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X-Ray Properties of LINERs, a biased review...

by
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The Main Questions

- What powers the emission lines?
- Do LINERs harbor weak AGNs?

These are two distinct questions!

If an AGN is present, it need not be the power source of the emission lines.

In the beginning (life before *Chandra*)...

- LINERs observed by the *Einstein* observatory.
  - General properties summarized by Halpern & Steiner (1983)
    L_X (0.5-4.5 keV) ~ 10^{39} - 10^{41} erg/s
- Morphology and soft X-ray spectra studied with *ROSAT* (5″/25″ beam)
  (Fabbiano et al.; Komossa et al.; Halderson et al.)
  - Wide variety of morphologies (central point sources with and without diffuse emission)
  - Spectra sometimes power laws and sometimes thermal.
- Spectroscopy with ASCA (3′-4′ beam)
  (Ptak et al.; Terashima et al.; plus others)
  - Composite spectra (with a universal shape):
    hard power law (Γ~1.7) + soft thermal plasma (kT~0.6 keV)
    consistent with morphological information from *ROSAT*

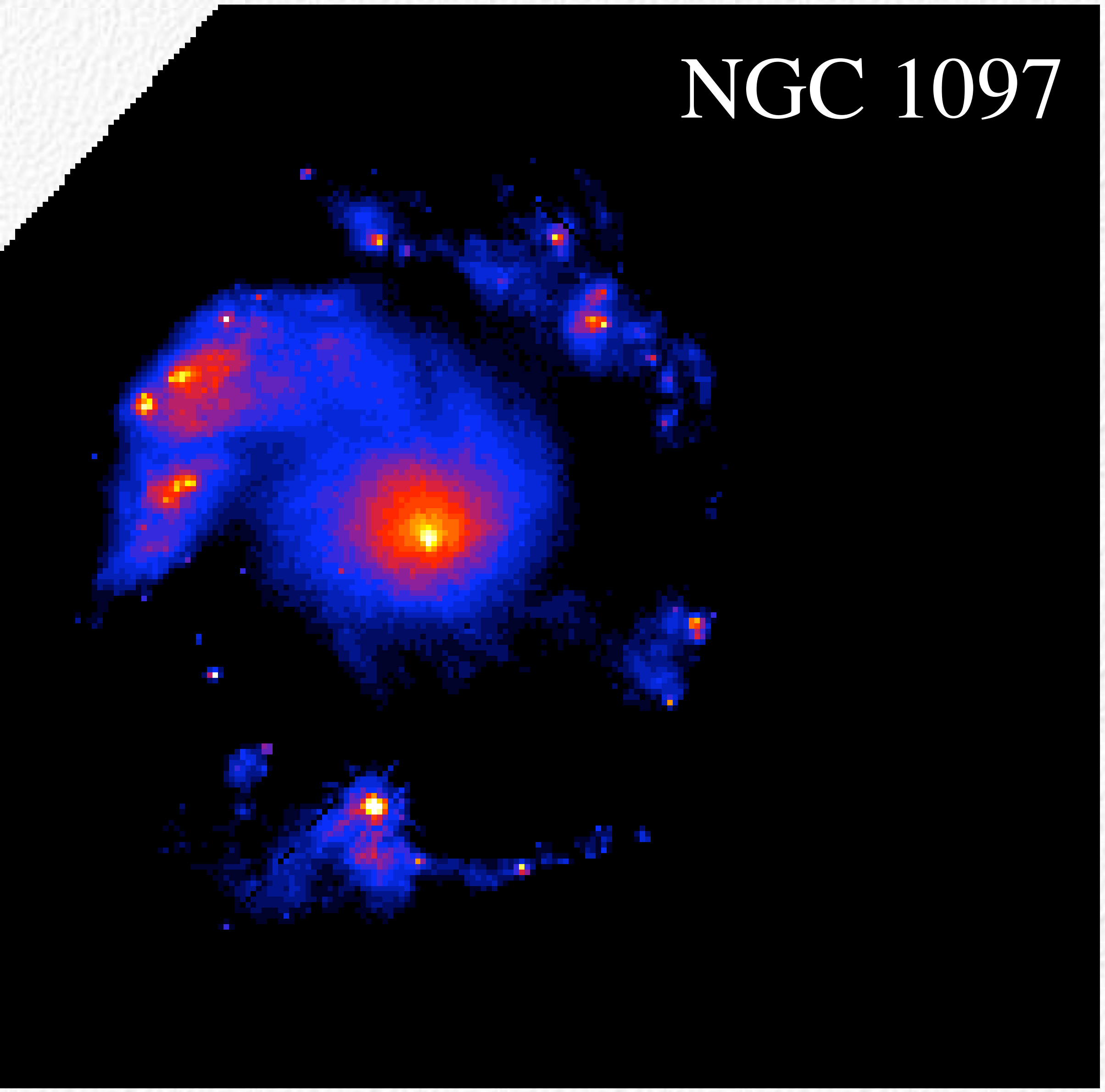
The Importance of Chandra

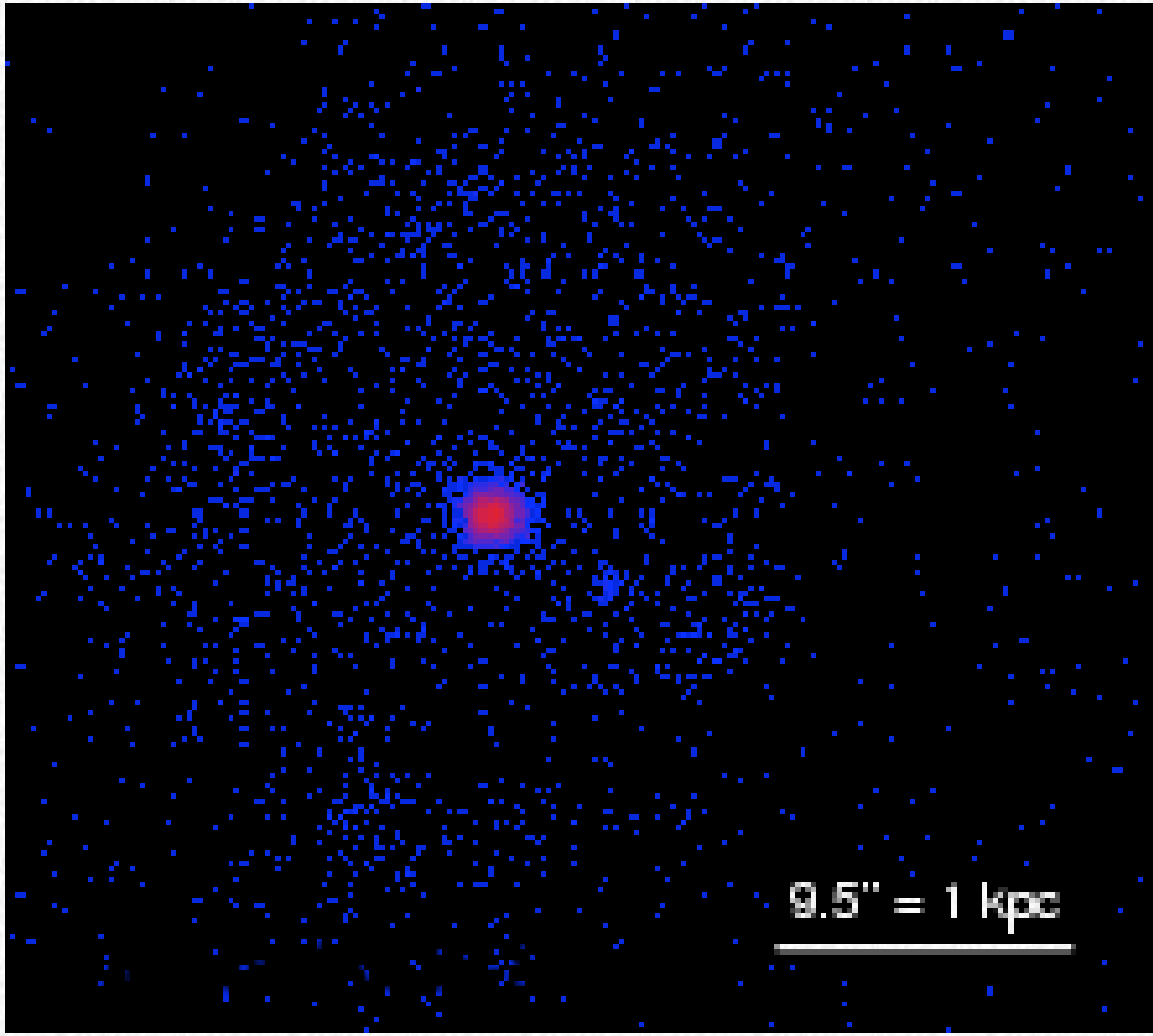
- High spatial resolution
  - Low background
  - High sensitivity
  - Good astrometry
  - Ability to resolve crowded fields

