Tracing metals beyond redshift 8 with ALMA

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Abstract

Forming a complete picture of star-formation through cosmic time is one of the main challenges of galaxy evolution studies. Our current understanding of star-formation at high redshifts ($z > 7$) is mostly formed through rest-frame ultraviolet (UV) observations of Lyman-Break Galaxies (LBGs), which directly probe their stellar light and ionized hydrogen. Complementary to this, ALMA has detected UV-selected high-redshift galaxies in sub-mm colours, tracing dust-obscured regions and far-infrared spectral lines (e.g. [OIII] at 88 micron) out to redshifts around 8 to 9. One such galaxy is the Y-dropout galaxy, MACS0416_Y1, where a previous ALMA detection of [OIII] (and dust continuum) confirmed its spectroscopic redshift to be $z = 8.312$. Modeling of its UV-to-FIR spectrum suggests both a young (age $\lesssim 4$ Myr) and old stellar component ($z \lesssim 14$) in a moderately high metallicity ($Z \lesssim 0.2$ Zsun) LBG. We continue this work with the highest-redshift detection of the [CII] 158 micron line to date in MACS0416_Y1 using ALMA. Its high [OIII]-to-[CII] luminosity ratio ($\sim 9$) implies a strong inter-stellar radiation field, and the [CII] velocity profile suggests a rotation-dominated system. Surprisingly, we fail to detect the dust continuum emission at 160 micron rest-frame, suggesting an extremely high dust temperature ($T_{\text{dust}} > 80$K), which implies that recent ALMA studies might have significantly over-estimated dust-masses in the Early Universe. Both the high [OIII]-to-[CII] ratio and dust temperature point to unusual star-forming environments existing within the Epoch of Reionization, which we explore further by comparing to other low- and high-redshift galaxies and results from hydrodynamic, dust formation and photoionization models.

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