Spitzer IRS spectroscopy of 3CR radio galaxies & quasars

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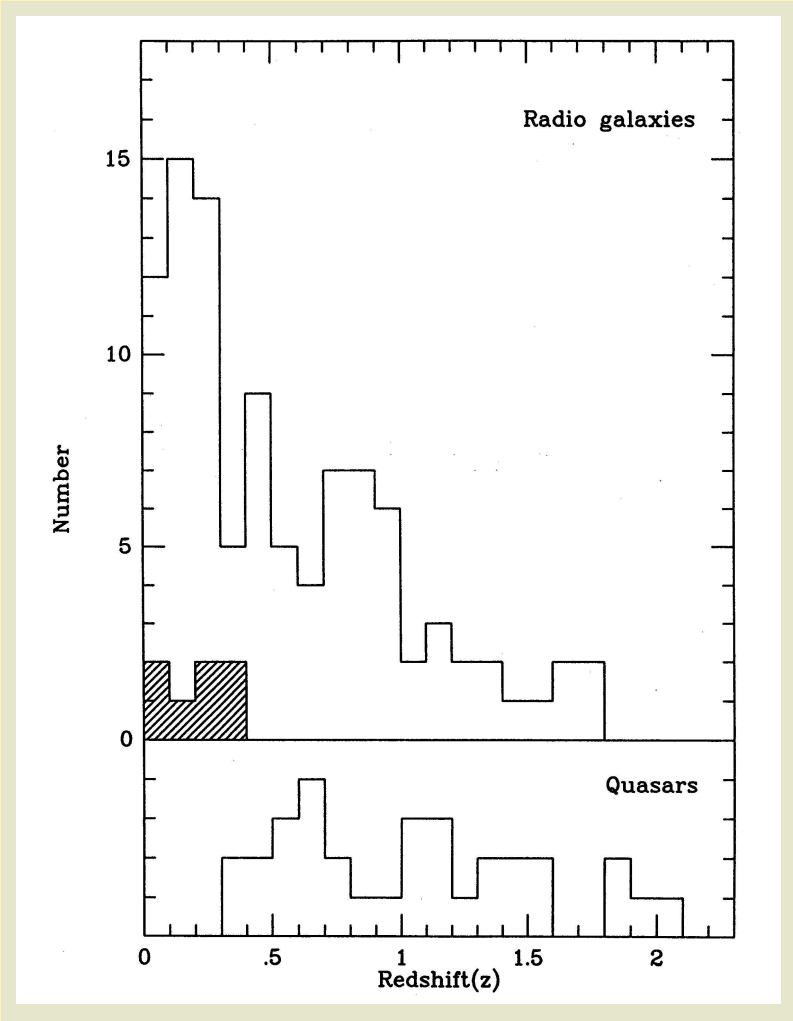
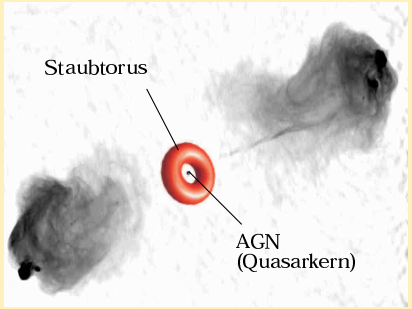


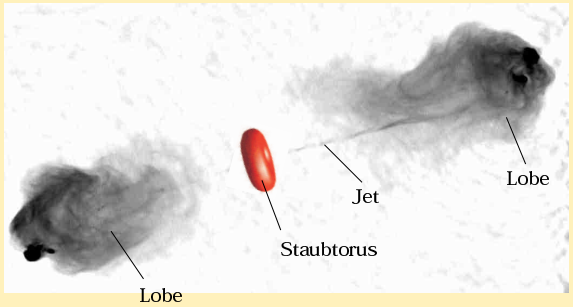
(Singal 1993)

... testing the unified model for powerful sources at z $<$ 1

Unification hypothesis: *(Barthel 1989)*

steep spectrum quasar

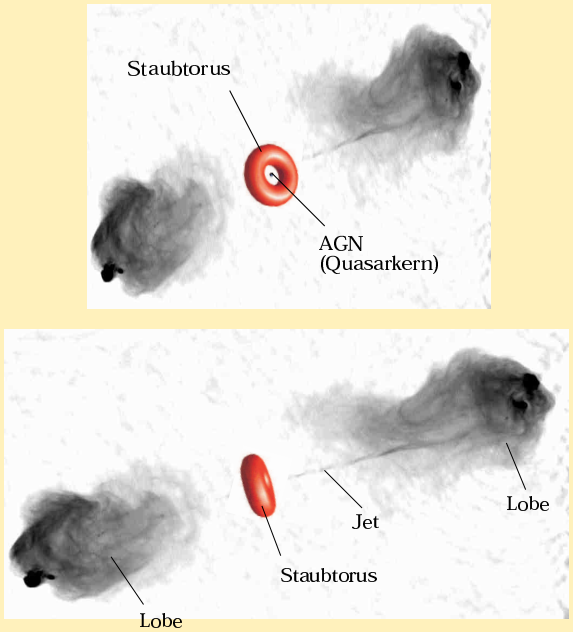




powerful FR 2 galaxy

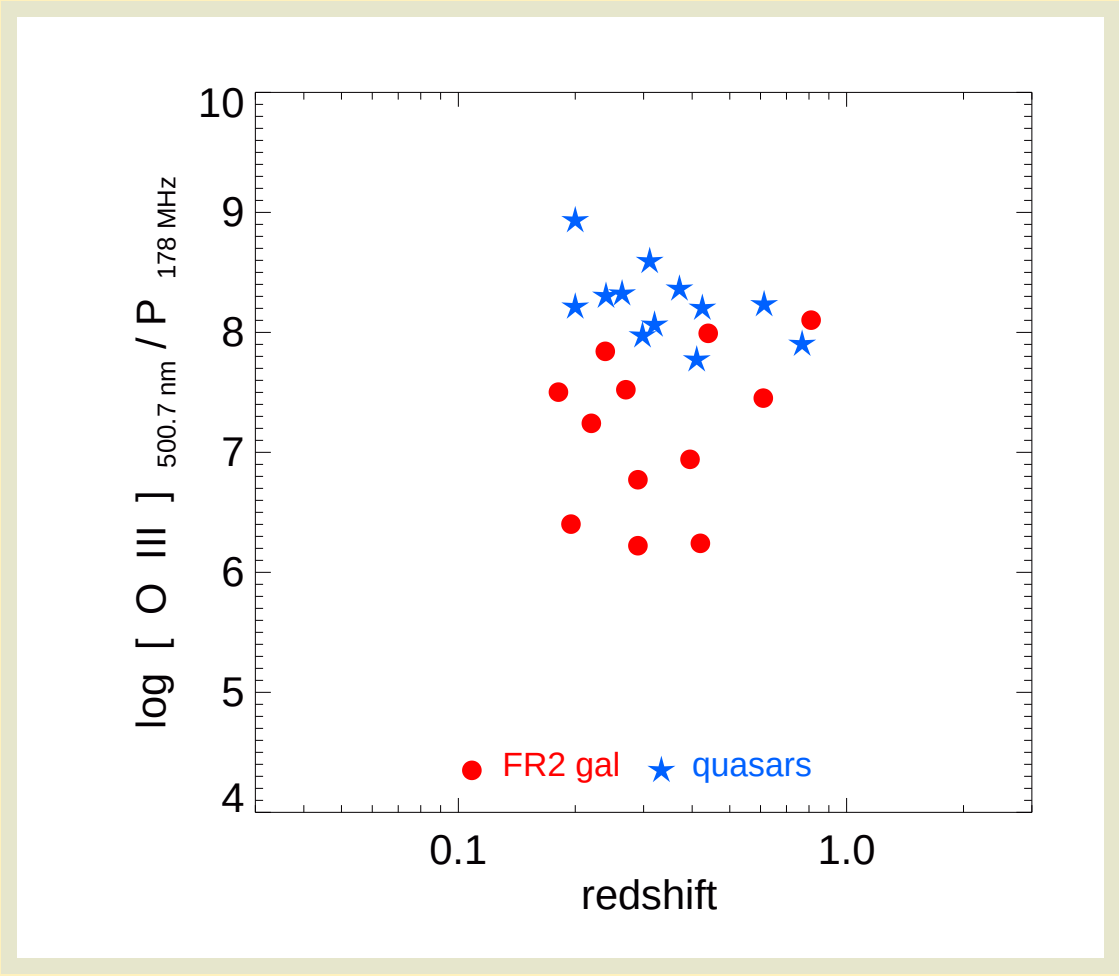
Old test: "isotropic" optical emission and radio lobes (178 MHz)

steep spectrum quasar



powerful FR 2 galaxy

(Jackson & Browne 1990)

