

MOLECULAR DISKS IN SOUTHERN RADIO GALAXIES

A SCIENCE VERIFICATION PROJECT FOR APEX1

Prandoni¹, R. Laing², P. Parma¹, H.R. de Ruiter¹, R. Verma²

¹Istituto di Radioastronomia del CNR, Bologna, Italy

²European Southern Observatory, Garching, Germany

Summary

It has been suggested that low luminosity radio galaxies (RG) are powered by direct accretion of the hot phase of the IGM onto the central BH. However, in some well studied objects we find substantial reservoirs of cold gas (dust, HI, CO): this is an alternative fuel supply.

Only a small number of RG have been detected in CO (and even fewer imaged), but it is already clear that the dynamics of the cold gas in the nuclei of RG may provide important clues to the fuelling mechanism.

The only instrument capable of imaging the molecular component on scales relevant to the accretion process is ALMA, but very little is known about CO in Southern RG.

We therefore have observed the CO(2-1) line in 3 nearby with APEX-1, in order to start creating a list of targets to be imaged in future with ALMA.

Aims

- 1) increasing the number of Fanaroff-Riley I radio galaxies with CO observations and thus improve our knowledge of the molecular gas masses typically found in such objects;
- 2) establishing whether the line profiles are always consistent with ordered rotation, or whether they are different for regular and irregular dust distributions;
- 3) providing targets for future interferometric follow-up, which will allow us to test the hypothesis that the cool gas is in stable orbits and search for evidence for accretion from the inner edge of the disks;
- 4) compare the occurrence of CO and dust, using the existing HST images.

CO(2-1) Observations & Line Measurements

Telescope used: **APEX 12 m**

Receivers and rms noise levels (output summed & $Dv_{\text{res}} \sim 40$ km/s):

Apex-1 (230 GHz) $\rightarrow$ 1 – 2 mK

Number of sources observed: **3** (Summer 2008)

Data reduction: **CLASS package**

Line measurements: **channels summed in the line profile (at FWHM)**

Detection criteria: **tentative detection $\rightarrow T_{\text{peak}}/T_{\text{rms}} > 2$**
reliable detection $\rightarrow T_{\text{peak}}/T_{\text{rms}} > 3$

Upper limits $\rightarrow T_a dv < 3 T_{\text{rms}} Dv_{\text{FWHM}} \sqrt{(Dv_{\text{FWHM}} / Dv_{\text{res}})}$

where $Dv_{\text{FWHM}} = 500$ km/s (av. FWHM line width of detected B2 RG, Prandoni+07)

$Dv_{\text{res}} = 40$ km/s (velocity resolution after smoothing)

$M(\text{H}_2) \rightarrow M(\text{H}_2) = 11.2 \times 10^{18} \text{ K} / [\eta_a (\text{H}_0 D)^2] \{ [(1+z) - \sqrt{(1+z)}]^2 / (1+z) \} S T_a^* dv$

where $D = 12$ m (telescope diameter); **$K = 1$** (for point sources); (Lim et al. 2000)

$\eta_a = 0.63$ (telescope efficiency at obs. frequency);

$H_0 = 65 \text{ km/s Mpc}^{-1}$

Observed Dataset

$^{12}\text{CO}(2\rightarrow 1)$

Source	redshift	$ST_a^* dv$ (K km/s)	Dv_{FWHM} (km/s)	$T_{\text{peak}}/T_{\text{rms}}$	$M(\text{H}_2)$ (M_{sun})
PKS 0336-35 (NGC 1399)	0.0048	0.20	127	2.1	$3.4 \cdot 10^7$
PKS 1107-372 (NGC 3557)	0.0102	1.52	248	3.5	$1.2 \cdot 10^9$
PKS 1333-35 (IC 4296)	0.0125	< 0.51	-	-	< $5.8 \cdot 10^8$

