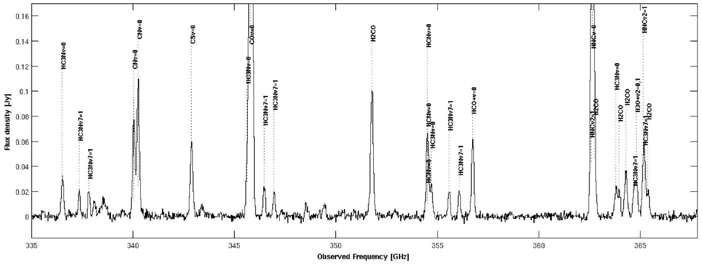


Physical Conditions and Chemistry of Molecular Gas in Galactic Centres

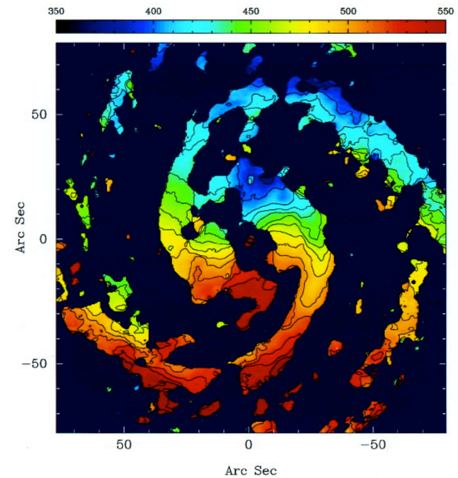
S. Aalto
Department of Earth and Space Sciences,
Chalmers University of Technology
Sweden

Outline

- Physical conditions and chemistry
- Dusty nuclei
    - Vibrational lines – peeking behind the veil of dust
- Starburst nuclei
- AGNs

Driving the gas to the center

- Spiral arms
  - Flocculent
  - Grand design
- Bars
  - Strong/weak
  - Nested
- Interacting galaxies
  - Polar rings, dust lanes counterrotating and infalling gas
  - Tidal gas
  - ”Overlap regions”

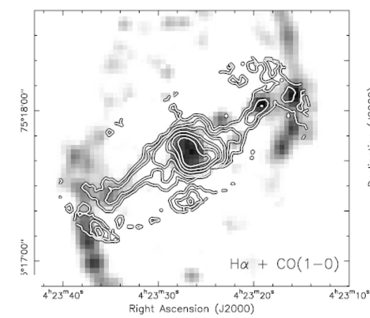


Grand design molecular spiral in M51

Aalto et al 1999

Molecular bar in NGC1530

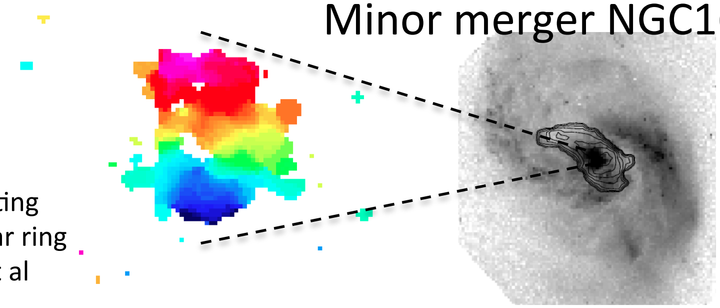
Reynaud et al 1999



...and it collects in: disks, rings, mini-bars, Compact Obscured Nuclei (CONs)

...Feeding AGNs, starbursts and driving outflows and winds

Minor merger NGC1614

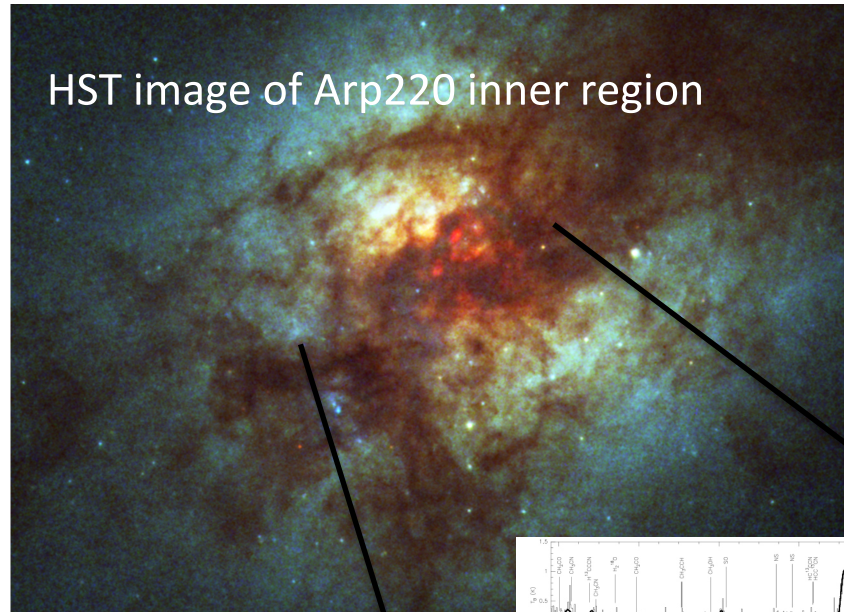


600 pc starbursting molecular ring (König et al 2013)

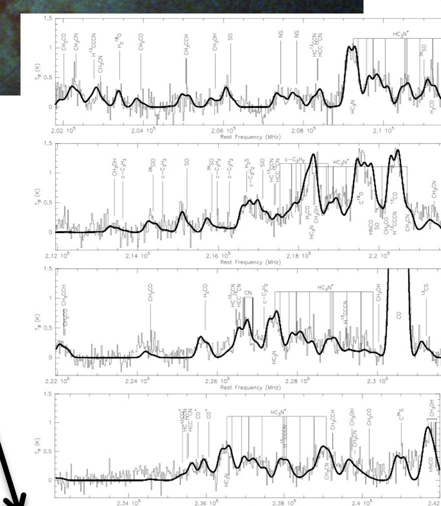
Olsson et al 2010

Why astrochemistry?

- Its there! …(and we are creatures driven by curiosity)
- We can use it as a tool to study galaxy evolution - in particular in dust-obscured objects:
  - Starburst and AGN (Active Galactic Nuclei) evolution
  - Starburst and AGN classification
  - Feedback mechanisms
  - Impact of shock, outflows, turbulence



The dusty cores of the Ultraluminous infrared galaxy Arp220. A_V>1000 in both nuclei

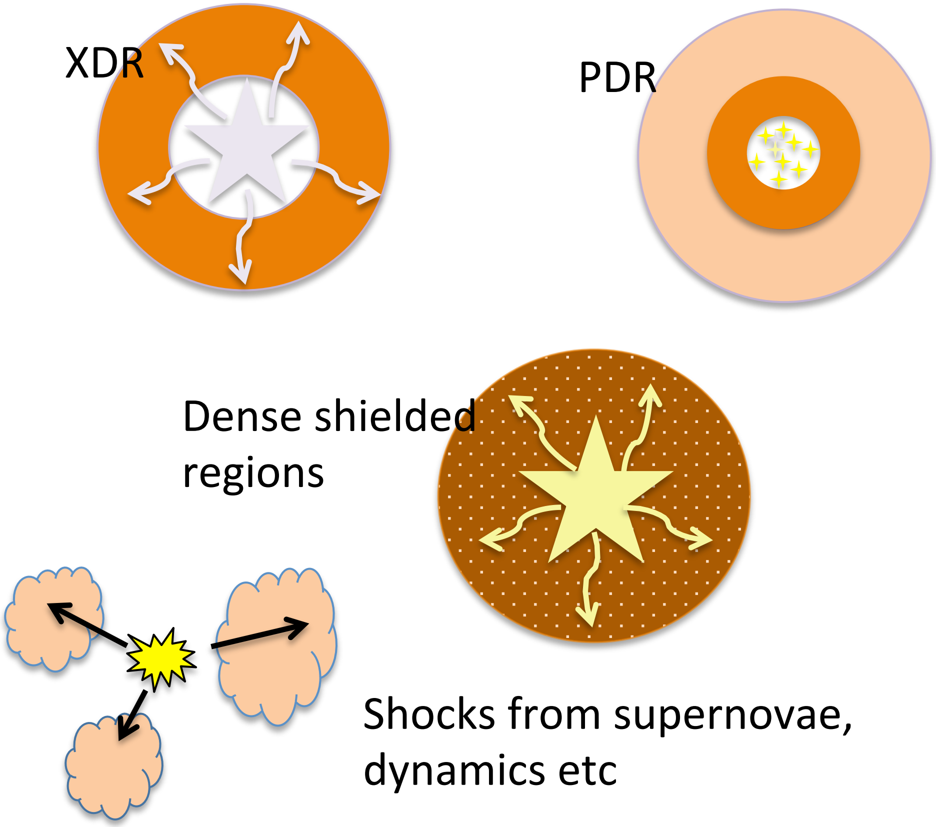


SMA spectral scan (Martin et al 2011)

Astrochemistry as a diagnostic tool

A few standard scenarios:

- X-ray dominated region (XDR) – large bulk temperatures > 100 K (e.g. Maloney et al 96; Lepp & Dalgarno 96; Meijerink and Spaans 05)
- Photon dominated region (PDR) – large surface temperatures 300-1000 K – moderate bulk temperatures 20-50 K (e.g. Hollenbach & Tielens 97)
- Cosmic ray dominated region (CDR) (e.g. Suchkov et al 93; Meijerink et al 11)
- Dense shielded regions – dusty hot core-like chemistry (IR pumping), 50-300 K (see e.g. work by Viti, Millar)
- Mechanically dominated region – shock-chemistry (e.g. Viti et al 11; Kazandjian et al 11)



Main question: What are the key spectral signatures of the above scenarios?

Extragalactic molecules

Table 5. Census of extragalactic molecular species and isotopologues detected

2 atoms	3 atoms	4 atoms	5 atoms	6 atoms	7 atoms
OH	H_2O, $H_2^{18}O$	H_2CO	c-C_3H_2	CH_3OH, $^{13}CH_3OH$	CH_3C_2H
CO {^{13}CO, $C^{18}O$, $C^{17}O$}	HCN {$H^{13}CN$, $HC^{15}N$, DCN}	NH_3	HC_3N {$H^{13}CCCN$, $HC^{13}CCN$, $HCC^{13}CN$}	CH_3CN	
H_2, HD	HCO^+ {$H^{13}CO^+$, $HC^{18}O^+$, DCO^+}	HNCO	CH_2NH		
CH	C_2H	H_2CS	NH_2CN		
CS {^{13}CS, $C^{34}S$, $C^{33}S$}	HNC {$HN^{13}C$, DNC}	$HOCO^+$	CH_2CO		
CH^+	N_2H^+, N_2D^+	C_3H			
CN	OCS	H_3O^+			
SO, ^{34}SO	HCO				
SiO, ^{29}SiO	H_2S				
CO^+	SO_2				
NO	HOC^+				
NS	C_2S				
LiH	H_3^+				
CH	H_2O^+				
NH					
OH^+					
HF					

From: Martin et al 2011

Popular diagnostic lines
Physical conditions

Gas density

Low-J CO to trace low density gas $n>10^2$ cm^{-3}

High dipole moment molecules such as HCN to trace dense gas $n>10^4$ cm^{-3}

Gas temperature

- NH_3, H_2CO
- CO ladder

Isotopomers

- e.g. $CO/^{13}CO$
  - tracer of optical depth and ISM/cloud structure, stellar processing

This only works when molecules excited by collisions – caveat for centers of galaxies

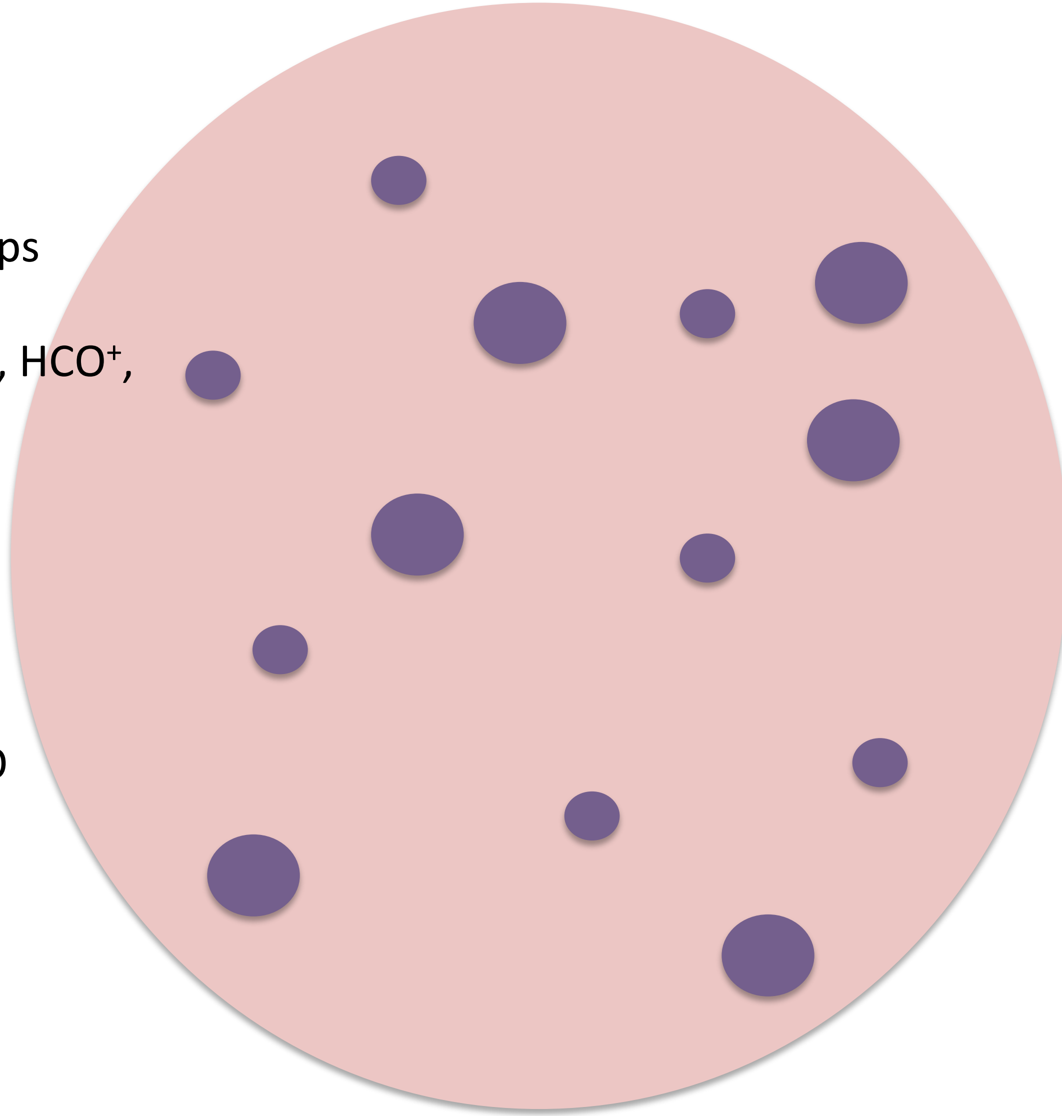
Rough trends

- CO/HCN ratio decreasing towards galaxy centers
  - Increasing average gas densities
  - Higher pressures
- CO/13CO ratio increasing towards galaxy centers
  - Elevated gas temperatures
  - Diffuse molecular gas

„Raisin roll" molecular medium?

