kapteyn astronomical institute

ASTRON

A LOW-POWER JET DEPLETING THE HOST GALAXY OF COLD GAS

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AGN – HOST GALAXY INTERPLAY

Gas accretion on to the SMBH (feeding)

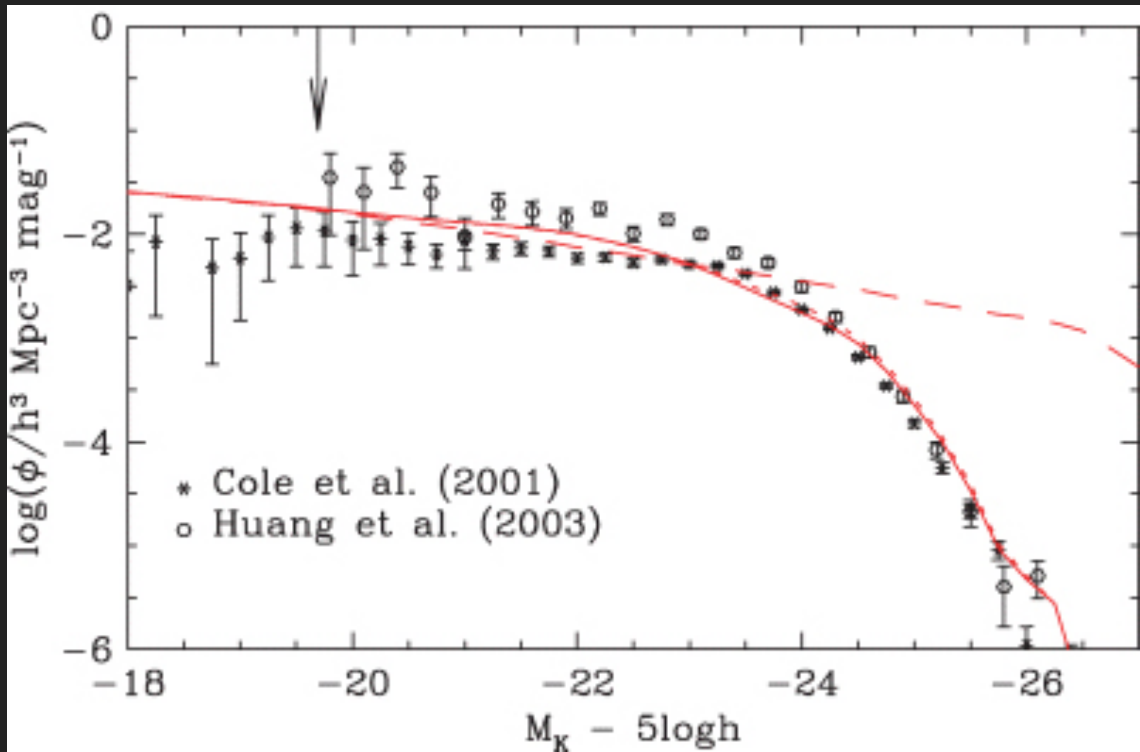
↓

AGN

↓

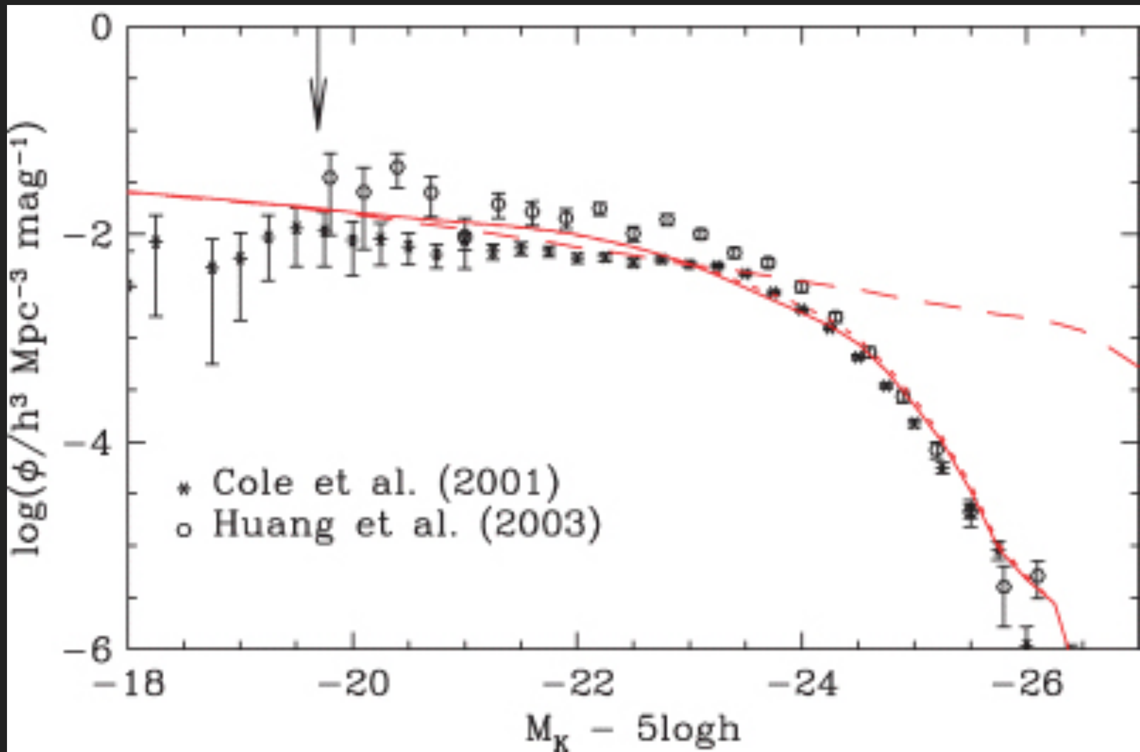
Host galaxy evolution (feedback)