Sensitivity (erg/s)	5 Mpc	15 Mpc
5 ks	1.7×10^{37}	1.5×10^{38}
30 ks	2.8×10^{36}	2.5×10^{37}

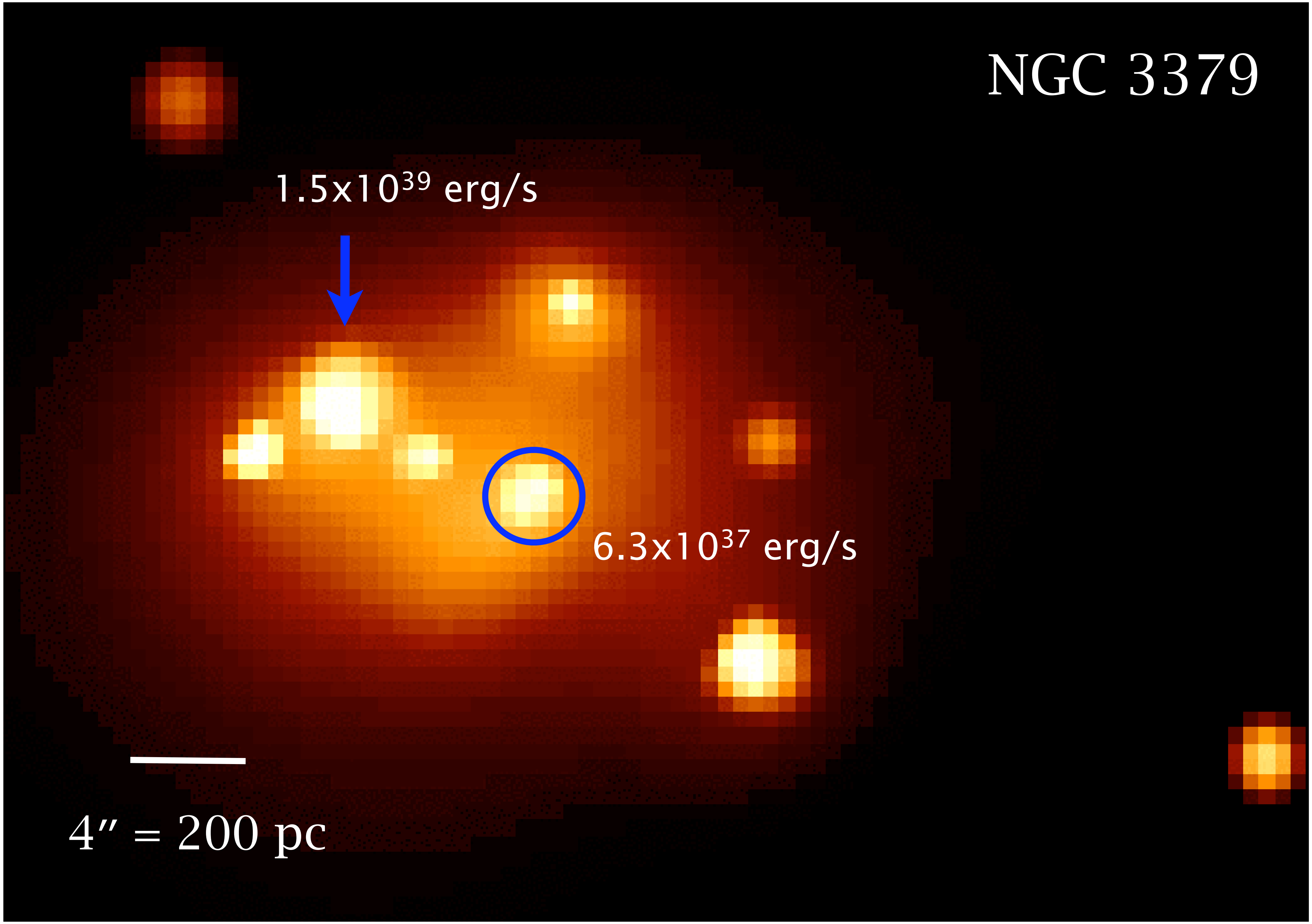
$\sim10^{-9}\ L_{Edd}\ /\ M_8$

- Broad energy response
  - Study morphology vs energy; separate thermal emission from discrete sources
  - Broad-band spectroscopy; identify source types by their spectra

