

# Feeding (and feedback) in nearby AGN and radio MOHEGs

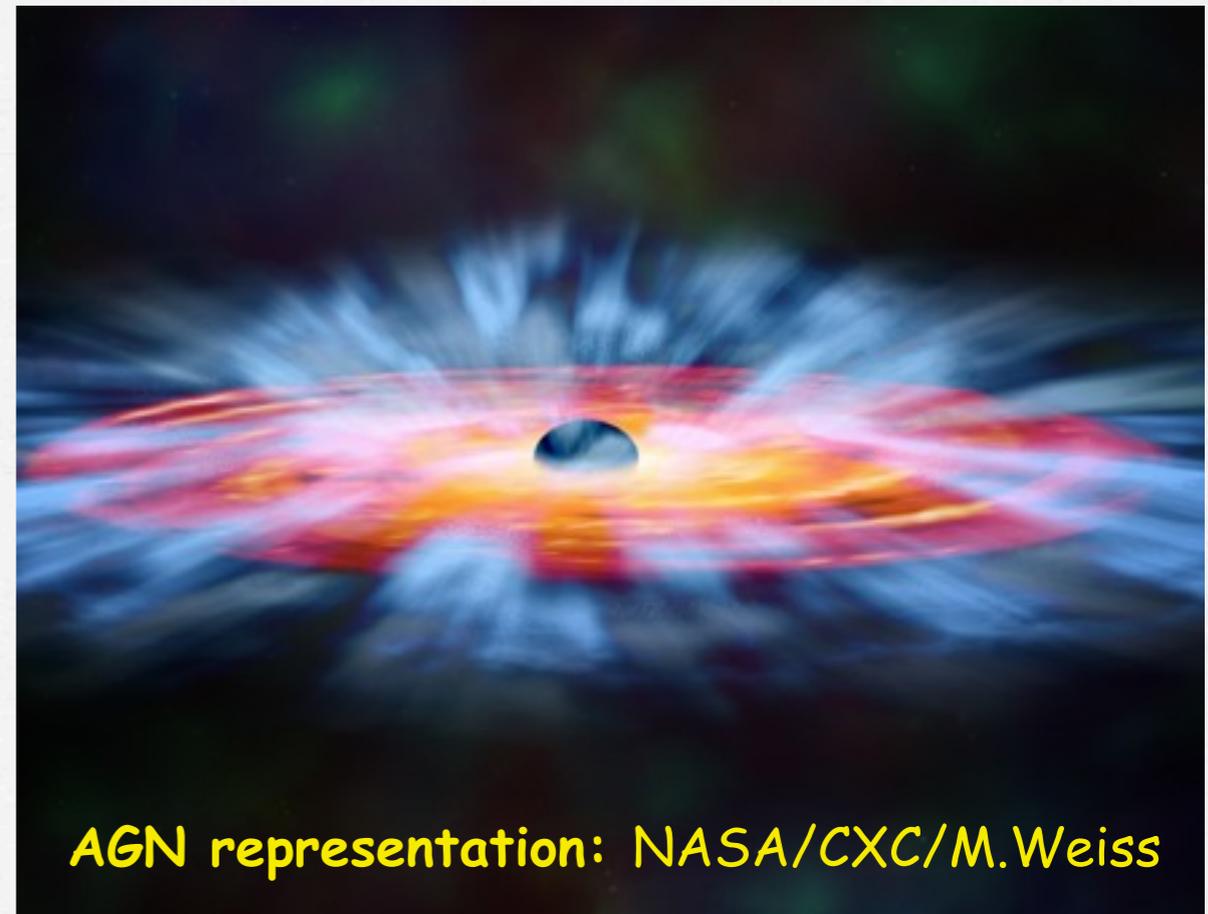
Viviana Casasola  
INAF-IRA, ITALIAN ARC

Bologna, 3 Aprile 2012

Secondo Workshop sull'Astronomia millimetrica e submillimetrica in Italia

# AGN fueling

- Super Massive Black Holes ([SMBHs](#)) reside in the nuclei of all galaxies with massive spheroids, both in the Local Universe and at high  $z$
- Nearby Seyfert nuclei and quasars are fueled by [accretion of material](#) onto the SMBH
- Relation of BH growth with galaxy formation and galaxy evolution is not completely understood.



# AGN fueling: Open Problem

Removal of the angular momentum from the disk gas and driving infall down to scales of tens of pc

- Cosmological simulations rely on merger-driven gas inflow driven by bar instabilities (e.g., Hopkins et al. 2006, di Matteo et al. 2008).
- Nevertheless, in the Local Universe, there has been no clear correlation between AGN either companions or the presence of bars (e.g., Combes 03, Jogee 06).
- It is possible that locally the relation between these large-scale phenomena and duty cycle of nuclear activity is masked by different timescales (Hunt & Malkan 99).

# AGN fueling: how do we study it?

We must examine the nuclear kinematics around local AGN:

MOLECULAR TRACERS

# AGN fueling: how do we study it?

## NUGA: NUClei of GALaxies

A high-resolution CO IRAM PdBI+30m survey of 12 nearby Seyfert or Liner galaxies. @ CO(2-1): spatial resolution of 50-100 pc.

