Title: CEERS: Forging the First Dust – Transition from Stellar to ISM Grain Growth in the Early Universe

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Background

Nucleosynthesis started in the first stellar population formed in the Universe: population III stars (pop.III), and shortly after pop.II stars.

Supernovae (SNe) and asymptotic giant branch (AGB) stars expelled the first metals that formed the first dust grains.

More crucial is the key role played by dust when cooling the ISM to form low-mass stars.

a transition between pop.III and pop.II

Background

JWST found an unpredicted excess of UV-luminous galaxies at z>10 compared to HST-calibrated models.

a top-heavy initial mass function (IMF), or an origin related to dust: either a low dust attenuation, and/or a special dust/star morphology.

In the last decade, we have detected dusty galaxies at z > 4 with large dust masses that cannot be explained by models.

a transition from galaxies only containing stardust created by SNe and AGB stars, to galaxies where grain growth by accretion of metals in interstellar clouds becomes dominant

Sample

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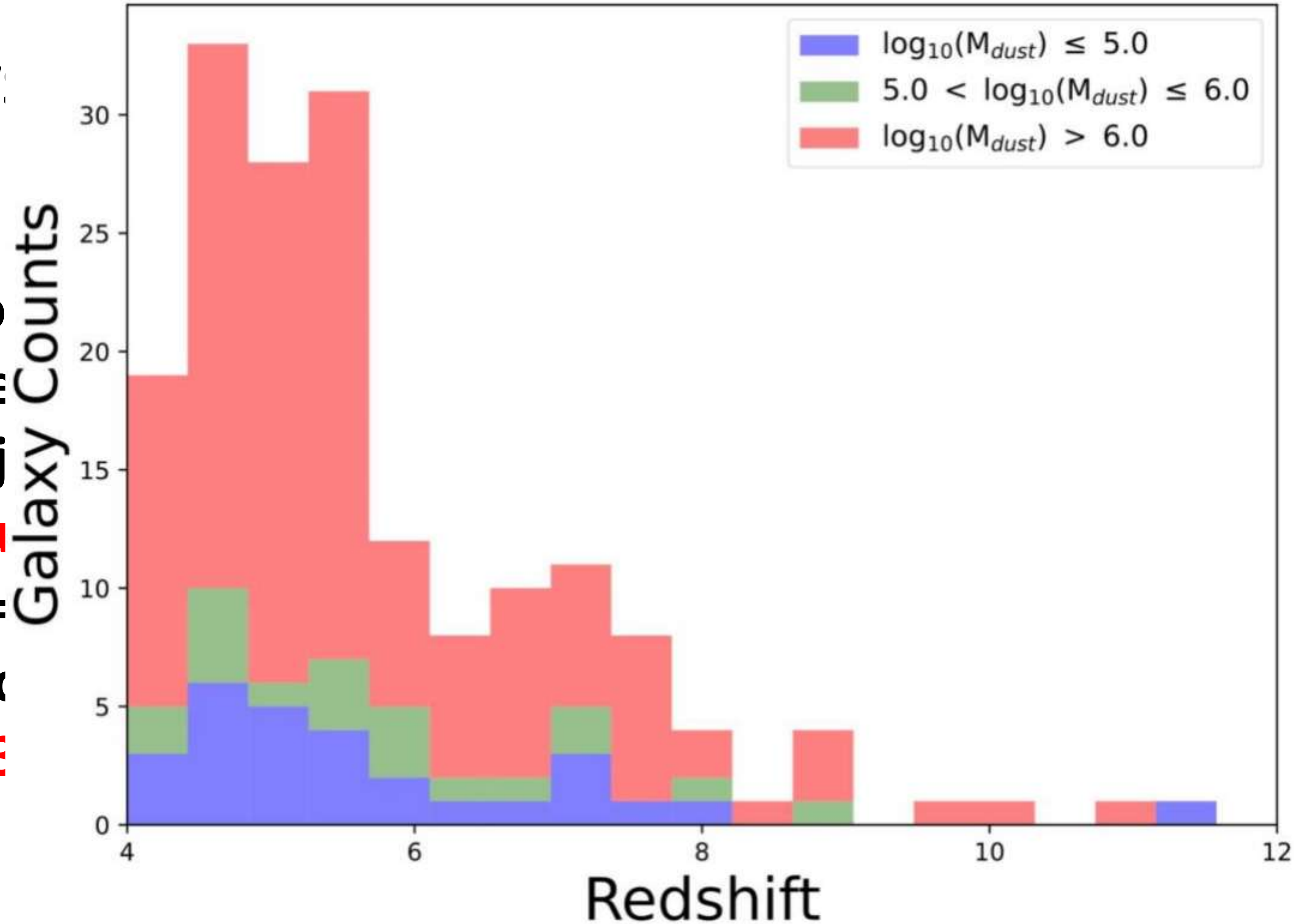


