

The nuclear dynamics of nearby extreme galaxies

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Vetenskapsrådet



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Nearby extreme galaxies

- **(Ultra) Luminous Infrared Galaxies [(U)LIRGs]**

- $L_{\text{IR}} > 10^{11} L_{\odot} \gg L_{\text{optical}}$

- Peculiar looking: interacting systems

- Energy source: starburst activity and/or AGN

- Lots of dust/molecular gas

- Become more common with z



NASA / ESA / CSA / Webb



IC 1623

L. Armus / A. Evans / R. Colombari

Nearby extreme galaxies



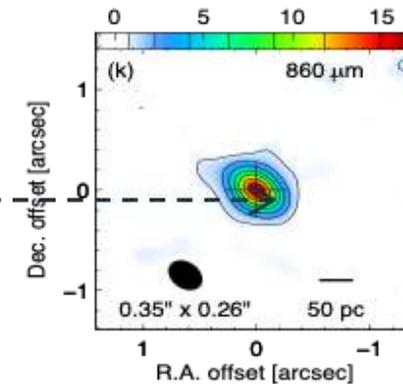
- **Compact Obscured Nuclei (CONs) of (U)LIRGs**

- For 25 % of (U)LIRGs significant fraction of the luminosity originates in inner $\lesssim 20 - 50$ pc

- Power source shielded by dusty gas
 $N_H > 10^{25} \text{ cm}^{-2}$ $A_V \gg 1000$

- Feedback: inflows and outflows to/from the nucleus common

- Extreme gas conditions: very high densities, temperatures and pressures



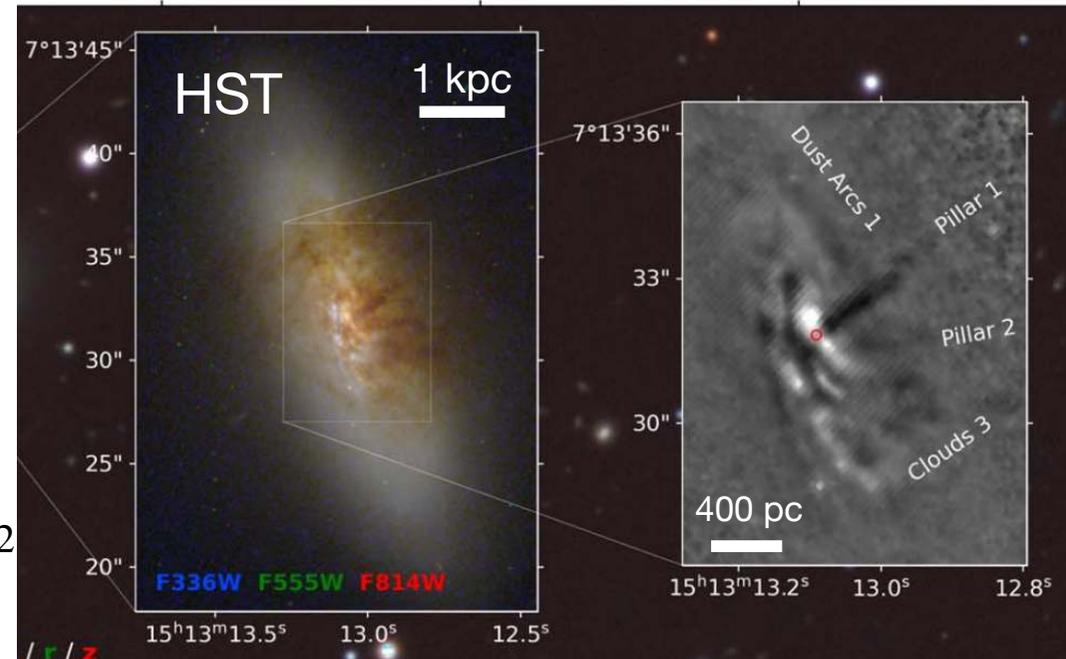
Sakamoto+21



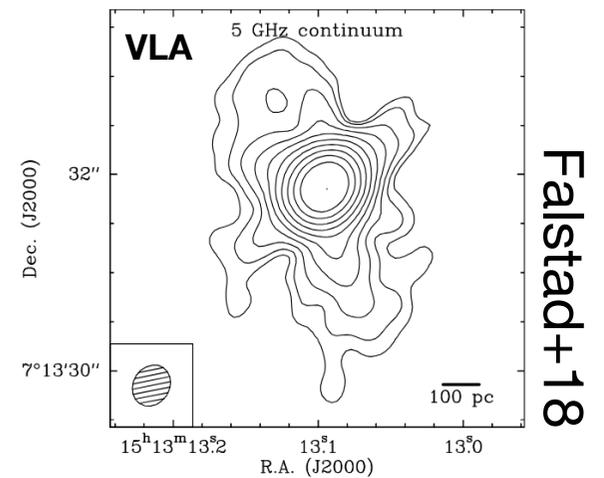
imgflip.com

Zw049.057

- Luminous infrared galaxy: $L_{\text{IR}} = 10^{11.3} L_{\odot}$
- Compact obscured nucleus: $N_H \sim 10^{25.1} \text{ cm}^{-2}$
- Feedback: evidence for inflows and outflows to/from the nucleus
- Dust pillars / radio jets betray complex nuclear activity!



