The AGN fueling/feedback cycle in LERGs

A multi-phase study of a sample of local early-type radio galaxies

Ilaria Ruffa
(IRA-INAF/University of Bologna)

In collaboration with: Isabella Prandoni (IRA-INAF) , Robert Laing (SKAO), Martin Bureau (Oxford University), Timothy Davis (Cardiff University), Paola Parma (IRA-INAF), Hans de Ruiter (IRA-INAF), Rosita Paladino (IRA-INAF)

AGN 13: Beauty and the Beast
Milano, 11 Ottobre 2018

The HERG and LERG paradigm

Two main class of radio galaxies in the local Universe:

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High Excitation Radio Galaxies (HERGs):

- High-power (FRII)
- High accretion rates ($\dot{M} \gtrsim 0.01 \dot{M}_{edd}$)
- Radiative-mode AGN

Low Excitation Radio Galaxies (LERGs):

- Typically low-power (FRI)
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- Jet-mode AGN

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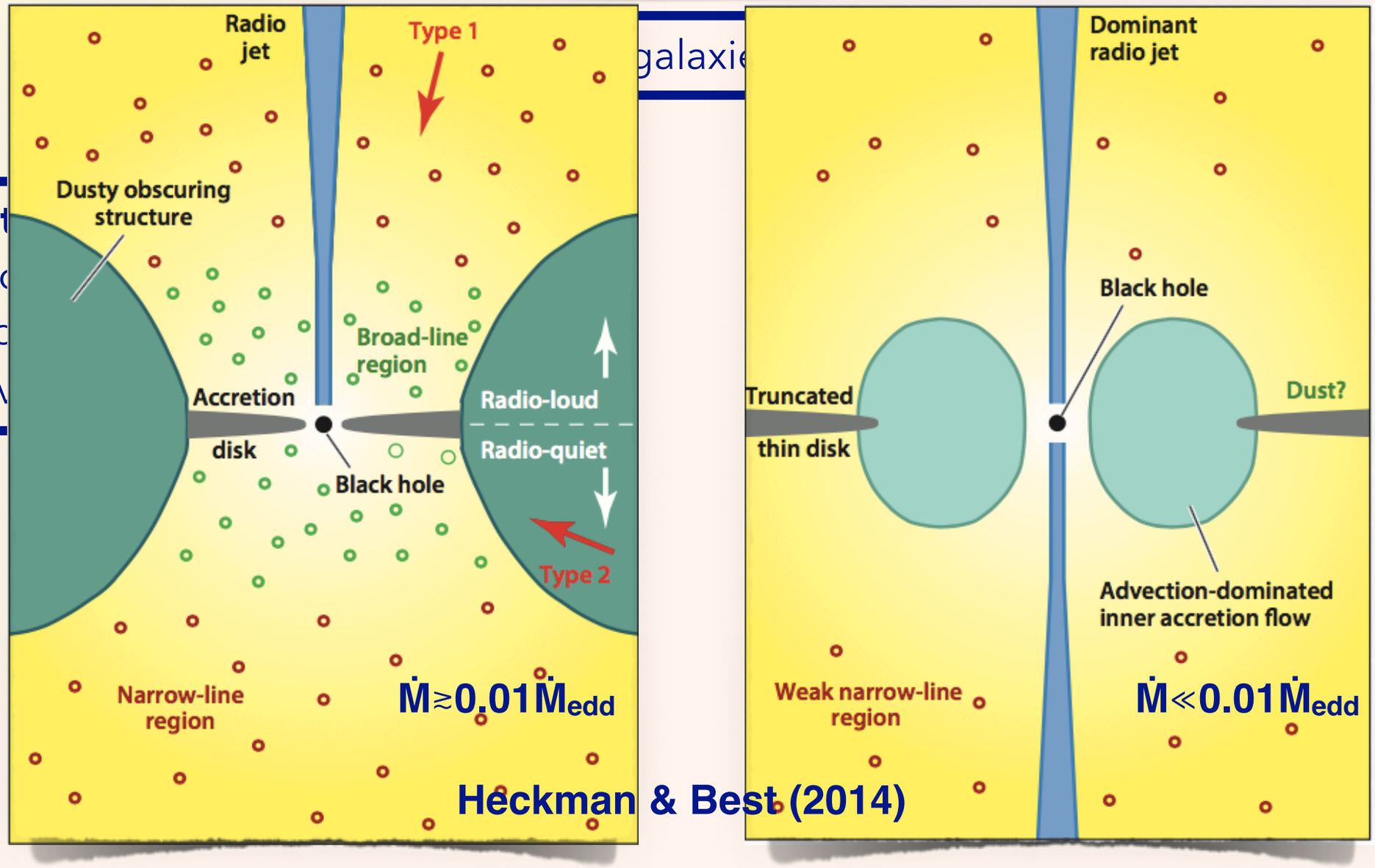

Heckman & Best (2014)

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- **Accreting hot gas from the hot halo?**

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Cold gas often detected in large amount in LERGs (Prandoni et al. 2007, 2010; Ocaña-Flaquer et al. 2010)

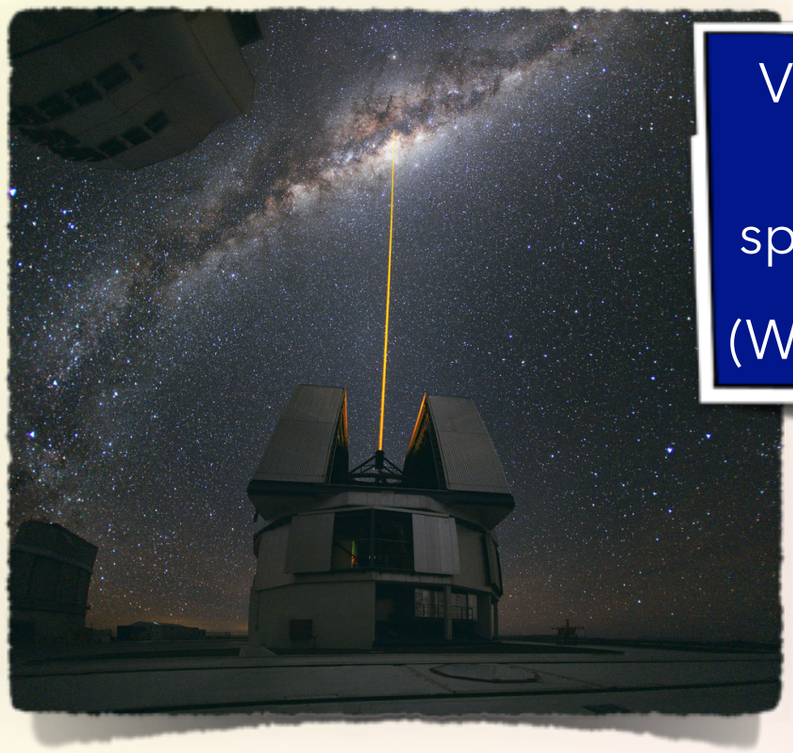
The goal

Investigate the AGN feeding/feedback loop in a sample of 11 nearby LERGs selected from the Southern Parkes 2.7 GHz Survey

Role of the cold gas in fueling LERGs?
Origin of the gas? Kinematics?
Jets/ gas interaction?

