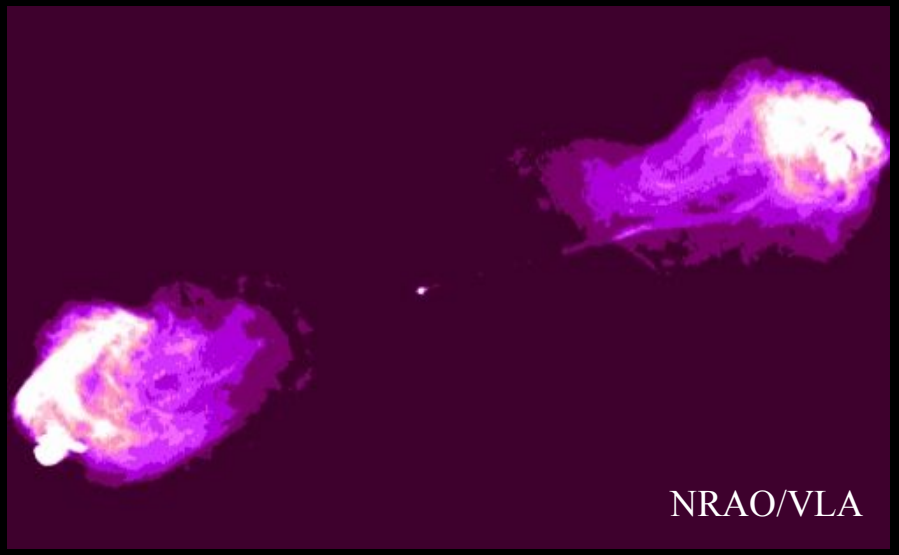
Mid-IR Spectroscopy of Radio Galaxies and Quasars

Patrick Ogle (SSC/Caltech)

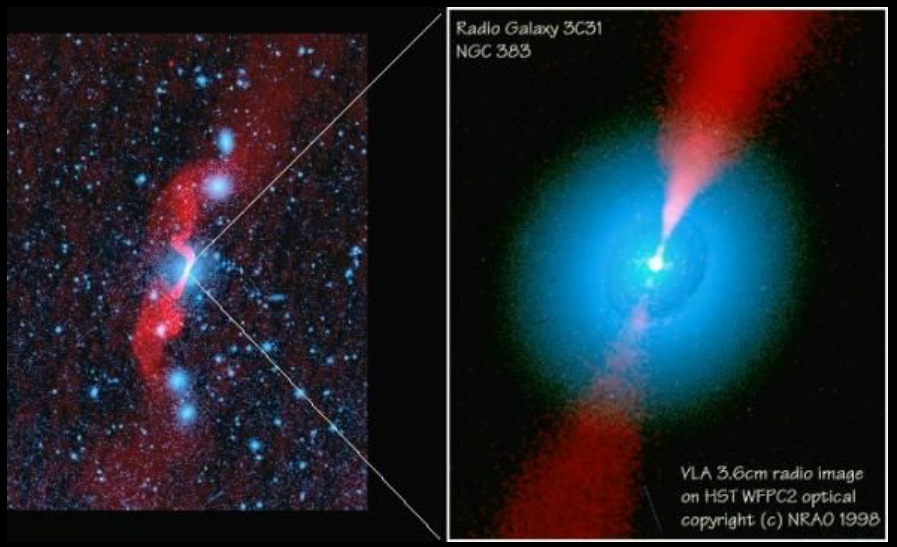
D. Whysong (NRAO), R. Antonucci (UCSB)

3CR Radio Galaxies and Quasars



FR II radio galaxy Cygnus A (3C 405)

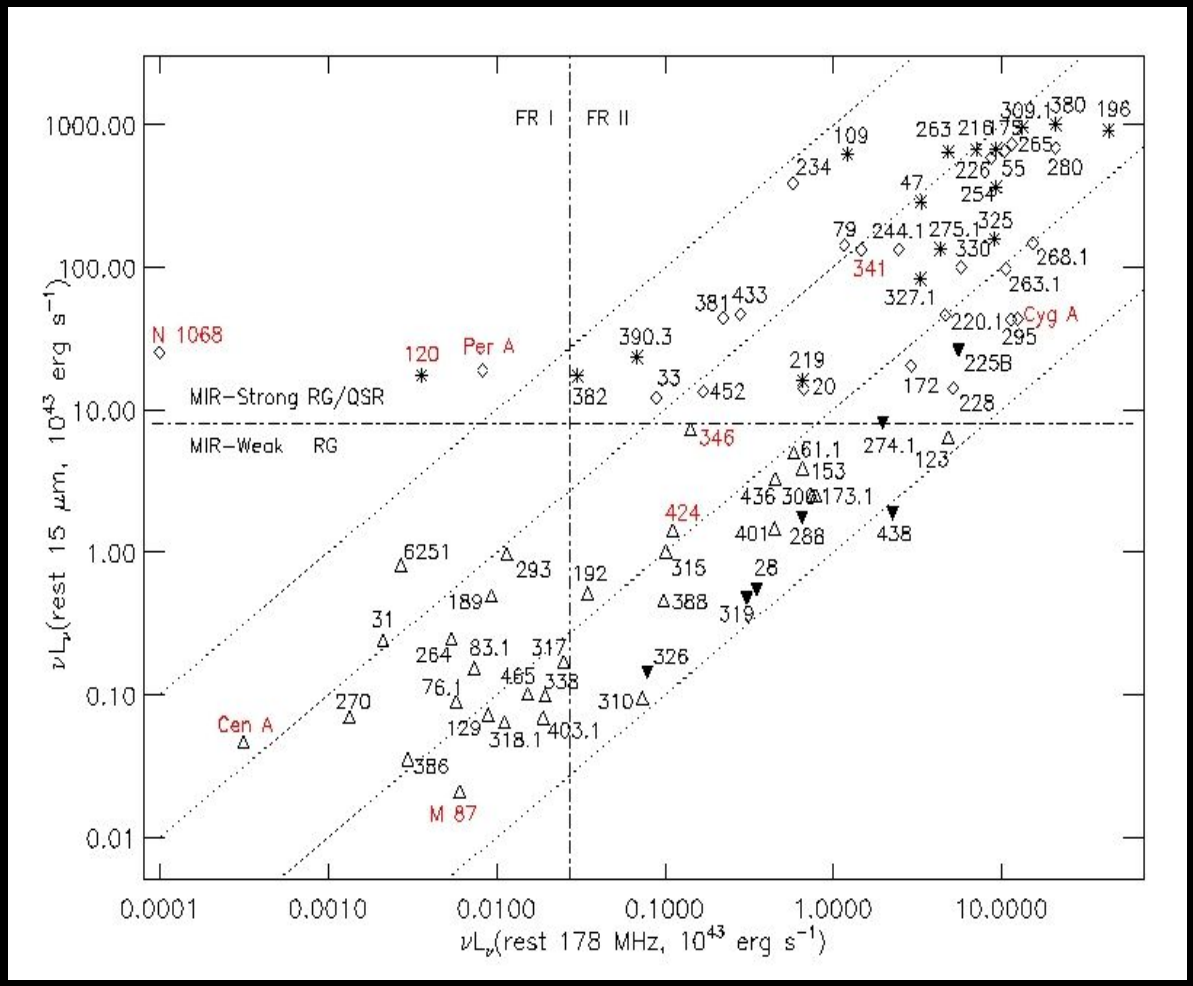
- L(radio) ~10^44 erg/s
- Hidden BLR, UV continuum
- High-ionization lines



