Molecular Gas in Nearby Infrared-Luminous Quasi-Stellar Objects and Radio Galaxies

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"QSOs"

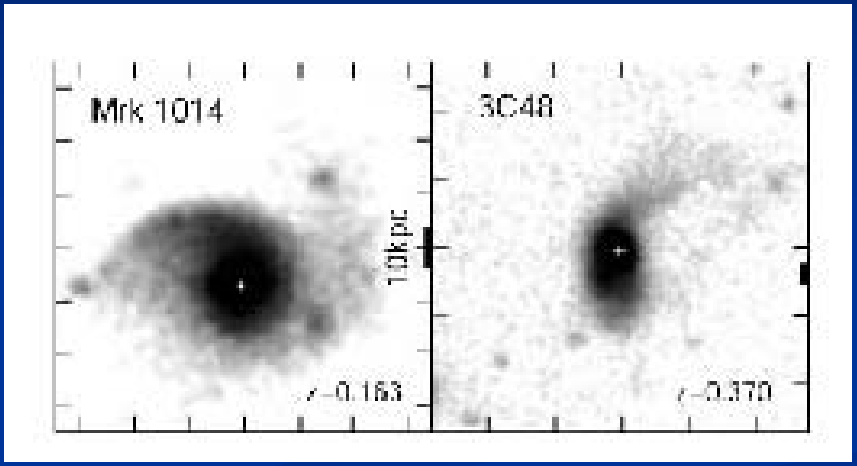
- D. Frayer (SIRTF)
- J. Surace (SIRTF)
- D. Sanders (U. Hawaii)
- P. Solomon (Stony Brook)
- D. Downes (IRAM)
- L. Tacconi (MPE)
- T. Vavilkin (Stony Brook)

"Radio Galaxies"

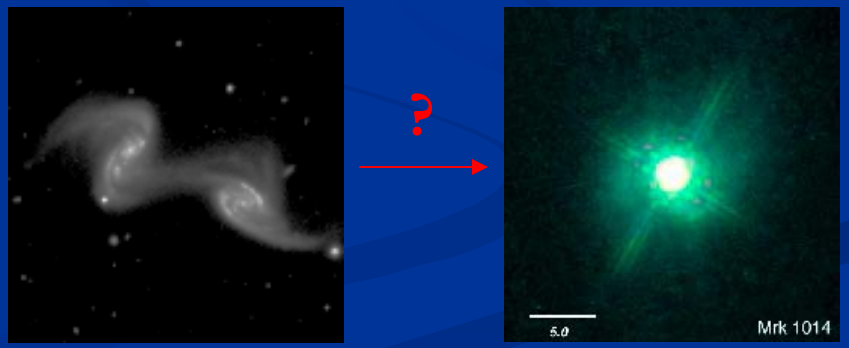
- J. Mazzarella (IPAC)
- J. Surace (SIRTF)
- D. Sanders (U. Hawaii)
- T. Vavilkin (Stony Brook)

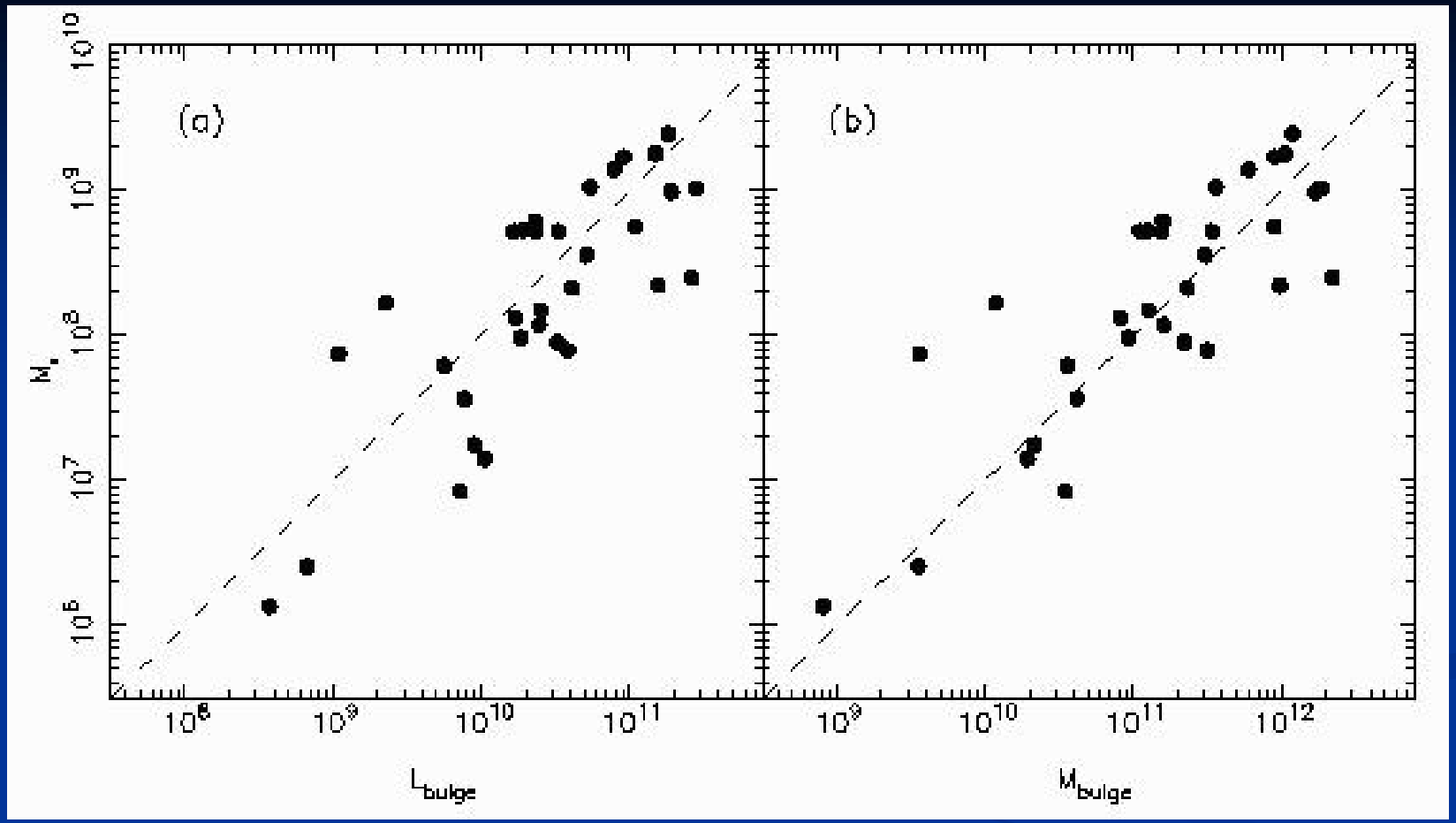
Molecular Gas as a fuel for AGN activity