AGN IN COSMOLOGICAL SIMULATIONS



Bower et al. 2006

AGN IN COSMOLOGICAL SIMULATIONS



Bower et al. 2006

Role of radio AGN?

Maintenance mode: prevent the cooling of ICM

Possible only for large powerful AGN

These are rare! e.g. Best et al. 2005, Sabater et al. 2019

GALACTIC-SCALE IMPACT OF YOUNG RADIO JETS

- Jet-ISM interaction more common

e.g. Maccagni et al. 2017, Gupta et al. 2006

- Turbulence, multi-phase outflows

e.g. Zovaro et al 2019, Santoro et al. 2020,
Molyneux et al. 2019, Venturi et al. 2021 …

Cold gas is the most massive component of these outflows!

e.g. Morganti et al. 2015, Alatalo et al. 2015,
Ferugilio et al. 2015 …

GALACTIC-SCALE IMPACT OF YOUNG RADIO JETS

- Impact depends on the radio power, morphology
- **High power**: break out quickly
- **Low power**: more time in the ambient medium => more impact?

e.g. Bicknell et al. 2007, Wagner et al. 2012, Mukherjee et al. 2016,2018

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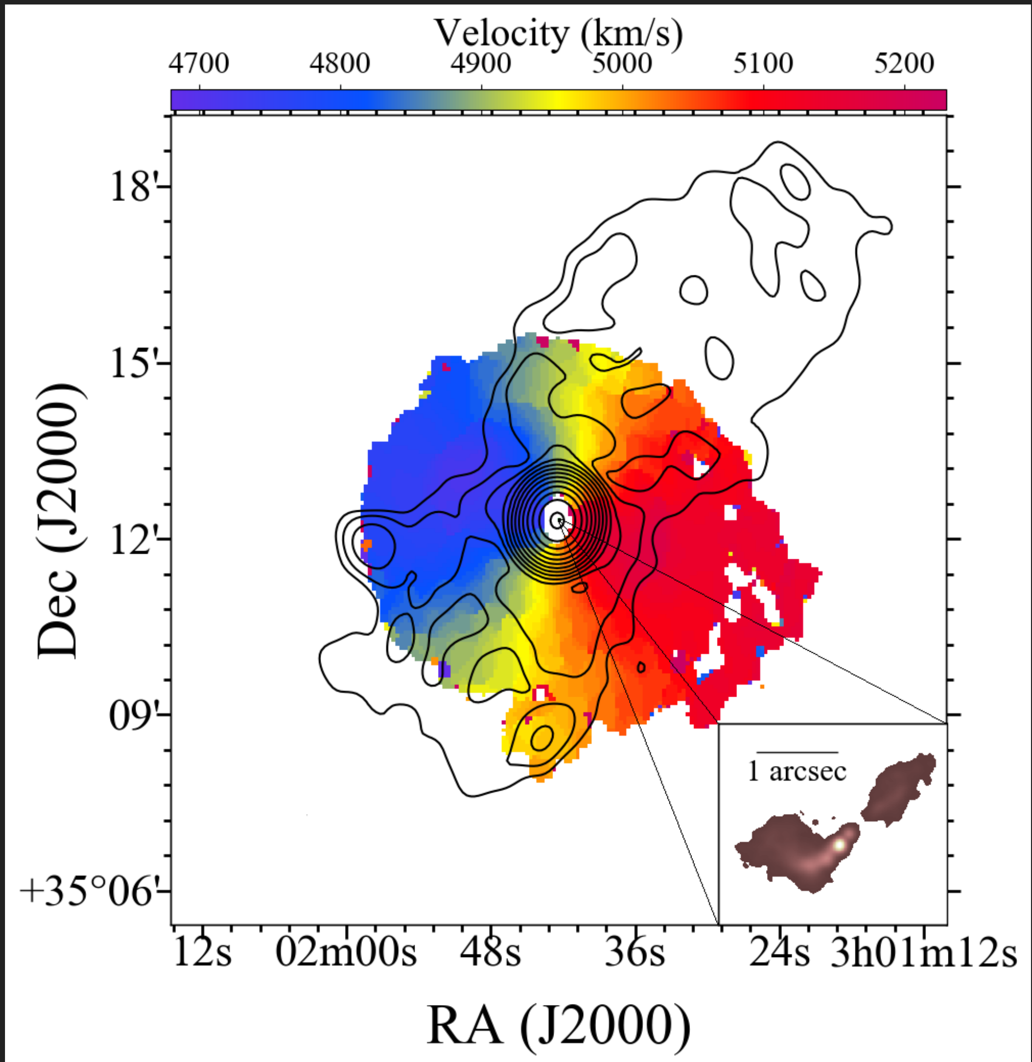
Low luminosity radio AGN are quite common