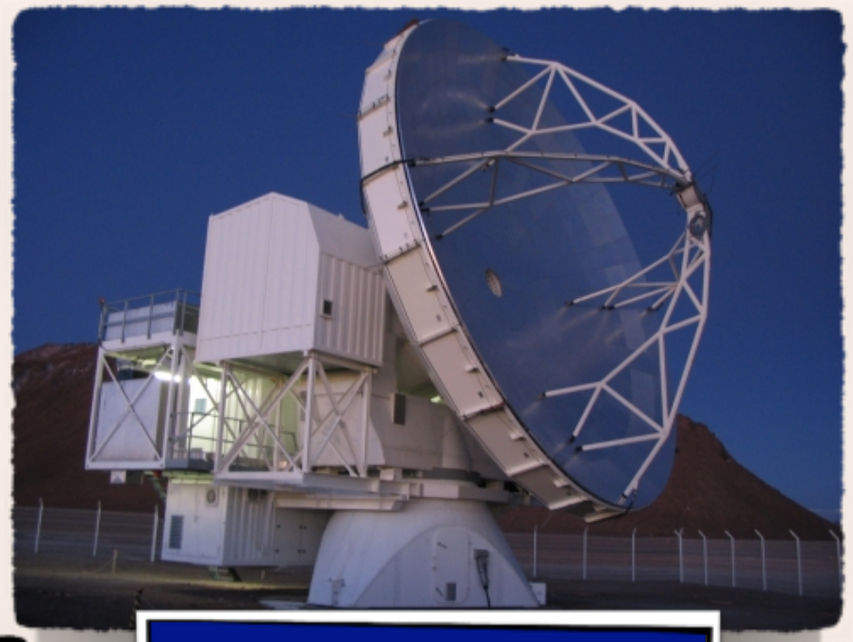
Different galaxy components (stars, warm and cold gas, dust, radio jets) using multi-wavelength data

The dataset



VLT/VIMOS integral-field-unit (IFU) spectroscopy + MUSE

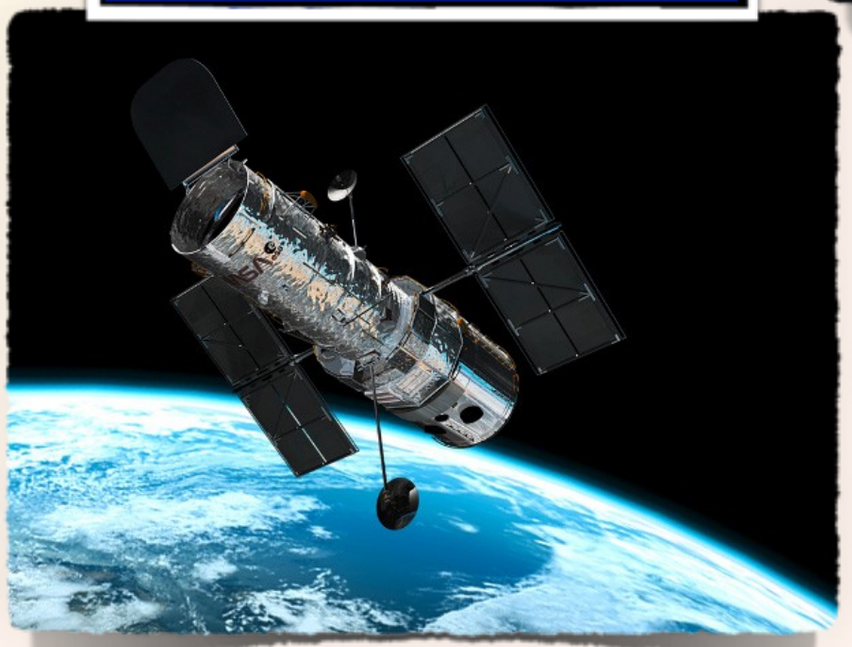
(Warren et al., in prep.)



APEX CO (2-1) integrated spectra (Prandoni et al. 2010, Laing et al. in prep.)

ALMA Cycle 3 CO (2-1) observations (Ruffa et al., submitted to MNRAS)

Archival HST data (or from ground telescopes, when useful)



Archival plus proprietary VLA high-res. imaging (Ruffa et al., in prep.)

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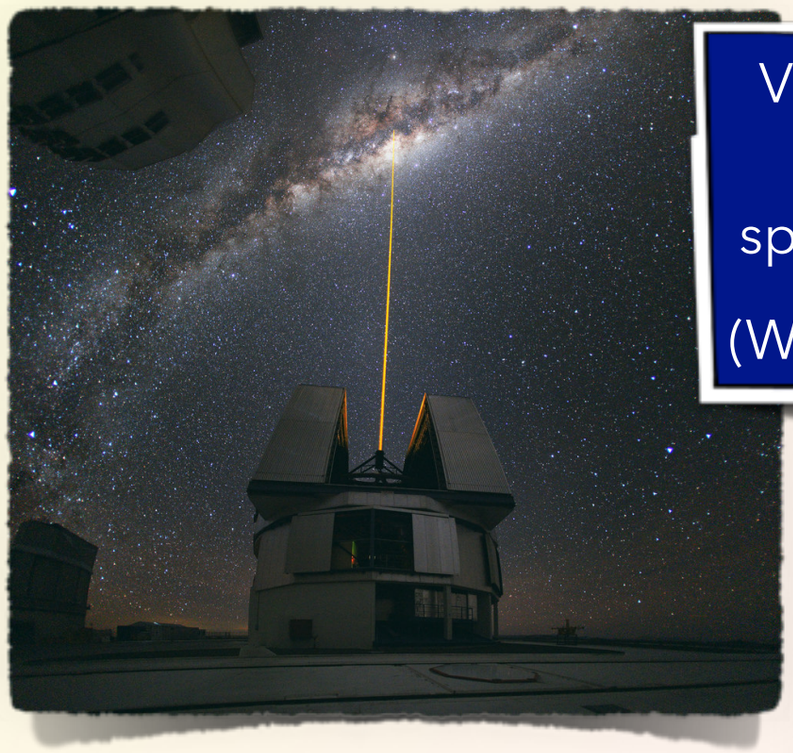

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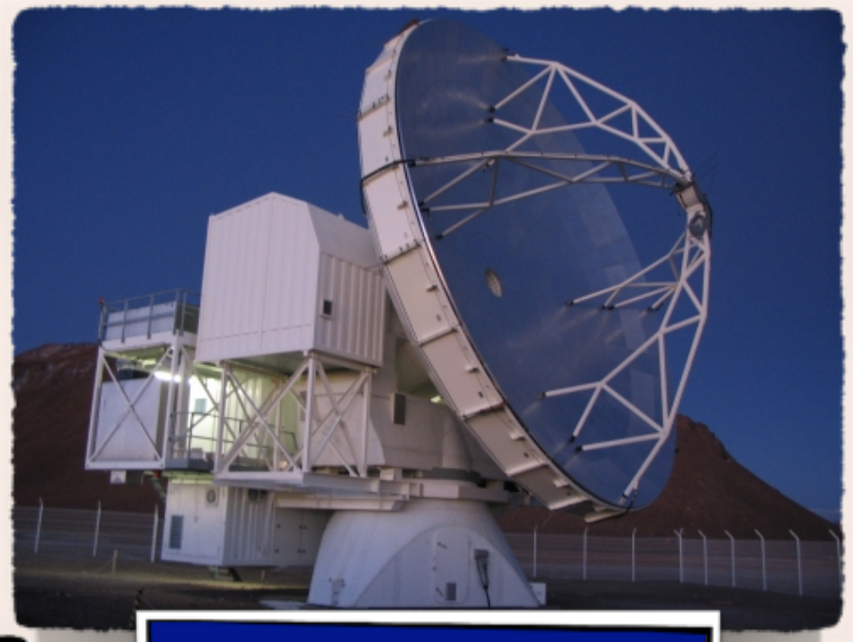