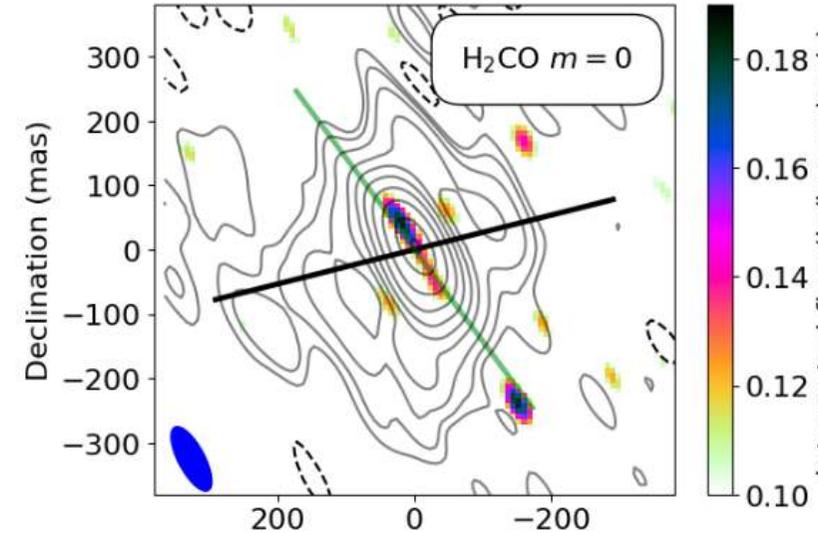
Gallagher+24



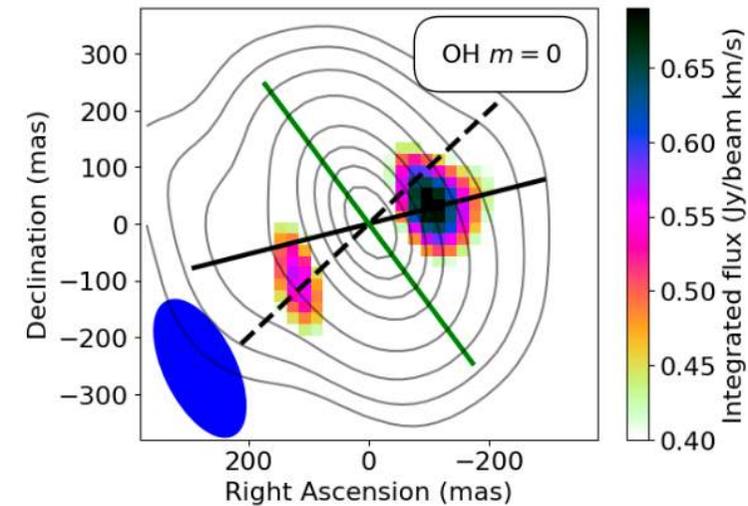
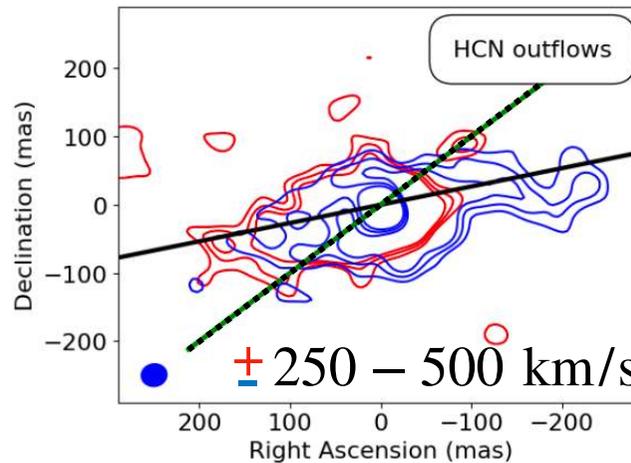
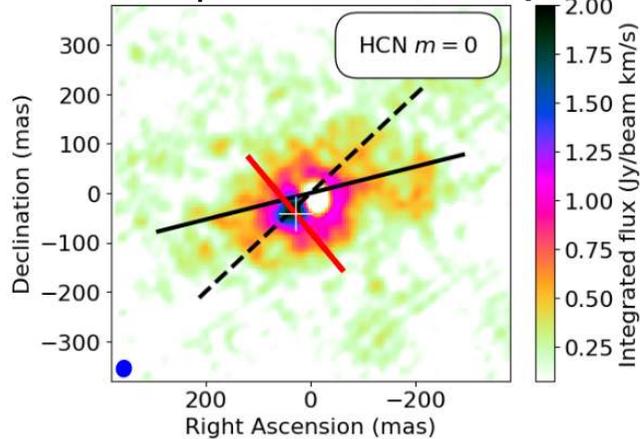
Nuclear dynamics of Zw049.057

