Rapid formation and destruction of dust in the multiphase gas of a simulated starburst

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Observations of early Universe galaxies with JWST indicate widespread and rapid formation of dust with diverse properties. We investigate dust formation in the dense interstellar medium (ISM), destruction and expulsion in a high-resolution simulation of a low metallicity merger triggered starburst. The solar mass and sub-parsec resolution simulation resolves the multi-phase ISM and follows the evolution and 'feedback' – stellar winds, HII regions, supernovae, of individual stars. We follow metal species in the gas phase, the solid phase for carbonaceous and silicate dust grains of different sizes as well as the non-steady-state chemical evolution (e.g. neutral, molecular, ionized hydrogen, CO). We find that dust grows in the dense ISM peaking at main star formation phases while gas phase metals are depleted. The onset of stellar feedback from forming star clusters initiates dust destruction by thermal and non-thermal sputtering. The variation in dust-to-gas-ratio between the cold and hot ISM increases strongly, driving considerable differences in attenuation on short time scales. Outflows are multi-phase on kpc scales and significant amounts of dust are expelled. In both formation and destruction processes grain size and grain porosity are relevant factors. For example for H_2-formation, where we utilize the dust mass and dust to gas relative velocity to improve the treatment of H_2-formation on grains surfaces, noticing a strong effect of the grain size distribution, increasing the rate coefficient by over an order of magnitude for our choice of two equal mass grans size bins compared to the previous treatment.

We discuss implications for the interpretation of JWST observations and the impact of early dust formation by supernovae. Our high-fidelity simulations, which are able to resolve the interplay of gas, stars and dust at low metallicities, are valuable tools for understanding dust properties at the early epochs of the Universe.

This work is part of an ongoing effort to implement a detailed dust evolution model in the GRIFFIN project GADGET3 SPH-code. Dust seeding by SNe, AGB stars and stellar winds is in development and the treatment of coagulation and shattering the next planned step.