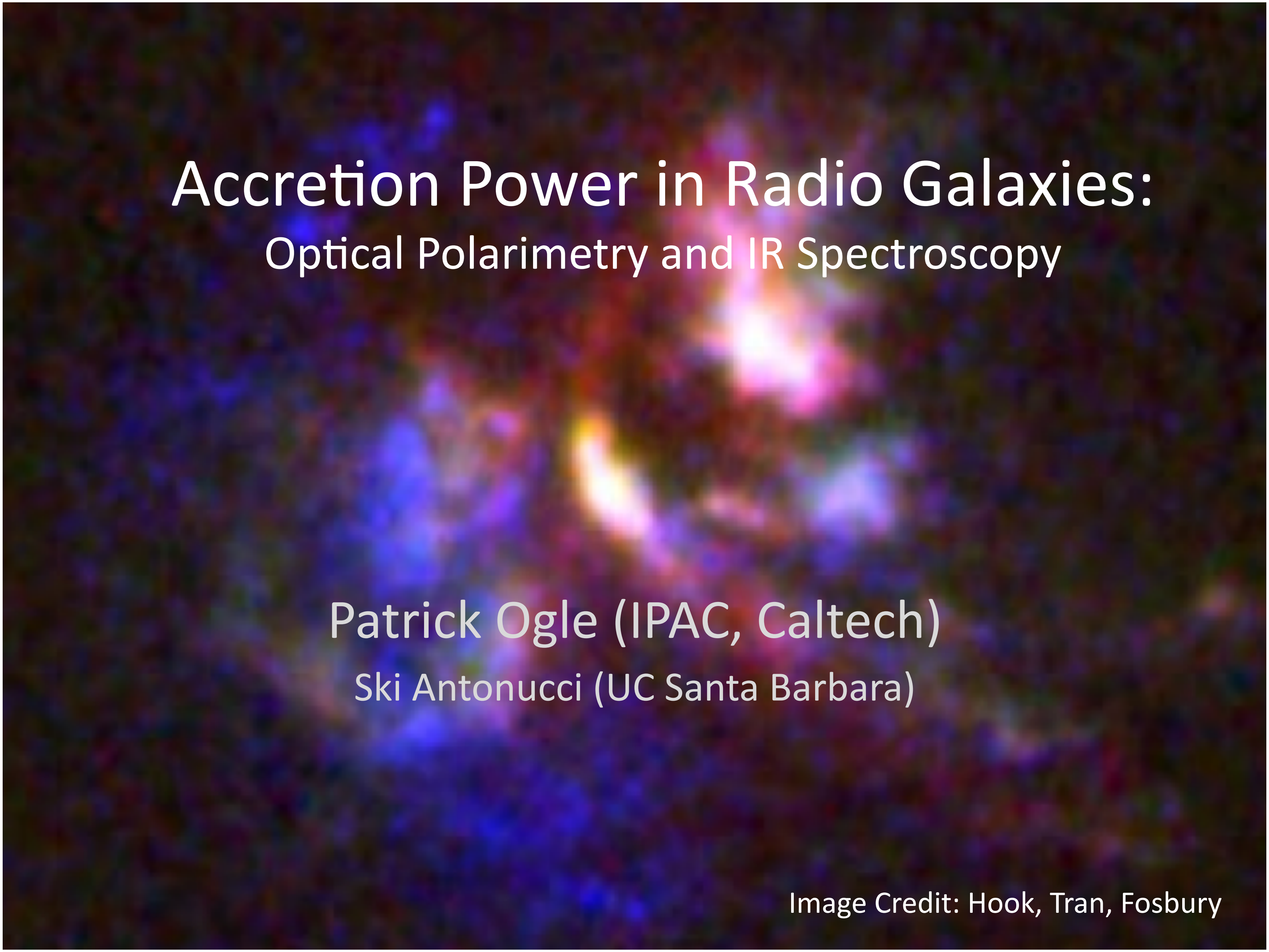


Accretion Power in Radio Galaxies:

Optical Polarimetry and IR Spectroscopy

Patrick Ogle (IPAC, Caltech)

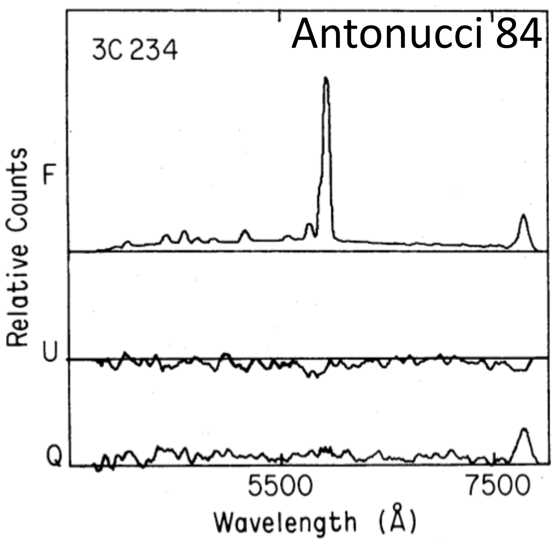
Ski Antonucci (UC Santa Barbara)

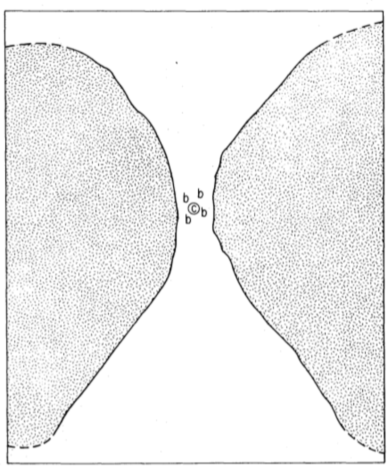
Image Credit: Hook, Tran, Fosbury

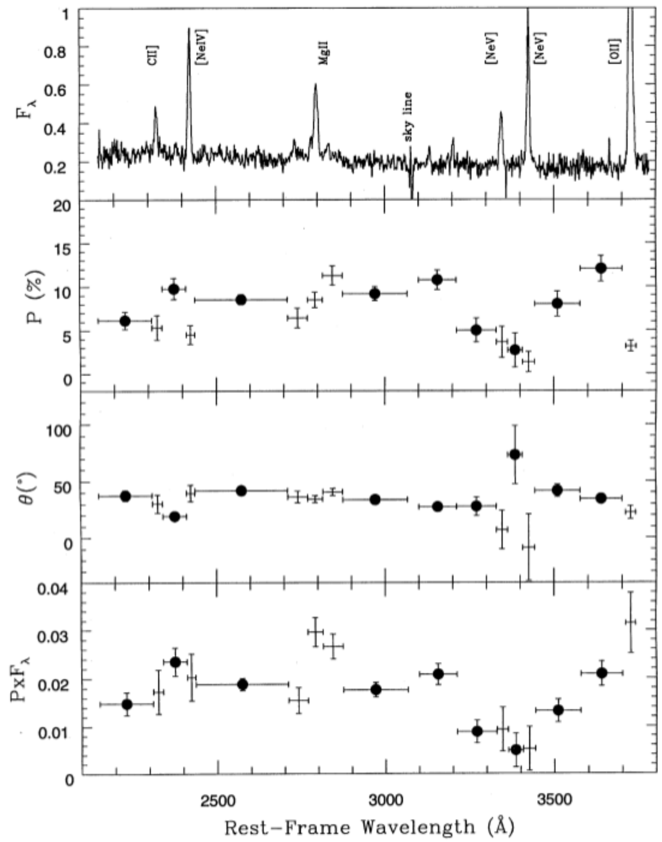
Radio Galaxy/Quasar Unification

- Radio galaxies come in 2 types:
  - Thermal = strong UV emission from accretion disk
    - High ionization lines (HIG==HEG)
    - Broad emission lines (BLRG, QSR, HBLR type 2 QSR)
  - Nonthermal = weak UV emission, weak accretion
    - Low ionization lines (LIG==LEG)
- Radio morphology (FR I, FRII)
  - Depends on radio power and environment
- FR II Unification—Antonucci 84, Barthel 89
  - Quasars and HIGs at $z>0.4$ unified by orientation
  - Both are powered by optically thick accretion onto BH