- Gas-rich, IRAS-luminous mergers as host galaxies of many QSOs & Radio Galaxies (e.g. Stockton & MacKenty 1984; Heckman et al. 1986)



- Putative evolutionary connection between Ultraluminous Infrared Galaxies ($L_{IR} > 10^{12} L_{sun}$) and QSOs (Sanders et al. 1988a,b)





- $M_{BH} \sim M_{bulge}$, $M_{BH} \sim \sigma^{4-5}$
  Mass accretion onto a center black hole is an important part of galaxy evolution (Magorrian et al. 1998; Ferrarase et al. 2000; Gebhardt et al. 2000)

Selection Criteria

QSOs

- PG QSOs with $L_{IR} / L_{0.1\text{-}1\mu m} > 0.46$ (Surace et al. 2001).
- $z < 0.16$
- $M_B < -22.0$
- Total of 17 objects

- Note: For PG QSOs, $L_{IR} = (0.2\text{-}0.4)L_{bol}$

Radio Galaxies

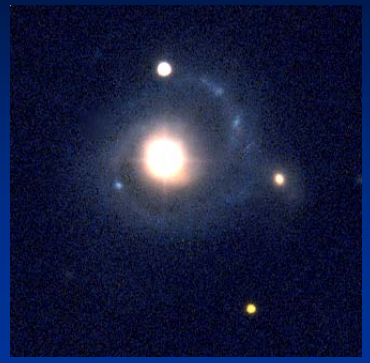
- IRAS-detected radio galaxies in Golombek et al. 1988 with f_{60} or $f_{100} > 0.3$ Jy.
- $z < 0.2$
- Total of 33 objects