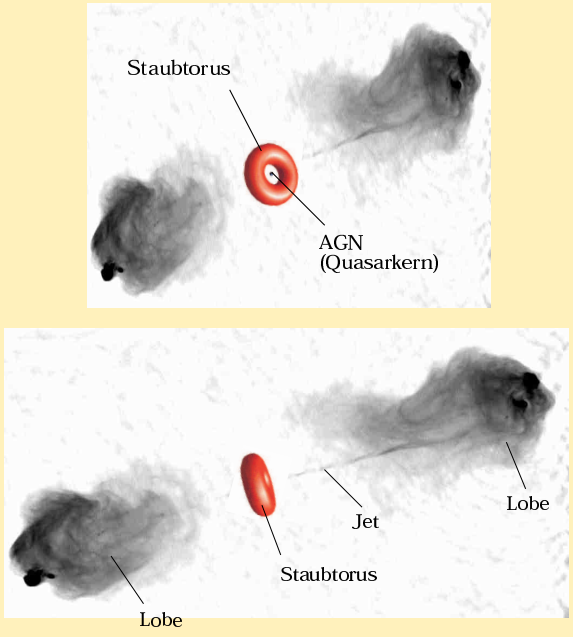


in galaxies [OIII] defi cit: 1.) "extended" NLR obscured ... or 2.) black holes different ?

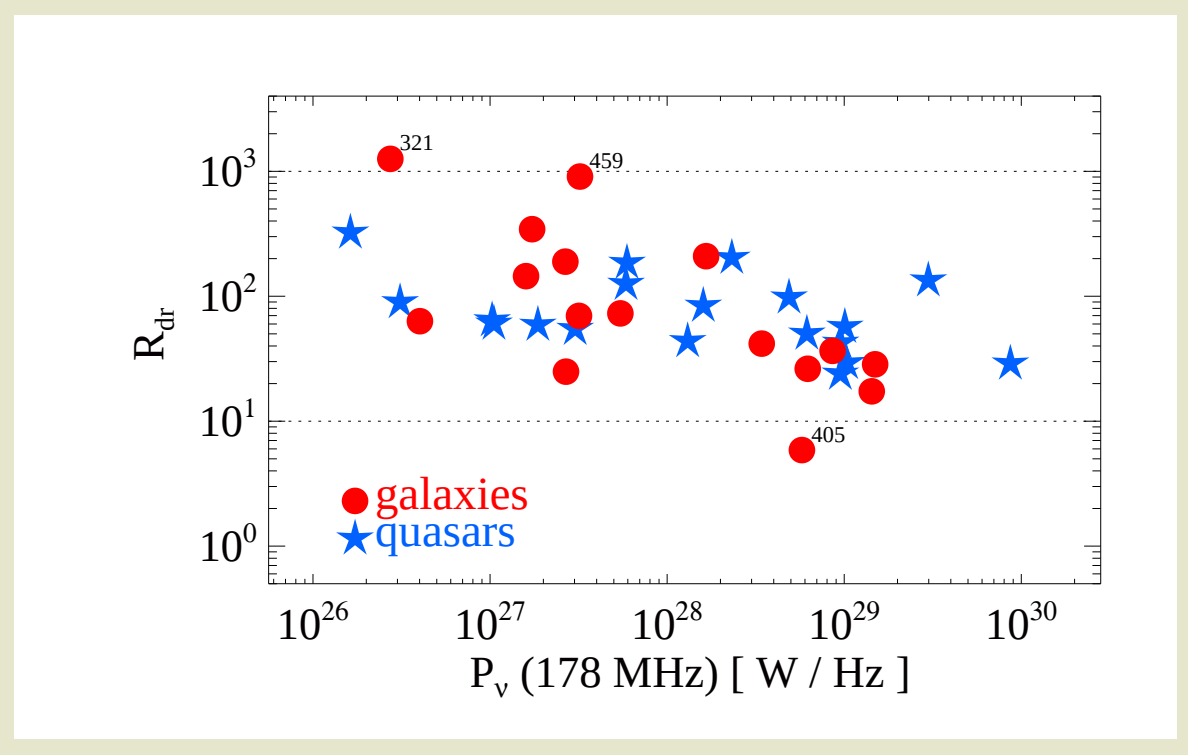
[OIII] polarised → 1.) *(di Serego-Alighieri et al. 1997)*

New test: isotropic emission from dust (FIR) and radio lobes (178 MHz)

steep spectrum quasar



powerful FR 2 galaxy



$R_{dr} = L_{dust} / L_{radio}$ **similar** for quasars and galaxies

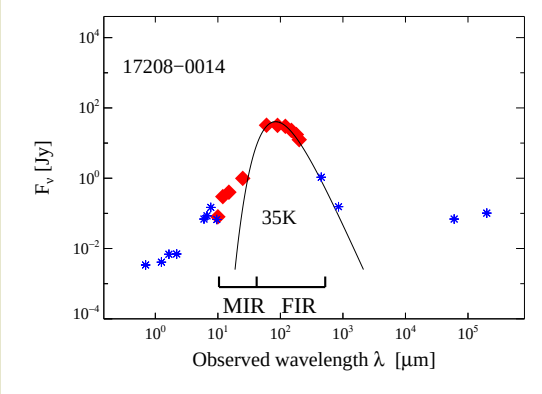
(van Bemmel+ 2000, Meisenheimer+ 2001, Andreani+ 2002, Siebenmorgen+ 2004, Haas+ 2004)

ISO observations: → evidence in favour of unification

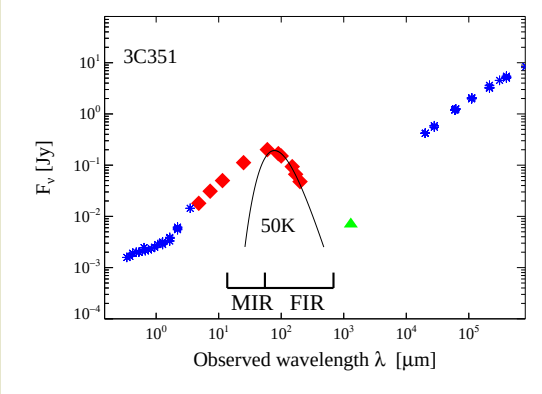
but ...

FIR due to starbursts? → check for AGN typical MIR emission

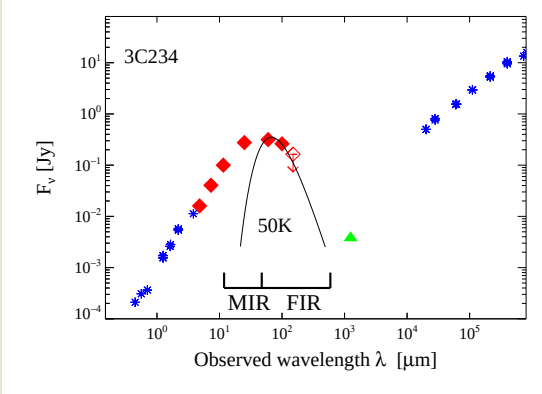
starburst ULIRGs



quasars



FR 2 galaxies



FIR due to starbursts? → check for AGN typical MIR emission

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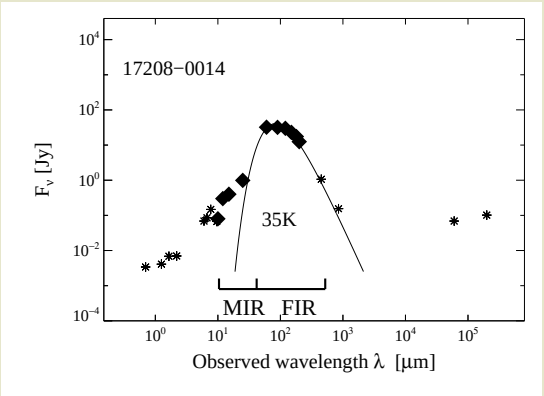
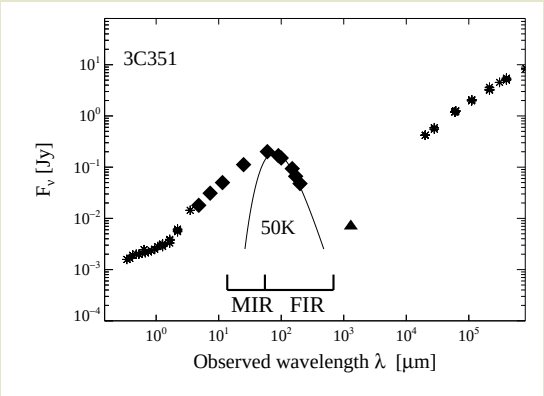
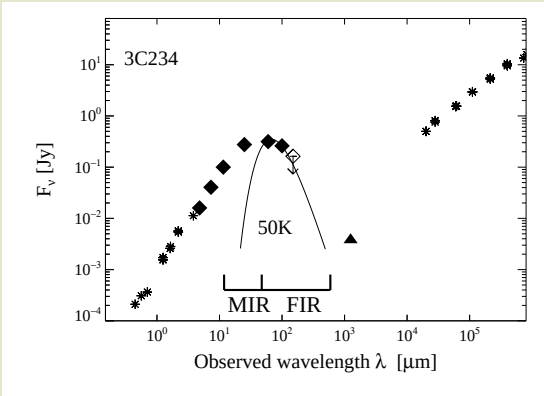