Spectropolarimetry





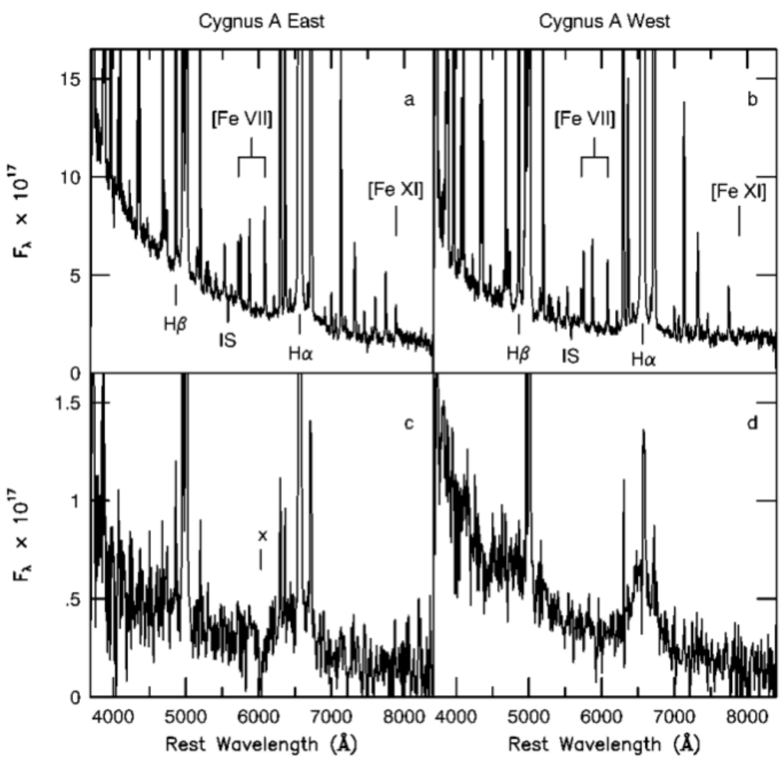


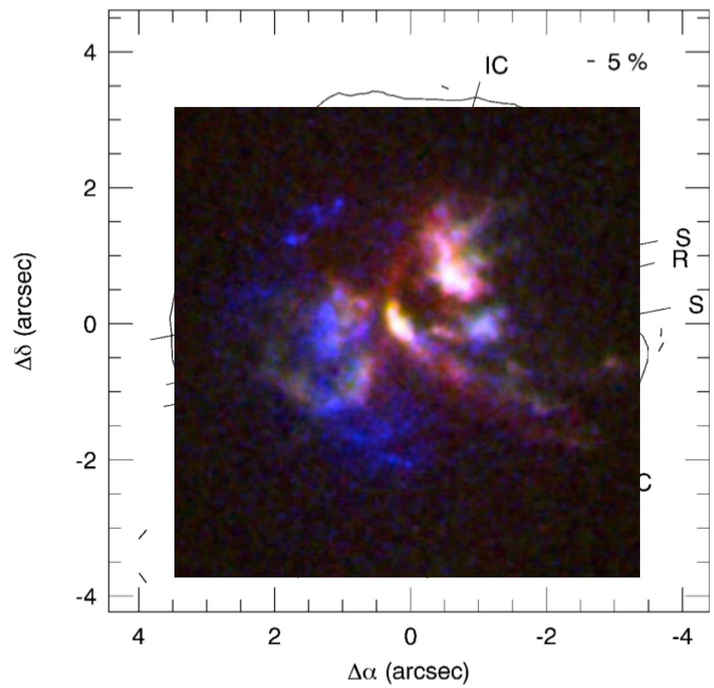
3C 265
z=0.8

Di Serego Alighieri, Cimatti, Fosbury, Perez-Fournon 96

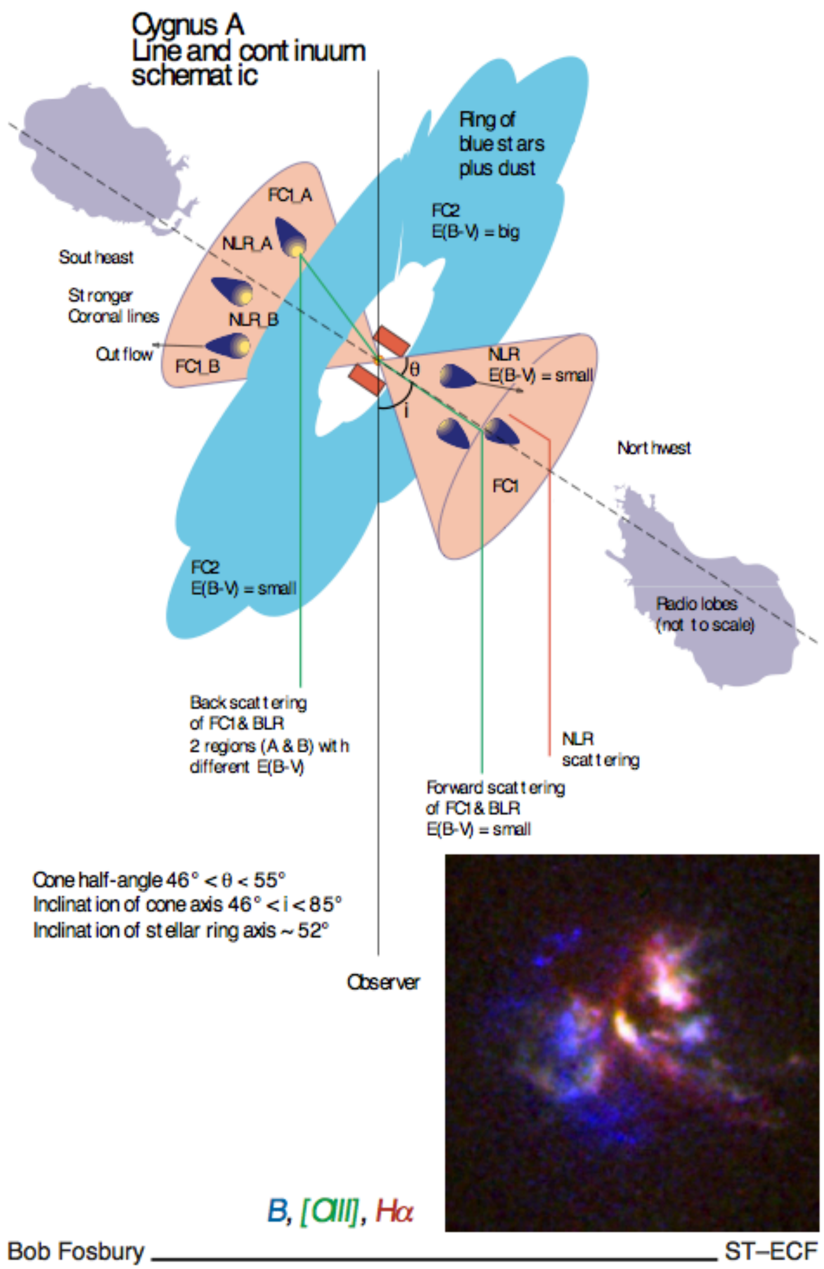
Later HZRG results: Vernet 01

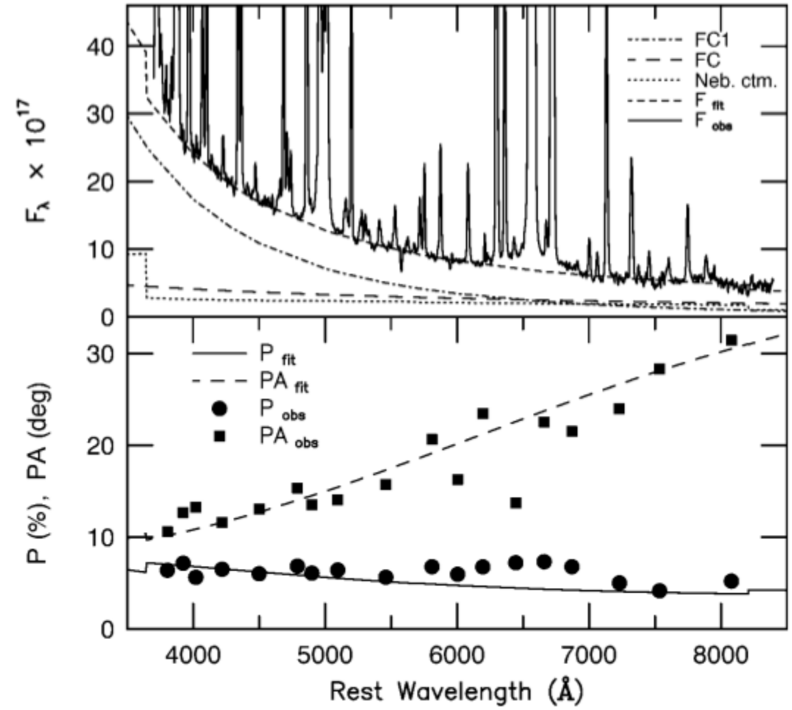
Polarimetry of Cyg A





Spectropolarimetry and Imaging Polarimetry (Keck LRIS, Ogle 97; Tadhunter 90)