- Combined eMERLIN & ALMA study
- Compact disk traced by H_2CO megamaser
- (Multi-phase) outflow traced by OH megamaser & HCN emission

6 cm | res = 37 mas = 10 pc

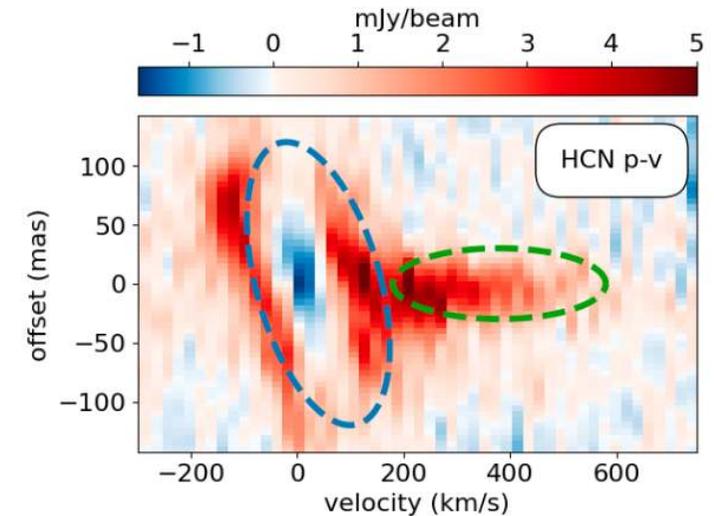
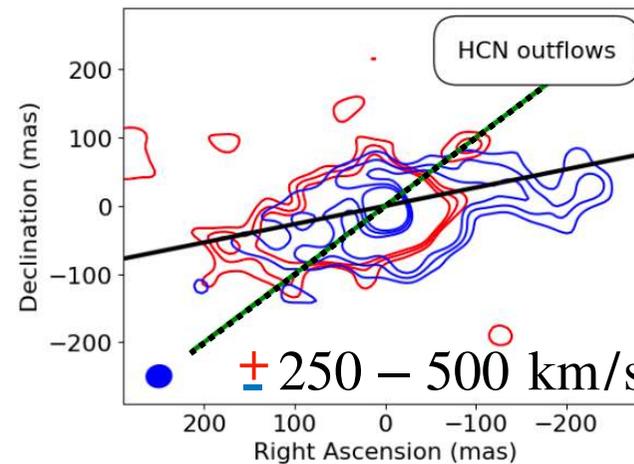
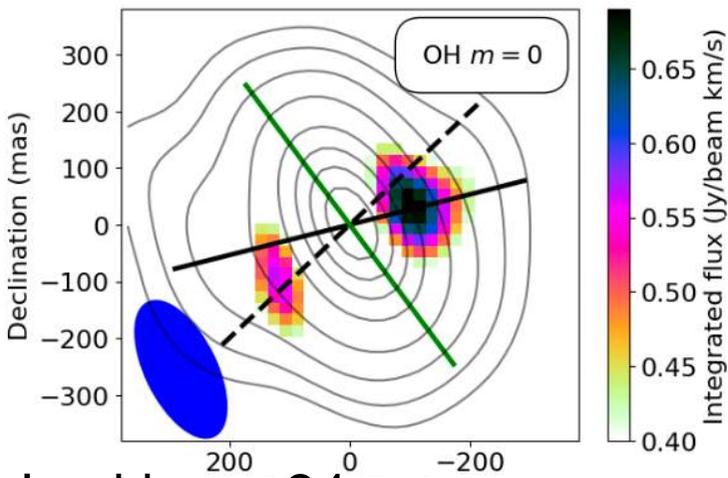
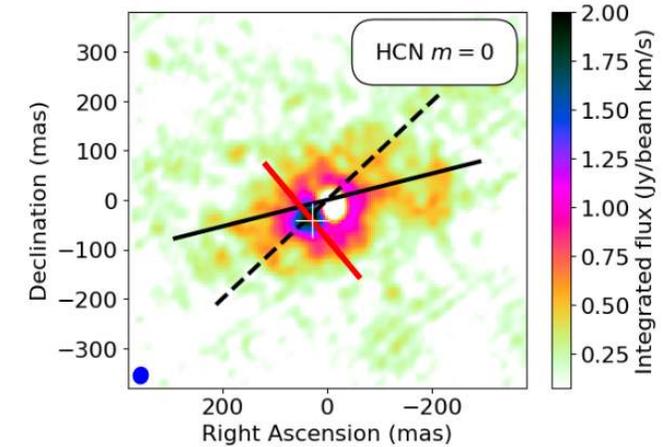


