Multi-wavelength and black hole mass properties of nearby Low Luminosity Active Nuclei

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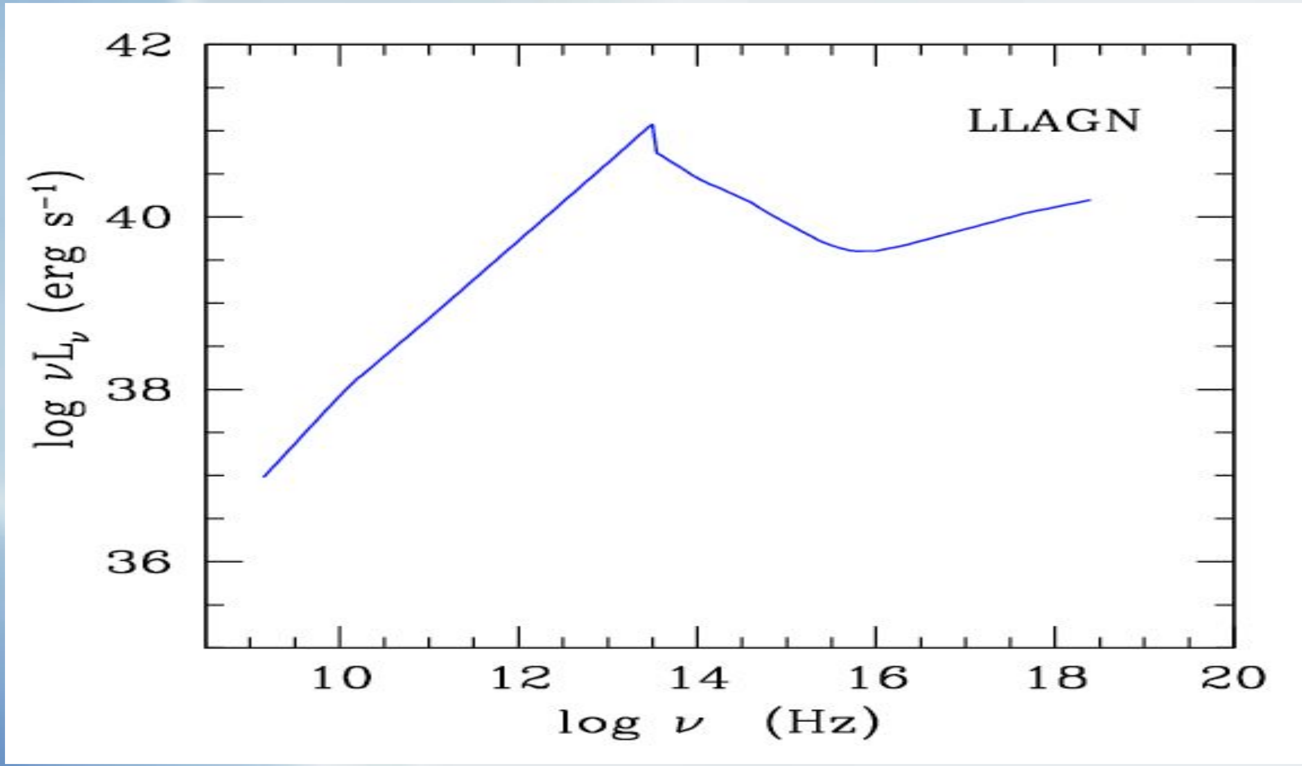
Low Luminosity AGN (LLAGN)

- Low luminosity Seyferts, LINERs, Transition nuclei
- Intrisically faint $L_{H\alpha} < 10^{40}$ erg/s
- Low activity levels ($L_{Bol}/L_{Edd} < 10^{-2}$)

Are LLAGN a scaled-down version of luminous AGN?

Observational properties of LLAGN



Ho 1999

SPECTRAL ENERGY DISTRIBUTION:

- Lack of the 'big blue bump' feature
- Radio emission higher than RQ AGN

Accretion theories for LLAGN

- JET-ONLY model: jet contributes from radio to X-rays

Scaled-up version of black hole binaries in a steady-jet, hard X-ray state? (Falcke et al. 2004) RI!