NB: *tentative detection *detection *upper limit

see Figures 1, 2 and 3

Figure 1 – low $M(\text{H}_2)$ [tentative CO detection] → No dust in galaxy core

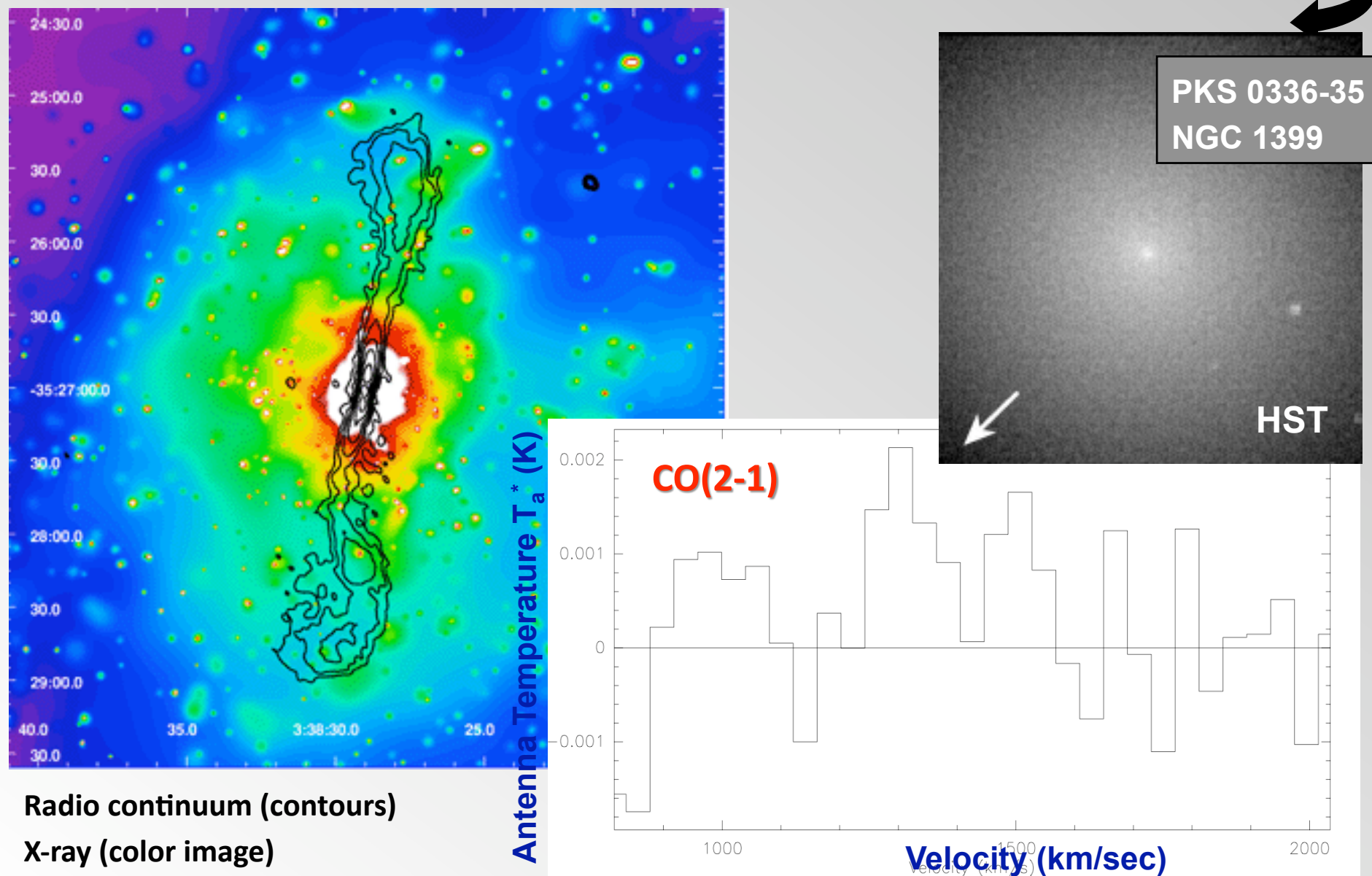
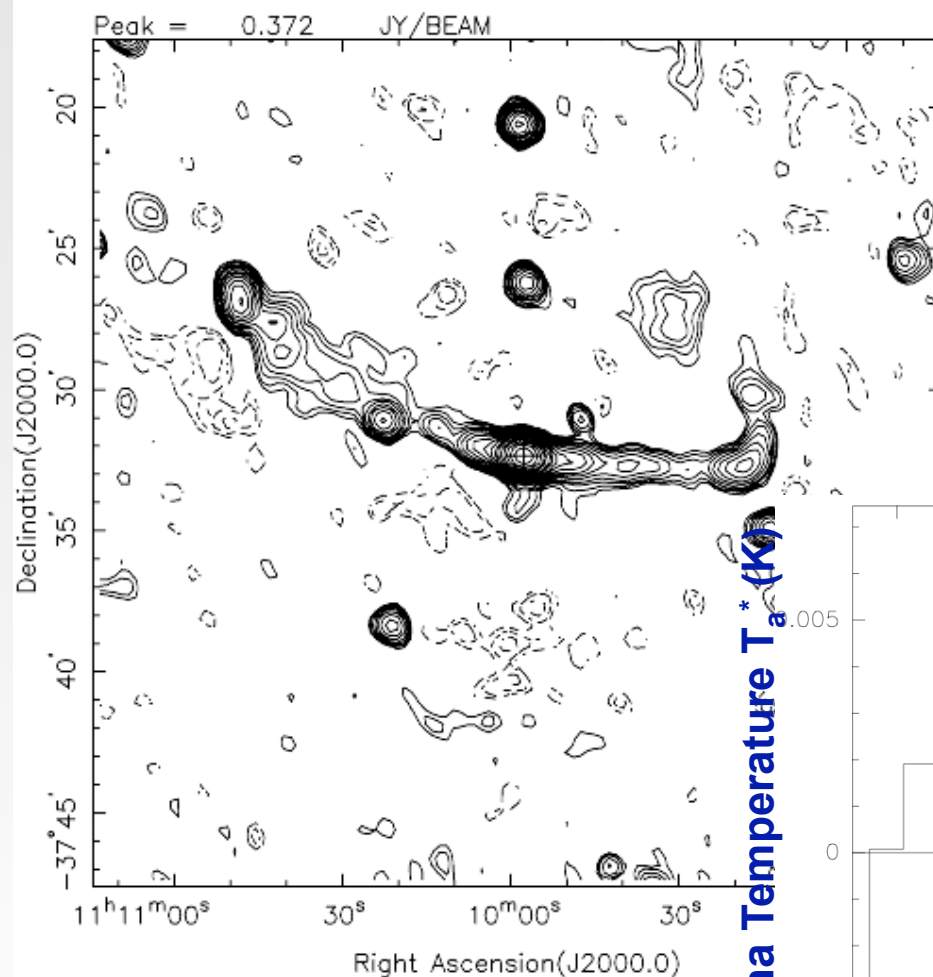


