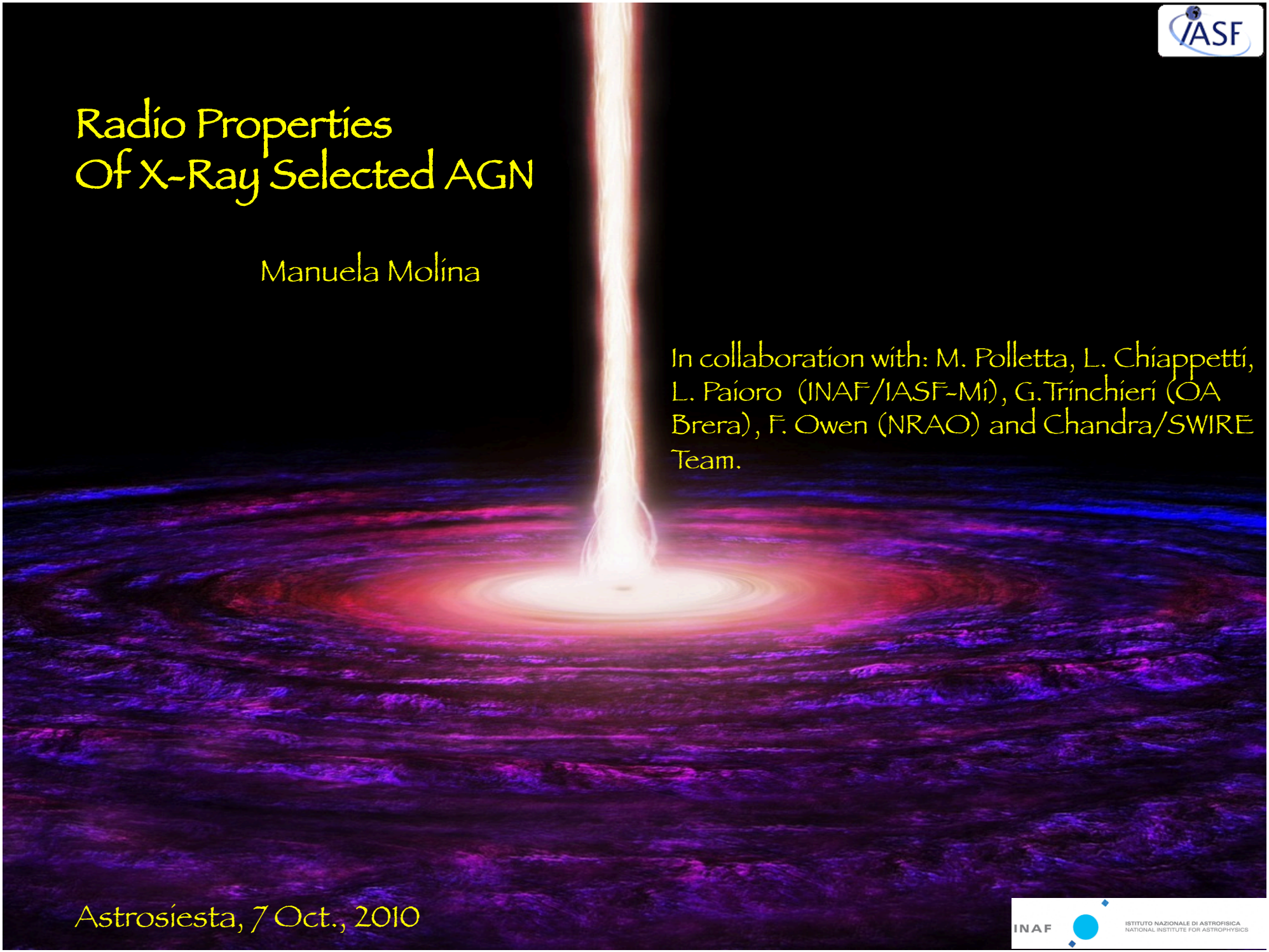


Radio Properties Of X-Ray Selected AGN

Manuela Molina

In collaboration with: M. Polletta, L. Chiappetti, L. Paioro (INAF/IASF-Mi), G.Trinchieri (OA Brera), F. Owen (NRAO) and Chandra/SWIRE Team.

Astrosiesta, 7 Oct., 2010

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

Talk Outline

THE DATASET

★ The *XMM-Chandra/SWIRE* Survey

★ Description of the *XMM* Sample

RADIO PROPERTIES OF THE XMM SAMPLE

★ Criteria for identifying AGN-driven radio activity

★ Fraction of sources with AGN-driven radio activity

★ Some examples of peculiar sources

SUMMARY & CONCLUSIONS

Open Questions & Objectives

AGN ⟺ Host Galaxy

AGN ⟺ Star Formation

⇒ **AGN FEEDBACK**

QUASAR or BRIGHT MODE ⇒

(e.g. Di Matteo+05)

- AGN driven emission from sources close to Eddington limit (EFFICIENT ACCRETION)
- X-ray bright sources