Dense cores/clumps
10^5 cm^{-3}
traced by HCN, CS, HCO^+, HNC etc

Low density
10^2 cm^{-3}
diffuse molecular gas
traced by low-J CO



Molecular mass in dense clumps

Volume dominated by diffuse gas

High pressure ISM with low columns of HI

Bright HCN 1-0 – subthermally excited CO and large $CO/^{13}CO$ 1-0 ratios

Popular diagnostic lines
Astrochemistry

Molecular ions:

- HCO^+
  - Elevated HCN/HCO^+ ratios in AGN cores? (e.g. Kohno et al 2003, Imanishi et al 2004). Elevated ratios in dense shielded gas? (Aalto et al 2007a)
- H_3O^+
  - Enhanced in XDRs? Proxy for water (van der Tak 2009, Aalto et al 2011)

Isomers:

- HNC
  - Elevated HNC/HCN ratios in cold gas, elevated ratios in XDRs, PDRs. Shocks remove HNC.
  - (e.g. Schilke et al 92; Aalto et al 2001; Aalto et al 2007b; Baan et al 2010)

Carbon chains

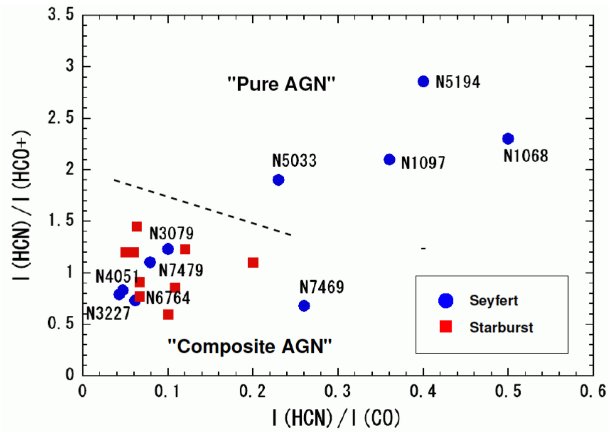
- HC_3N
  - Elevated HC_3N/HCN ratios in dense, shielded gas. Tracing IR field? (see later slides). (e.g. Aalto et al 2007a; Costagliola and Aalto 2010)

Radicals

- CN
  - Enhanced in XDRs, PDRs (e.g. Aalto et al 2001; Baan et al 2010; Meijerink and Spaans 2005)

Shock tracers

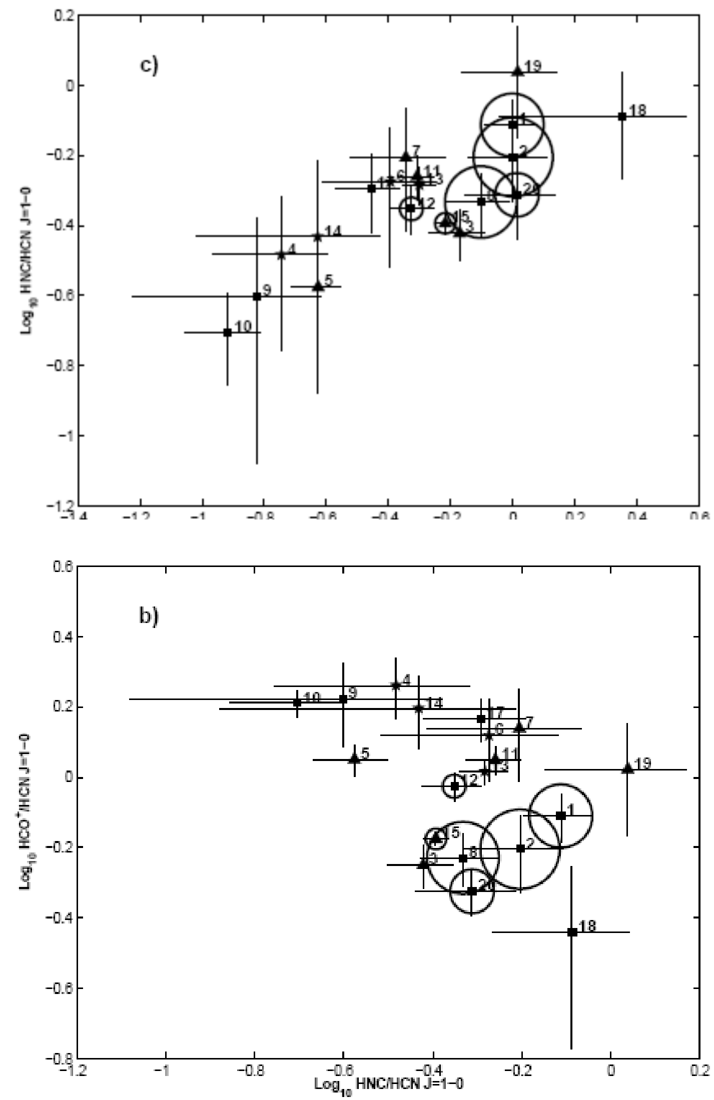
- SiO, H_2O
  - Enhanced in strong shocks – for SiO grain sputtering is required.
- HNCO and CH_3OH, NH_3
  - Enhanced in spiral and bar shocks



HCN/HCO+ plot of Kohno et al – is it an AGN tracer?

Global line ratio trends

Correlation plots from Costagliola et al 2011



No *strong* trends in the brightest tracers.

- ***In general: HNC 1-0 luminosity is anticorrelated with HCO^+ 1-0***
- ***C_2H is everywhere…***

Stronger trends for weaker lines – e.g. HC_3N:

- ***HC_3N luminous galaxies (circles) always appear for HCO^+ faint and HNC luminous galaxies***

All HC_3N luminous galaxies have significant mid-IR silicate absorption features → obscured galaxies → young activity?

Strategy:

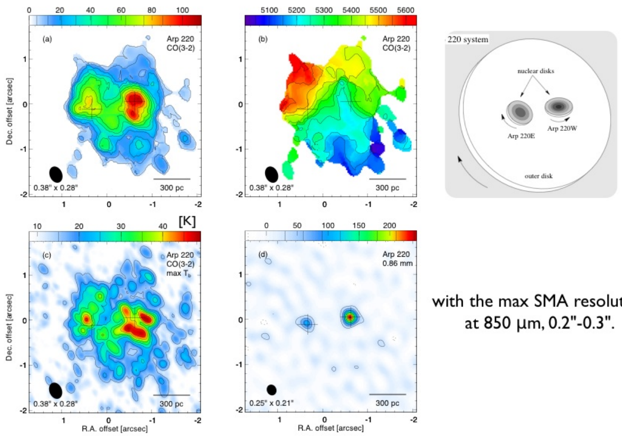
- Use *spectral scans* to find weaker lines and identify dominant chemistry.
- Observe at higher resolution.

What is buried behind the veil of dust?

HOT CORES

Compact Obscured Nuclei (CONs): Extreme, nuclear molecular disks.

Arp 220 : SMA 860 μm obs.

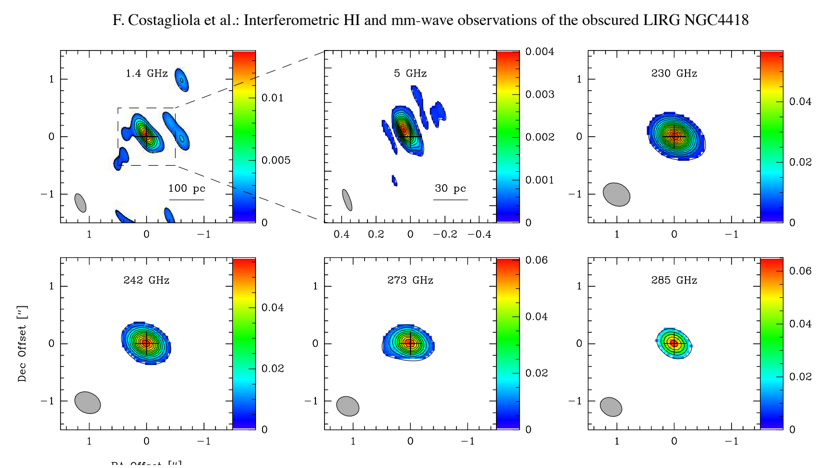


with the max SMA resolution at 850 μm, 0.2"-0.3".

Rotating disks & warm gas, confirmed

(Sakamoto et al. '08)

NGC4418 SMA 1 mm & Merlin 1.4 GHz continuum



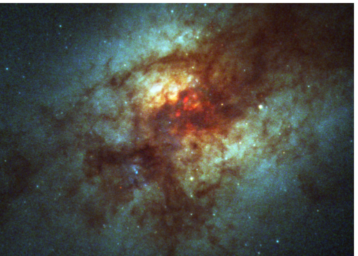
Costagliola et al 2013, Sakamoto et al 2013

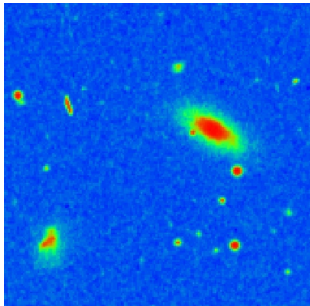
Arp220 is a system of two merging gas-rich disk galaxies.
It is not known if its enormous IR luminosity 10^{12} Lsun Is driven by star formation or accreting black holes

Compton thick, hot dusty cores:

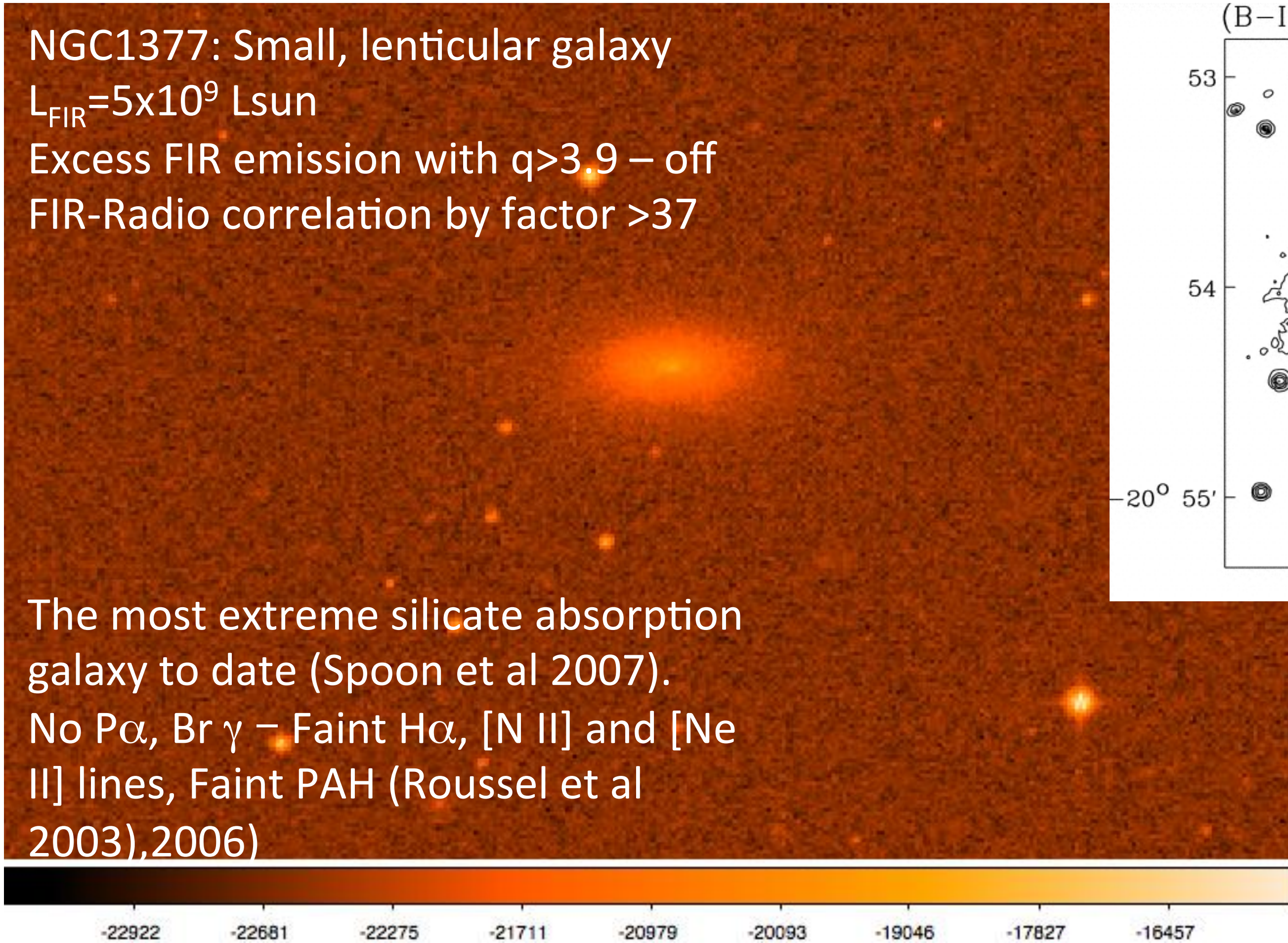
- Nuclear column densities > 10^{24} cm^{-2},
- gas surface densities >10^4 M_{sun} pc^{-2}

NGC4418 is an interacting Sa LIRG with two orders of magnitude lower luminosity than Arp220 – but shows a similar compact obscured nucleus



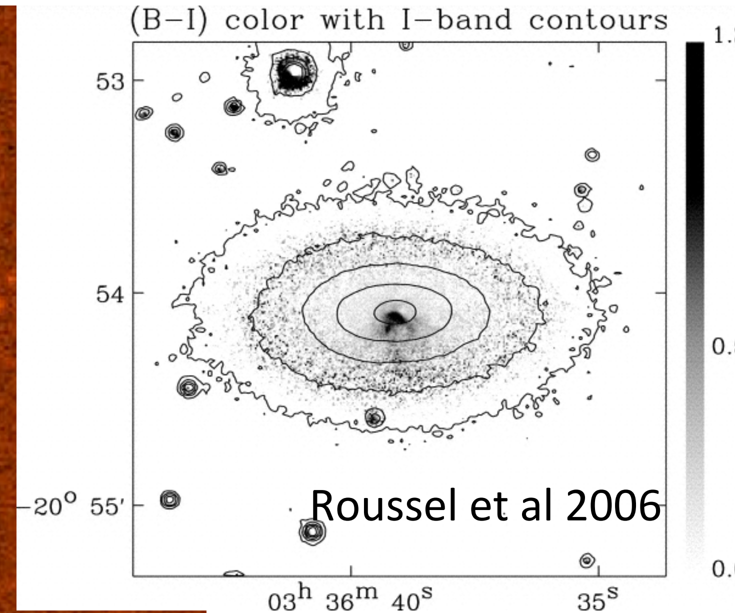


Winds of change - a molecular outflow in the most extreme FIR-excess, radio-quiet galaxy



NGC1377: Small, lenticular galaxy
$L_{FIR}=5\times10^{9}$ Lsun
Excess FIR emission with q>3.9 – off FIR-Radio correlation by factor >37

The most extreme silicate absorption galaxy to date (Spoon et al 2007).
No Pα, Br γ – Faint Hα, [N II] and [Ne II] lines, Faint PAH (Roussel et al 2003),2006)



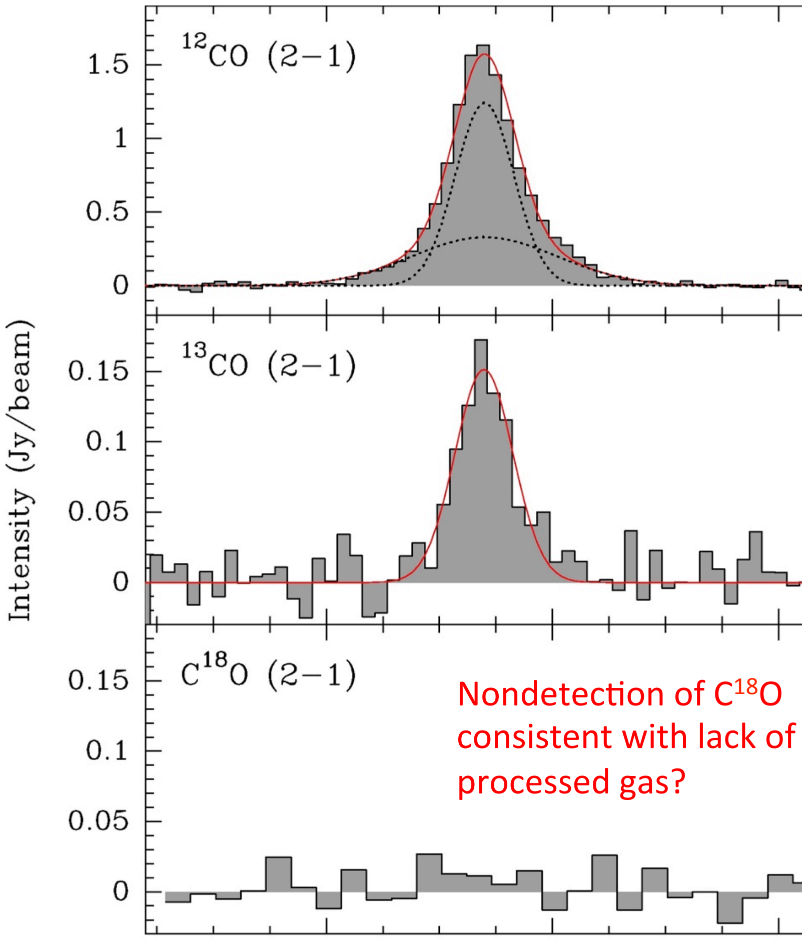
Roussel et al 2006

Featureless morphology apart from southern minor axis dust structure

Post starburst/LINER optical characteristics

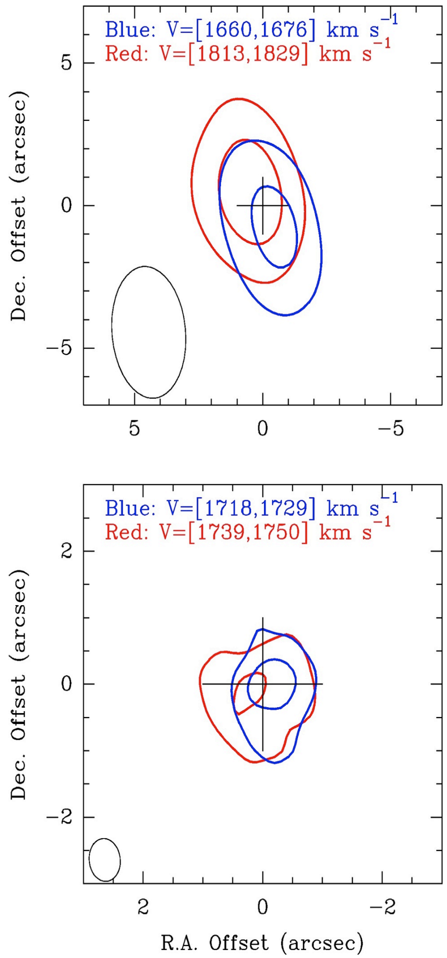
What is powering the compact IR luminosity - Obscured AGN or nascent starburst?