- ADAF/JET model: radio from the jet - X-rays from the accretion flow

Jet and Accretion flow strongly coupled (Merloni et al. 2003) RI!

- DISK/CORONA + JET model: radio from the jet - X-rays from the hot corona/accretion disk

Jet and Corona/disk system strongly coupled (Ghisellini et al. 2004) RE!

- Others?

RI= Radiatively Inefficient accretion flows
RE= Radiatively Efficient accretion flows

Sample of nearby Seyfert galaxies

Palomar optical spectroscopic survey
of nearby galaxies (Ho et al. 1997)

Separation between nuclear and host
galaxy allows the detection
of weak nuclei

Selected all known northern
Seyfert galaxies

TOTAL SAMPLE = 60

(13 Type 1 – 39 Type 2 - 8 “Mixed Seyfert”)

Optical emission in LLAGN

OPTICAL EMISSION LINE PROPERTIES:

- Detection of broad emission line components (Ho et al. '01)
- Optical emission lines correlates with ionizing continuum (Ho & Peng '01)

X-rays in LLAGN

X-RAY PROPERTIES:

- High detection of nuclei
- Spectral shape similar to luminous AGN
- High fraction of heavily absorbed objs

(Cappi et al. '06, Terashima & Wilson '03, Ho et al. '01)

X-rays in Seyfert sample

- XMM-Newton
- Chandra
- ASCA

47/60 have X-ray data

Compton thick canditates $N_H \geq 10^{24}$ cm^{-2}
(30% of type 2s)

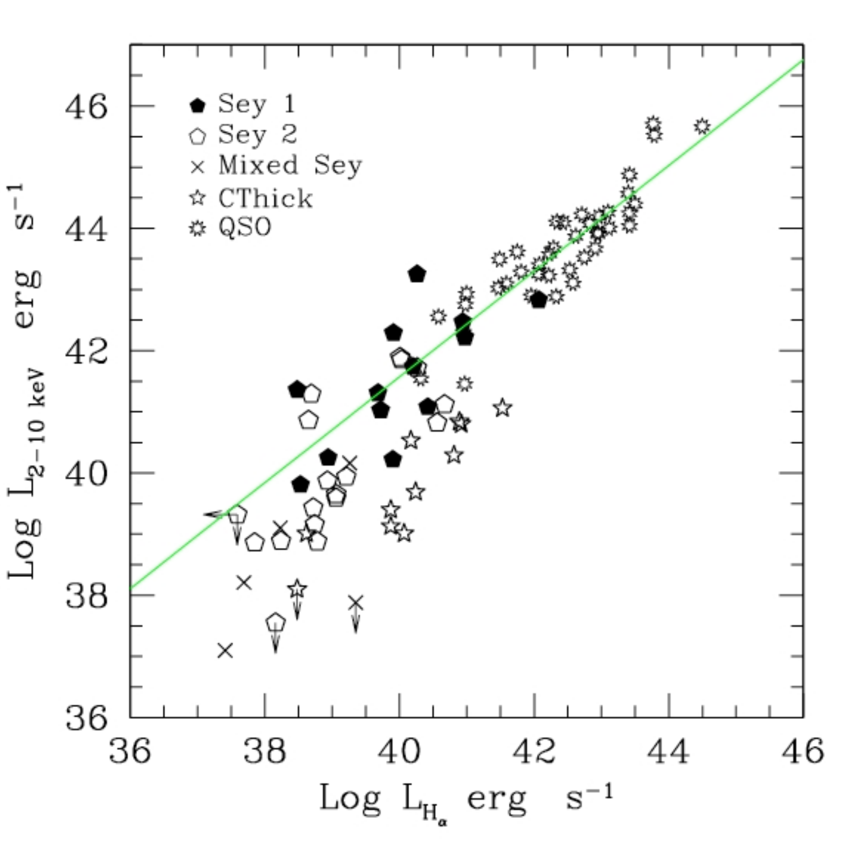
X-RAY LUMINOSITY increased by the
Correction factor