RADIO MODE ⇒

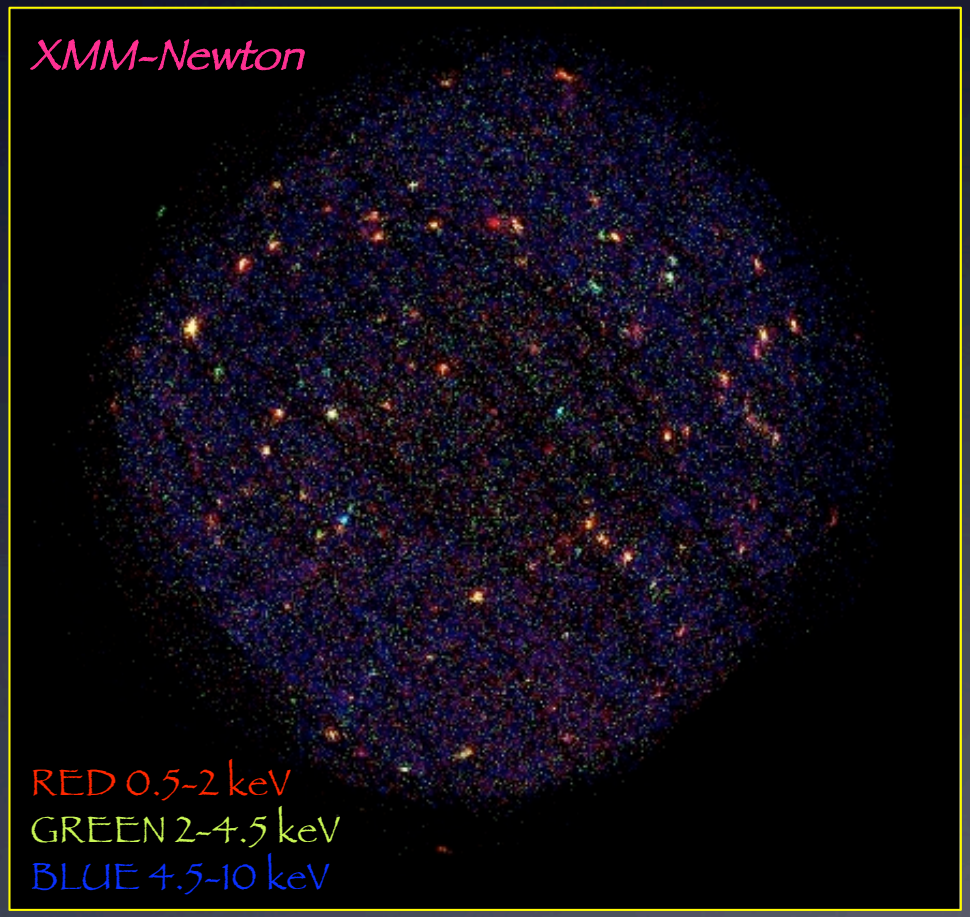
(e.g. Croton+06)

- Mechanical Origin
- INEFFICIENT ACCRETION
- Jets on small/large scales
- Outflows and winds

How to discriminate between Accretion Modes? ⇒

- X-RAY OBS. (ACCRETION)
- RADIO OBS. (JETS)

The *XMM-Chandra/SWIRE* Survey in the Deep *SWIRE* Field



The Deep SWIRE Field

- Lockman Hole North
- RA = 10^h45^m, DEC = 58°58′
- Area: 0.2 deg^2

The Multi-λ Data

- VLA @ 90 and 20 cm (12μJy@5σ)
- GMRT @ 50 cm
- MIPS @ 24, 70 and 160 μm
- IRAC @ 3.6, 4.5, 5.8 and 8.0 μm
- UH/UKIRT J, H, K
- KPNO Ugriz
- GALEX @ FUV (1500Å) and NUV (2500Å)
- *Chandra* @ 0.3-8 keV (3 bands)
- *XMM* @ 0.3-10 keV (5 bands)

(Polletta et al. 2006; Owen at eal. 2008; Wilkes et al. 2009)

The Sample

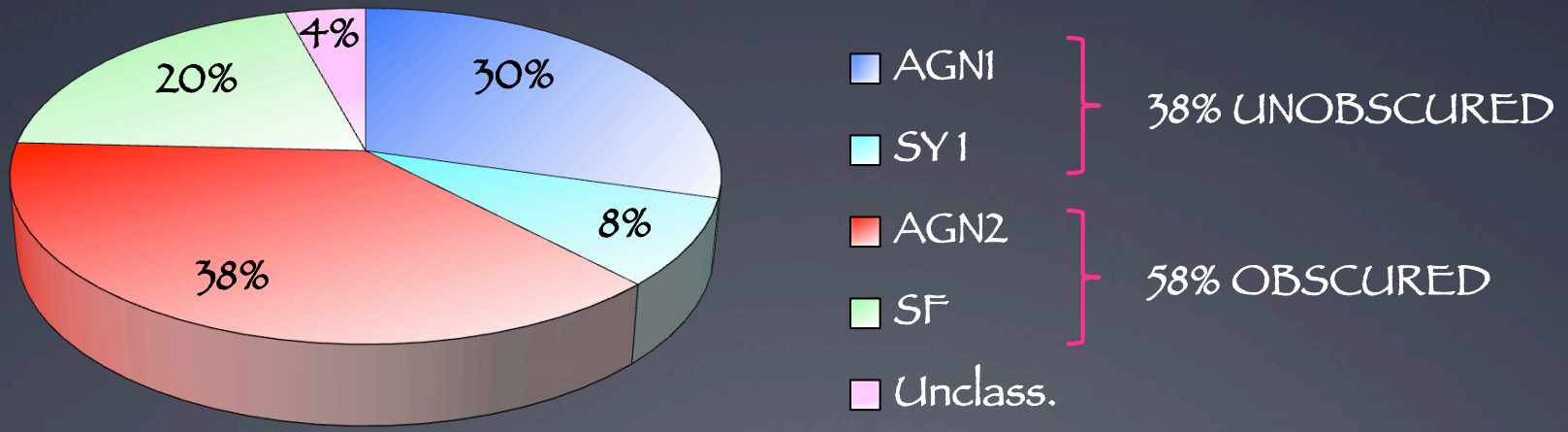
Selection: XMM Detected AGN (95)

★ Count rates and fluxes in 5 bands
★ 3 Hardness Ratios
★ N_H estimated from Xspec or HR

★ 93 sources with *Chandra* counterpart
★ 71 with spectroscopic z
★ 24 with photometric z
★ All detected in Optical and/or Infrared (IR)

FUV-Mid IR Spectral Energy Distribution (SED)

