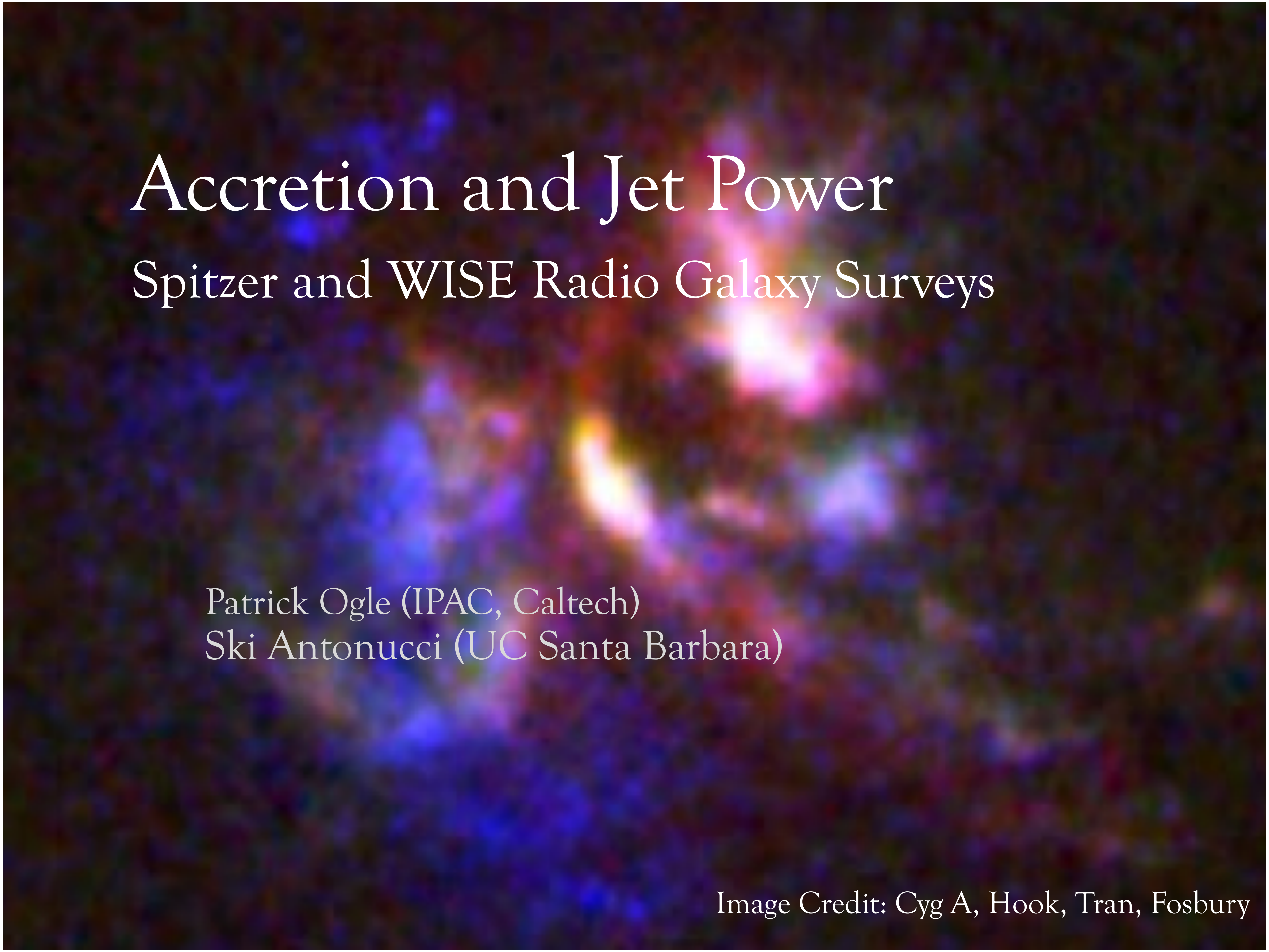


Accretion and Jet Power

Spitzer and WISE Radio Galaxy Surveys

Patrick Ogle (IPAC, Caltech)
Ski Antonucci (UC Santa Barbara)

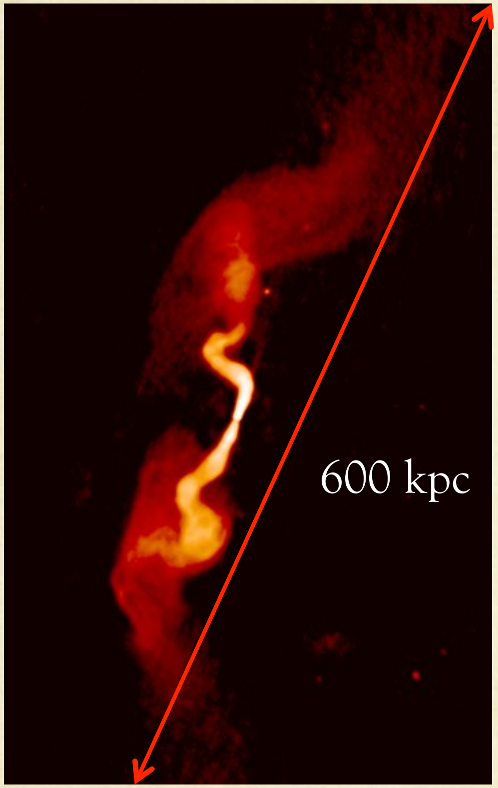
Image Credit: Cyg A, Hook, Tran, Fosbury