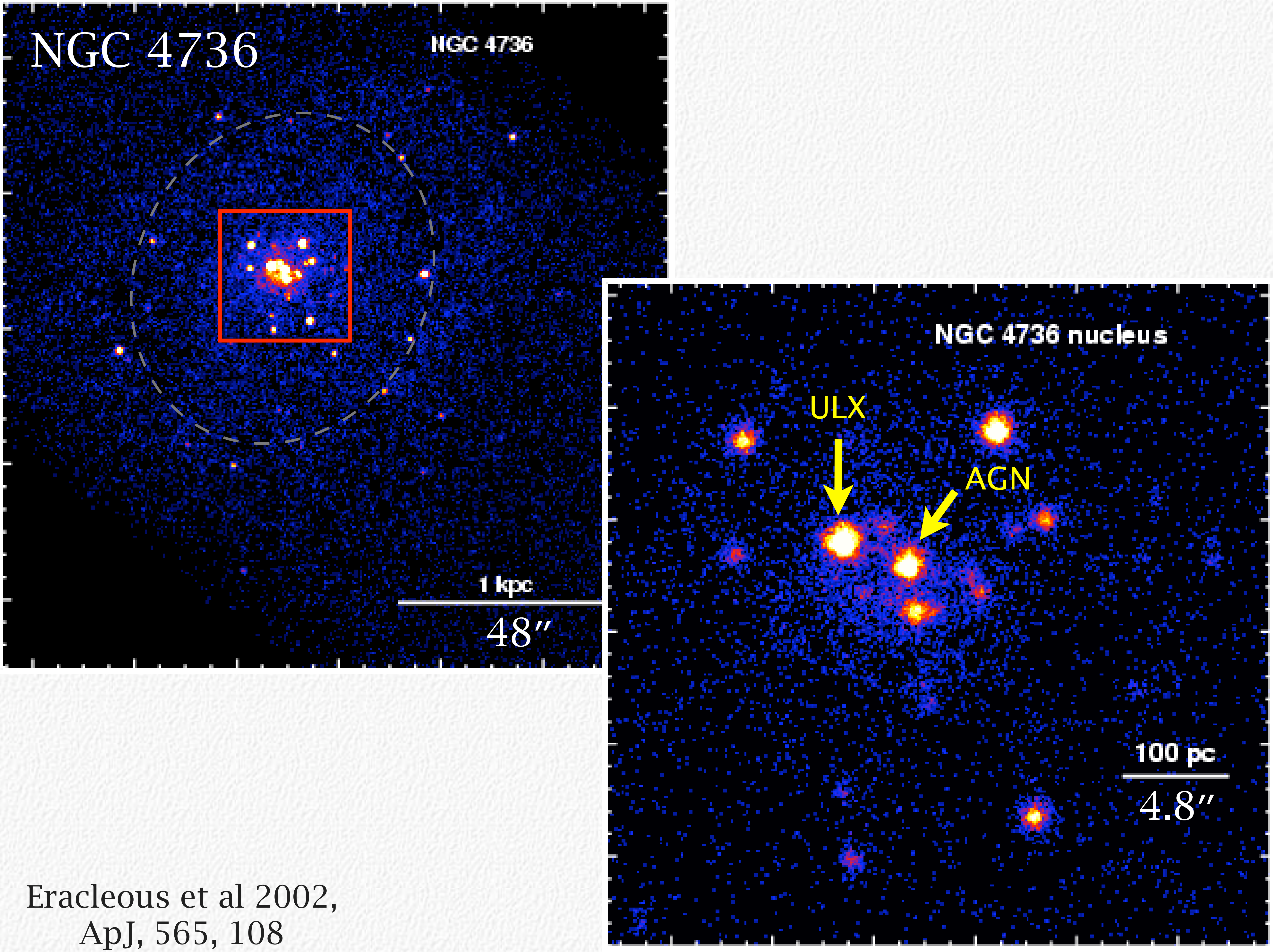




Nemen et al. 2006, in press



Flohic et al. 2006, submitted



Eracleous et al 2002,
ApJ, 565, 108

Selection of *Chandra* LINER Samples

- Snapshot Surveys (2-5 ks):
  - Ho et al. (2001); Sipior (2003) ➡ Palomar spectr. sample
  - Terashima & Wilson (2002) ➡ compact radio cores
  - Dudik et al. (2005) ➡ IR-bright LINERs (from IRAS)
- Case Studies (>20 ks) ➡ selected bright objects
  Eracleous et al.; Pelegrini et al.; Trinchieri & Goudfroij; Lira et al.; Fabbiano et al.; Nemen et al.
- "Archival" Surveys:
  - Filho et al. (2004) ➡ radio composites (core+diffuse)
  - Satyapal et al. (2004,2004) ➡ more IR bright LINERs
  - Flohic et al. (2006) ➡ 19 **long** *Chandra* exposures
  - Gonzalez-Martin et al. (in prep) ➡ everything (broad scope)

Archival Survey of 19 LINERs *(Flohic et al.)*

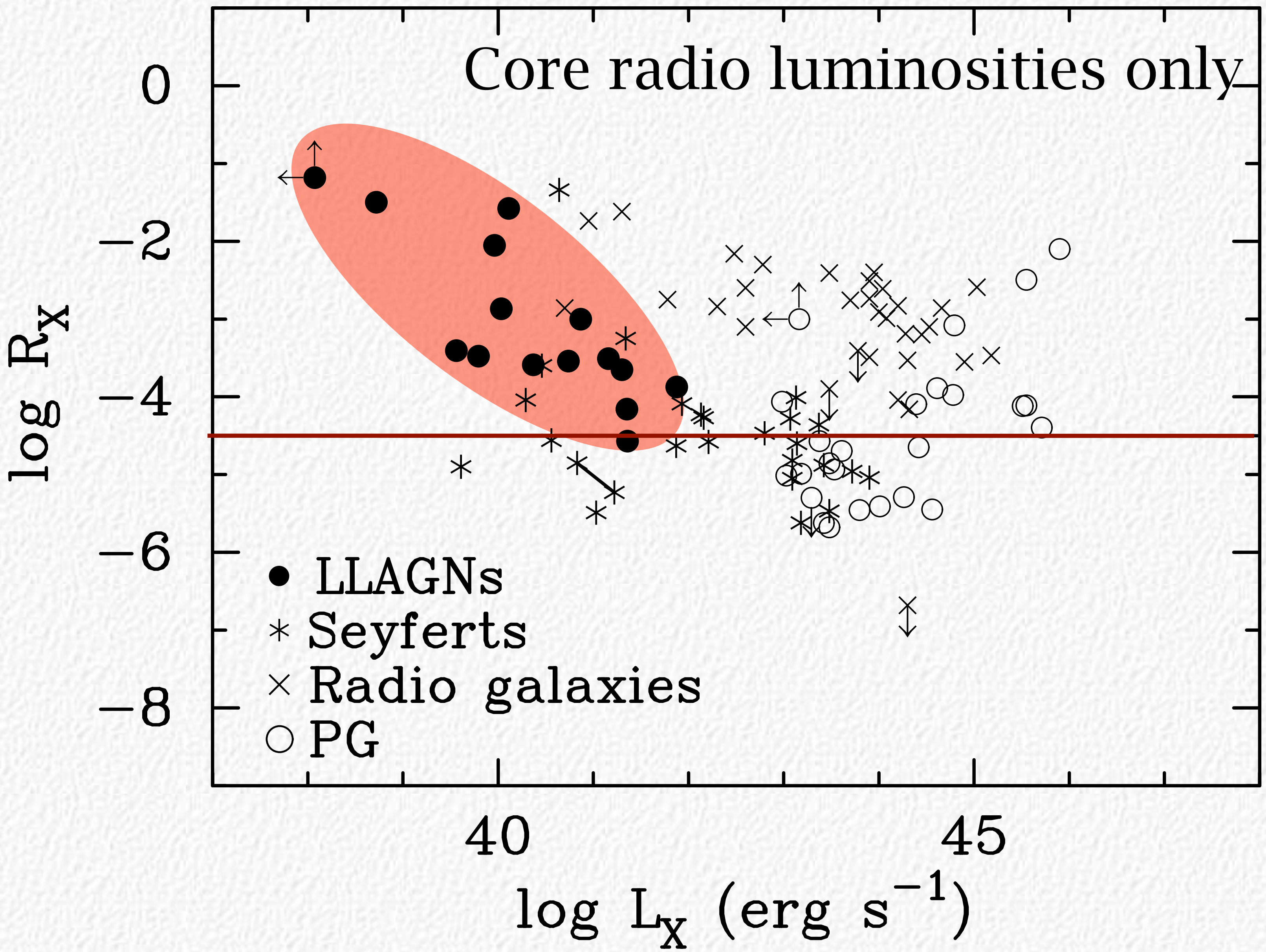
- t_{exp} > 15 ks, D < 25 Mpc, L_{min}~10^{36}-10^{37} erg/s
- Representative mix of LINER types (L1.9, L2, T2).
- Concentrate on inner kiloparsec.
- Look for AGNs, study point source populations, and properties of diffuse gas.
- Consider all available multi-wavelength data
  - Careful astrometry
  - Radio, UV, emission-line images
  - Properties of stellar population from spectroscopy
- Careful spectral fitting whenever possible.
- Examine energy budget.

Summary of AGN Properties

- LL AGNs found in > 60% of cases (up to 74%?)
- $L_X \sim 10^{37} - 10^{40}$ erg/s; $L/L_{Edd} \sim 10^{-8} - 10^{-5}$
- All LINERs with a compact radio core harbor a hard nuclear X-ray source (LL AGN).
- But only 50% of hard nuclear X-ray sources in LINERs are associated with compact radio cores.
- In some rare cases the AGN is highly obscured, but typically $N_H \sim 10^{21}$ cm^{-2}
- Eddington ratios span a wide range of values