Source Classification



Criteria for identifying AGN–driven radio activity

q_{24} parameter

$$q_{24}=Log(F_{24\mu m}/F_{20cm})$$

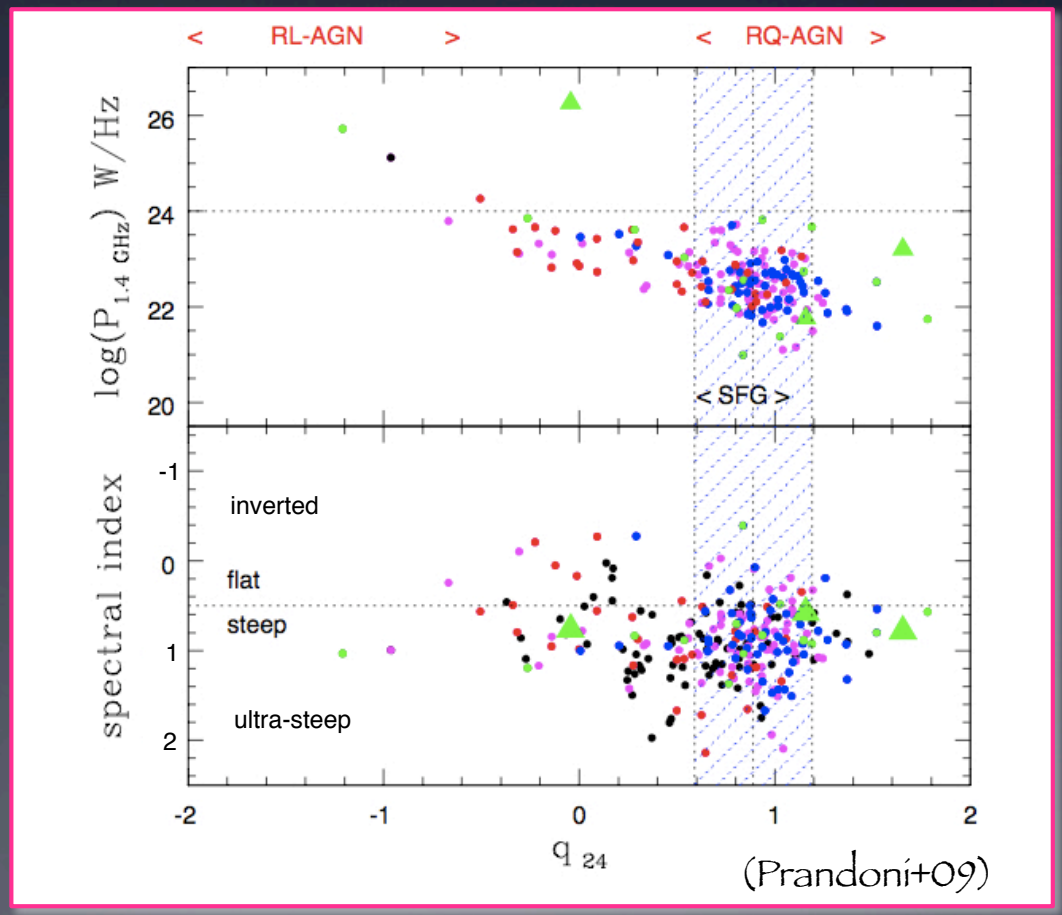
$\langle q_{24}\rangle=0.83\pm0.31$ for RQ and SFGs (Appleton+04)

- $q_{24}<0.21$: Radio Loud (RL) / Radio Intermediate (RI)
- $0.21<q_{24}<1.45$: Radio Quiet (RQ)
- $q_{24}>1.45$: Radio Weak (RW)