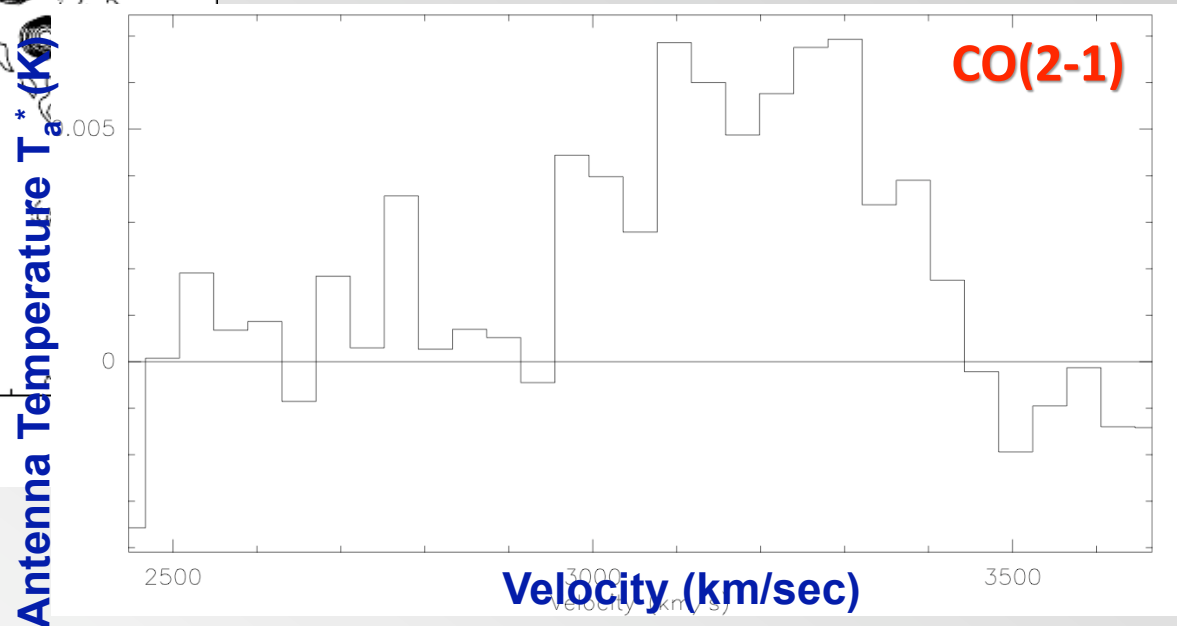
Figure 2 – double-horn CO line associated to rotating dusty disk

