AGN-induced heating in the cores of low-redshift 3CRR galaxies

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The 3CRR *Spitzer* low-*z* project

- Image all 3CRR radio galaxies in *z* < 0.1 (35 objects) in seven *Spitzer* imaging bands (3.6, 4.5, 5.8, 8.0, 24, 70, 160 μm)
- Dissect the structures into core + galaxy + other components
- Basic questions
  - Does the core IR output correlate with source core or total radio power (timescales of core variability)?
  - Are the AGN spectra composite (multi-component dust, non-thermal)?
  - Do the galaxies show any IR colour peculiarities (fuel)?
  - Any non-core IR components (jets, hotspots)?
  - Any clues about cold environment effects on structure?

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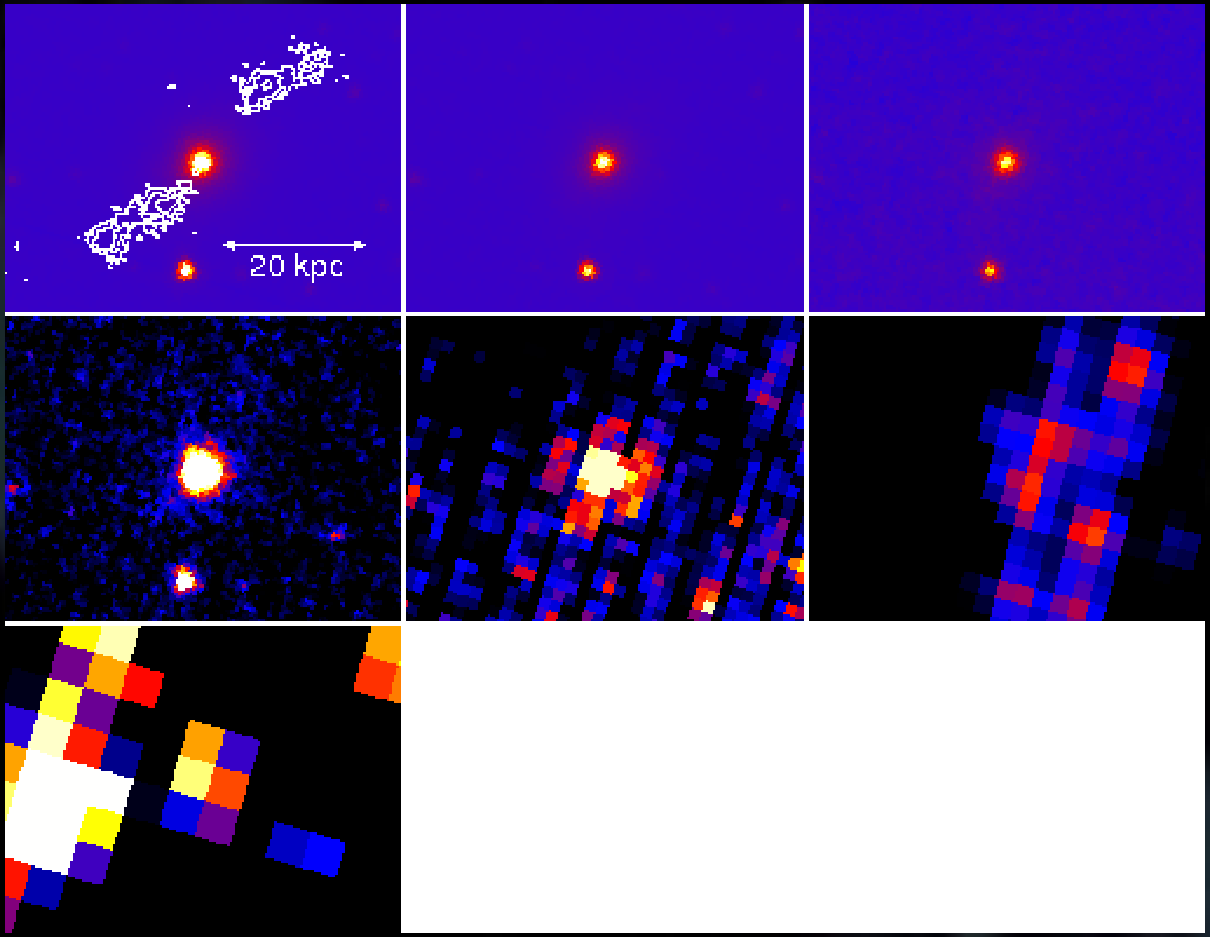
IR images in seven bands