SMA CO and ^{13}CO 2-1 observations

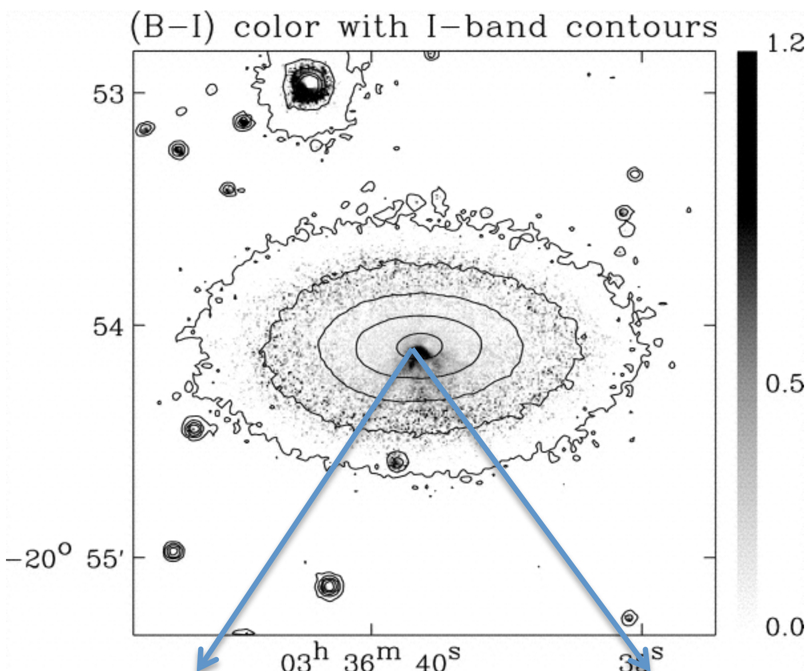


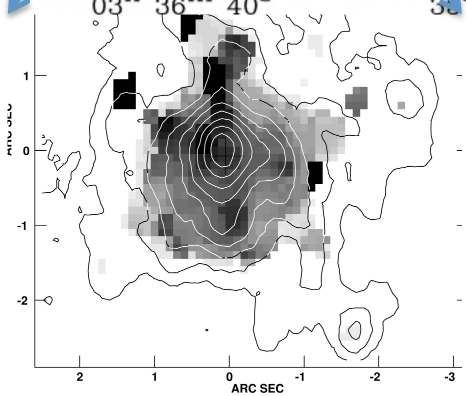
Nondetection of $C^{18}O$ consistent with lack of processed gas?

Line wings (top panel) and disk rotation (lower panel) reveal a disk-outflow system



(Aalto et al 2012)





X-shaped structure outlining the walls of a bicone

Overlay of CO integrated intensity contours on CO dispersion

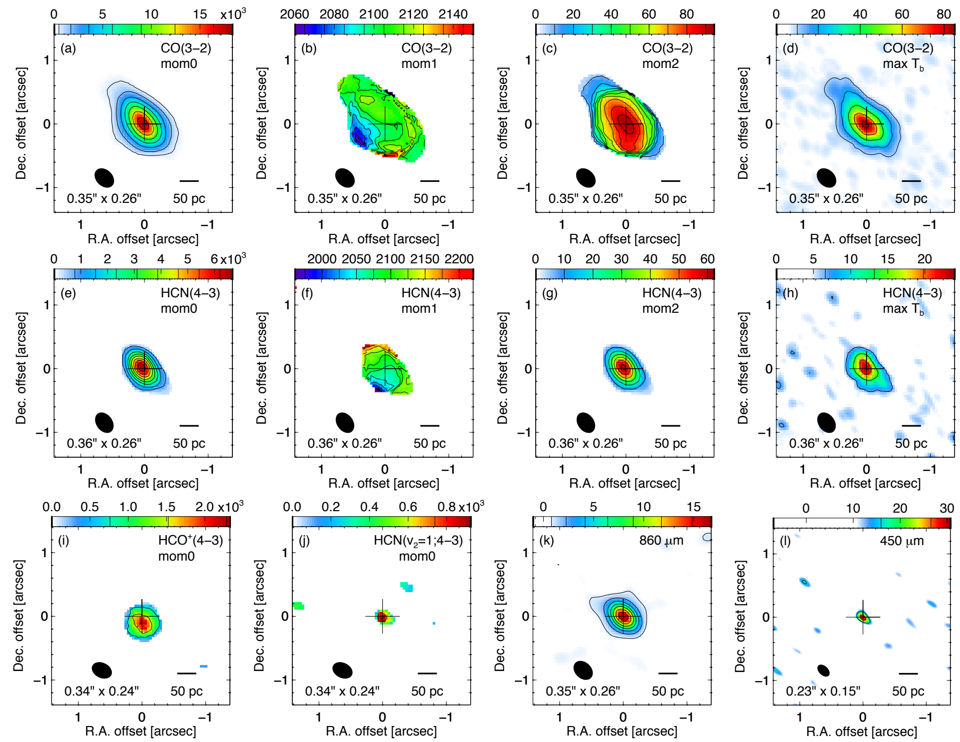
- Molecular mass: 1-6x10^7 M$_\odot$
- Extent: 400 pc
- Opening angle: 60°–80°
- Age(?): 1.4 Myr
- Outflow velocity: 150 - 200 kms^{-1}
- dM/dt: 8–38 M$_\odot$ yr^{-1}
- Molecular core of N(H_2)>10^{23} cm^{-2}

Outflow appears to accelerate to maximum speed already at nucleus

NGC4418

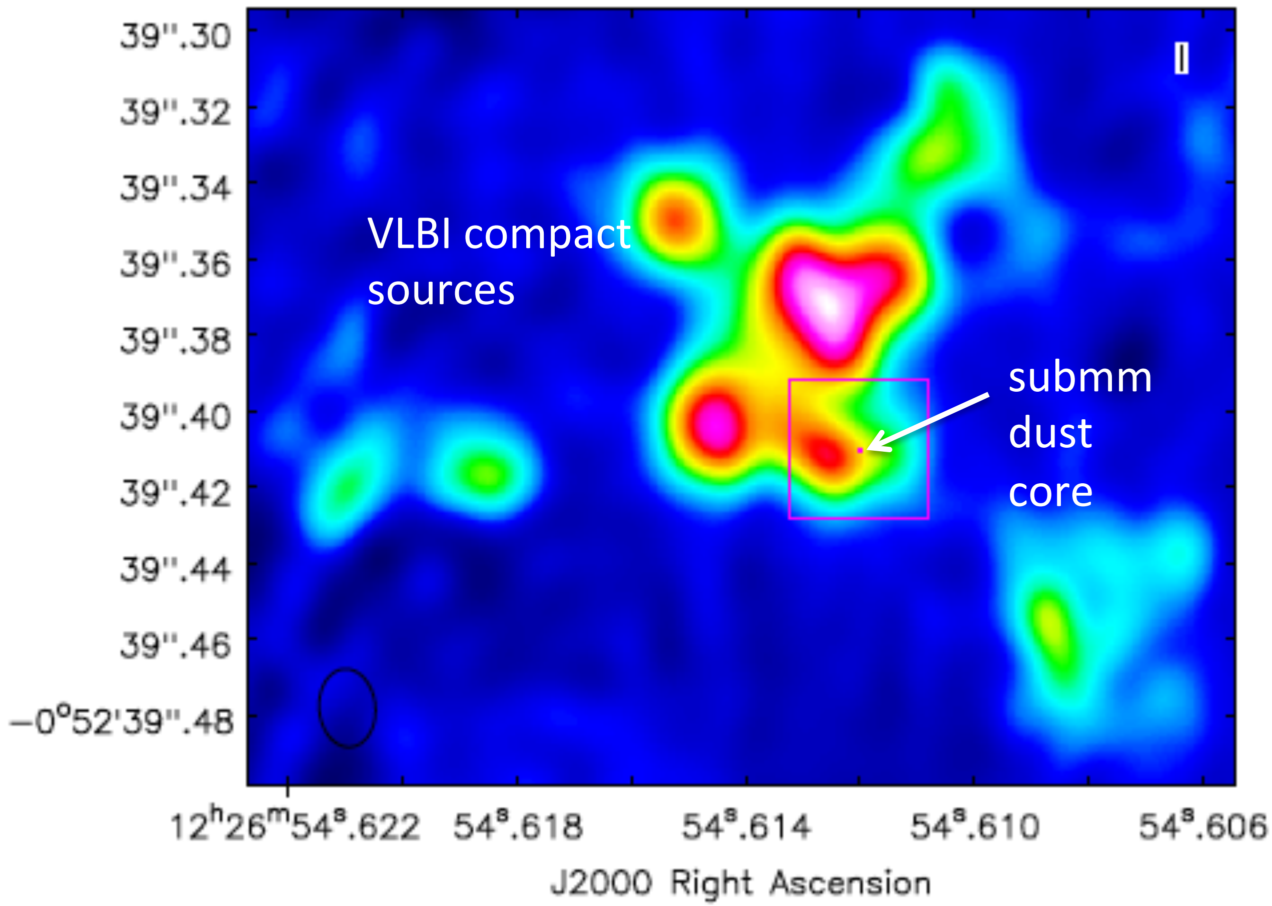
345, 230 GHz SMA observations + MERLIN HI

- Submm continuum at 860 μm emerges from a <0. "1 (~20 pc) core at the nucleus. *The 1.4 GHz continuum has a source size of 0."5.*
- Total luminosity of the 20 pc core is approx $10^{11.0}$ $L_{\odot}$ - the bulk of the total luminosity of NGC4418.
- T_B(860 μm)=120-210 K, τ(860 μm) = 1 (i.e., $N_H>10^{25}$ cm^{-2}).



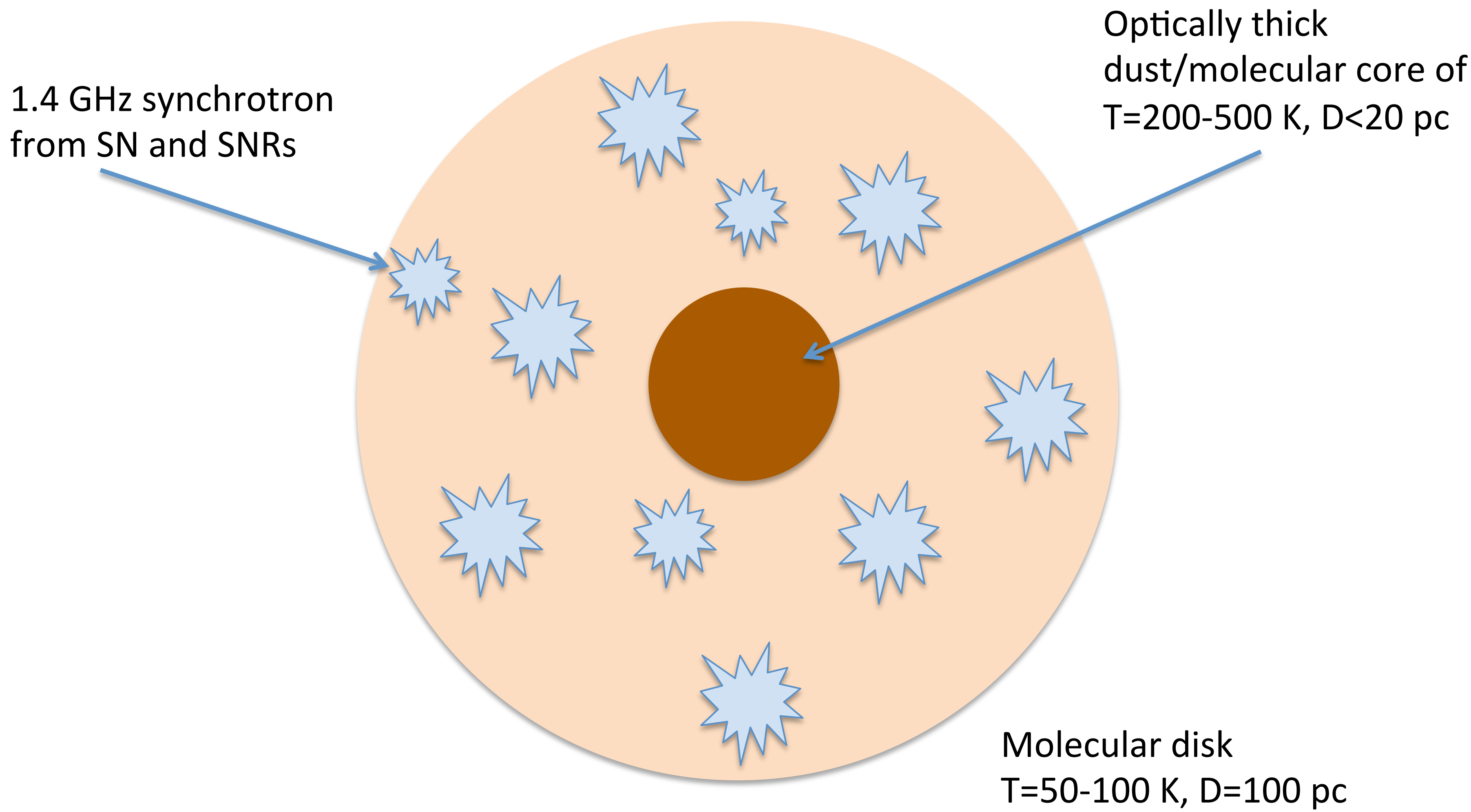
Sakamoto et al 2013, Costagliola et al 2013

Lines include: CO 3-2, 2-1, HCN 4-3 v=0, v_2=1, HCO+ 4-3, HC_3N (ro+vib), $C^{34}S$, N_2H^+, CS 7-6, HNC (ro + vib).



VLBI 1.4 GHz structures found outside of submm continuum (Varenius et al 2013)

Inner region of NGC4418?



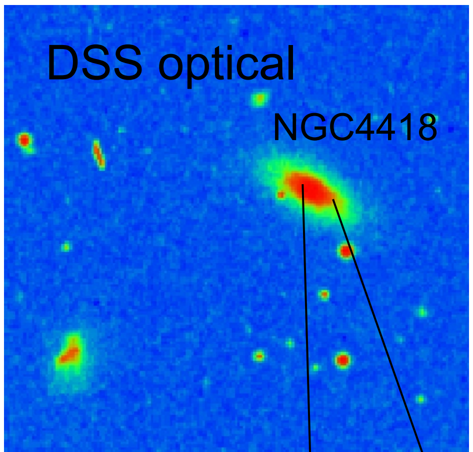
- How common are optically thick dust/molecular cores? What are their impact on our understanding of AGN and starburst evolution?
  - Half of the AGN population may be deeply buried.
- How can we study them?
  - Hard X-rays? Possibly – but they may be too thick?
  - High resolution ALMA observations
    - Continuum cores
    - Vibrationally excited lines to probe inside optically thick dust veil

VIBRATIONALLY EXCITED MOLECULES

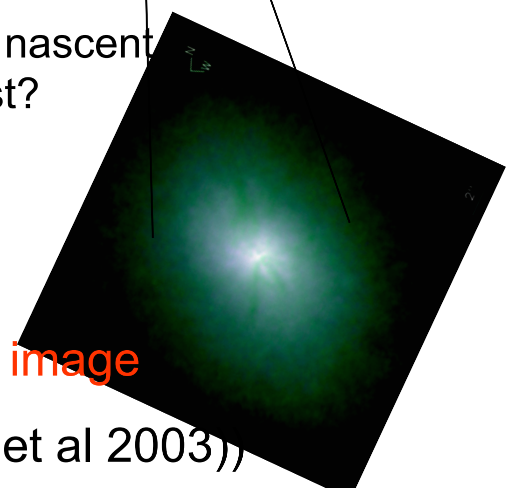
IR pumping of HC_3N, HCN in LIRGs and ULIRGs

(Costagliola and Aalto 2010, Sakamoto et al 2010,2013, Martin et al 2011, Costagliola et al 2013, Imanishi et al 2013, Aalto et al 2013)

An example: NGC4418

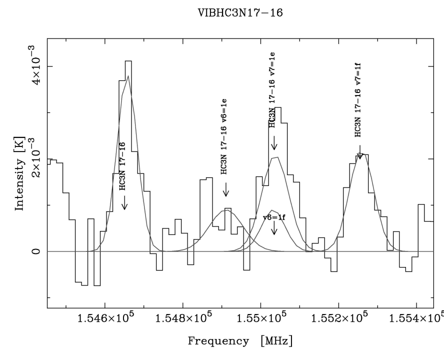


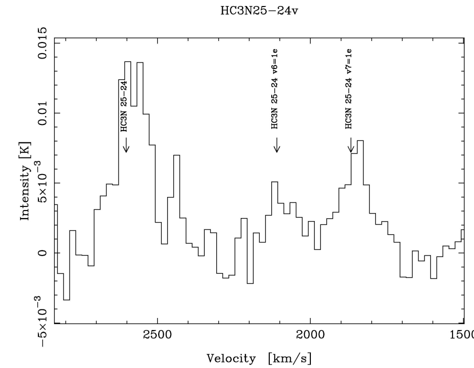
AGN or nascent starburst?