NUCLEAR INTRINSIC LUMINOSITY
in the 2-10 keV energy band

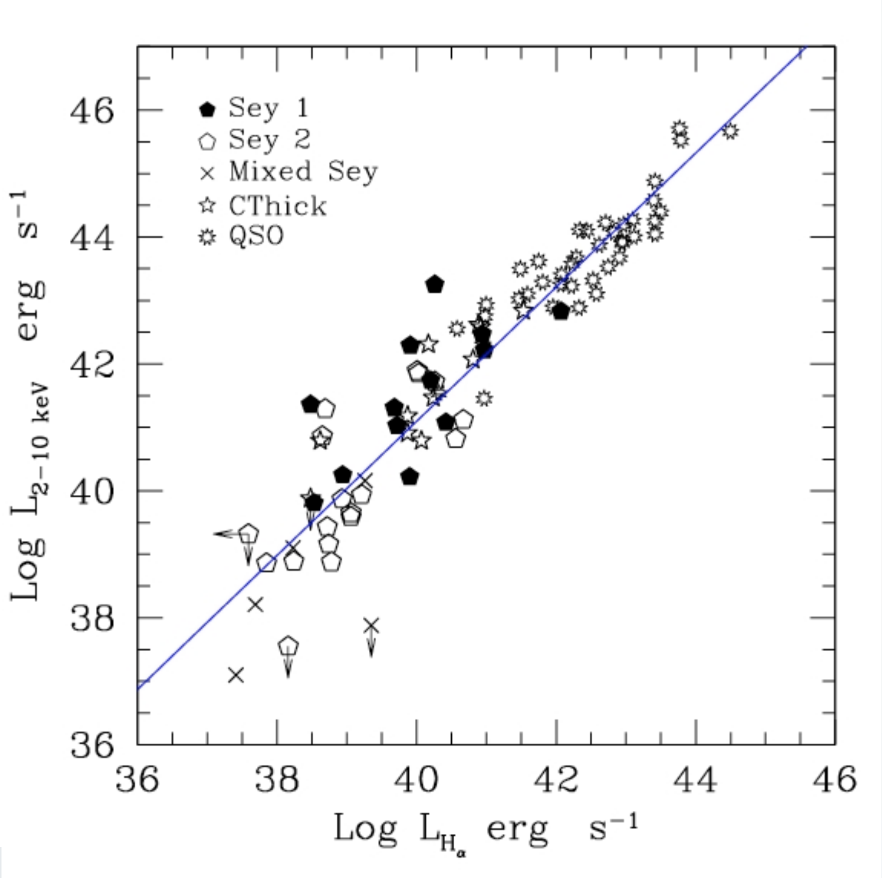
(Cappi et al. 2006, Panessa et al. 2006)

