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RESOLVING JET-DRIVEN AGN FEEDBACK IN CENTAURUS A'S NORTHERN FILAMENTS ON A CLOUD-SCALE WITH ALMA

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Abstract. AGN feedback is thought to play a key role in regulating star formation in galaxies. Yet the detailed mechanisms, in particular specific impacts of mechanical feedback via AGN jets, remain poorly understood. In Centaurus A's northern filaments a jet-gas interaction is observed to induce star formation, making it uniquely suitable to explore the dissipation of mechanical jet feedback at the scale of resolved molecular clouds. We identify distinct dense molecular clouds of H_2 in this region, as traced by CO(1-0) measurements from ALMA. An improved segmentation algorithm and novel ACA-7m and TP short-spacing observations of CO(1-0) lead to a more complete cloud catalog than previous studies, which mostly confirms previous findings of cloud property statistics. In a comparison with standard star-forming discs at matched resolution and noise, the clouds of the northern filaments appear much more turbulent and pressurized. This is interpreted as a suppression of star formation due to mechanical AGN feedback and is further discussed in a paper in preparation.

Keywords: galaxies: active, galaxies: jets, galaxies: individual: Centaurus A, radio lines: galaxies

1 Introduction: AGN jet interaction with clouds in Cen A's northern filaments

Active galactic nuclei (AGN) are thought to regulate star formation in their hosts through feedback. Understanding the detailed mechanisms is crucial for models of galaxy evolution. Jet-driven feedback is typically associated with maintaining galaxies quenched, though a few cases show star formation in jet-gas interaction zones (Salomé et al. 2015).
Cen A is the nearest radio-loud AGN host (D ≈ 3.8 Mpc) and the perfect target for the study of jet-driven AGN feedback on a cloud-scale. In its northern filaments, about 15-20 kpc from the AGN, the jet is observed to interact with HI shells. The presence of young stars and molecular gas is interpreted as a result of this interaction (Neff et al. (2015); Salomé et al. (2017) hereafter S17). In this work we revisit S17 with new ALMA short- and zero-spacing observations of CO(1-0) to study the molecular cloud population and AGN feedback in this region.

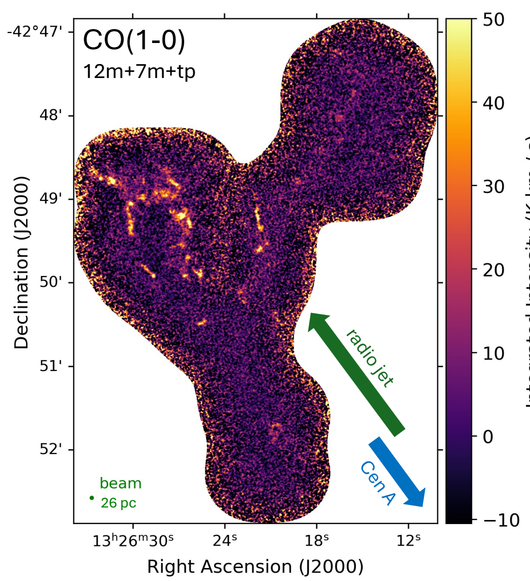

Fig. 1. Moment 0 map of the CO(1-0) cube of the northern filaments. Directions of radio jet and Cen A's disc are indicated.

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2 Molecular cloud statistics along the AGN jet

The CO(1-0) emission from the northern filaments of Centaurus A was observed with ALMA, ACA, and TP during Cycles 3 and 7, calibrated with CASA, imaged with imager, and combined into datacubes with rms noise of 6.7 mJy/beam at a resolution of 26 pc and 1.5 km s^{-1} (see moment 0 map in fig. 1).

We adopt the PHANGS-ALMA pipeline and the pycprops segmentation algorithm (Leroy et al. (2021); Rosolowsky et al. (2021) - hereafter R21). We first homogenize the cube by adding artificial noise with spatial correlations on the beam scale. At our high resolution of 26 pc, the signal-to-noise ratios are significantly lower than in R21. To mitigate this along with persisting inhomogeneities, we run the cloud segmentation on the not primary-beam-corrected cube before computing physical properties with the corrected cube. We further apply stringent post-segmentation filters to remove spurious and unresolved detections. To derive H_2 masses, a standard value of $\alpha_{CO} = 4.35\,M_\odot\,pc^{-2}(K\,km\,s^{-1})^{-1}$ is adopted (Bolatto et al. 2013).

As presented in table 1, we recover more mass in clouds from the 12m-array (2) than the previous study, S17 (1). This increase is attributed to improved data homogenization and cleaning with the PHANGS-ALMA pipeline, as well as pycprops, which extrapolates signal profiles and thereby yields higher cloud masses. The improved u-v coverage from adding 7m-array and total power observations captures previously missed and more extended emission (3), leading to more cloud detections and higher total mass, but cloud statistics are not changed drastically (see medians in table).

Table 1. Overview of cloud properties in Cen A's filaments. M_{CO}, R, σ_v refer to median properties.

Array, reference, resolution	N_{clouds}	M_{tot} [10^7 $M_\odot$]	M_{CO} [10^5 $M_\odot$]	R [pc]	σ_v [km s^{-1}]
1) 12m, S17 (24 pc)	140	1.58	$0.7^{+1.3}_{-0.4}$	$21.00^{+5.72}_{-3.90}$	$5.14^{+2.48}_{-1.56}$
2) 12m, this work (26 pc)	115	2.89	$1.5^{+3.3}_{-0.8}$	$17.23^{+6.84}_{-6.28}$	$5.90^{+2.51}_{-2.21}$
3) 12m+7m+TP, this work (26 pc)	164	3.76	$1.5^{+2.3}_{-0.8}$	$18.18^{+6.56}_{-6.10}$	$5.31^{+2.37}_{-1.82}$

3 Implications on AGN feedback and star formation

Overall, we find low star formation efficiencies $\epsilon_{ff} = t_{ff}/t_{dep} \leq 0.034\%$, much lower than $\epsilon_{ff} = 0.5^{+0.7}_{-0.3}\%$ found for galaxy discs (Salomé et al. 2016; Schinnerer & Leroy 2024). This is in line with previous studies suggesting that the AGN jet feedback is compressing atomic gas into the molecular phase while injecting turbulence that suppresses star formation.

To test this interpretation, we match the resolution and noise levels of our data to those of clouds in star-forming discs (PHANGS galaxies, R21), at 90 pc & 75 mK and additionally to two galaxies at 30 pc & 270 mK. In both cases, Cen A clouds show systematically higher line widths and virial parameters, consistent with stronger turbulence than in efficiently star-forming clouds on the main sequence.

The main uncertainties lie in the poorly constrained α_{CO} and in interpreting line widths as turbulence signature. Line width may also trace rotation or shear (Liu et al. 2021). In different galaxy types or environments different processes tend to dominate. However, comparisons across such environments favor AGN-induced turbulence. This analysis and a full updated cloud catalog will be published in Flesch et al. (2025 in prep.).

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