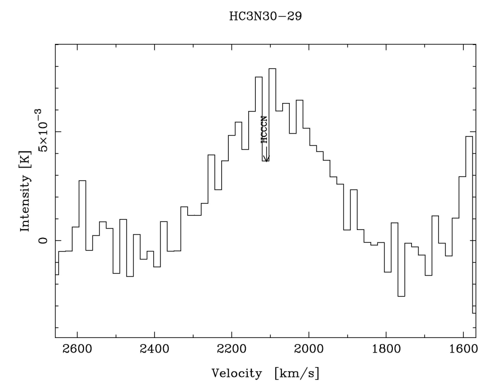
NIR image

(Evans et al 2003))



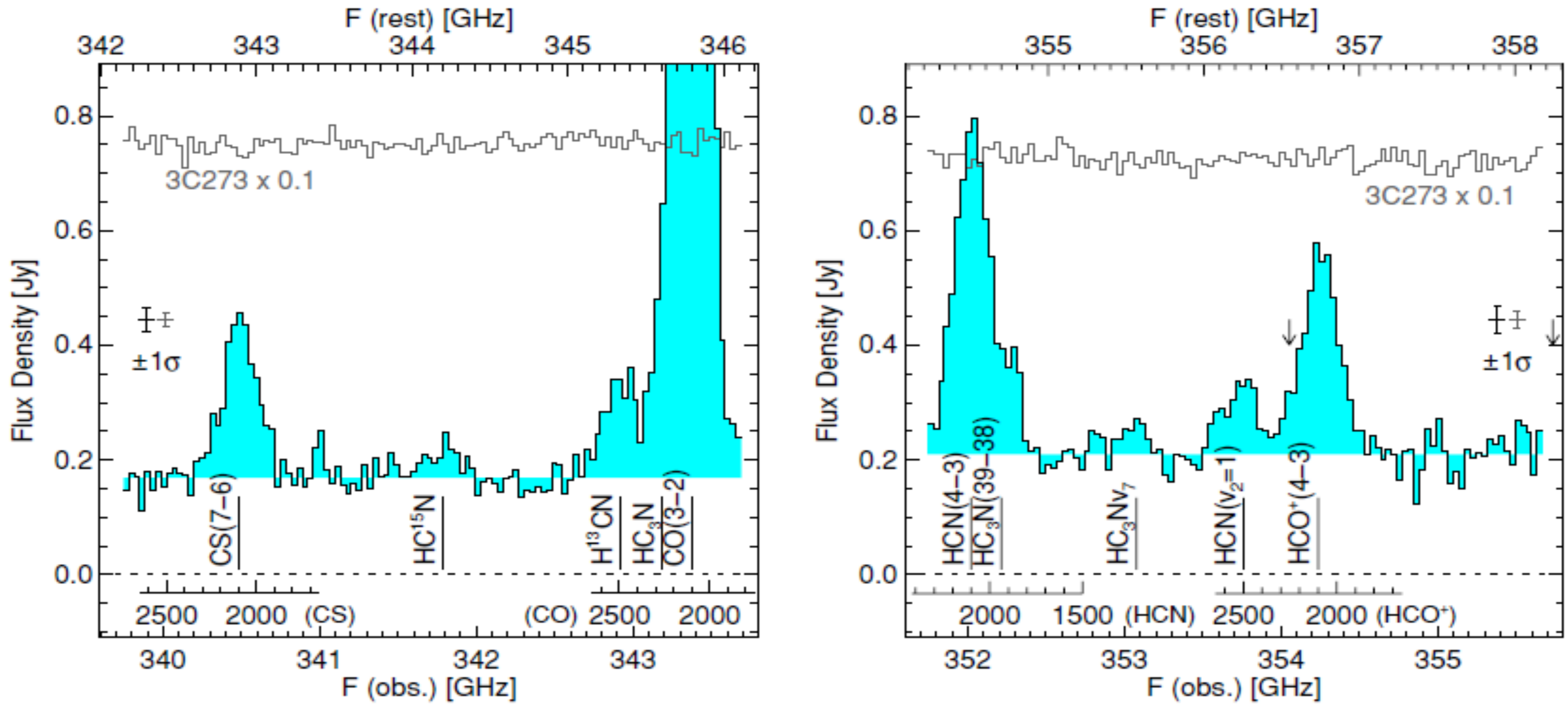


- Bright high-*J* lines detected with APEX, JCMT, IRAM 30m, SMA
- Intense vibrational lines, v_6 v_7



HC_3N, HCN, HNC respond to intense radiation field of buried nucleus - revealing hot, compact 300 - 500 K component.

Vibrationally excited HCN



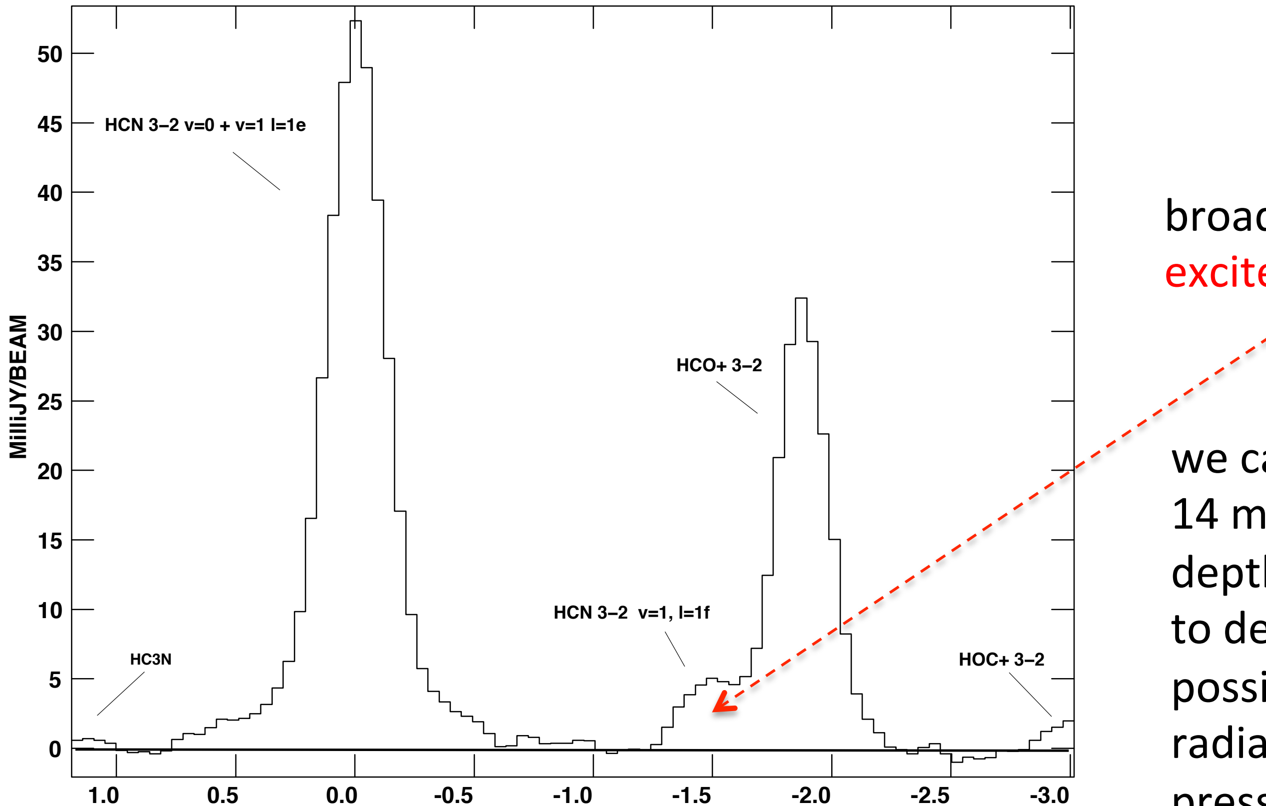
Sakamoto et al. 2010, ApJ, 725, L228

Combining vibrational lines from IR-pumped species let us probe the inner few pc of dusty active galaxies – beyond the optically thick atmosphere of dust. We can address issues on:

- the nature of the buried source
- if the source can cause a radiation pressure driven outflow

HCN 3-2 v_2=1 in Mrk231

HCN T_{vib}=300 – 500 K
= tracing dust component in inner 20 pc of Mrk231



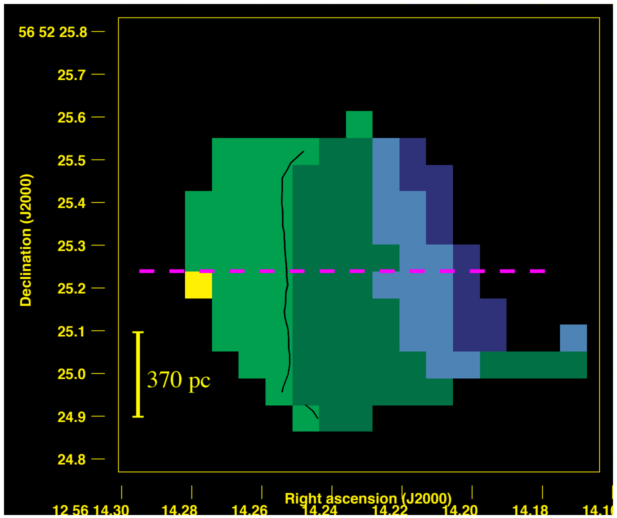
broad vibrationally excited HCN

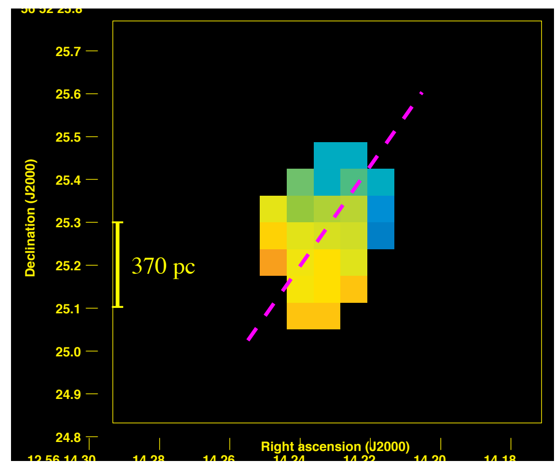
we can use the 14 micron optical depth to determine the possibility of radiation pressure as a driving force of the flow.

(Aalto, Muller, Garcia-Burillo, Winters, Gonzalez-Alfonso, Neri, Henkel, van der Werf in prep)

Vibrational dynamics – tracing the nuclear warped disk

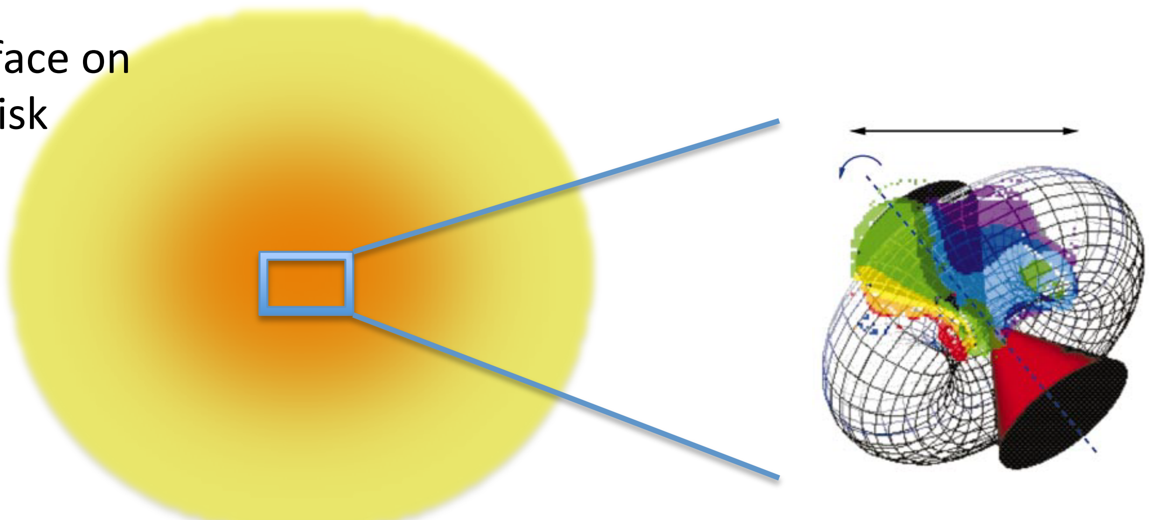
HCN 3-2 v=0





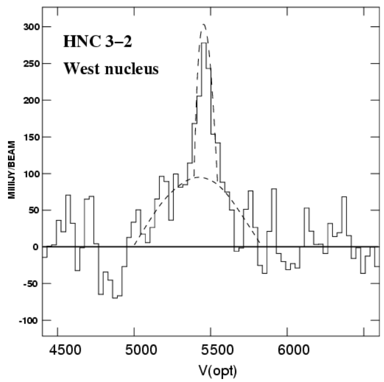
HCN 3-2 v2=1

Almost face on stellar disk

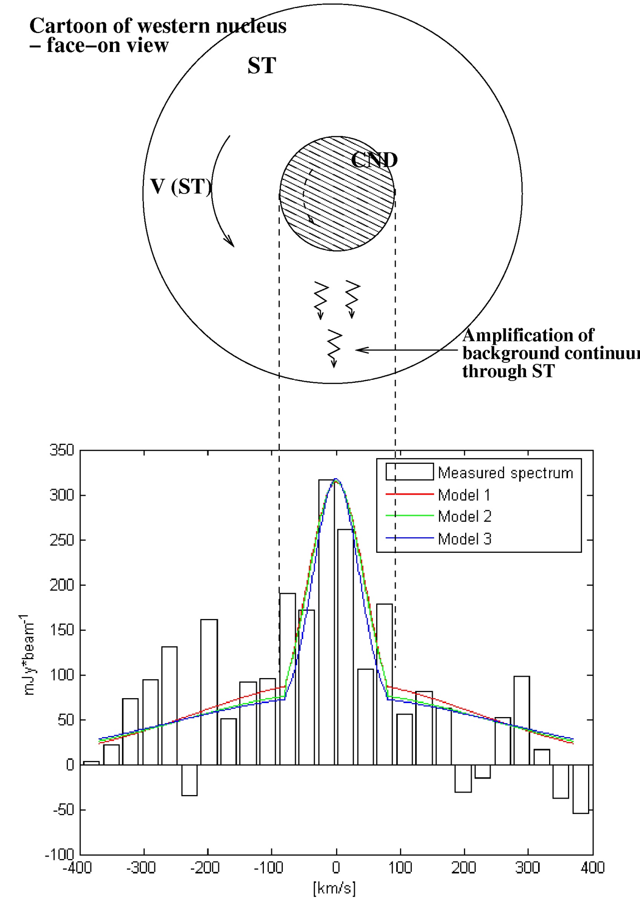


Inner 0."2 – 0."3 warped disk (Davies et al 2004). Inner 0."1 nuclear OH torus or disk (Klöckner et al 2003)

Amplified IR-pumped HNC in Arp220W



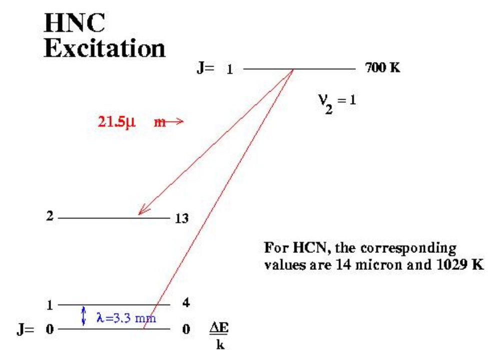
Narrow, bright emission feature where CO and HCO^+ show absorption