Accretion and Radio Galaxy/ Quasar Unification

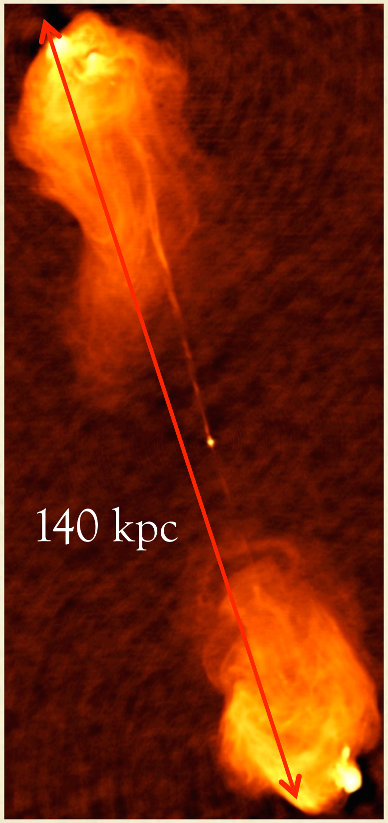
- Radio galaxies accrete in two modes:
  - Thermal = strong UV emission from accretion disk
    - High ionization lines (HIG)
    - Broad emission lines (BLRG, QSR)
  - Nonthermal = weak UV emission, weak accretion
    - Low ionization lines (LIG)

- HIG/Quasar Unification—Antonucci 84, Barthel 89
  - Quasars and HIGs at $z>0.4$ unified by orientation
  - Both are powered by optically-thick accretion onto BH