F. Combes, Obs. Paris, France

PIs

S. García-Burillo, Obs. Madrid, Spain

L. K. Hunt, Oss. Arcetri

ITALY

V. Casasola, INAF-IRA, IT-ARC

R. Neri, IRAM Grenoble, France

L. J. Tacconi, MPE, Garching, Germany

M. Krips, IRAM Grenoble, France

A.J. Baker, Rutgers, NJ, USA

E. Schinnerer, MPIA, Garching, Germany

F. Boone, Obs. Paris, France

S. Leon, Joint ALMA Obs., Chili

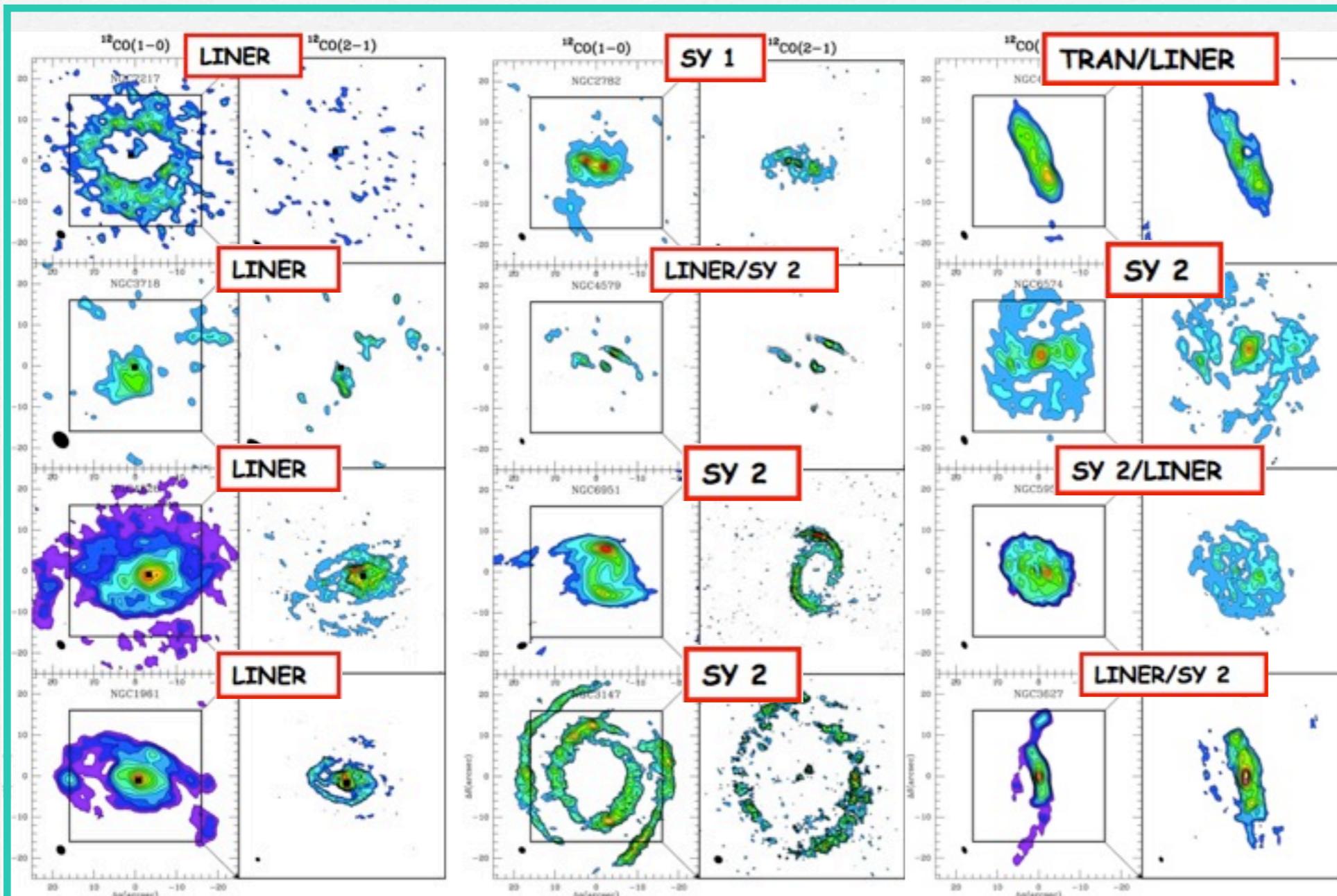
S. Haan, MPIA, Heidelberg, Germany

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# Morphologies found in NUGA

17 papers: Boone et al. 07; Casasola et al. 08, 10, 11; Combes et al. 04, 09; García-Burillo et al. 03, 05, 09; Hunt et al. 08; Krips et al. 05, 07; Lindt-Krieg et al. 08; .....



On-going fueling at 0.1-1 kpc scales for only 5/12 cases.

The most common feeding mechanism: kinematically decoupled embedded bars.

IRAM observations have insufficient resolution to probe the gas within 100 pc of the AGN.

# AGN fueling with ALMA

We **MUST IMPROVE** spatial resolution to resolve the inner gas distribution: **ALMA-ES Cycle 0** has offered this opportunity.

# AGN fueling with ALMA

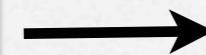
We **MUST IMPROVE** spatial resolution to resolve the inner gas distribution: **ALMA-ES Cycle 0** has offered this opportunity.

## ALMA Cycle 0 accepted proposals

1.

Feeding and feedback in two nearby Seyfert Galaxies

PI: F. Combes



**NUGA SOUTH**

2.

The footprints of SF and AGN activity in NGC 1068:  
a case study for ALMA

PI: S. García-Burillo



Smoking gun  
evidence of  
feeding

# AGN fueling with ALMA

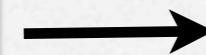
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Smoking gun  
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3.

The ALMA view of the cool dust in an  
extreme low-metallicity starburst

PI: L. Hunt



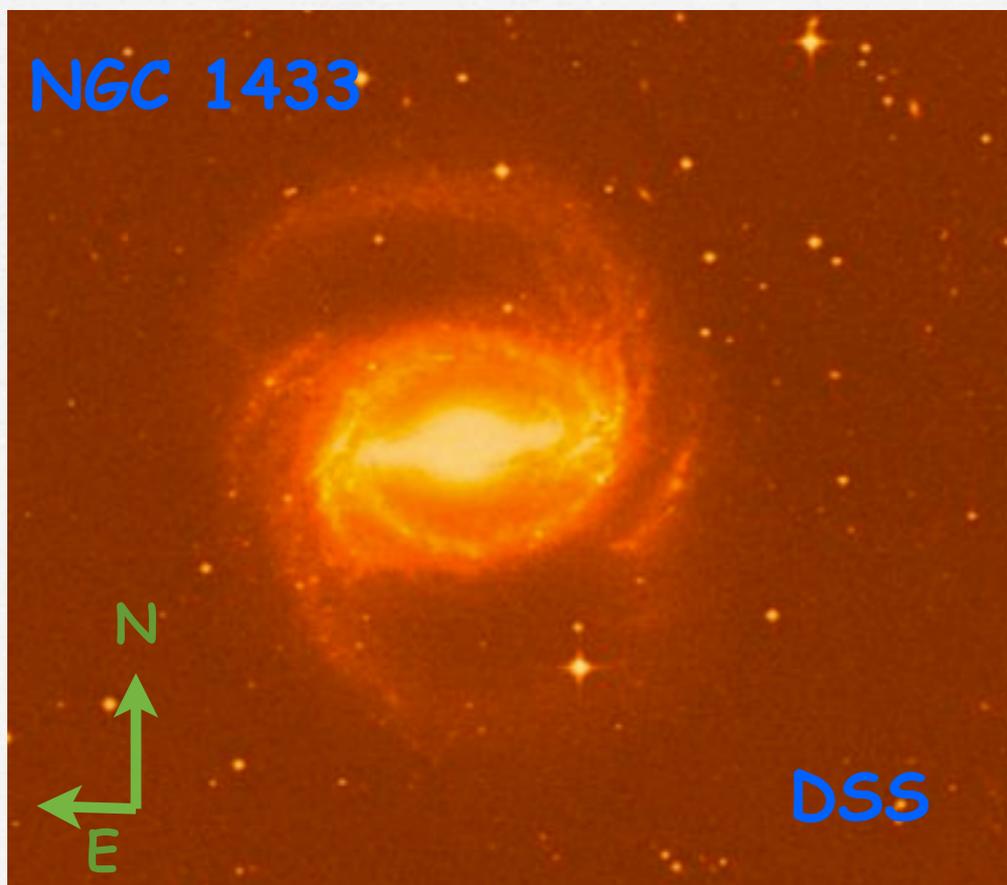
Leslie's Talk

# NUQA SOUTH

Two Targets selected among barred spiral nearby southern AGN with existing wealth of data and CO detection:

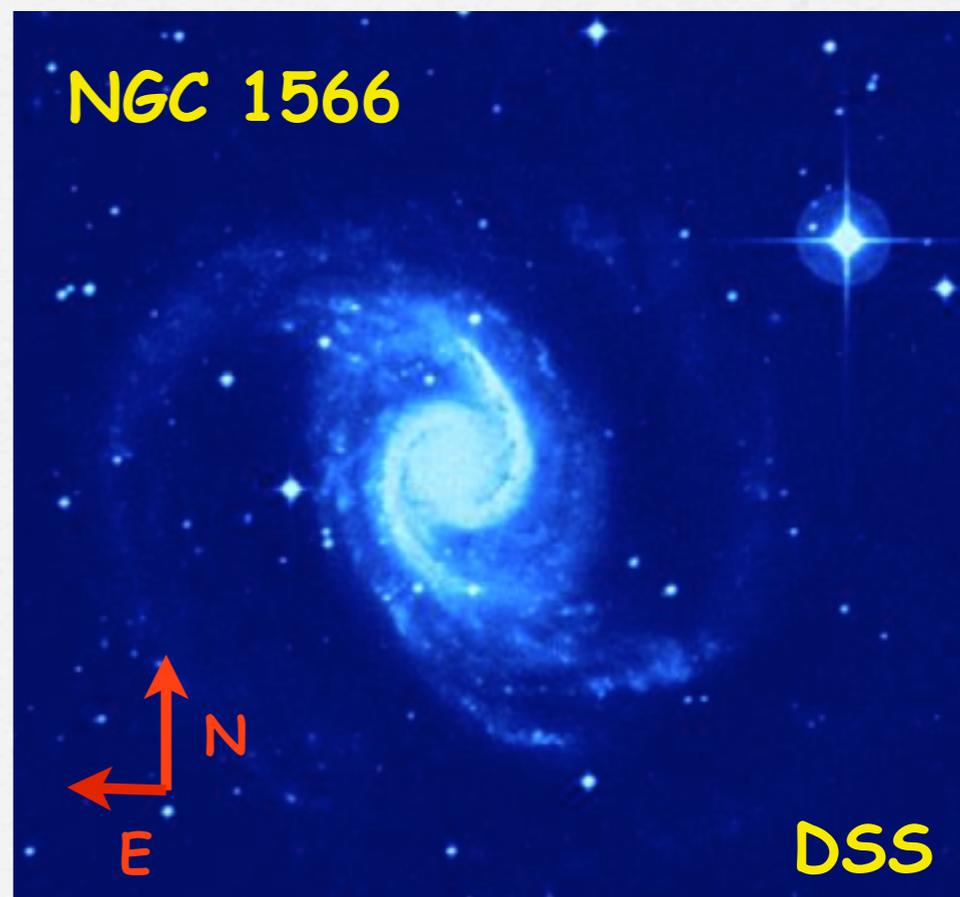
NGC 1433 (Seyfert 2) and NGC 1566 (Seyfert 1)

NGC 1433



Both at  $D \sim 10$  Mpc  
with embedded bars

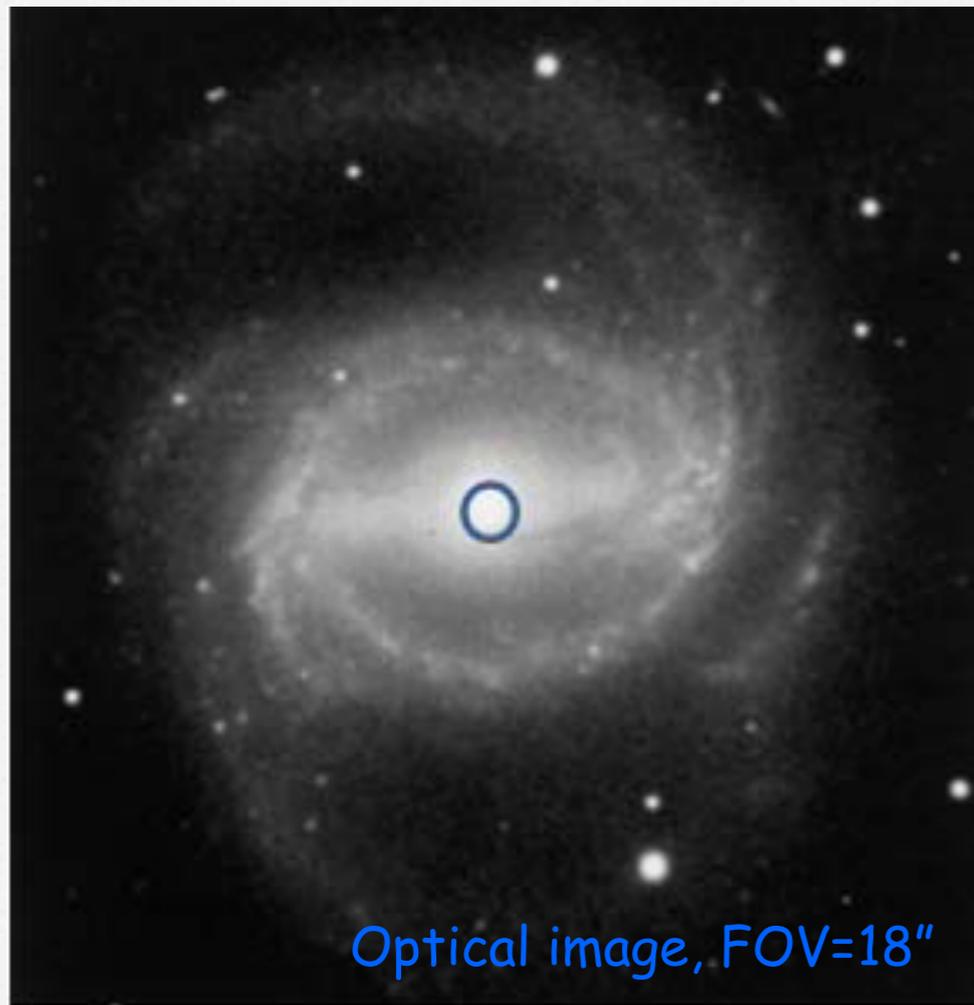
NGC 1566



# NUQA SOUTH

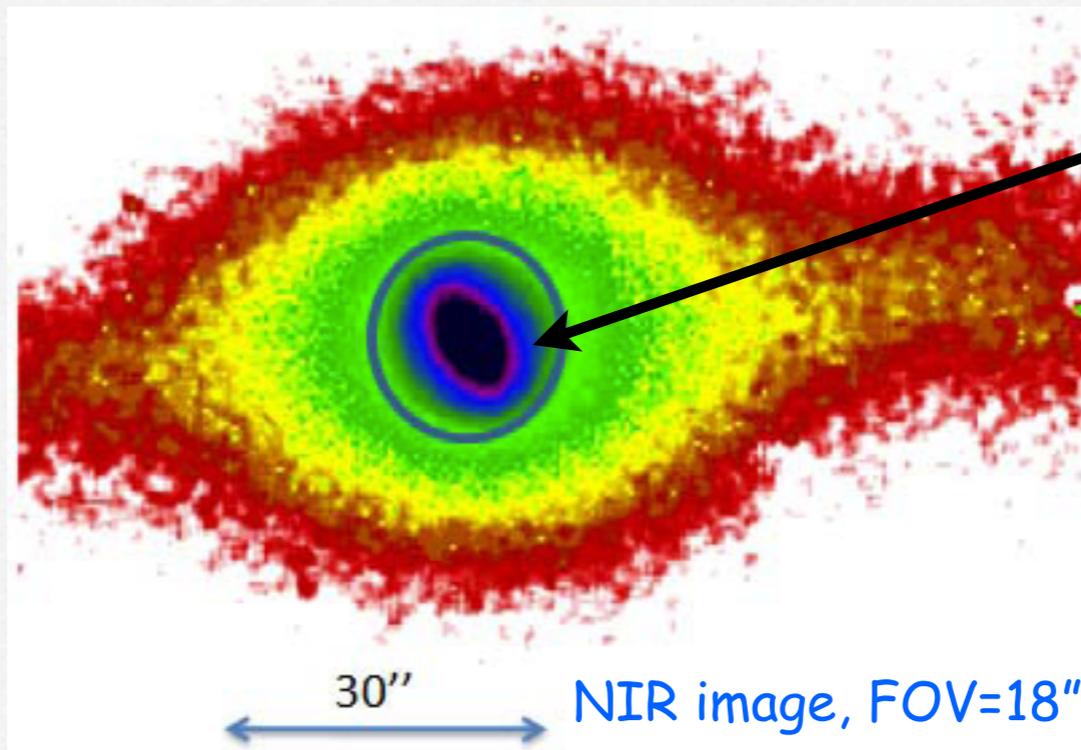
1

NGC 1433 (Seyfert 2) -- "Lord of rings":  
nuclear, inner, and outer rings (Buta & Combes 96)



Optical image, FOV=18"

120"



30"

NIR image, FOV=18"