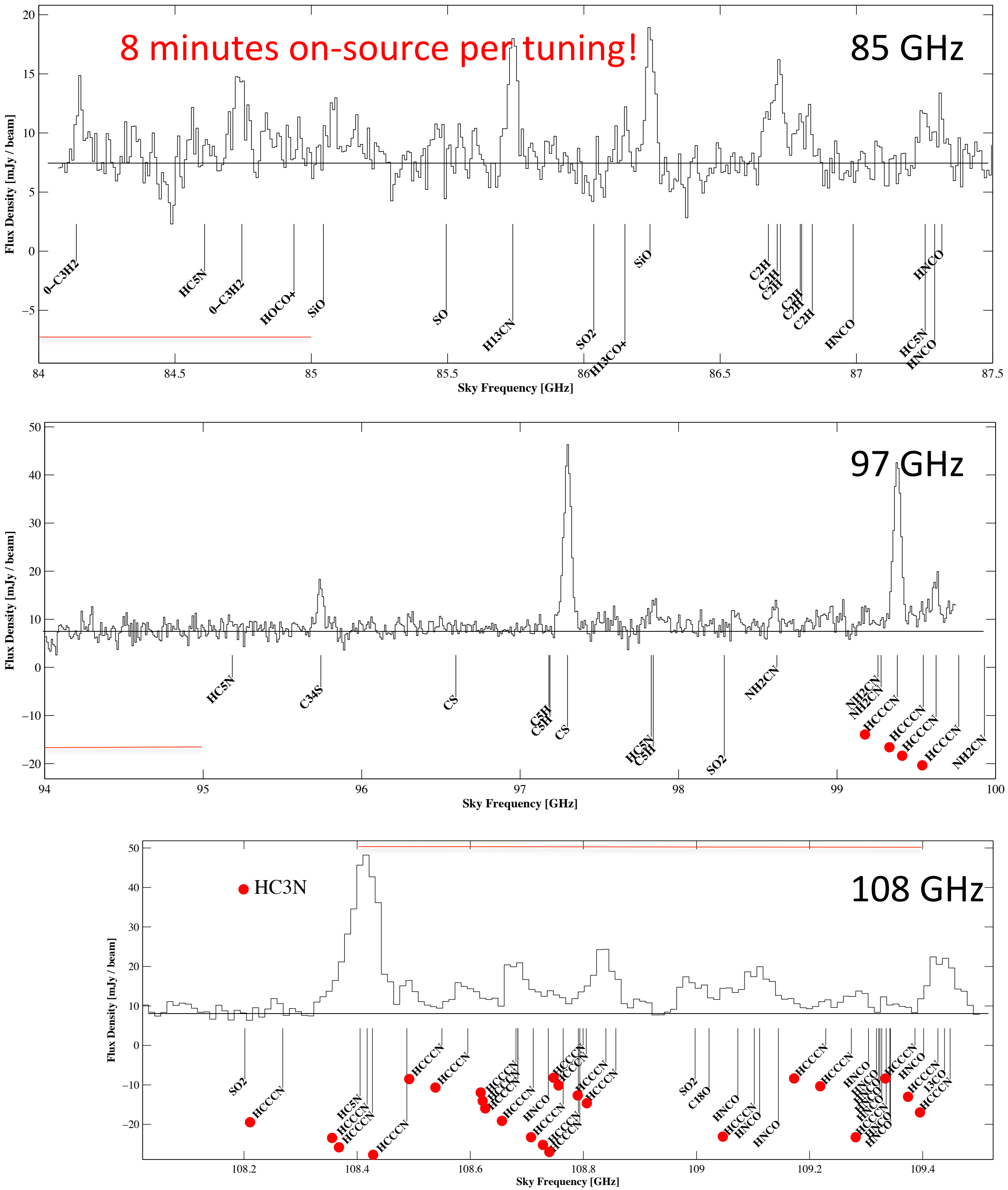


SMA Interferometric detection of *HNC weak maser in ULIRG Arp220* (Aalto et al 2009)
Potentially pumped by 21.5 micron continuum – amplifying background submm continuum.

Reflects unusual and extreme conditions in ULIRG, LIRG nuclei

mid-IR pumping of HNC via bending mode occurs at 21.5 mm at 669 K –pumping starts to become effective at TB(IR) = 50 K (Aalto et al 2007)





ALMA NGC4418 spectral scan

Cycle 0 scan in Band 3,6,7.
Band 3 now complete

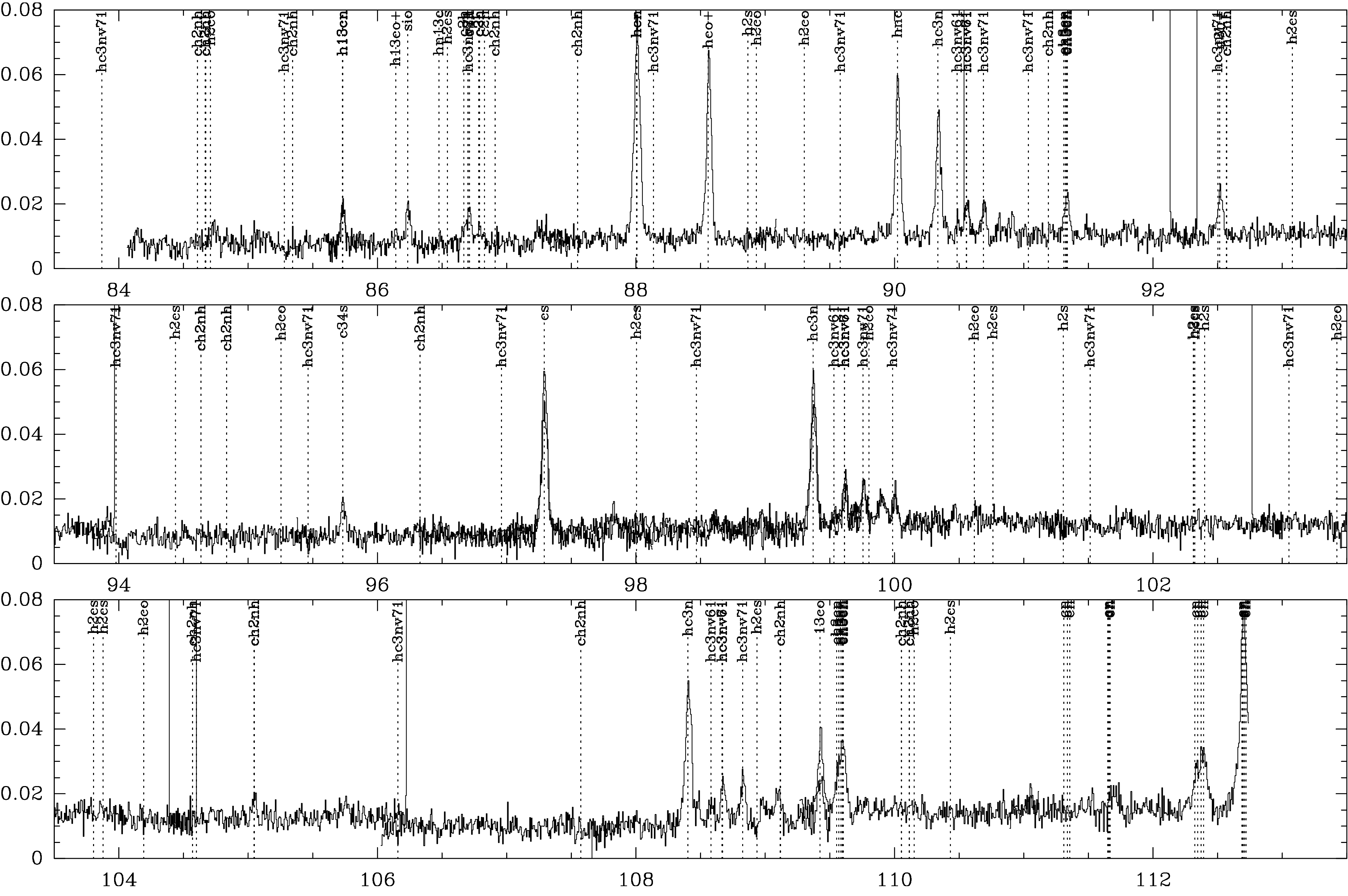
Science goals:

- Obtaining a template chemistry/excitation for LIRGs
- Use IR pumped molecules to probe nature of buried nucleus
- Physical conditions in the gas
- Search for signs of outflows

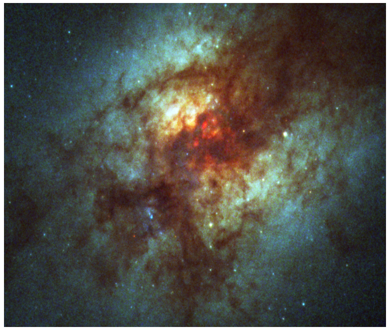
Collaborators:
European MasTER network
(PI: Costagliola)
K. Sakamoto – ASIAA, Taiwan
A. Evans – U. of Virginia, USA

SPECTRAL SCANS

…and here is almost the whole Band 3:



SMA 1mm spectral scan of the enshrouded ULIRG Arp220



The dusty cores
of the ULIRG Arp220.
A_V> 1000 in both
nuclei…

SMA 1mm spectral scan of Arp220 shows the stunning richness of the molecular spectrum. utilizing the broadband backend of the SMA. (Martin et al 2011). The survey covered the 40 GHz frequency range between 202 and 242 GHz of the 1.3 mm atmospheric window.

The Arp220 scan shows 73 features identified from 15 molecular species and 6 isotopologues. *Note the multitude of HC_3N lines – both vibrational and rotational.*

28% of the total measured flux is due to the molecular line contribution, with CO only contributing 9% to the overall flux

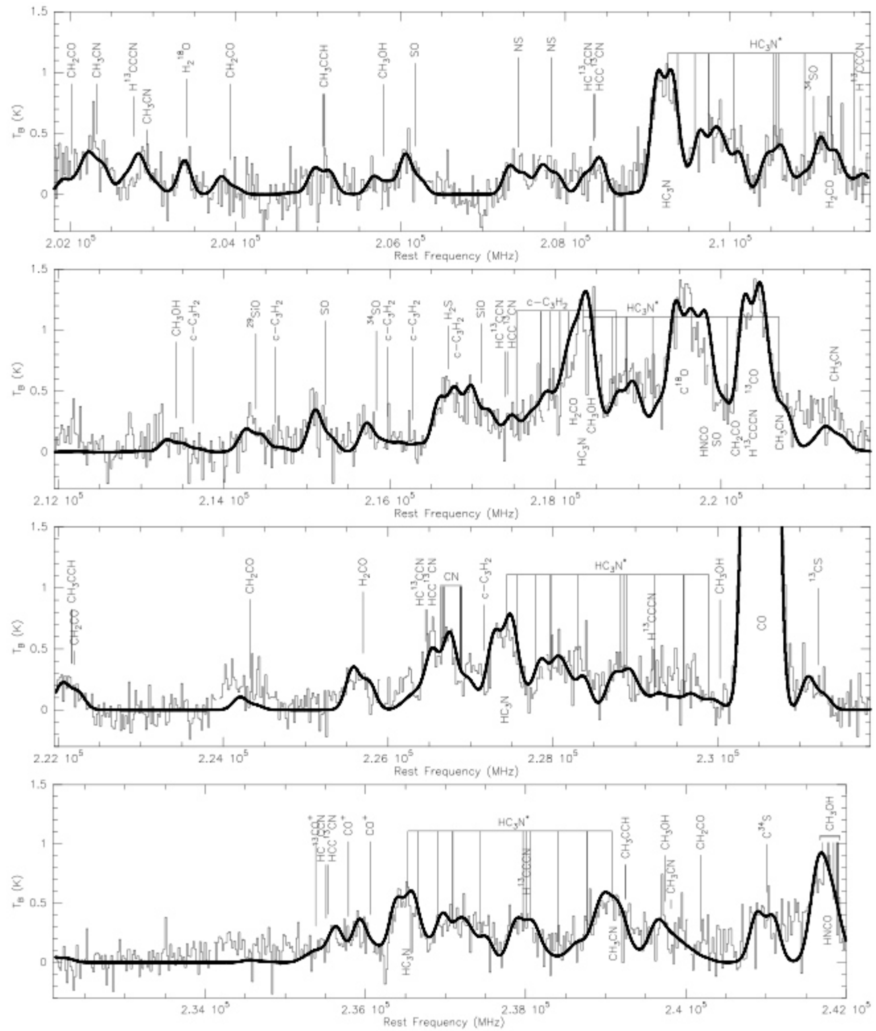


Fig. 6.— Detailed view of the spectral line survey. Spectral resolution of the observed data is smoothed to 20.5 MHz (25 – 30 km s^{-1}accross the covered range). The LTE model of the identified molecular species is represented in thick continuous line. Identified molecular features are indicated.

Accepted cycle 1 band 6 programme for Arp220 spectral scan

Tracking evolution

STARBURSTS

Starburst have been the evident target for large molecular line searches

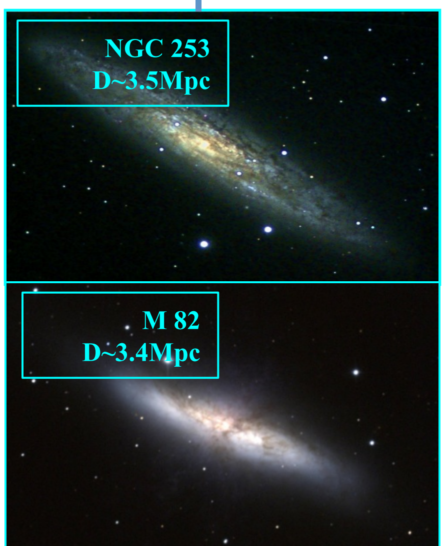
First unbiased mm line surveys of the two brightest extragalactic sources

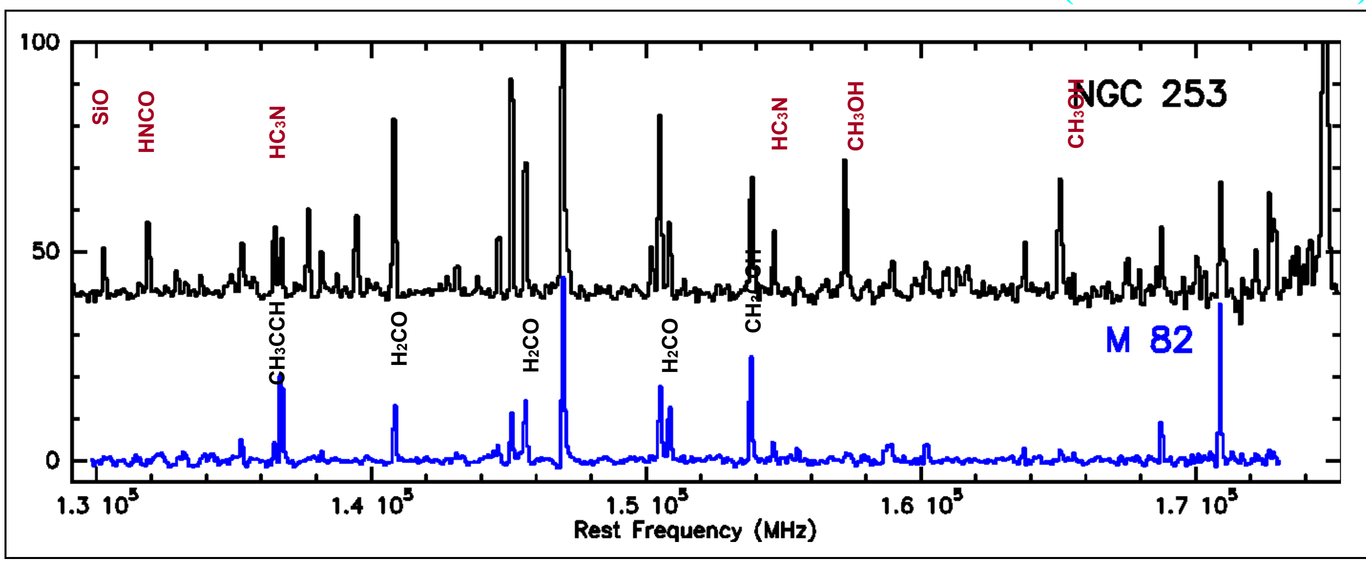
IRAM 30m
2mm Atm window ~46 GHz (129–175 GHz)
+ 19 GHz (241-260 GHz) in M82

2 x 1 GHz FB

111 lines / 25 species

(Martin et al. 2006)





(Aladro et al. 2011)

