The AGN Component in Deep Radio Fields

Current understanding & LOFAR perspectives

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I - Modeling the sub-mJy sources

EXCESS @ S<1 mJy

Classical RL-AGNs → PLE

→steep/flat *(e.g. Dunlop & Peacock 80)*

→FRI/FRII *(e.g. Willott+ 01, Clewley & Jarvis 04, Sadler+ 06)*

SF gals. → PLE

→ local F(L) + L ~ $(1+z)^p$ p~3

(e.g. Condon 89, Saunders+ 90, Machalski & Godlowski 00, Yun+ 01, Sadler+ 02)

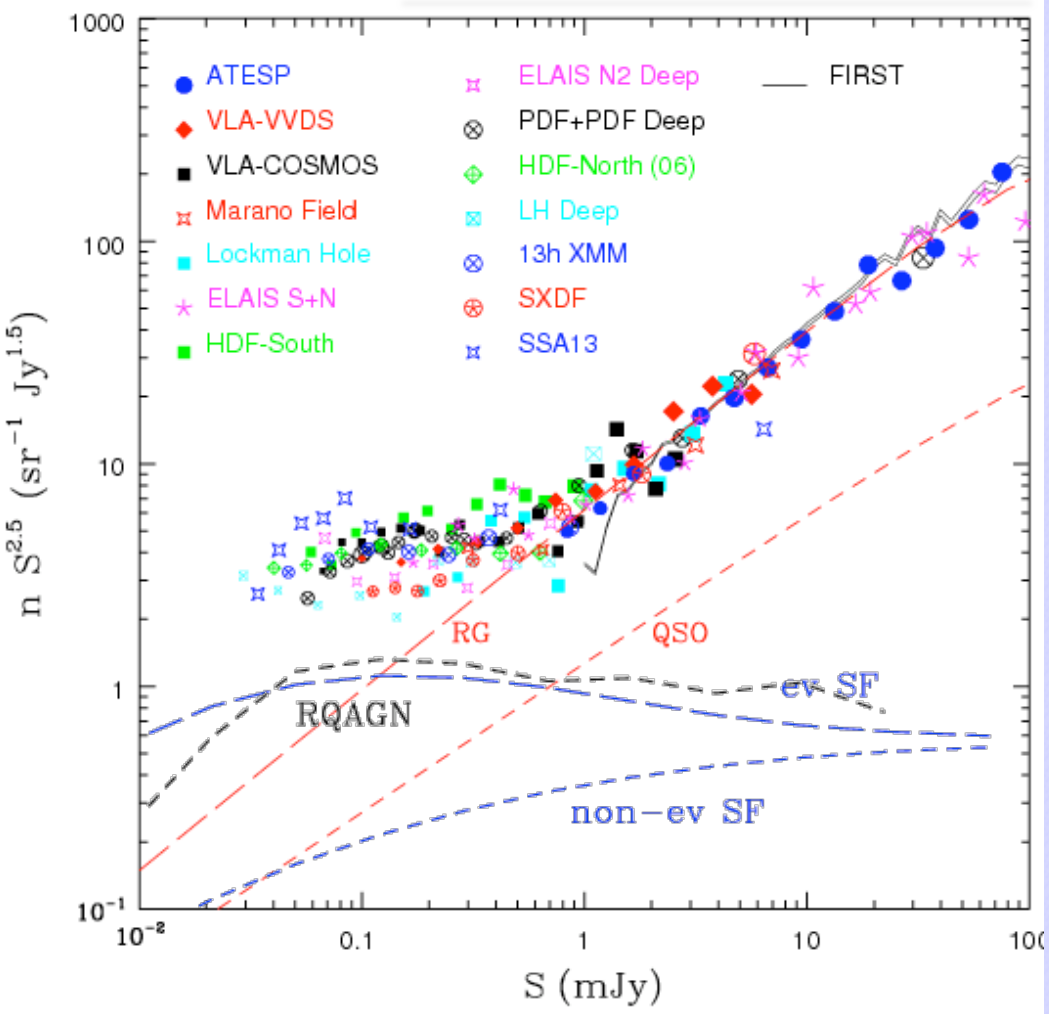
RQ-AGN: (*Jarvis & Rawlings 04*)

→LDDE [largest comp. at z<1

RS →compact & steep (<<10 kpc)
22< logP <24

host galaxy → (em. line spectrum)

1.4 GHz Source Counts



I - SCIENCE DRIVERS

- SFGs → SF History (z>2) (Dust-enshrouded obj)
- AGNs → BH Accretion History (Type II AGNs)
  - low/high accr. rates → FRI vs. RQQ [Radio vs.QSO mode] AGN feedback
  - RQ/RL dichotomy
  - Ev. Of LLAGNs: Downsizing? LLAGNs peak at lower z? [NB: as recently found for opt/X-ray AGNs]
- Connection between SFH & MBH accretion

II - The AGN component @ S< 1mJy

ATESP-DEEP1 Sample:115 RS with S>0.4 mJy in 1 sq. degr.