ALMA | res = 24 mas = 6.5 pc



A rotating multiphase outflow

- Two parts:
 - Blue dashed: rotating slow outflow
 $v_z = 40$ km/s
 $v_{rot} = 60$ km/s
 - Green dashed: fast collimated outflow
 $v_z = 200-600$ km/s



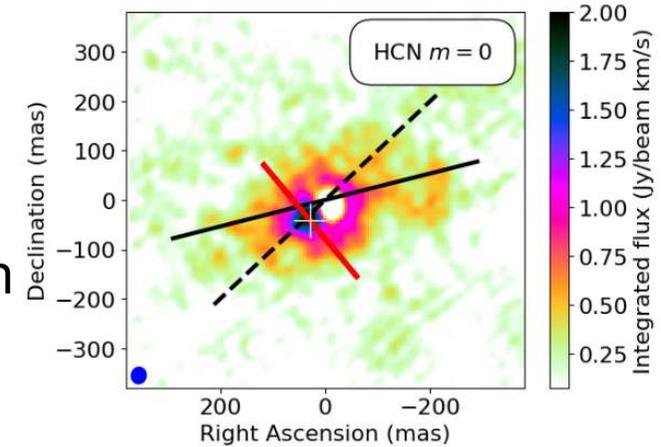
Lankhaar+24

A rotating multiphase outflow

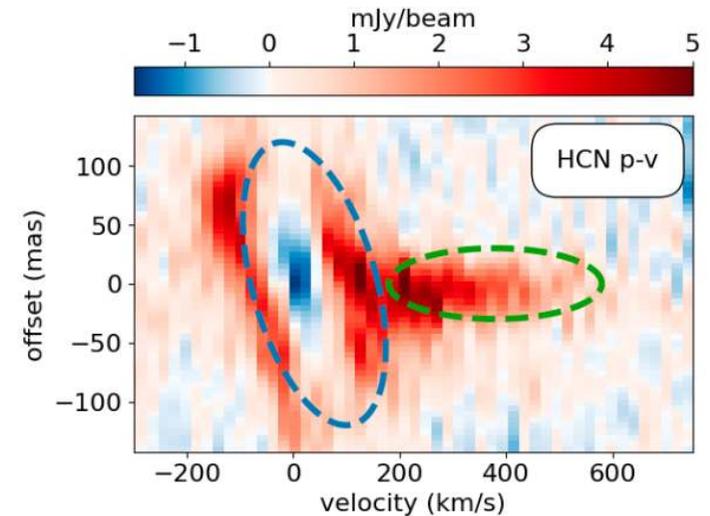
- Two parts:
 - Blue dashed: rotating slow outflow
 $v_z = 40 \text{ km/s}$
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 - Green dashed: fast collimated outflow
 $v_z = 200\text{-}600 \text{ km/s}$



About the same as OH MM expansion

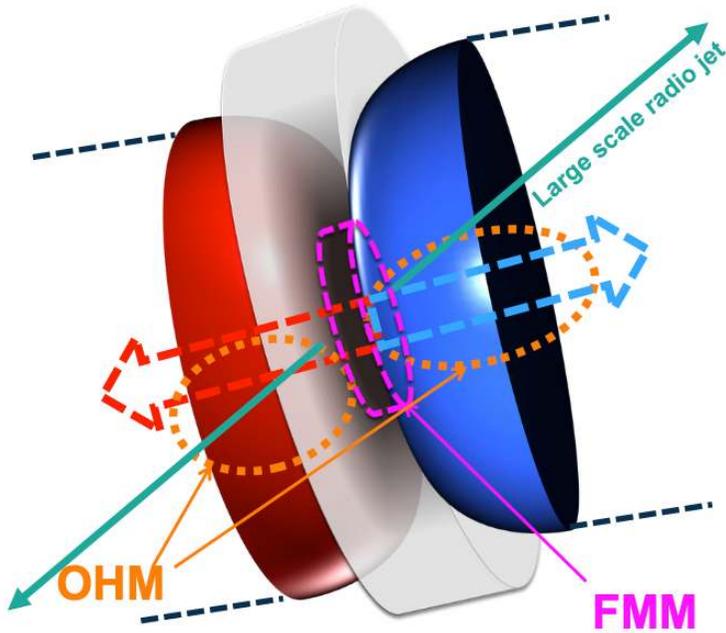


- Fast collimated outflow
 - $L_{\text{HCN}} \sim 12.7 \text{ Jy km/s}$ (250-500 km/s)
 - $M_{\text{outflow}} \sim 1 - 6 \times 10^7 M_{\odot}$
 - $\dot{p}_{\text{outflow}} \sim 1.3 - 6.5 \times 10^{12} L_{\odot}/c$