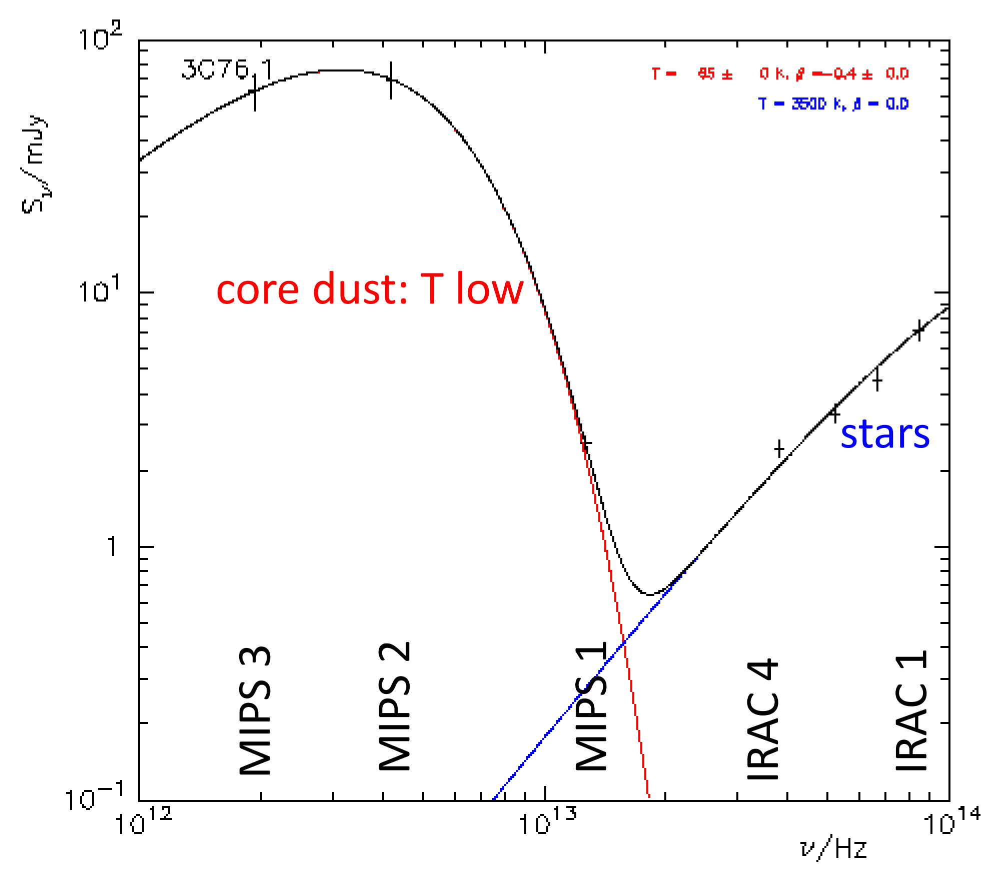
IRAC1-3

IRAC4
MIPS1-2

MIPS3

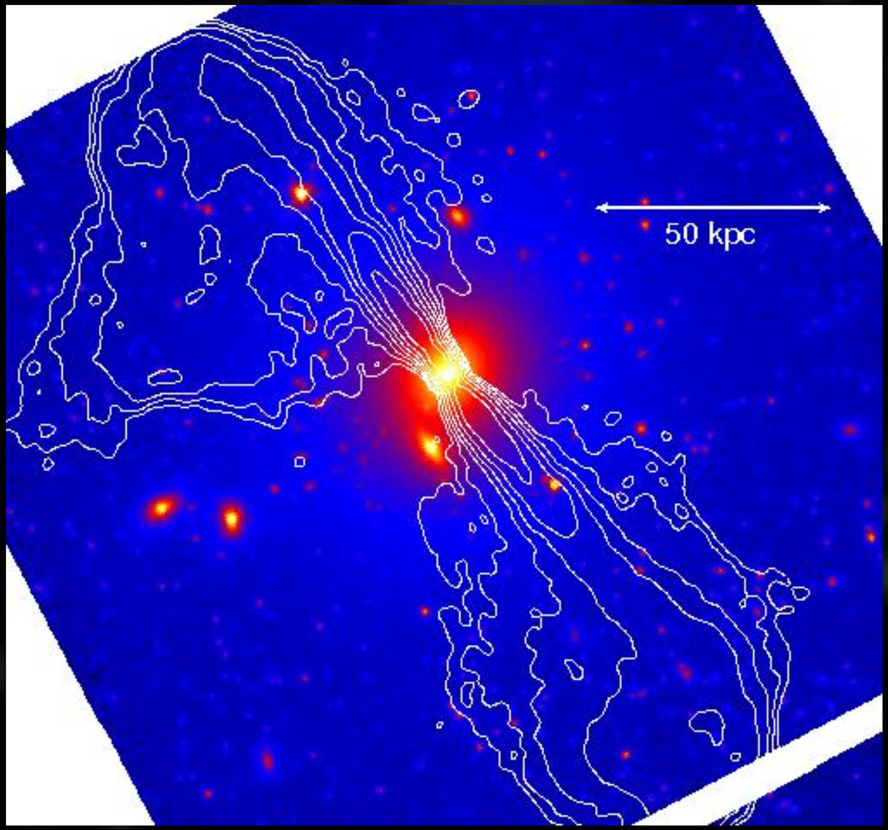
3C 76.1: **typical** image depths and qualities