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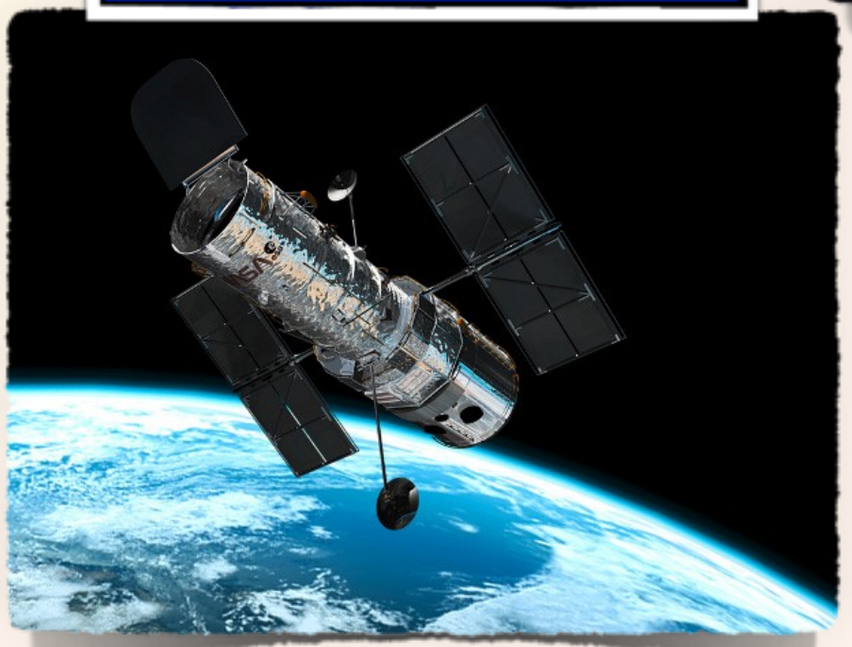

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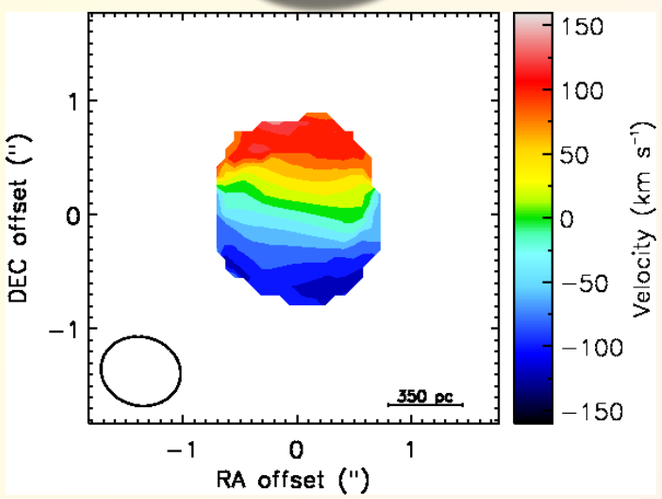
ALMA observations

Cycle 3 CO(2-1) and 230 GHz continuum ALMA observations of 9 targets (PI: I. Prandoni).
CO (2-1) detected in 6 out of 9 sources (Ruffa et al., submitted to MNRAS)

Target	Redshift	CO peak (mJy/beam)	SNR	$\Delta\nu$ (km/s)	θ_{synth} " (pc)
IC 5131	0.0256	12.4	18	20	0.7 (360)
NGC 612	0.0298	18.3	14	20	0.3 (180)
PKS 0718-34	0.0284	<0.6	–	80	0.7 (400)
NGC 3100	0.0088	28.3	45	10	0.9 (160)
NGC 3557	0.0103	16.3	38	22	0.6 (130)
ESO 443-G 024	0.0170	<0.6	–	75	0.7 (240)
IC 4296	0.0125	2.0	8	40	0.6 (150)
NGC 7075	0.0185	4.0	10	40	0.6 (230)
IC 1459	0.0060	<1.8	–	80	1.0 (120)

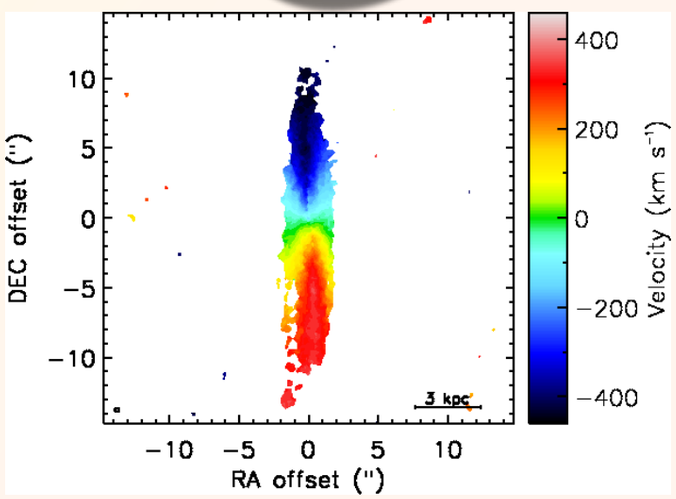
CO(2-1) detections

IC 1531



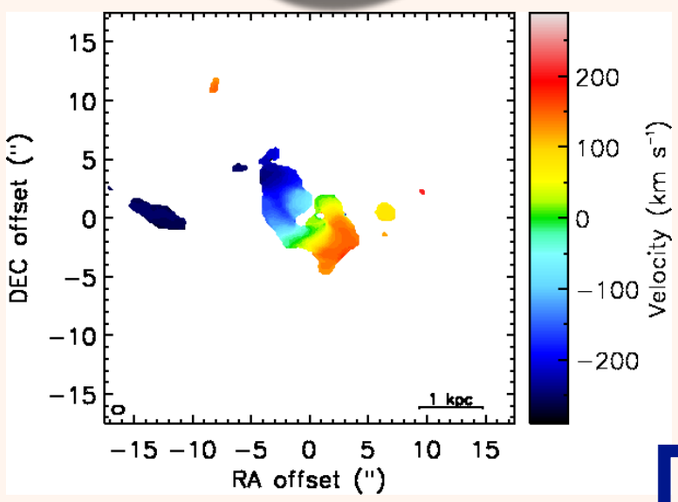
Size = 250 pc
M_{H2} = 1.1 x 10^8 $M_\odot$