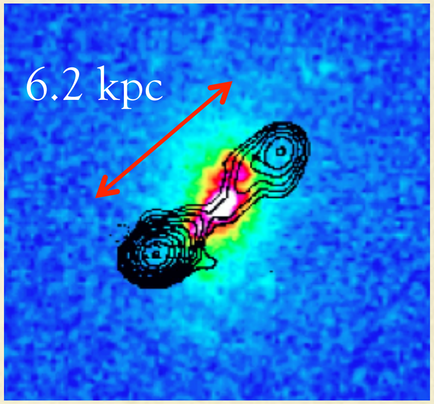
Radio Power, Morphology, Environment



FR I 3C 31, cluster



FR II Cyg A, cluster

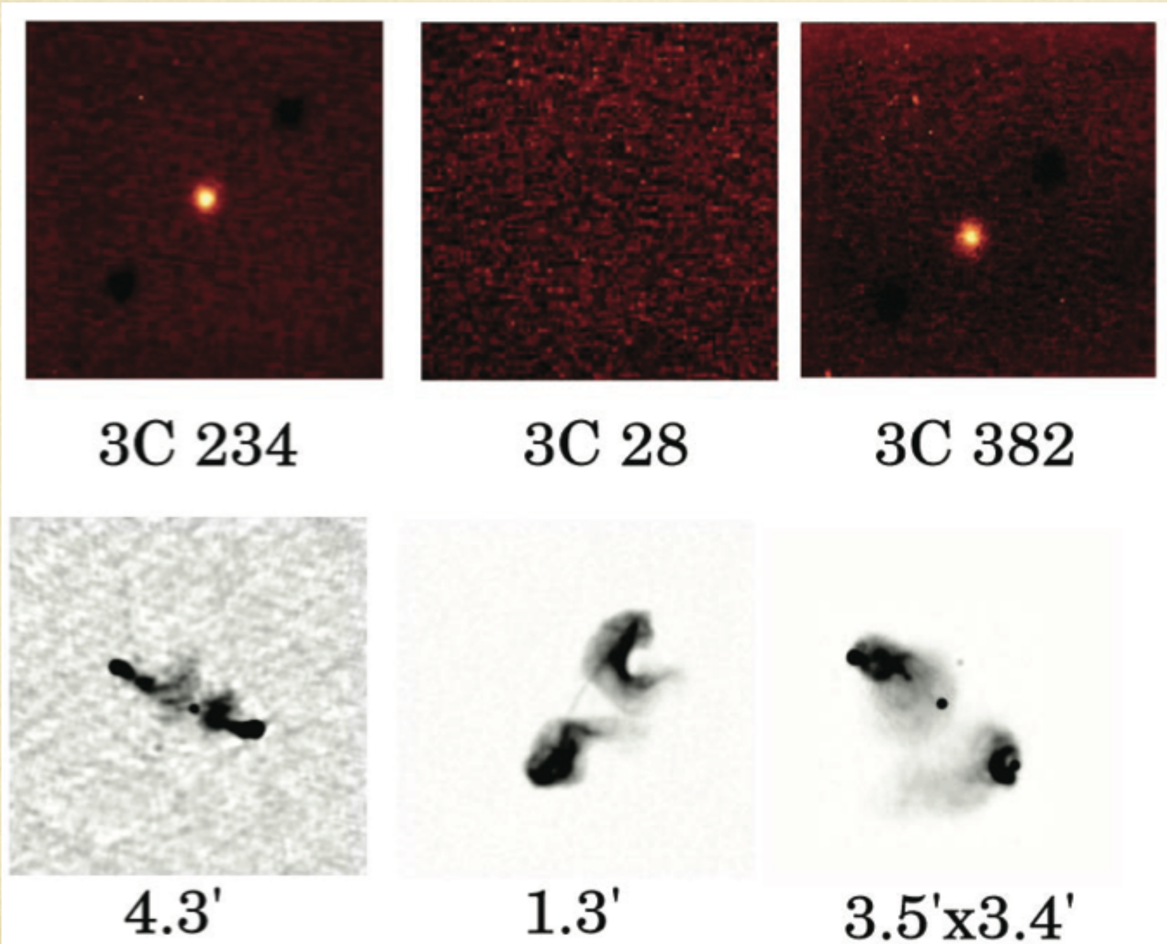


CSS 3C 303.1, host galaxy

Increasing 178 MHz Power

Image credits: NRAO; DeVries 97

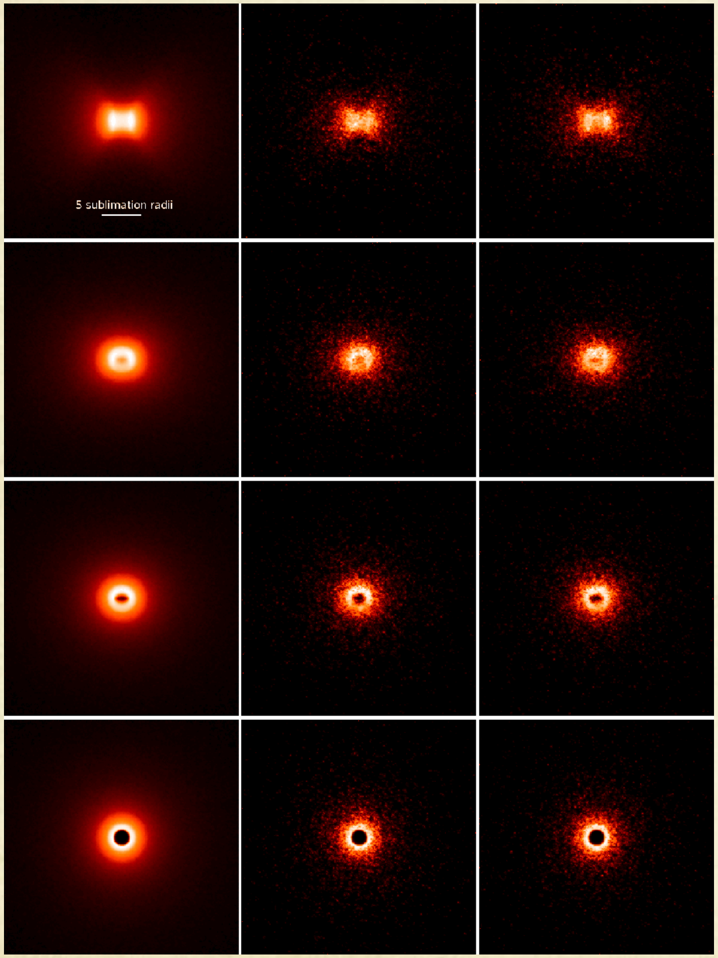
The Dust Torus as IR Calorimeter



Some FRII RGs have bright thermal MIR emission, but others do not...

Keck LWS 11.7 μ m images from Whysong 05 Thesis, Antonucci 11 arxiV:1101.837

Dusty Torus Models



•Thermal dust emission at 12-24 μm is more-or less isotropic (factor 2-10).

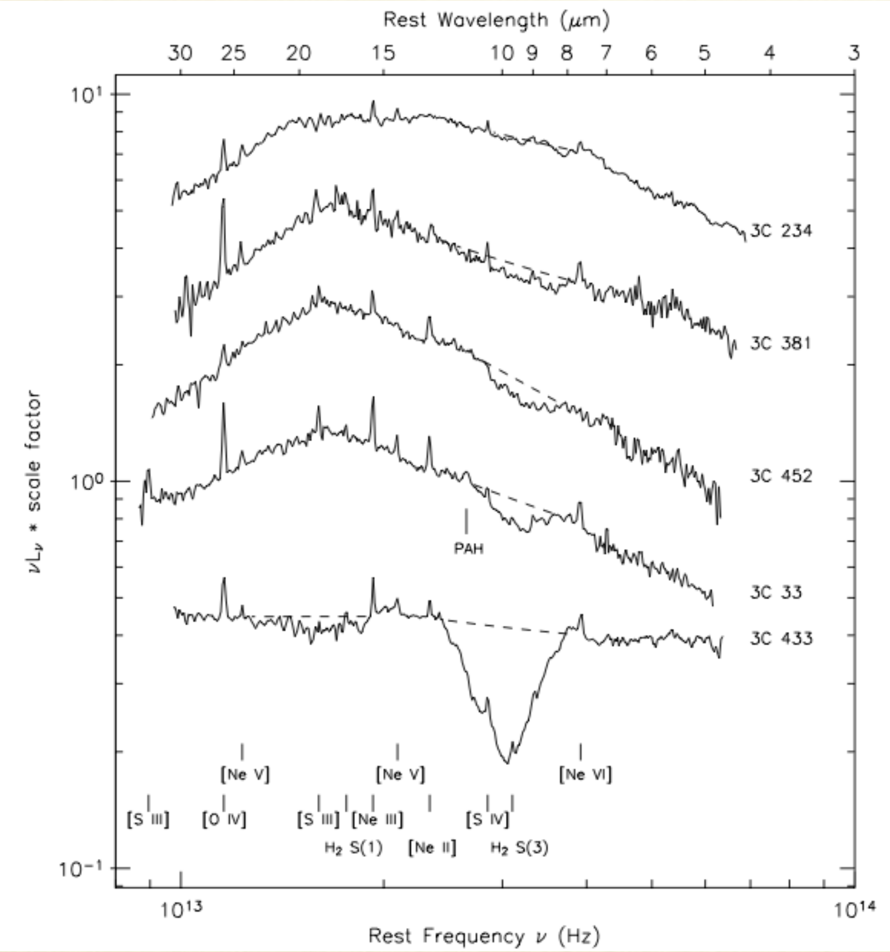
→ Orientation-insensitive measure of quasar accretion luminosity