FR I radio galaxy 3C 31

- L(radio) ~10^40 erg/s
- No BLR, weak UV continuum
- Low-ionization lines

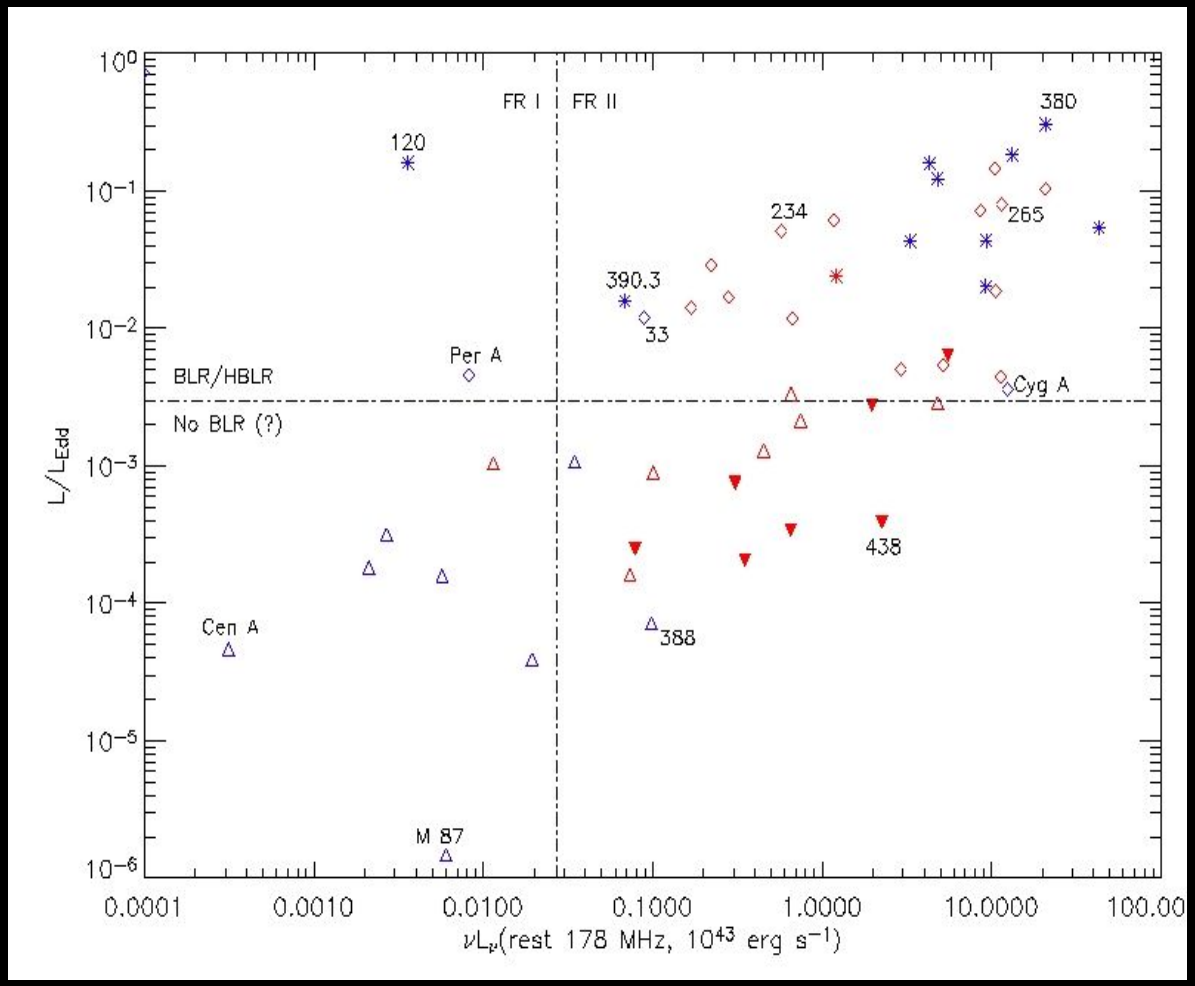
3C Radio Galaxy and Quasar Luminosities (z<1)



