Bursty star formation prevents significant dust survival in radiation-hydrodynamical simulations of the first galaxies

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Recent JWST observations revealed a much larger number of UV bright galaxies at z> 10 than previously expected. A common explanation is to assume that star formation was much more bursty than assumed in these systems. I will present a systematic analysis of the dust properties in the Thesan-Zoom simulations, the only suite of radiation-hydrodynamical zoom-in simulations that naturally produces bursty star formation histories. Thesan-Zoom self-consistently models a spatially- and time-varying background UV field, a multi-phase ISM, and dust formation, growth, and destruction coupled to radiative transfer.

We find that dust is strongly time-variable and tightly linked to bursty star formation: during starbursts, young stars heat dust, and stellar feedback rapidly destroys and ejects dust from star-forming regions, while in post-burst phases low gas densities suppress efficient regrowth. This cycle yields short-lived IR-bright phases and longer dust-poor phases, naturally producing a correlation between dust temperature and distance from the star-forming main sequence. The predicted attenuation at 1500Å is very low compared to observations, although assuming that unresolved birth-cloud dust can reconcile this measurement without significantly altering global dust scaling relations.

Interestingly, the simulated galaxies reproduce the observed trends of dust-to-gas and dust-to-metal ratios with gas metallicity, while showing a dust deficit at high specific star-formation rates. They also broadly match observed dust temperatures and UV-IR spatial offsets, although their origin is physical dust displacement rather than obscured star formation.

These results imply that bursty star formation is not compatible with large dust masses over a significant fraction of cosmic time, at odds with the popular explanation of bursty star formation as the reason for the large number of UV-bright galaxies observed by JWST. Thus dust provides a sensitive diagnostic of feedback and ISM physics in early galaxies. Our results also have imply that future surveys targeting dust at z>8 (e.g., ALMA-PHOENIX) are key to unveil the physics of the first galaxies.