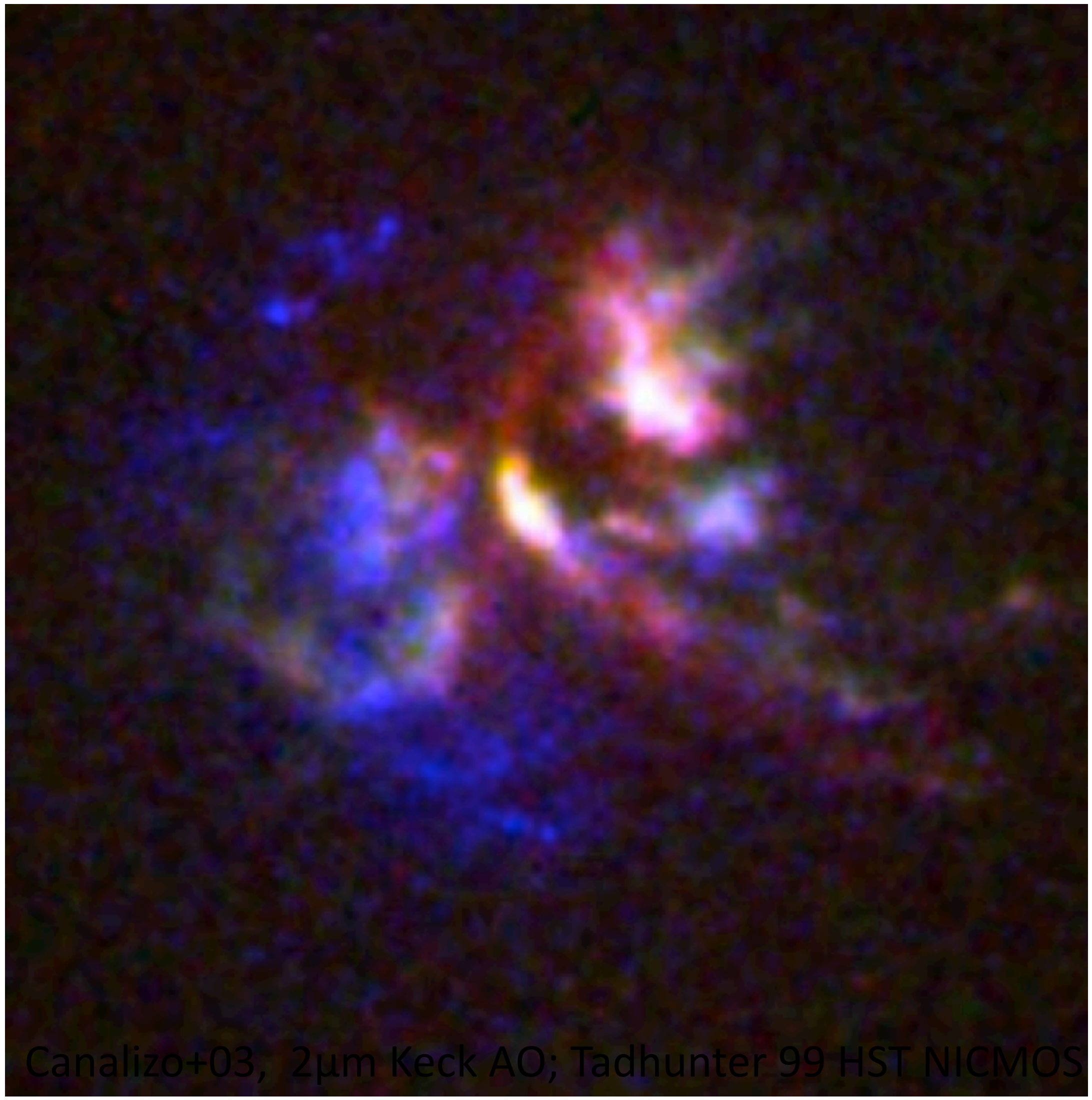


Cyga polarimetry (Ogle 97)

Slide from Fosbury 98 talk explains it all!

NLR and dust kinematics:
Van Bemmel,Vernet, Fosbury+03;
Tadhunter 94

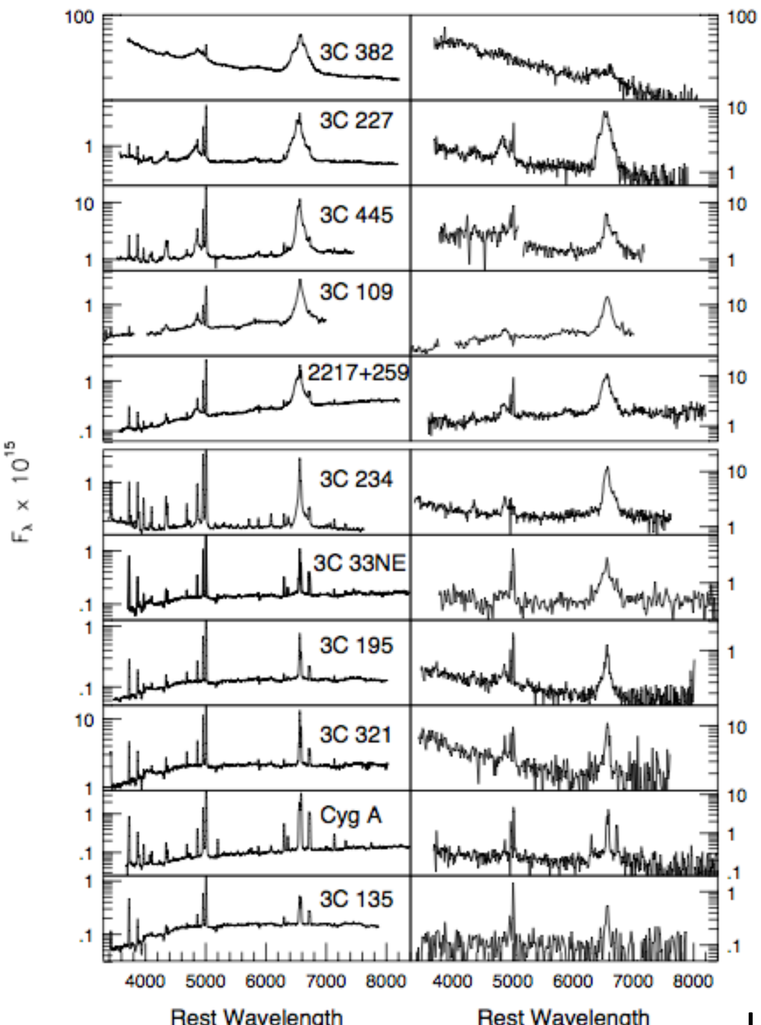
Ionization Cone in CygA

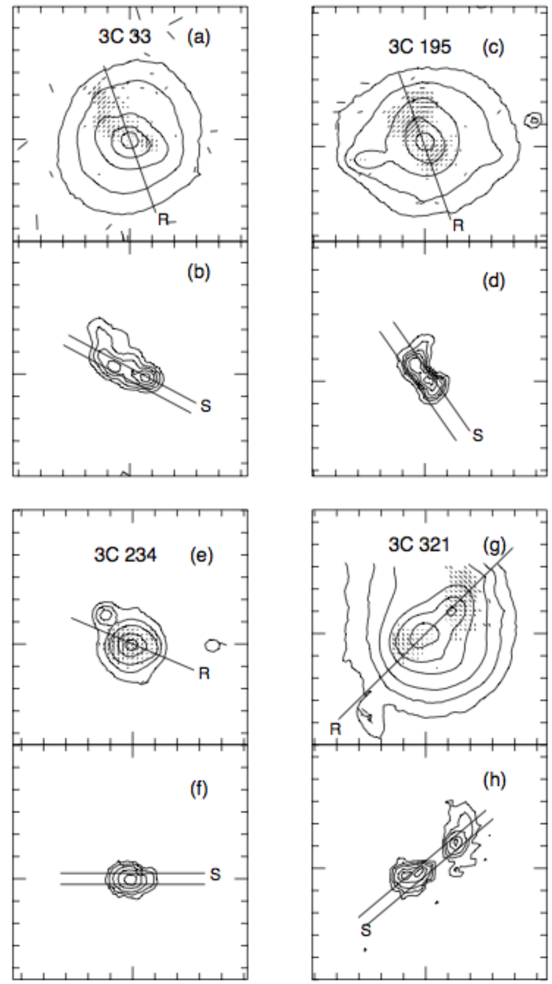


HST optical:
Jackson 98;