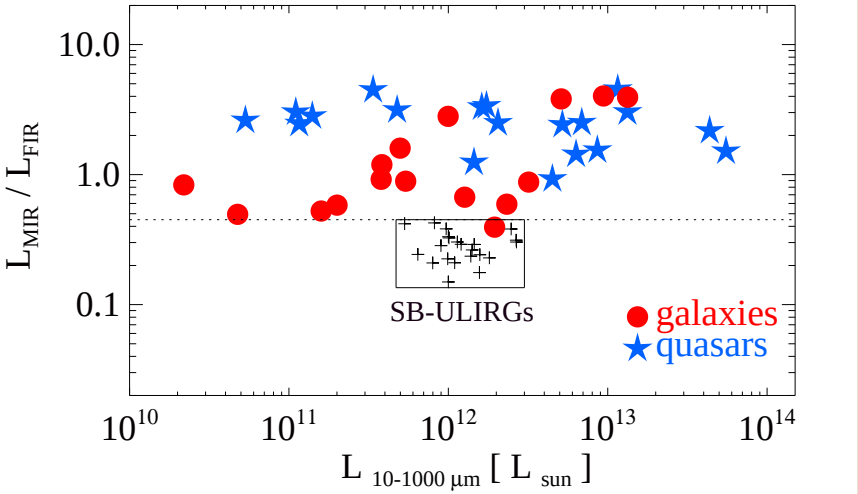
quasars



FR 2 galaxies



L_{MIR} / L_{FIR} distribution:

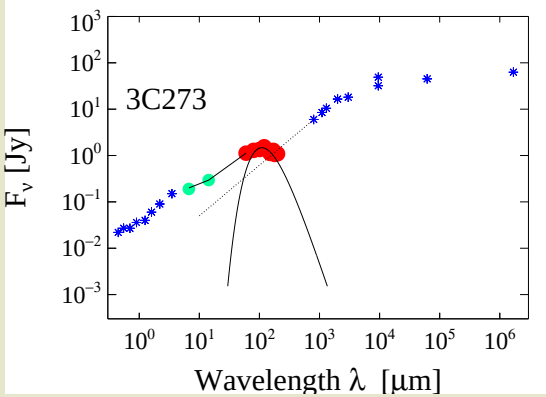


- higher in gal & qso than in starburst-ULIRGs
  → **powerful AGN in galaxies & quasars**

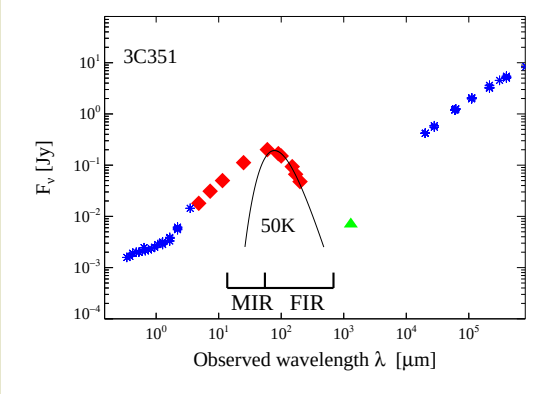
- higher in quasars than in galaxies
  → **MIR continuum enhanced in quasars?**

MIR continuum enhanced in quasars? → check synchrotron contribution

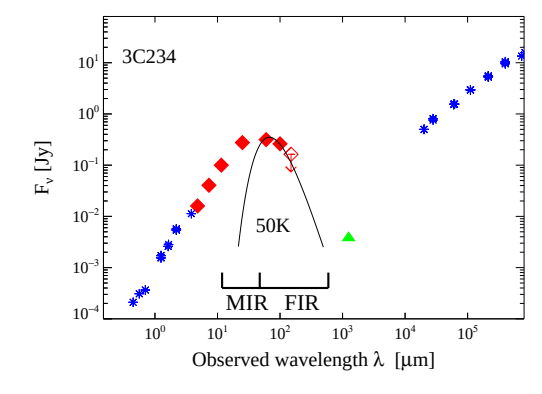
flat spectrum quasar



steep spectrum quasar



FR 2 galaxy



MIR continuum enhanced in quasars? → check synchrotron contribution

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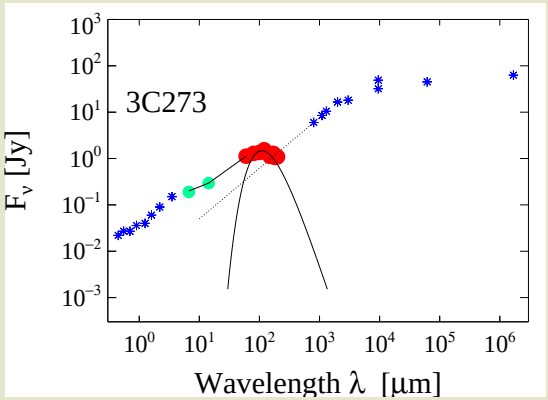

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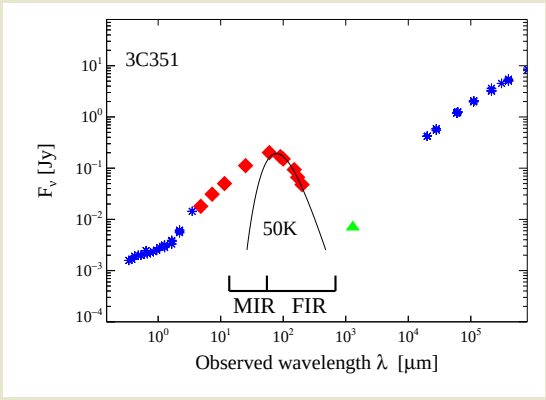