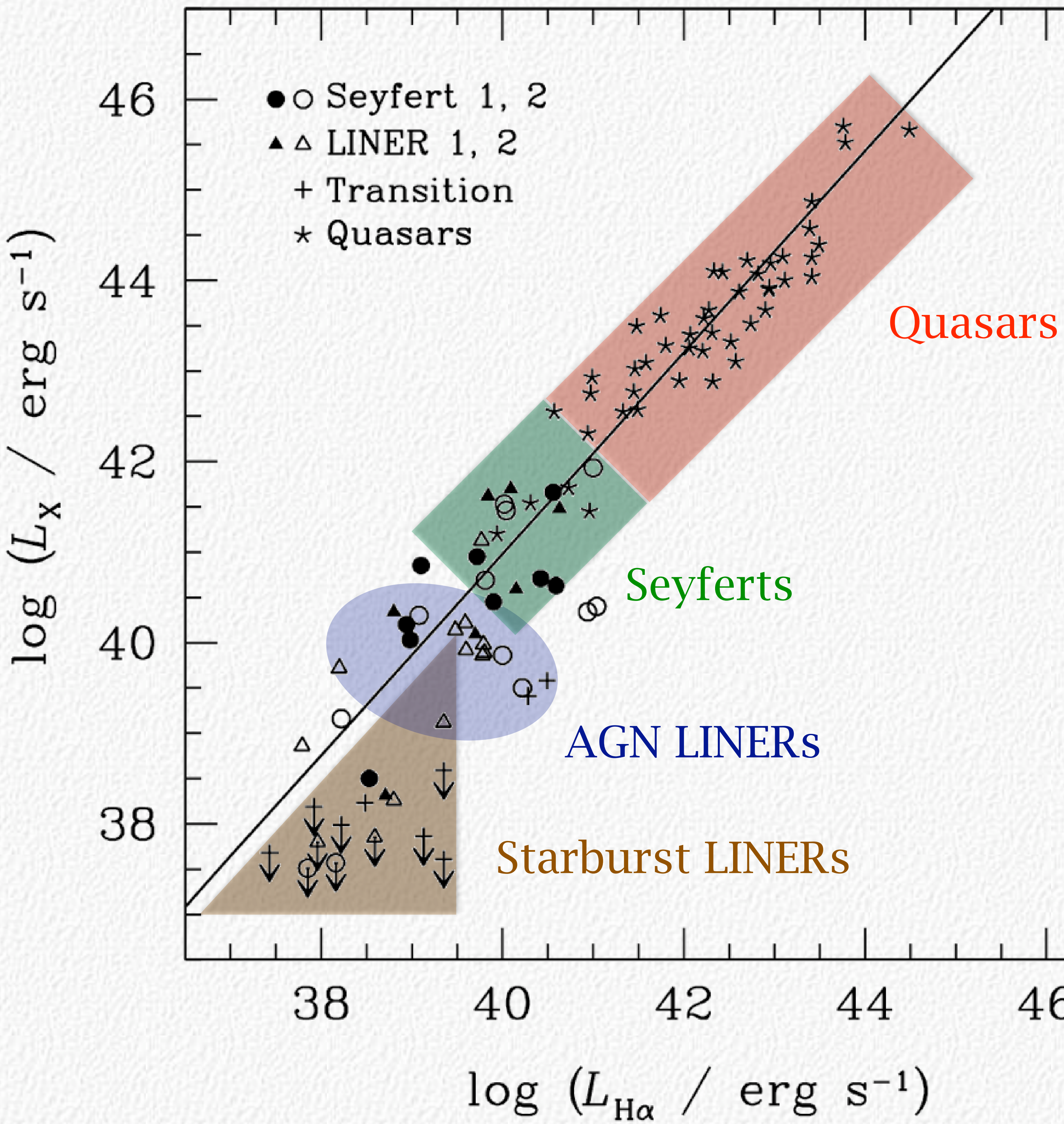
X-Ray Radio Loudness *(Terashima & Wilson 2002)*

$$R_X \equiv \frac{\nu L_\nu(5\ \mathrm{GHz})}{L_X(2\text{-}10\ \mathrm{keV})} > -4.5$$

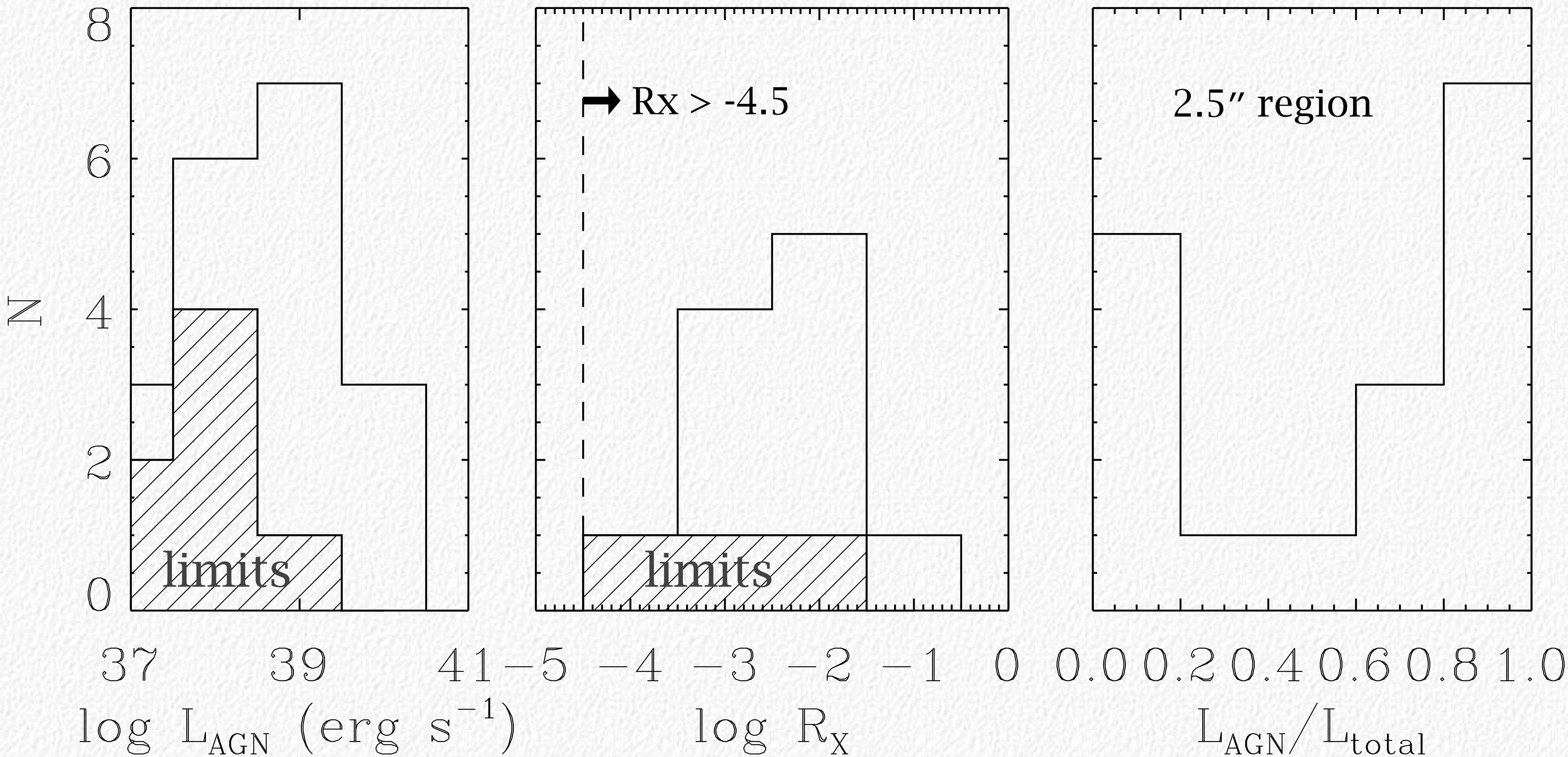


- All LINERs with a compact radio core harbor a LL AGN.
- But only 50% of LL AGNs in LINERs have compact radio cores
- Sometimes the AGN is highly obscured