Ogle et al. 2006

- 20/38 FR II radio galaxies and 15/15 quasars have L(MIR)>10^44 erg/s
- 18/38 FR II radio galaxies and 16/18 FR I radio galaxies have L(MIR) <10^44 erg/s.
- L(MIR)/L(Radio) ~1-10^4

Eddington Luminosity

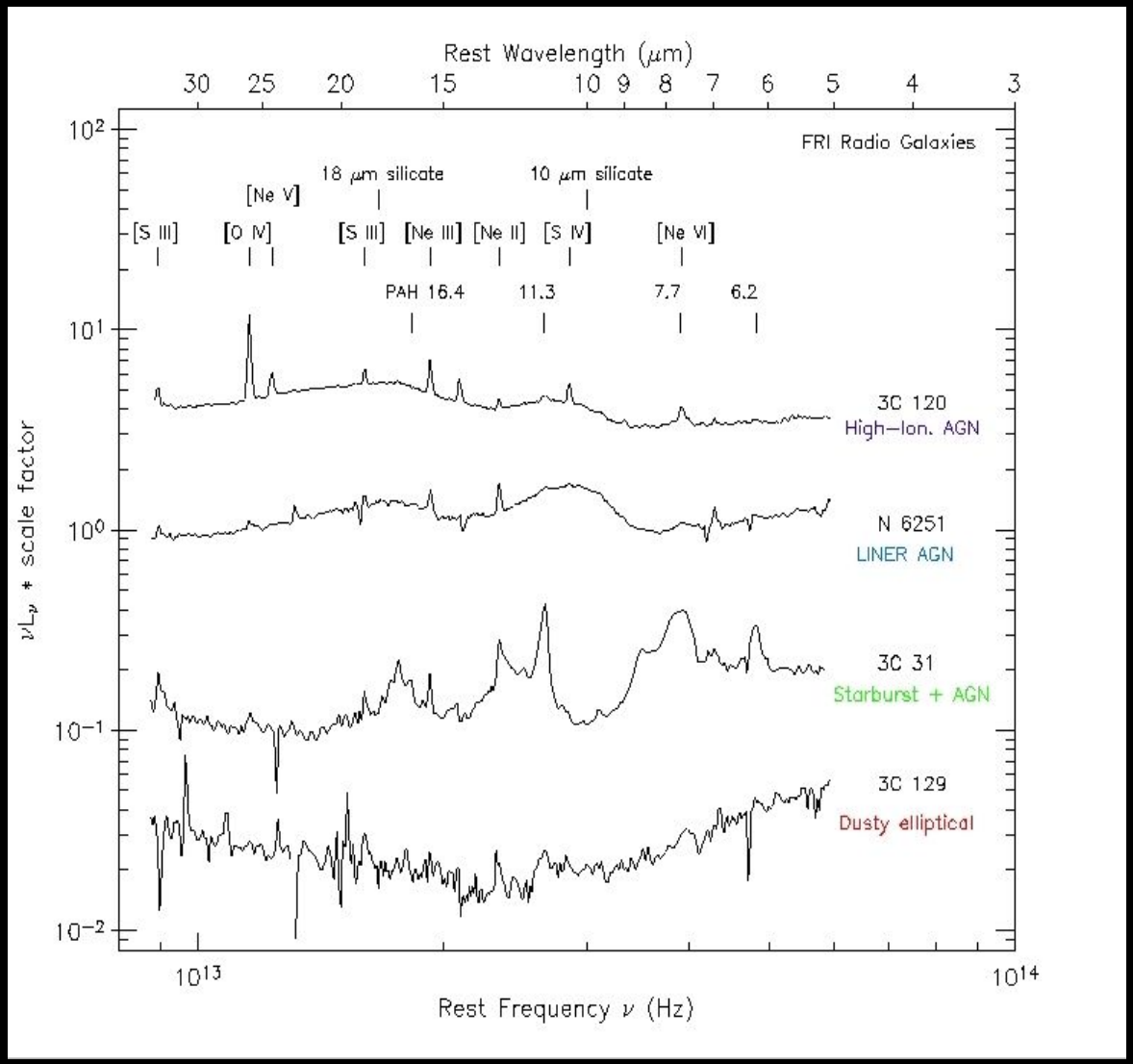


Ogle et al. 2006, ApJ, 647, in press

- Mbh estimated from σ or K band luminosity of bulge.
- L=1.7 L(15μ) / 0.6
- All sources with broad Balmer lines have L/Ledd > 3E-3
- Most FR Is and 50% of FR IIs have L/Ledd < 3E-3.

  Jets may be powered by radiatively inefficient accretion and/or black hole spin.