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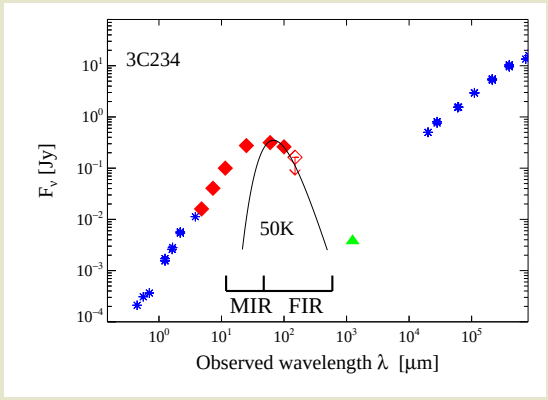
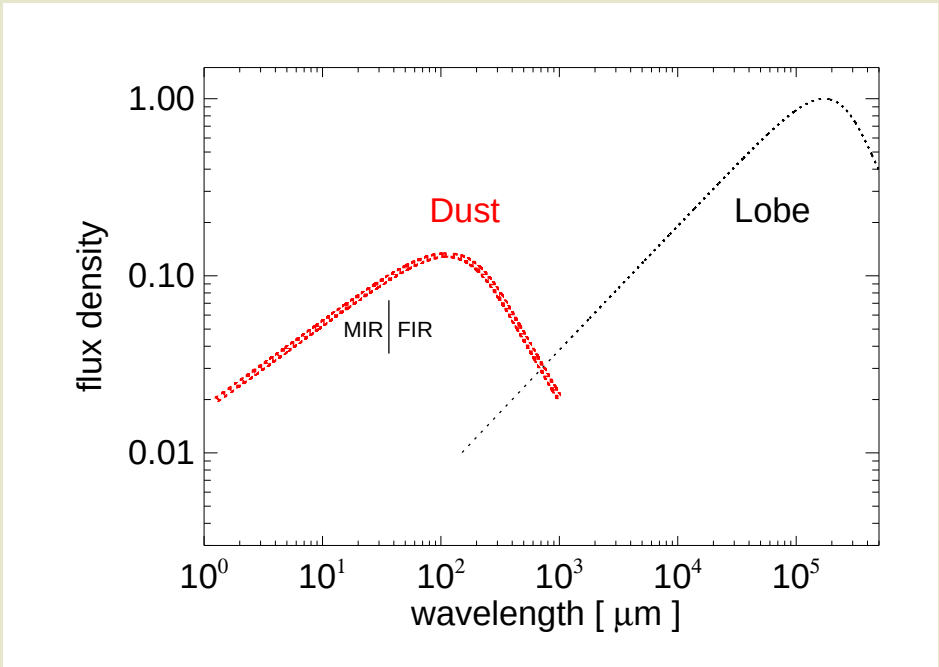
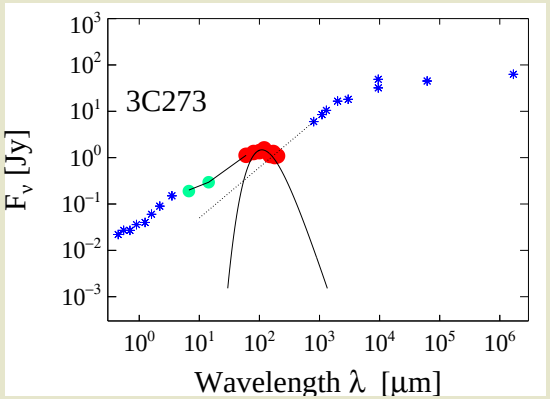


Scheme of emission components:



MIR continuum enhanced in quasars? → check synchrotron contribution

flat spectrum quasar



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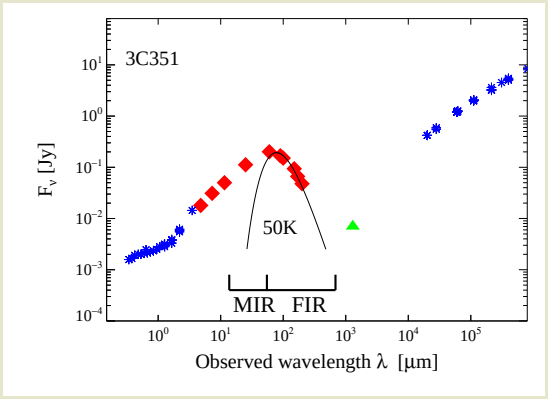
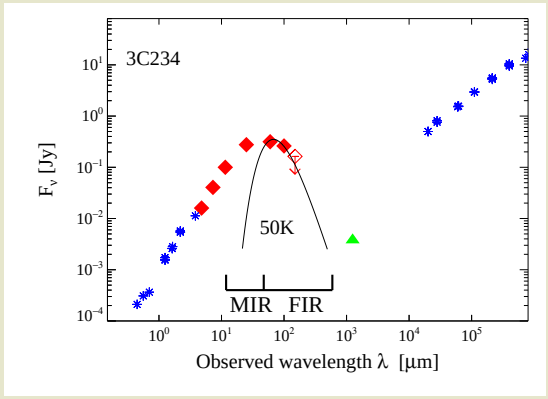


FR 2 galaxy



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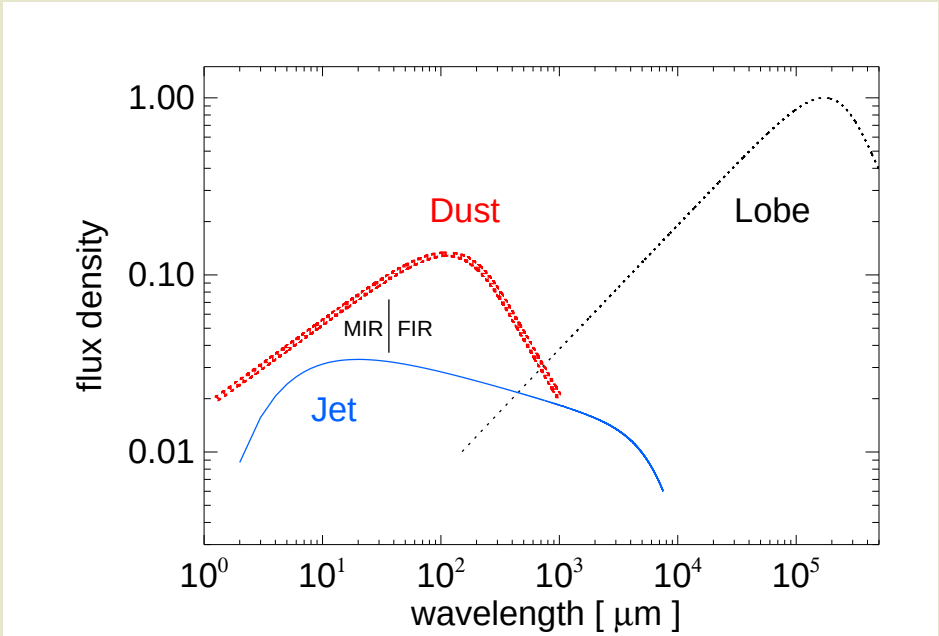


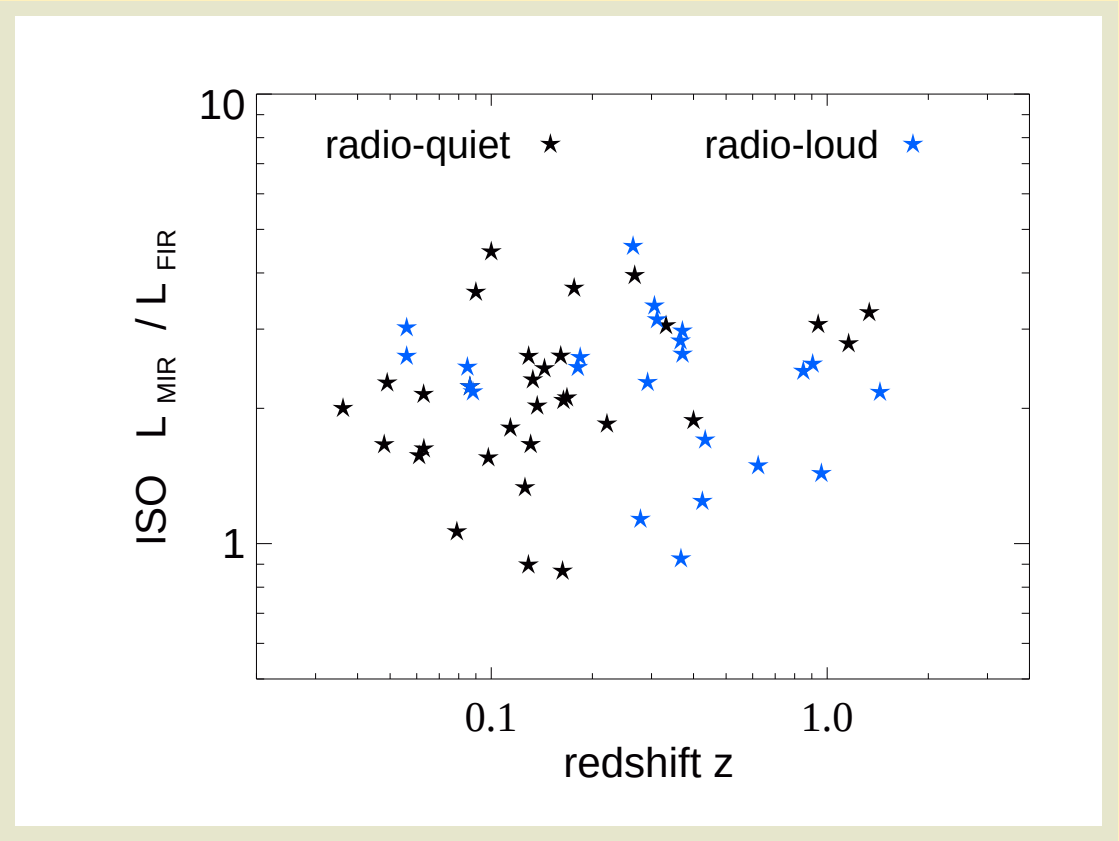
- dust and jet models:

  in **some** "flat" spectrum quasars (FSQ)
  SED fitting possible, but not unique
  (e.g. Cleary et al. 2007)

- is jet of **general** importance for MIR of SSQ?