Radio Power Distribution: (DEEP1abc)

- ETS → 10^{23-25} W Hz^{-1}

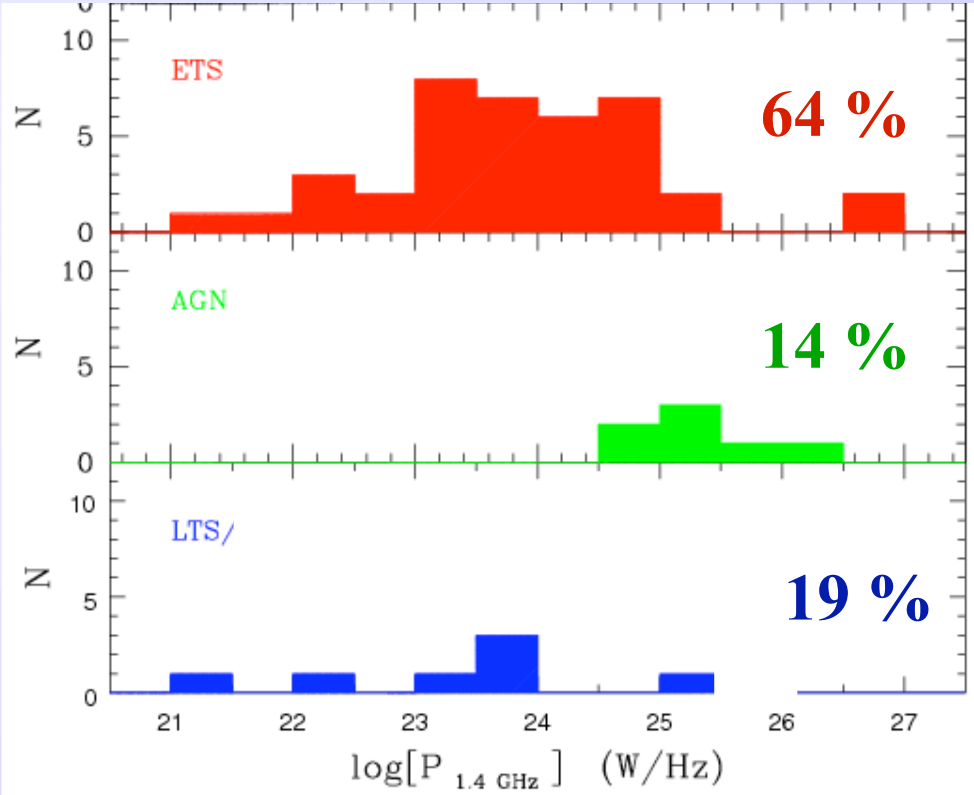
  Low-intermediate power AGNs

- QSO → P < 10^{25-26} WHz^{-1}

  RI-QSOs [RQ-QSOs: 22<logP<24]

- LTS → 2/3 P < 10^{24} W Hz^{-1}

  Star-forming gals



(Mignano,IP+ 08)

→Sample largely dominated (78%) by AGN activity

→AGNs: mostly associated to abs. systems (FRI-like)