IR flux densities in seven bands

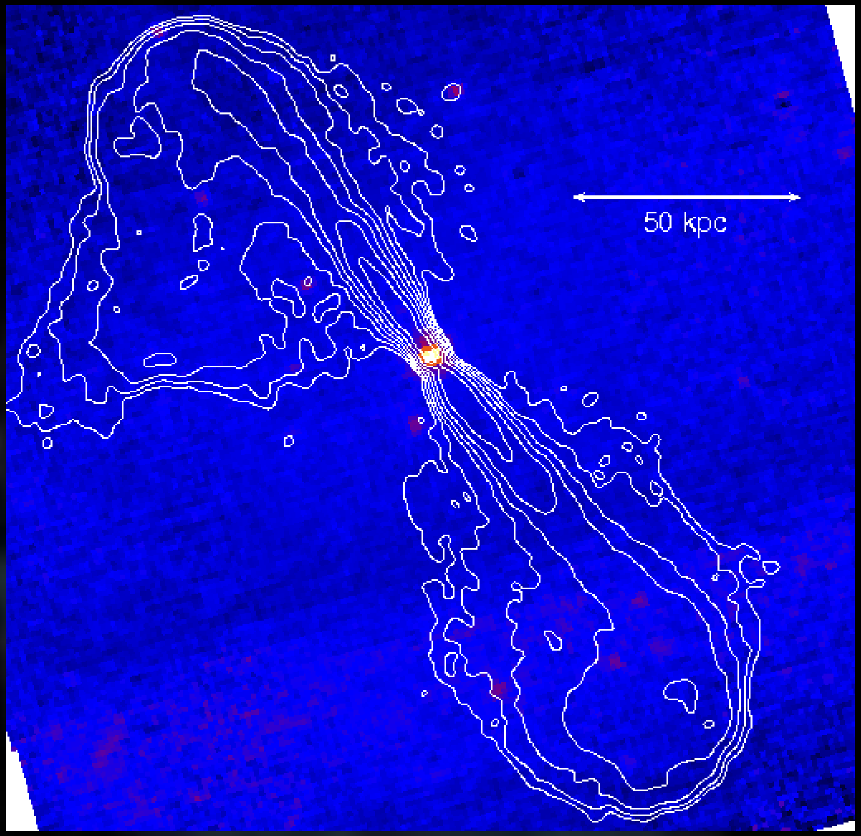


3C 76.1: **total** flux densities, representative fit

IR emission from 3C 296



IRAC1 (3.6 μm): galaxy dominates



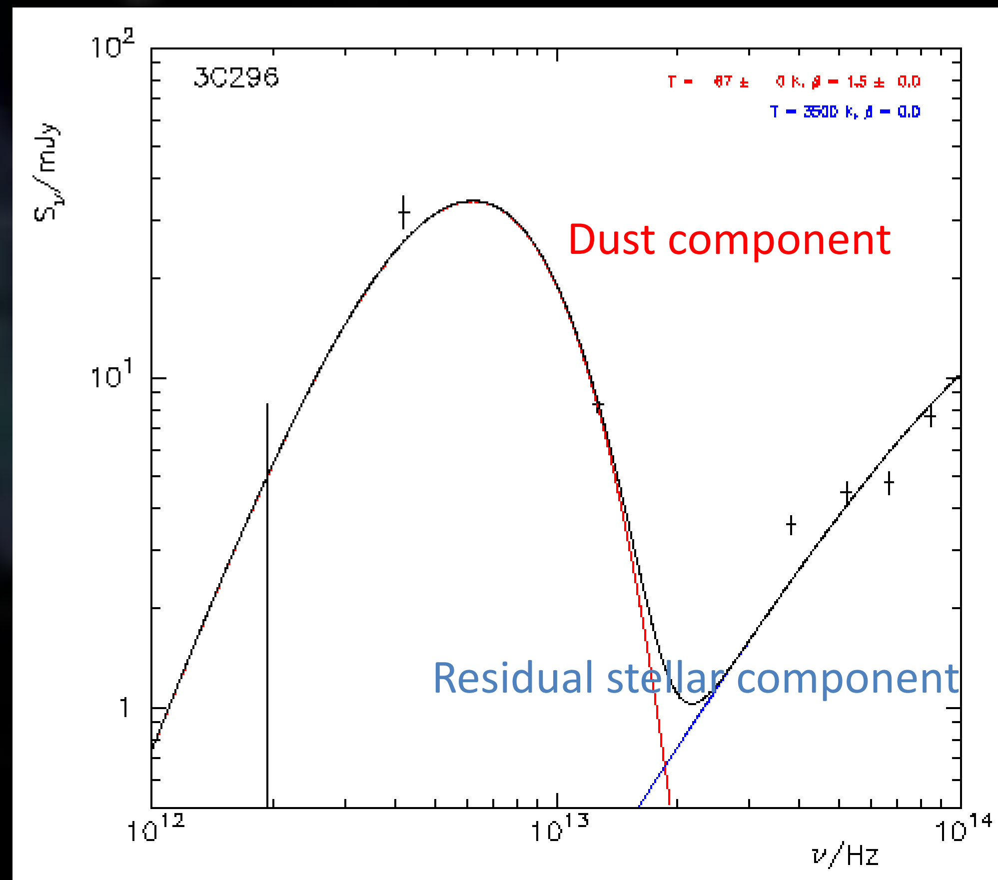
MIPS1 (24 μm) : core dominates

IR emission from 3C 296

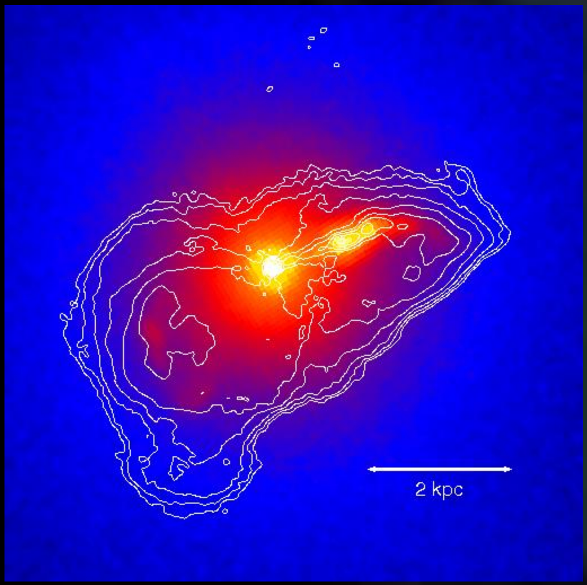
3C 296 (z = 0.0237)

Core IR flux densities (after image fitting)

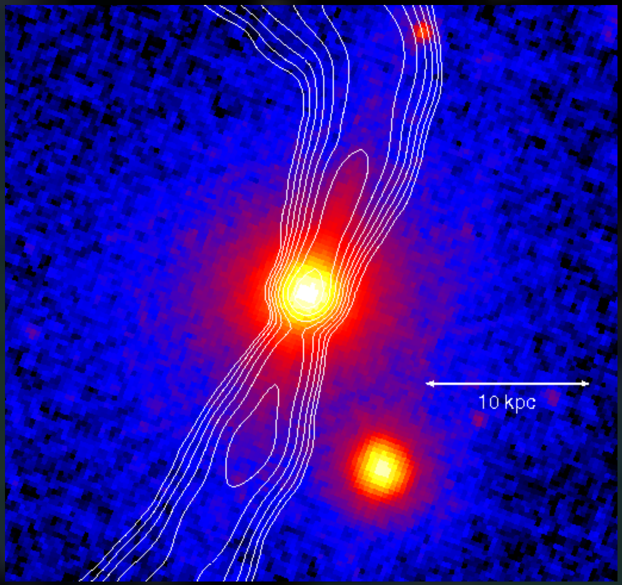
Simple case: stellar core in IRAC bands (< 10% of total galaxy); dust in MIPS bands, $T_{dust} \approx 70$ K, dust spectrum normal in shape.