Keck+HST:
The Bob

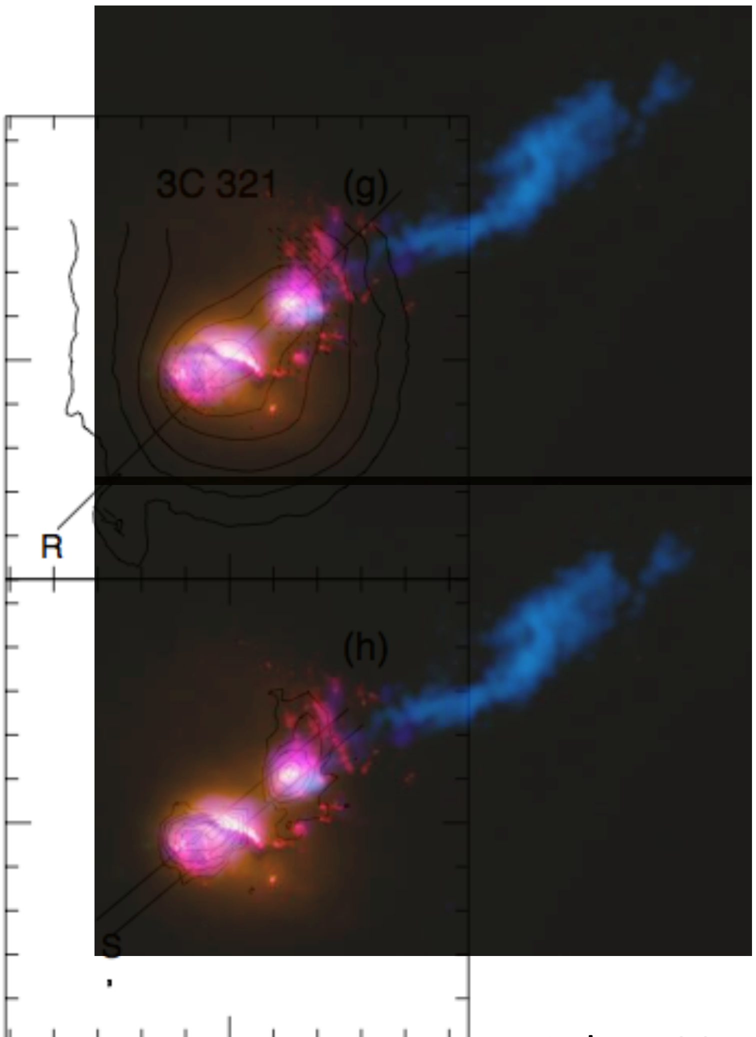
Other Polarized Radio Galaxies





Low-redshift radio galaxies: Cohen 99, Ogle 97, Tran 95; Tadhunter 90,96; Young 96; Corbett 98

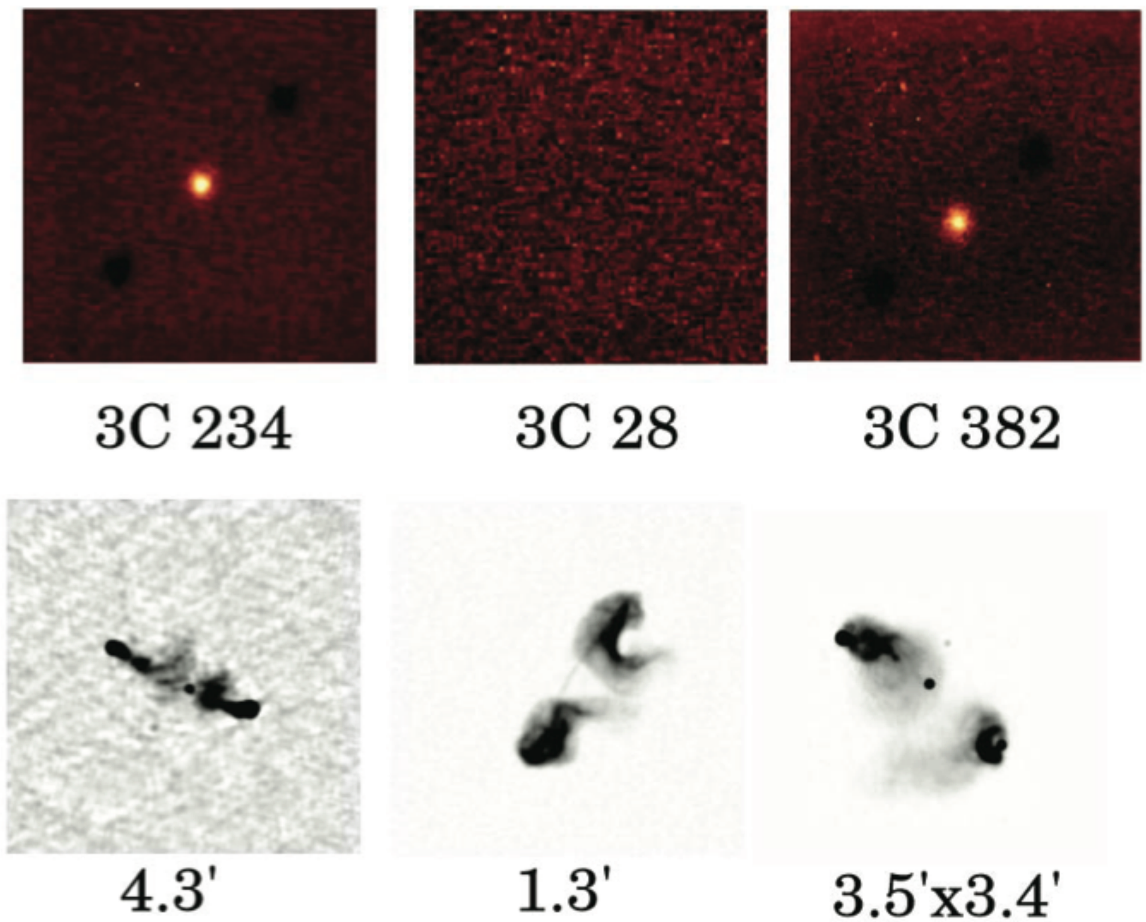
3C 321



D. Evans 08: HST+Chandra+Radio
Image of "Death Star" galaxy

Cohen 99

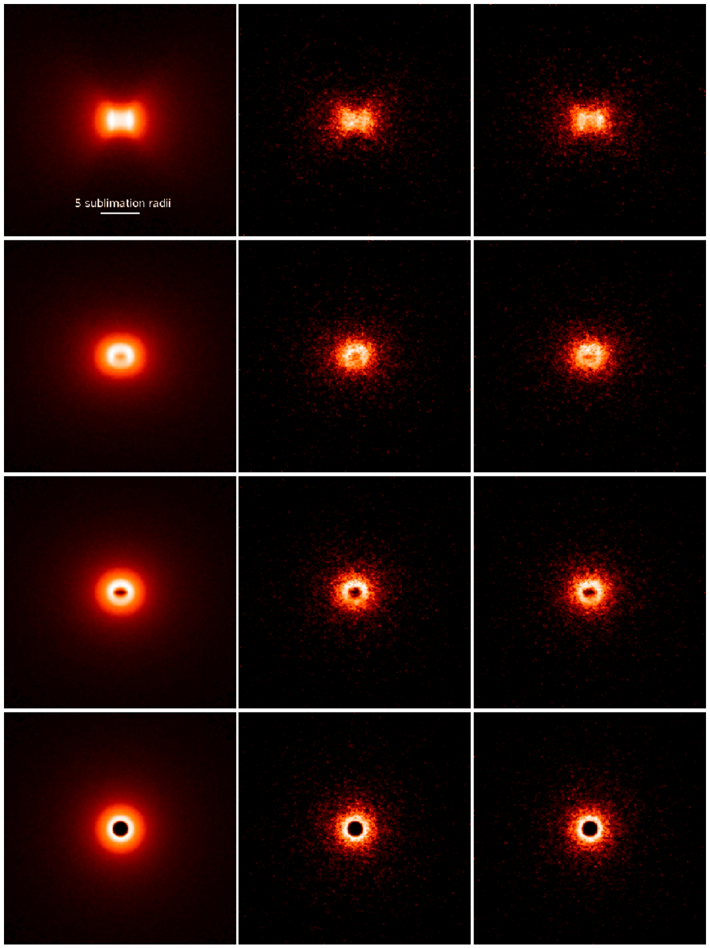
The Torus as IR Calorimeter



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

Keck LWS 11.7 μm 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 3-10).