NGC 612



Size = 9.6 kpc
M_{H2} = 2.0 x 10^{10} $M_\odot$

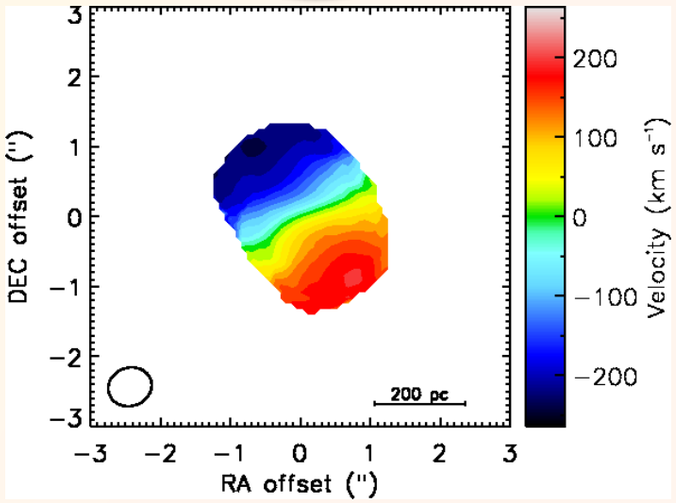
NGC 3100



Size= 1.6 kpc
M_{H2} = 1.2 x 10^8 $M_\odot$

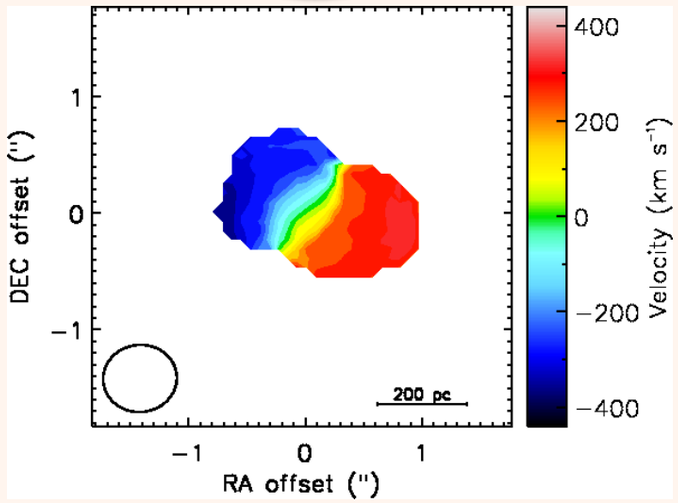
- Rotating CO discs
- Large molecular gas masses
- Sizes from ≈ 200 pc to 9.6 kpc
- Signs of asymmetries and/or warping in some cases

NGC 3557



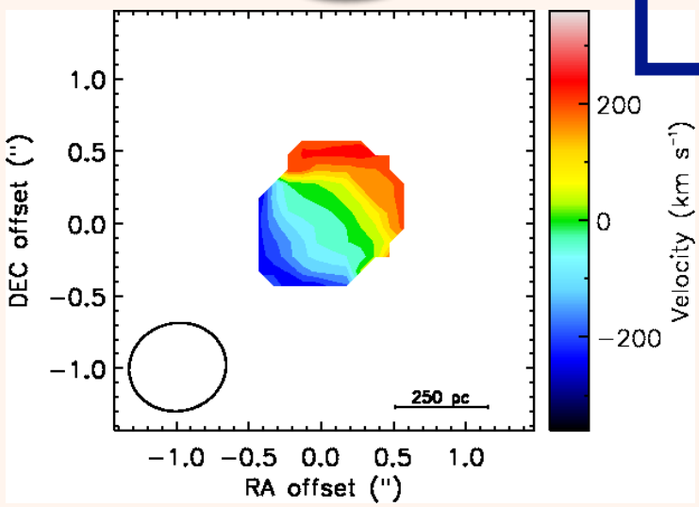
Size = 300 pc
M_{H2} = 6.2 x 10^7 $M_\odot$

IC 4296



Size = 200 pc
M_{H2} = 2.0 x 10^7 $M_\odot$

NGC 7075

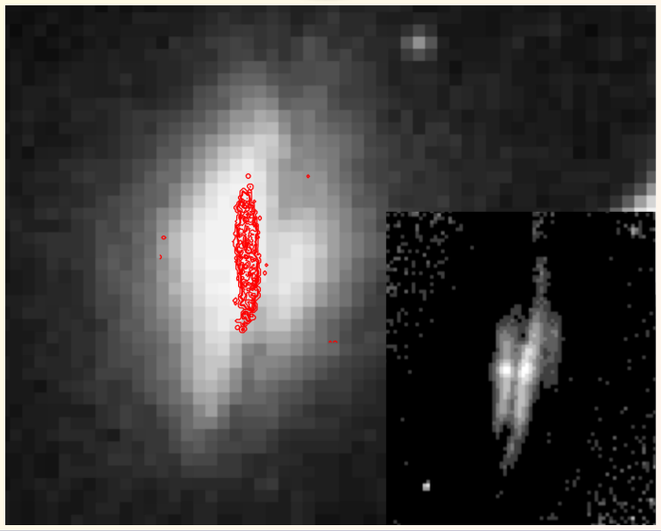


Size < 200 pc
M_{H2} = 2.9 x 10^7 $M_\odot$

Ruffa et al., submitted to MNRAS

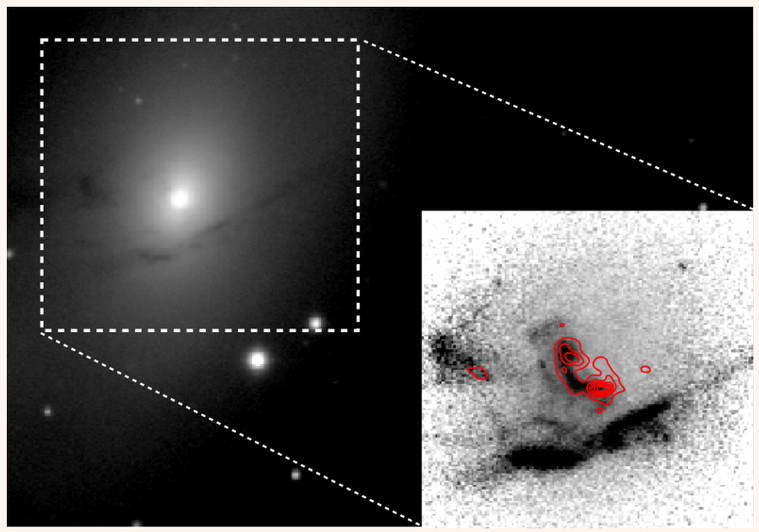
Dust and molecular gas

NGC 612



UK Schmidt Telescope image (468 nm). Resolution = 1.7 arcsec. B-I color map adapted from Veron-Cetty & Veron (2001)