Analysis of the spectrophotometric data

build the spectral energy distributions (SEDs) using all photometric data with SNR > 1.0

Two star-formation histories (SFHs) are used to test the stability of the results: a delayed-plusburst , and a periodic one.

- The delayed SFH assumes that star formation is active over a few tens to hundreds Myrs, with a final burst.
- The periodic SFH does not assume any kind of continuous SFH. Instead, a series of bursts, separated by regular quiescent periods, is used.

Analysis of the spectrophotometric data

To estimat the dust mass for these objects, we make use of deep 450 and 850 μm SCUBA-2 and NOEMA-1.1 mm observations.

the inferred upper limits are useful to put constraints on the total IR luminosities and dust masses.

the far-IR information for this sample is limited

the ALMA-ALPINE sample presents physical properties similar to ours. We thus assume we can make use of the same best model.

The information on the amount of dust attenuation comes from the line ratios, especially Hα/Hβ when available, the UV slope βFUV, and from any available IR/sub-mm data

Analysis of the spectrophotometric data

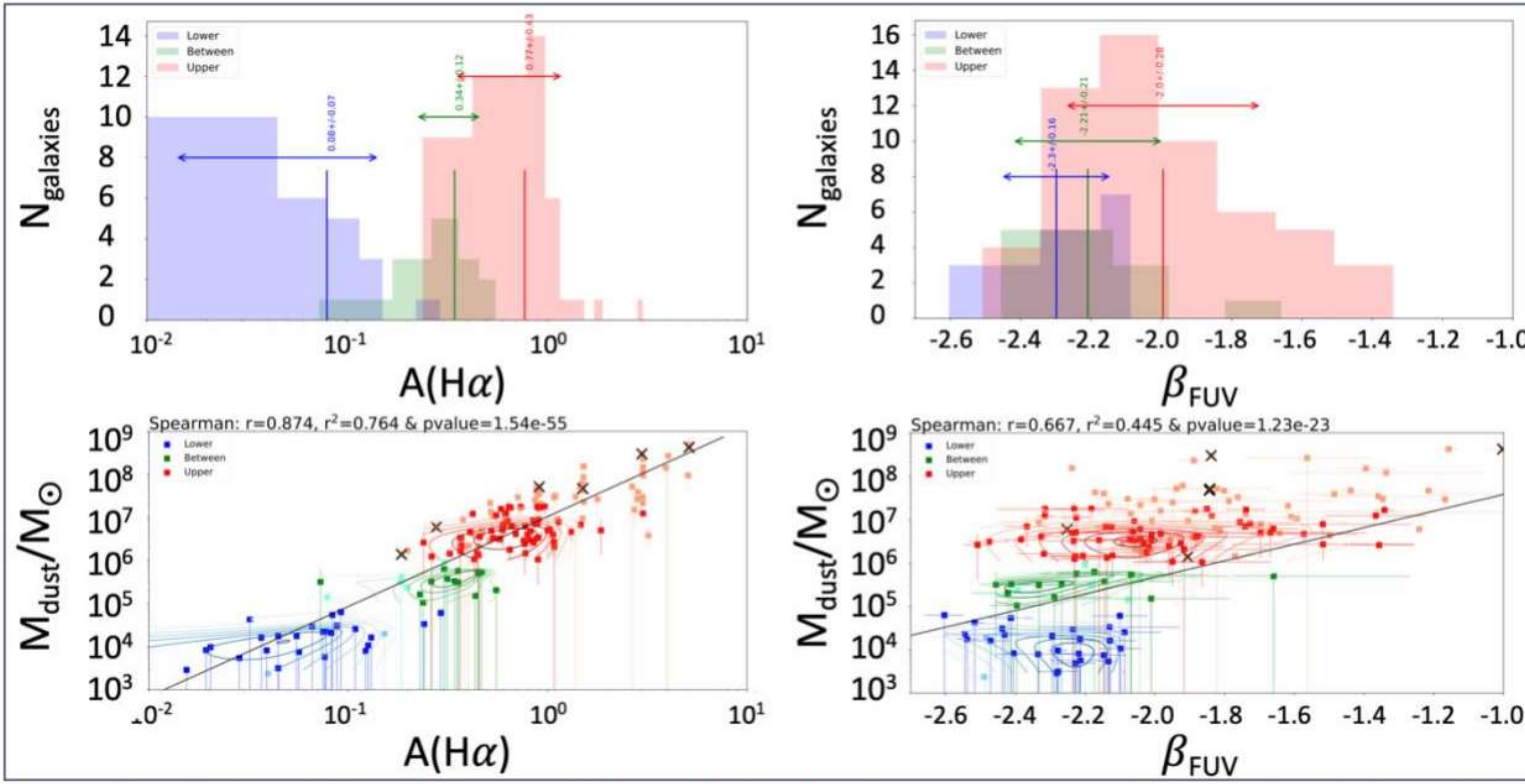
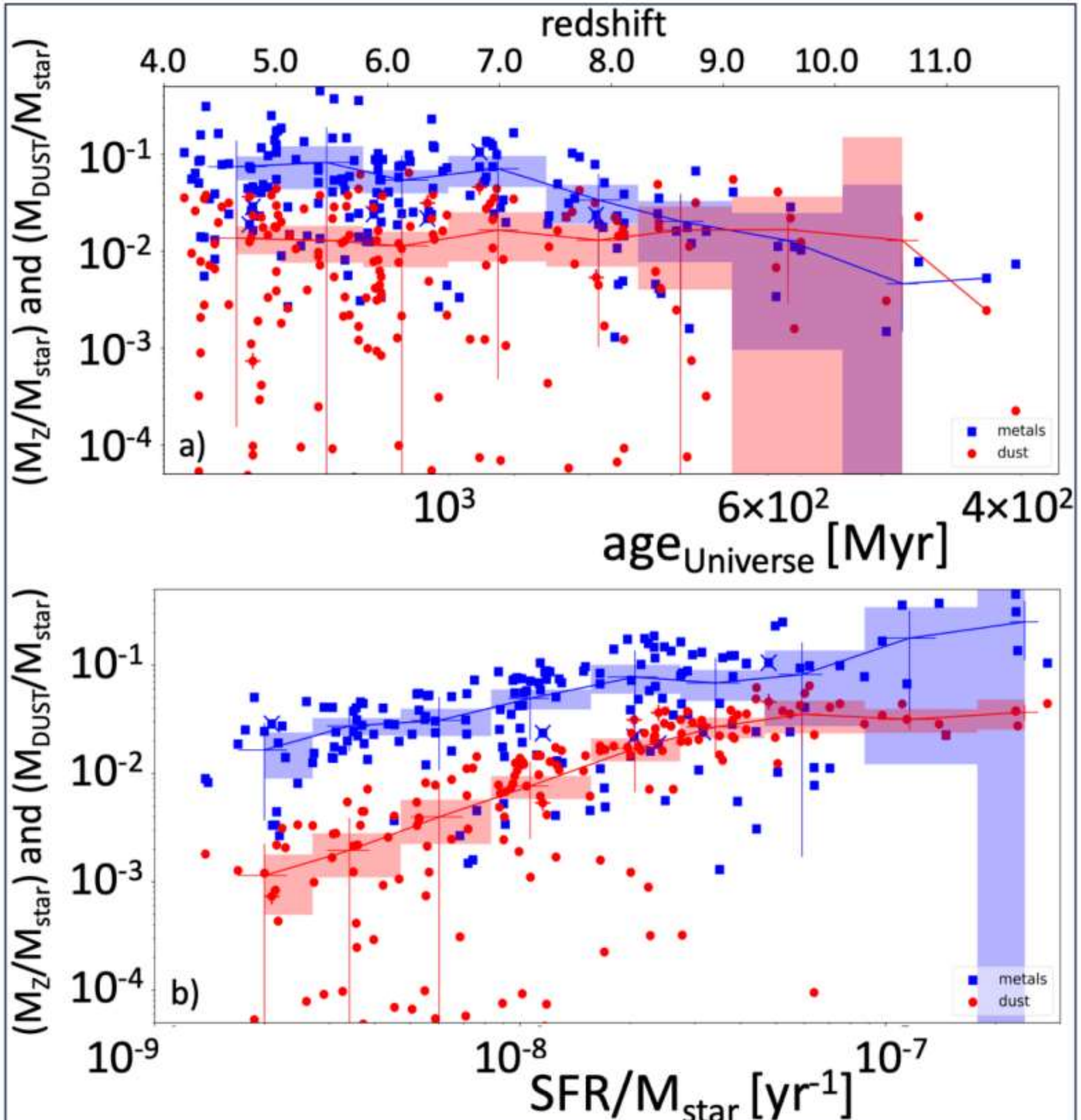
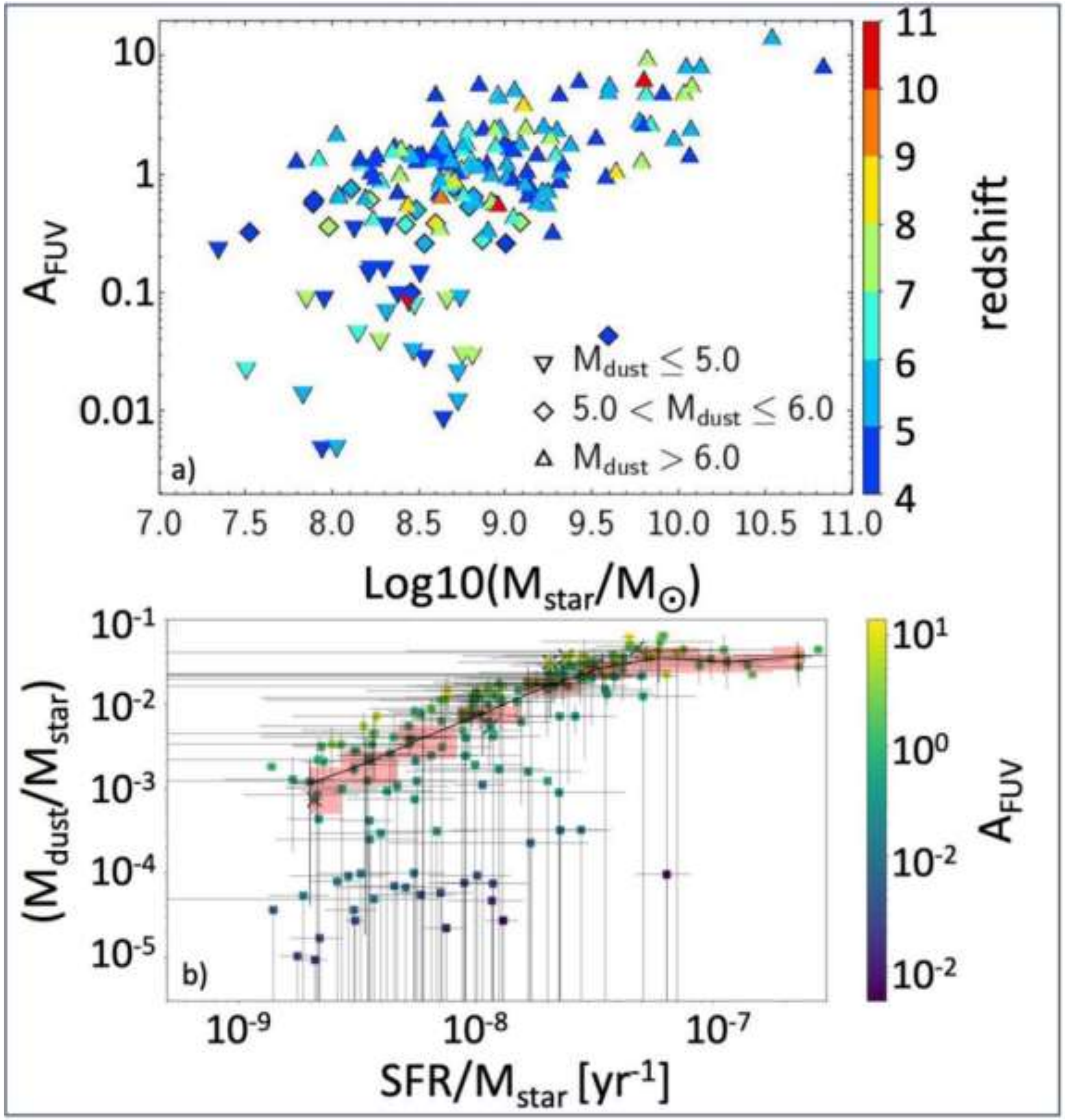