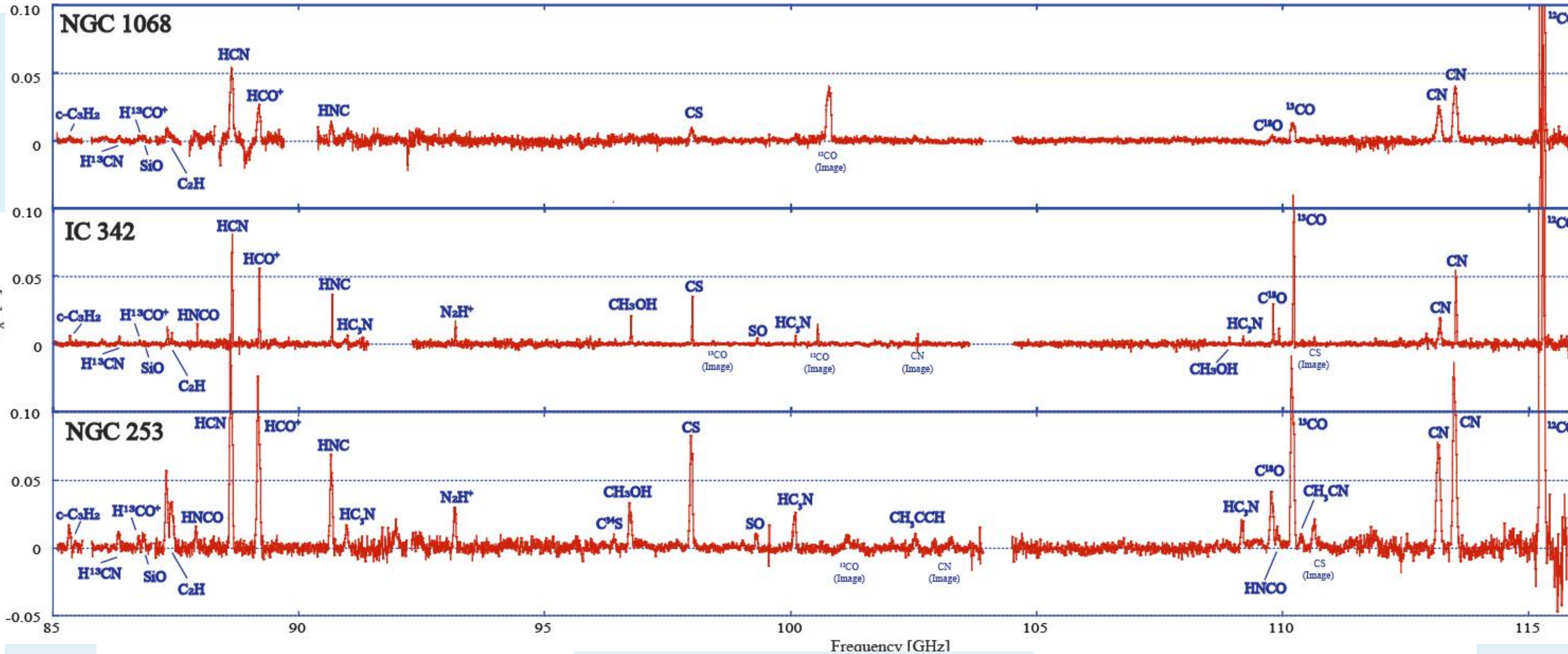
72 lines / 18 species

Nobeyama: NGC 1068, NGC 253, and IC 342

- Completed: 85~116 GHz
- Sensitivity: rms ~ typically 1-4 mK for NGC 1068, 2-13 mK for NGC 253, and 1-2 mK for IC 342

0 - 0.1 K

T_A* (K)



85

Frequency (GHz)

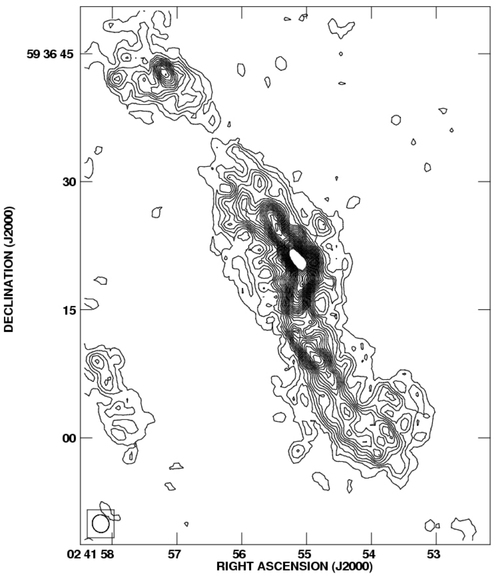
Figure by Nakajima

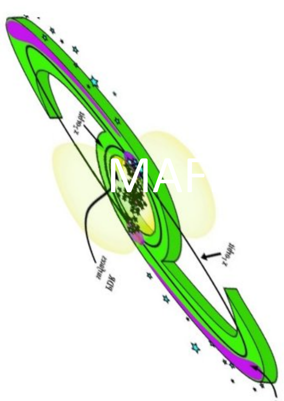
116

Initial results published: Nakajima et al. ApJL 728, L38 (2011)

Chemistry in starbursts – IC 342, Maffei 2

(Meier and Turner 2006, 2012)





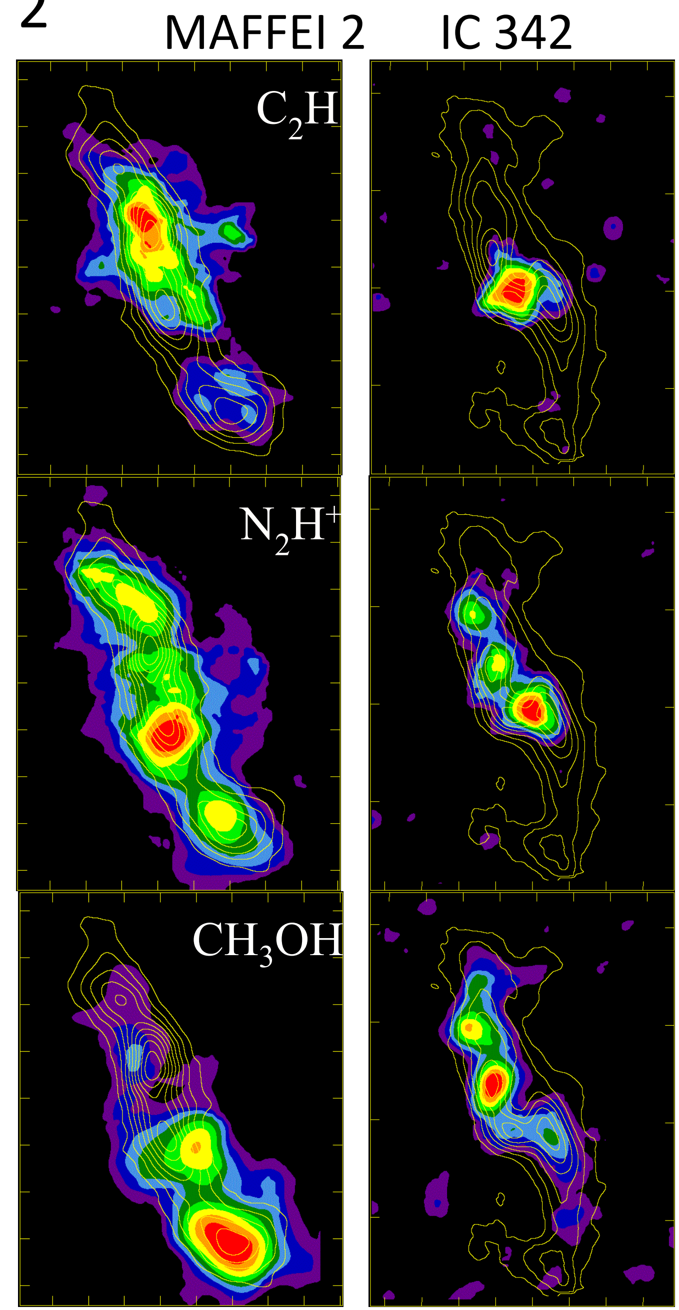
CH_3OH & HNCO follow the molecular bar arms, especially the bar ends

In Maffei 2, C_2H prefers the starburst region, but is more extended and there is an outflow

In IC342, C_2H is found near the nuclear star cluster and NOT the current star formation

HCN, HNC, HCO+ & 3mm continuum tightly correlated, indicating a close connection to star formation

HNCO, CH_3OH, and SiO are tightly correlated with each other and anti-correlated with the star formation molecules

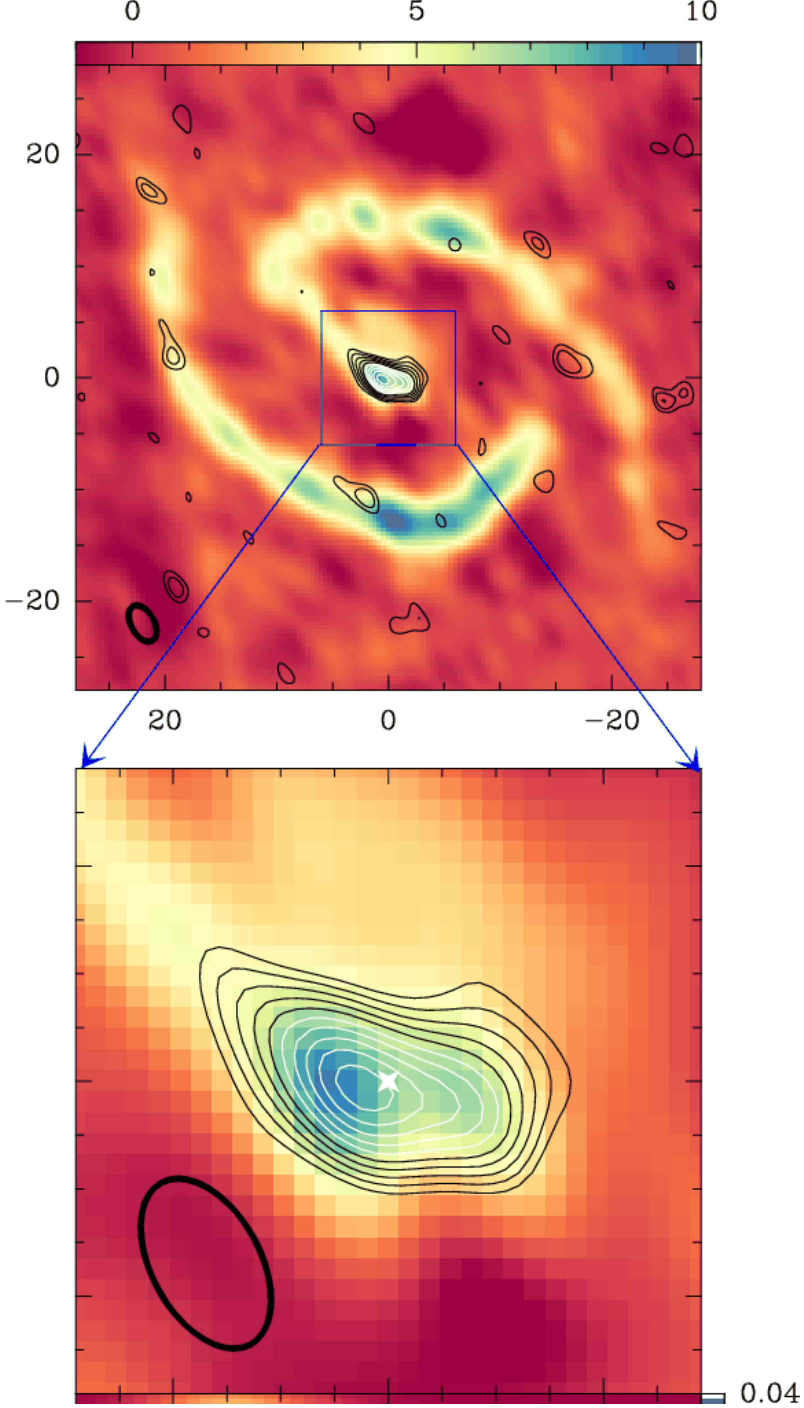


Meier & Turner 2006, 2012

Impact on environment

AGNS

PdBI map of CO 1-0 and SiO 2-1



Top: SiO integrated intensity map overlaid on the CO(1-0) integrated intensity map. Lower: Zoomed view on the inner 12" around the AGN (identified by the cross). (Garcia-Burillo et al 2010)

Work in progress

ALMA CO 3-2 map of NGC1068

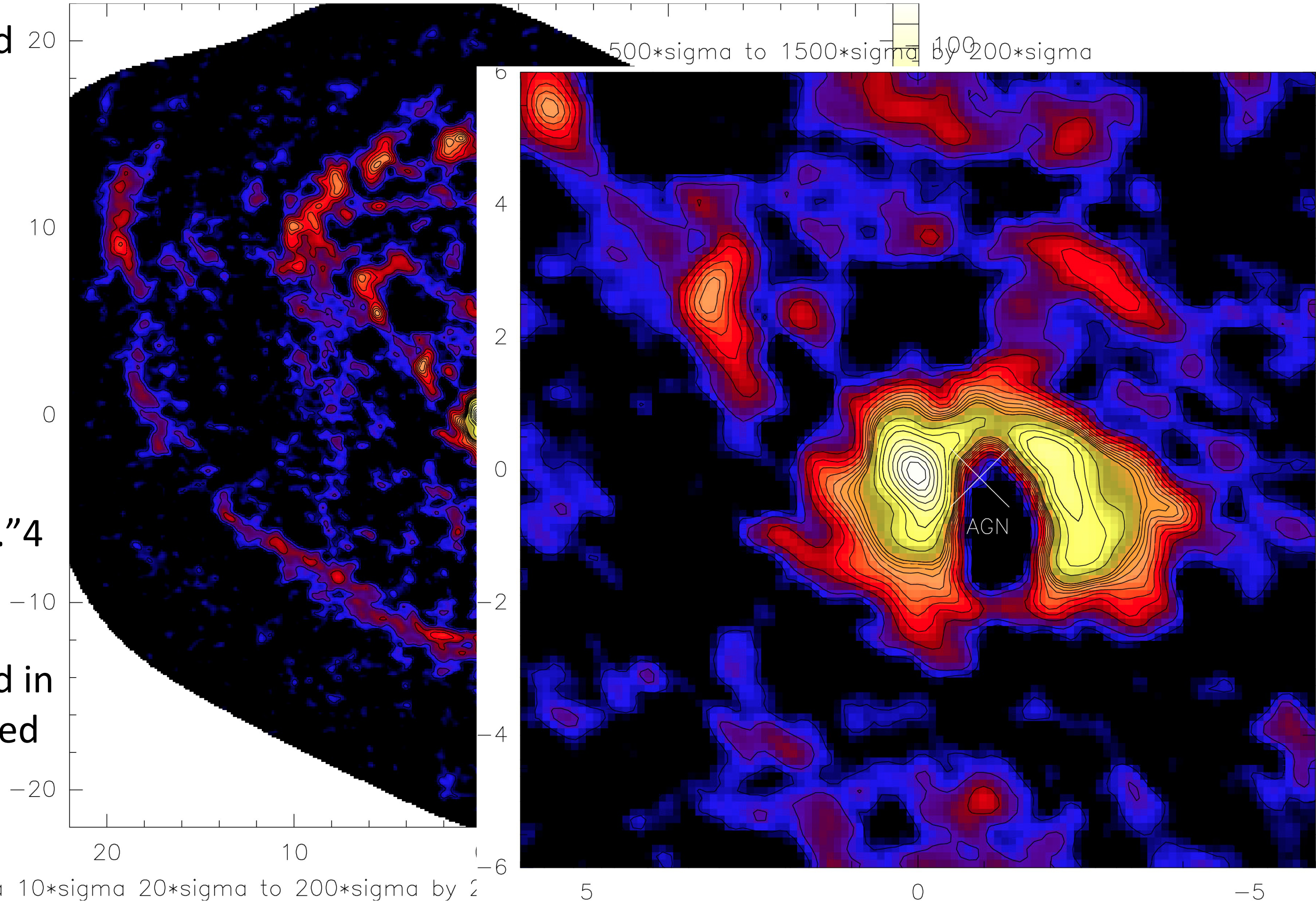
molecular cloud structure and dynamics in unprecedented detail