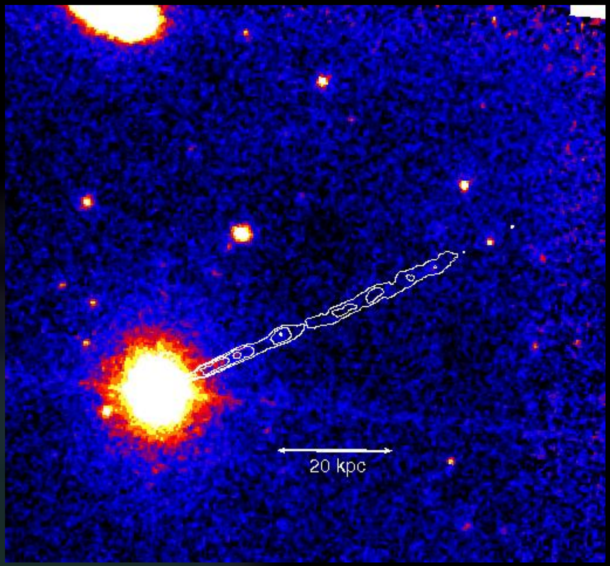
IR jets



M 87: IRAC4 (8 μm)



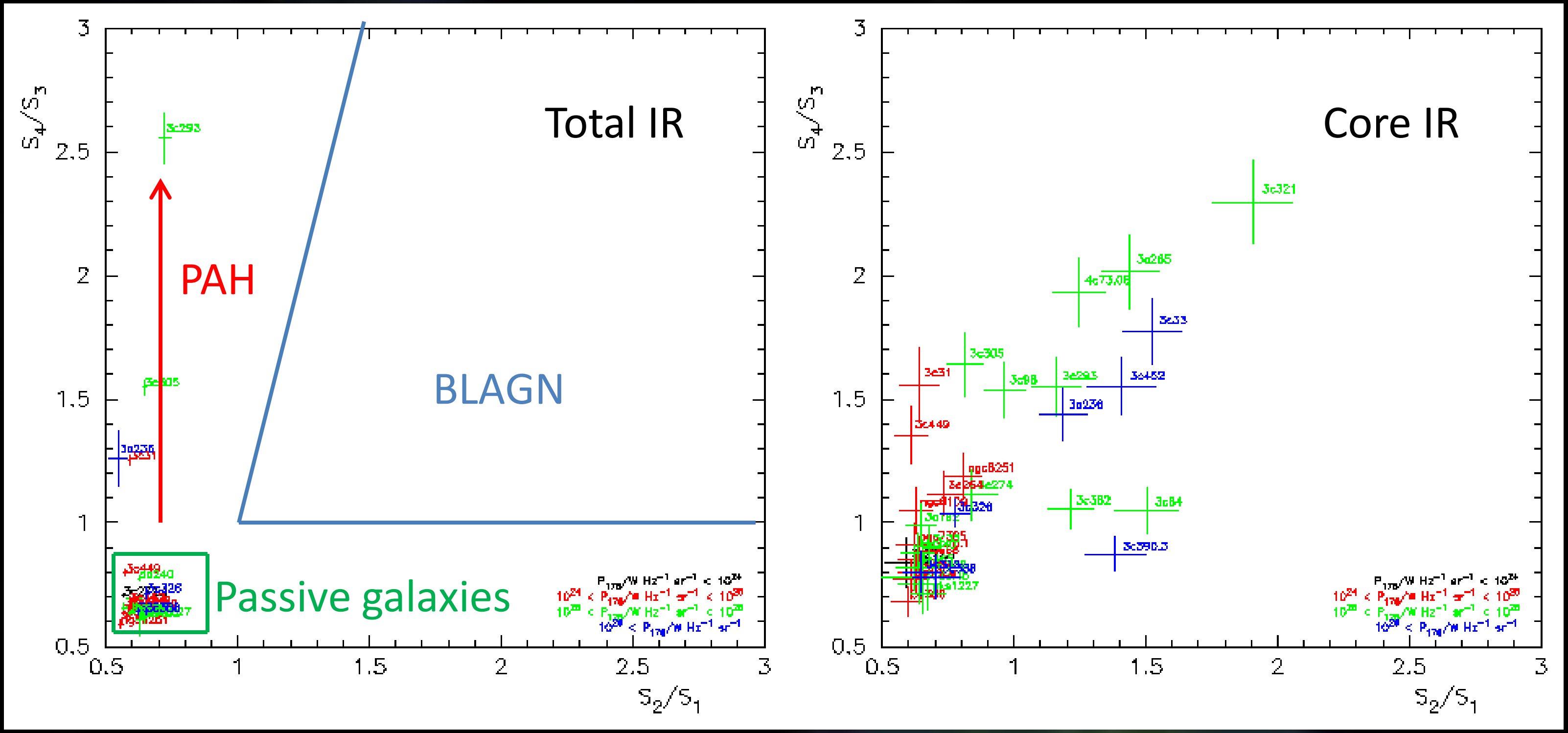
3C 31: IRAC4 (8 μm)