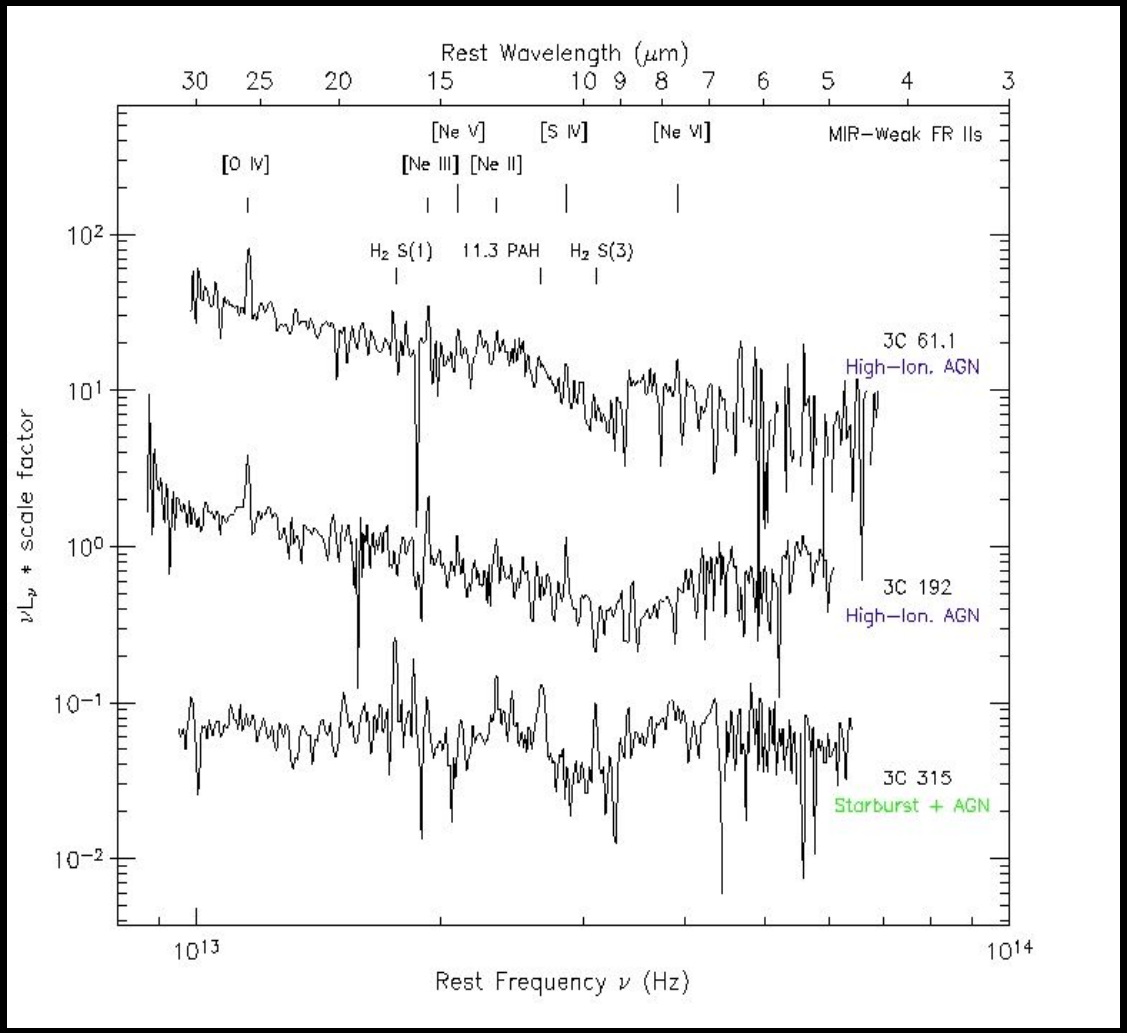
FR I Radio Galaxies



Spitzer IRS

- 30 3C galaxies, 480 sec Spitzer IRS exposures.
- Continuum: stellar + dust + synchrotron
- Silicate emission--AGN
- PAH emission--starburst
- Low or high-ionization lines