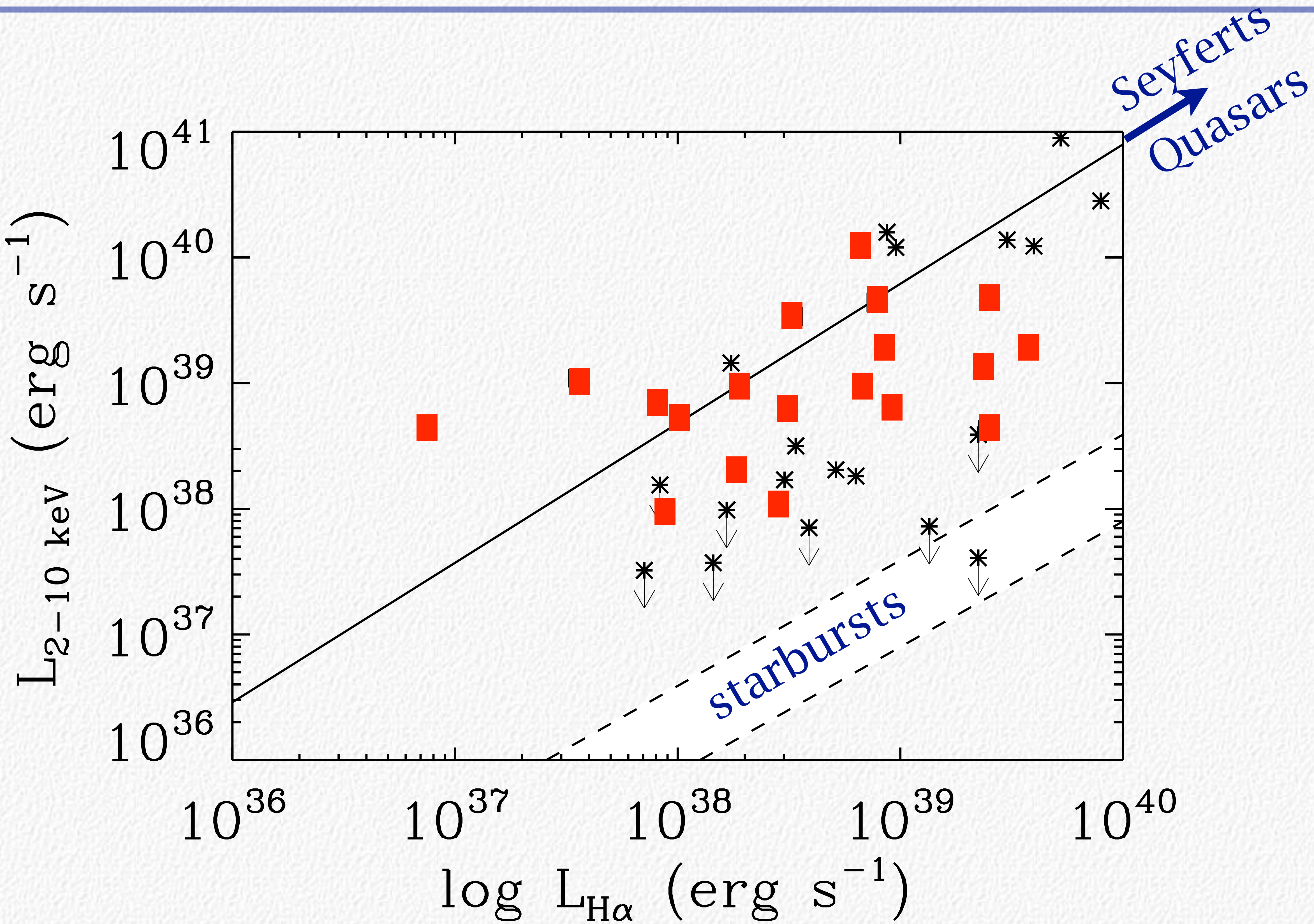
L_X-$L_{H\alpha}$ Correlation *(Ho et al.; Terashima et al.)*



Distribution of AGN Properties *(from Flohic et al.)*



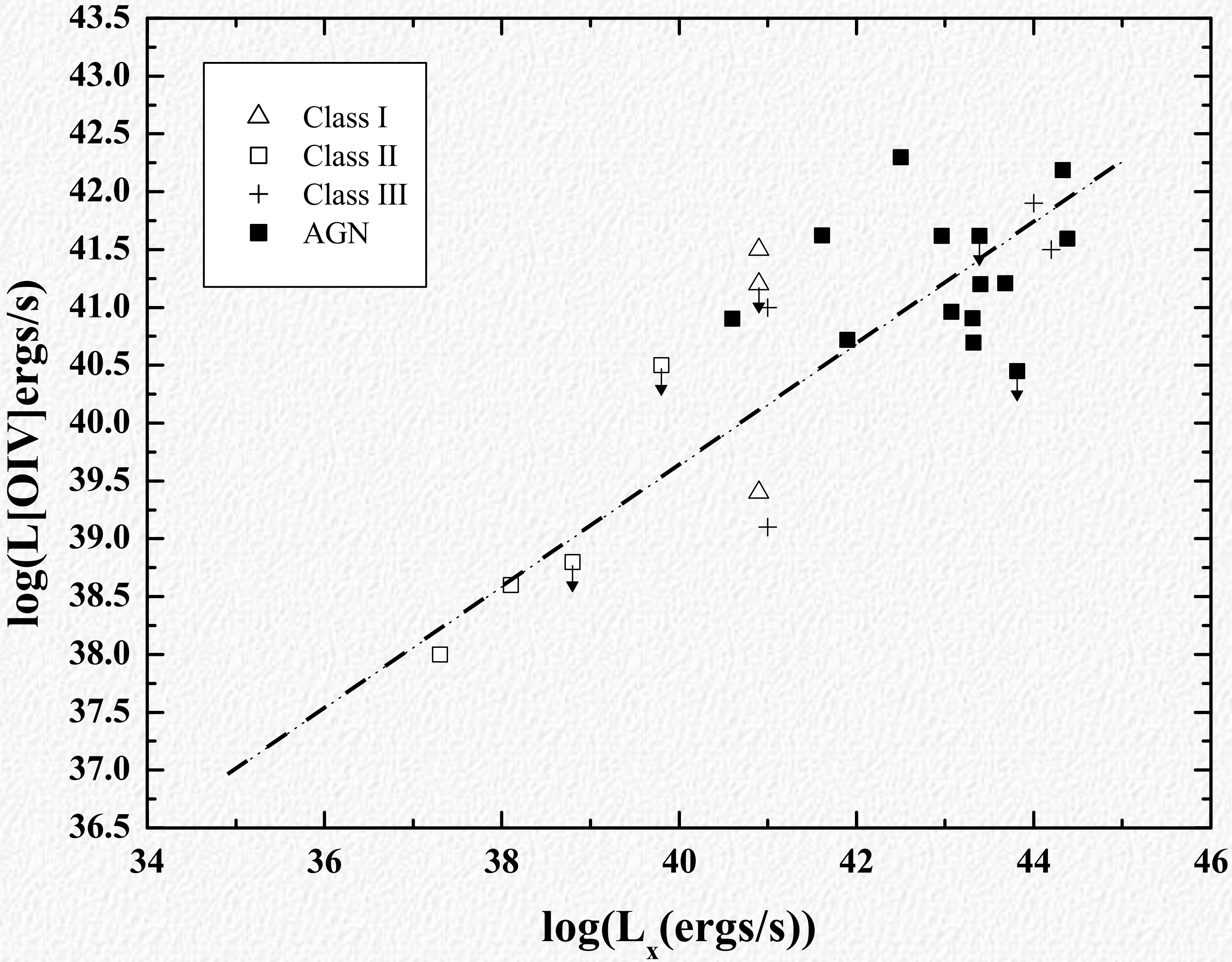
L_X-$L_{H\alpha}$ Correlation at Low L_X (Flohic et al. 2006)