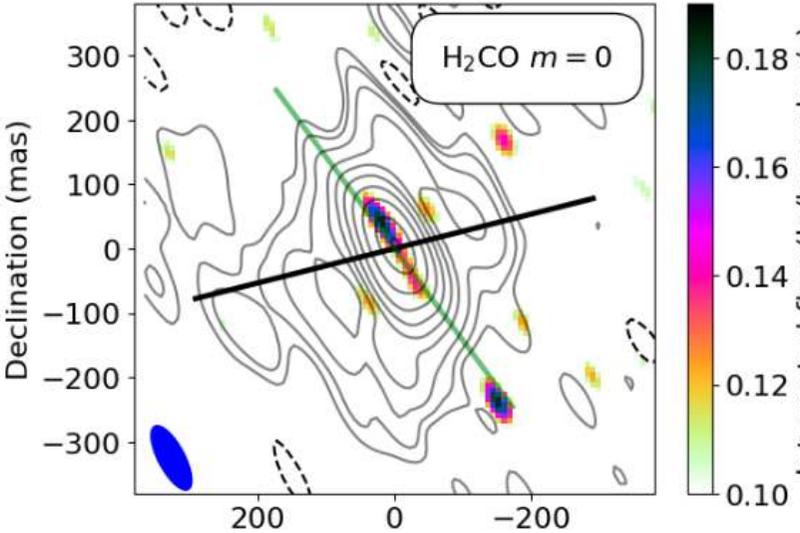


$$L_{\text{IR}}^{\text{Zw049.057}} = 1.8 \times 10^{11} L_{\odot}$$

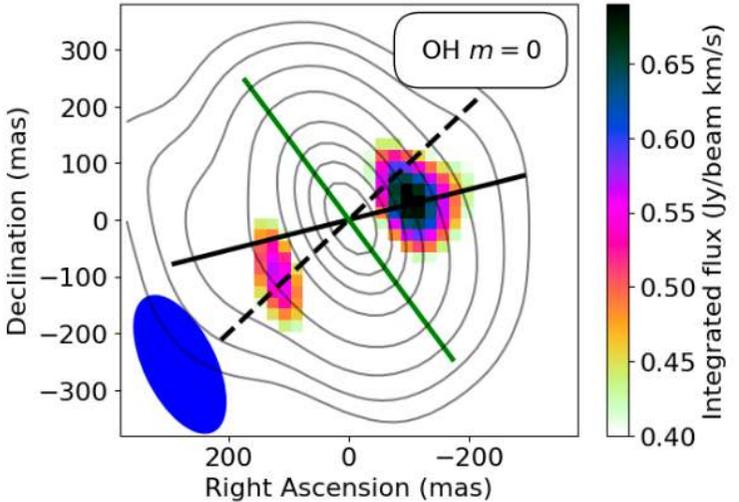
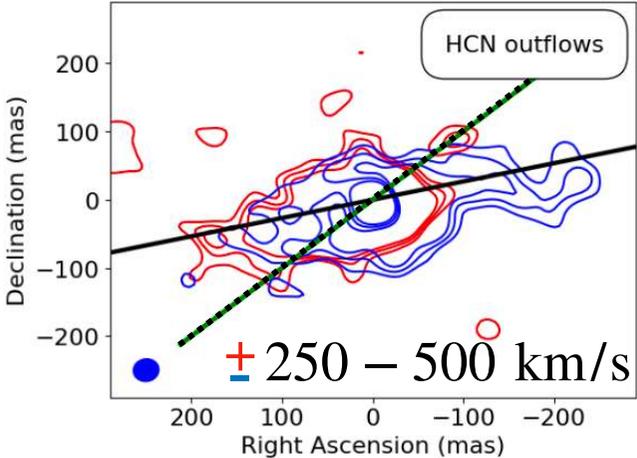
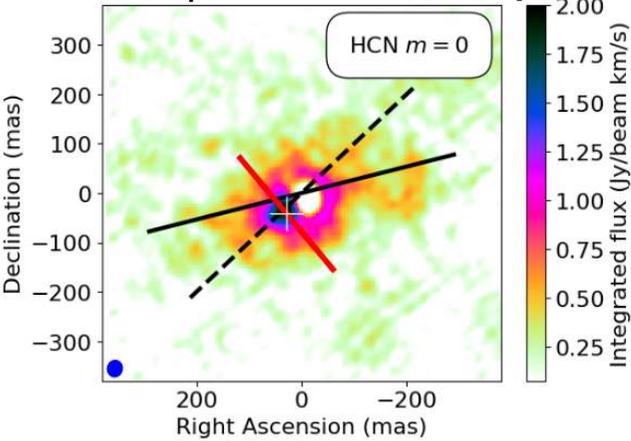
Zw049.057