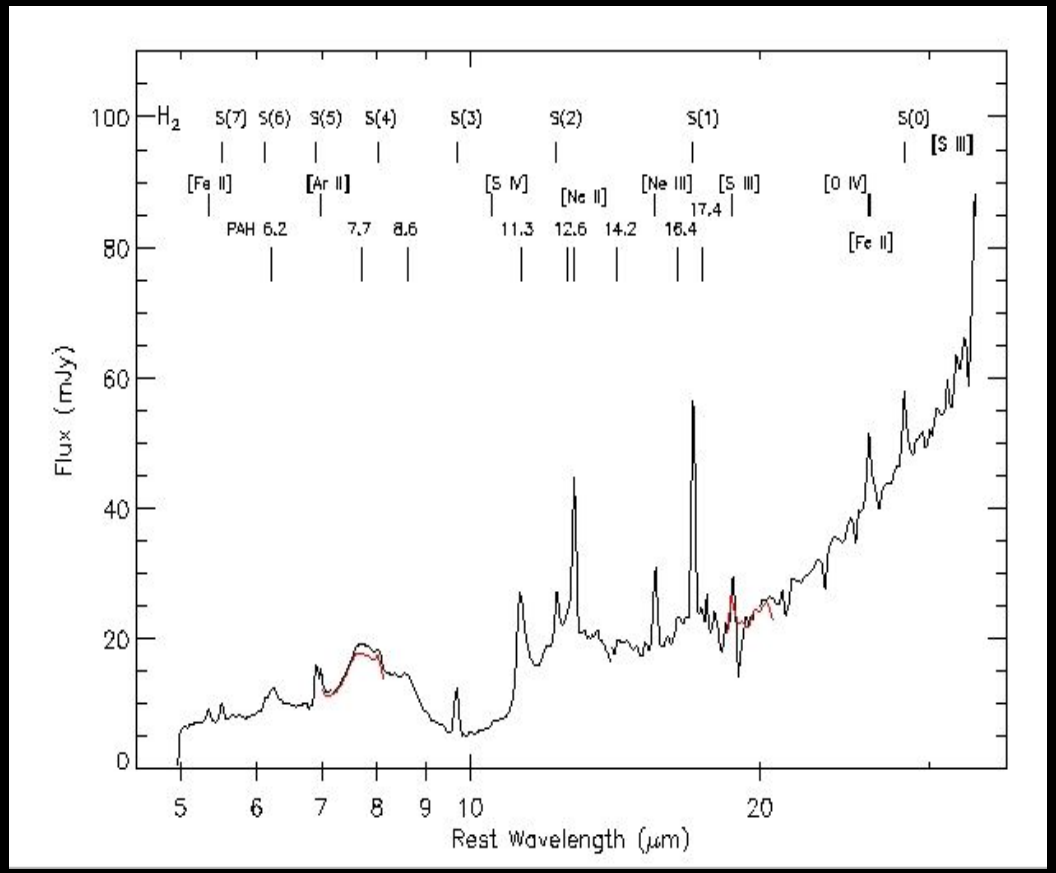
MIR-Weak FR II Radio Galaxies



Spitzer IRS

- Nonthermal or cool dust cont.
- 9.7 μm silicate absorption.
- Low or high-ionization lines
- Starburst activity is present in some sources.
- Properties and luminosities are intermediate between FR Is and powerful FR IIs.

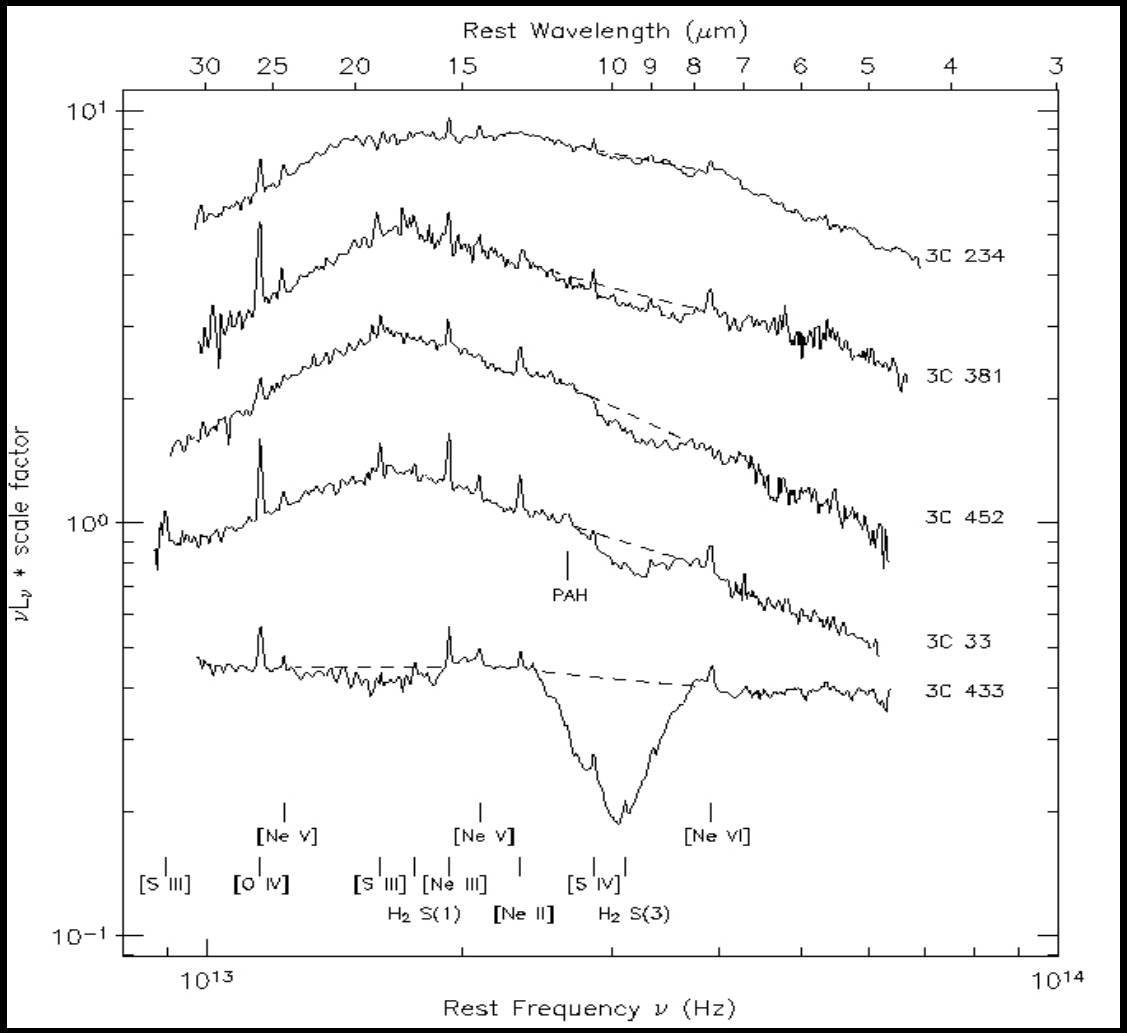
3C 293—Strong H2 Emitter



Spitzer IRS

- FR I, z=0.045
  L(178 MHz) =1.0E41 erg/s
- H2 Pure rotational lines:
  S(0)-S(7), L(H2)=5.6E41 erg/s
- Shocked molecular gas!
- Low ionization states of O, Ne, Ar, S, Fe
- LIRG-like dust continuum and PAHs, L(15u)=1E43 erg/s
- Silicate absn: 9.7 microns