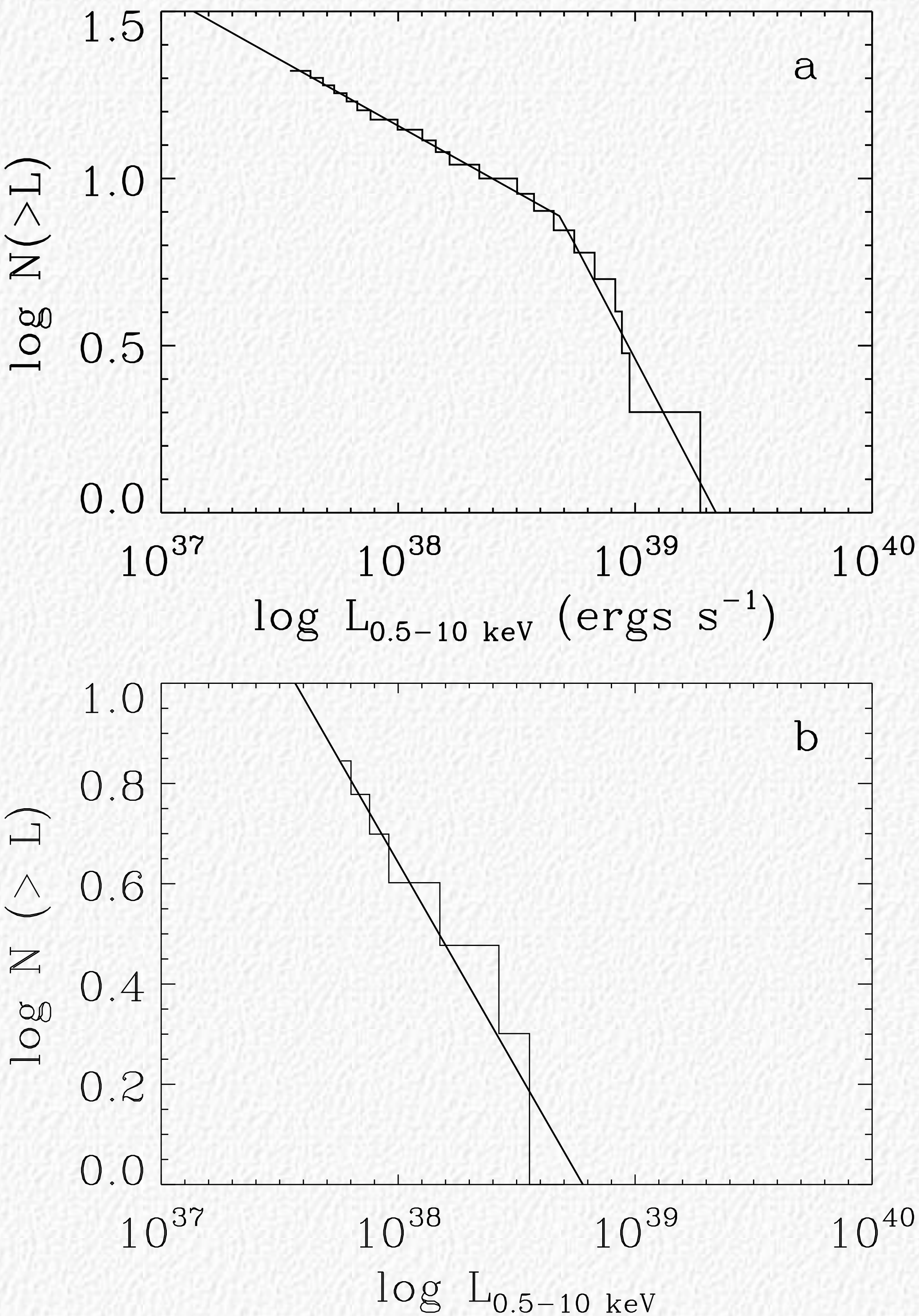
FIR vs X-Ray properties (Satyapal et al 2004,2005)

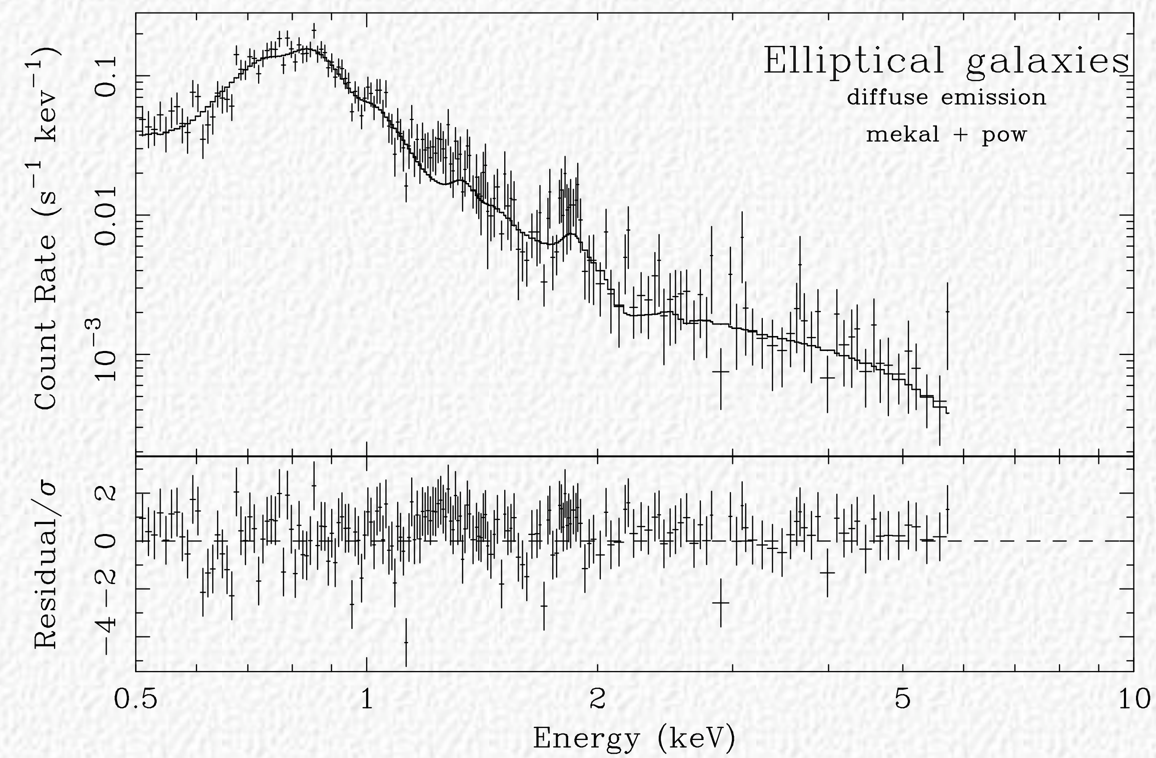
[O IV] 26μm line vs L_X

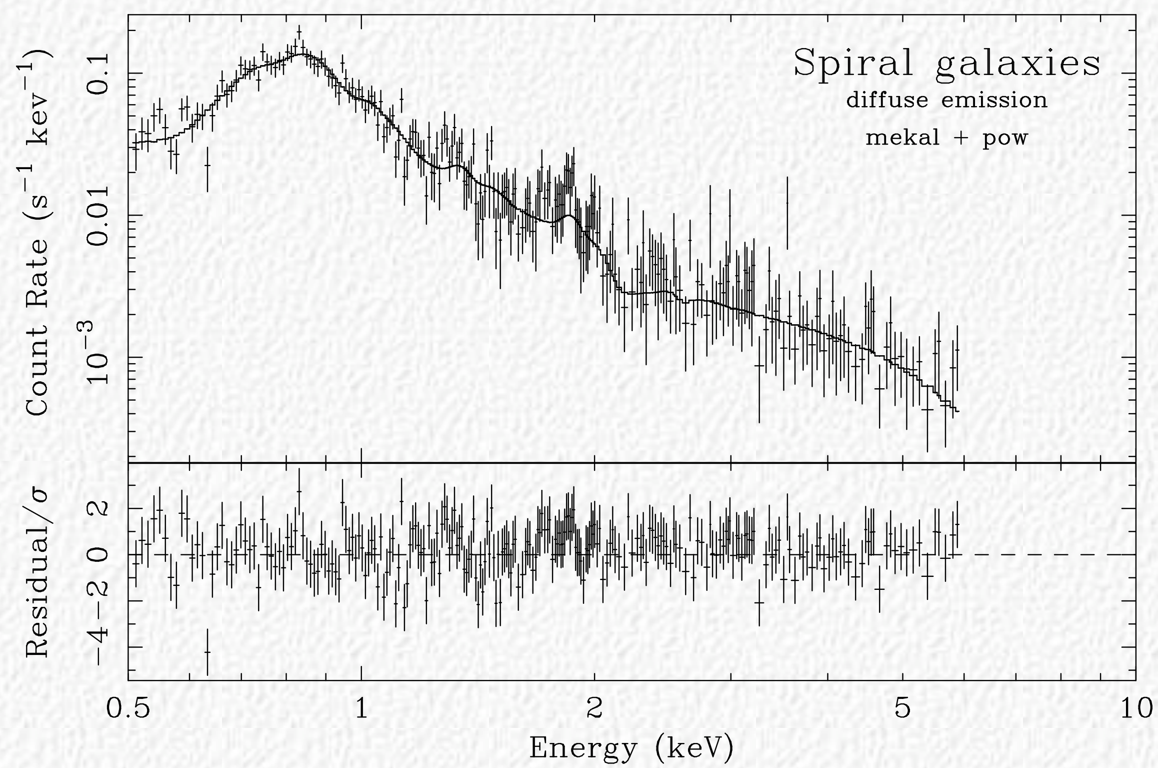
(Spitzer + Chandra)