Correlation $L_{2-10keV}$ vs. $L_{H\alpha}$

Observed X-ray luminosity



Corrected X-ray luminosity



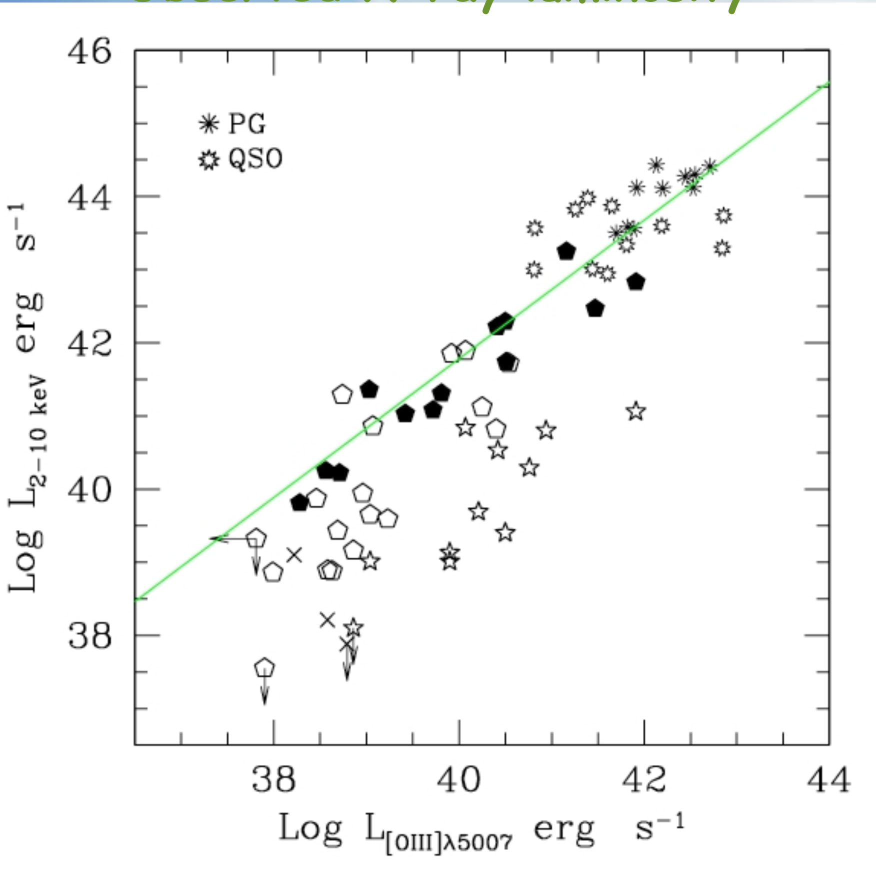
The strength of the hydrogen lines scales with the X-ray luminosity for Seyferts and quasars

The L_X versus $L_{H\alpha}$ correlation extends down to the regime of Low-Luminosity AGNs (r=0.95)

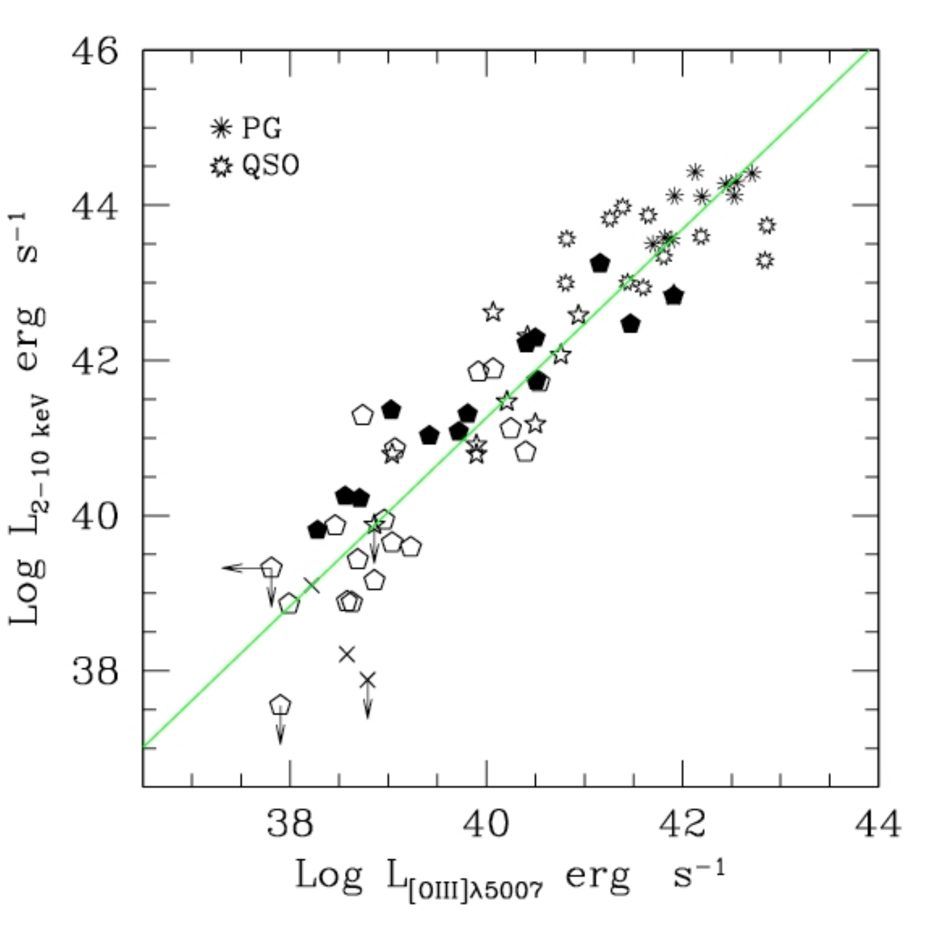
<10% of the sample could be powered by stellar processes