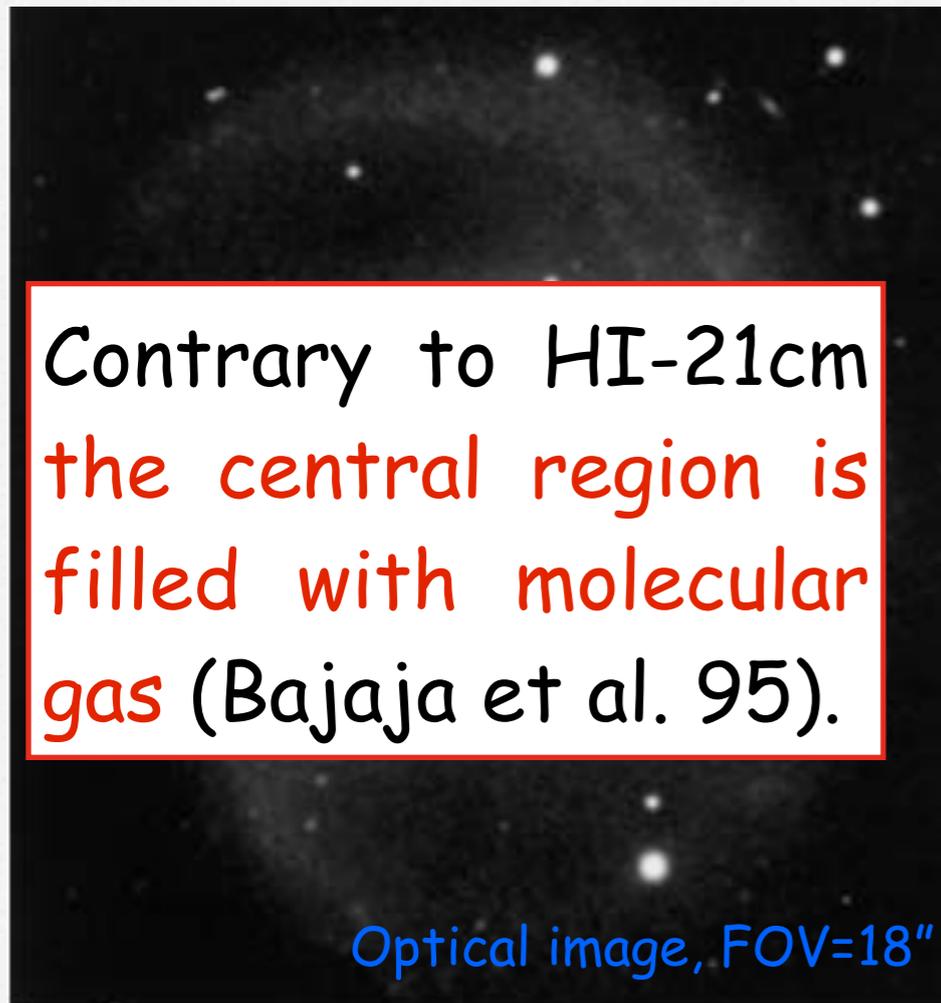
Nuclear bar  
inside the  
nuclear ring  
( $r = 200 \text{ pc}$ ,  
Jungwiert et al. 97).

Atomic gas (HI-21cm map) concentrated in the inner and outer rings, with depletion in the nuclear ring and bar (Ryder et al. 96).

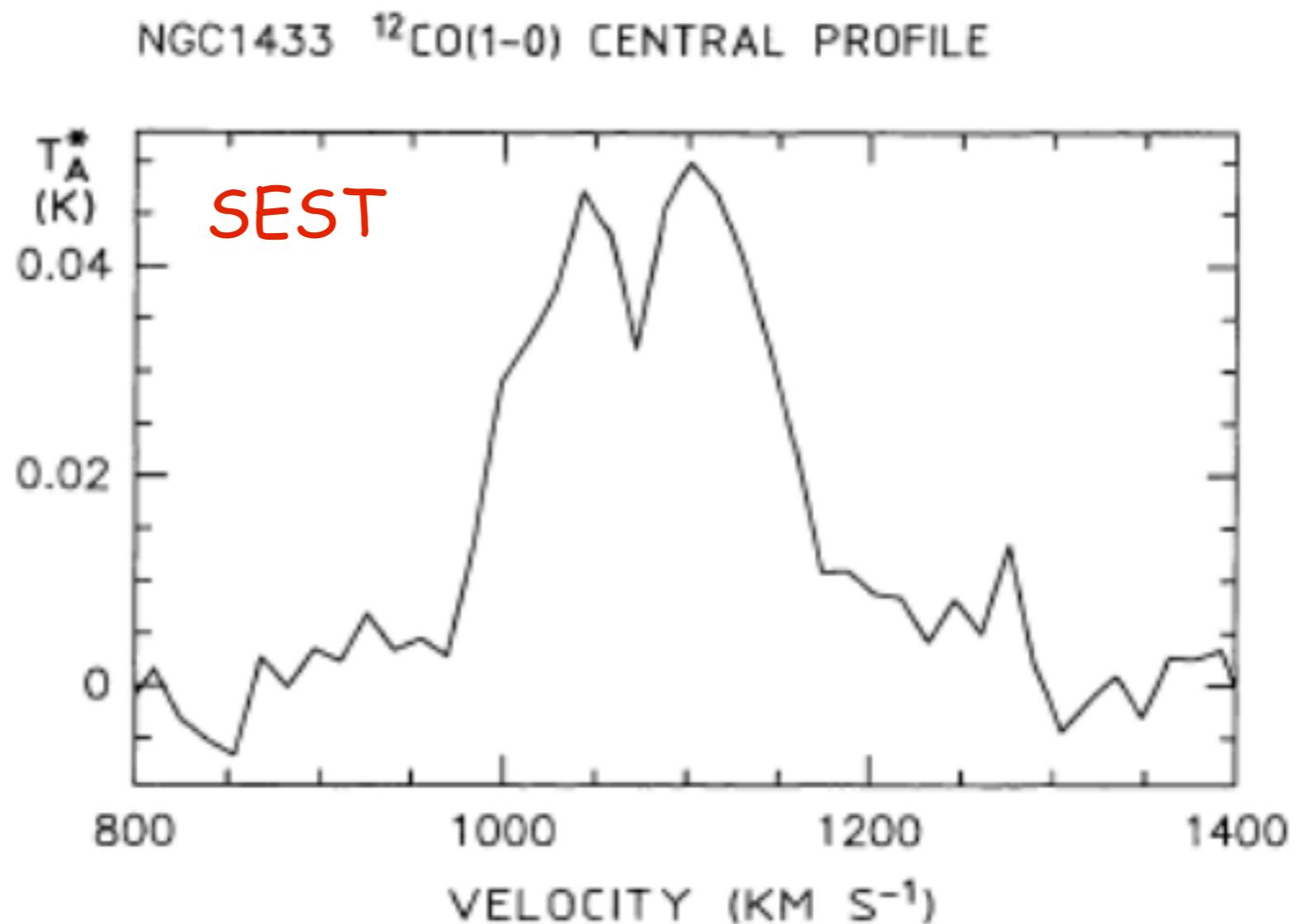
# NUQA SOUTH

1

NGC 1433 (Seyfert 2) -- "Lord of rings":  
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120"