NGC 6251: IRAC4 (8 μm)

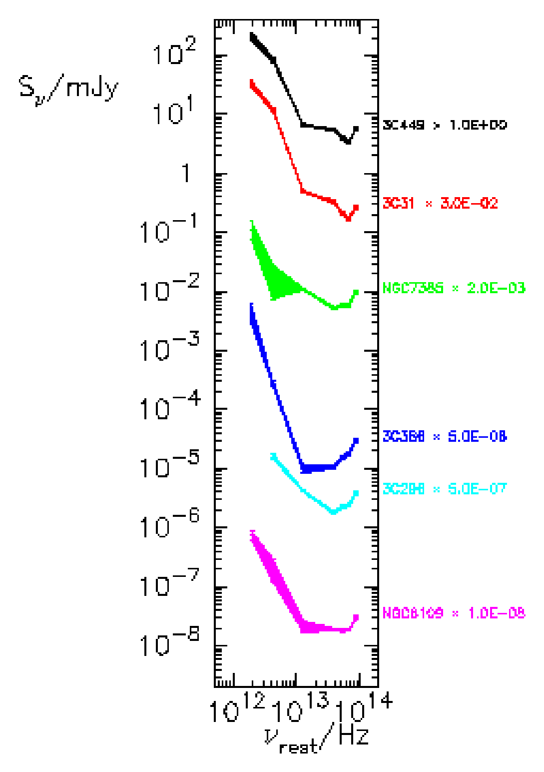
Synchrotron emission. IR jets < 10 kpc long. NGC 6251 is exceptional, jet IR to > 50 kpc.
Jet contrast against stellar emission usually low (resolution).

IRAC colours

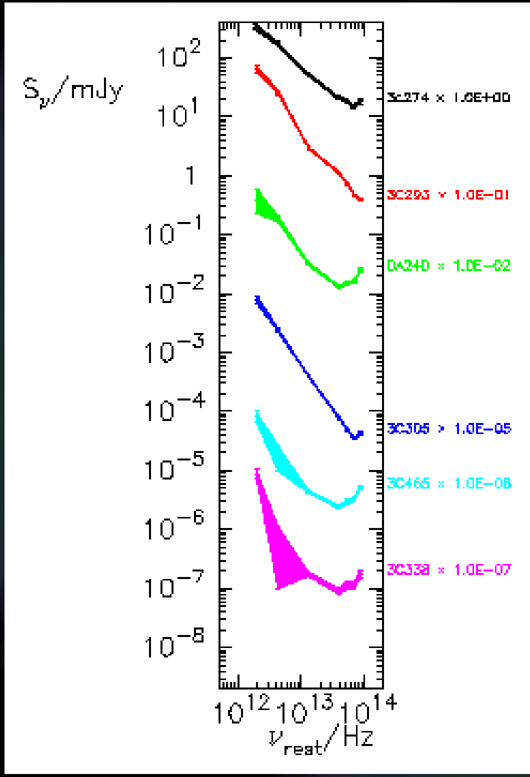


Total light: low-*z* 3CRR within envelope of normal galaxies. Core light: weak indicator of AGN activity (resolution). Selection regions based on Stern *et al*. (2005). High-*z* active galaxies lie in BLAGN sector (Seymour *et al*. 2007).

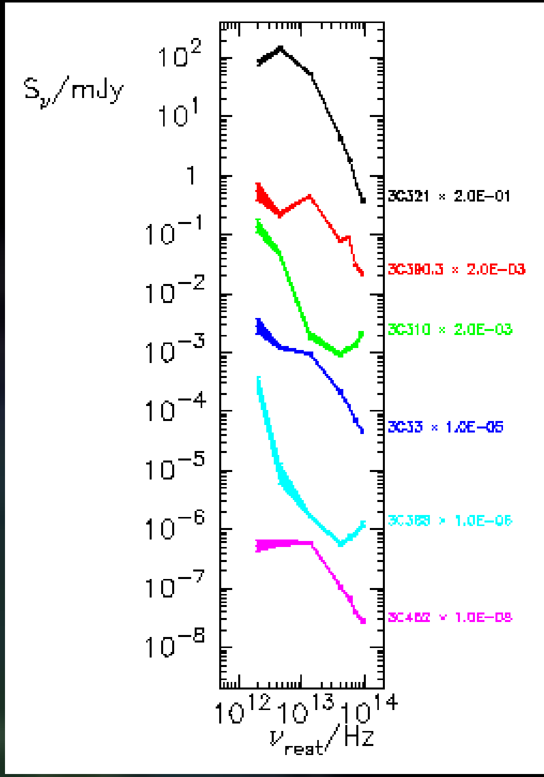
IR emission: core spectra



Low P_{178}



Medium P_{178}



High P_{178}

P_{178} increases down. Low power: residual starlight + cold dust.

