Deep and wide-field submillimeter surveys have uncovered dust-obscured star-forming galaxies at high redshift (referred to as submillimeter galaxies; SMGs). SMGs have intense star-forming activity with star-formation rates (SFRs) of a few 100–1000 $M_{\odot}$ yr$^{-1}$, which could be triggered by gas-rich galaxy mergers. SMGs and local ultra-luminous infrared galaxies are known to be on the same relation on the molecular gas mass–far infrared (FIR) luminosity plane ($M_{\text{H}_2}$–$L_{\text{FIR}}$) or molecular gas surface density–SFR surface density plane ($\Sigma_{\text{H}_2}$–$\Sigma_{\text{SFR}}$), so-called ‘burst sequence’ high above that of ‘normal’ star-forming galaxies at local and $z \sim 1–3$ universe. In order to investigate the star-forming properties of SMGs, spatially resolved observations of molecular gas are essential. However, only a handful of studies exists due to the limited spatial resolution and sensitivity of existing instruments.

We studied spatially-resolved properties of molecular gas and dust in a gravitationally-lensed SMG H-ATLAS J090311.6+003906 (SDP.81) at $z = 3.042$ revealed by the Atacama Large Millimeter/submillimeter Array (ALMA) [1]. We identified 14 molecular clumps in the CO(5–4) line data. The surface density of molecular gas and star-formation rate of the clumps are more than three orders of magnitude higher than those found in local spiral galaxies (Figure 1). The clumps are placed in the ‘burst’ sequence in the $\Sigma_{\text{H}_2}$–$\Sigma_{\text{SFR}}$ plane, suggesting that $z \sim 3$ molecular clumps follow the star-formation law derived for local starburst galaxies. With our gravitational lens model [2], the positions in the source plane are derived for the molecular clumps, dust clumps, and stellar components identified in the Hubble Space Telescope image. The molecular and dust clumps are confined within a ~2 kpc region, while the spatial extent of the stellar components is as large as ~6 kpc and offset toward the west. The molecular clumps have a systematic velocity gradient in the north-south direction, which may indicate a rotating gas disk. One possible scenario is that the components of molecular gas, dust, and stars are distributed in a several-kpc scale rotating disk, and the stellar emission is heavily obscured by dust in the central star-forming region. Alternatively, SDP.81 can be explained by a merging system, where dusty starbursts occur in the region where the two galaxies collide, surrounded by tidal features traced in the stellar components.

References