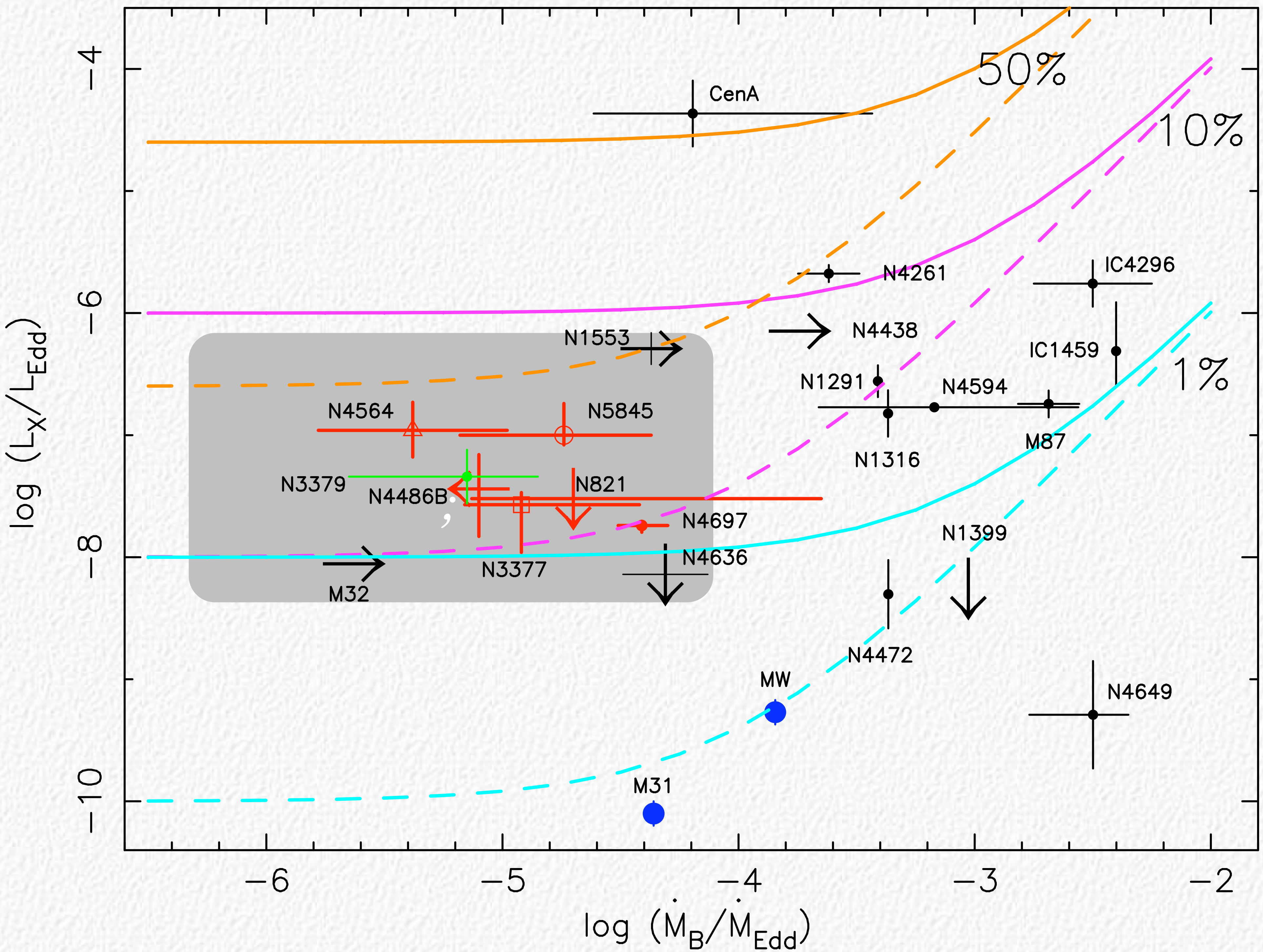
Environs *(Flohic et al. 2006)*







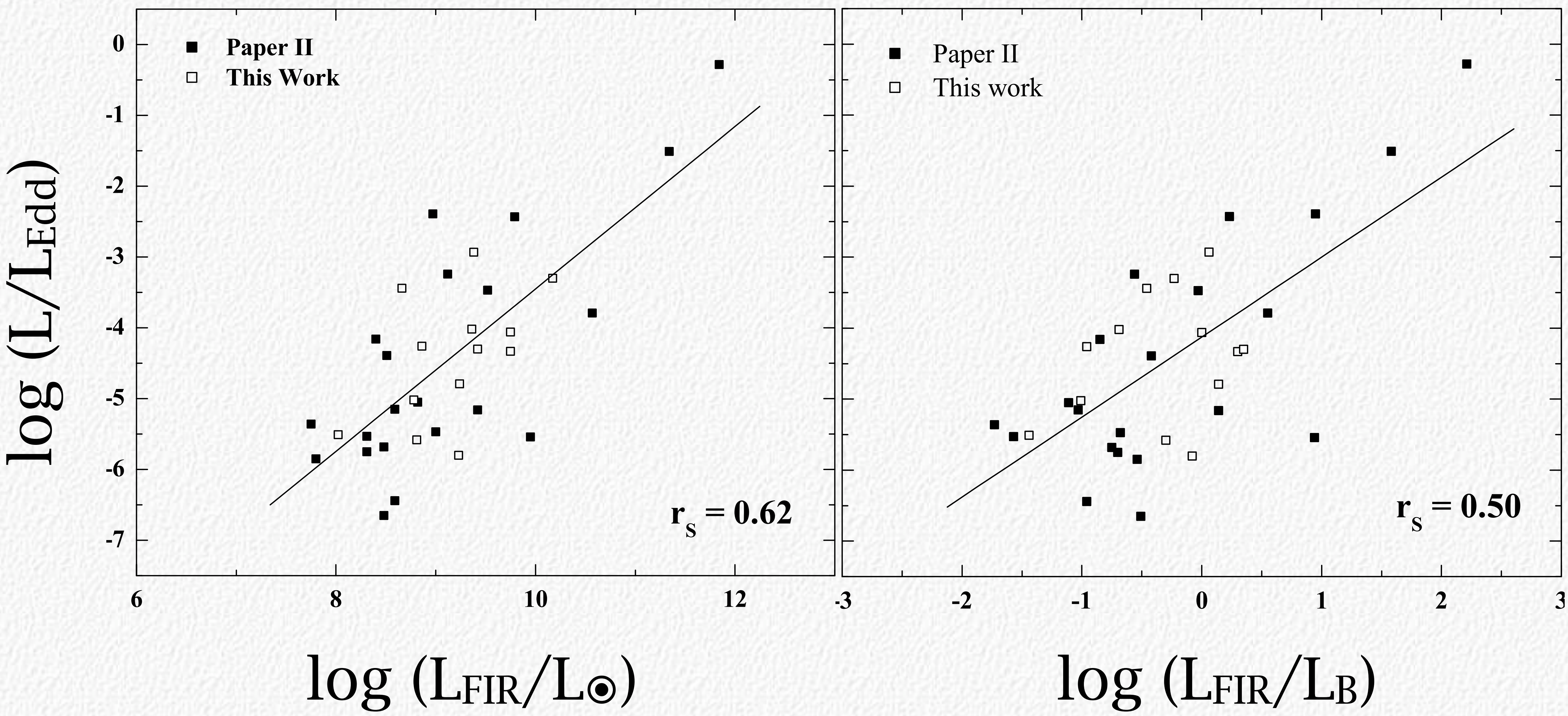
Soria et al. 2006, in press



FIR vs X-Ray properties (Satyapal et al 2004,2005)

