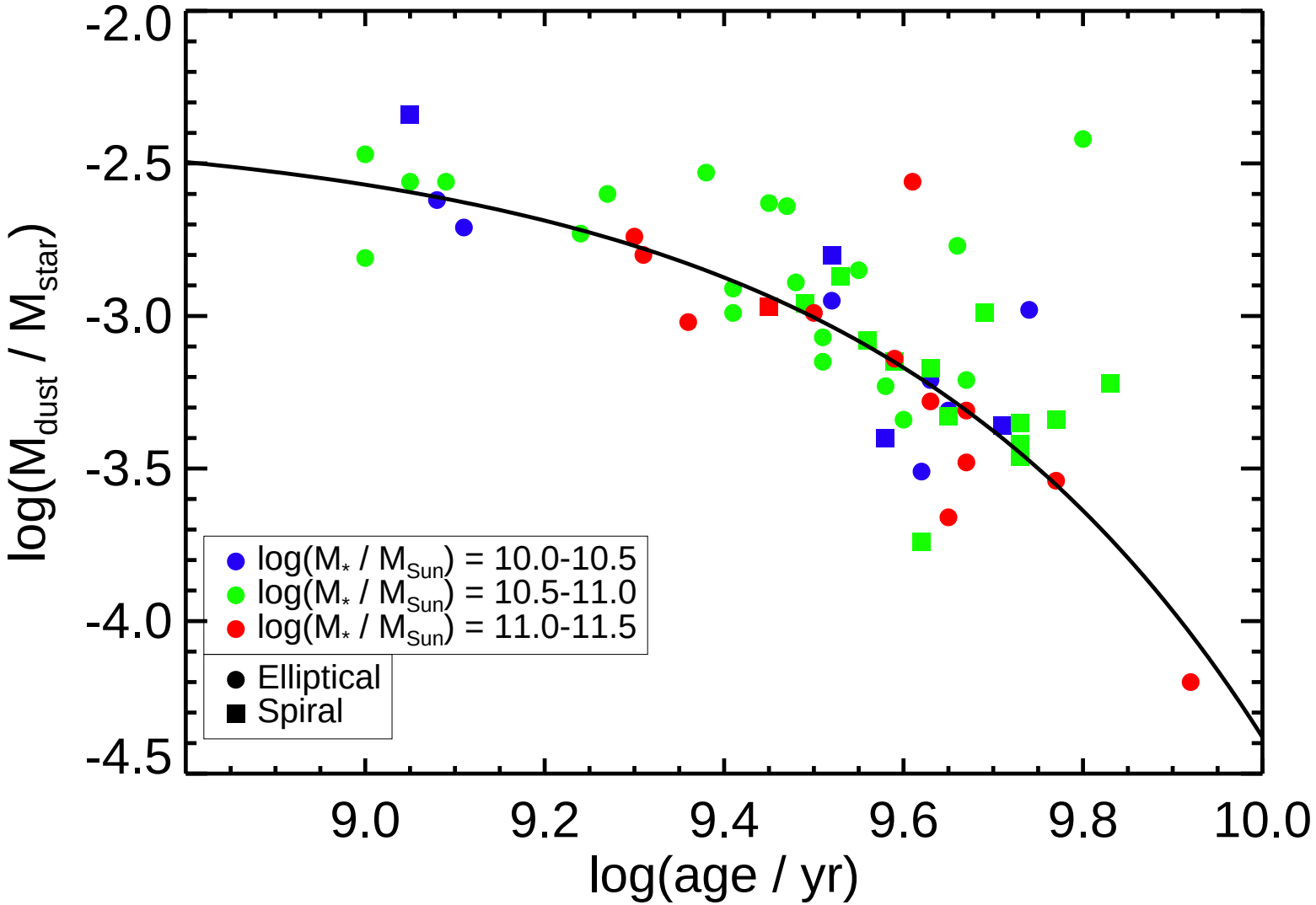
Short-wavelength peak (hot gas): NO



Dust temperature increasing with age: NO



The trend driven by mass or morphology? NO



Age - D4000 relation