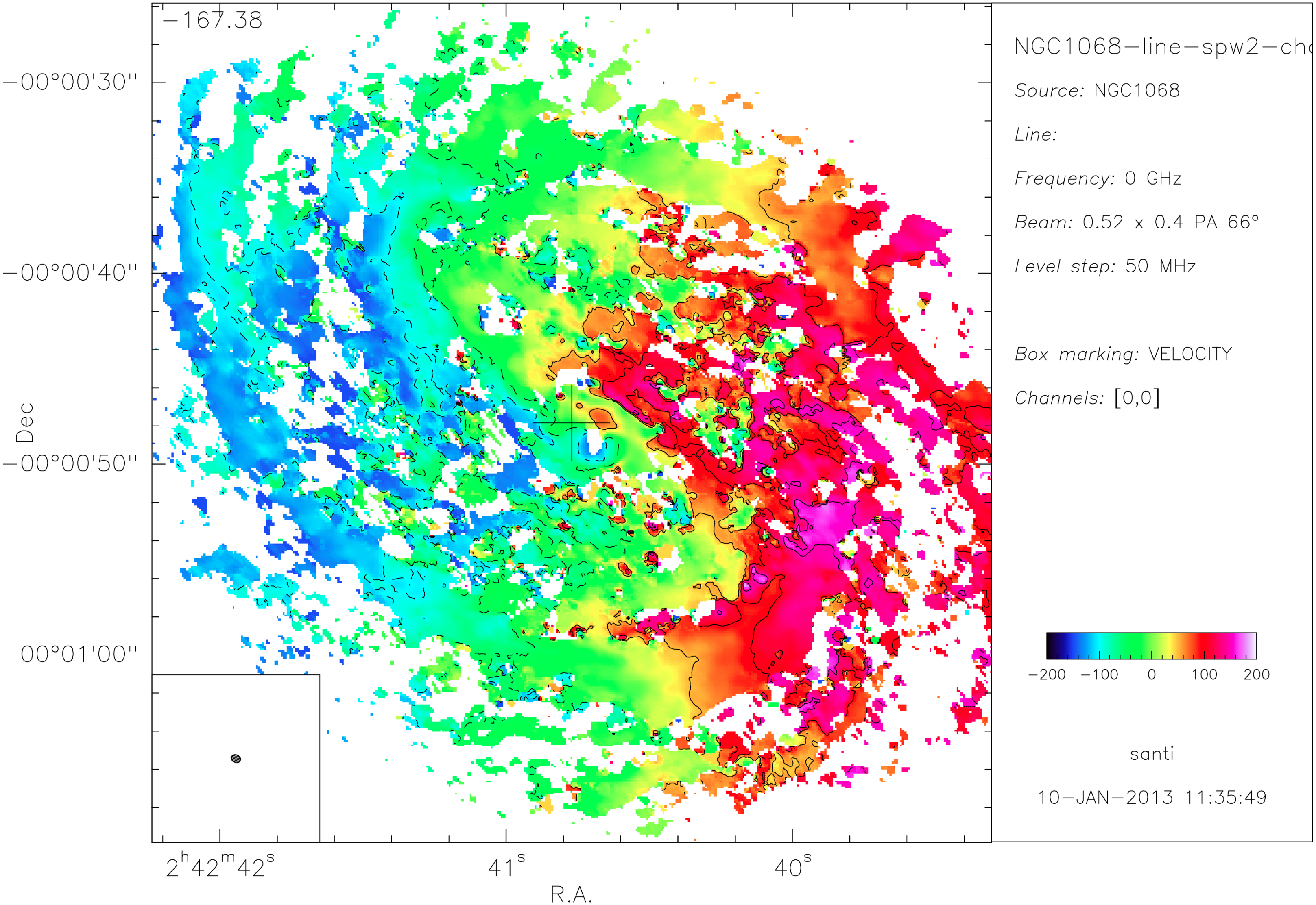
Emission detected throughout the disk: central CND bar, spiral arms and SB ring

- and interarm regions.

(Noise 1.8 mJy, dynamic range= 1500. Spatial resolution 0.”5x0.”4 (35x28 pc)

Emission detected in CND in off-centered closed ring.

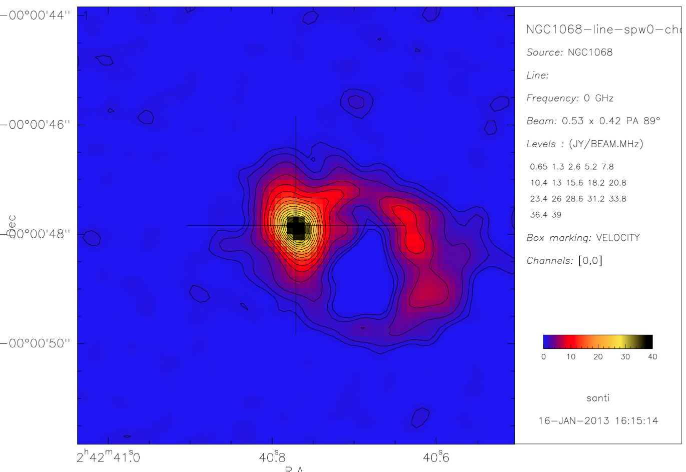




Velocity field shows overall rotation of disk (PA 90 deg). Non circular motions in spiral arms and bar. PA rotates to 0 degrees in central region.

work in progress

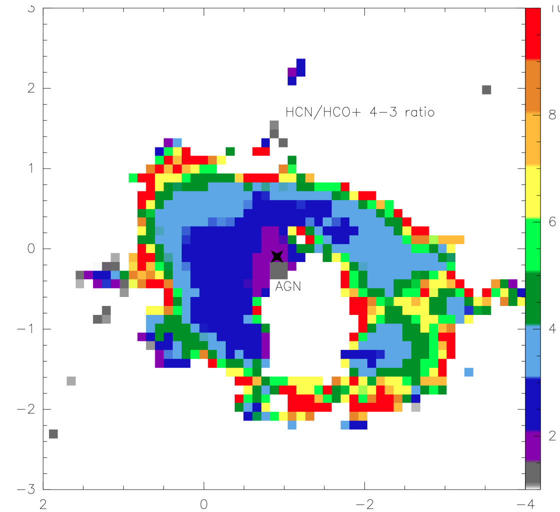
HCN/HCO+ 4-3, CO 6-5

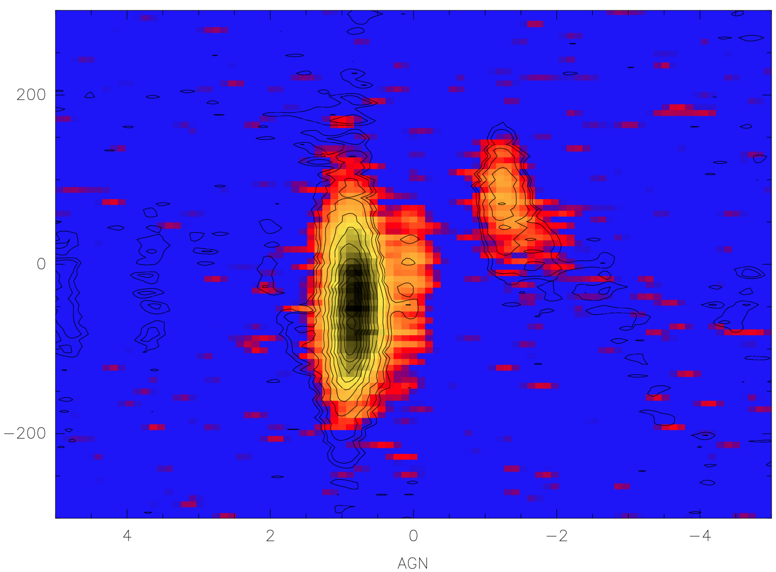


CO65=contours // HCO43=color

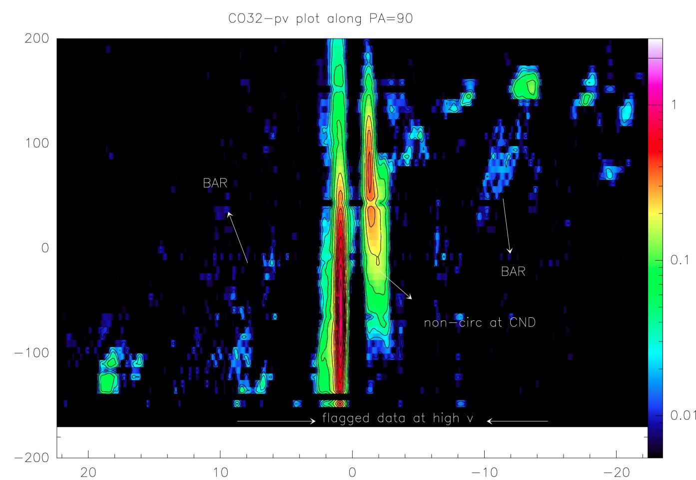
HCN 4-3 in the CND

HCN/HCN+ ratio in CND





pV plots along PA=90, CO 6-5 contours, HCO+ 4-3 colour. Note HCO+ peaking on AGN



The Seyfert 1

NGC 1097

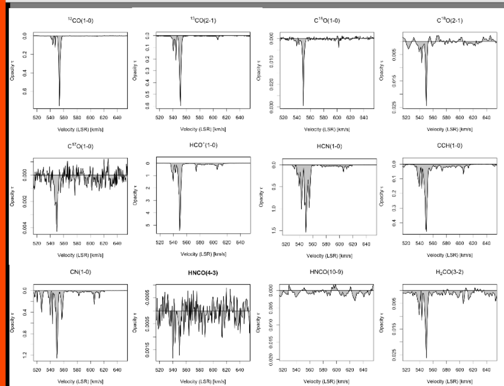
An ALMA and ATCA Molecular Line Survey toward Centaurus A

Jürgen Ott[1], Marc McCoy[2], David Meier[2], Sebastien Mueller[3], Alison Peck[1], Violette Impellizzeri[1], Fabian Walter[4], Susanne Aalto[3], Christian Henkel[5], Sergio Martin[6], Paul van der Werf[7], Ilana Feain[8], Crystal Anderson[2]

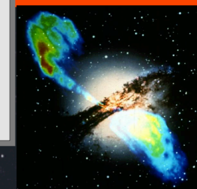
[1] National Radio Astronomy Observatory, USA, [2]New Mexico Institute of Mining and Technology, USA, [3]Chalmers University of Technology, Onsala Space Observatory, Sweden, [4]Max-Planck-Institut für Astronomie, Germany, [5]Max-Planck-Institut für Radioastronomie, Germany, [6]European Southern Observatory, Chile, [7]Leiden University, The Netherlands, [8]CSIRO Astronomy and Space Science, Australia

Abstract

We present Atacama Large Millimeter/submillimeter Array and Australia Telescope Compact Array data of molecular absorption lines toward the bright central core of Centaurus A. The line of sight crosses the prominent dust lane and continues through the disk and eventually through gas that may be very close to the central supermassive black hole. The goal of our the survey is to determine the physical conditions of the gas via analyses of molecular line tracers including molecular abundances and excitation conditions that are sensitive to changes in temperature, density, ionization, and shocks. This study allows us to derive the physical conditions of each absorption line complex and allows us to define the main process shaping its environment. We present a first analysis of our data in the 13, 7, 3, and 1mm wavebands.

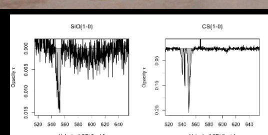


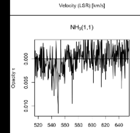
Left:
We observed Centaurus A with ALMA in 20 different spectral lines at bands 3 (3mm) and 6 (1mm). Our main science goal focuses on the molecular absorption profiles against the bright supermassive black hole in the heart of Cen A's host galaxy NGC 5128. The line of sight crosses the dust lanes in the outer parts of the giant elliptical, further through the warped disk into the influence zone of the supermassive black hole. This is reflected by the different absorption components. The HCO^+(1-0) shows the overall profile the best: very narrow, deep absorption features at the systemic velocity of CenA (~550 km s^{-1}), as well as a broad component at higher velocities that exhibits some narrow spikes. The broad component may indicate outflow or infall from/into the black hole. The molecular spectra trace the chemistry and physical conditions in each component. Surprisingly, the CO isotopologues are very weak in the broad component, and might be dissociated in this particular gas phase. Photon-dominated region tracers such as CCH and CN seem to be much more abundant (the CN spectrum is centered in the brightest hyperfine structure line). HNCO traces weak shocks and is faint in every spectral component. HCN and H_2CO plus the other tracers all indicate the presence of very dense gas.



Above: The elliptical host of CenA NGC5128 with the prominent dust lane and the inner radio lobes overlaid. The supermassive black hole is at the origin of the radio lobes behind the dust lane.

Below: The larger, fainter outer radio lobes (Feain et al. 2011)

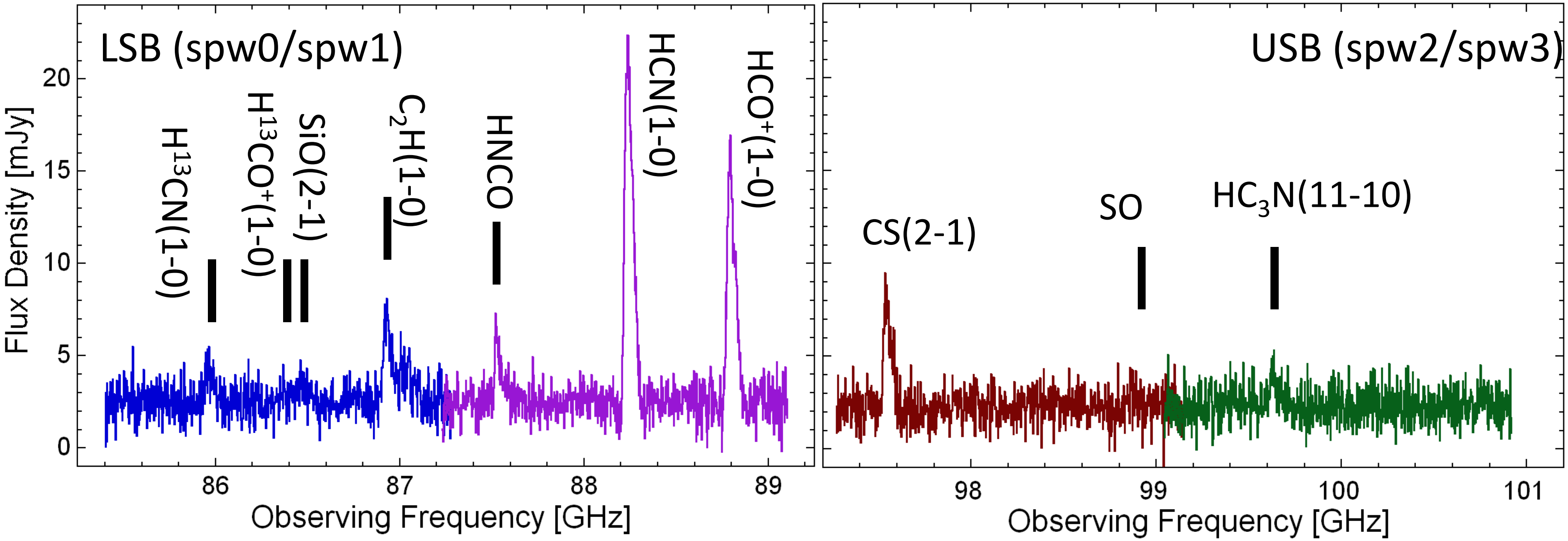




Left: Corresponding spectra of CenA from an ATCA survey in the 1.5-0.7cm range. The most prominent lines are the CS(1-0) line followed by SiO(1-0), a tracer for strong shocks. We also detect NH_3 (1,1) and (2,2) which is used to trace the temperature of the gas.