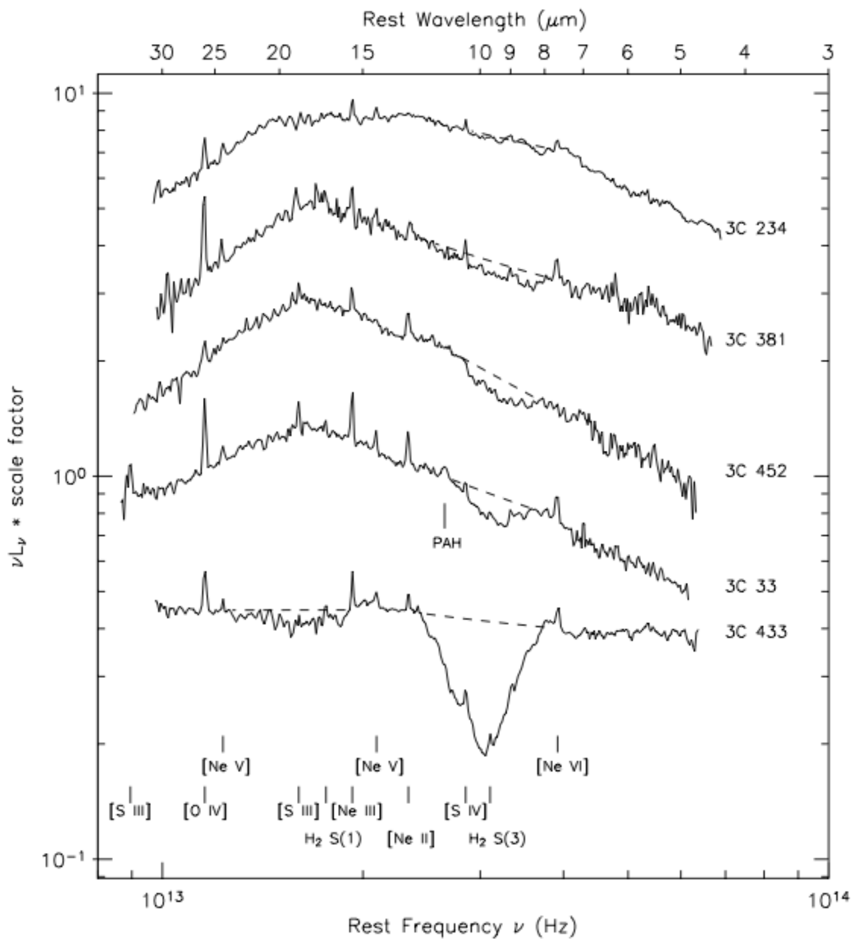
→ Orientation-insensitive measure of quasar accretion luminosity

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

•Dust emission concentrated near the sublimation radius

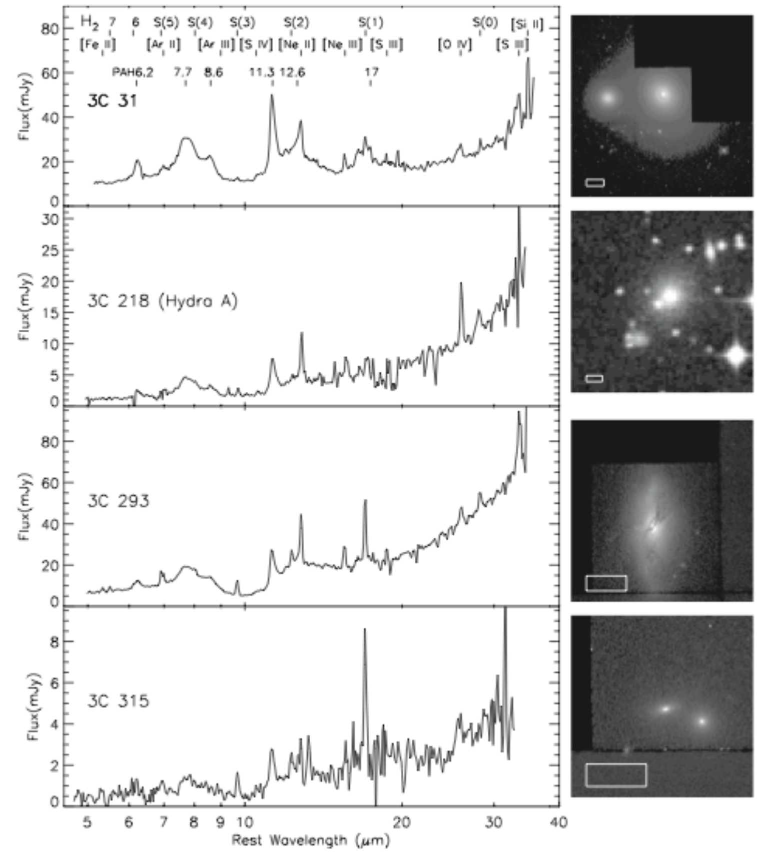
Honig 06—Clumpy Torus Monte Carlo Simulations

Spitzer IRS 5-35 μm Spectra



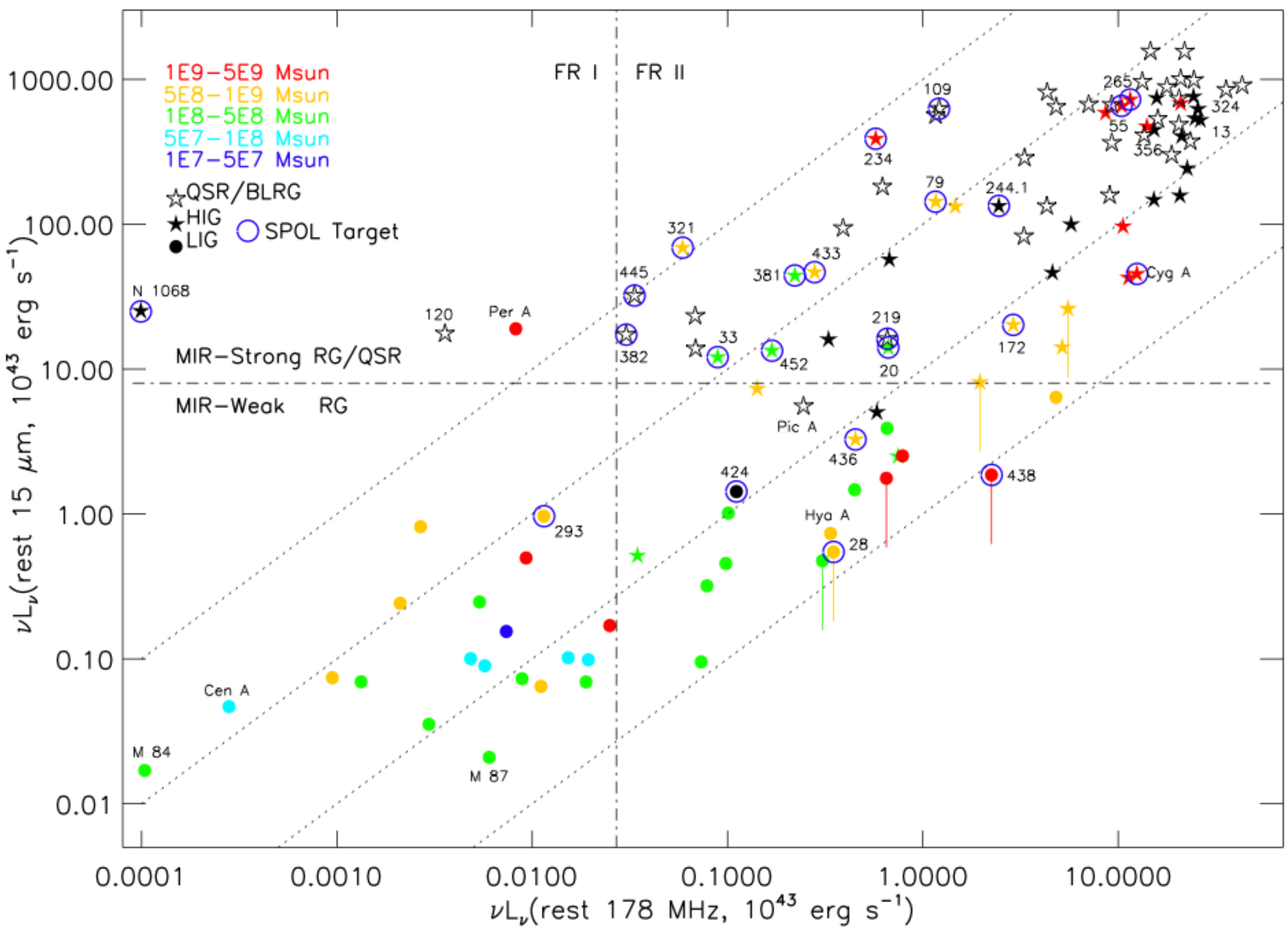
z<1 3CRR Ogle 06

20 μm peak from 200 K dust.