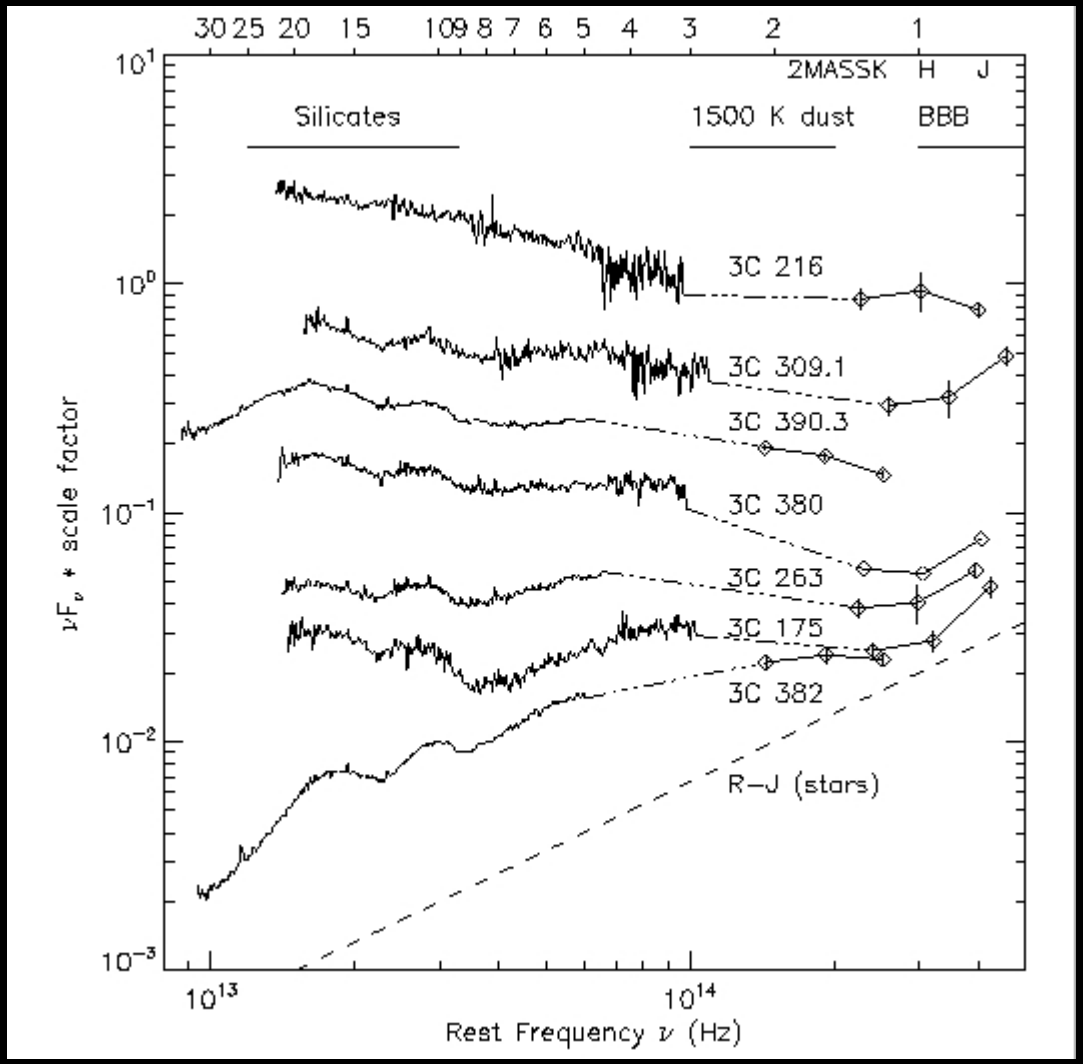
FR II Galaxies With Hidden Quasars



- Thermal emission from warm (220-670 K) dusty torus, heated by a hidden quasar.
- 9.7 μm silicate absorption.
- High ionization lines: [Ne V], [Ne VI], [S IV] powered by quasar UV cont.
- Weak PAH features—star formation is energetically insignificant.