e.g. Best et al. 2005, Sabater et al. 2019

Cold ISM - jet interaction in low-power, young radio sources could be significant

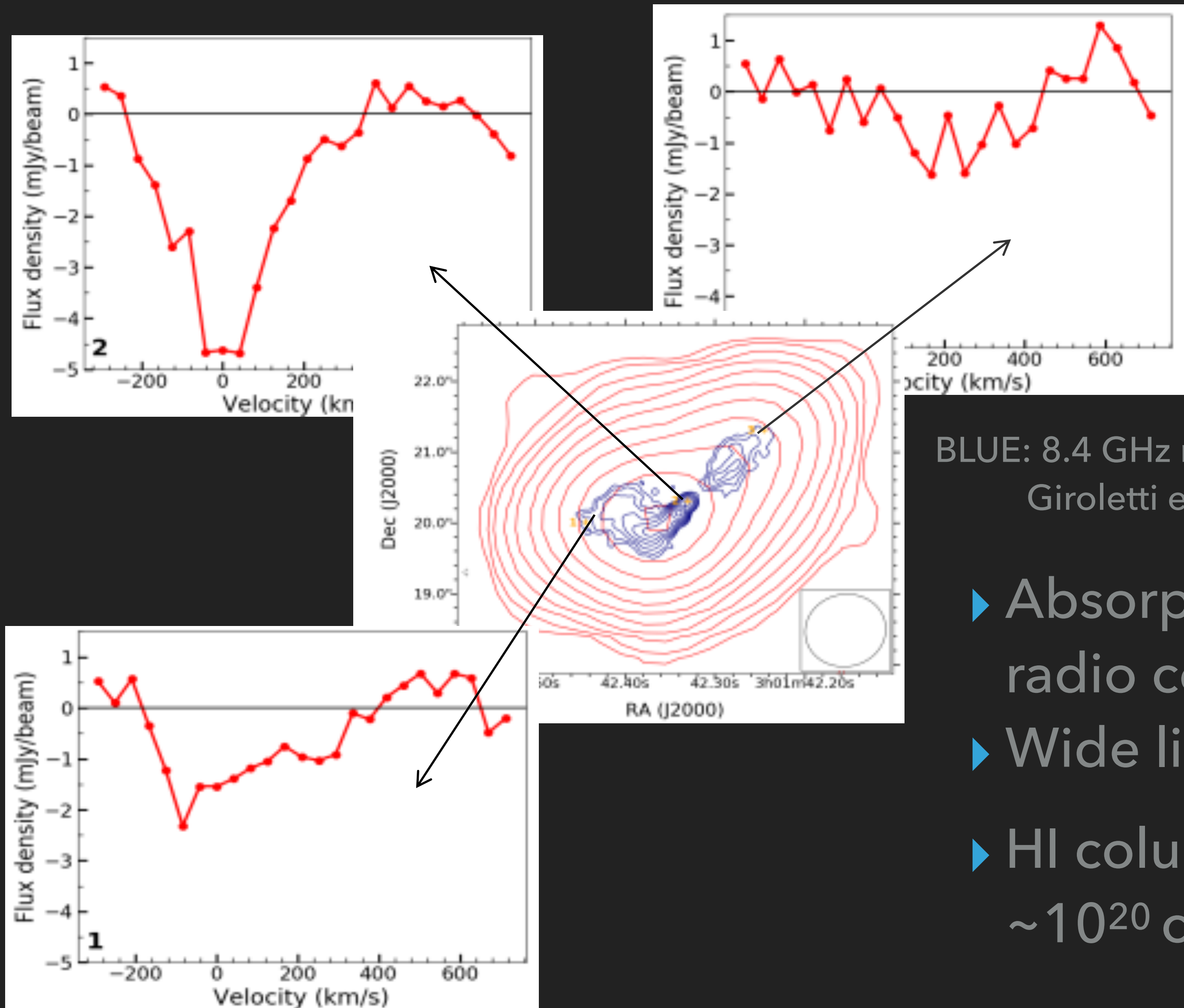
LOW POWER CSS SOURCE: B2 0258+35



- $L_{1.4GHz} = 10^{24}$ W/Hz
- ~ 1 Myr; ~ 1 kpc
  Giroletti et al. 2005
- 160 kpc HI disc
  Struve et al. 2010
- 240 kpc low surface brightness lobes
  Shulevski et al. 2012, Brienza et al. 2018
- Condition of cold gas?