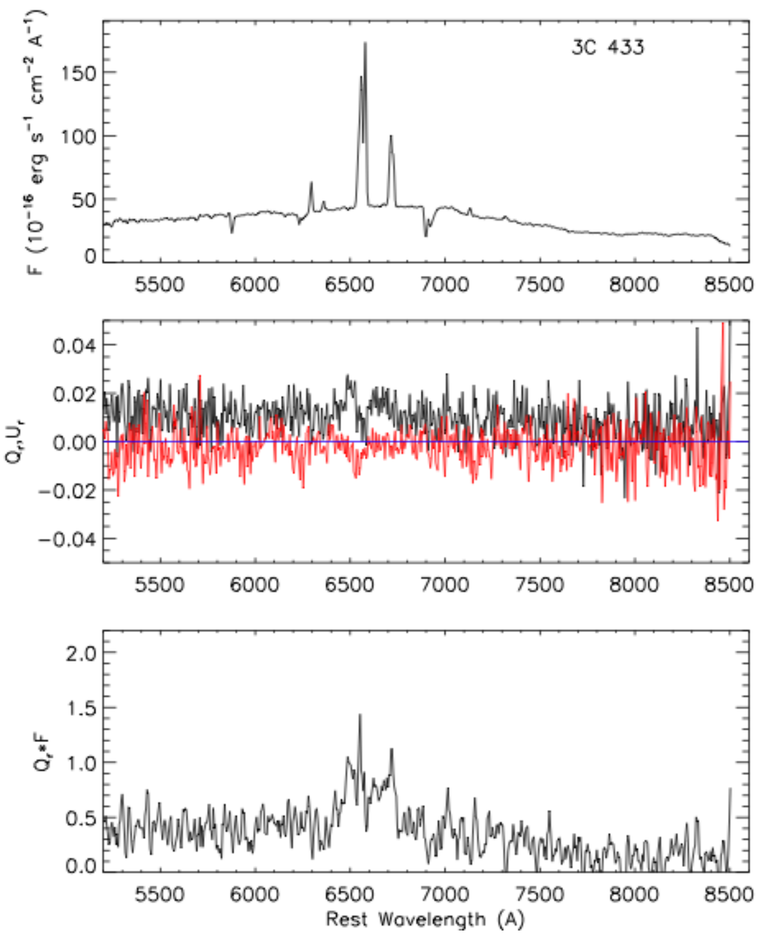
Jet-shocked H_2.   Ogle 10

IR (15 μm) vs. Radio Luminosity



Spitzer IRS 3C LZRG: Ogle 06; Leipski 09; HZRG: Seymour 08; Leipski 10; De Breuck 10

3C 433 Spectropolarimetry

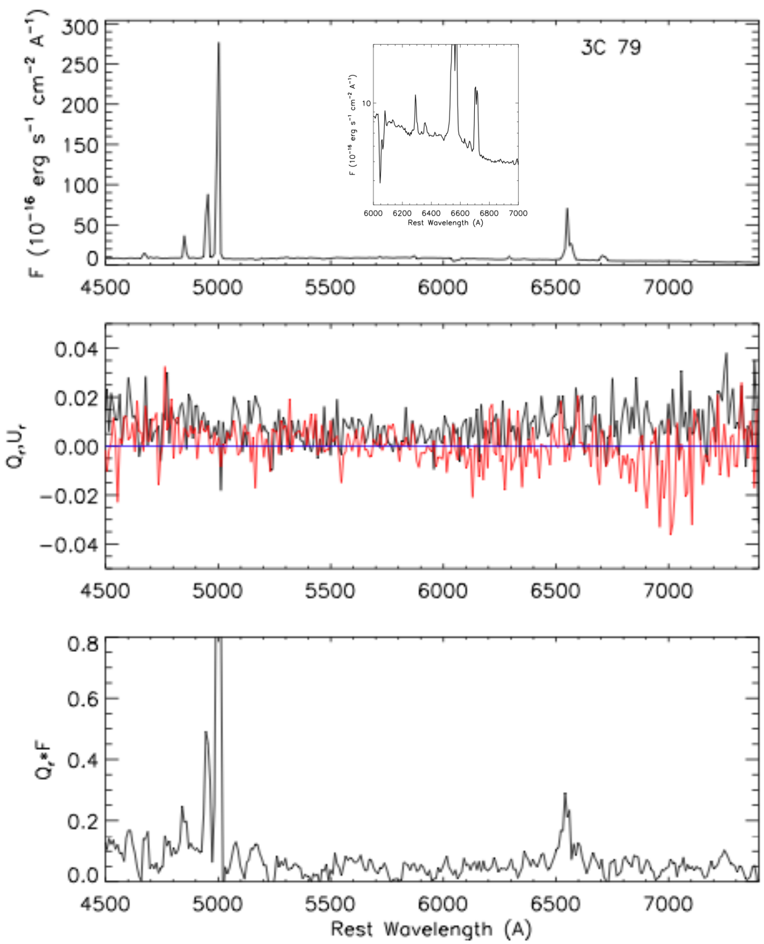


Ogle+11

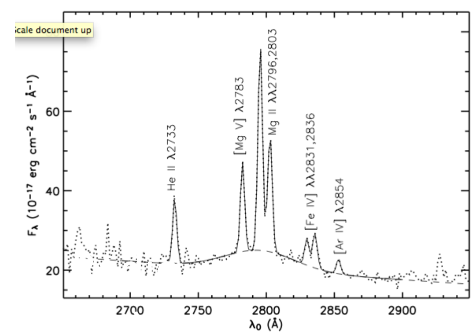
Narrow line spectrum in total flux

Broad, double peaked Hα in polarized flux

3C 79 Spectropolarimetry

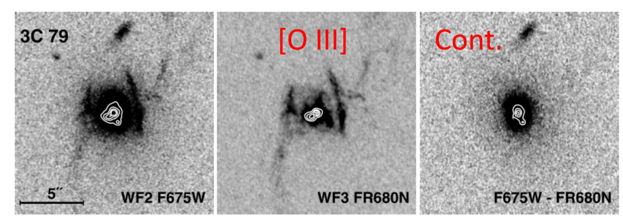


Ogle+11

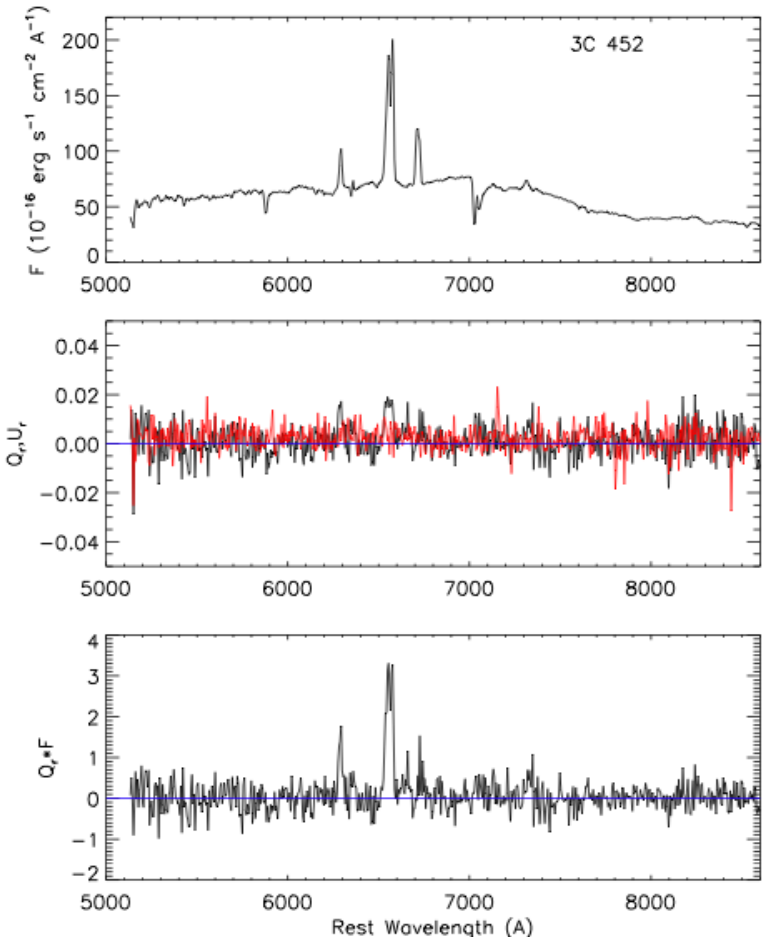


Fu+09, Keck LRIS:
Broad Mg II detected in total flux

HST ENLR:



3C 452 Spectropolarimetry

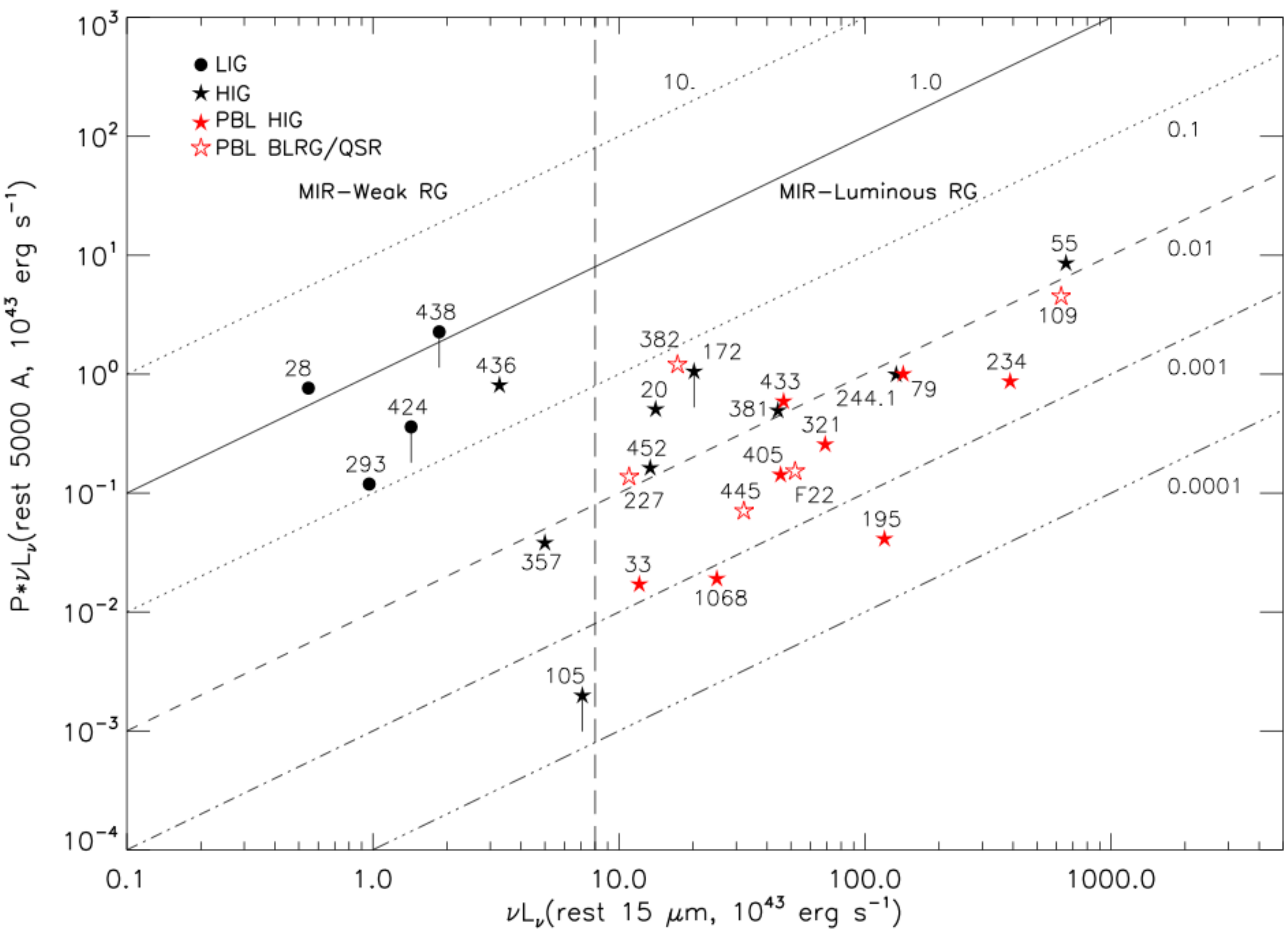


Ogle+11

Polarized narrow lines, but no broad lines. Lower density [S II] emission is extended and unpolarized.

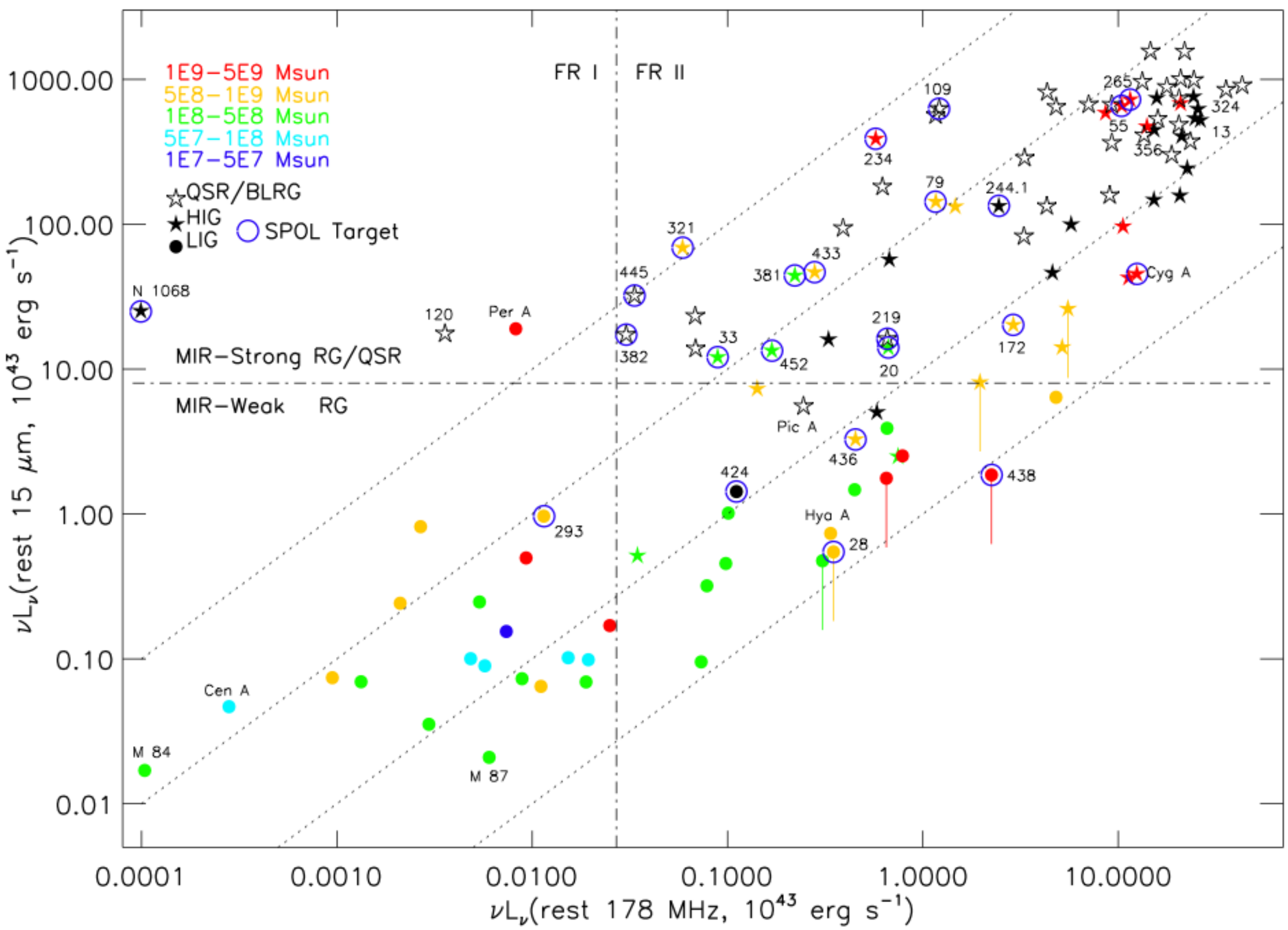
Similar [S II] behavior seen in NGC 4258 (Barth 99).