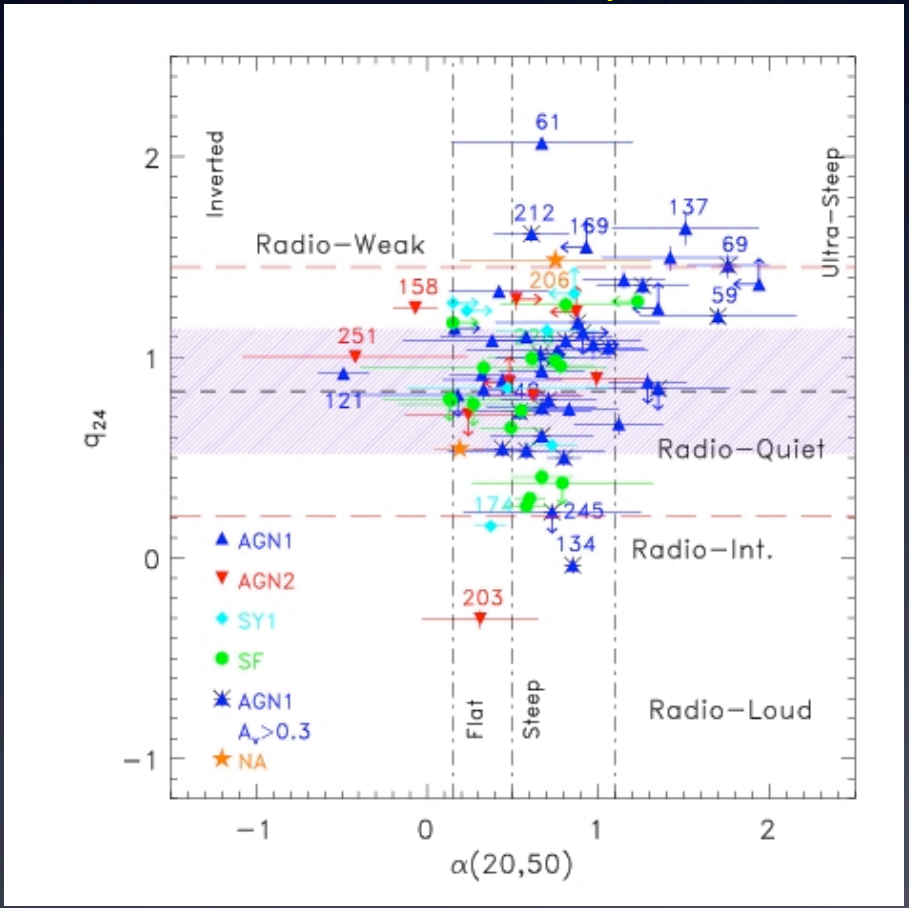
Radio Spectral Index

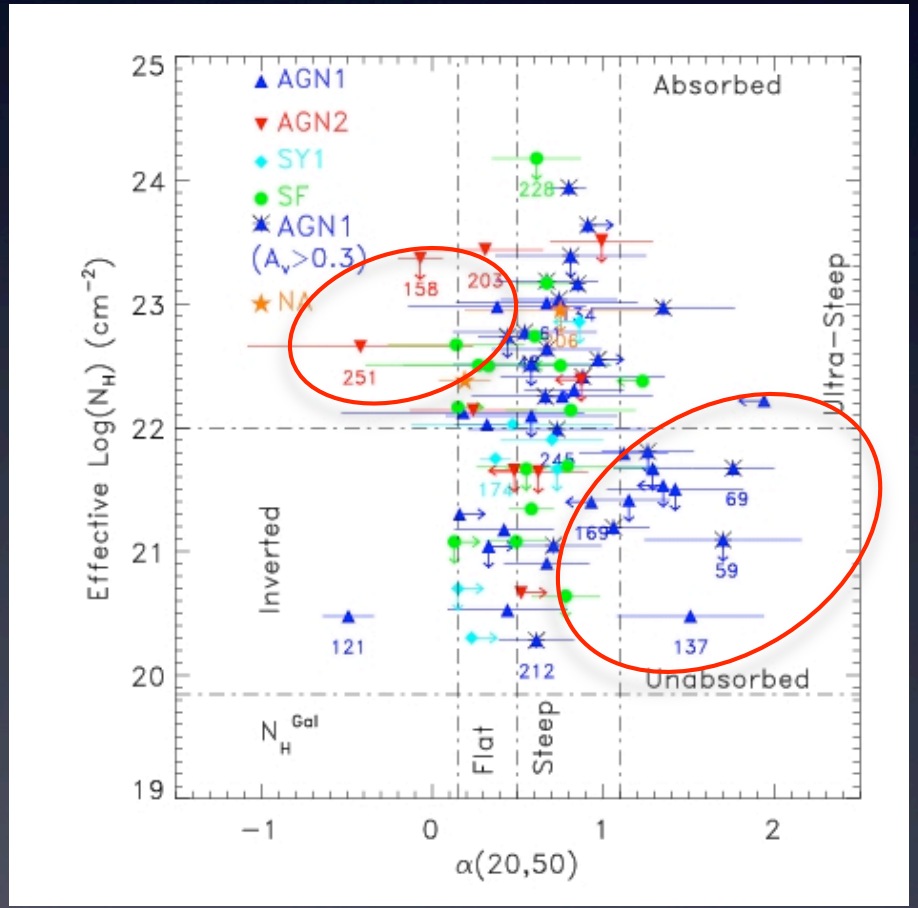
$$\alpha_{20,50}\ (S_\nu \propto \nu^{-\alpha})$$

- $\alpha_{20,50}<0.15$: Inverted
- $0.15\leq\alpha_{20,50}\leq0.5$: Flat
- $0.5<\alpha_{20,50}<1.1$: Steep
- $\alpha_{20,50}\geq1.1$: Ultra Steep



Radio Properties of the X-Ray Sources





★ Majority with STEEP spectra (51%), only 7% with INVERTED spectra.
★ RW and RI/RL have steep/flat spectra
★ ULTRA-STEEP spec. sources mostly RW or in between RQ/RW class.
★ INVERTED spec. sources are RQ

★ Inverted spectrum sources tend to be absorbed and obscured.
★ Steep/ultra-steep spectrum sources tend to be unabsorbed and unobscured.

Opposite to UM expectations

Radio Emission Mechanisms

INVERTED/FLAT RADIO SPECTRA

- Synchro-Self Absorption (SSA): abs. intrinsic to radio source, originating in presence of optically thick plasma.
- Free-Free Absorption (FFA): originating in compact sources (dusty torus).

STEEP RADIO SPECTRA

- SN explosions in star forming regions in RQ AGN and SF galaxies.
- Optically thin synchrotron emission, from extended sources in RL AGN.