VLA HI ABSORPTION

Murthy et al. 2019

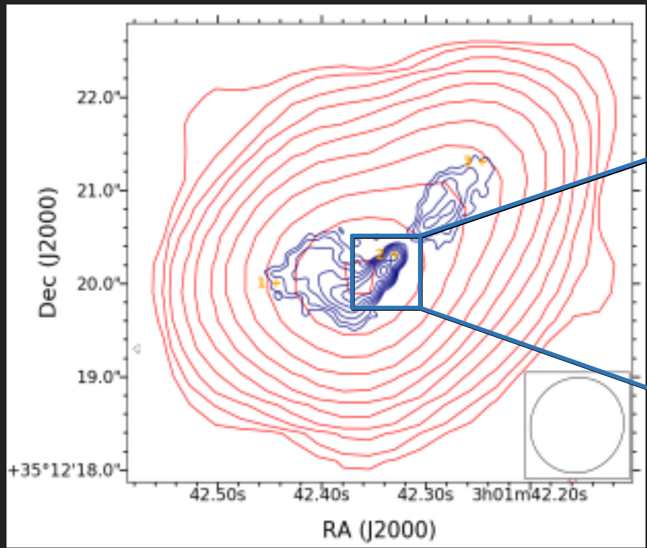


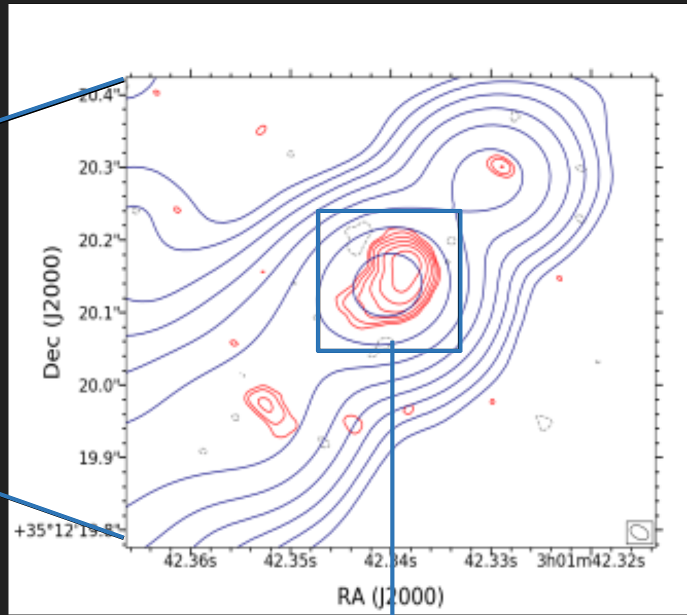
BLUE: 8.4 GHz map from Giroletti et al. 2005

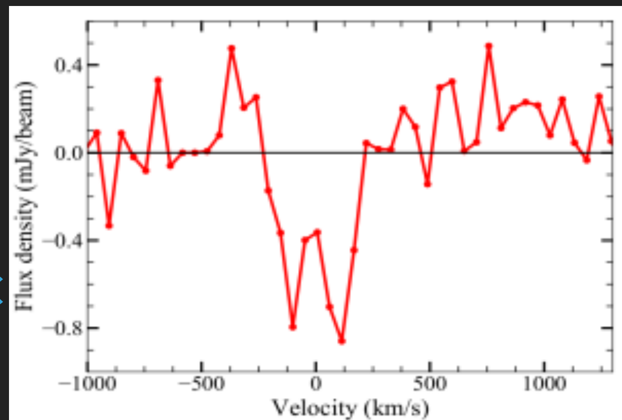
- Absorption all across the radio continuum
- Wide lines ⇒ turbulence
- HI column density: $\sim 10^{20}$ cm^{-2} (for Tspin=100K)