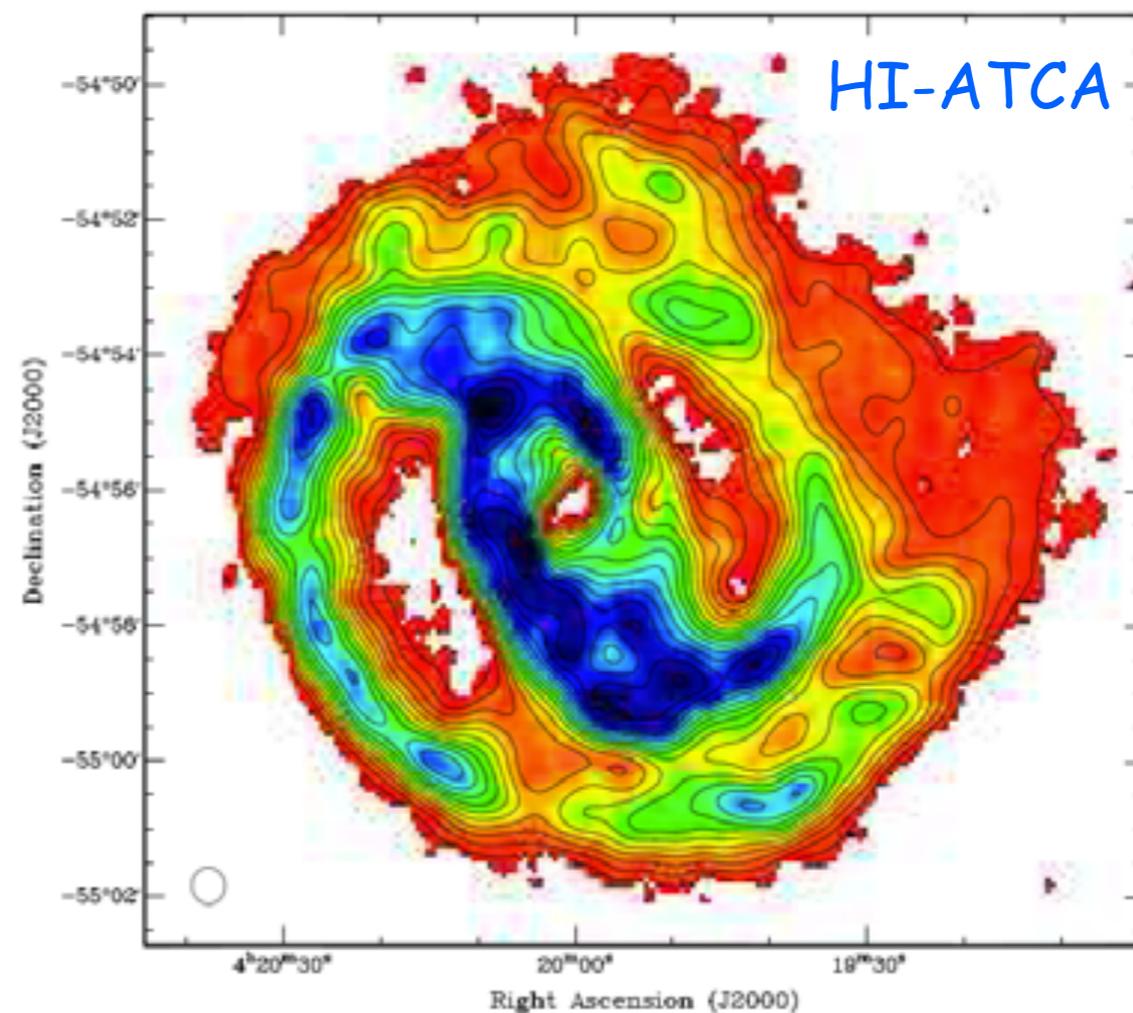
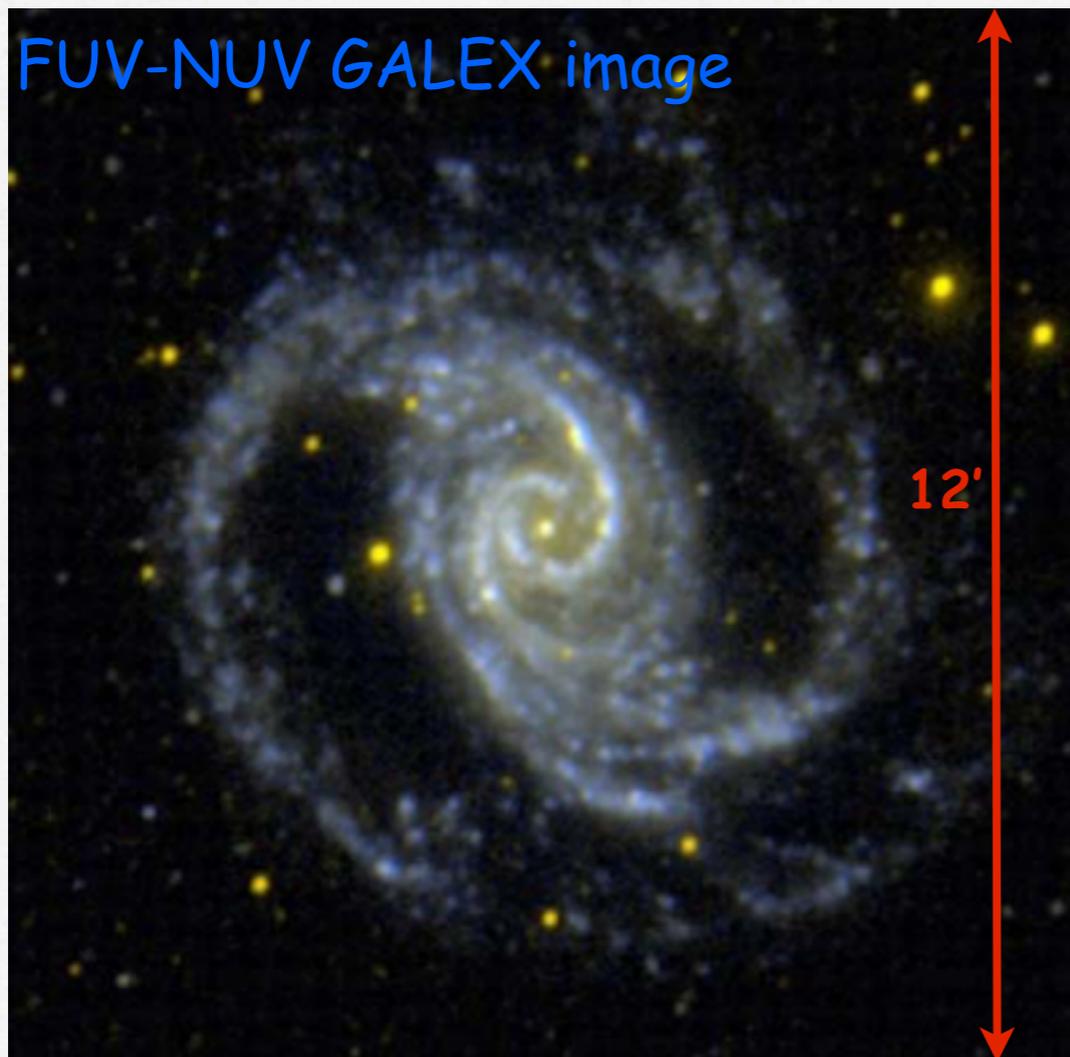


# NUQA SOUTH

2

## NGC 1566 (Seyfert 1):

It has intermediate bar (SAB) and two strongly contrasted spiral arms, emanating from the bar, and winding up in an outer pseudo ring