•Clumpy torus models give large range of dust temperatures, in a compact configuration.

•Dust emission concentrated near the sublimation radius

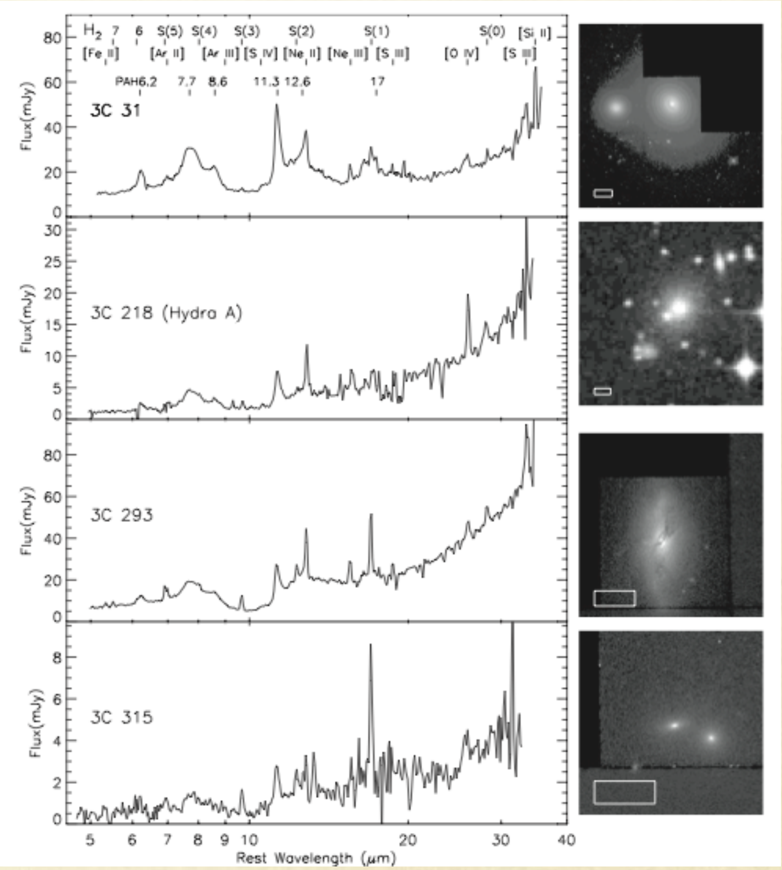
Honig 06—Clumpy Torus Monte Carlo Simulations

Spitzer IRS Spectra



z<1 3CRR type 2 QSRs (Ogle 06)

