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ALMA 400 pc Imaging of a $z = 6.5$ Massive Warped Disk Galaxy

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ABSTRACT

We present $0\farcs075$ ($\approx$400 pc) resolution ALMA observations of the [C II] and dust continuum emission from the host galaxy of the $z = 6.5406$ quasar, P036+03. We find that the emission arises from a thin, rotating disk with an effective radius of $0\farcs21$ (1.1 kpc). The velocity dispersion of the disk is consistent with a constant value of 66.4 ± 1.0 km s^{-1}, yielding a scale height of 80 ± 30 pc. The [C II] velocity field reveals a distortion that we attribute to a warp in the disk. Modeling this warped disk yields an inclination estimate of $40.4 \pm 1.3°$ and a rotational velocity of 116 ± 3 km s^{-1}. The resulting dynamical mass estimate of $(1.96 \pm 0.10) \times 10^{10} M_\odot$ is lower than previous estimates, which strengthens the conclusion that the host galaxy is less massive than expected based on local scaling relations between the black hole mass and the host galaxy mass. Using archival MUSE Ly-α observations, we argue that counterrotating halo gas could provide the torque needed to warp the disk. We further detect a region with excess (15-σ) dust continuum emission, which is located 1.3 kpc northwest of the galaxy's center and is gravitationally unstable (Toomre-Q < 0.04). We posit this is a star-forming region

ALMA-наблюдения пыли и [CII]