QSO Host Galaxies

BI Images

PG 0007+106

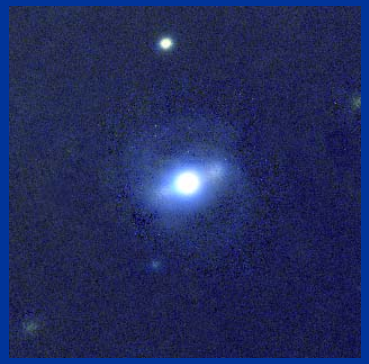
PG 1613+658



IZw1

PG 1229+204

PG 2130+099



PG 0838+770

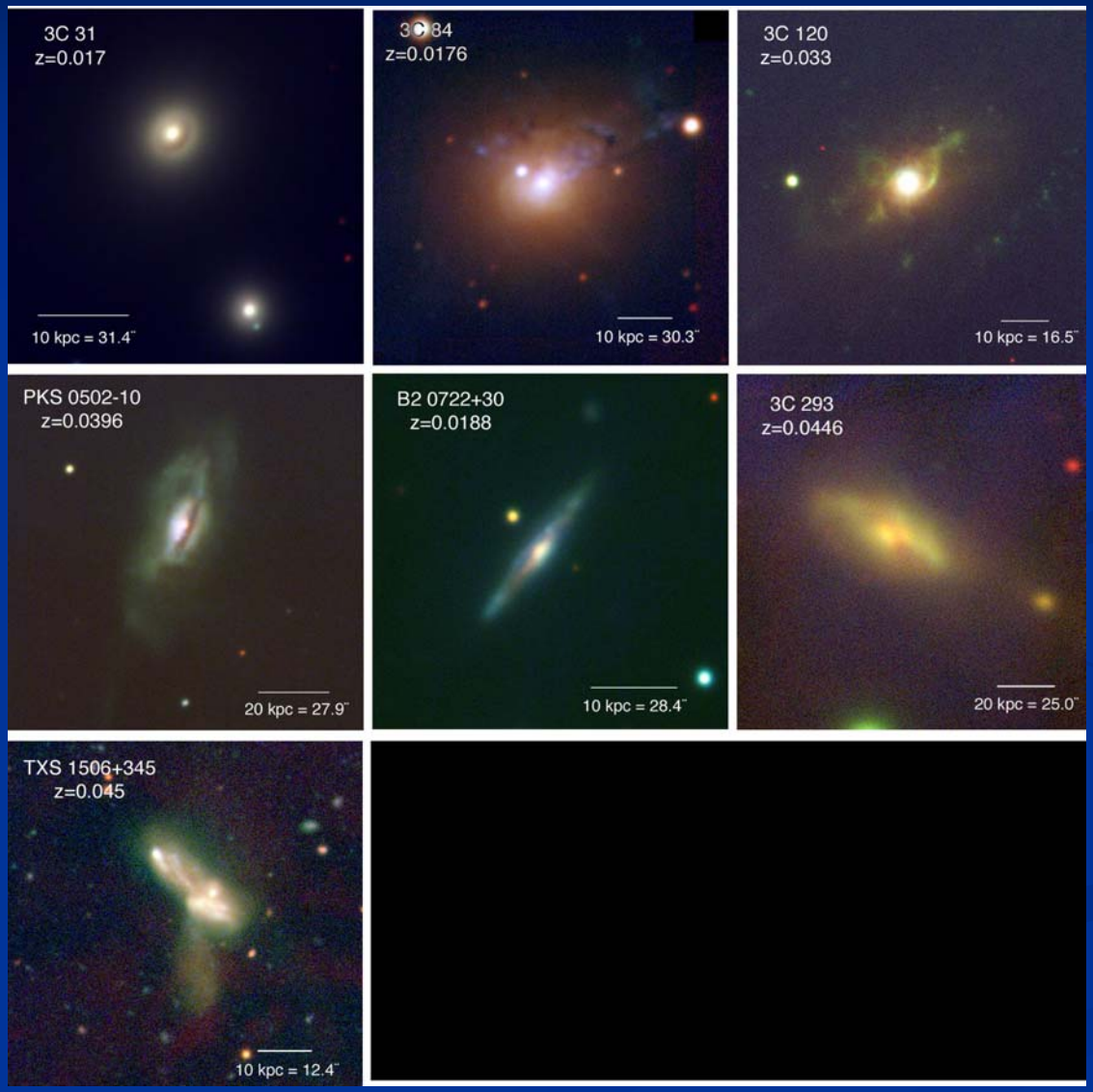
PG 1119+120

PG 1411+442

- 50% Spiral-like hosts with & without bars
- 25% Clear major mergers
- 25% Featureless/Elliptical-like galaxies

(Surace, Sanders & Evans 2001)

Radio Galaxies – An Analysis in Progress



- 30% Elliptical-like
- 50% mergers/galaxies with close companion
- 20% ??

