ADF22-WEB: Massive galaxy formation shaped by cosmic web filaments in the z = 3.1 proto-cluster core

○梅畑 豪紀[1] 中西 康一郎[2, 3] 廿日出 文洋[2, 3] 久保 真理子[4] 田村 陽一[1] 萩本 将都[1] ADF22-WEB Team[5] (1.名古屋大学 2.国立天文台 3.総合研究大学院大学 4.関西学院大学)

We present a comprehensive census of dust, molecular gas, and galaxy structure in 18 dusty star-forming galaxies (DSFGs) at $z = 3.09$ embedded in Lyα-traced cosmic web filaments in the core of the SSA22 proto-cluster, based on multi-band ALMA observations, JWST imaging, and CO(1–0) measurements with JVLA. Using up to six-band ALMA photometry combined with Herschel/SPIRE data, we construct rest-frame far-infrared spectral energy distributions. The DSFGs exhibit relatively low dust temperatures, with a median Td = 25K. For eight DSFGs with high-resolution ($\sim$ 1 kpc) JWST and ALMA imaging, we measure stellar and dust surface densities and find a positive correlation, suggesting that structural compaction of the stellar component proceeds together with that of the interstellar medium. We report 12 detections of CO(1–0), 18 of CO(3–2), four each of CO(8–7) and CO(9–8), and one of CO(12–11). The median brightness temperature ratio between CO(3–2) and CO(1–0) is r31 = 0.66, consistent with field galaxies at similar redshifts. Comparison between dust-based gas masses and CO(1–0) luminosities suggests CO-to-molecular gas conversion factors similar to those adopted for main-sequence galaxies. The high-J CO lines show relatively low excitation, and the CO(8–7)/CO(3–2) ratio correlates with star-formation rate surface density, suggesting that molecular gas excitation is primarily regulated by star formation. Lower-mass galaxies show excess molecular gas fractions and depletion times relative to field scaling relations. By combining quiescent galaxy samples in the same field, we identify a sequence from gas-rich systems with low stellar surface density to gas-poor, compact systems with high stellar surface density. These results suggest that massive galaxy evolution in dense environments is governed by a baryon cycle linking gas supply, star formation, and structural transformation within the cosmic web environment.