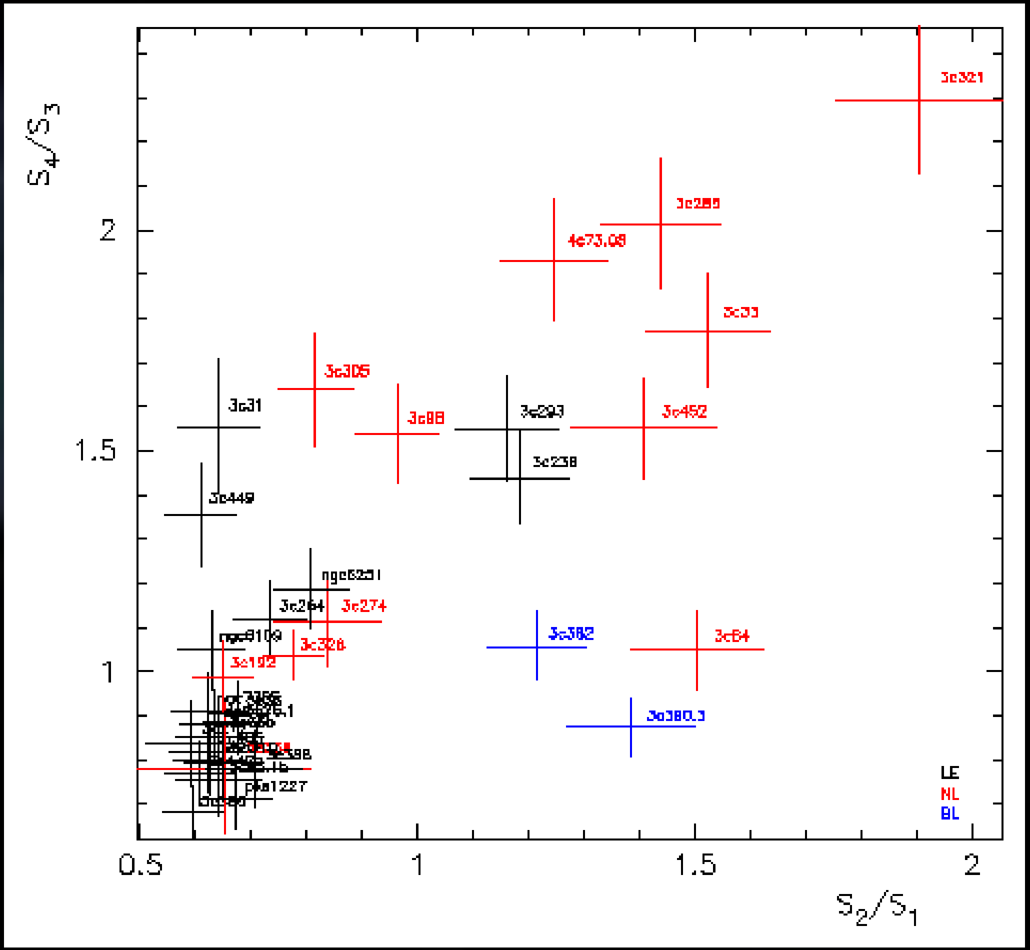
Higher power: more and hotter dust emission.

Little/no synchrotron (quasars, not RGs – Cleary *et al*. 2007).

IRAC colours: cores

Strong narrow or broad optical emission lines correlate with distinct IRAC colours in most cases, with 15% of line-emitting objects indistinguishable.

3.6 – 8 μm colours find mostly radio galaxies with strong emission lines.