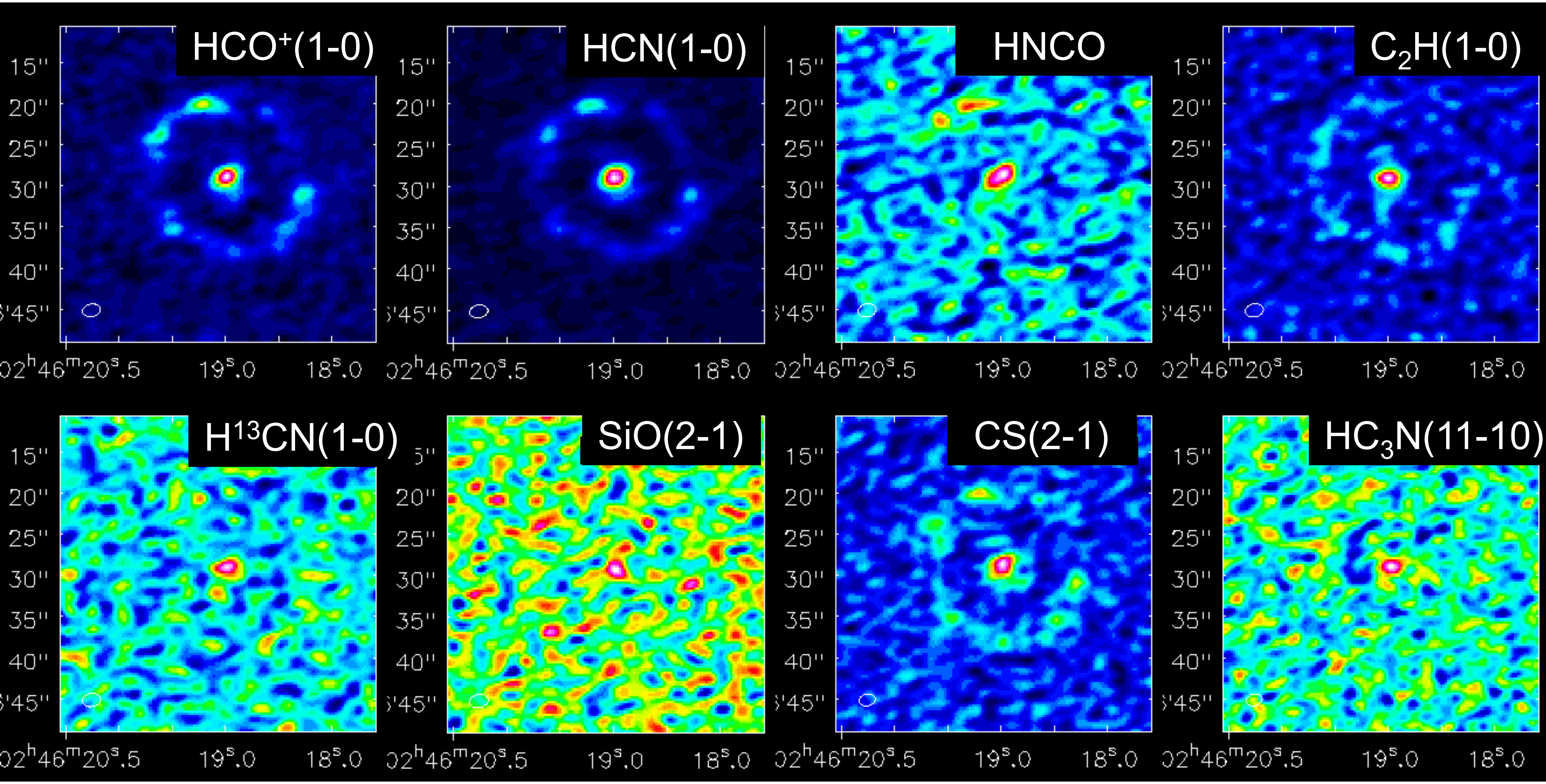
email: jott@nrao.edu

NGC 1097: First spectral scan toward type-1 low-luminosity AGN



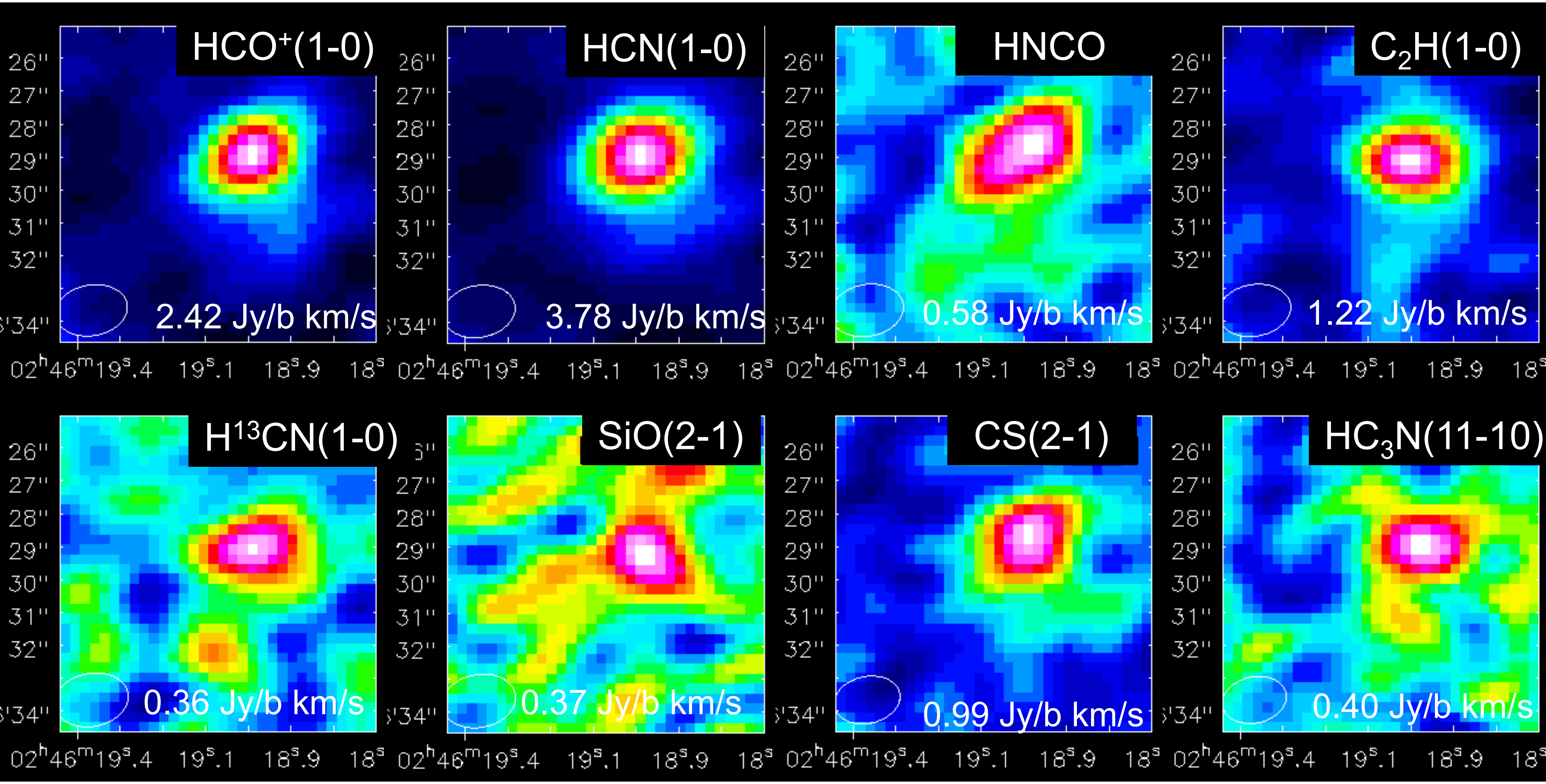
- New detections: $H^{13}CN$(1-0), C_2H(1-0), HNCO, CS(2-1), HC_3N(11-10)
- Possibly?: SiO (blended with $H^{13}CO^+$(1-0))
- Upper limit?: SO

Multi-molecular view of NGC 1097



Starburst ring is detected in HCN, HCO+, C2H, CS, and partly in HNCO

Nuclear emission



Comparison of 3mm line survey data in starburst galaxies

➔ striking HCN enhancement w. r. t. CS !?

Serendipity – bright HC_3N in Mrk231 core

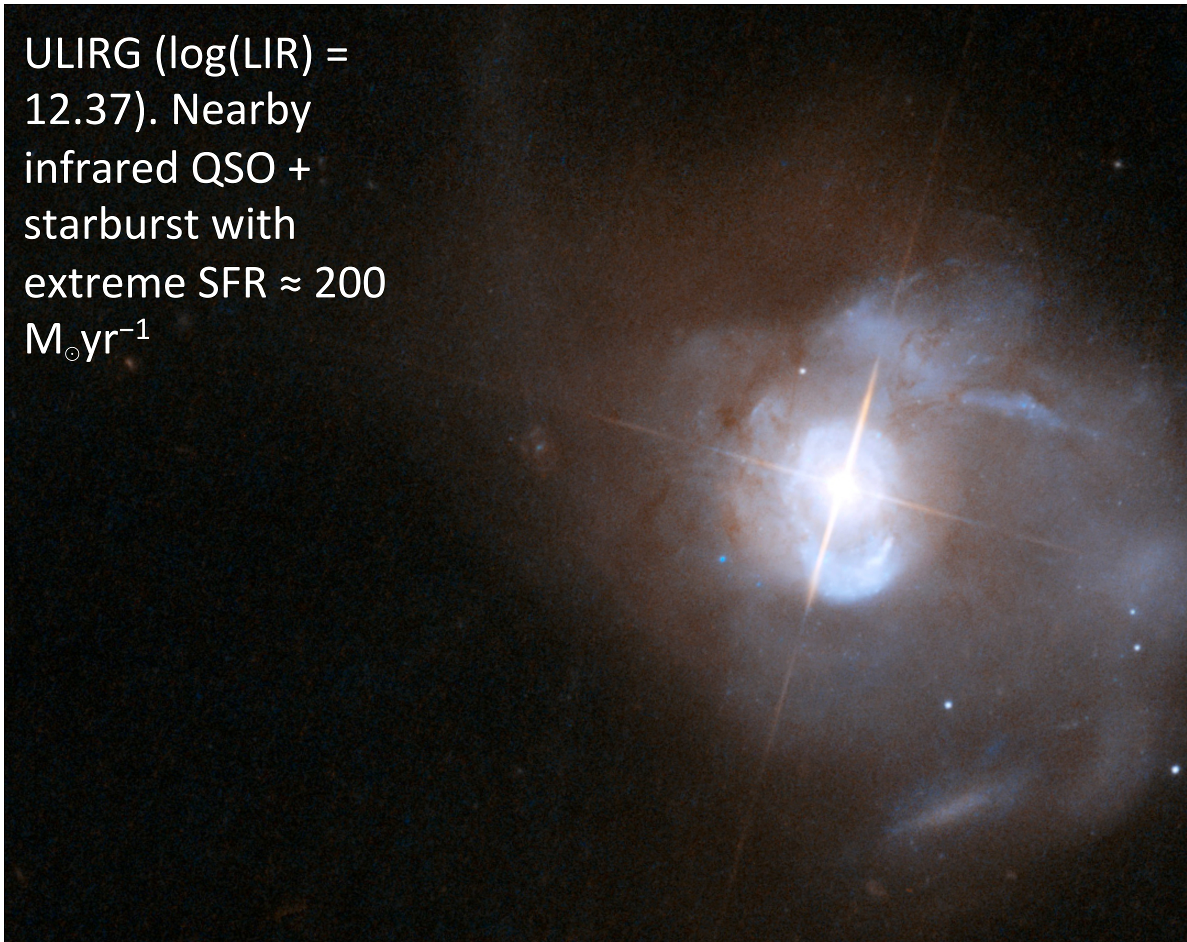
- Source size fit suggest upper limit of 300 pc –
  - Inner part of starburst disk ?
  - Or in the shielded dusty gas near the AGN?

Need high resolution observations to pinpoint

- For T>300 K HC_3N abundances may become very high: 10^{-6} in the dusty midplane gas near an AGN (Harada et al 2012)
- Signature of the final stage of the obscured, X-ray absorbed (Page et al. 2004) accretion phase of the QSO?

It puts the luminous HC_3N emission in some LIRGs and ULIRGs in a new light – is this a signature of a buried AGN (Aalto et al 2007, Lindberg et al 2011)?

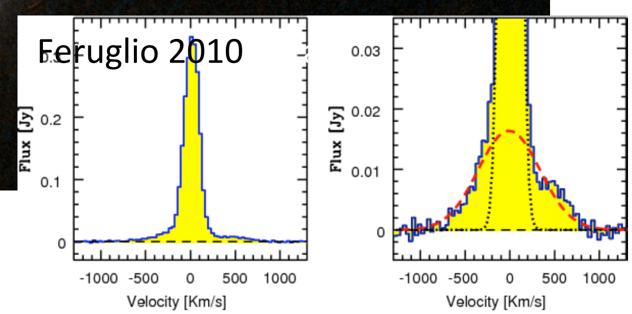
Mrk231- high velocity molecular gas in the QSO outflow



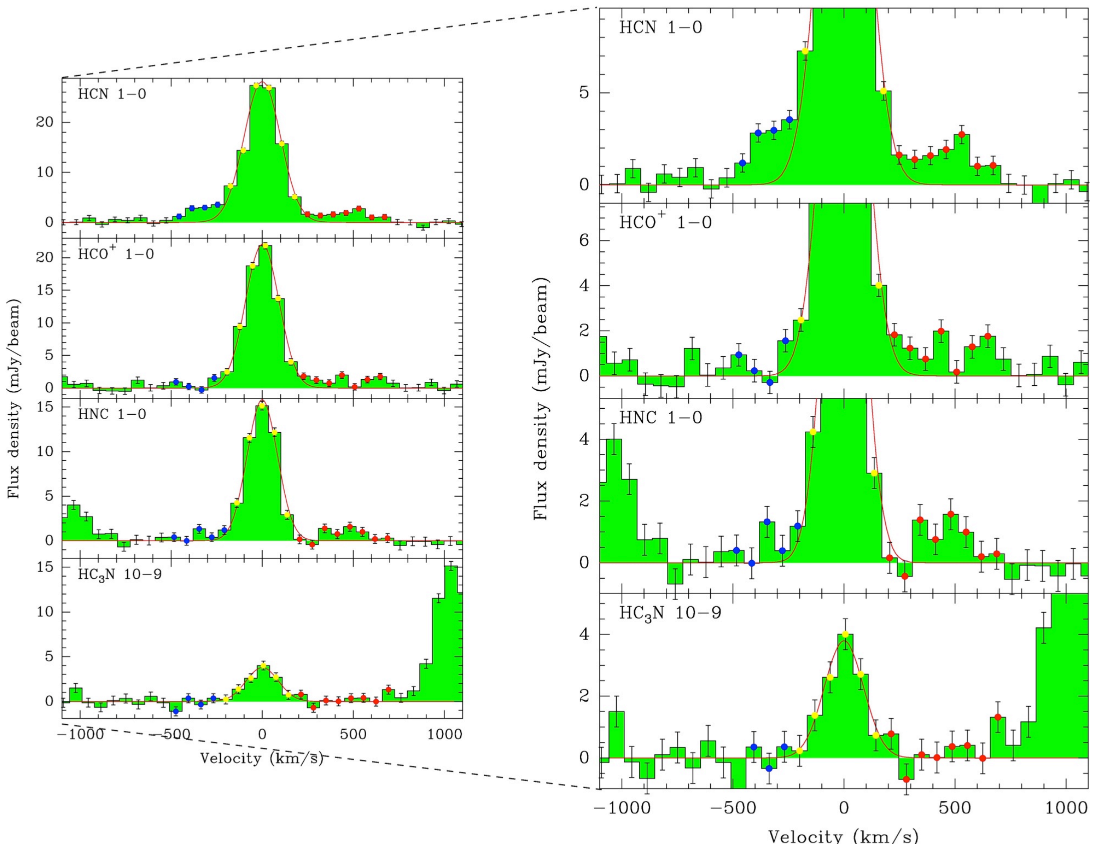
ULIRG (log(LIR) = 12.37). Nearby infrared QSO + starburst with extreme SFR ≈ 200 $M_{\odot} yr^{-1}$

Wide, kpc-scale, high-velocity (≈ 1000 kms^{-1}) outflow seen in neutral gas (Rupke and Veilleux 2011). Line wings in CO 1-0 are v≈ 750 kms^{-1}

Molecular mass loss rate is 700 $M_{\odot} yr^{-1}$



First detection of HCN, HCO^+, HNC 1-0 in an AGN wind dense ($n>10^5\ cm^{-3}$) gas



IRAM Plateau de Bure – (Aalto et al 2012)

Outflow also detected in OH and H_2O absorption by Herschel (Fischer et al 2010, Gonzalez-Alfonso 2010)

Why would HCN be luminous in the outflow?

1. Dense clumps in the outflow? ”Raisin roll” scenario.
2. Mid-IR pumping of HCN?
3. Extreme HCN abundances?

Multi-wavelength information and modelling necessary to separate options.

High HCN abundances are expected in warm regions, in particular in AGNs (Harada et al 2010) and in shocks (Tafalla et al 2010).

Speculation: Will AGN driven outflows have elevated HCN emission? - and can that be an additional method of identifying the driving source?

Conclusions

- Molecular diagnostics offer a unique glimpse into the properties of AGN and starburst nuclei.
- Bulk temperatures and densities often high: T= 50-100 K, >100 K in inner 100 pc, n=10^3-10^5 cm^{-3} – but molecular diffuse medium surround dense clumps (”raisin roll”)
- Vibrational lines (HCN, HC_3N, HNC) trace optically thick dust cores of T_B(IR)=200-500 K. Can help find buried AGNs?
- New masers detected: HNC
- Chemistry will become powerful diagnostic tool with ALMA:
  - HCN/HCO^+, HNC, H_2O, H_3O^+ (hydronium), HC_3N, C_2H, CH_3OH, H_2CO, isotopic variants etc
  - Can help date evolutionary state of starburst – distinguish between different types of starbursts.
  - Still looking for unambigous tracer of AGN chemisty – H_3O^+ promising candidate.