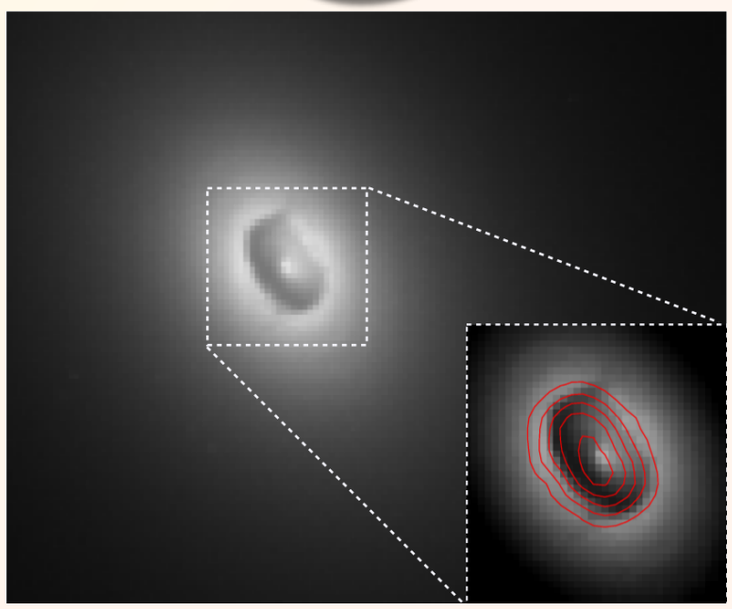
NGC 3100



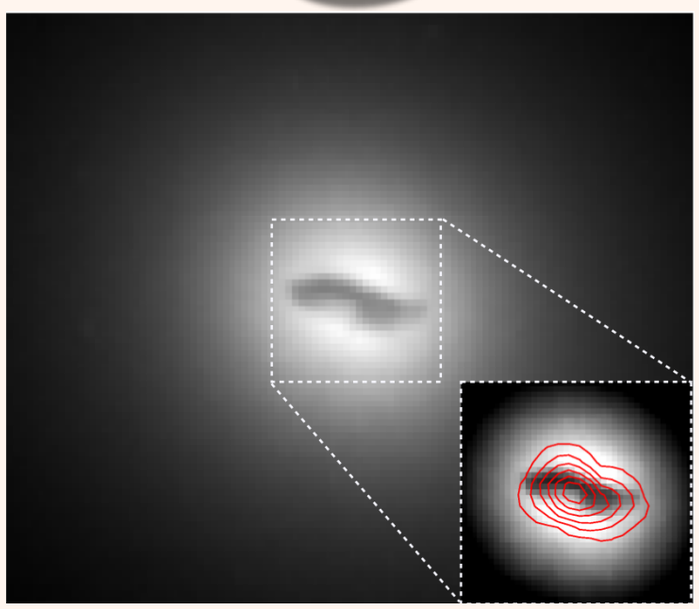
Las Campanas Obs. image (300-400 nm). Resolution = 0.77 arcsec.

- **Evidences of dust and molecular gas co-spatiality**

NGC 3557



IC 4296

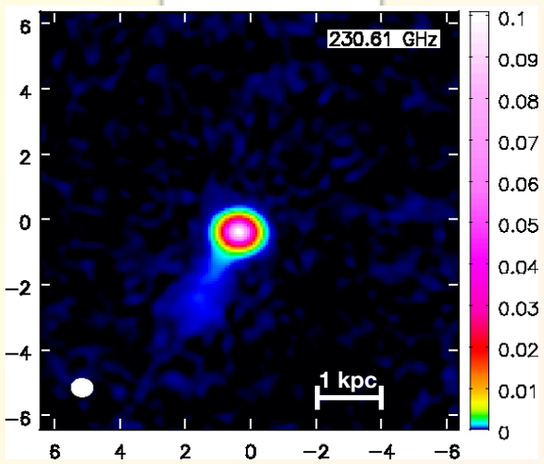


Archival HST images in the F555W filter. Resolution: 0.1 arcsec/pixel. CO moment 0 contours in red