EVN HI ABSORPTION

Murthy et al. 2019



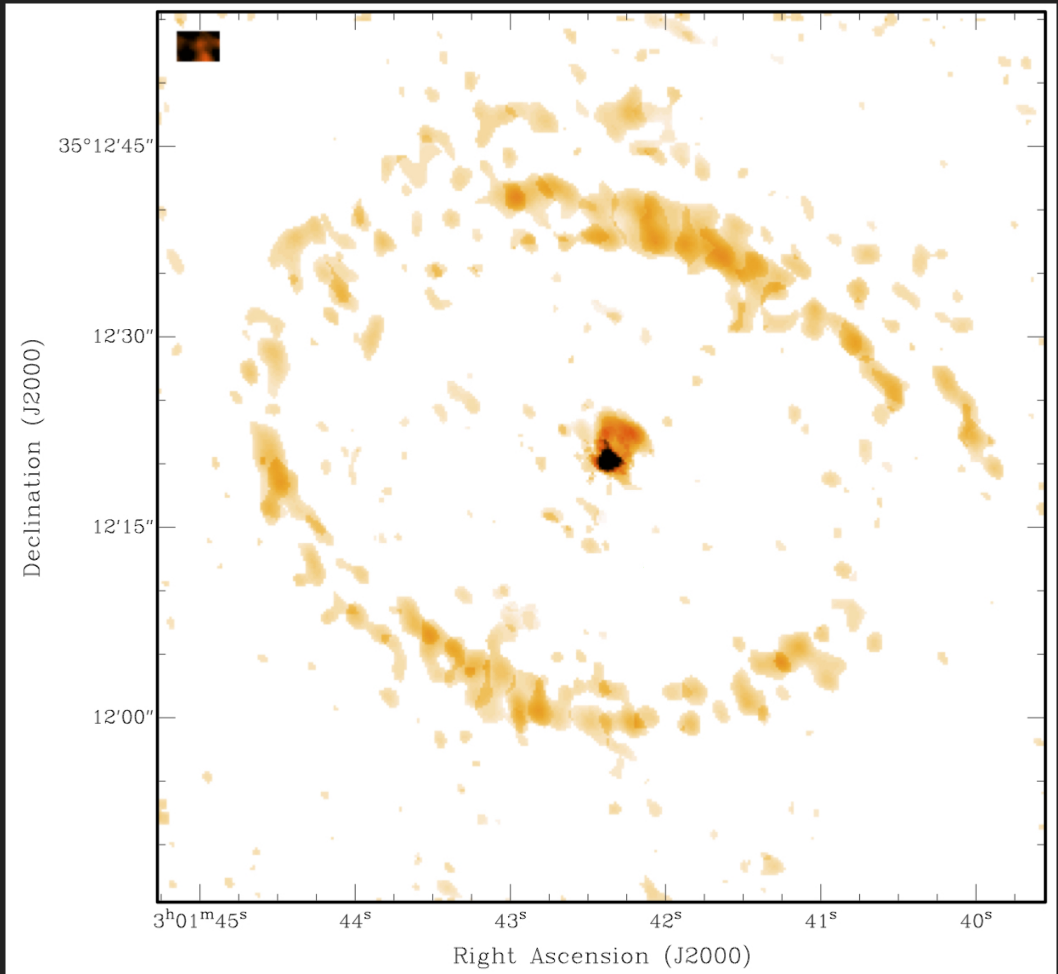




- 10% of VLA continuum
- HI column density same as before
- Gas covers the entire radio continuum
- Jets expanding into a circumnuclear disc
- Also, injecting high turbulence

MOLECULAR GAS: NOEMA CO(1-0)