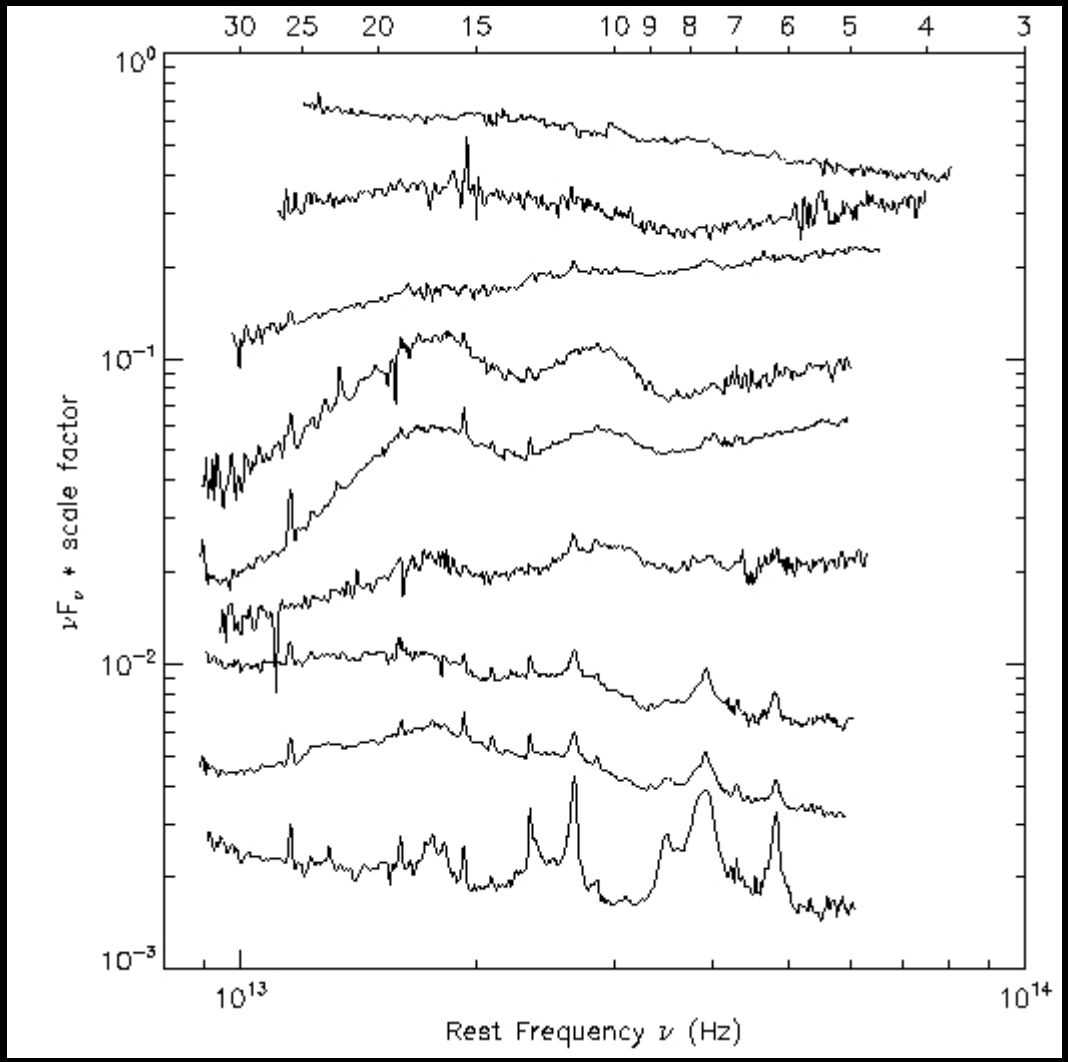
Ogle et al. 2006a, ApJ 647, 161

3CRR Quasars



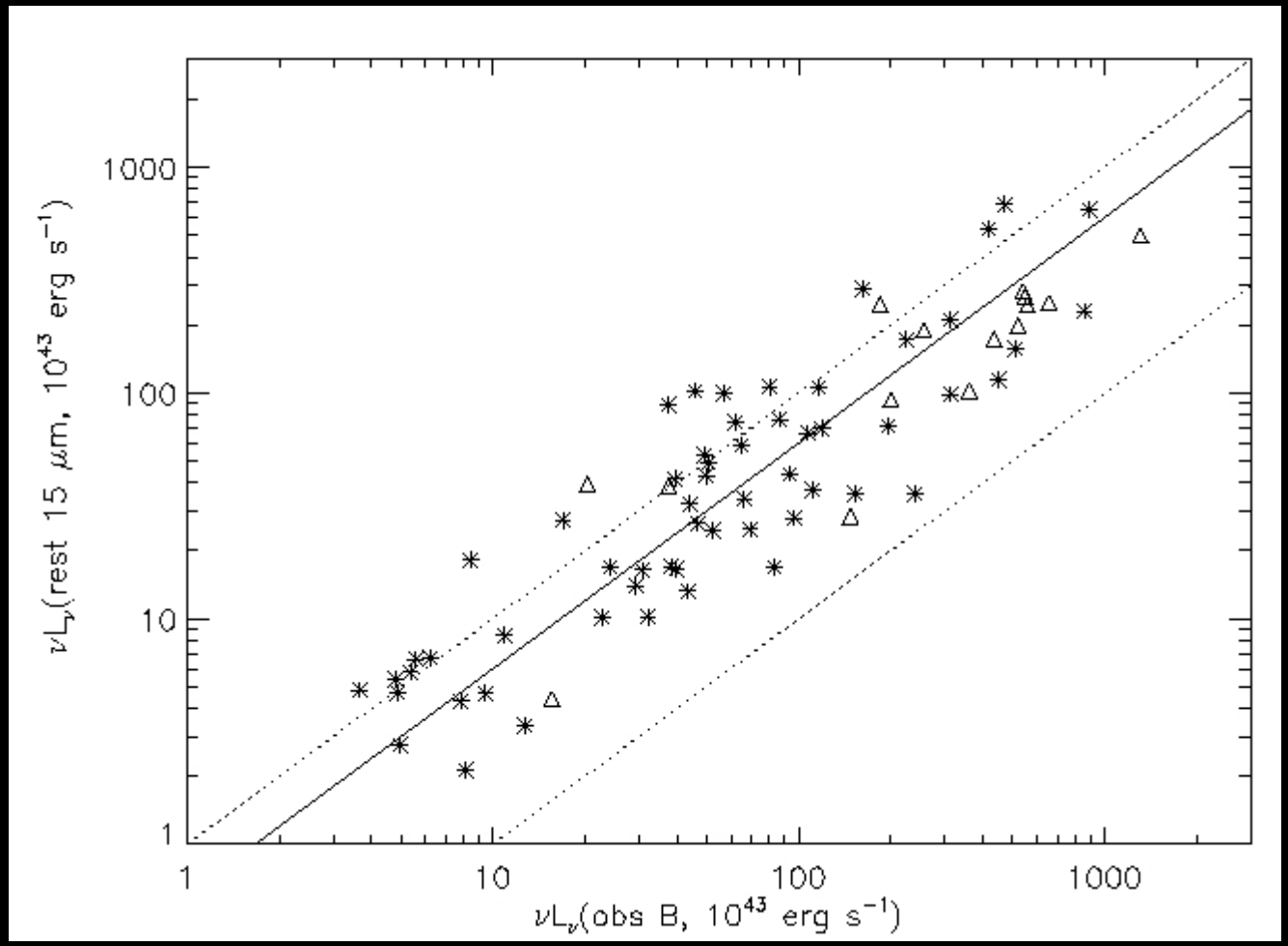
- Strong silicate emission bumps at 10, 18 microns. (Hao et al., Siebenmorgen et al. '05)
- Large range in 7-15 micron continuum slope (0.2-1.7)
- 3C 216 is dominated by beamed synchrotron emission.
- BLRG 3C 382 has a large stellar component.