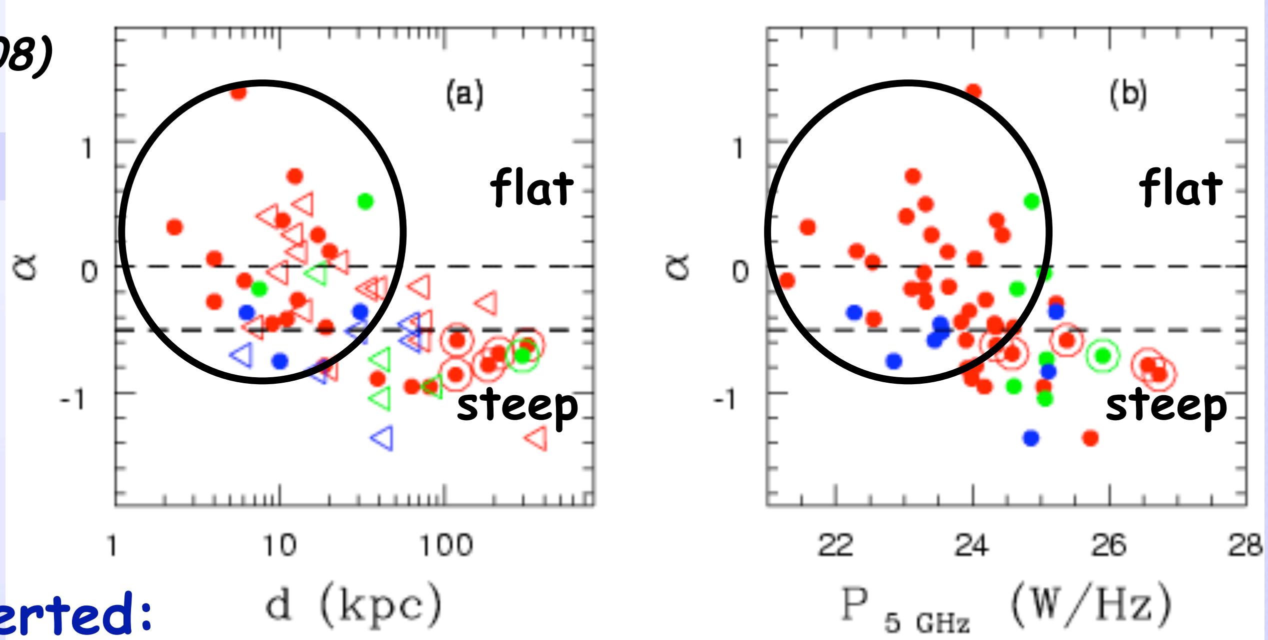
II - Flat spectrum ETS

(Mignano, IP+ 08)

• AGN • ETS •LTS/SB

◁ Upper limits

⊙ Double/Extended RS



In DEEP1abc:

24/39 ETS are flat/inverted:

- $P_{5\,GHz} \sim 10^{22-24}$ W Hz^{-1} (+ ETS spectra)
- Typically compact (<10-20 kpc) (+ flat) ➔

FRI larger & steep
core-dominated FRI?
[base-jet emission]

eg. Falcke & Biermann 99

- Beamed component of FRI (BLLac) ?
- ADAF-ADAF+jet systems? (local LLAGNs)
- Obscured flat-spectrum RQ-AGNs ?

II - AGN Component in FLS

First Look Survey (FLS)
[area ~ 4 sq. degr.]

Multi-band information:

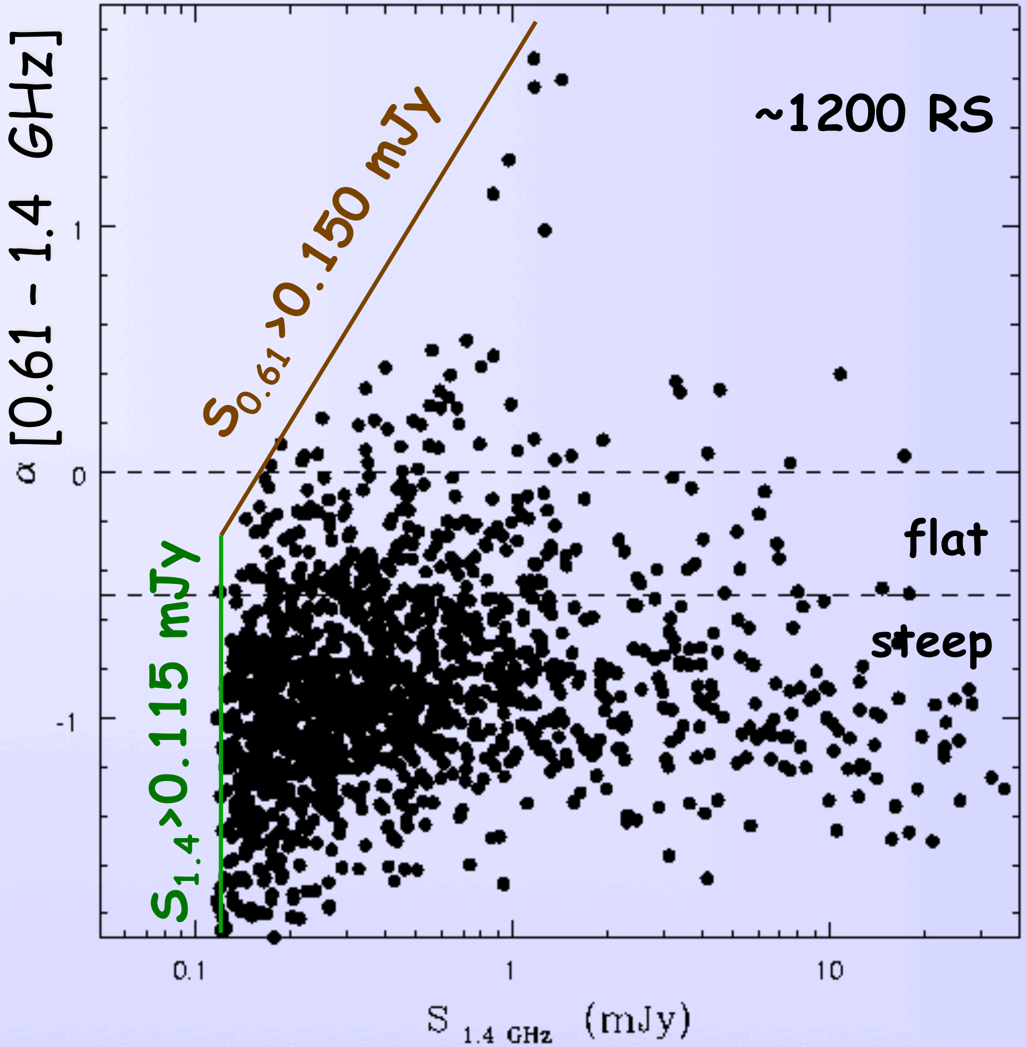
- 1.4 GHz → VLA/WSRT
- 0.61 GHz → GMRT
- 3.6, 4.5, 5.8, 8, 24, 70, 160 μm
  → Spitzer IRAC/MIPS
- opt. spectra → MMT Hectospec
  [330 RS]