UBI Images

Observations

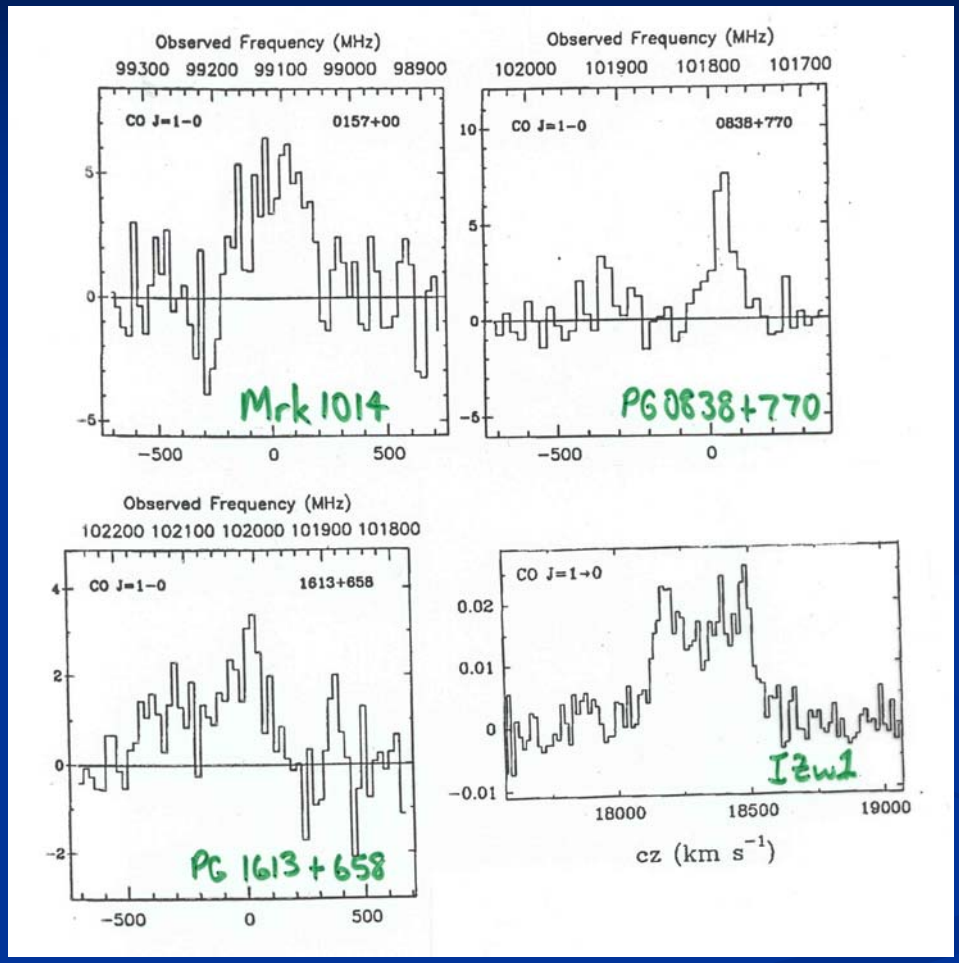
QSOs

- Two transits per source
- 4” beam
- Detection Limit of S_{CO} (3σ rms) = 8 mJy with 280 km s^{-1} smoothing
- I.e., M(H_2) = 10^9 M_{sun} at z = 0.1

Radio Galaxies

- 10-40 hours per source
- Detection limit L'_{CO} (3σ rms) ~ 6x10^8 K km s^{-1} pc^2 for 250 km s^{-1} line

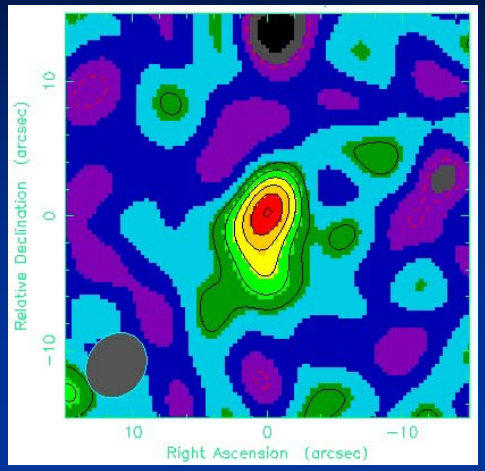
Previous CO detections of QSOs

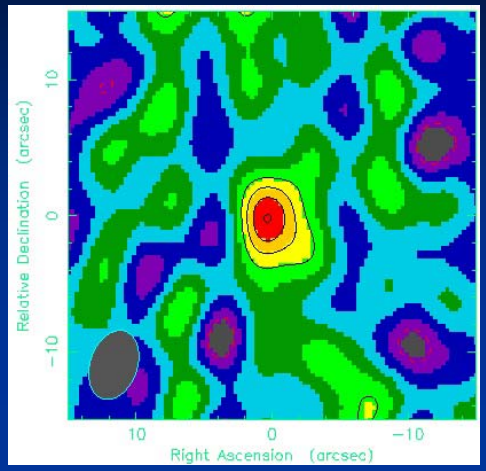


(Sanders et al. 1988; Barvainis et al. 1989; Alloin et al. 1992)

