X18a Dust, gas, and metal content in star-forming galaxies at $z \sim 3.3$

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Sub-mm/mm observations over the past decade revealed the dust and gas properties of not only sub-mm bright galaxies but also UV/optical-selected galaxies at high redshifts. At $z > 3$, however, the number of UV/optical-selected galaxies with individual gas measurements is still small and how the gas properties of galaxies evolve at $z > 3$ is not conclusive yet. We conducted sub-mm observations with ALMA of 12 star-forming galaxies at $z \sim 3.3$ with the individual gas-phase metallicity measurements. We investigate the dust and gas masses of the galaxies at $z > 3$. We then study how galaxies are interacting with their circumgalactic/intergalactic medium at this epoch by probing their gas mass fractions and gas-phase metallicities. We find that the estimated gas mass fractions and gas depletion timescales show a wider spread at a fixed stellar mass than expected from the scaling relations. This result suggests a diversity of fundamental gas properties among star-forming galaxies on the main sequence. Comparing gas mass fraction and gas-phase metallicity between our sample and samples at lower redshifts from the literature, star-forming galaxies at $z \sim 3.3$ appear to be more metal-poor than local galaxies with similar gas mass fractions. Using the gas regulator model, we find that this offset can be explained with the model tracks assuming higher mass-loading factors, which suggests that the mass-loading factor in outflows increases at earlier cosmic times.