High $M(H_2)$ [reliable CO line detection]

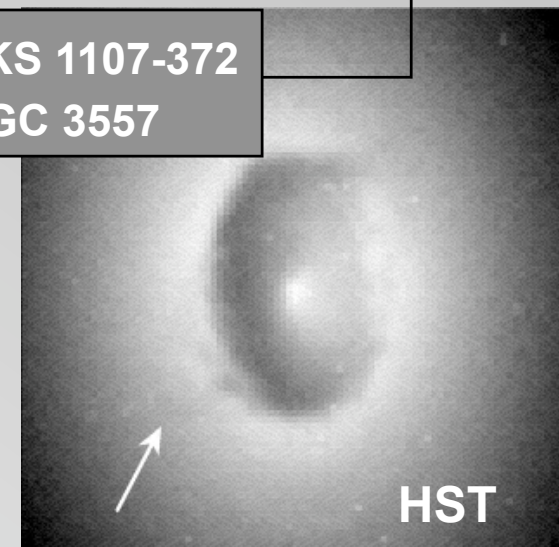
PKS 1107-372
NGC 3557



Radio continuum (NVSS)

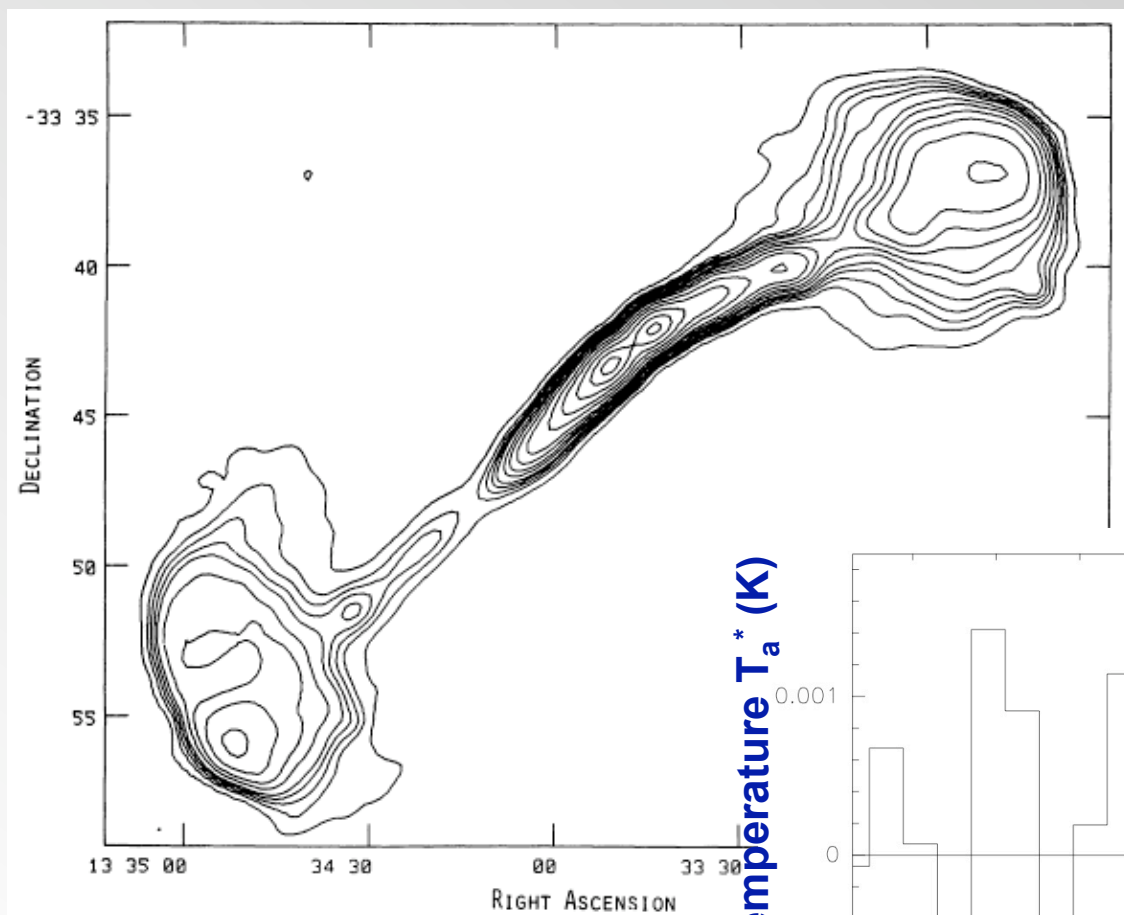


Velocity (km/sec)



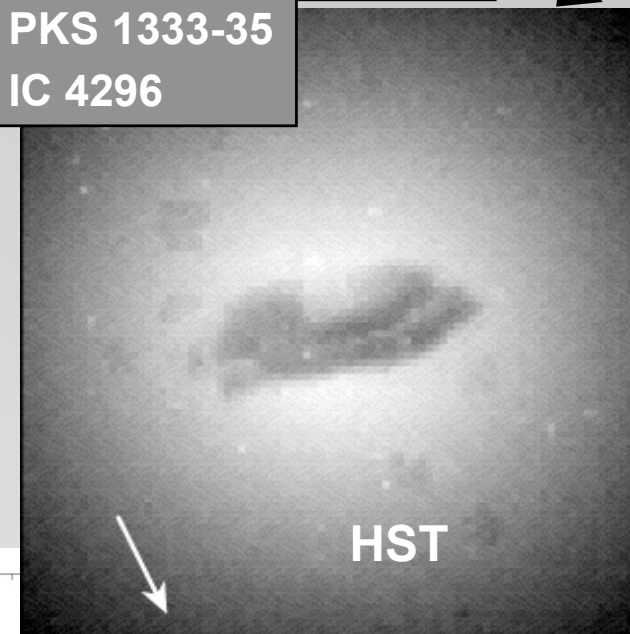
HST

Figure 3 – Intermediate $M(H_2)$ constraint [CO line undetected] →
Prominent dust ring in galaxy core