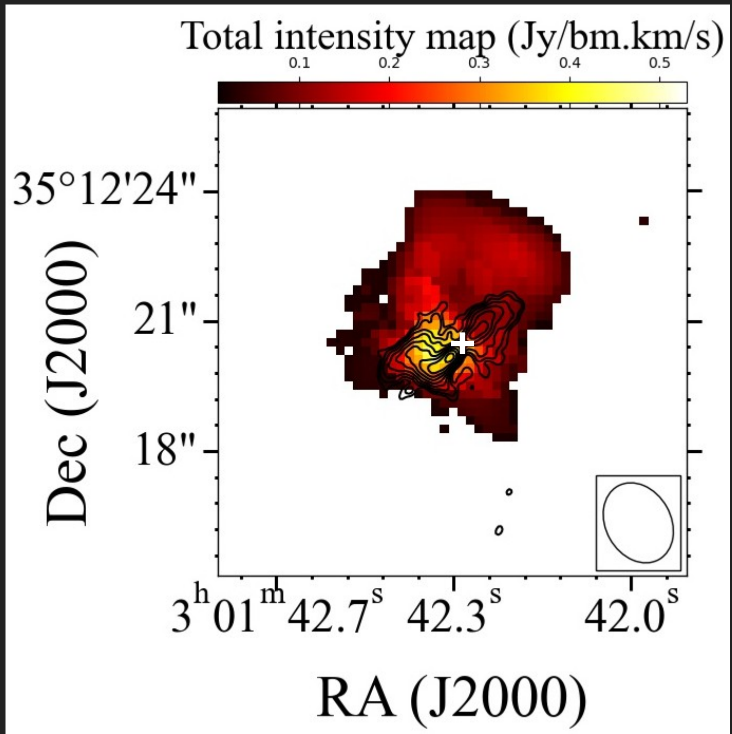
Murthy et al. in prep

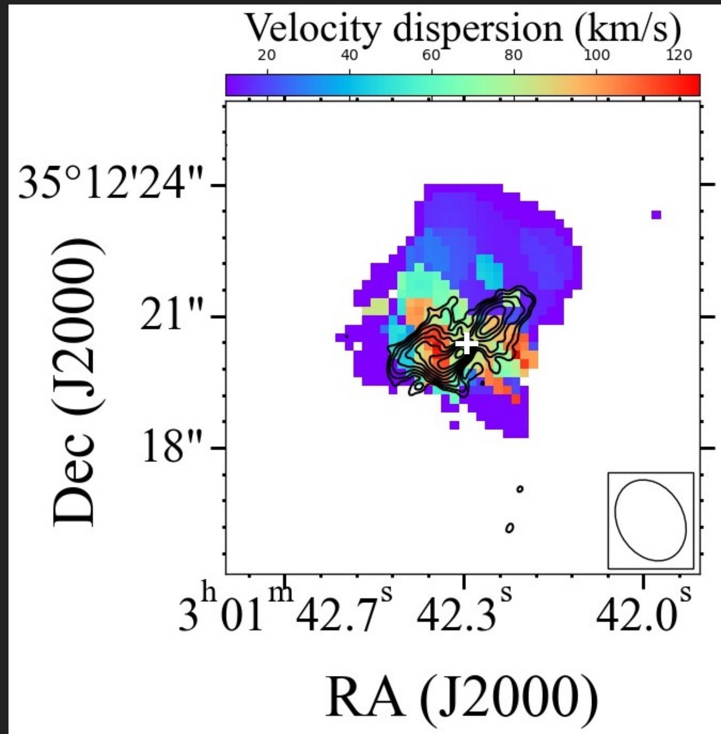


A circumnuclear disc and a large ring

MOLECULAR GAS: NOEMA CO(1-0)

Murthy et al. in prep





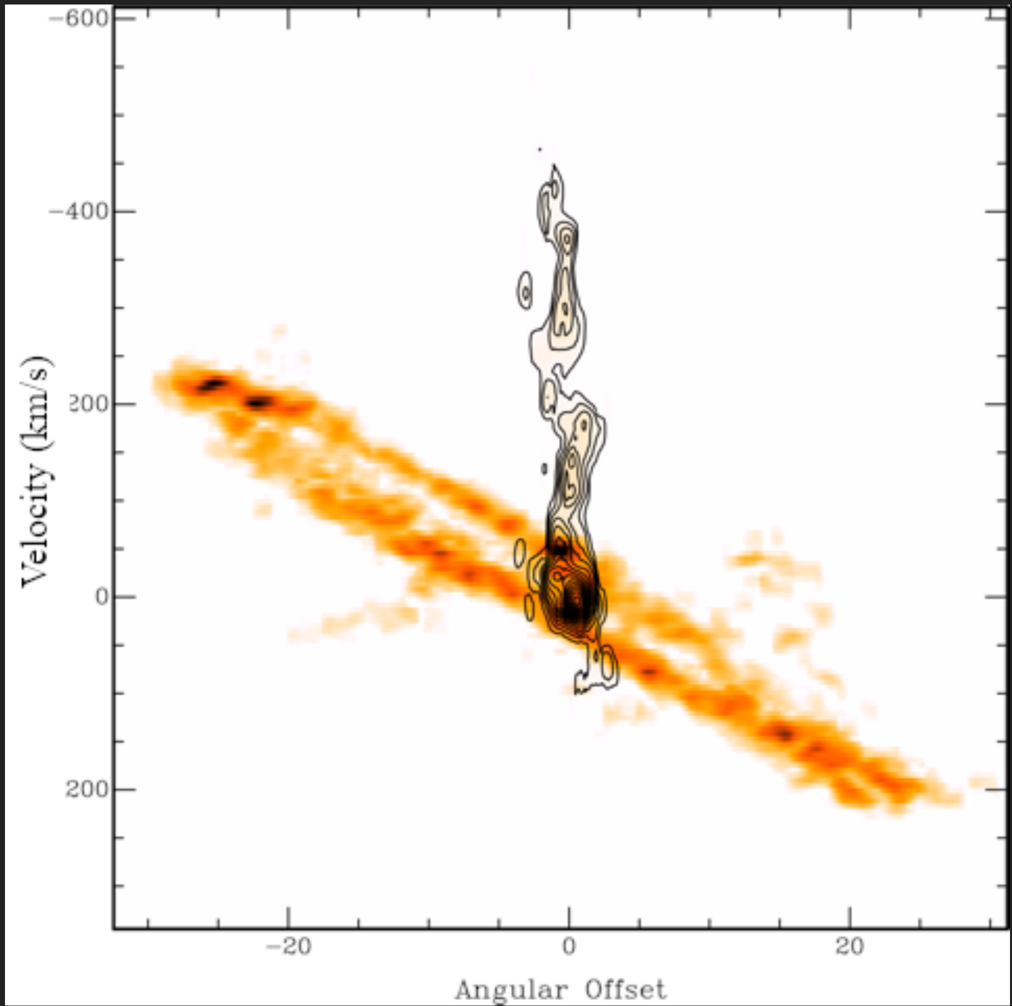
Spatial resolution: 1.9″ x 1.5″

Circumnuclear disc: high velocity dispersion where the jet is bent

Region with the maximum velocity discretion is offset from the radio core

MOLECULAR GAS: NOEMA CO(1-0)