→ Spectral index α(0.61-1.4)

→ MIR-Radio correlation

→ MIR Color-Color plot

→ Redshifts & Spectral types



Prandoni, Morganti+ in prep

II - AGN Component in FLS

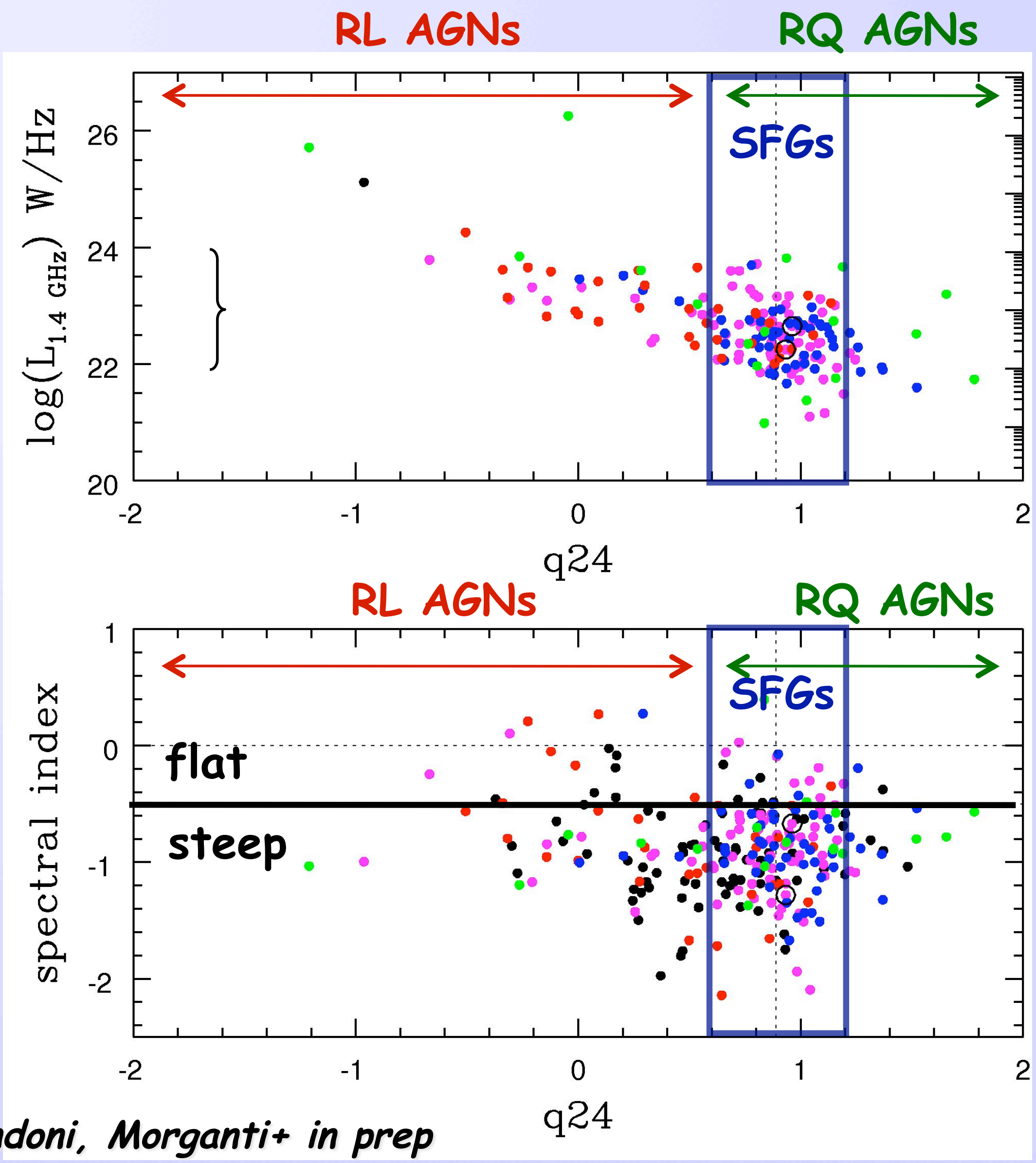
→**MIR-Radio correlation:**

q24=log(S24/S1.4)=0.83±0.31
for SFGs (Marleau+07)

At $S_{1.4}$ >0.115 mJy
➔ Composite Population of
RL-AGN & RQ-AGN