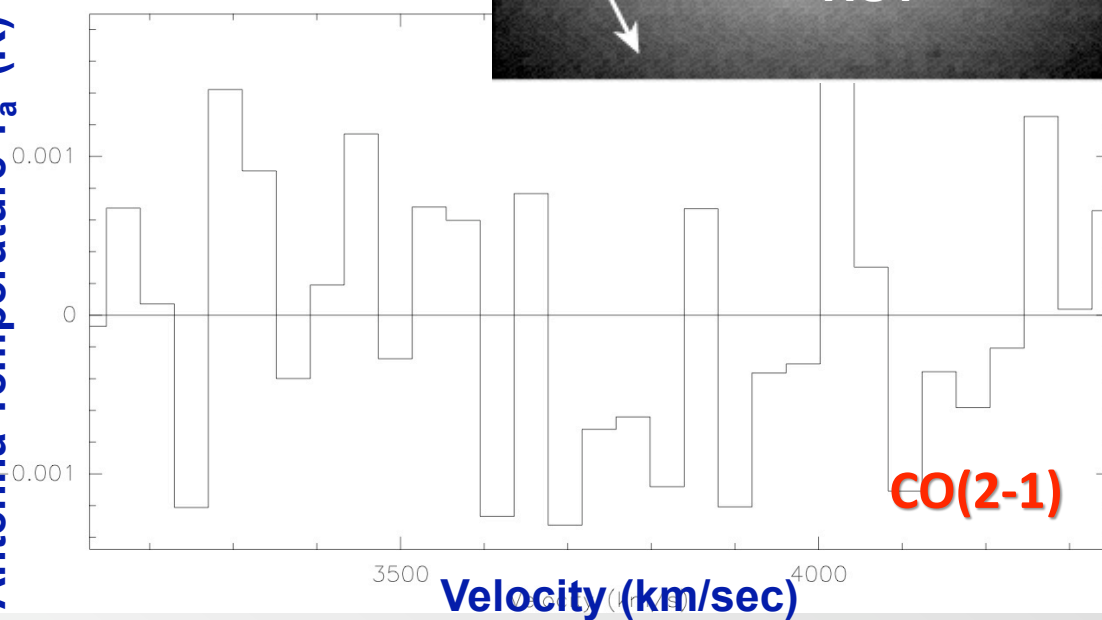


Radio continuum (VLA)

PKS 1333-35
IC 4296



Antenna Temperature T_a^* (K)



Comparison Samples in the Northern Emisphere

A) B2: All B2 low luminosity radio galaxies with $z < 0.03$

volume limited sample of 23 objects

Ref. → Prandoni et al. 2007

B) 3C: All 3C radio galaxies with $z < 0.03$

volume limited sample of 23 objects

Ref. → Lim et al. 2003

C) UGC: All galaxies with → $v < 7000 \text{ km/s}$ ($z < 0.0233$)

→ optical diameter $> 1 \text{ arcmin}$

→ radio jets

volume limited sample of 18 objects

Ref. → Leon et al. 2003

NB: Samples A, B and C are partially overlapping

Redshift distribution & CO detection rates

A) B2: most at $z < 0.023 \rightarrow N_{\text{tot}} = 23 \ N_{\text{obs}} = 16 \ N_{\text{det}} = 9$

D) This work

B) 3C: most at $z > 0.02 \rightarrow N_{\text{tot}} = 23 \ N_{\text{obs}} = 22 \ N_{\text{det}} = 4$

C) UGC: all at $z < 0.0023$

Samples probe different volumes

→ comparison in same z range ($z < 0.023$):