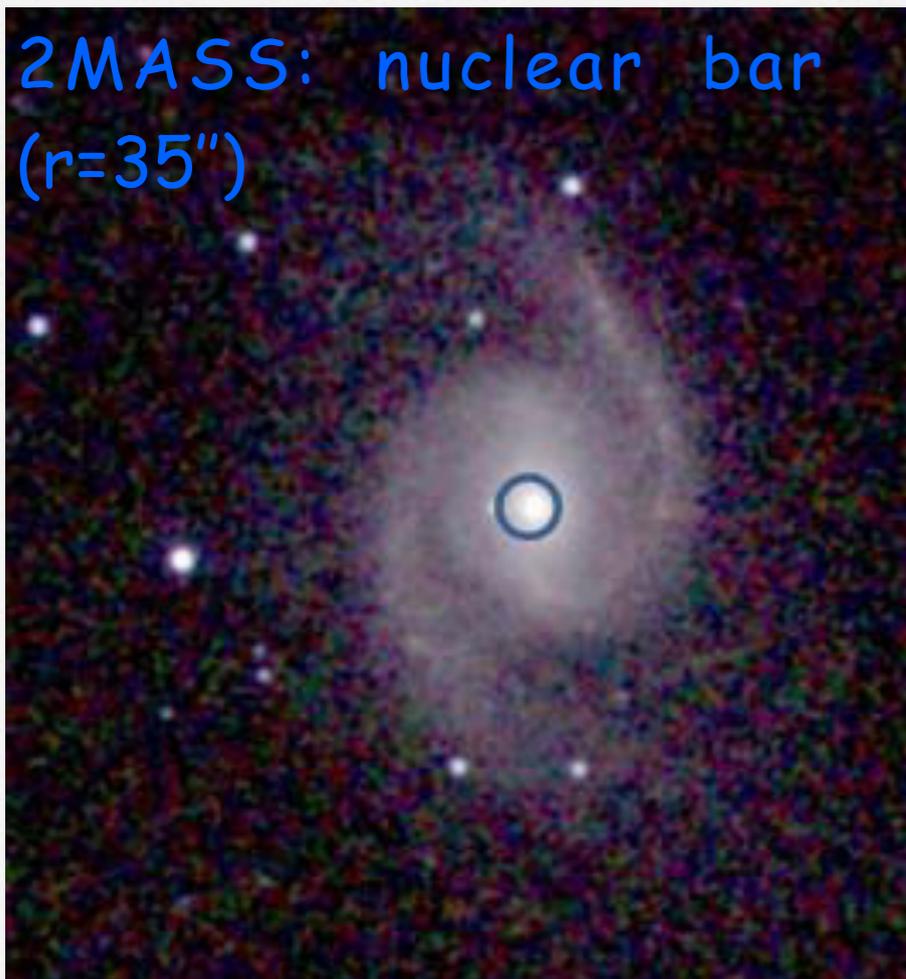


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2

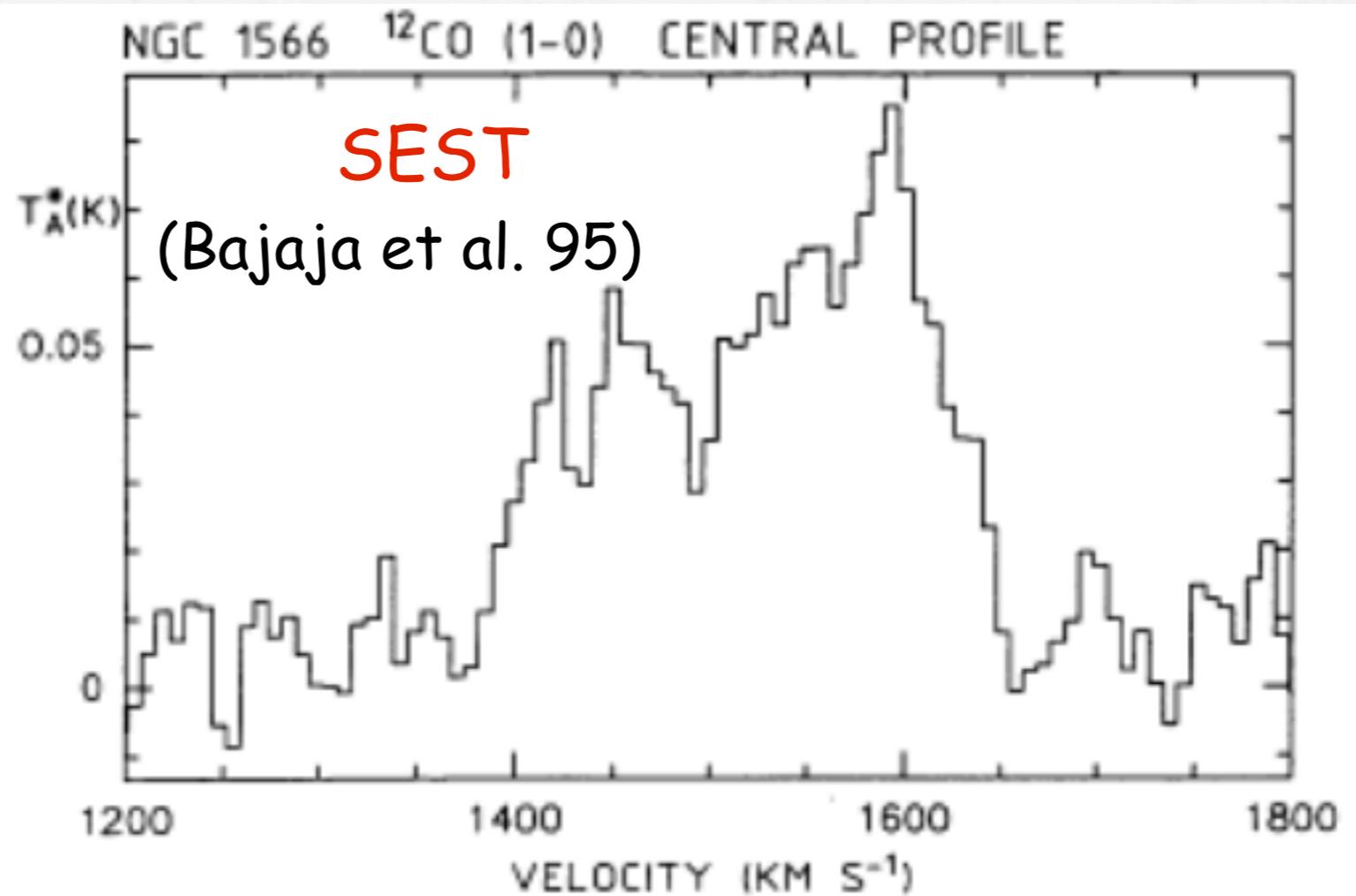
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It has intermediate bar (SAB) and two strongly contrasted spiral arms, emanating from the bar, and winding up in an outer pseudo ring



2'

FOV=18"



# NUQA SOUTH: Proposed Observations

We proposed to map the morphology and kinematics of the cold dense gas in two Seyfert nuclei, known to have embedded bars, at the unprecedented spatial resolution.