optical spectral type:

- •Early Type (ETS)
- • Sy 1 & Sy2 (AGN)
- •Star Forming (SFG)
- • Narrow lines
- •Unclassified



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II - AGN Component in FLS

→**IRAC Color-Color diagram:**

$S_{8.0}/S_{4.5}$ vs. $S_{5.8}/S_{3.6}$

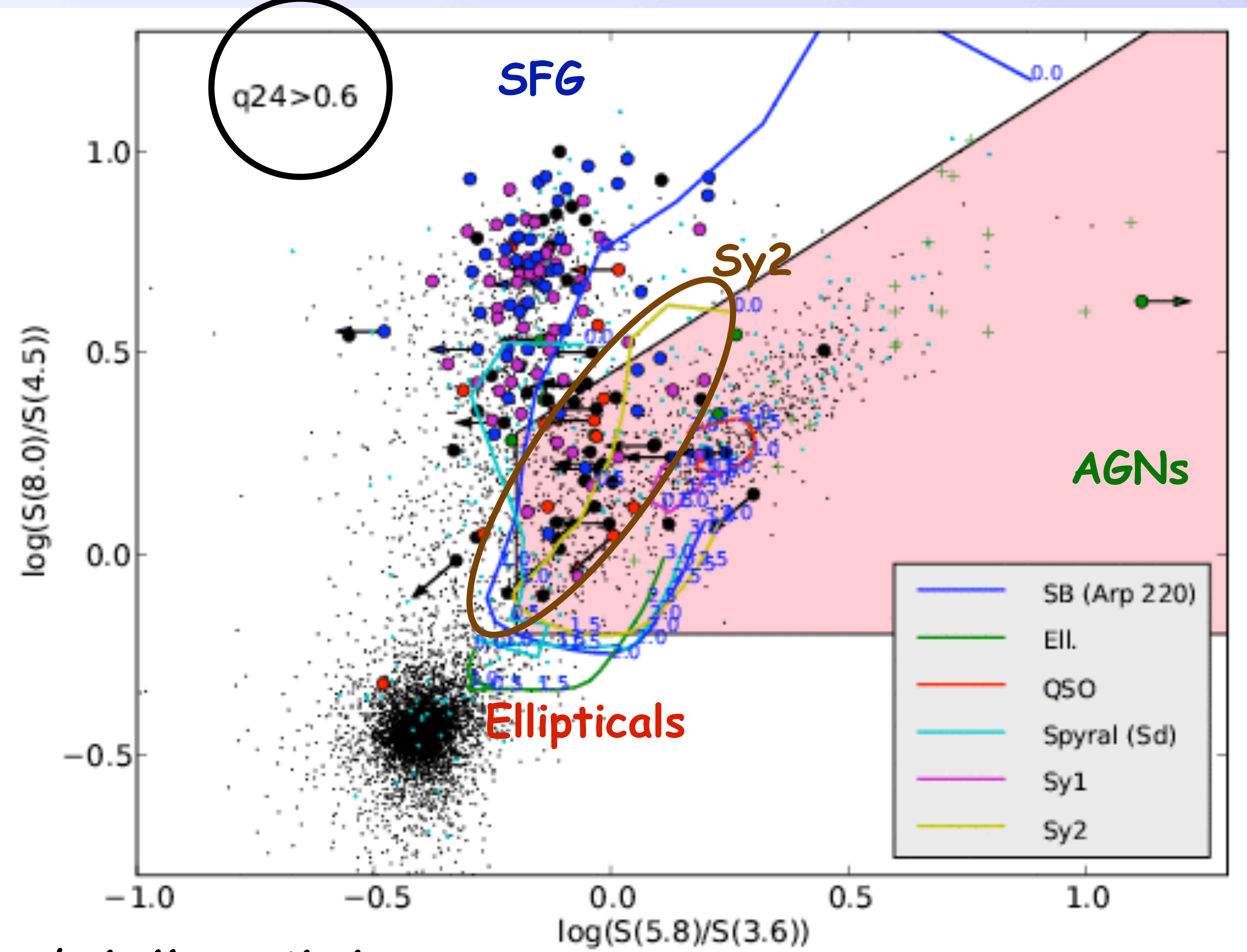
Sources with q_{24} >0.6:

➔Mostly have MIR colors typical of SFGs

➔ Some have MIR colors typical of AGNs

➔ Genuine RQ-AGN!

SFGs + RQ AGNs



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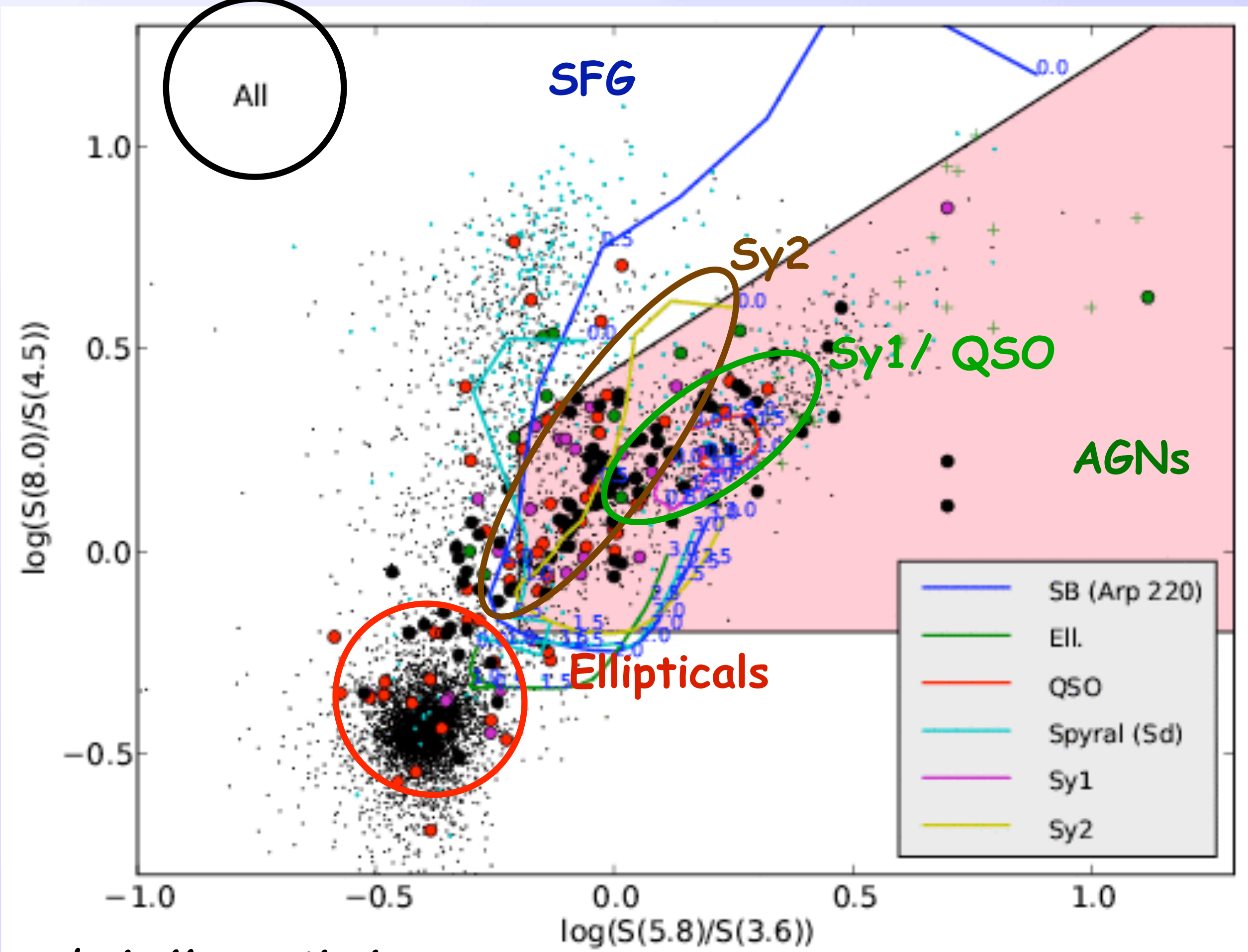
II - AGN Component in FLS