A) $N_{\text{tot}} = 14 \ N_{\text{obs}} = 12 \ N_{\text{det}} = 9$

→ $N_{\text{det}}/N_{\text{obs}} = 75 \pm 25\%$

B) $N_{\text{tot}} = 13 \ N_{\text{obs}} = 12 \ N_{\text{det}} = 4$

→ $N_{\text{det}}/N_{\text{obs}} = 33 \pm 17\%$

C) $N_{\text{tot}} = 18 \ N_{\text{obs}} = 17 \ N_{\text{det}} = 8$

→ $N_{\text{det}}/N_{\text{obs}} = 47 \pm 17\%$

D) $N_{\text{tot}} = \text{tbd} \ N_{\text{obs}} = 3 \ N_{\text{det}} = 2$

→ $N_{\text{det}}/N_{\text{obs}} = 66 \pm 50\%$

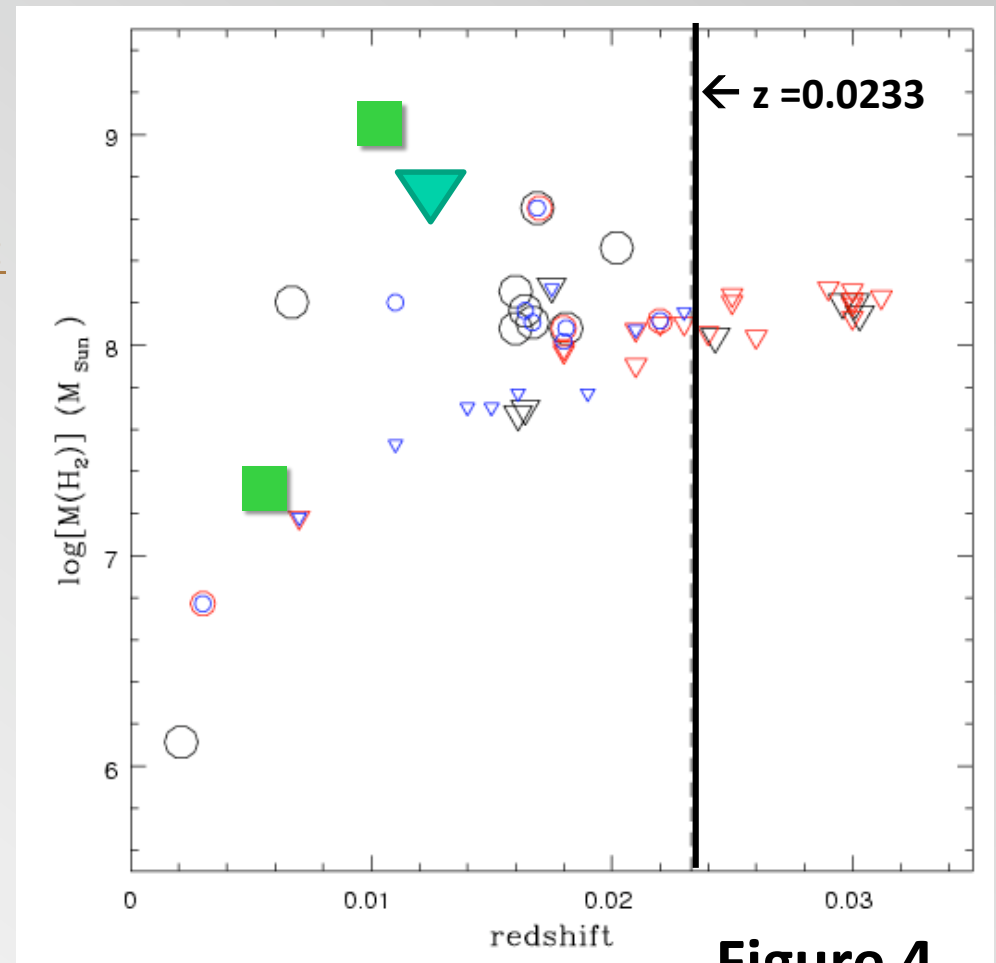


Figure 4

Conclusions

- 1) Evidences for a relation between CO and the dusty disks observed with HST
 - ➔ Detected sources are suitable targets for CO interferometry with ALMA to confirm such evidences
- 2) No significant difference in detection rates among different samples of local radio sources
 - once corrected for volume effects
- 3) others.....?