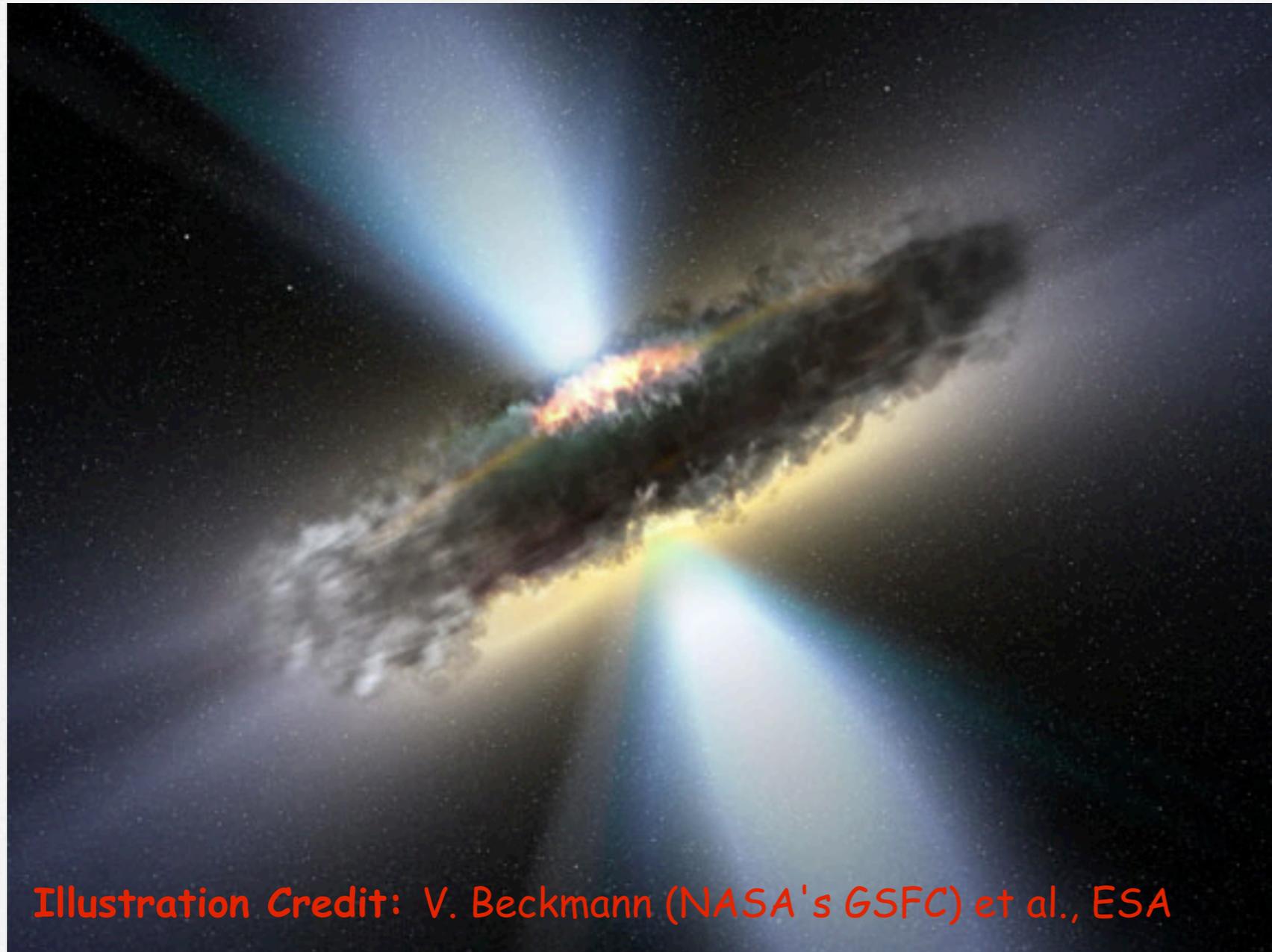
- To map the  $\text{CO}(3-2)$  (high density gas,  $10^4-10^5 \text{ cm}^{-3}$ ) line in both galaxies, simultaneously with  $\text{HCN}(4-3)$  and  $\text{HCO}^+(4-3)$  (densest clumps, excitation and chemistry)
- Nuclear *single pointing* of  $\text{FOV}=18''$  (1 kpc)
- Extended Configuration, Band 7, *spatial resolution* =  $0.45''$  (20 pc)
- *2 hrs* of integration time for each galaxy,  $S/N=25$  for  $\text{CO}(3-2)$  and  $S/N=4-6$  for  $\text{HCN}(4-3)$  and  $\text{HCO}^+(4-3)$
- To map continuum emission of the dust: @0.85 mm we expect  $S/N > 100$

## NUQA SOUTH: Expected Results

In 5 hrs (including calibrations) we expect to obtain results able to shed light on the way SMBH are fueled in each spiral galaxy, like our own.

The high S/N images obtained and kinematics will make the link the bar-spiral dynamics at large scales and the accretion onto the monster.

## NUQA SOUTH: Expected Results



This clear progress is also an essential step to prepare even higher resolution observations, to tackle the **molecular torus** below 10 pc in the future.

Illustration Credit: V. Beckmann (NASA's GSFC) et al., ESA

# RADIO MOHEGS

MOHEGs = Molecular Hydrogen Emission Galaxies

- A population of H<sub>2</sub>-luminous ( $L(\text{H}_2) = 10^{40}$ - $10^{43}$  erg s<sup>-1</sup>) radio galaxies ( $z < 0.22$ ) whose molecular gas does not appear associated with SF (Spitzer, Ogle et al. 2010)
- mid-IR spectra are dominated by bright, pure rotational emission lines of warm (100-1500 K) H<sub>2</sub>
- Previous works (Ogle et al. 2010; Nesvadba et al. 2011) did not study the impact of the cold (10-50 K) molecular gas in the AGN fueling of radio galaxies

Do radio MOHEGs have cold molecular gas coexisting with warm molecular gas?

# RADIO MOHEGS

Nobeyama 45m



9 radio MOHEGs in CO(1-0)

7 already observed: 4 detected

PI: V. Casasola

F. Combes (**NUGA**, Obs. Paris)

L. Hunt (**NUGA**, Arcetri)

S. García-Burillo (**NUGA**, Madrid)

L. Magrini (**Arcetri**)

A. Mignano (IRA, **IT-ARC**)

R. Paladino (IRA, **IT-ARC**)

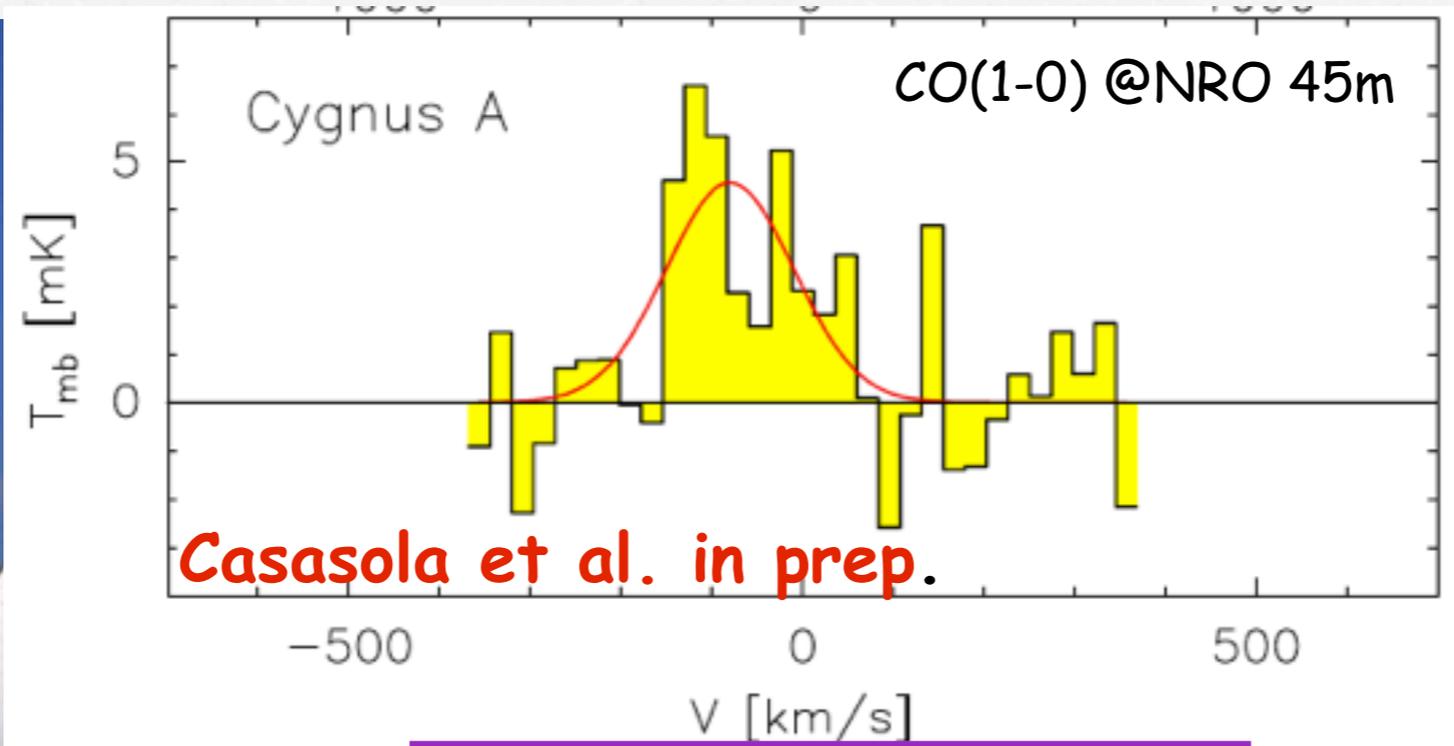
I. Prandoni (IRA, **IT-ARC**)