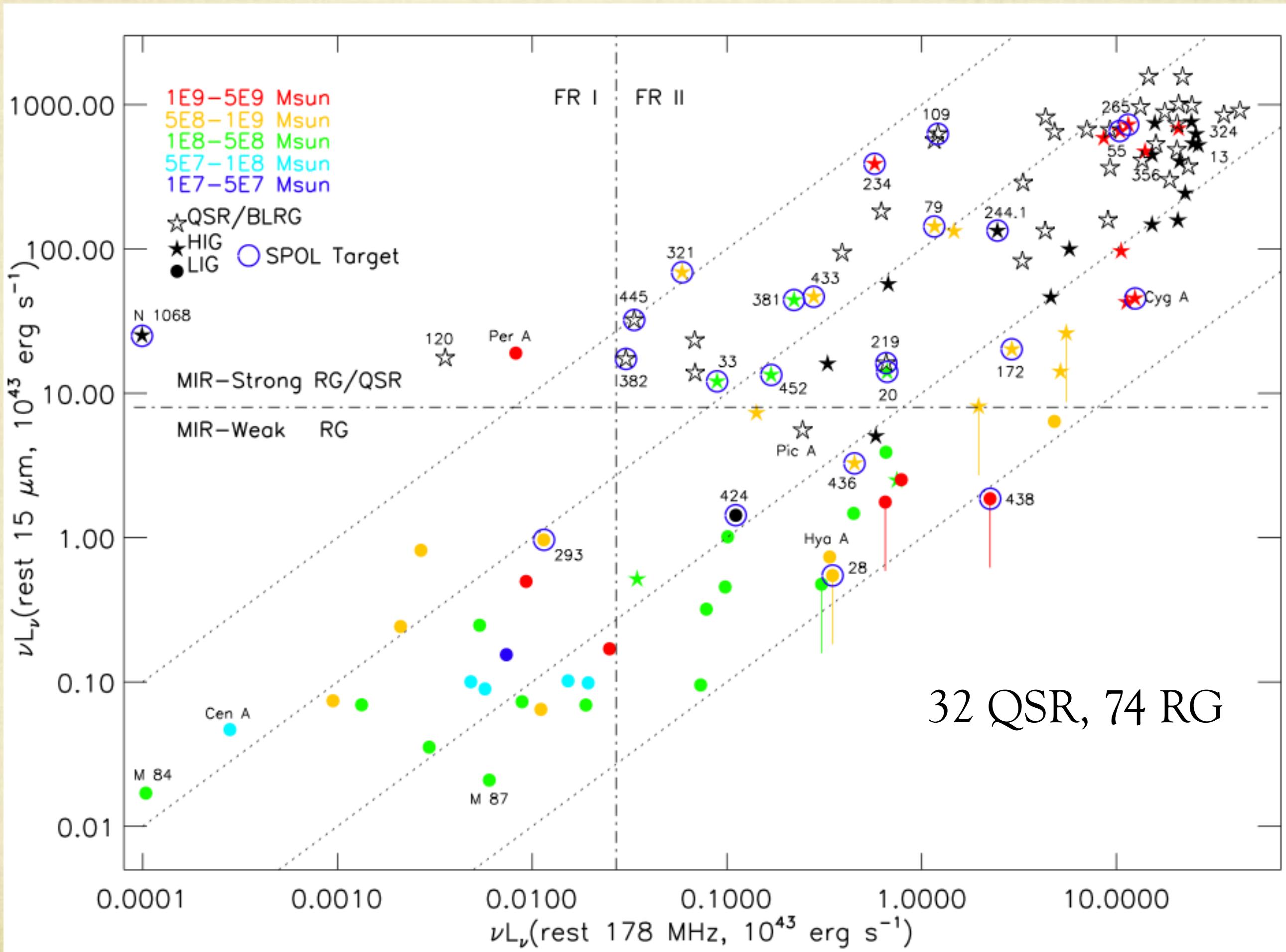
18 μm peak from 200 K dust.



MIR-weak LIGs:

PAHs, Jet-shocked H_2. (Ogle 10)

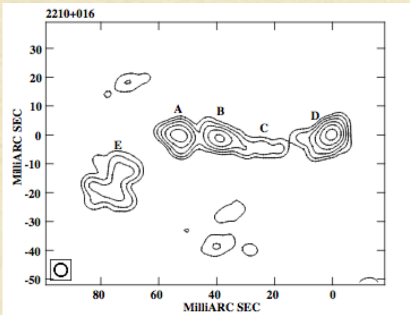
Spitzer IR vs. Radio Luminosity (z<1 3C)



8×10^{43} erg/s

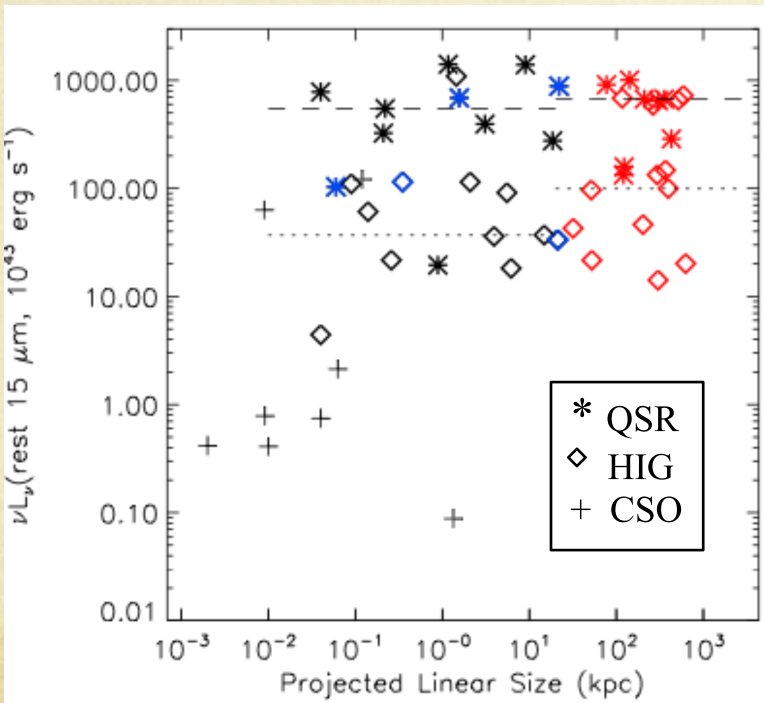
Spitzer IRS z<1 3C: Ogle 06; Leipski 09; +archival data