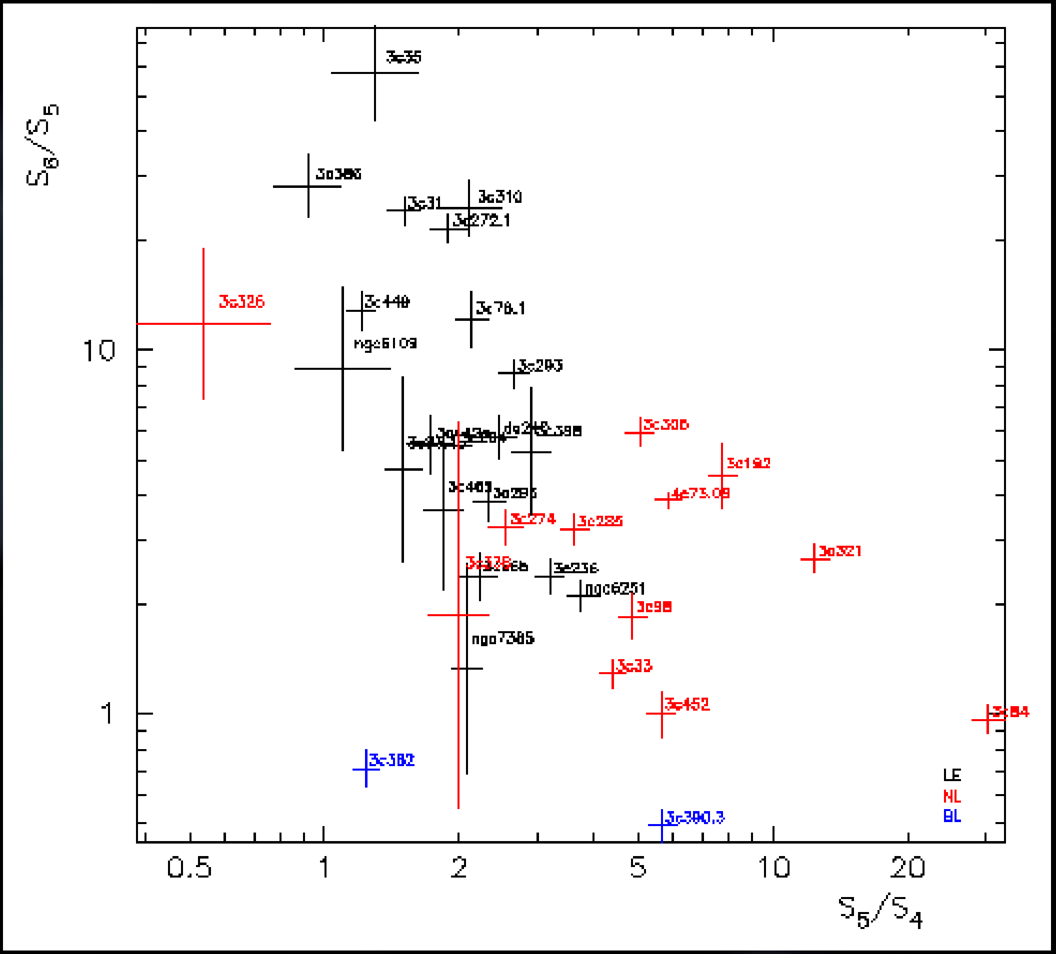


IRAC + MIPS colours: cores

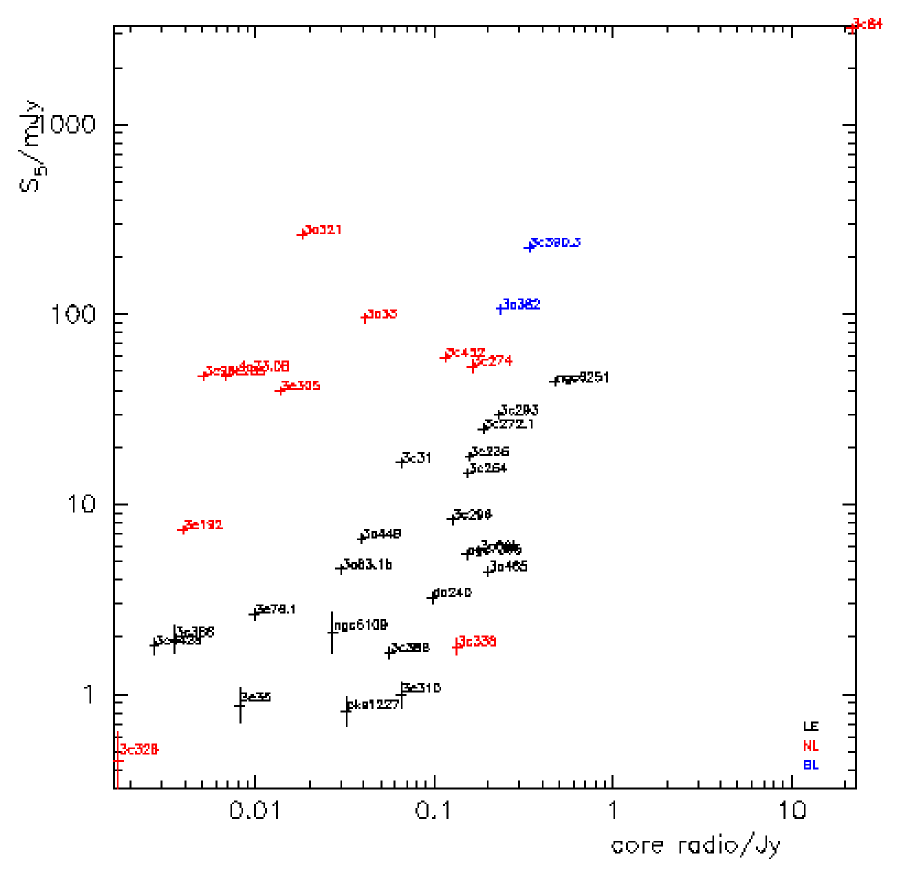
Line-emitting classes better separated in the 70 µm/24 µm vs 24 µm/3.6 µm colours.

Cold dust objects are mostly low-excitation. Hot dust objects are stronger line emitters.

3C 326 anomalous – but core ID uncertain.