→IRAC Color-Color diagram:

$S_{8.0}/S_{4.5}$ vs. $S_{5.8}/S_{3.6}$

RL AGNs + RQ AGNs



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MIR properties of AGNs

- RQ-AGNs:
  - ➔ Mostly Sy2
- RL-AGNs:
  - ➔ Sy2, Sy1, QSO
  - + Ellipticals (FRI-like)

optical spectral type:

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II - AGN Component in FLS

→ IRAC Color-Color diagram: $S_{8.0}/S_{4.5}$ vs. $S_{5.8}/S_{3.6}$

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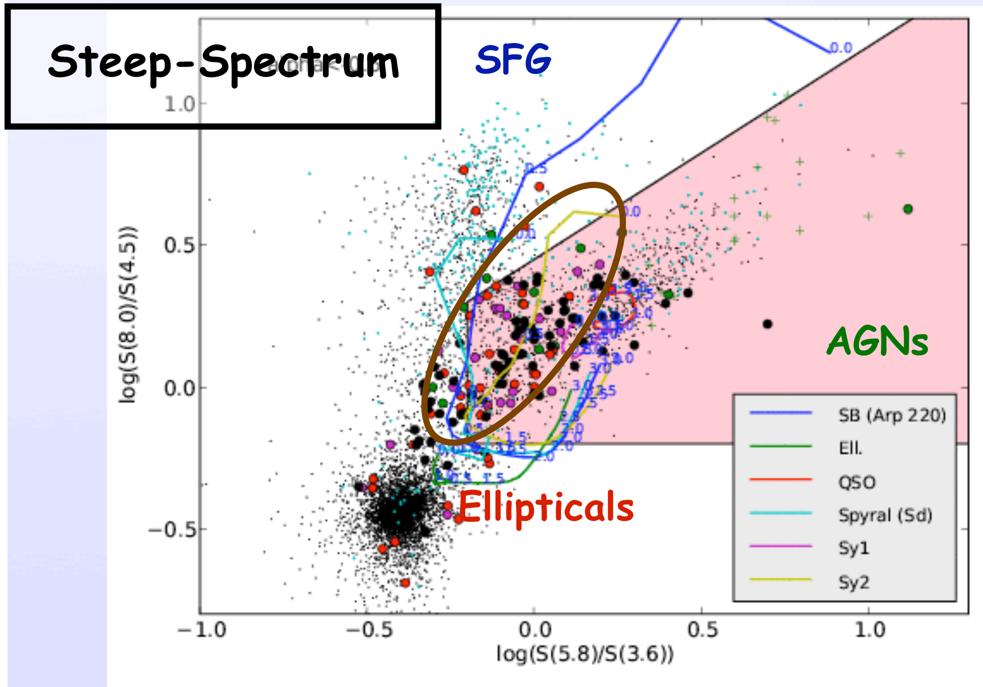
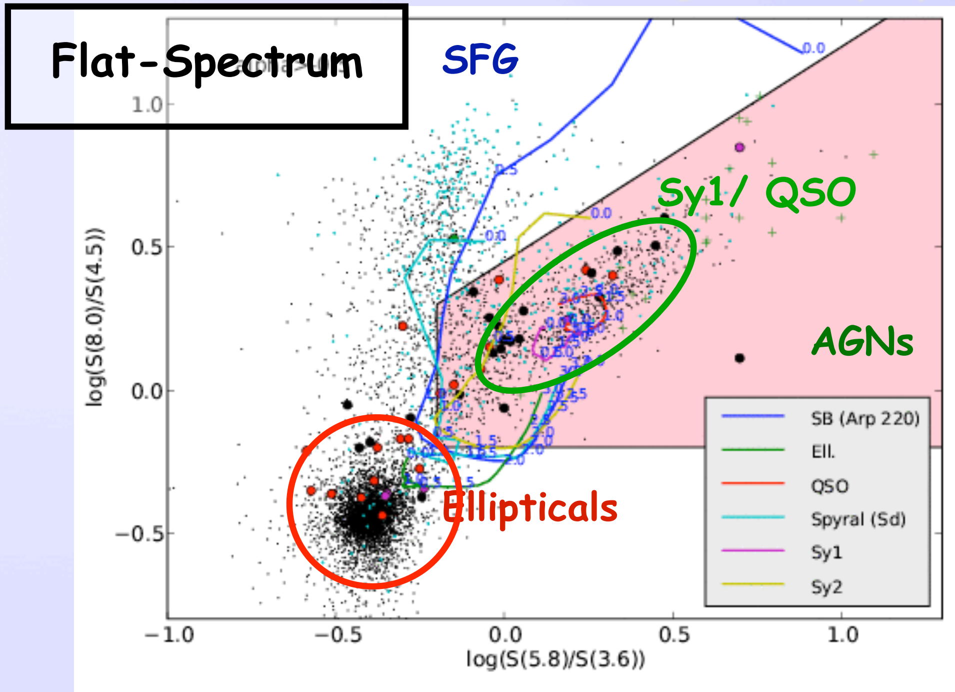




- Steep-spectrum:
  Mostly Sy2 plus Sy1, QSO

- Flat-spectrum:
  Mostly Sy1, QSO plus Ell.

