Large Population of ALMA Galaxies at $z \geq 6$ with Very High [OIII]88μm to [CII]158μm Flux Ratios

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Abstract

We present our new ALMA observations targeting [OIII]88μm, [CII]158μm, [NII]122μm, and dust continuum emission for three Lyman break galaxies at $z=6.0293$-$6.2037$ identified in the Subaru/Hyper Suprime-Cam survey. We clearly detect [OIII] and [CII] lines from all of the galaxies at 4.3-11.8σ levels, and identify multi-band dust continuum emission in two of the three galaxies, allowing us to estimate infrared luminosities and dust temperatures simultaneously. In conjunction with previous ALMA observations for six galaxies at $z \geq 6$, we confirm that all the nine $z=6$-$9$ galaxies have high [OIII]/[CII] ratios of $L_{\text{[OIII]}}/L_{\text{[CII]}} \sim 3$-$20$, $\sim 10$ times higher than $z \sim 0$ galaxies. We carefully investigate physical origins of the high [OIII]/[CII] ratios at $z=6$-$9$ using Cloudy, and find that high density of the interstellar medium, low C/O abundance ratio, and the cosmic microwave background attenuation are responsible to only a part of the $z=6$-$9$ galaxies. Instead, the observed high [OIII]/[CII] ratios are explained by 10-100 times higher ionization parameters or low photodissociation region (PDR) covering fractions of 0-10%, both of which are consistent with our [NII] observations.

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