Correlation $L_{2-10keV}$ vs. $L_{[OIII]}$

Observed X-ray luminosity



Corrected X-ray luminosity



The L_X versus $L_{[OIII]}$ correlation extends down to the regime of Low-Luminosity AGNs (r=0.93)

<10% of the sample could be powered by stellar processes

X-ray vs. Optical emission lines

- Correlations are highly significant --> X-ray and UV linked
- Correlations scale with luminosity --> same physical mechanisms in LLAGN as luminous QSO
- Halfa and OIII luminosities good tracer of AGN power

Tools to estimate the expected X-ray luminosity:

$$\text{Log } L_{2-10keV} = (1.05 \pm 0.04) * \text{Log } L_{Halpha} + (-0.89 \pm 1.82)$$

$$\text{Log } L_{2-10keV} = (1.21 \pm 0.06) * \text{Log } L_{[OIII]} + (-7.25 \pm 2.55)$$

Panessa et al. 2006

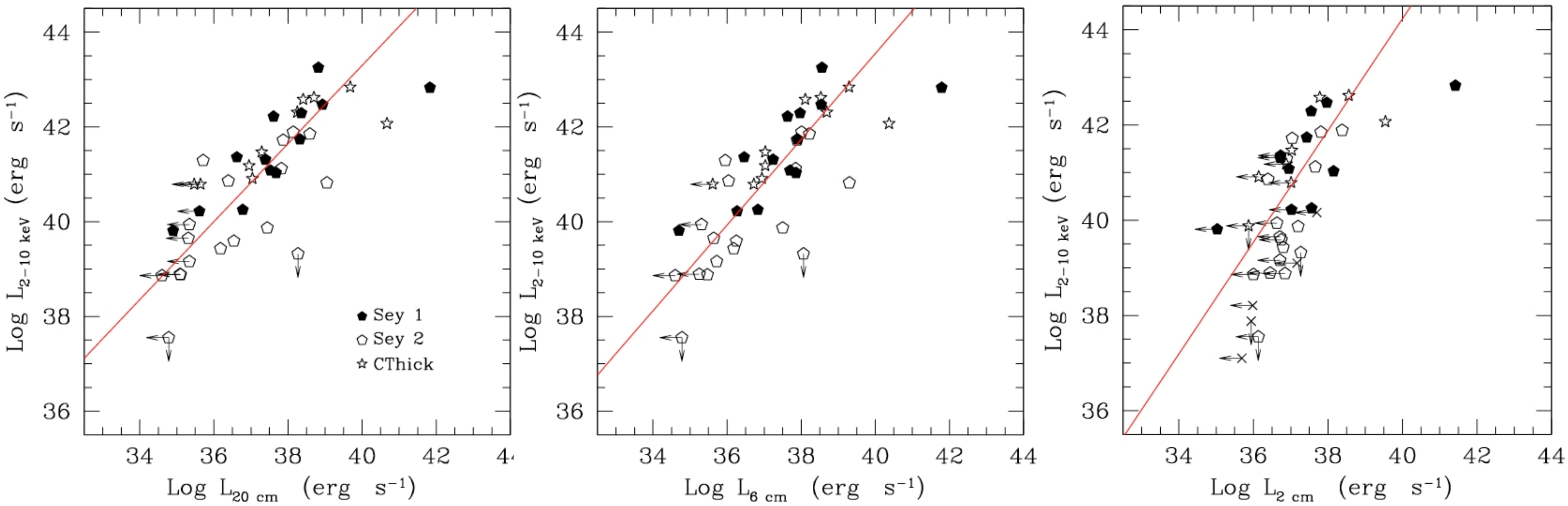
Radio Emission in LLAGN

RADIO PROPERTIES:

- High detection of pc-scale radio cores
- Occasionally jet-like features

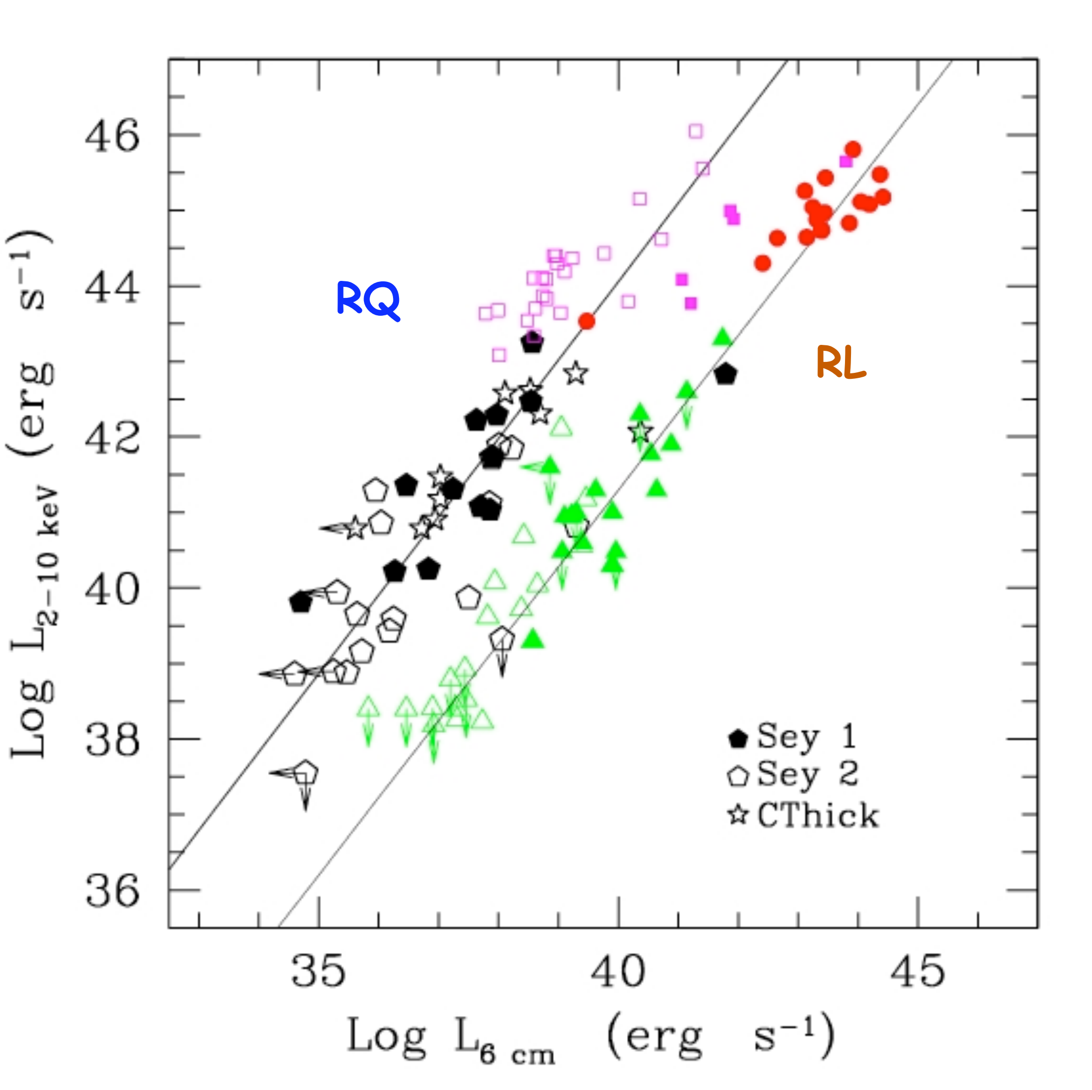
- Radio data VLA and VLBI surveys (Ho & Ulvestad '01, Nagar et al. '02)