➔ We find again a class of flat-spectrum AGNs associated to ellipticals!

II - Conclusions

1) Probing the RQ-AGN component

- At $S_{1.4}$>0.4 mJy (ATESP) no evidence of RQ-AGN component
- At $S_{1.4}$>0.1 mJy (FLS) RQ-AGNs emerge in significant numbers

RQ-AGN obs. properties:

- steep radio spectra;
- Sy2 opt. spectra/MIR colors

→Agreement with AGN Unification
→radiatively efficient systems

2) A class of flat spectrum (RL) ETS found in both samples

- ATESP: compact & low luminosity
- FLS: show no sign of AGN activity in both optical and MIR

→no obscuring torus?
→radiatively inefficient systems?
→Jet-driven kinetic feedback?

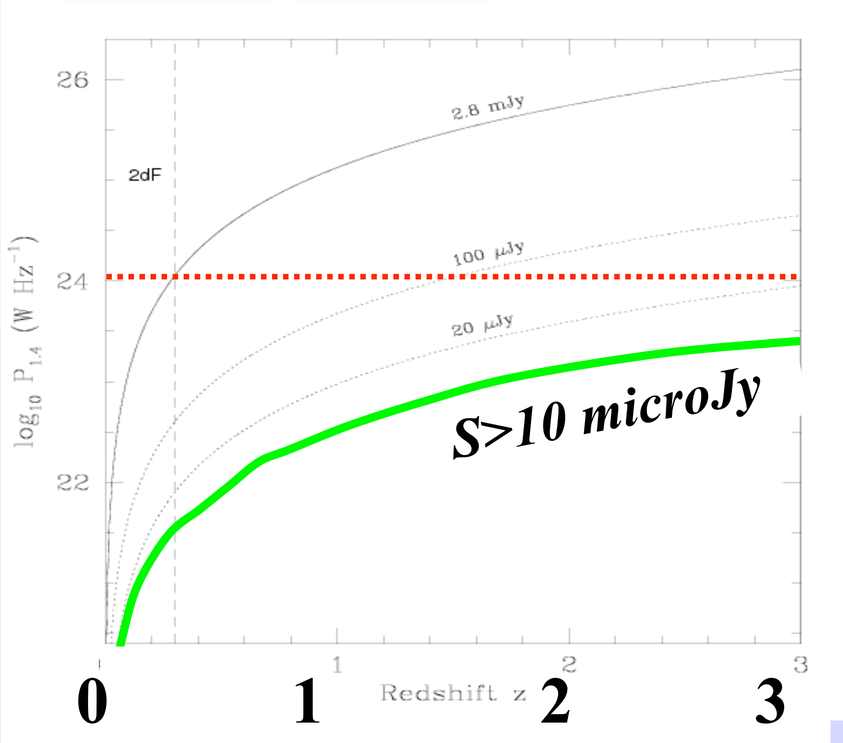
3) Multi-λ info is very important

III - Benefits of LOFAR

1. Large FoV → Tier 2 Deep Survey best suited to probe evolution of low-P AGNs (RL-AGN + RQ-AGN component)

→ constraints to AGN models for P< 10^{24} W/Hz @ z<4

240 MHz: 2 10^4 RS in PB [1.5 sq.deg.] @ 100-km LOFAR conf. limit of S>14 μJy



2. Low frequencies

→ steep sources (eg RQ-AGN)

→ Radio spectra in poorly explored freq. range

NB:Not only steep LLAGNs

For flat AGNs LOFAR 240 MHz deep fields as faint as current VLA deep fields

III- Benefits of E-LOFAR

• European bs increase resolution:

Max Baseline (km)	Freq. (MHz)	Angular resol. (")	Confusion Limit (3σ) (μJy)
150	240	2.4	13
500	240	0.6	5
1000	240	0.3	1

High spatial resolution important

→ separate SB and AGN

NB: sub-arcsec resolution →

AGN/SF morphology on kpc scales

➔ embedded AGNs in SFGs (cfr. eMERLIN → 0.15" @ 1.5 GHz)

→ Lower confusion limit (sensitivity limited surveys)

S_{lim}~1 μJy → factor 10 lower P @ same z