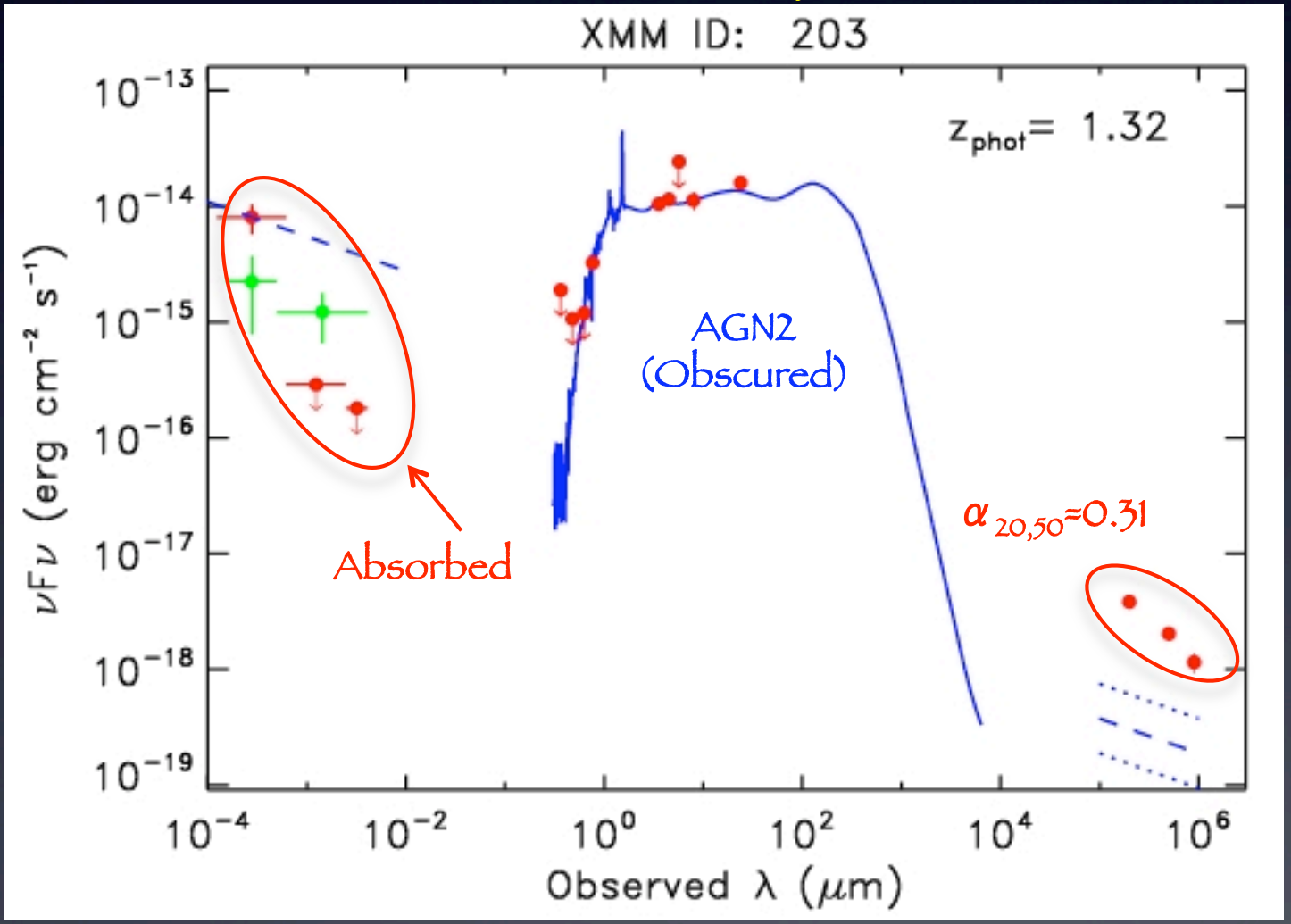
ULTRA-STEEP RADIO SPECTRA

- Optically thin synchrotron emission from radiative losses of aging electrons, associated with relic of past radio activity.

AGN-driven radio emission

- Radio Intermediate (RI) / Radio Loud (RL) (q_{24}<0.21): 3 sources (excess of radio emission in the host due to the AGN).

A RL, Flat Spectrum Source



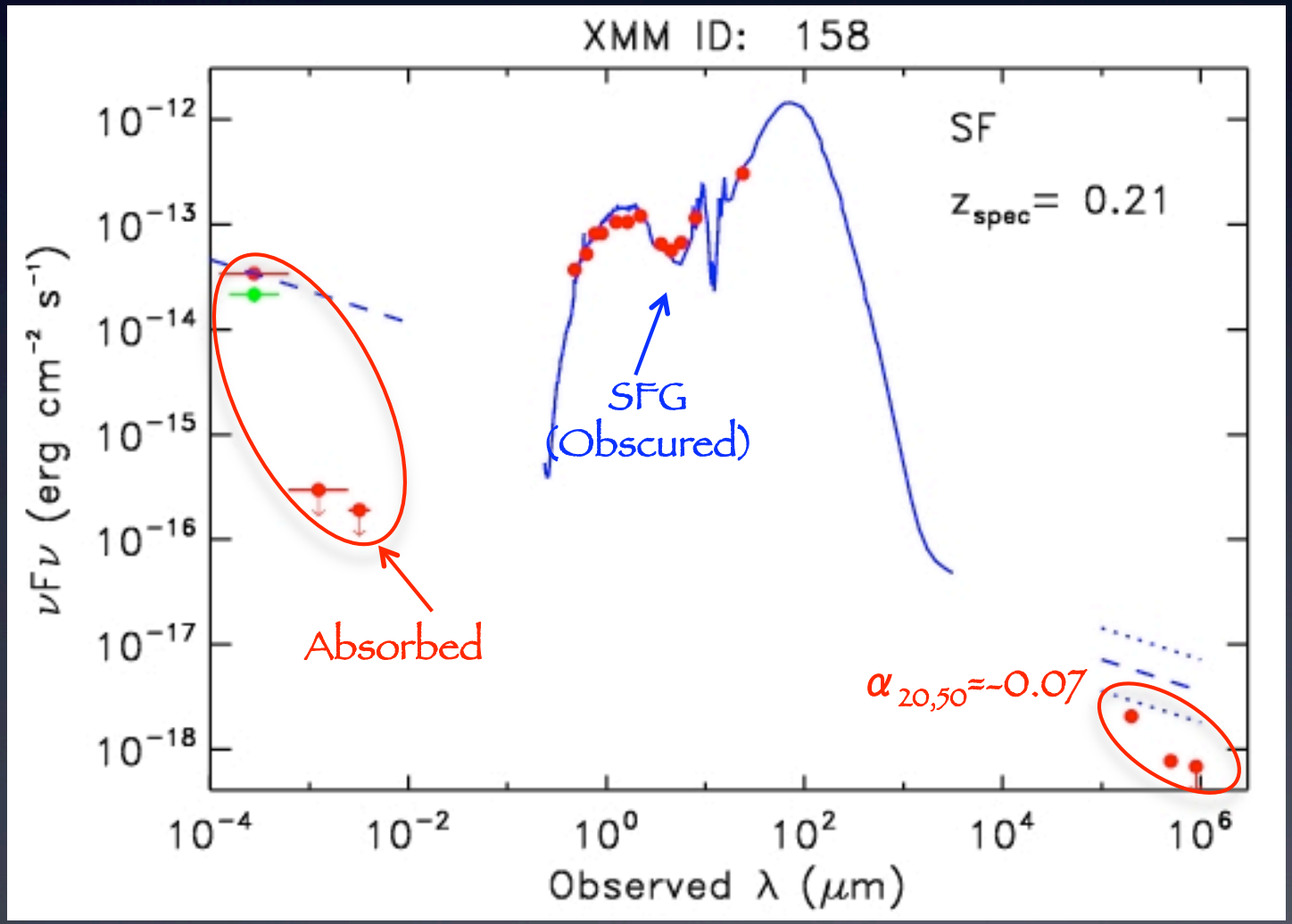
- RL
- Slightly extended
- Beamed QSO?
- Obscuration from host galaxy?