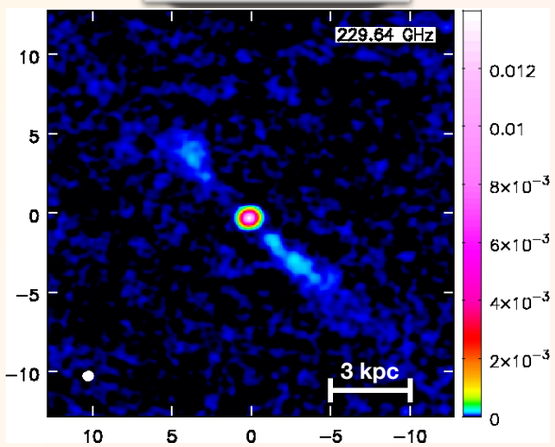
Ruffa et al., submitted to MNRAS

230 GHz continuum emission

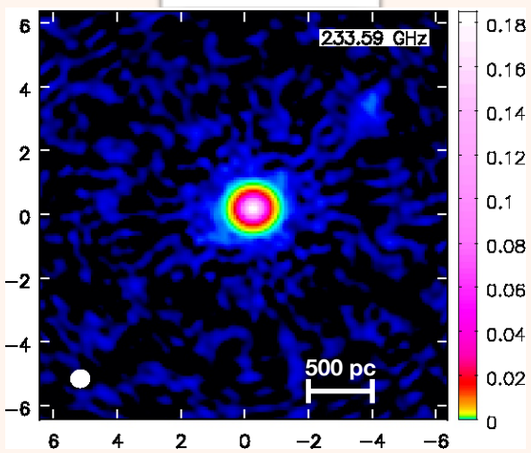
IC 1531



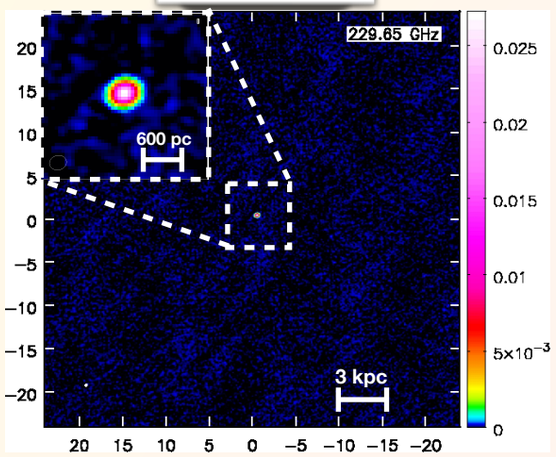
PKS 0718-34



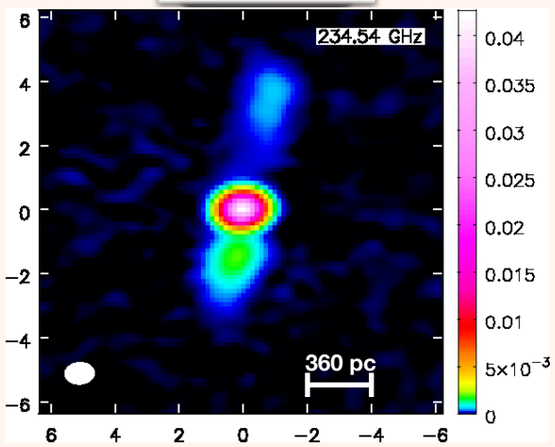
IC 4296



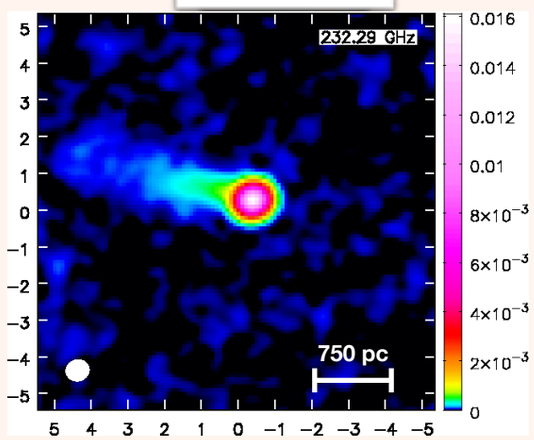
NGC 612



NGC 3100

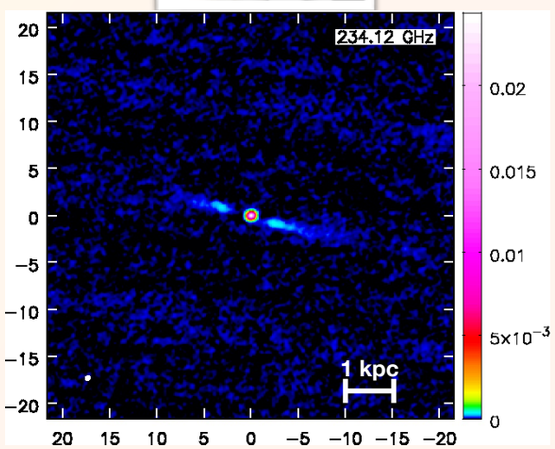


NGC 7075

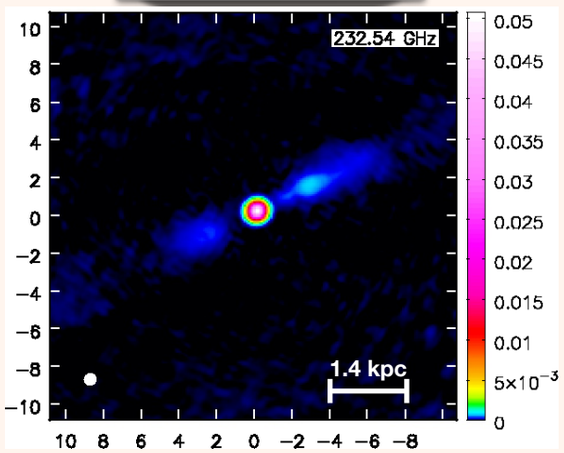


- All the sources detected in continuum
- Six of them show extended emission from the jets, perfectly matching that visible in the archival radio images (1.4-10 GHz)