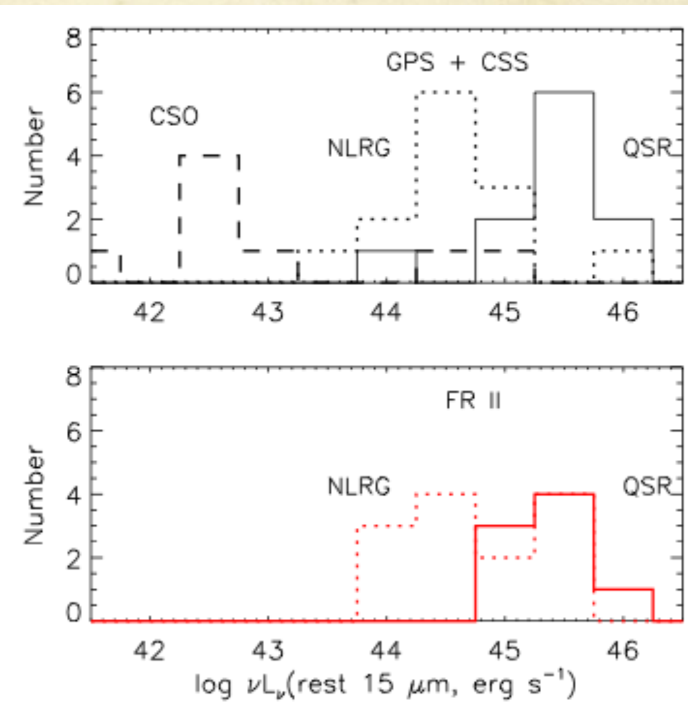
Compact, Young Radio Sources



Small (10^{-3} -10 kpc), Young (10^3-10^6 yr) radio sources:

GPS = Gigahertz-Peaked Spectrum
CSS = Compact Steep Spectrum (3C)
CSO = Compact Symmetric Object





Spitzer, z=0.4-1 GPS, CSS, and FR IIs: Ogle 11; z<0.3 CSOs: Willett 10

Eddington Luminosity Ratio

- Lbol from L(15 μm)
  - Torus covering fraction $<f_c>= 0.55$ (Ogle 06)
  - Mid-IR anisotropy factor $<f_a>= 1.9$ at 15 μm
  - Bolometric correction $L_{IR} = 1.7\ \nu L_\nu$ (15μm)

- M_{BH} from K-band luminosity of host galaxy:

  $\log M_{BH} = 8.21 + 1.13(\log L_{K,\odot} - 10.9)$ (Marconi 03)

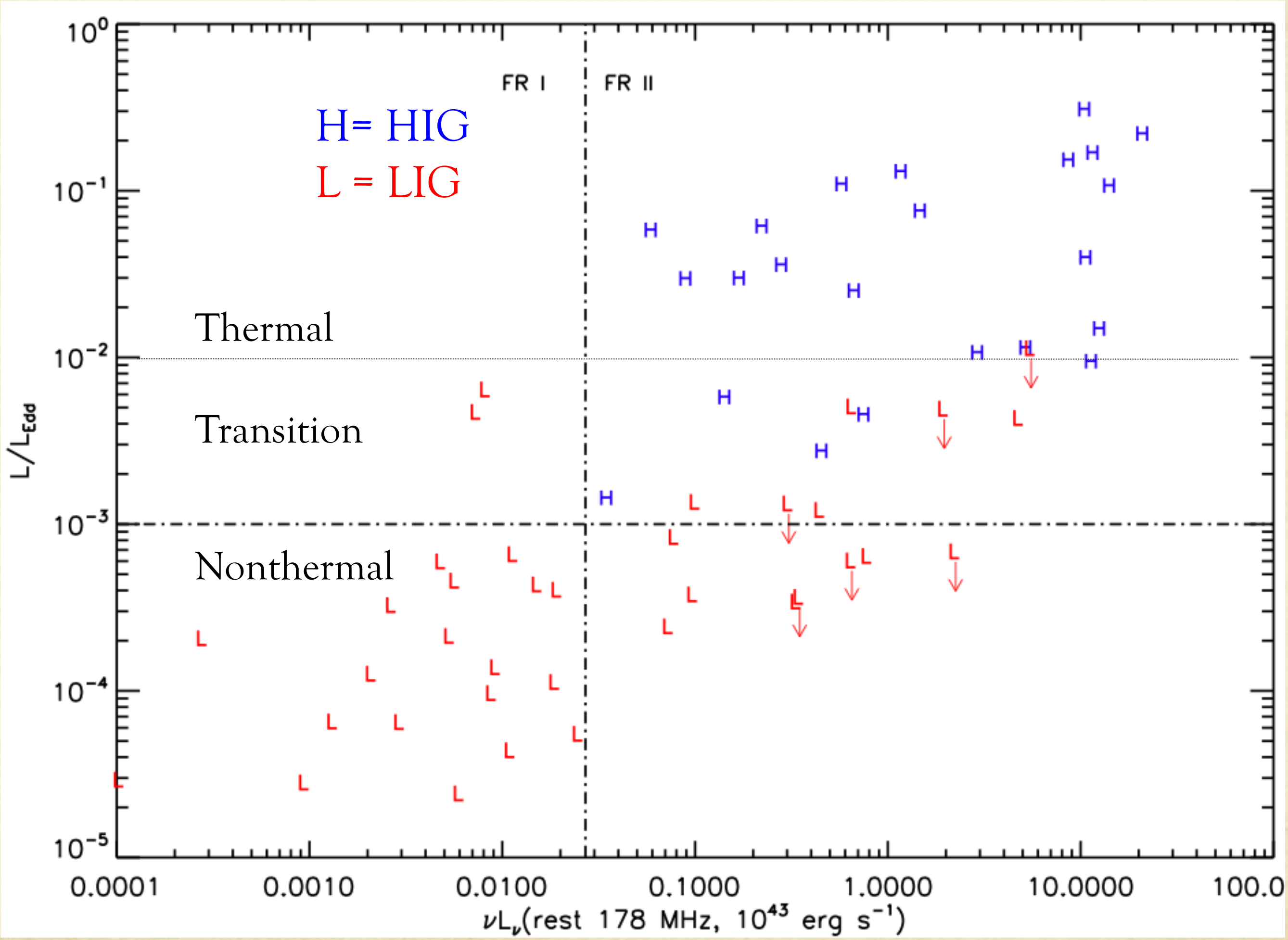
  [Must exclude quasars, where host is overwhelmed by AGN.]