Fig. 2: Correlation of the dust mass, M_{dust} with the dust attenuation, A(Hα) and the UV slope β_{FUV}. The most relevant parameter to predict the dust mass is the dust attenuation A(Hα) derived from the Hα/Hβ Balmer decrement. The correlation with A(Hα) alone (lower left) accounts for 76% of the variation in M_{dust}, whereas the correlation with β_{FUV} alone (lower right) accounts for 44% of this variation. The other tested parameters: metallicity (~ 2%) and redshift (< 1%), but also the level of the sub-mm upper limits are not significantly correlated with M_{dust} in this analysis. The brightest H II regions in local galaxies show a correlation between the Balmer line reddening and the dust mass surface density (47, 48). Our high-redshift galaxies are small (<RH_{F200W}>=1.7±0.6 kpc) and probably dense; They might also be dominated by H II regions. The spectral information brought by NIRSpec is fundamental to estimate the dust masses.

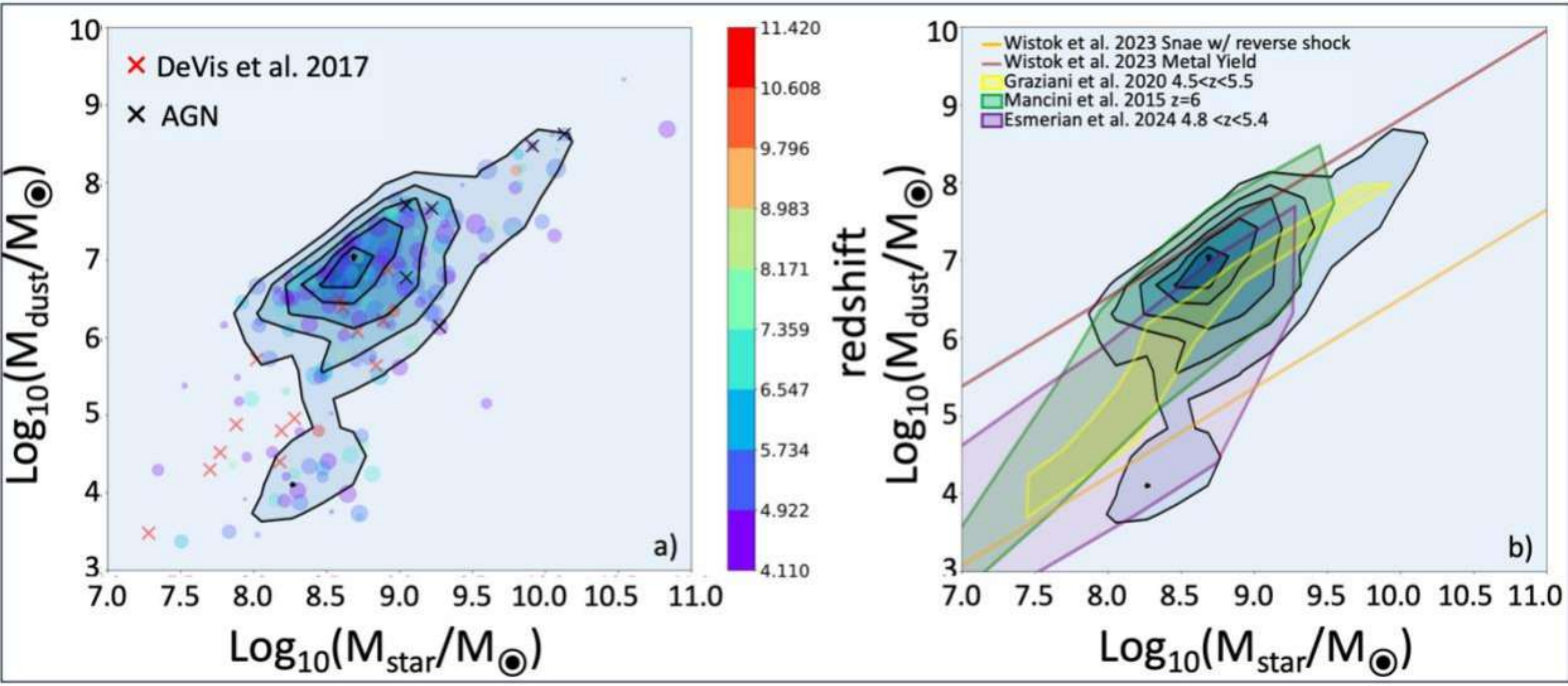
The coevolution of metals and dust, and the critical metallicity



The transition from stardust to ISM dust in galaxies



The transition from stardust to ISM dust in galaxies



The transition from stardust to ISM dust in galaxies

This population of stardust galaxies provides a natural explanation for the excess of UV-bright galaxies at z>10 detected by JWST. If the proportion of stardust galaxies increases when the redshift increases, the dust attenuation would be much lower, thus producing more UV light.

Summay

We detect a downturn in the M_{dust} vs. M_{star} diagram at $\log10(M_{star})\sim8.5$, marking the shift from dust solely produced by stellar evolution (stardust) to dust growth in the ISM of galaxies. This transition aligns with the prediction of dust evolution models.

The galaxies with low M_{dust}/M_{star} and blue UV slopes contain young, metal-poor stars that may be forming their first dust grains from Pop.II—and at $z>9$, possibly Pop.III—stars, along with their first metals.

Such stardust galaxies would be ideal suspects to produce the excess of UV-bright galaxies in the early Universe [*12*, *13*]. They might be dominant in the early Universe.

We do not detect any extremely low-metallicity values at $z>8$, suggesting either a bias in our sample, or a rapid rise of metals in the early Universe.