Molecular Gas in PG QSOs

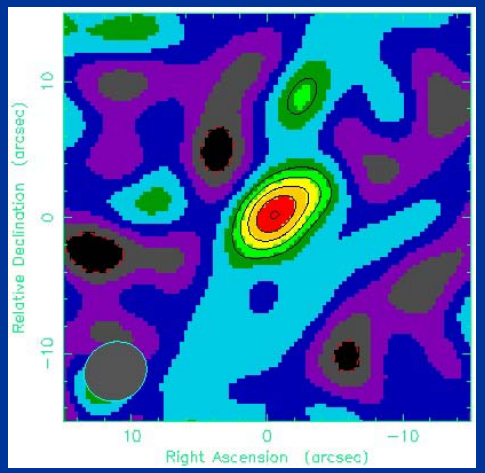
PG 0838+770

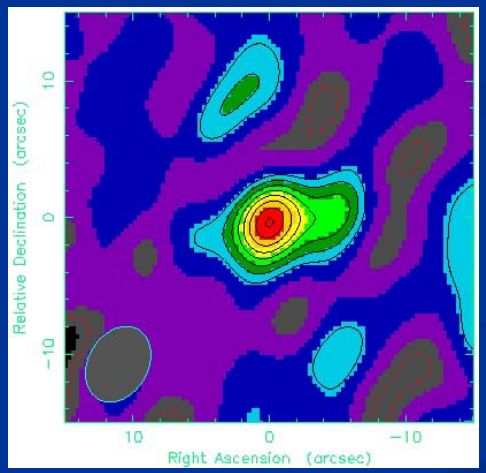




PG 1119+120

PG 1440+356

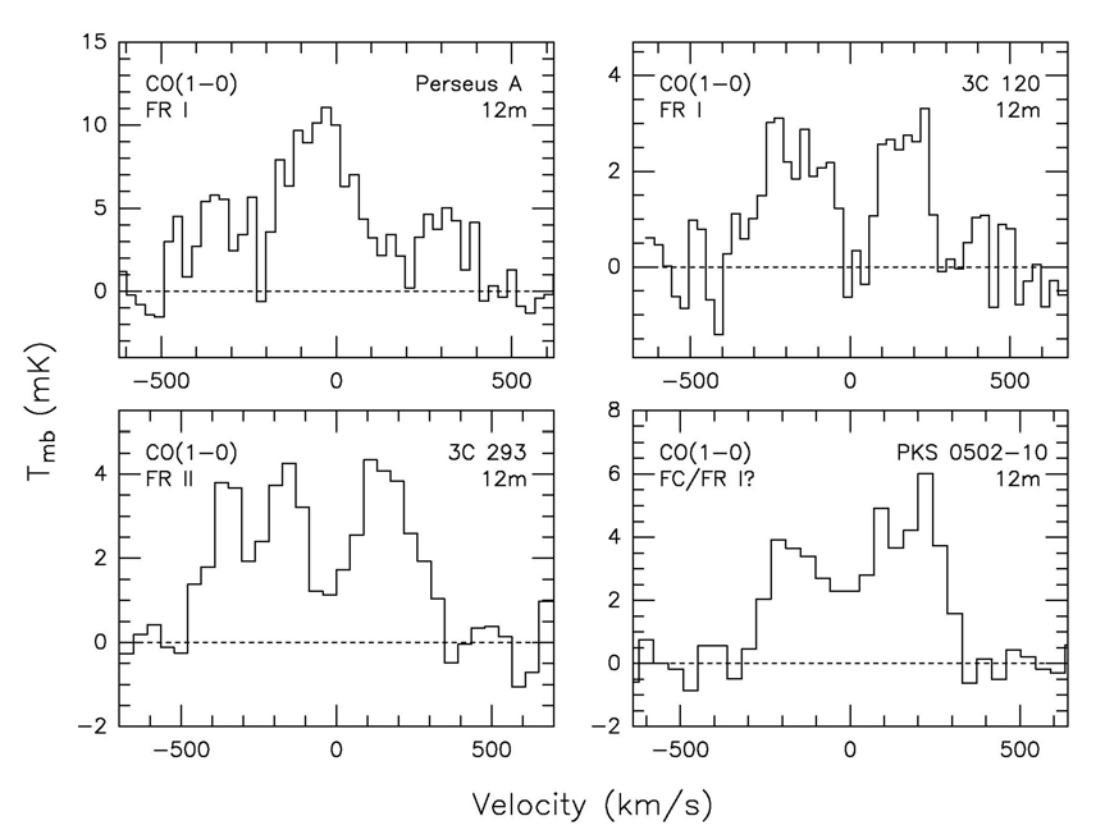




PG 1613+658

- 10 out of 15 QSOs (2 by Scoville et al. 2003)
- $\Delta v_{FWHM} \sim 50 - 600$ km/s

