X75a ADF22-WEB: A giant barred spiral starburst galaxy in the z = 3.1 SSA22 protocluster core

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In the present-day universe, the most massive galaxies are ellipticals located in the cores of galaxy clusters, harboring the heaviest super-massive black holes (SMBHs). However the mechanisms that drive the early growth phase and subsequent transformation of these morphology and kinematics of galaxies remain elusive. Here we report (sub)kiloparsec scale observations of stars, gas, and dust in ADF22.A1, a bright dusty starburst galaxy at $z = 3.1$, hosting a heavily obscured active galactic nucleus and residing in a proto-cluster core. ADF22.A1 is a giant spiral galaxy with the kinematics of a rotating disk with rotation velocity $V_{\rm rot} = 530 \pm 10\,{\rm km\,s^{-1}}$ and diameter $> 30\,{\rm kpc}$. The high specific stellar angular momentum of this system, $j_* = 3400 \pm 600\,{\rm kpc\,km\,s^{-1}}$, requires a mechanism to effectively spin-up ADF22.A1, indicating the importance of accretion from the cosmic web to supply both gas and angular momentum to the galaxy. At the core, gas flows along dust lanes in a bar connected with the bright dusty core and the estimated mass ratio of a bulge to SMBH matches the local relation, suggesting that bars are a key mechanism to shape the early co-evolution of these components. Comparison with cosmological simulations shows that ADF22.A1 will likely evolve into a massive elliptical at the present day, experiencing a significant reduction in angular momentum.