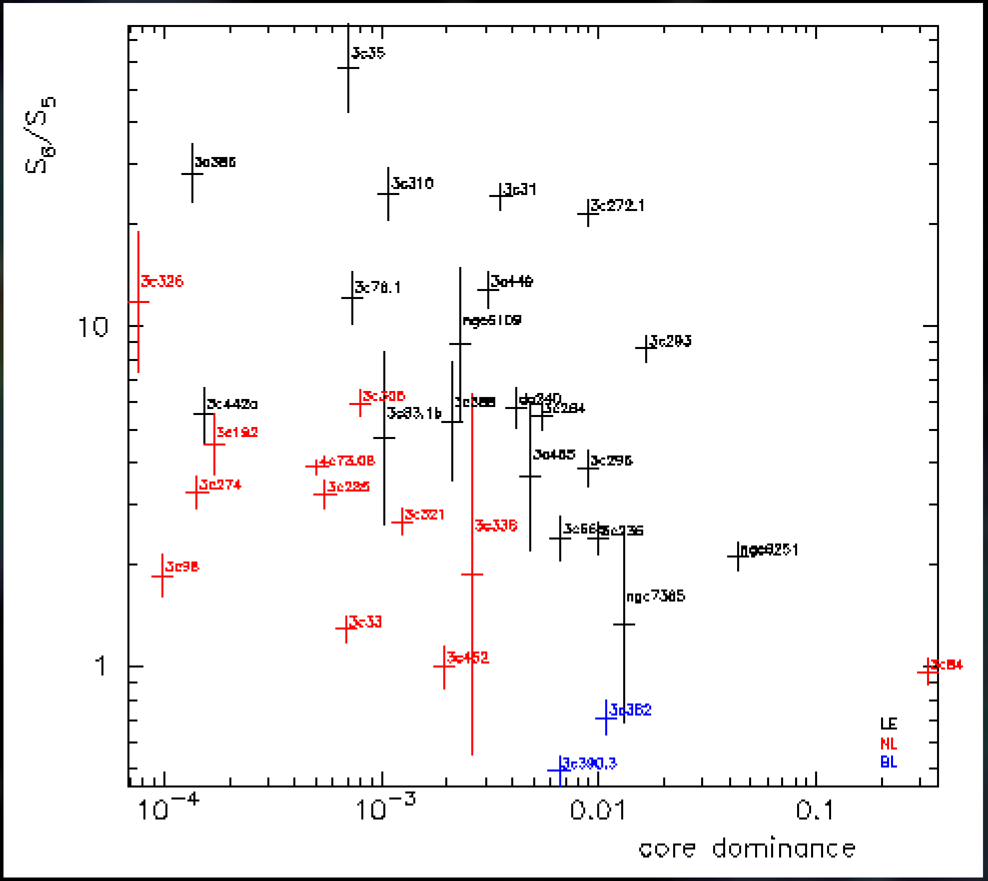


Core IR/radio correlation



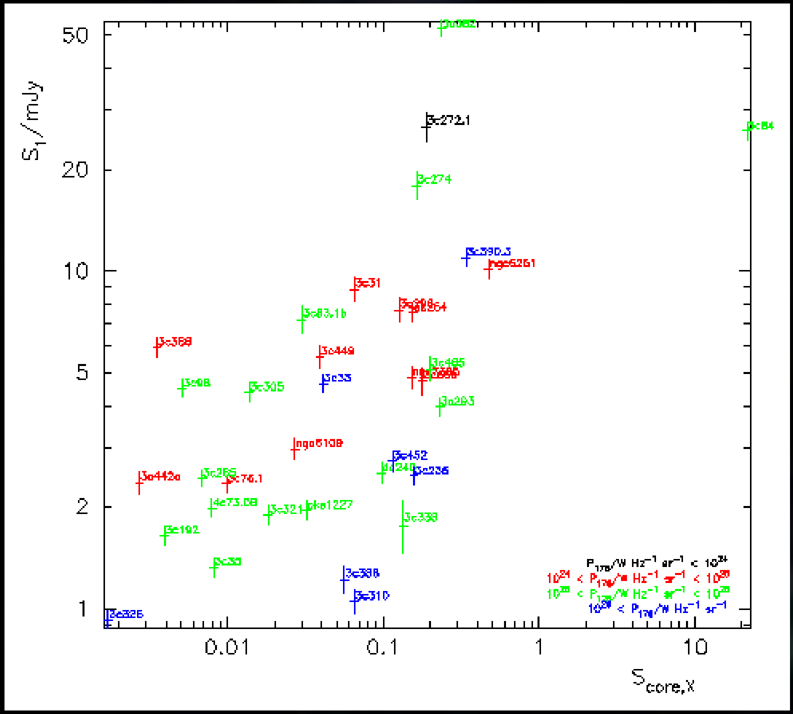
MIPS 24 μm flux density correlates with core flux density, with 10 × more IR in NL/BL than NE objects: warm/hot dust.

Dust and core dominance

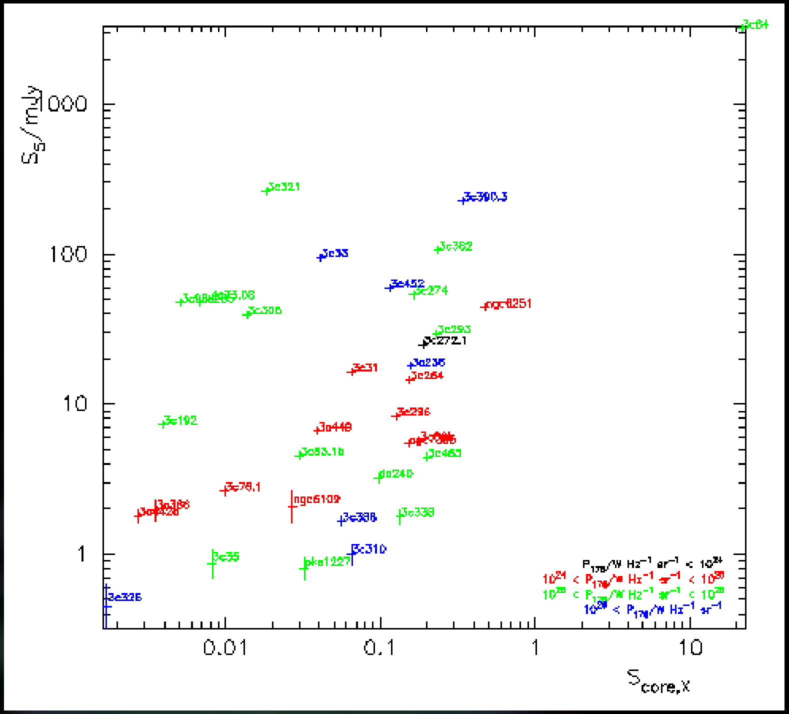


MIPS colours (dust dominated) are weak function of radio core dominance, but strongly related to line-emitting type.

Core IR/radio correlation



IRAC1 (3.6 µm)



MIPS1 (24 µm)

No obvious core radio/IR correlation. Core radio is only slightly better predictor of core IR than total radio flux density. Powers show meaningless correlation induced by *z*.

Questions

Does the core IR output correlate with source power (timescales)?

- **Yes** – distinct differences in spectra at $\lambda > 24$ μm
- Core type steady on timescale of core dust cooling

- **No** - IR component not well correlated
- Outer material for future activity or star formation seems to weakly related to non-thermal emission

Questions

Are the AGN spectra composite (multi-component dust, non-thermal)?

- **Yes** – hot dust component + cold dust + residual starlight
- Hot dust component increases in power with radio core power

- No non-thermal component is needed in the decompositions
- Cold component not closely related to core power

Summary

- IR spectra show progressive change as source power rises
  - All sources show strong dust continuum with T ≈ 60 K (basic material reservoir)
  - Higher-power sources add a hot component, T ≈ 300 K (calorimeter for core output)
  - Strength of hot component (integrated core output over Myr) related to current intantaneous core power
- IR jets, hotspots, gas interactions are seen
- IRAC integrated colour-colour diagrams miss some or many low-power sources: even after core/galaxy separation