X33a High-resolution ALMA observations of the brightest unlensed SMGs II: Finding a gravitationally unstable gas disk in an extreme star-forming galaxy at $z = 4.3$

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We have made $0''.08$-resolution (550 pc) observations of CO (4-3) emission line in an extreme starburst galaxy at $z = 4.3$, COSMOS-AzTEC-1, using ALMA. The high-quality ALMA maps of CO, 3.2 mm, 860 μm continuum emission independently reveal clumpy structures in the central 2 kpc region. The CO velocity field indicates that the underlying component is a rotation-dominated disk with a rotation velocity-to-velocity dispersion ratio of 3.1 ± 0.1. We have also successfully detected the galaxy-integrated emission of [C I] (1-0) and (2-1) lines to determine the total molecular gas mass in AzTEC-1. Exploiting the kinematic properties and the spatial distribution of molecular gas mass surface density, we find a strong evidence that the starburst disk is gravitationally unstable, implying that the self-gravity of gas overcomes the differential rotation and the internal pressure by stellar radiation feedback. The observed molecular gas would be consumed by star formation in a timescale of 100 million years, that is comparable to those in merging starburst galaxies. Our results suggest that the most extreme starburst in the early Universe originates from efficient star formation due to a gravitational instability in the central 2 kpc region.