N. Nakai (**Tsukuba**, Japan)

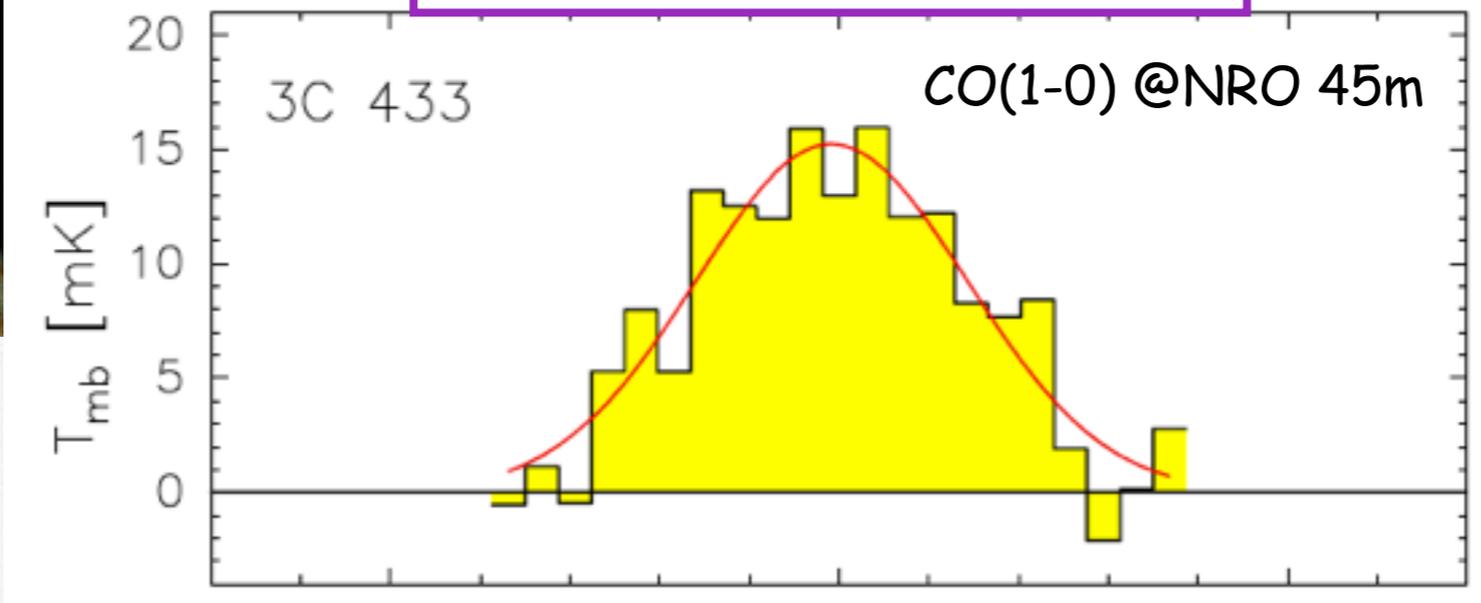
Y. Miyamoto (**Tsukuba**, Japan)

# RADIO MOHTEGS

Nobeyama



$M(\text{cold H}_2) \sim 10^{11} M_{\odot}$

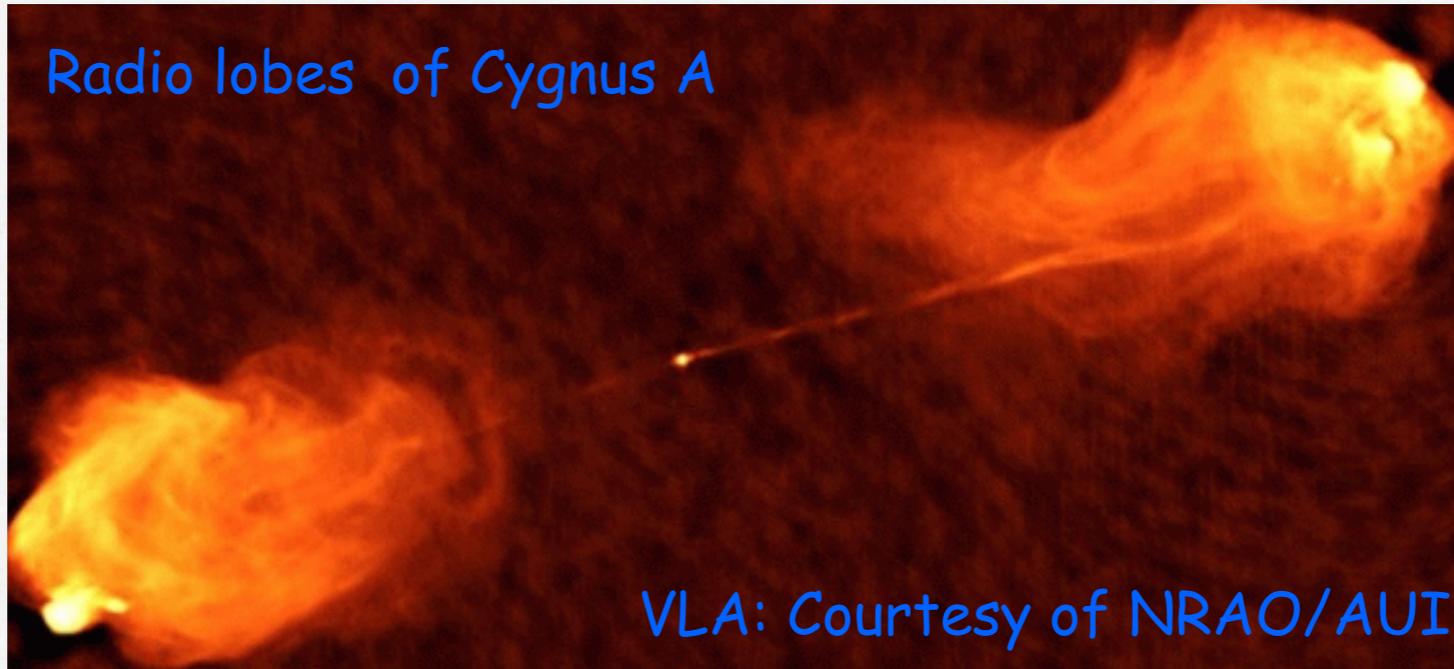


IGs in CO(1-0)  
 erved: 4 detected

- (A, Obs. Paris)
- Arcetri)
- (NUGA, Madrid)
- etri)
- (IT-ARC)
- (IT-ARC)
- (IT-ARC)
- ba, Japan)
- sukuba, Japan)

# RADIO MOHTEGS

Radio lobes of Cygnus A



VLA: Courtesy of NRAO/AUI

IRAM PdBI



We also obtained observations @ IRAM PdBI to map the detected CO(1-0) emission in Cygnus A, to check its nature and origin, and to relate it to the AGN fueling/feedback mechanisms.

Grazie