PG Quasars (z<0.5)



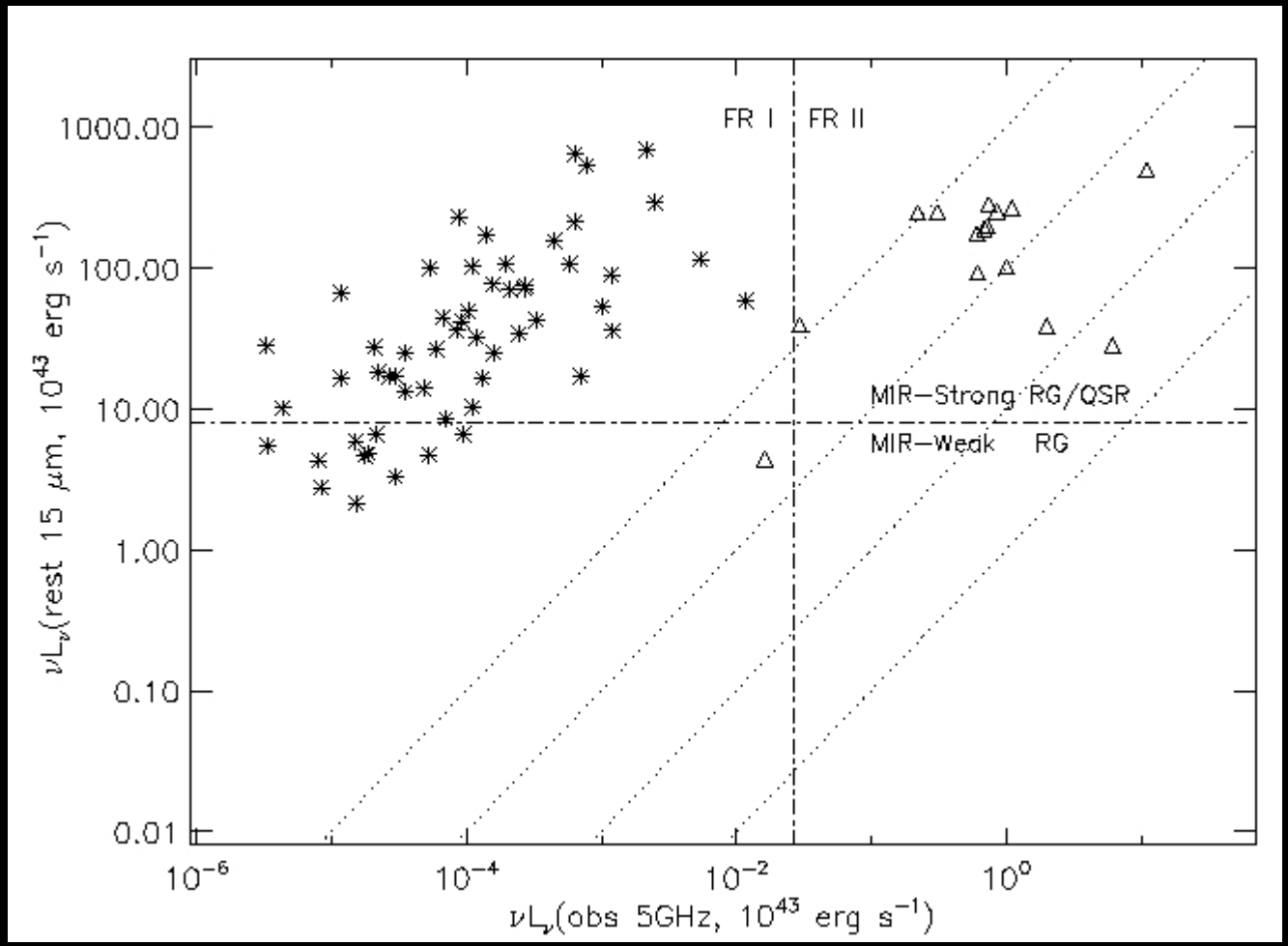
- Range in starburst/AGN fraction indicated by PAHs (e.g., Schweitzer et al. 2006)
- Large variation in silicate bump strength for AGN dominated sources.
- Quiz:
  a) Which of the quasars are radio loud?
  b) Which are NLS1's? (1,6,8)
  c) Which have the broadest H-beta? (4,9)

Mid-IR/Optical for PGs



L(15micron)/L(B) ~ 0.6

Radio Loud vs. Quiet PGs



Who says there's no dichotomy?

Conclusions

- Spitzer reveals two classes of radio galaxy:
  1) MIR-Luminous (>10^44 erg/s):
     hidden quasar with 10^4 K (UV-emitting) accretion disk.
  2) MIR-Weak (< 10^44 erg/s):
     radiatively inefficient accretion flow (?)
- MIR-Weak sources can have either FR I or FR II morphology.
- PG Quasars show a huge range in mid-IR color, silicate feature strength, and PAH EW—partly intrinsic, partly starburst 'contamination'.