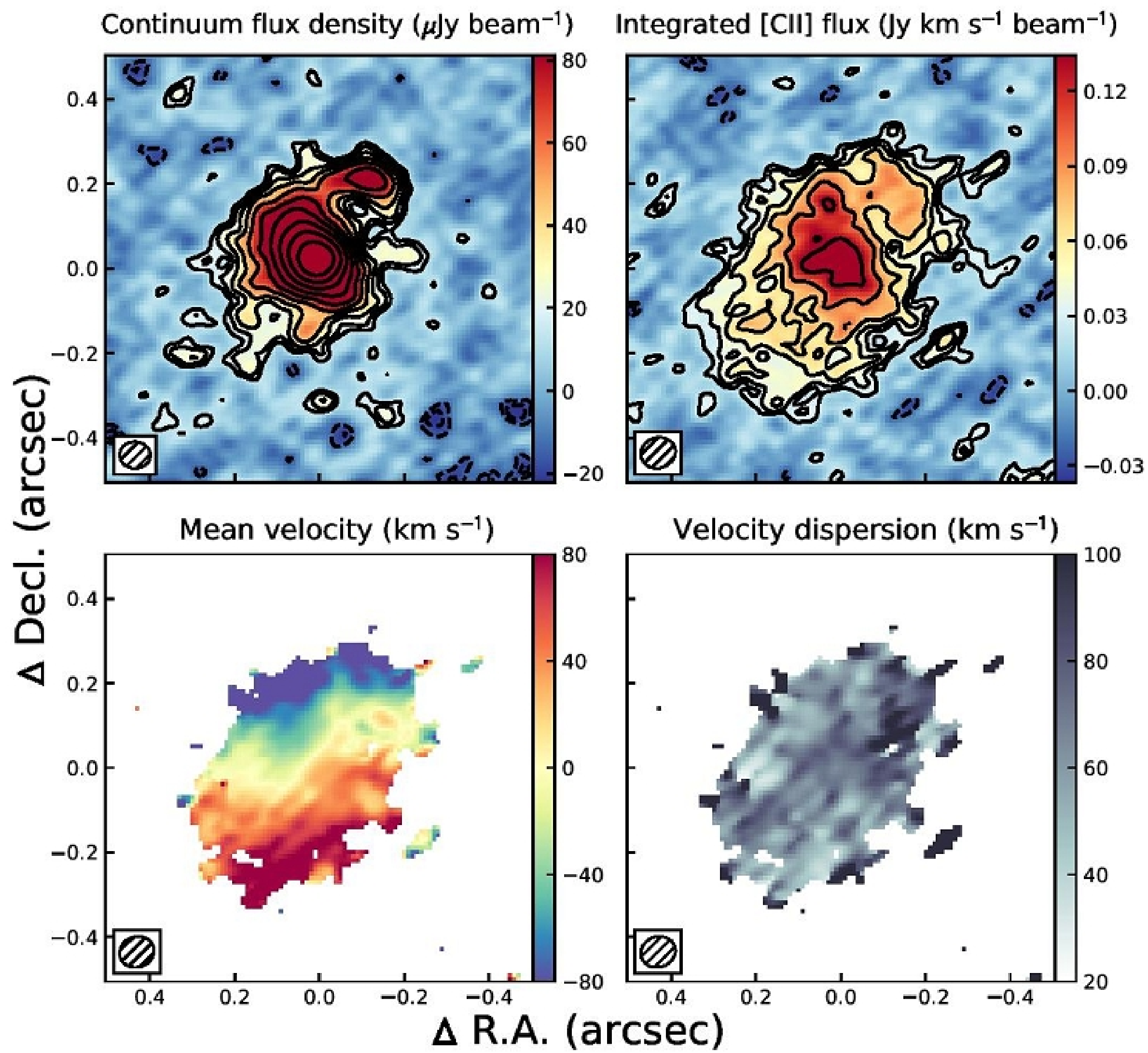


Figure 1. Rest frame 1900 GHz continuum (top left), integrated [C II] flux density (top right), mean [C II] velocity field (bottom left) and [C II] velocity dispersion field (bottom right) of the quasar P036+03. In the top two panel the contours start at 2σ and increase by powers of $\sqrt{2}$;

Тонкий диск с изгибом?

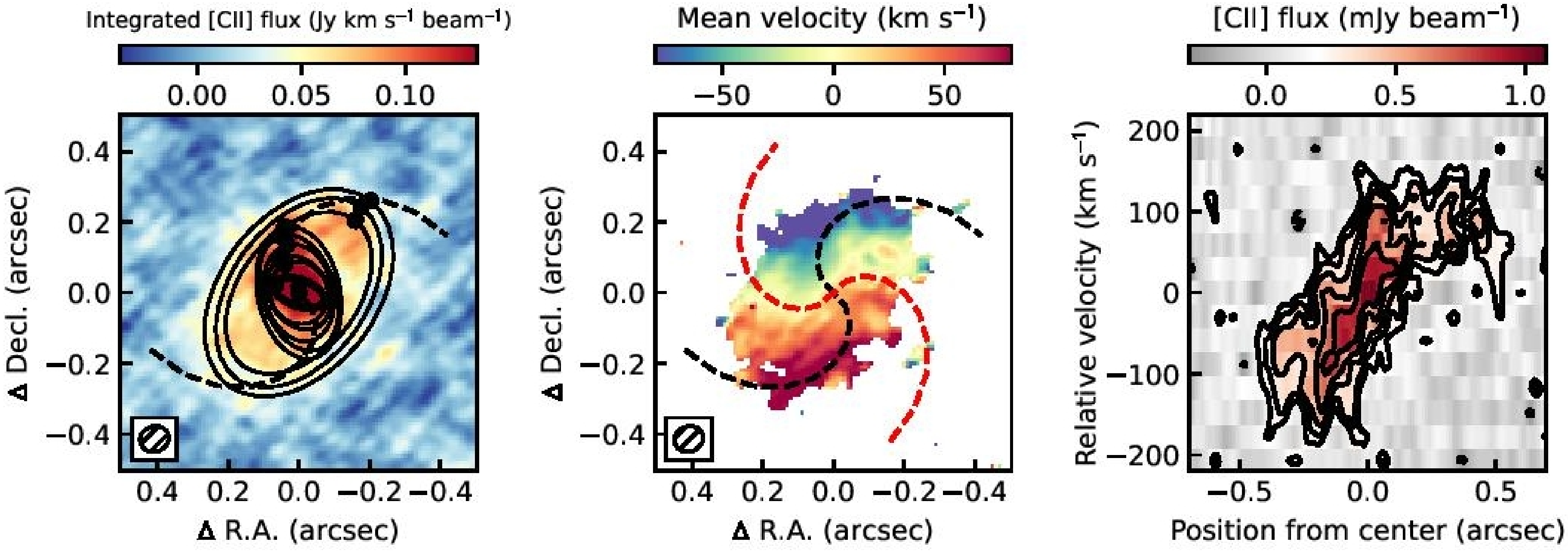
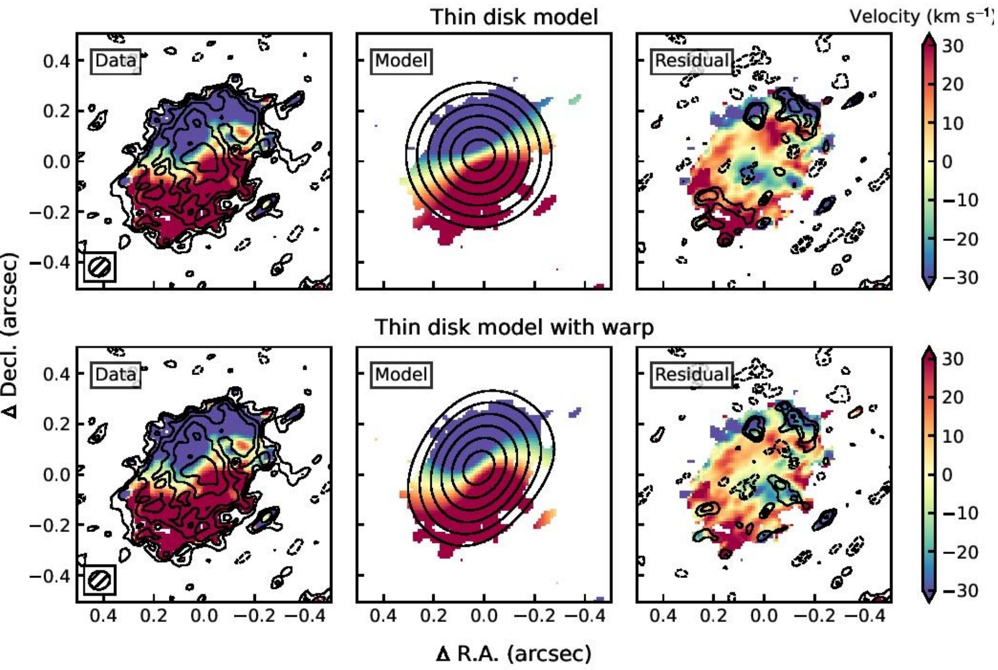