L2-10 keV vs. LRadio



The L_x versus L_R correlations are highly significant at 20 cm, 6 cm and 2 cm (r = 0.82, 0.86, 0.78)

L2-10 keV vs. LRadio



Compared Samples:

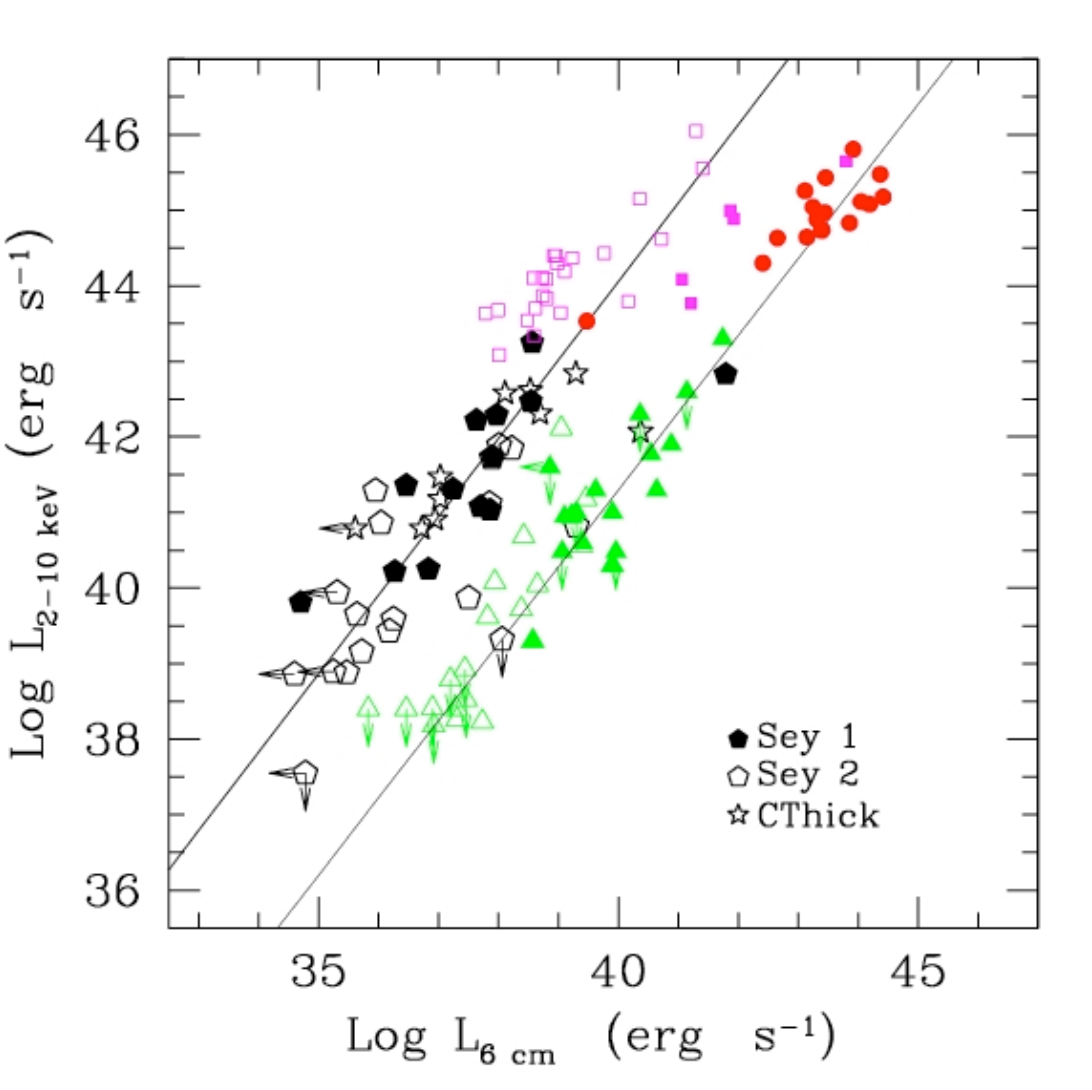
Seyfert I and II (this work)