- $L_{bol}/L_{edd} = L_{IR}\ (<f_a>/<f_c>)/(4\pi G c m_p M_{BH}/\sigma_T) = (\dot{M}/\dot{M}_{edd})\ (\eta\ /\ \eta_{edd})$

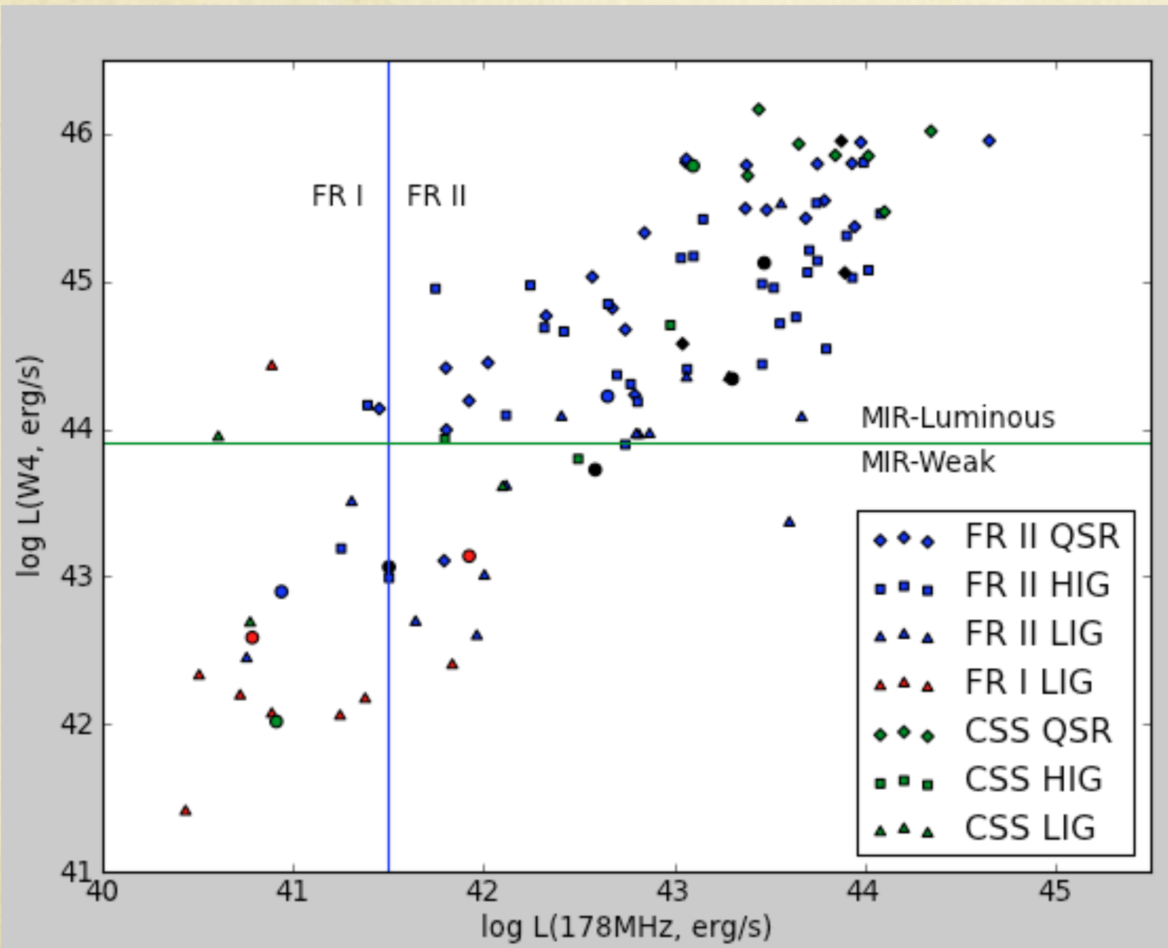
  $L_{edd} \sim (10^{46}\ \mathrm{erg\ s^{-1}})\ M_{BH,8}$ $\dot{M}_{edd} \sim 1\ M_\odot\ \mathrm{yr}^{-1}$, $\eta_{edd}=0.1$

- Radiative Efficiency $\eta = L_{bol}/\dot{M}c^2$ drops by a large factor at $\dot{M}/\dot{M}_{edd} <\cong 10^{-2}$. Accretion flow becomes optically thin and hot (SS disk, $\alpha=1$).