Radio emission indicative of Synchro-Self Absorption occurring in a jet

AGN-driven radio emission

- Radio Intermediate (RI) / Radio Loud (RL) (q_{24}<0.21): 3 sources (excess of radio emission in the host due to the AGN)
- Inverted or Flat radio spectrum ($\alpha_{20,50}\leq 0.5$): 25 sources (synchrotron emission from optically thick plasma)

An Inverted Spectrum Source



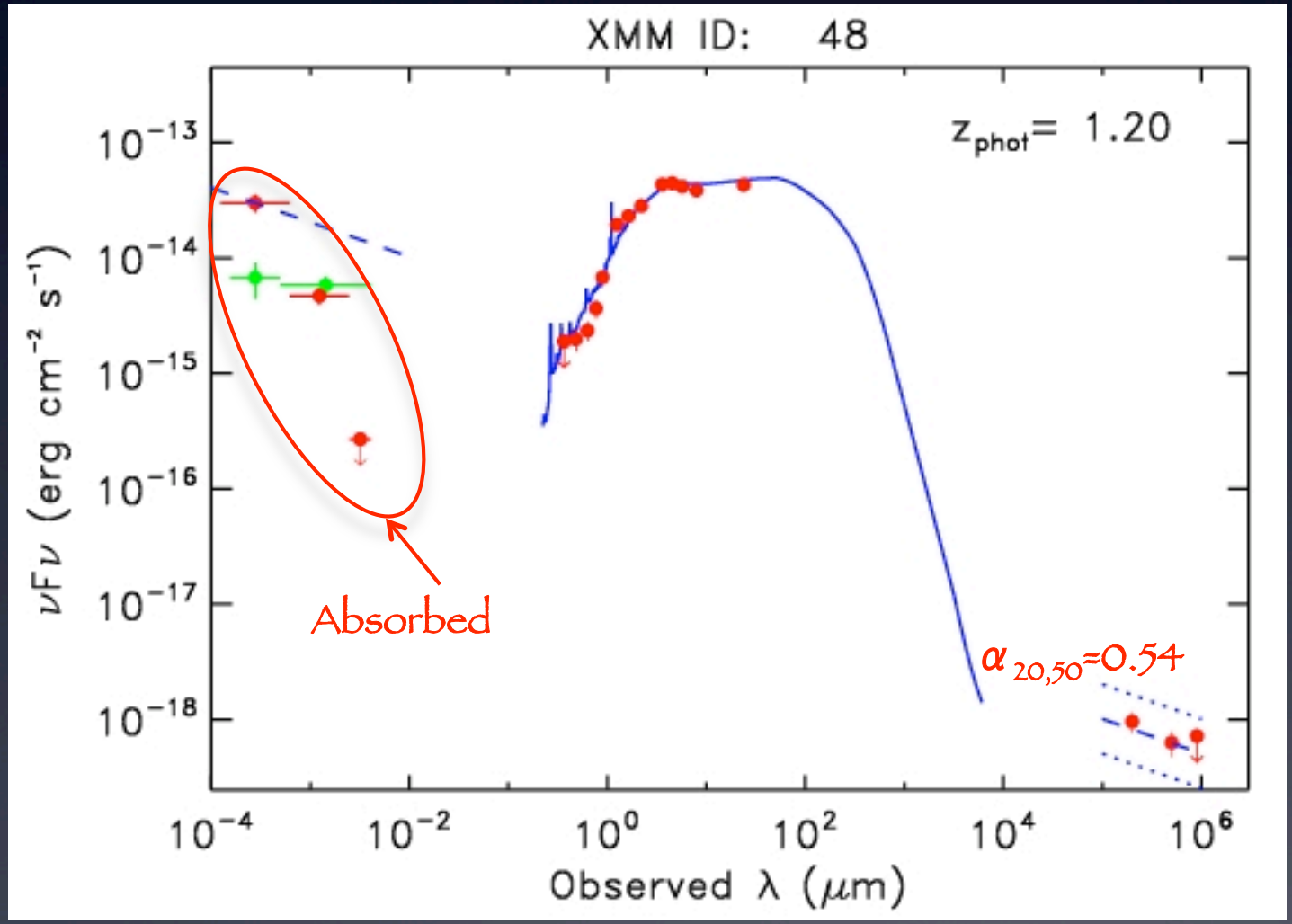
- Extended Source: 3.8"x2.2" (12x6.9 kpc)
- AGN driven radio emission
- Radio Weak

Free-Free Absorption responsible for inverted spectrum? UNLIKELY, since source is extended. Self-absorbed synchrotron emission more likely.

AGN-driven radio emission

- Radio Intermediate (RI) / Radio Loud (RL) (q_{24}<0.21): 3 sources (excess of radio emission in the host due to the AGN)
- Inverted or Flat radio spectrum ($\alpha_{20,50} \leq 0.5$): 25 sources (synchrotron emission from optically thick plasma)
- Extended radio size (>3″): 2 sources (radio source more extended than the host, likely a jet or lobes)

Extended Radio Source



- Extended: 5.4" (45kpc)
- AGN driven radio emission
- Radio Quiet

AGN-driven radio emission

- Radio Intermediate (RI) / Radio Loud (RL) (q_{24}<0.21): 3 sources (excess of radio emission in the host due to the AGN)
- Inverted or Flat radio spectrum ($\alpha_{20,50} \leq 0.5$): 25 sources (synchrotron emission from optically thick plasma)
- Extended radio size (>3″): 2 sources (radio source more extended than the host, likely a jet or lobes)

There are 29 sources (38%) with AGN-driven radio emission!

Most of them are Radio Quiet AGN, are

absorbed in the X-rays and show large radio sizes.