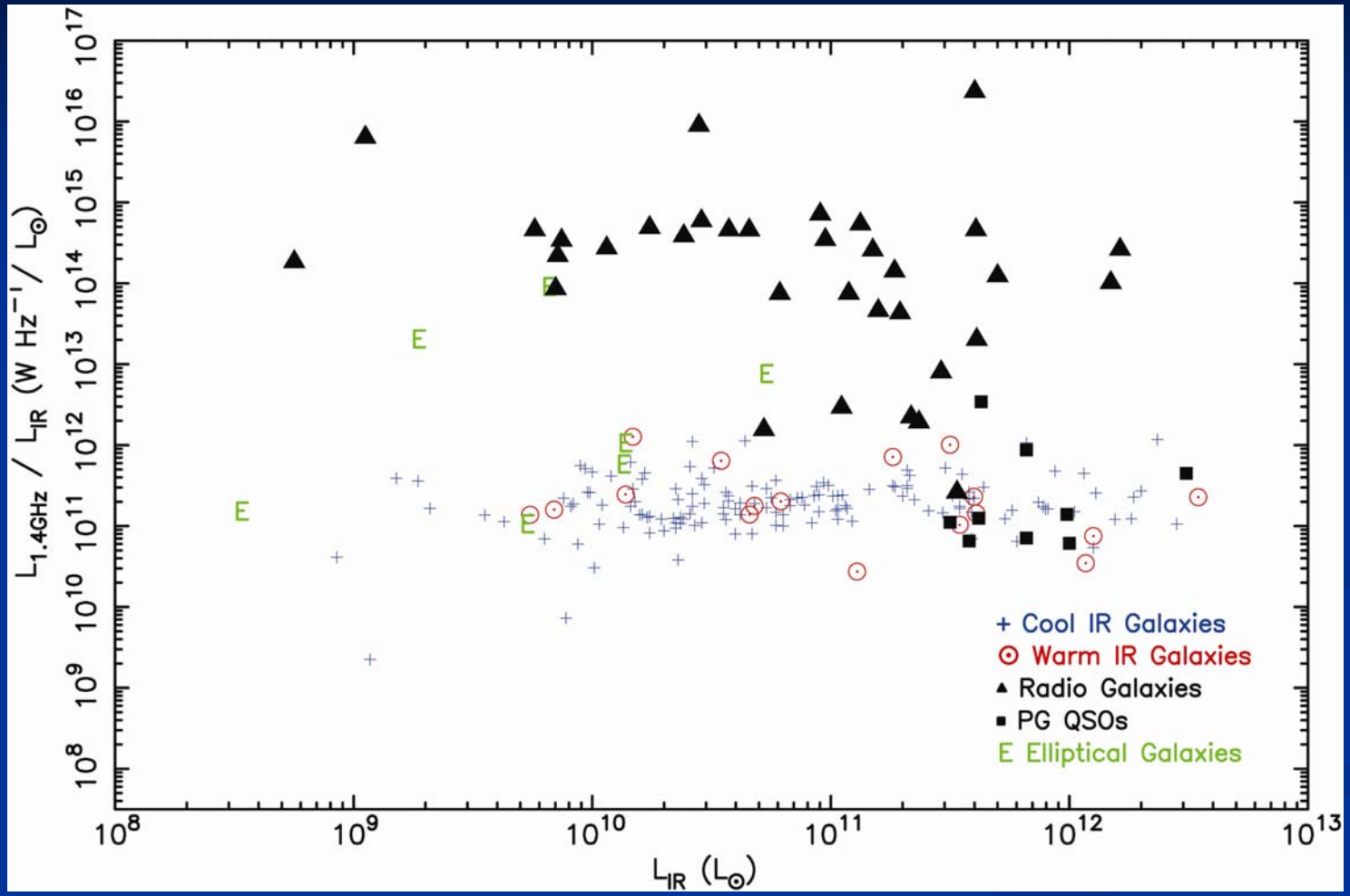
Molecular Gas in Radio Galaxies



- Nine out of 33 detected.
- Δv_{FWHM} ~ 200 - 600 km/s

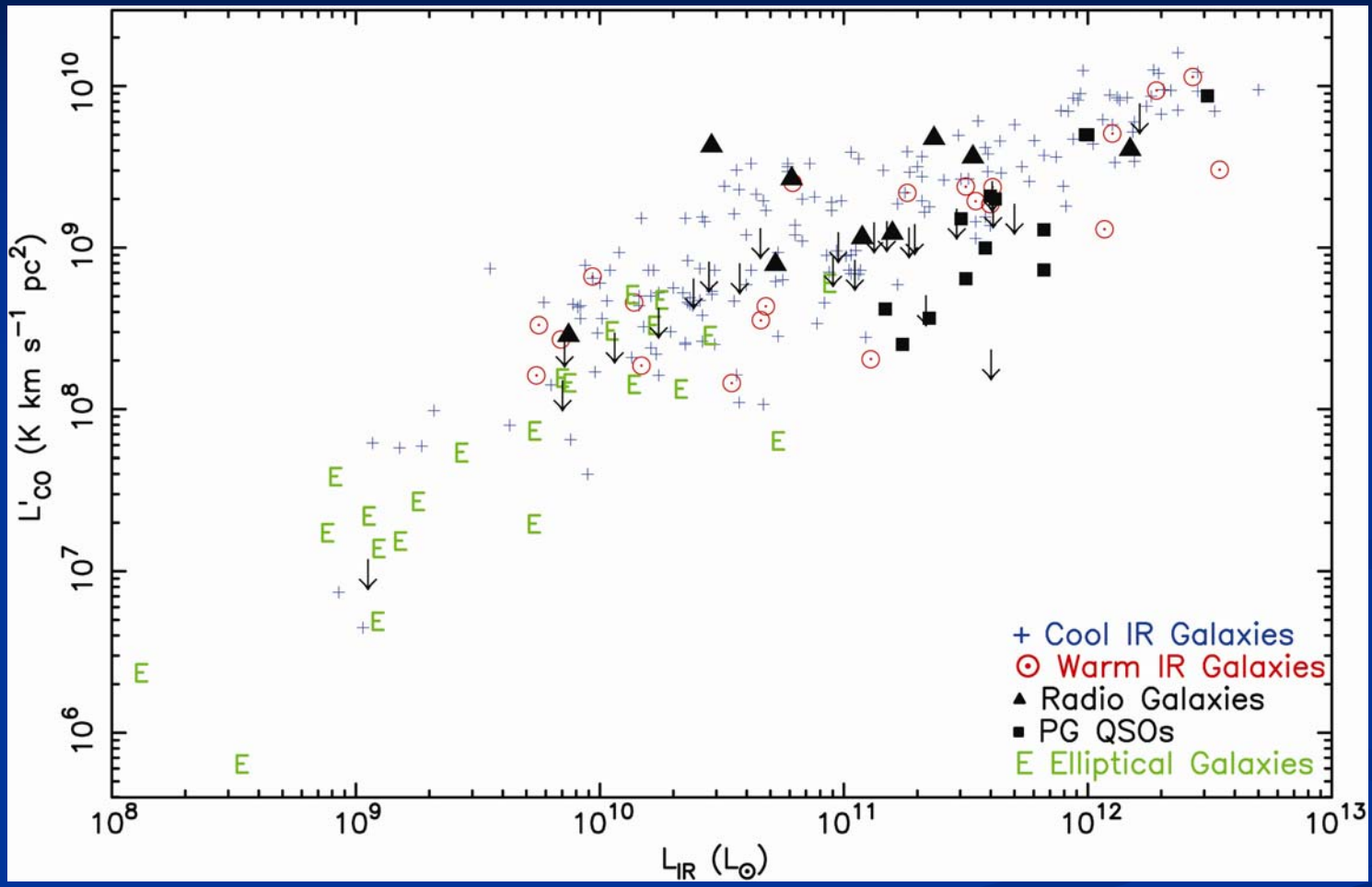
(Previous detections:
Phillips et al. 1987;
Mirabel & Sanders 1989;
Mazzarella et al. 1993)