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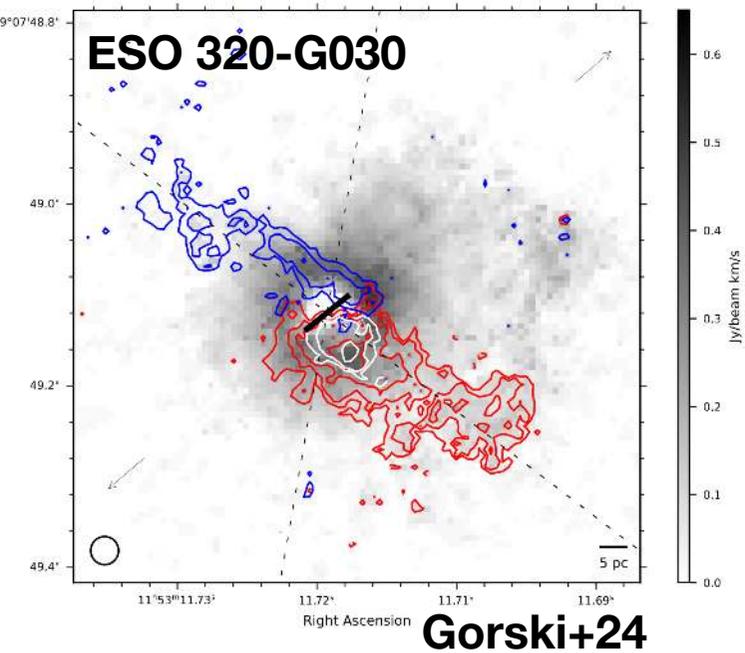


ALMA | res = 24 mas = 6.5 pc

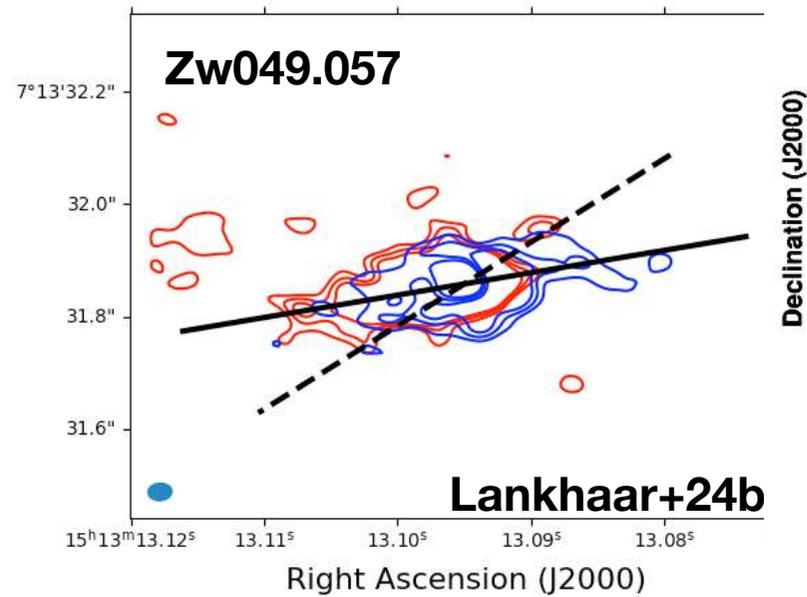


Lankhaar+24

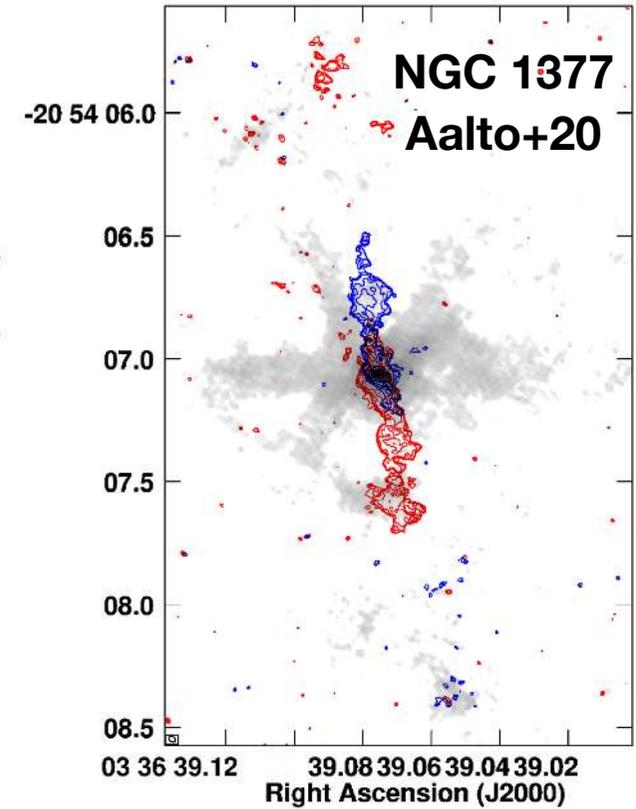
A trend for CON LIRGs?