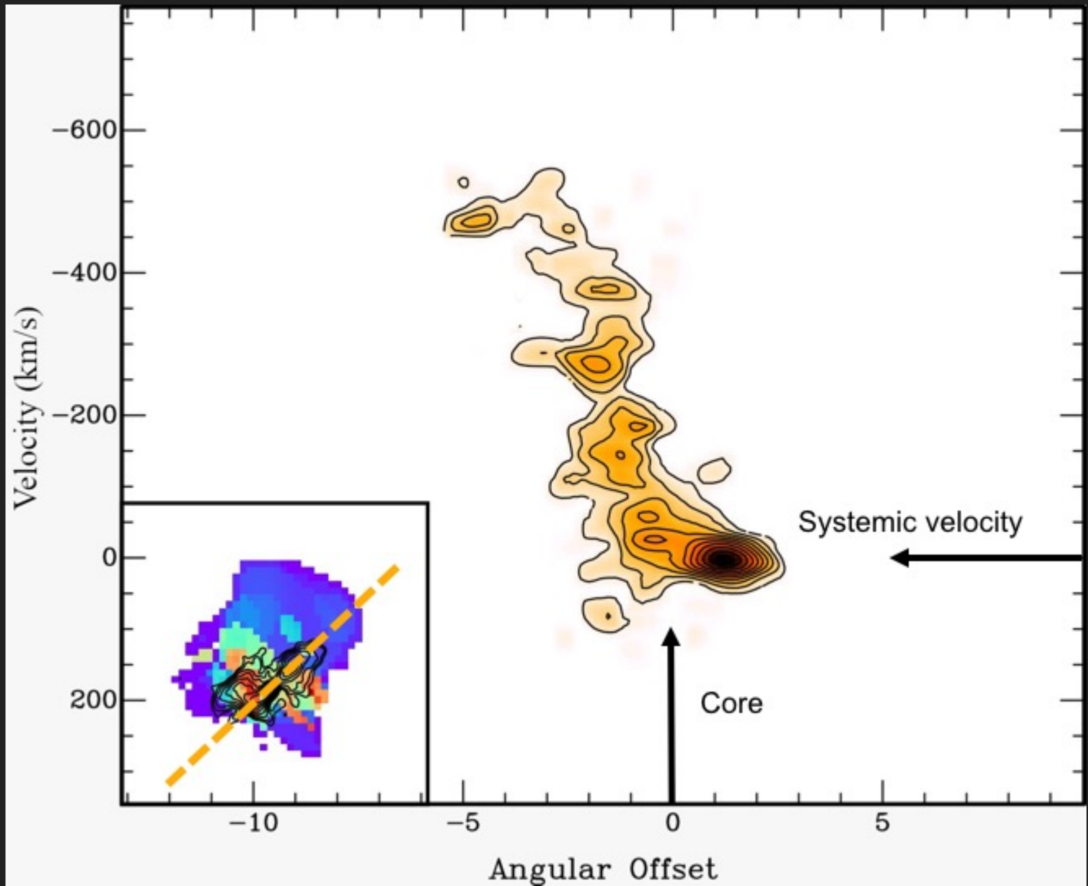
Murthy et al. in prep



Kinematics of the nuclear CO clearly different from the large ring

MOLECULAR GAS: NOEMA CO(1–0)

Murthy et al. in prep



The outflow
spatially offset from
the radio core!

MASS ESTIMATES & ENERGETICS

Murthy et al. in prep

- Molecular gas mass: 16 x 10^7 $M_\odot$
- Outflow mass: 11 x 10^7 $M_\odot$
- Outflow rate: 10 $M_\odot$/yr
- Kinetic power: 1.3 x 10^{42} erg/s
- Bolometric luminosity: (0.3 - 7) x 10^{42} erg/s
- Jet power: ~10^{44} erg/s (based on Cavagnolo et al. 2010)