Radio-Infrared Correlation



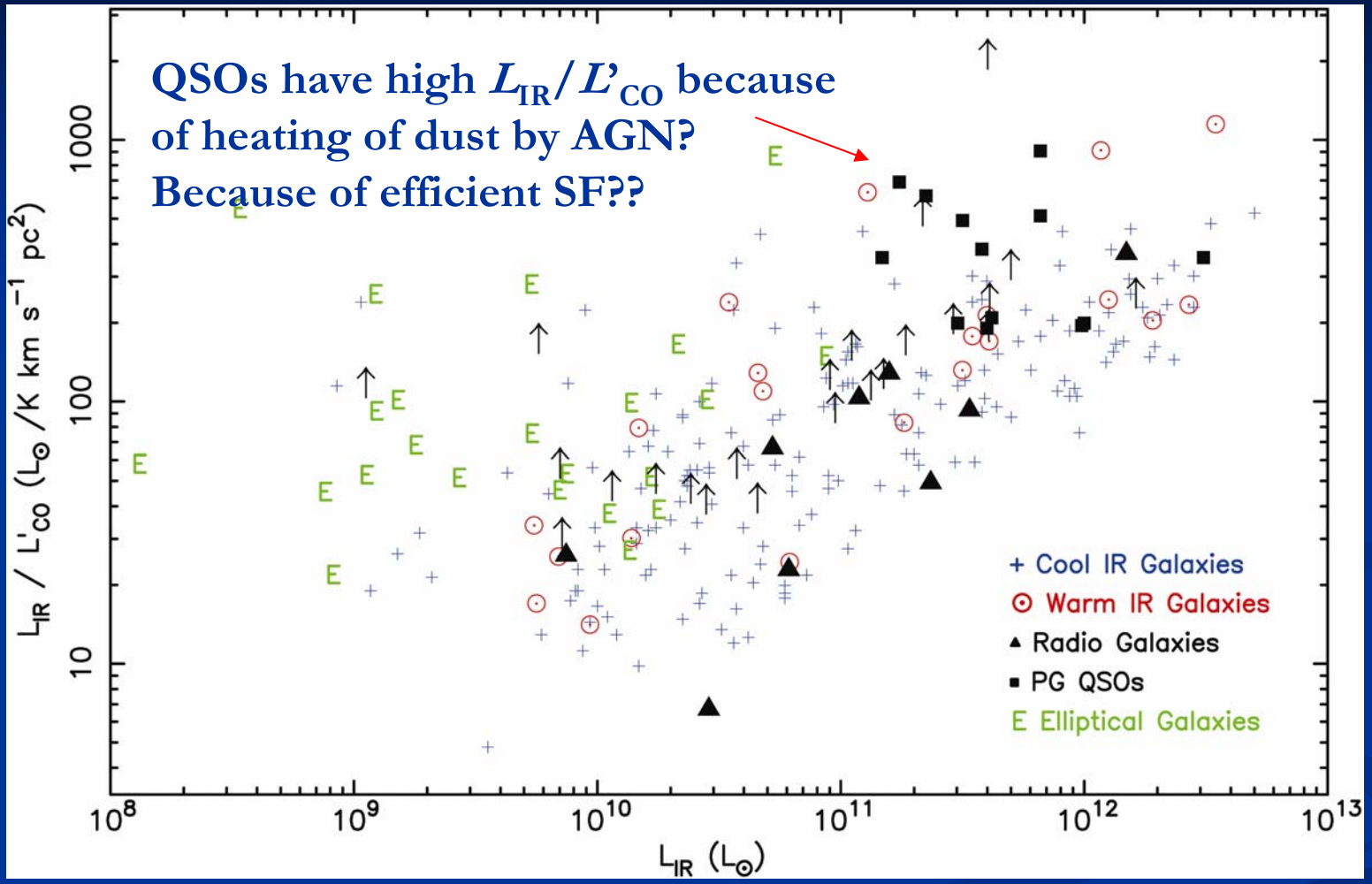
- Radio Galaxies really are radio AGN (exception B2 1318+34 - IC 883)
- PG QSO fall on Radio-Infrared Correlation