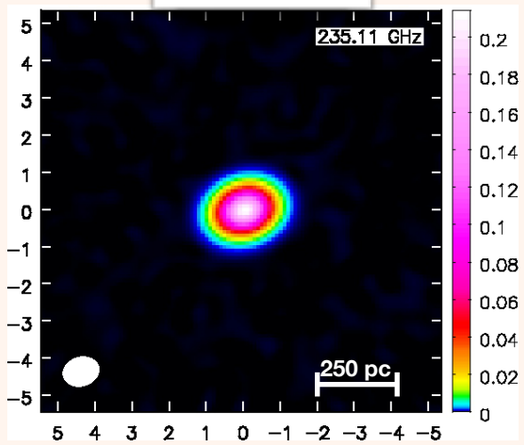
NGC 3557



ESO 443-G 024



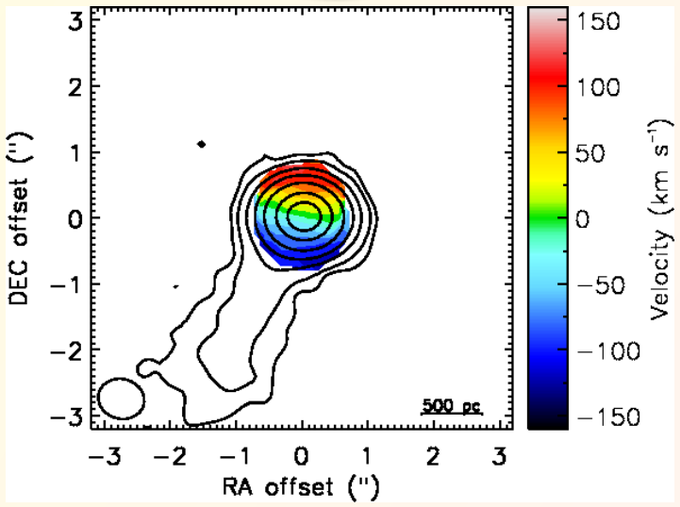
IC 1459



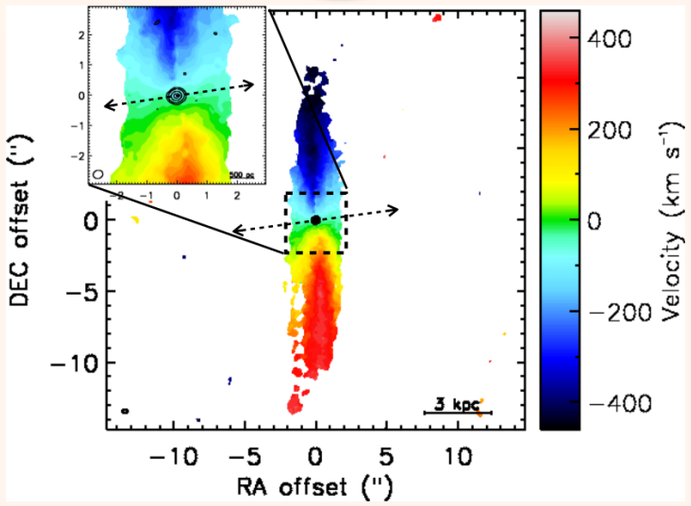
Ruffa et al., submitted to MNRAS

Jets and CO discs

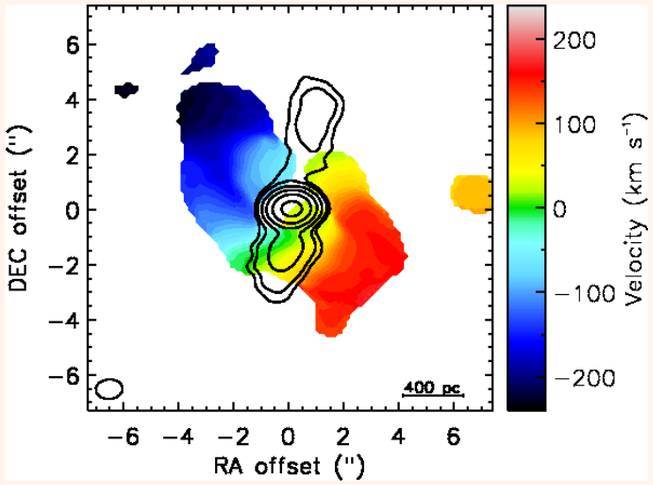
IC 1531



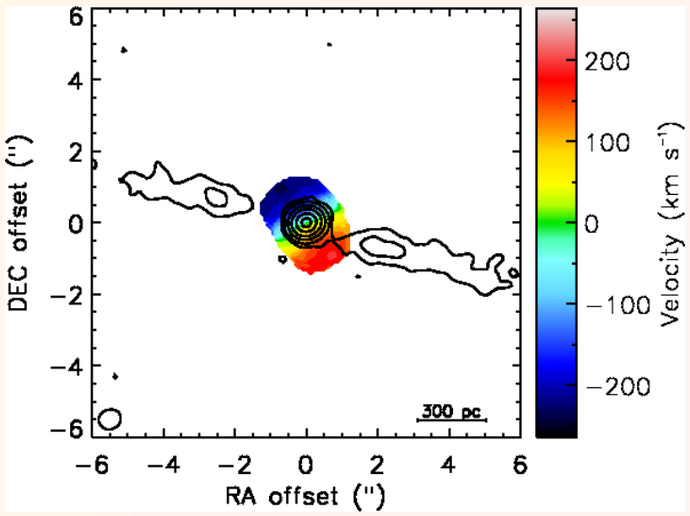
NGC 612



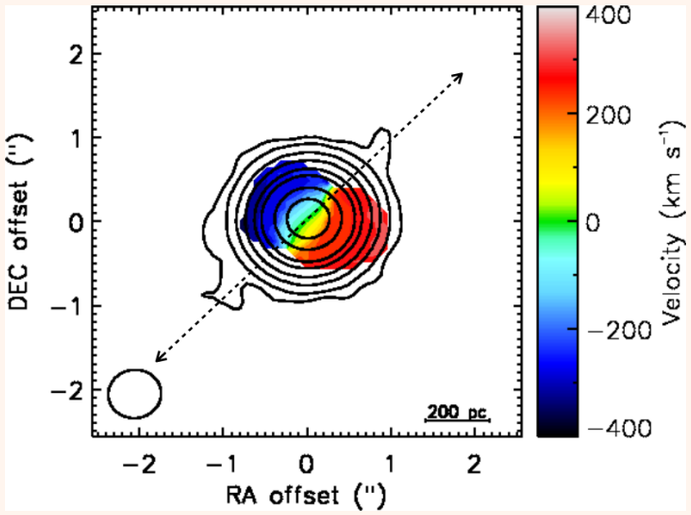
NGC 3100



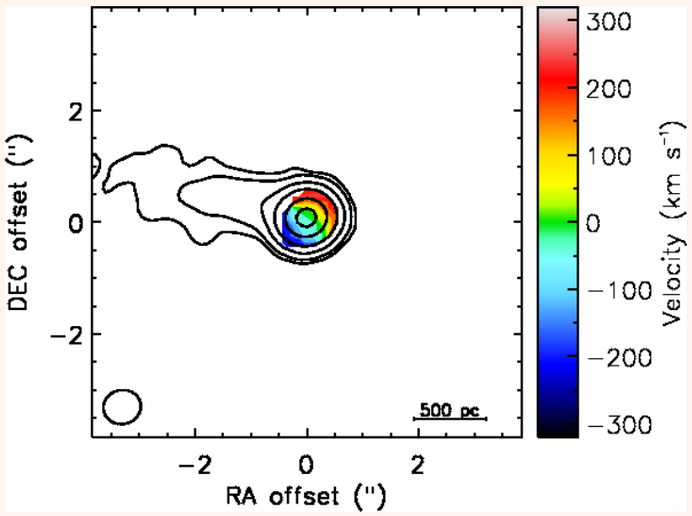
NGC 3557



IC 4296



NGC 7075

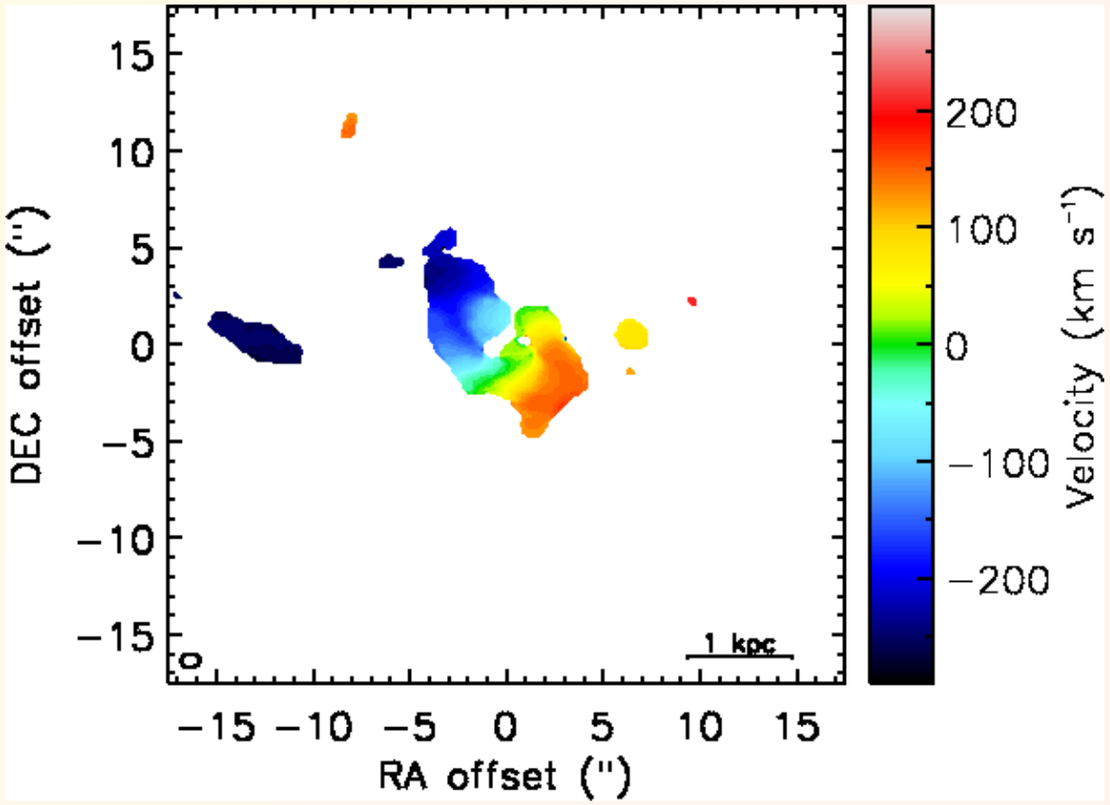


- CO disc/jet axes aligned (in projection) in four cases (NGC 612, NGC 3100, IC 4296, NGC 7075)
- Significant misalignments in NGC 3557 and IC 1531

- Assuming dust/CO co-spatiality: consistence with results of de Ruiter (2002), de Koff (2000)
- Origin of the misalignment?