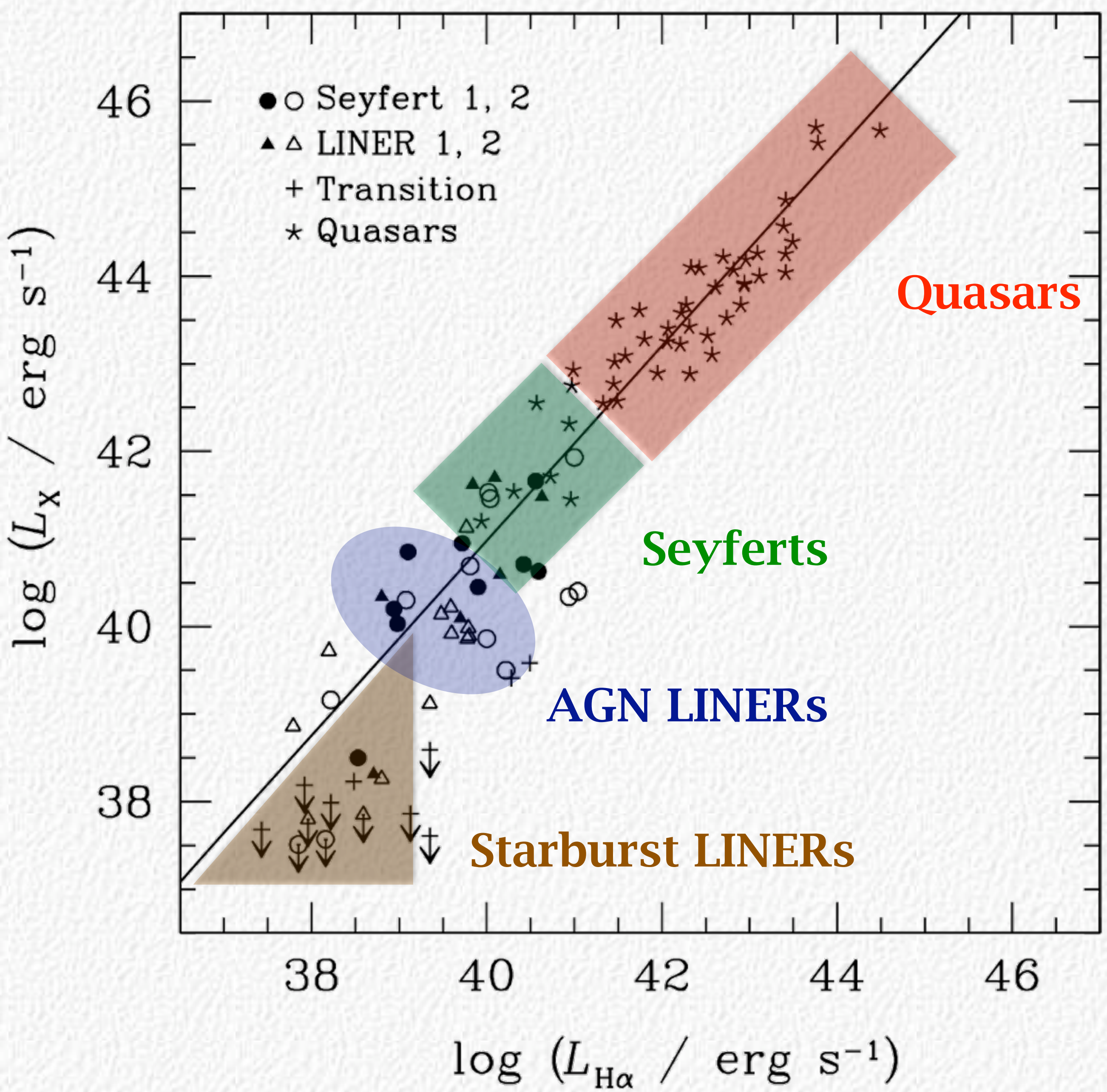
L/L$_{Edd}$ *vs* L$_{FIR}$ and L$_{FIR}$/L$_B$

(IRAS + Chandra)



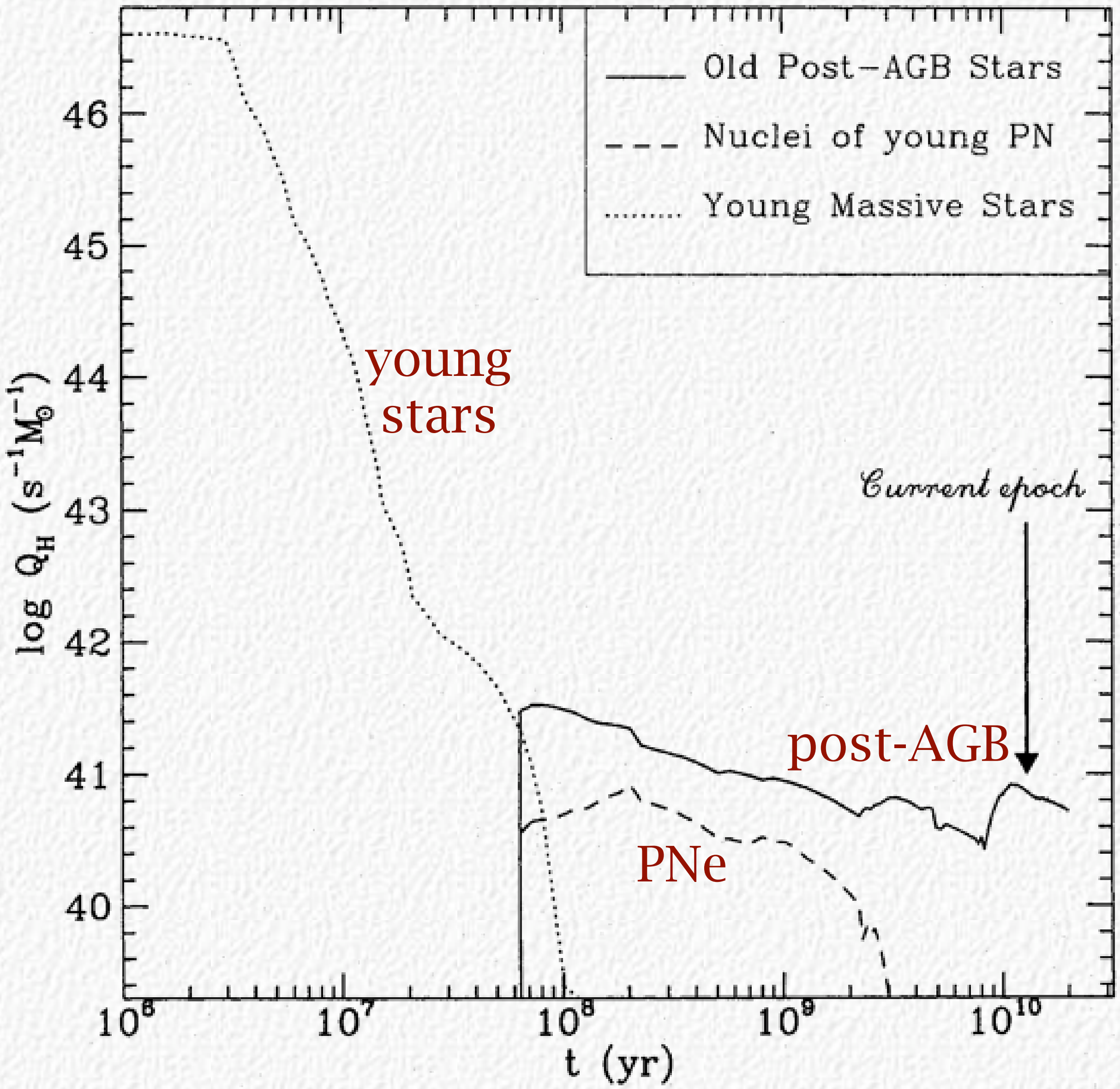
Balancing the budget… *(from Flohic et al.)*

- Assume power-law SED from 1 Ry to > 100 keV
  - Energy balance
    ➡ $L_{H\alpha} < 0.2\ L_{2\text{-}10\ \mathrm{keV}}$
  - Photon counting
    ➡ $L_{H\alpha} < 0.02\ f\ L_{2\text{-}10\ \mathrm{keV}}$
- Oooops!
  - Something wrong with assumed SED?
  - Is the L_X - $L_{H\alpha}$ correlation right?



Balancing the budget: other power sources?

Photoionization by stars:
young stars? very rare!
post-AGB stars? quite likely!



Binette, Stasinska, & Bruzual
1994, A&A, 292, 13

Mechanical interaction of AGN with ambient gas via jet or wind

$$P_{jet} \sim 10^3 \, L_{bol}$$

Nagar, Falcke, & Wilson
2005, A&A, 435, 521

The End