L/Ledd vs. Radio Power (z<1 3C)



WISE (22μm)Photometry of z<1 3C Radio Galaxies and Quasars



WISE band 4 Detections by…

Radio Morphology:

127/269	total 3C	(0.47)
83/147	FRII	(0.56)
17/34	CSS	(0.50)
17/33	FRI	(0.52)
10/55	unk.	(0.18)

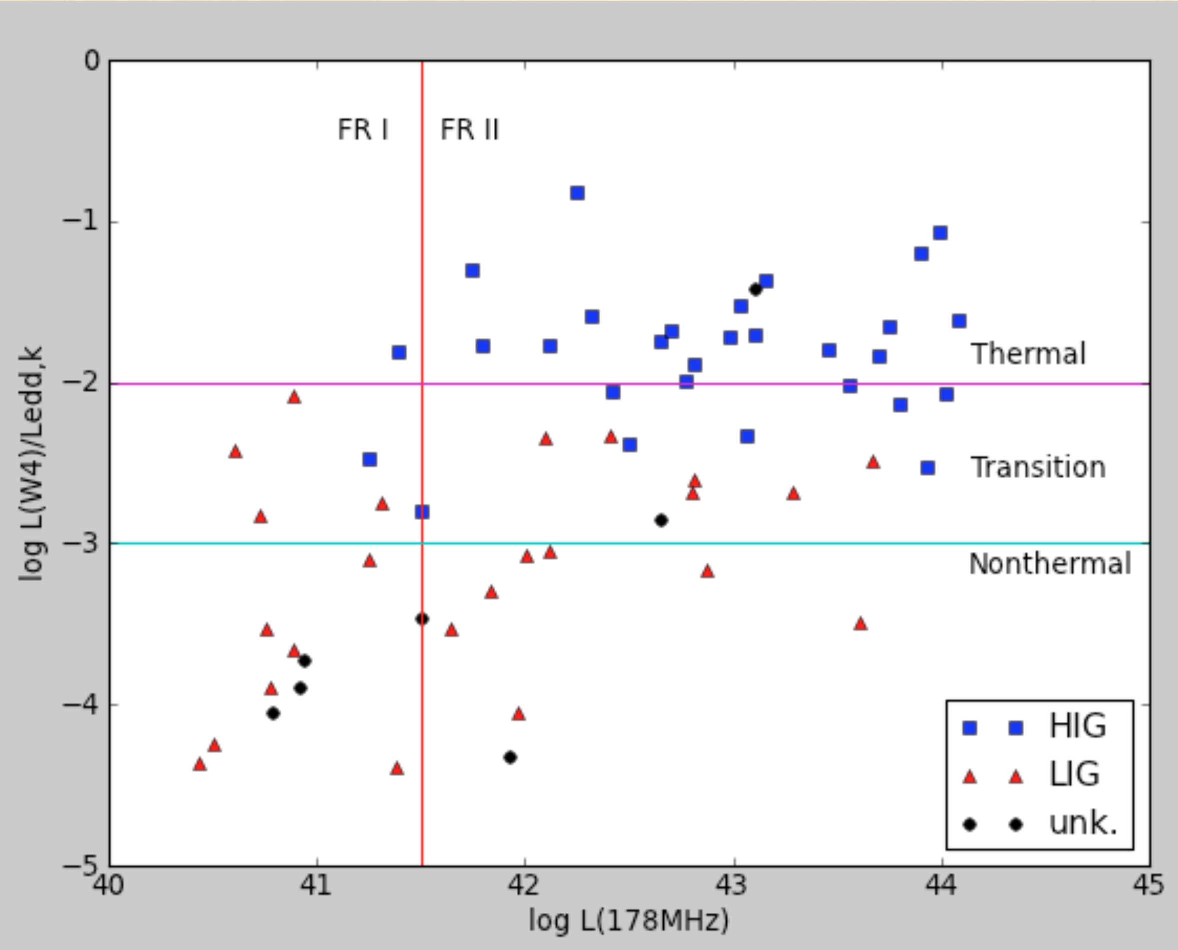
Optical Type:

35/74	type1 QSR	(0.47)
39/88	type2 QSR	(0.44)
27/56	LIG	(0.48)
26/50	unk.	(0.50)

QSR torus covering frac:

<fc> = 39/(35+39)=0.53 (.09)

WISE L/Ledd vs. Radio Power



32 FRII type 2 QSR
15 FRII LIG
2 FRII unk.

0 FRI type 2 QSR
8 FRI LIG
3 FRI unk.

3 CSS type 2 QSR
3 CSS LIG
2 CSS unk.

Avail. K-band photometry limits sample size!

Summary of Results

- RL-AGN M_{BH} accretion occurs in 2 modes:
  - Thermal: 0.3>L/Ledd>$10^{-2.5}$ Quasars (HIGs)
  - Nonthermal: $10^{-2.5}$> L/Edd>10^{-5} LIGs
- Possible transition from filled to empty inner accretion disk at L/Ledd =10^{-2} to 10^{-3}
- Radio/IR Power ratio varies by factor 10^3
  - Jet power must depend on a 2nd parameter, e.g. BH spin
- Mean torus covering fraction $\langle f_c \rangle = 0.53 \pm 0.09$
- Larger WISE/radio samples→ better statistics and AGN evolution studies.