Ruffa et al., submitted to MNRAS

The case of NGC 3100



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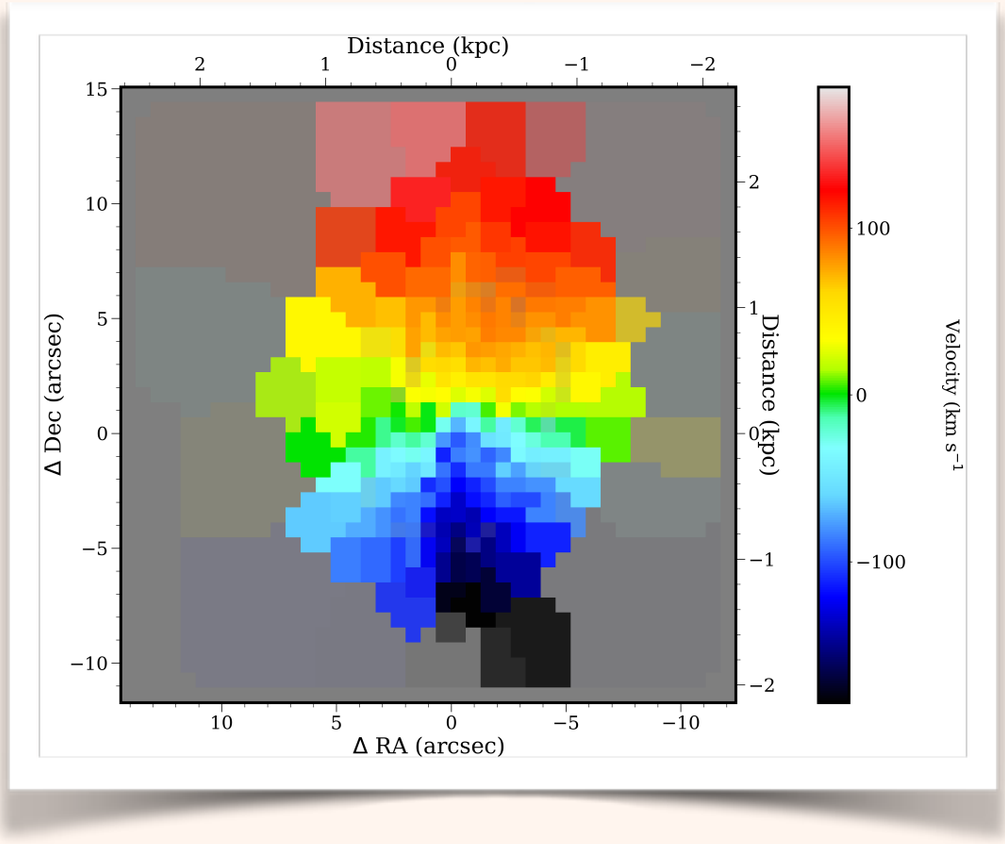

Warren et al., in prep.

- Possible external origin
- Best candidate for a jet/ISM interaction
- Requested (and obtained) 10 hours ALMA observations (PI: I. Ruffa) of different molecular transitions in NGC 3100

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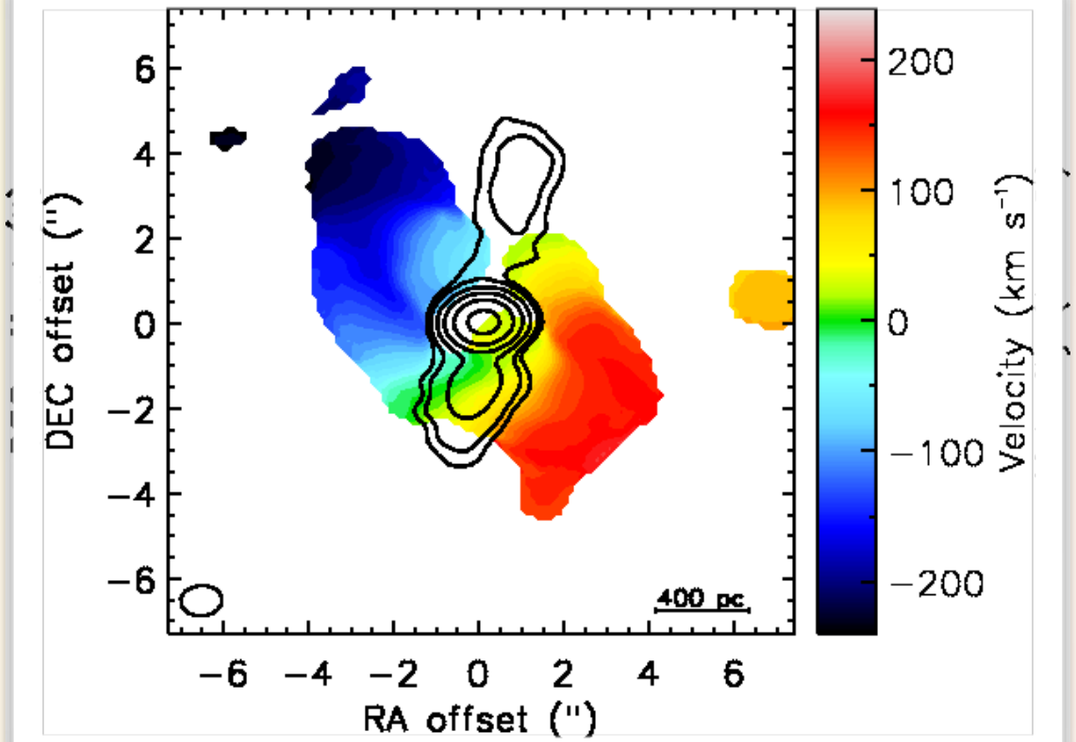

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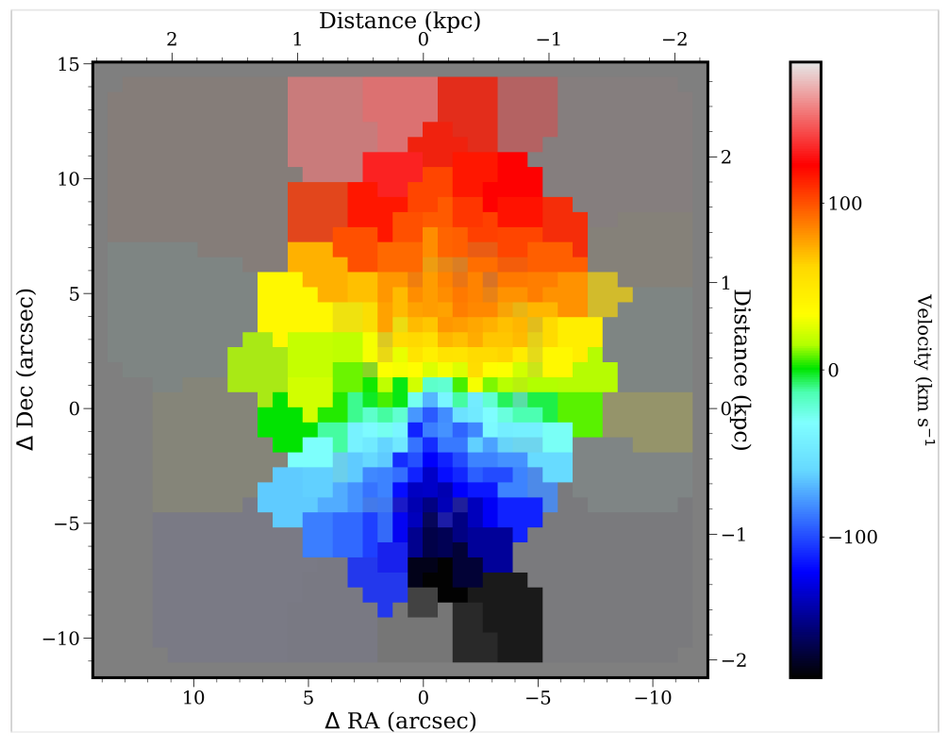

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Future perspectives

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- Detailed analysis of the radio jets using recently acquired high-resolution JVLA 10 GHz continuum data (Ruffa et al., in prep)
- Detailed comparison with optical VIMOS/IFU data (Warren et al., in prep)

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Work in Progress

Thank You