X39a Radiative-driven dusty outflows by compact $z > 10$ galaxies

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JWST has observed several galaxies at redshifts exceeding 10. The observed UV luminosity function at $z \gtrsim 10$ suggests an overabundance of UV-bright ($M_{\rm UV} \lesssim -20$) and massive galaxies in comparison to pre-JWST theoretical predictions. Several scenarios can explain this discrepancy, one of which is the negligible dust attenuation due to outflows (e.g., Ferrara+23, 24). The condition of outflow requires the system to be super-Eddington (i.e., Eddington ratio $\lambda_{\rm E} \geqq 1$). However, the classical Eddington luminosity does not account for radiation pressure by dust and the gravity of surrounding gas, making it inapplicable to galaxy systems.

In this study, we calculate the modified Eddington luminosity by setting parameters such as gas column density, stellar mass, and metallicity (a total of nine parameters) to reproduce $z > 10$ galaxy environments. We introduce a boost factor A as a ratio of the modified Eddington luminosity to the classical one. As a result, we find that the modified Eddington luminosity decreases by a factor of $A \sim 2000(Z/Z_\odot)$ at $N_{\rm H} \gtrsim 10^{21}{\rm cm}^{-2}$. This is because dusty gas is optically thick and A can be expressed as the product of the dust-to-gas ratio and the cross-section ratio of dust to Thomson scattering ($A \sim \mathcal{D}\sigma_{\rm d}/\sigma_{\rm T}$). We apply this formula to $z > 10$ simulated galaxies and evaluate the modified Eddington ratio. The obtained results suggest that galaxies might have experienced a super-Eddington phase before the observed period.