→ compare with radio quiet quasars

MIR/FIR in quasars: radio-quiet and steep-spectrum radio-loud:



- MIR/FIR distributions similar for RQQ and RLQ, no evidence for factor 2 difference

→ **Synchrotron jet plays minor role for MIR of SSQ** *(Leipski+ 2007, in prep.)*

- Why MIR/FIR lower in radio galaxies than in quasars?

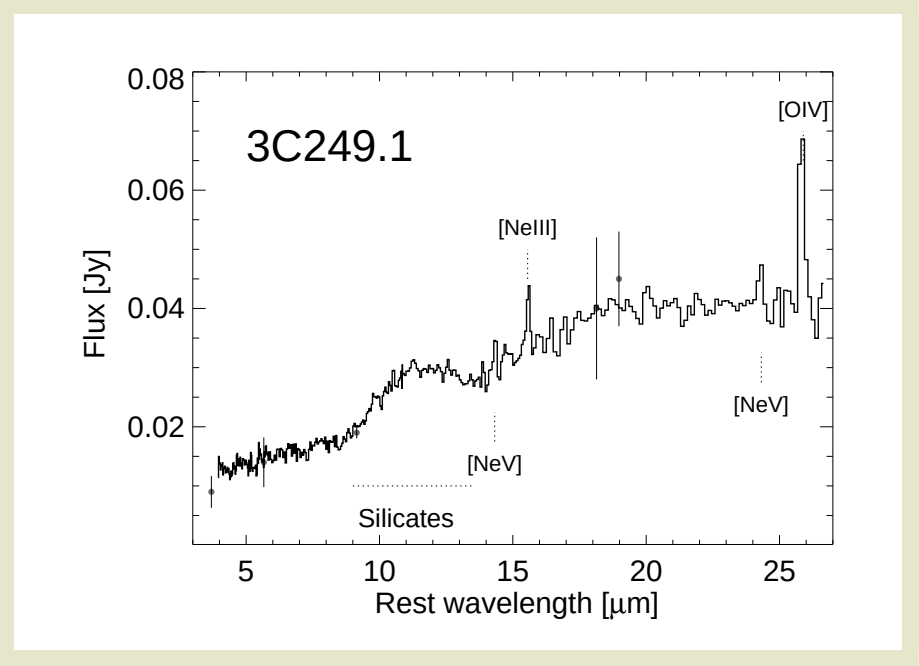
→ **MIR continuum absorbed in galaxies?** ... try MIR spectroscopy ...

Spitzer MIR spectroscopy of 7 radio galaxies & 7 quasars

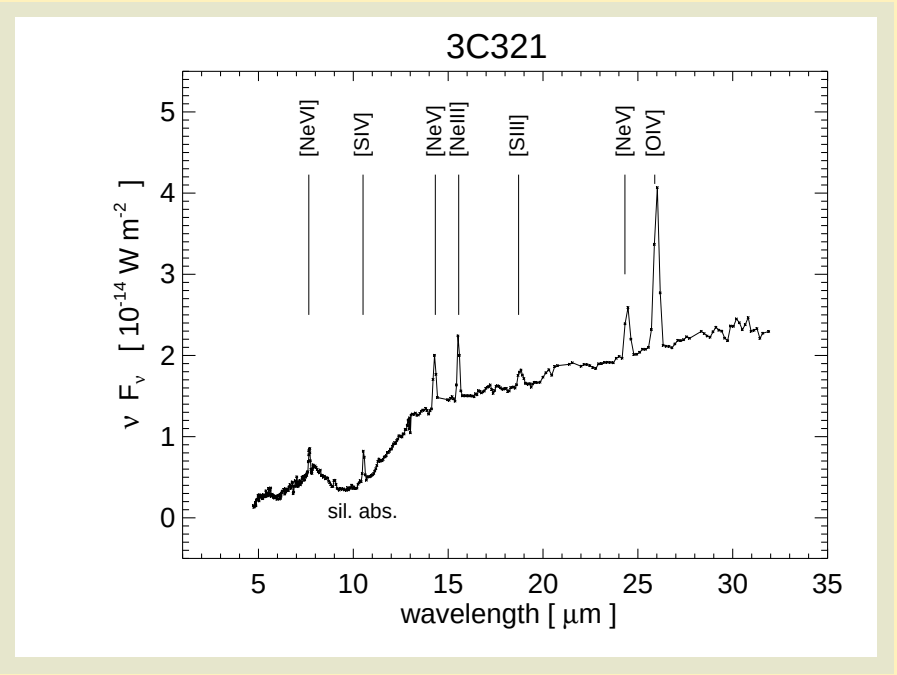
pilot study covering powerful 3CR sources at $0.05 < z < 1$,

Results: example spectra

quasar



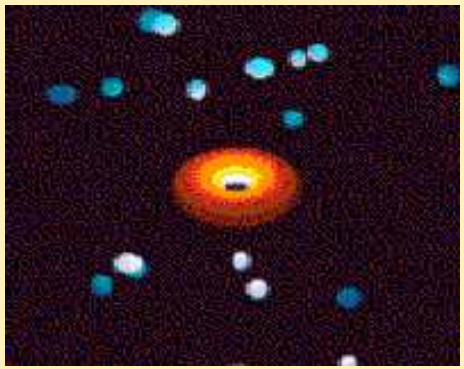
galaxy

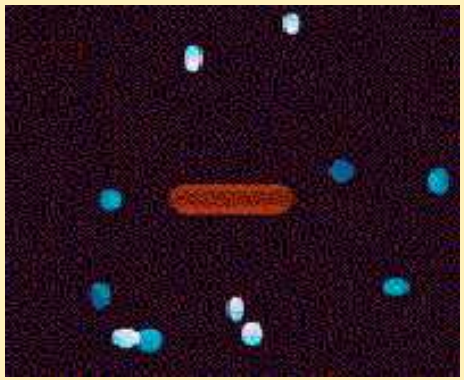


→ high- and low- excitation lines ... and other features...

a) Discovery of 10 μm silicate emission in quasars:

predicted from models:





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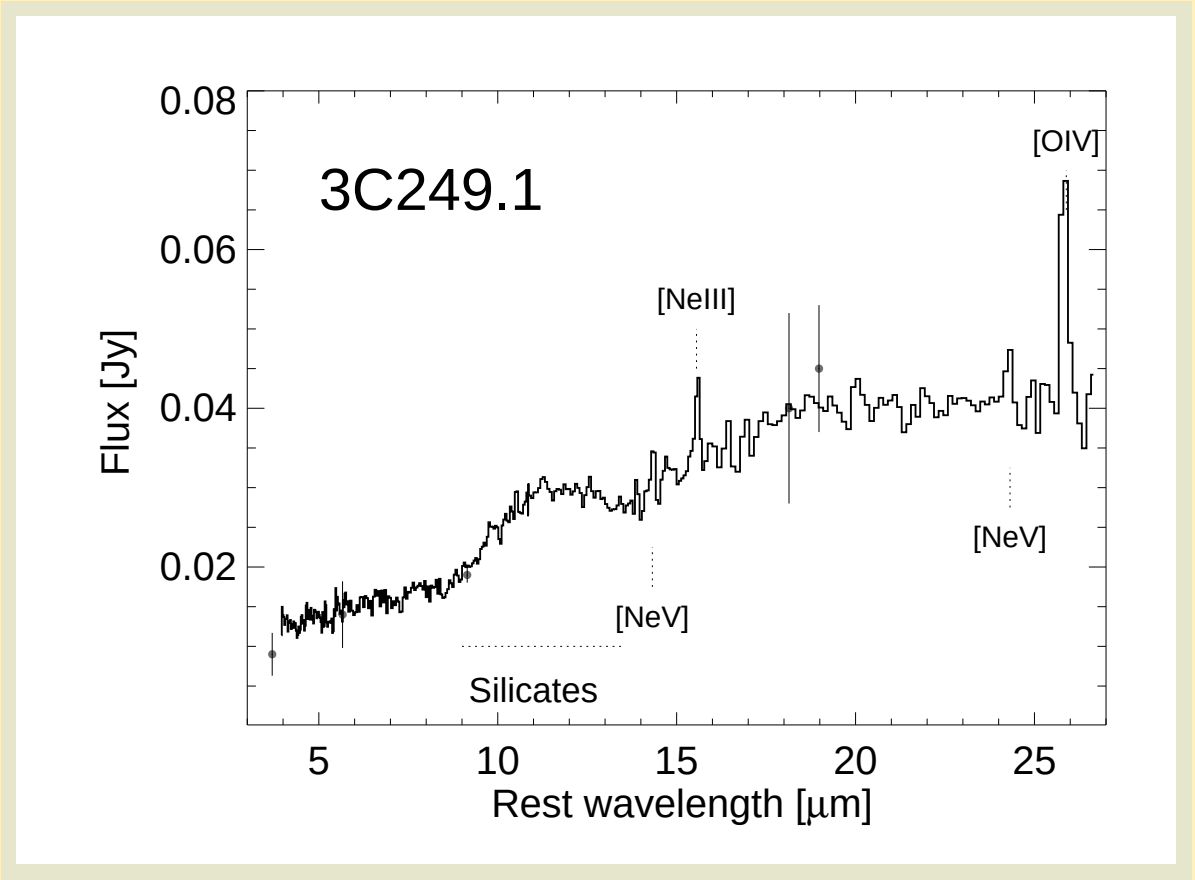
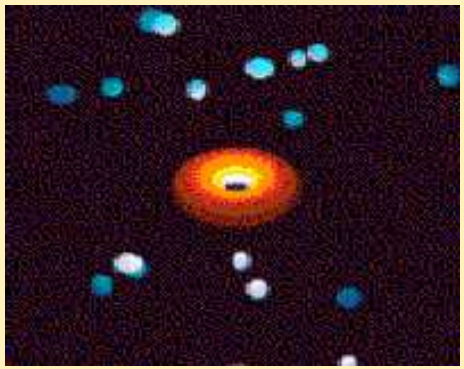
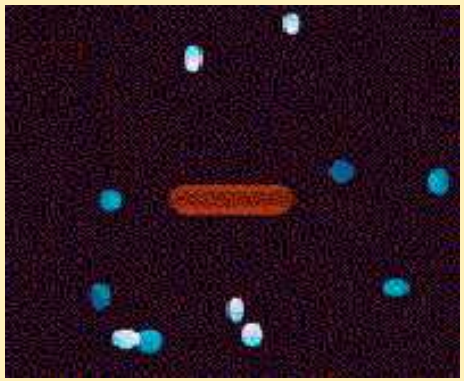


→ **spectroscopic evidence for "face-on dust torus"**

(Siebenmorgen et al. 2005; also: Hao et al. 2005, Schweitzer et al. 2005, Ogle et al. 2006)

b) In galaxies: typically 10 μm silicate absorption





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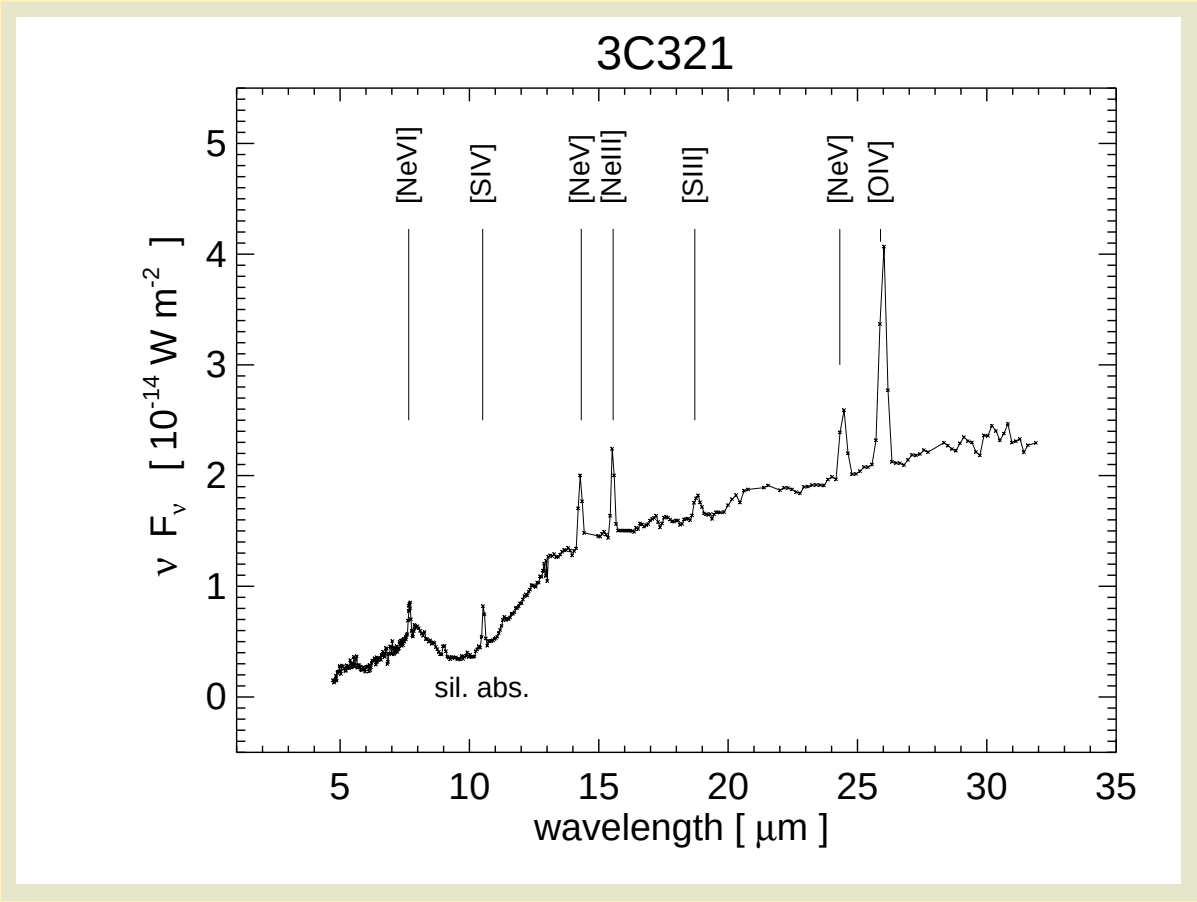


→ **dust features consistent with expectations for edge-on view**

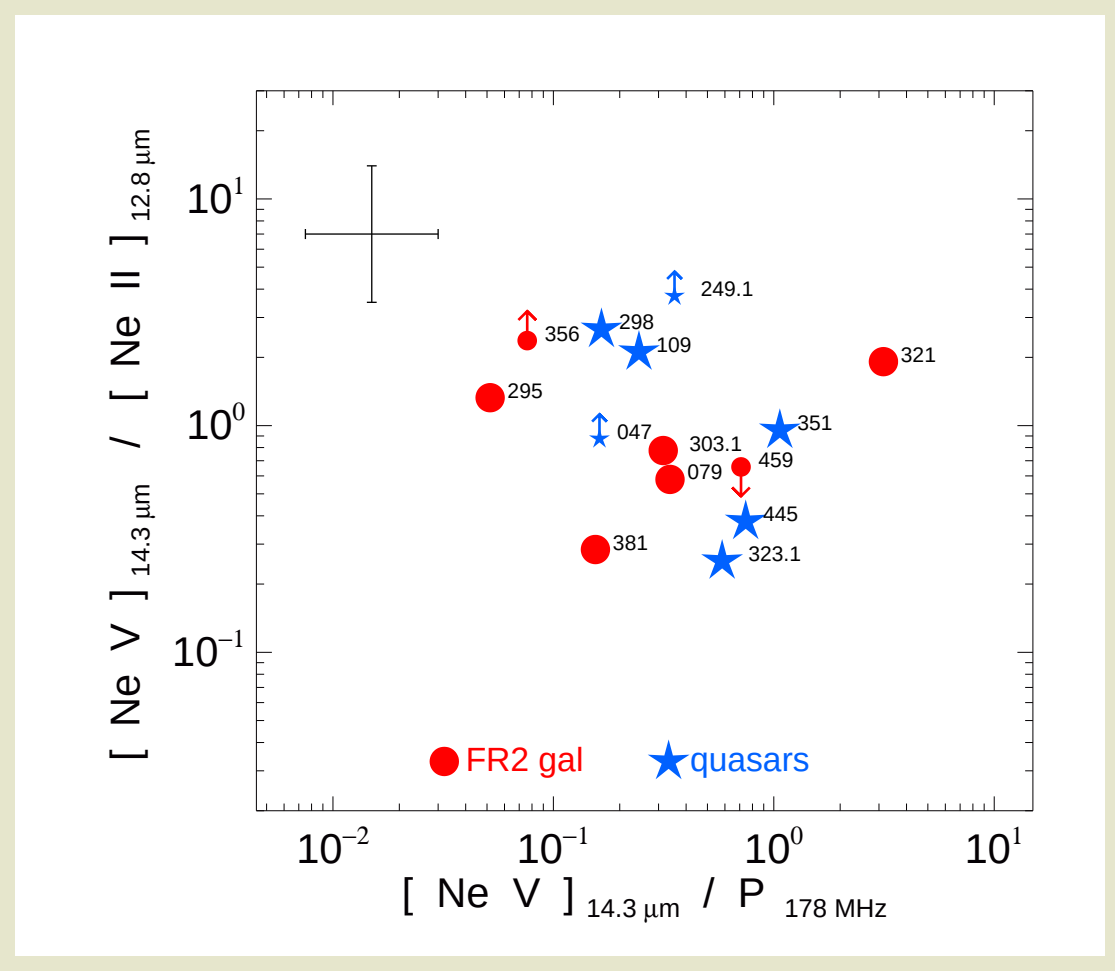
c) High-/low-excitation line and radio power