[L/c]_{norm} ~ 50



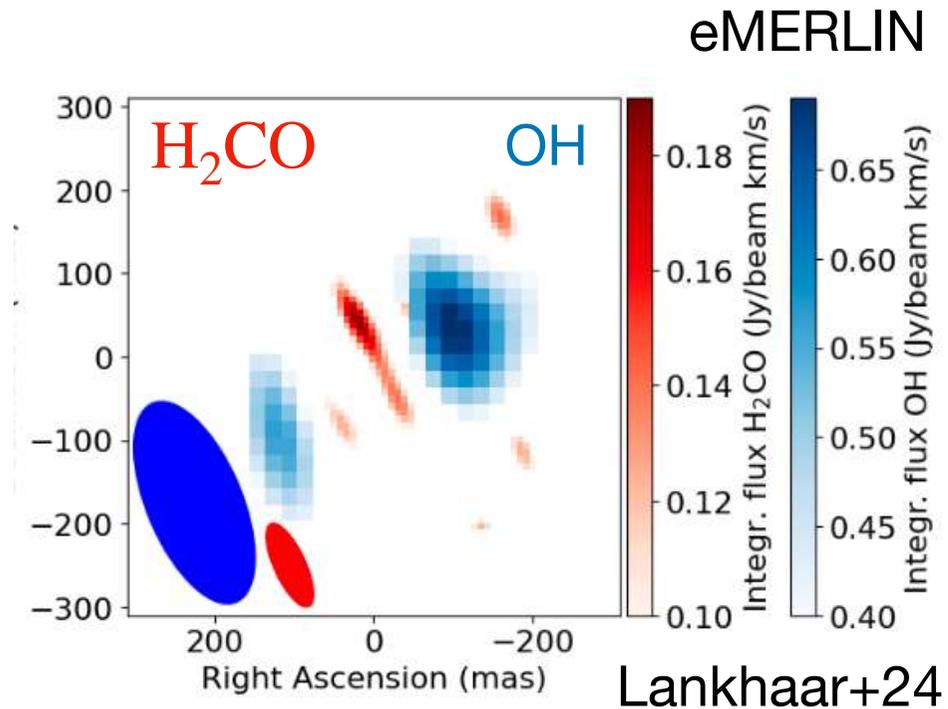
[L/c]_{norm} ~ 20



[L/c]_{norm} > 14

The megamasers of Zw049.057

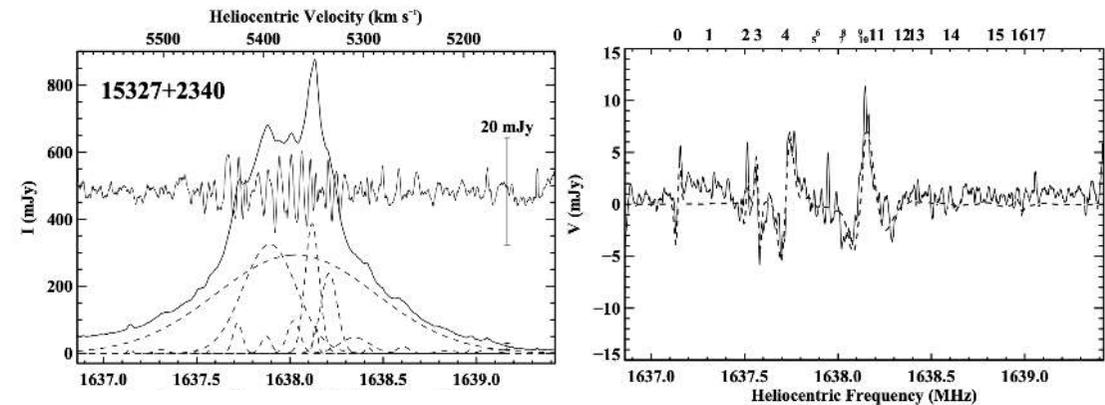
- OH megamaser galaxies: well studied, yet this is first confirmation that OH MM traces outflow
- All H₂CO megamasers are found in OH megamaser sources (and 5/6 are CONs!)
- But maser excitation precludes their direct association
- Spatial and kinematic disassociation required for other OH/H₂CO systems | disk-outflow systems?