A significant number of Radio Weak sources

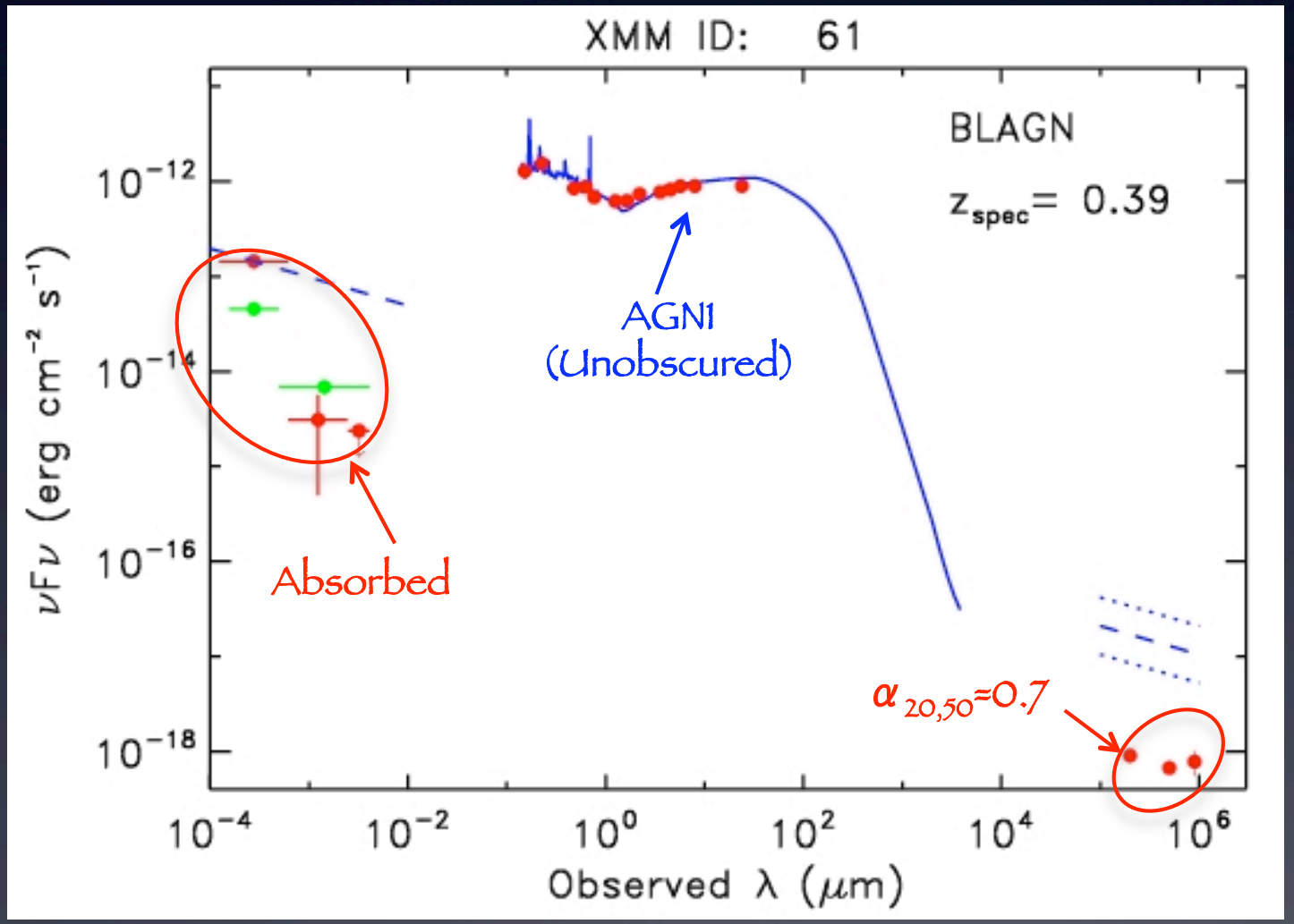
- Radio Weak (RW) sources (q_{24}>1.45): 7 sources (9%).

Excess of mid-infrared emission or deficit of radio emission ?

- Excess of mid-infrared emission from the dusty torus.

- Deficit of radio emission due to the absence of a radio jet or core or to the lack of SN explosions as in the case of a nascent starburst or a galaxy with no active star formation.

A RW with Steep Radio Spectrum



- Radio: synchrotron
- *b*=2.2" (10.6 kpc)
- Lobes/bubbles?
- Radio Weak: no SF?

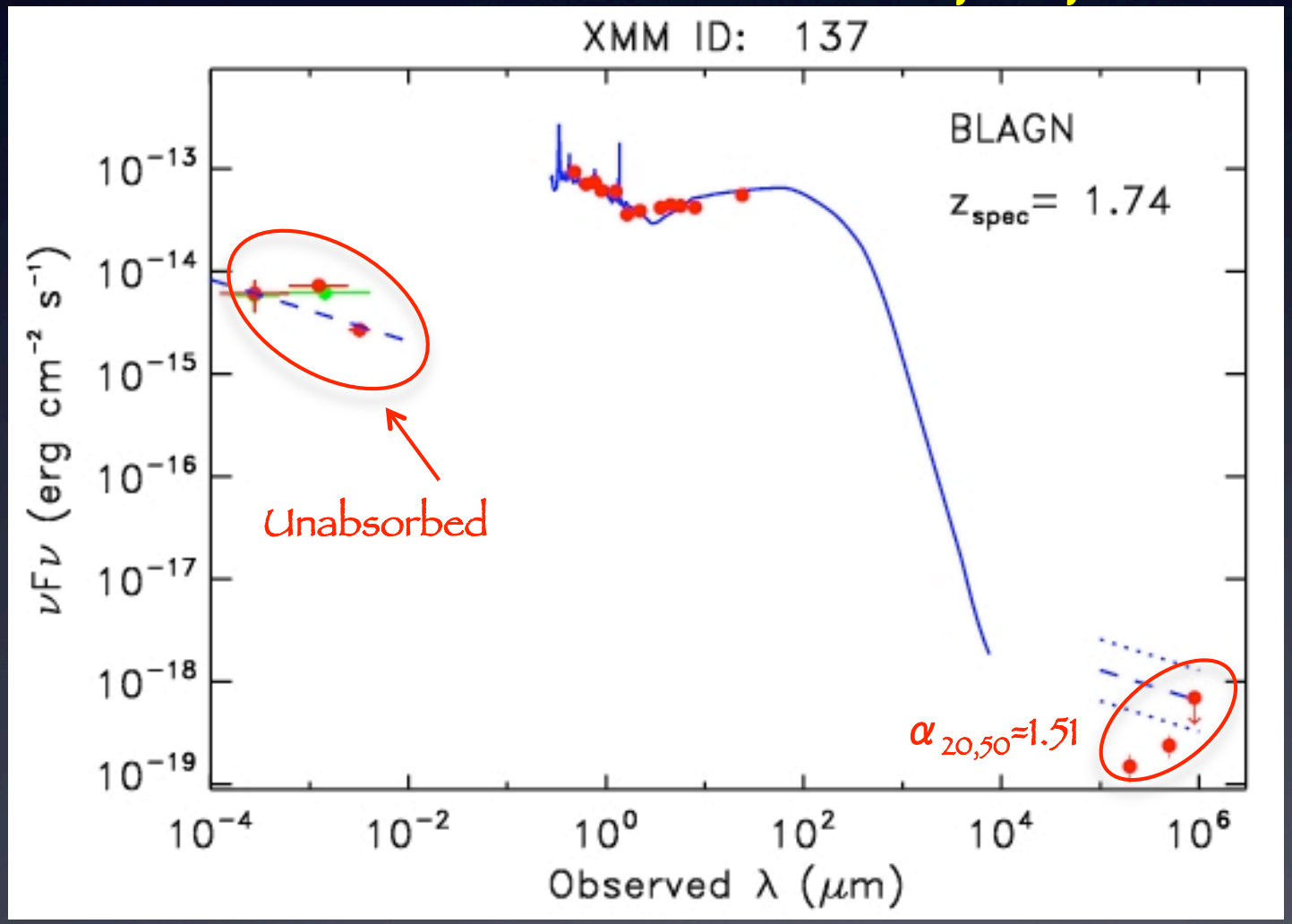
Weak radio emission: nucleus+host weak radio sources and host radio emission much fainter than expected