Figure 2. *Left panel:* integrated [C II] emission of P036+03. The black ellipses are elliptical fits to the contours in the integrated [C II] emission image, starting at 3σ and increasing by 1σ. The solid black circles mark the position of the apexes of the ellipses along the major axes. The dashed line is a simple parametric fit to these circles. *Middle panel:* mean velocity field of the [C II] emission line for P036+03 with the parametric fit overlayed. Also shown is the perpendicular curve to this fit (red dashed line). *Right panel:* Position - velocity diagram along the parametric fitted line (black dashed line in left and middle panel). Positive x-values correspond to the southern 'arm' of the parametric fit.

Анализ кинематики газа



gure 4. Kinematic modeling of the [C II] emission line for P036+03. The top row shows the results from a simple thin disk model, wherea

For the warped disk model, we find that the position angle varies from $(226 \pm 3)^\circ$ in the center to $(164 \pm 5)^\circ$ in the outskirts of the galaxy with a constant inclination of $(40.4 \pm 1.3)^\circ$. This inclination estimate is consistent with the inclination estimate obtained from comparing the major and minor axis (Section 3). The best-fit model has a constant, inclination-corrected rotational velocity of (116 ± 3) $\mathrm{km\,s^{-1}}$ and constant velocity dispersion of (66.4 ± 1.0) $\mathrm{km\,s^{-1}}$. This maximum rotational velocity is significantly

Масса галактики 20 млрд, а черной дыры - 3.7 млрд солнечных масс

ALMA+MUSE: в изгибе газового диска виновато газовое гало?

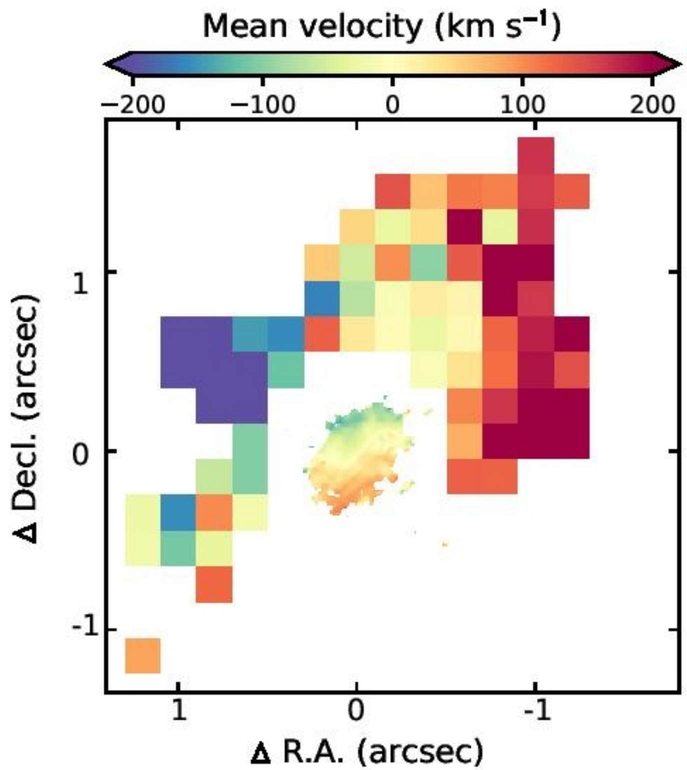


Figure 5. Velocity field for the interstellar medium and circumgalactic medium of P036+03 as traced by [C II] and Lyα, respectively. The velocity field of the [C II] emission line is the same as Figure 1 albeit at a different velocity scale. The velocity field of the Ly-α line is described in detail in Drake et al. (2022) and is shown here at the native pixel scale of the VLT/MUSE observations (0.″2). For the MUSE observations, only Ly-α emission belong-