[Ne V] / [NE II]

[Ne V] / P $_{178\,\mathrm{MHz}}$

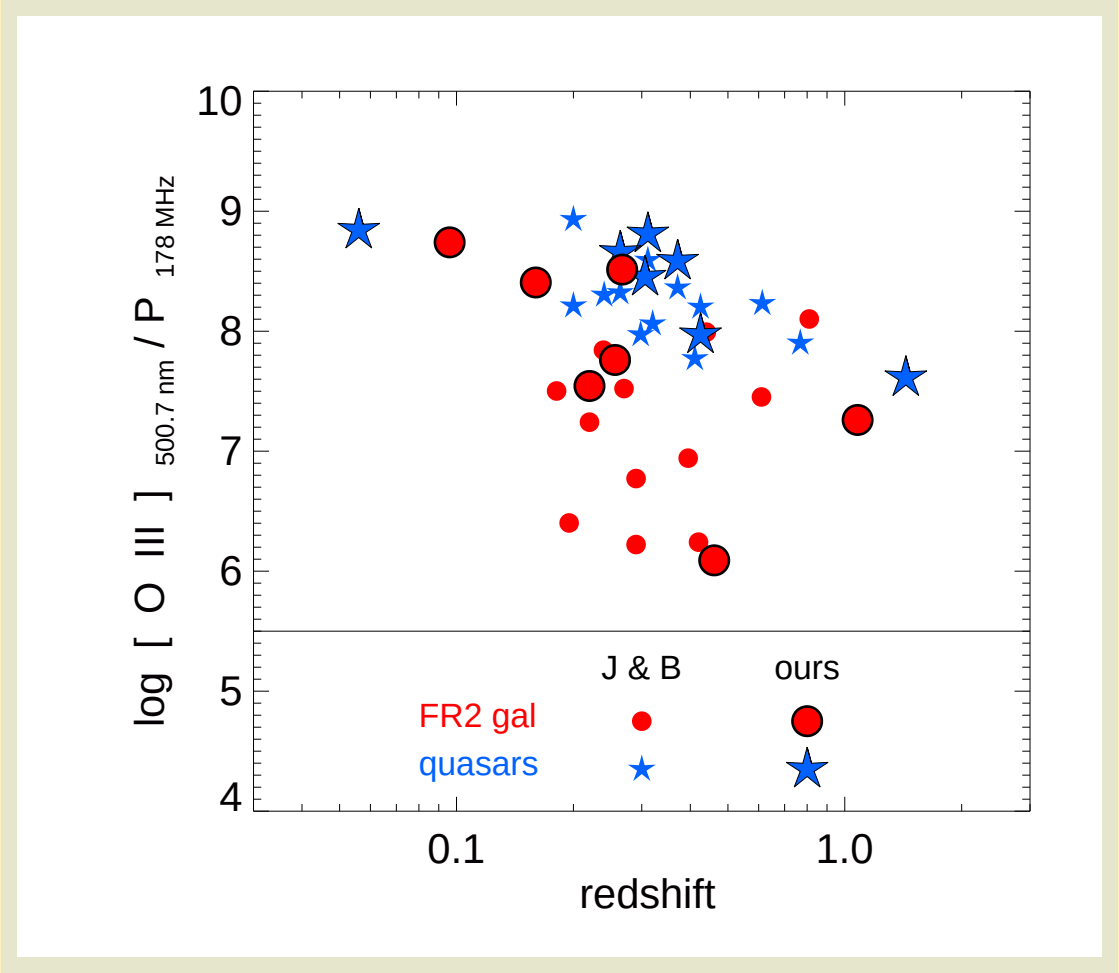
distributions similar

for galaxies and quasars



→ **evidence for the unified model at z $<$ 1** *(Haas et al. 2005)*

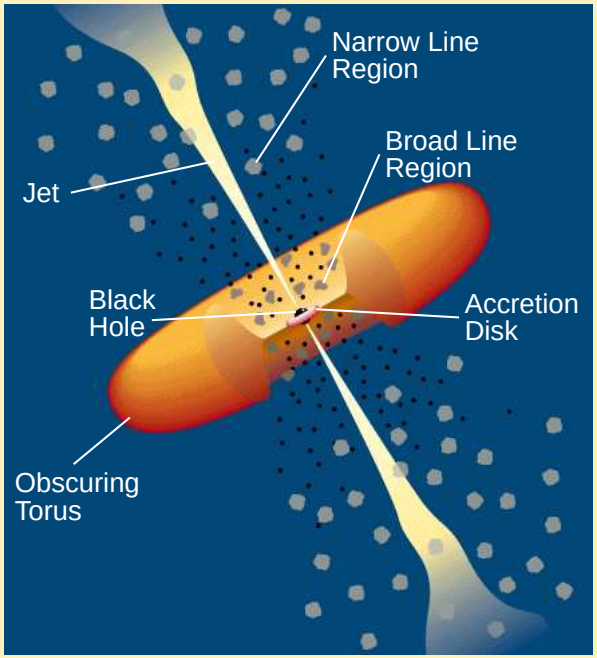
d) Compare with optical results *(Jackson & Browne 1990)*