L'_{CO} vs. L_{IR}



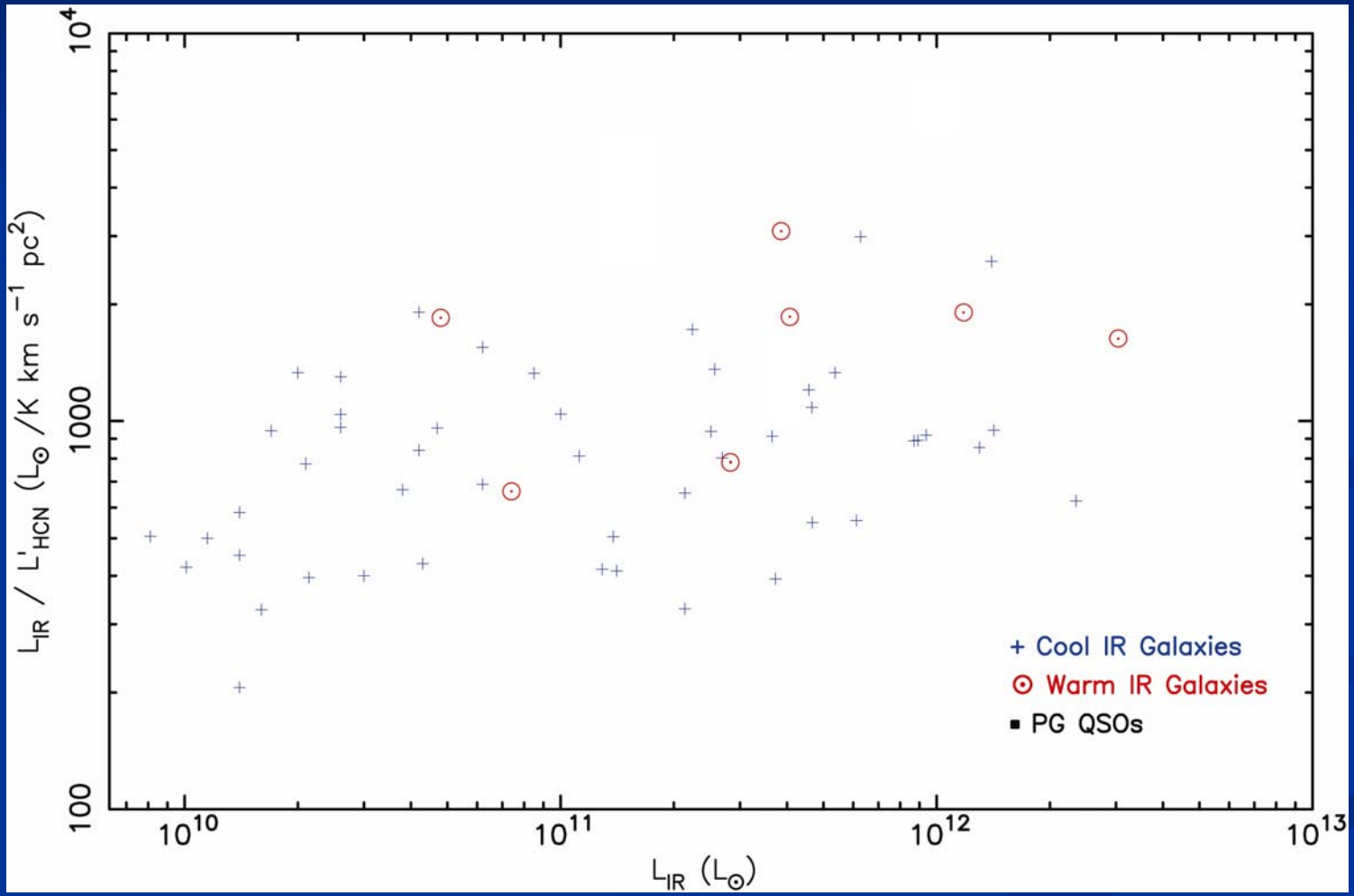
- L'_{CO} (radio galaxies) = 3 – 50x10^8 K km s^{-1} pc^2
- L'_{CO} (PG QSOs) = 2 – 90x10^8 K km s^{-1} pc^2

"Star Formation Efficiency"



- L_{IR} / L'_{CO} (radio galaxies) = 6 – 300
- L_{IR} / L'_{CO} (PG QSOs) = 200 - 1000

The L_{IR} – L'_{HCN} Relation



(Gao & Solomon 2003)

High-Density Gas (HCN) – Further Evidence of AGN Dust-Heating in QSOs?