Polarized Optical vs. IR (15 μm)



Ogle+2011

IR (15 μm) vs. Radio Luminosity

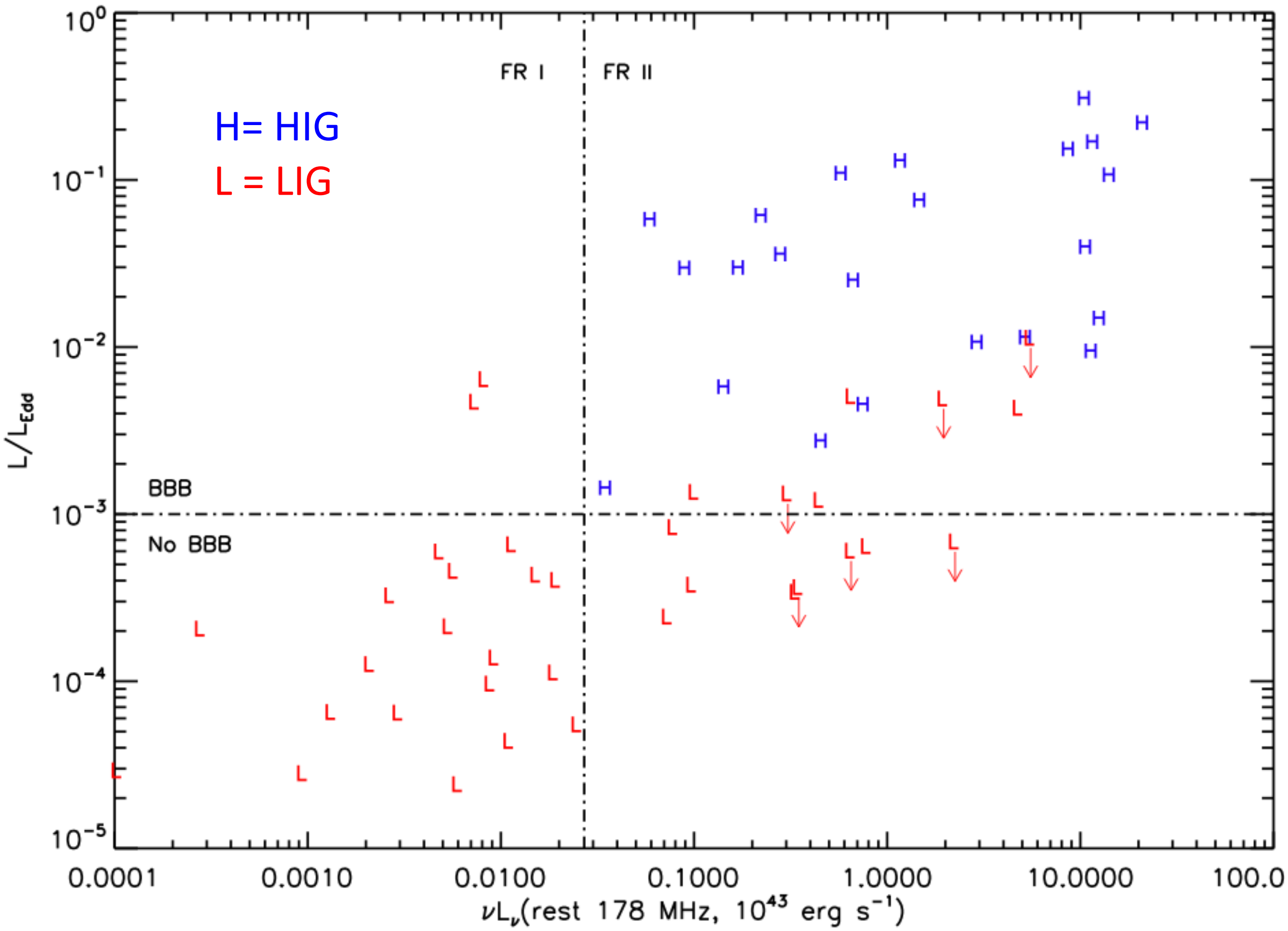


Ogle+2011, 2006

IR to L_{bol} Conversion; M_{BH}

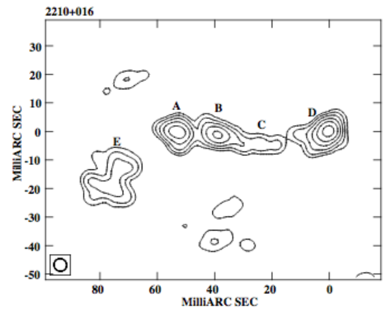
- Torus covering fraction = 0.55
- Mid-IR anisotropy factor ~3-10 at 15 μm.
- $L_{IR} \sim 2\ \nu L_\nu$ (15μm)
- M_{BH} from K-band absolute magnitude M_K of host galaxy and M_{BH}- L_{bulge} relation.

L/Ledd vs. Radio Power



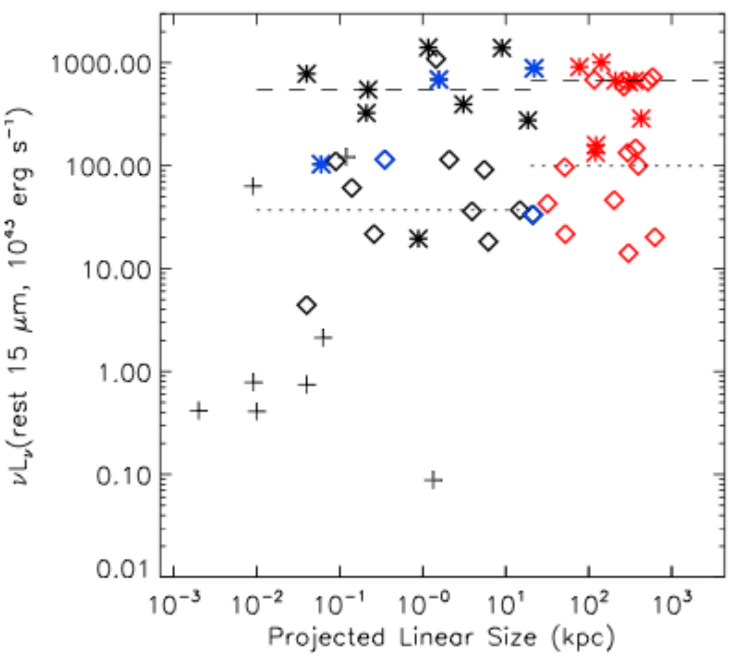
Ogle+2011

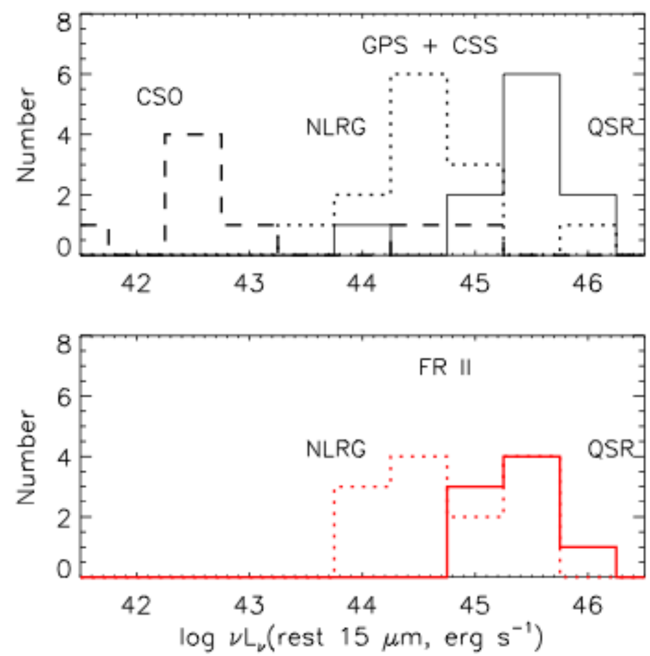
Unification of Compact Radio Sources



VLBI of GPS radio sources, Stanghellini 97

GPS = Gigahertz-Peaked Spectrum
CSS = Compact Steep Spectrum, 3C, size <20 kpc
CSO = Compact Symmetric Object





Z=0.4-1 GPS, CSS, and FR IIs: Ogle, Antonucci, O'Dea+11; z<0.3 CSOs: Willett 10