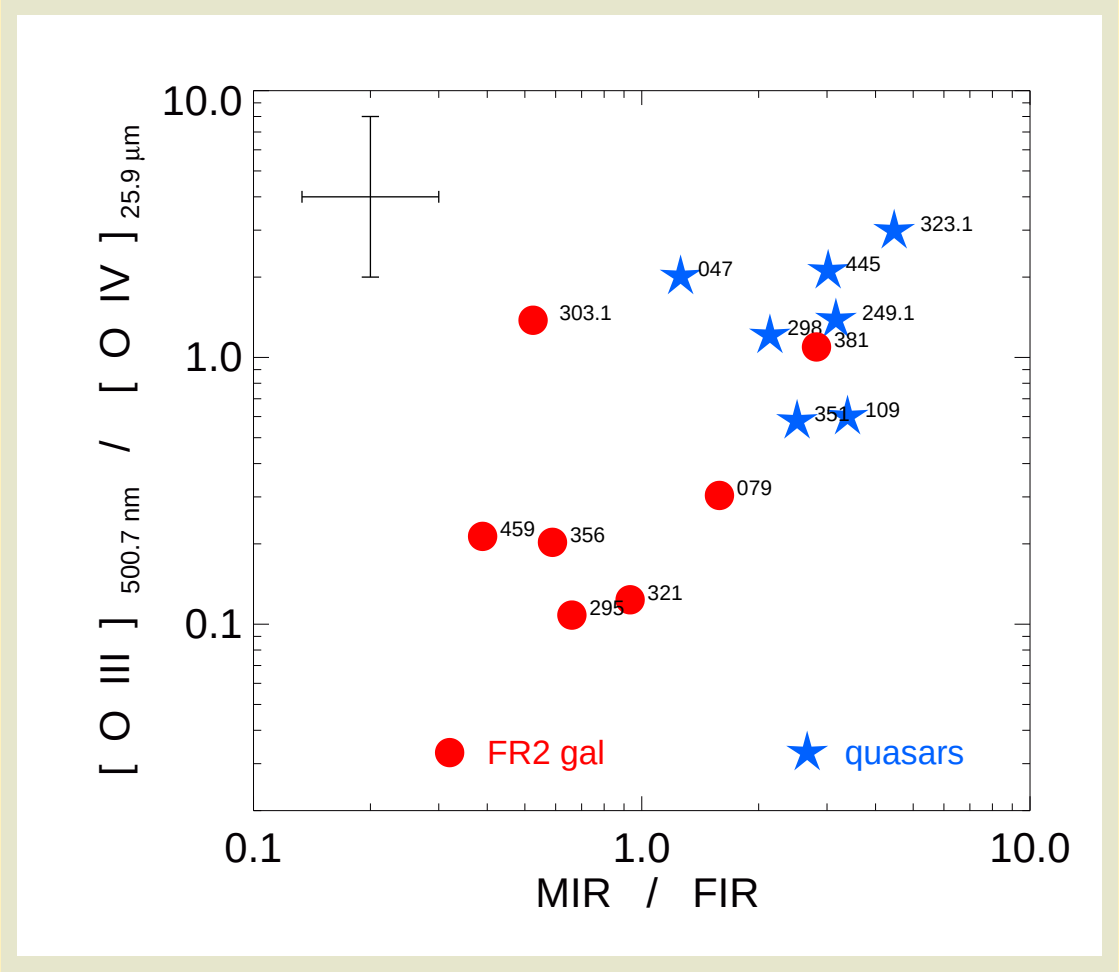


Why is OIII weaker in galaxies than quasars?

$\rightarrow$ test with [O IV] $_{25.9\mu\mathrm{m}}$, 50 $\times$ less extinction!

e) optical versus MIR: [O III] $\lambda 500.7\,\mathrm{nm}$ / [O IV] $25.9\mu\mathrm{m}$





for radio galaxies:

mean [O III] / [O IV] $\sim$ 5 $\times$ lower

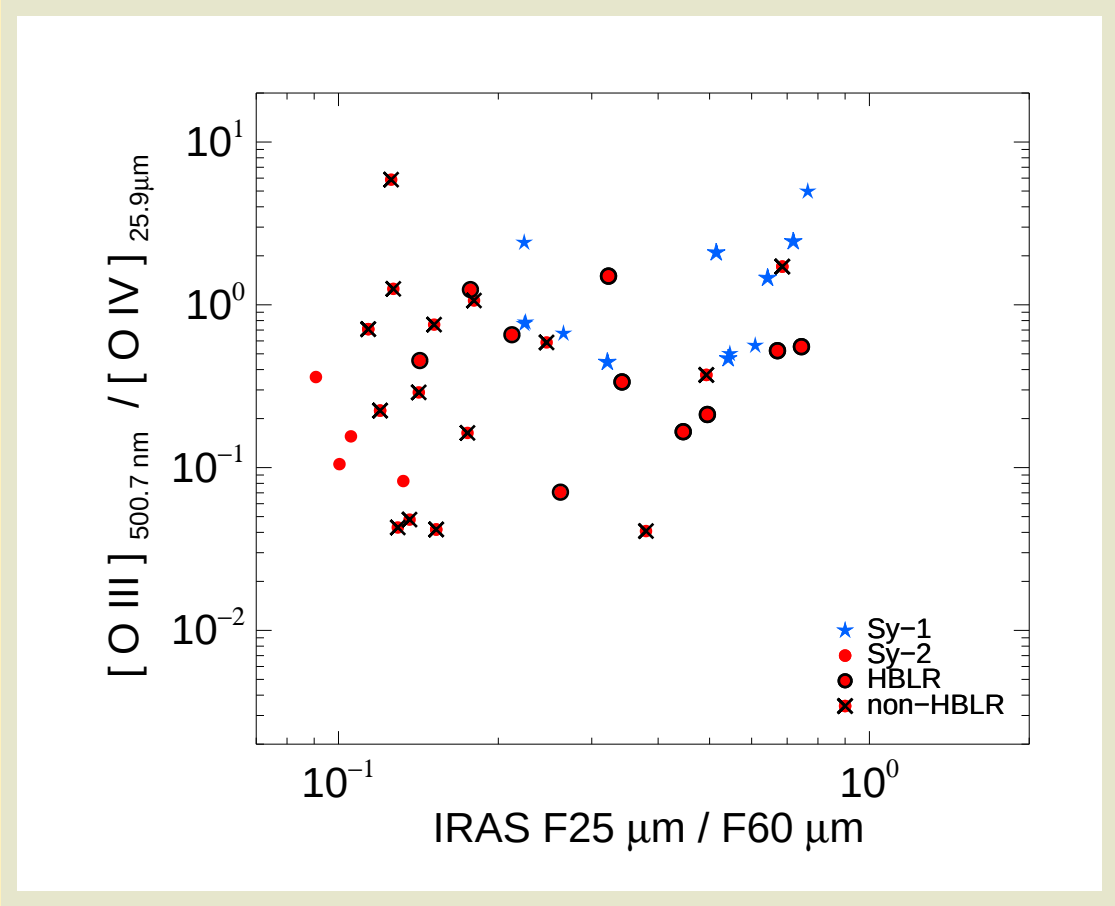
$\rightarrow$ central [O III] $\lambda 500.7\,\mathrm{nm}$ absorbed ($A_V > 3$), not isotropic !

f) Seyfert galaxies [O III] $\lambda 500.7\,\mathrm{nm}$ / [O IV] $25.9\mu\mathrm{m}$

from CfA & 12μm samples:

radio-quiet,

low AGN luminosity,



- **Sy-2: [O III] / [O IV] lower than in Sy-1**
- also for Sy2 with no spectropolarimetric hidden BLR detection:

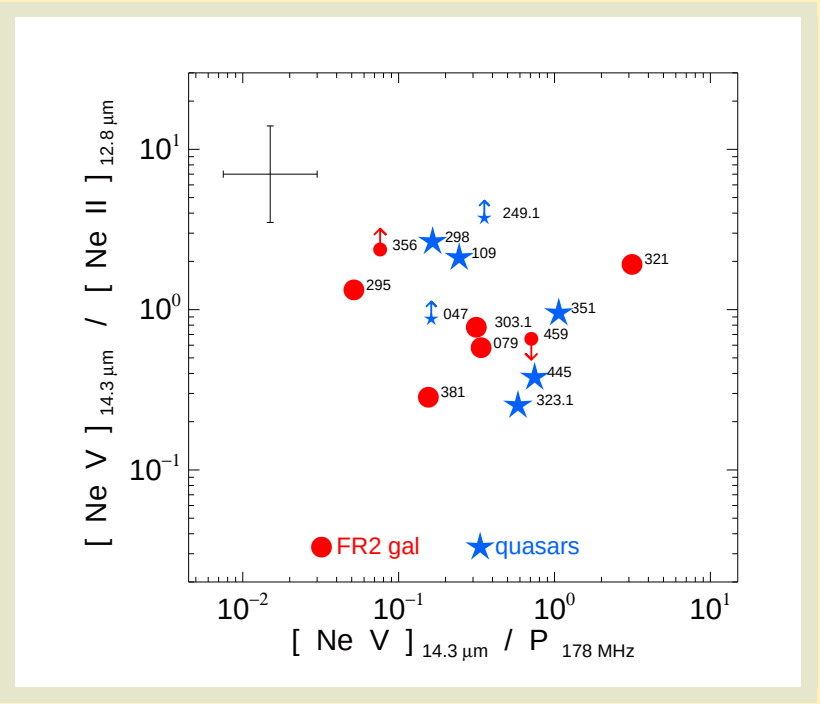
$\rightarrow$ AGN in HBLR and non-HBLR similar *(Haas & Huchra, in prep.)*

Spitzer IRS spectra of powerful 3CR galaxies & quasars

Conclusions at z $<$ 1:

- SSQ: jet contribution to MIR low
- silicate absorption & emission
- similar AGN-line/radio power
- AGN typical NeV/NeII
- OIII/OIV: optical NLR absorbed in AGN-2

$\rightarrow$ **evidence for the unified model at z $<$ 1**



Outlook at z $>$ 1:

- Complete 3CR has 63 sources at z $>$ 1, epoch of peak cosmic activity
- **Spitzer** 3-24μm maps *(PI Fazio)* + IRS spectra of 20 brightest *(PI Haas)*
- **Herschel** OT Key project planned *(PIs Haas, Barthel, Wilkes + 30 Co-Is)*: **UniQuE** = **Unification** in the **Quasar Era** at 1 $<$ z $<$ 4