OR

Synchrotron from e^- that are cooling down, as in relic radio activity

(e.g. Barvainis&Lonsdale 98)

RW with Ultra Steep Spectrum

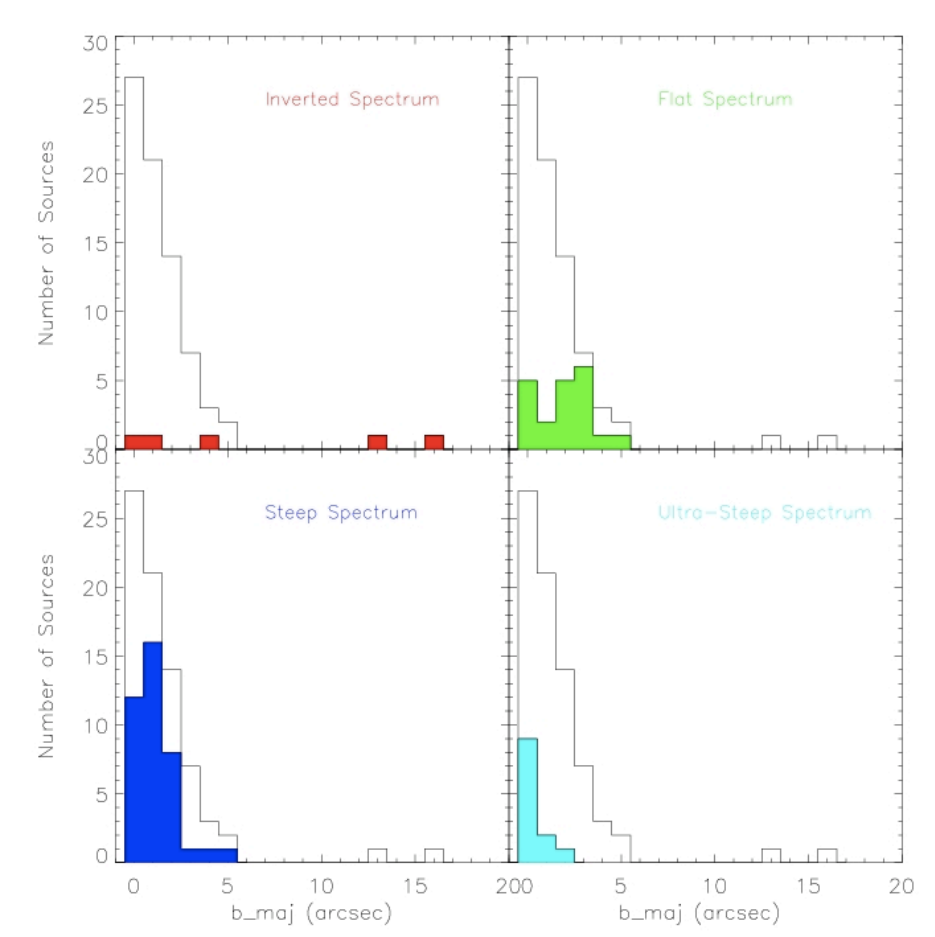


- Compact Source
- Lobes/jets?
- Radio Weak

Synchrotron emission from electrons which are cooling down due to the lack of a reacceleration mechanism.

(e.g. Barvainis&Lonsdale 98)

Radio Semimajor Axis Distribution



- Indicator of AGN-driven activity
- About half of inverted and flat radio spectrum sources are extended (>3″): jets (?)
- Most steep and ultra-steep spectra sources are compact (<3″): radio from compact cores, small jets or host

Increasing radio size as the radio spectrum flattens !

Summary

- Radio properties of a sample of 95 X-Ray detected AGN in the Lockman Hole Northern field (aka Chandra/SWIRE, or deep VLA field).

- AGN-driven radio activity identified through the q_{24} parameter, radio spectral index $\alpha_{20,50}$, and the radio source size.

- Efficiently radiating (X-Ray Bright) AGN are mostly Radio Quiet with typical radio spectra and contain only a few bona fide Radio Loud AGN (3%).

- Large fraction (39%) of sources with AGN-driven radio activity. The main emission process is synchrotron radiation produced by optically thick plasma (SSA) in an extended structure. The small fraction of bona-fide RL AGN and the large q_{24} values suggest possible selection effect against radio faint objects in previous studies.

- Significant number of Radio-Weak sources with steep radio spectra and associated with unobscured AGN.

- Inverted and flat spectrum sources are mostly extended and absorbed. Steep/ultra-steep spectrum sources are mostly compact and unabsorbed.

Conclusions

- X-ray brightness and radio-loudness might correspond to different phases of an AGN lifetime and be triggered and fuelled by different environments.

- Radio Weak sources might represent a post-feedback phase where the radio emission is the relic of a past AGN or Star Forming activity.

- Evidence of AGN-driven radio activity and flat radio spectra during the obscured phase and radio weakness and steep radio spectra during the unobscured phase. The plasma responsible for the radio emission is at first optically thick (flat spectra) and compact (small sizes) and then optically thin (steep spectra) and extended (large sizes).

- These results provide new constraints to AGN evolutionary models.