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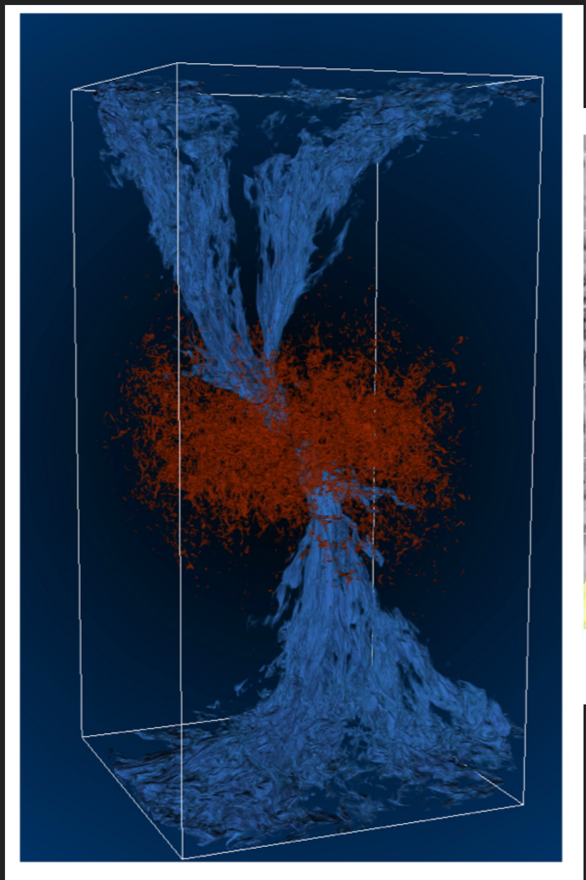
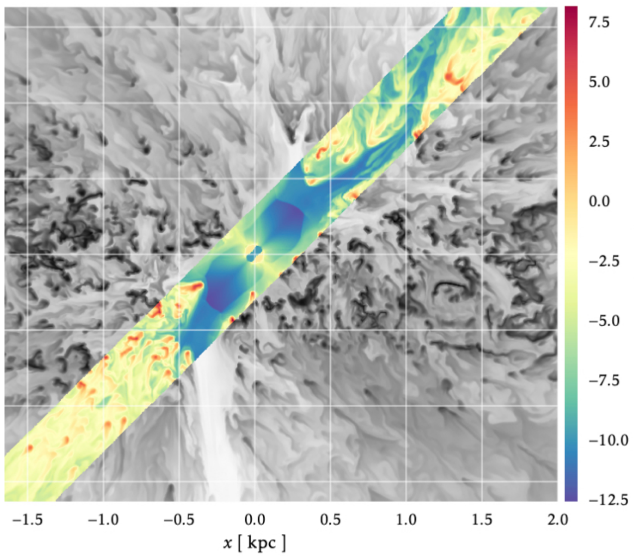
75% of the gas in the outflow!

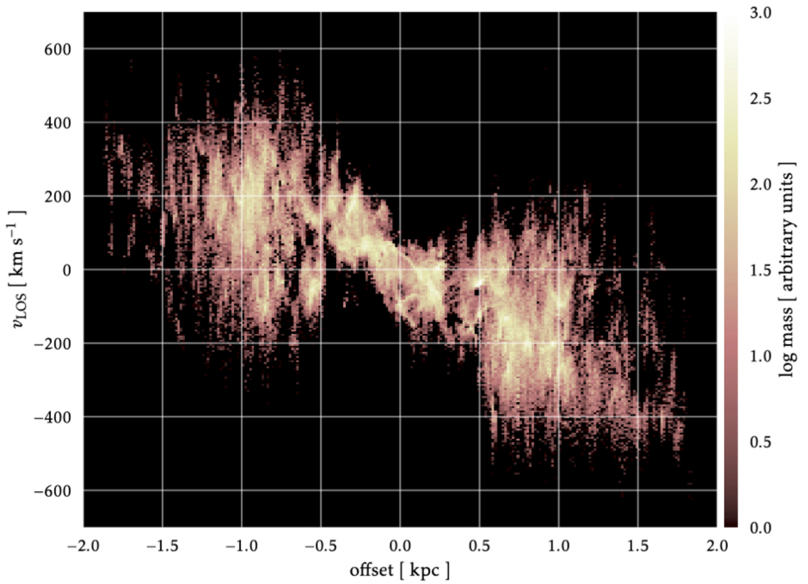
Solely driven by the low power radio jet!

WHAT DO THE SIMULATIONS SAY?

- Do simulations reproduce such velocities?







From the simulations of Mukherjee et al. 2018

IMPLICATIONS

- Significant impact at (sub) kpc scales
- ~30% of the massive galaxies host low-power radio AGN
- May help resolve some of the tensions between observations and cosmological simulations

see Weinberger et al. 2017

- Crucial inputs to models of galaxy evolution: energetics, time-scales, spatial scales …

e.g. Dubois et al. 2012, 2013, Talbot et al. 2021

SUMMARY

- Cold gas: most massive component of multi-phase outflows
- B2 0258+35: *first case* with
  - massive, **spatially localised** CO outflow
  - **driven solely** by low power jets

Murthy et al. in prep

- Low-power jets: more common
- Cosmological simulations may want to take this class of radio AGN more seriously!