The next phase with the SKA



- OHM detections expected to increase 2 orders of magnitude with untargeted HI surveys
- SKA sensitivity allows for (interferometric) probing of the Zeeman effect through circular polarization observations



The Atacama Large Aperture Submm Telescope (AtLAST)

- ✓ First high-res (< 2" at $\nu > 650$ GHz) and wide-field (> 1 deg) single-dish submm observatory
- ✓ Pioneering sustainable astronomy: tailored off-grid renewable energy system
- ✓ Global effort building upon European and Japanese submm expertise
- ✓ A facility for >30 yr, committed to open science

MILKY WAY, GALAXIES, AND COSMOLOGY

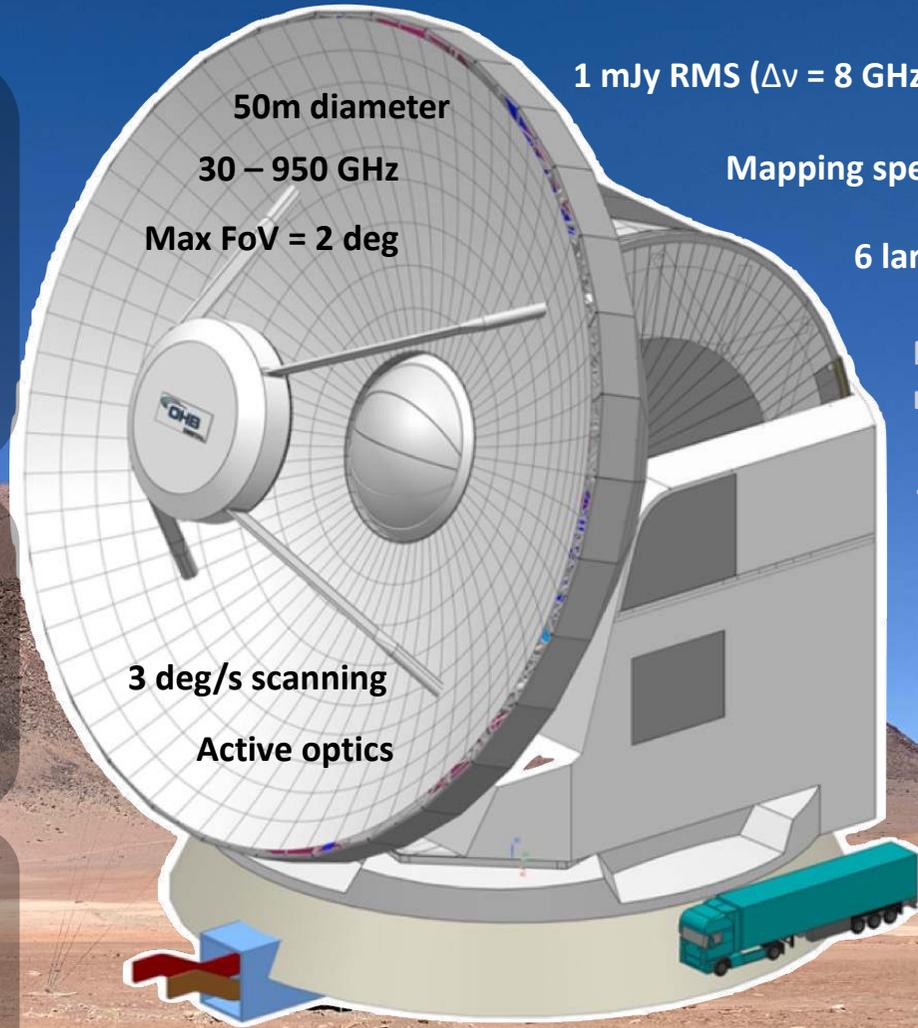
- Link sub-pc protostellar cores & disks with their large-scale environment in our Galaxy
- Resolve the cosmic infrared background
- SDSS-like submm surveys of the local Universe
- Map elusive gas flows and cosmic web filaments

CROSS-FIELDS

- Discover transient & time-varying submm sky
- Solve missing flux issue of interferometers

SOLAR SYSTEM

- Track solar activity driving space weather
- Survey HDO & D₂O in comets



1 mJy RMS ($\Delta\nu = 8$ GHz) @ 350 GHz in < 8 s

Mapping speed $10^3 - 10^5$ x ALMA

6 large instrument cabins

Multi (>10⁵)- beam & multi-band receivers

Time domain science

Solar observations

Continuum & line polarization

Find out more: atlast-telescope.org



Funded by the European Union

The nuclear dynamics of nearby extreme galaxies

- Luminous infrared galaxy Zw049.057
- Nuclear activity: complex outflow system
- Radio + submm study: megamasers + HCN emission
- With the SKA: target magnetic fields