PG QSO
(XMM by Piconcelli et al. 2002)
RQ open squares
RL solid squares

LLRG (Balmaverde&Capetti 2005)
From VLA surveys + HST + Chandra
Core galaxies (open triangles)
LL 3C/FRI (solid triangles)

Radio-Loud QSO (Gambill al. 2003)
Chandra + HST (biased toward radio jet)
Flat Spectrum RL FSRL
Steep Spectrum RL SSRL
ALL are FRII - high power radio sources

$L_{2-10\ keV}$ vs. L_{Radio}



The L_X versus L_R luminosities correlates:

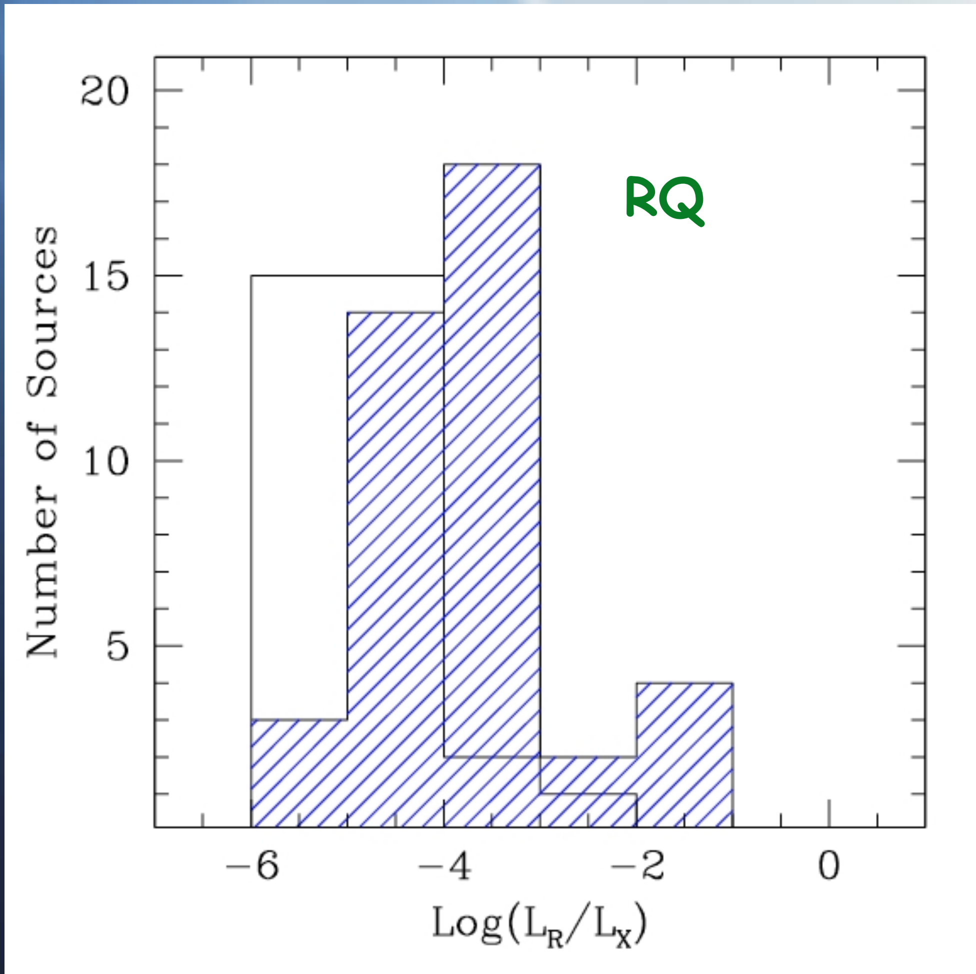
- Two correlations founds => RL & RQ?
- Same slope (??)
- The two correlations extend for 8 orders of magnitude - down to the regime of Low-Luminosity AGNs

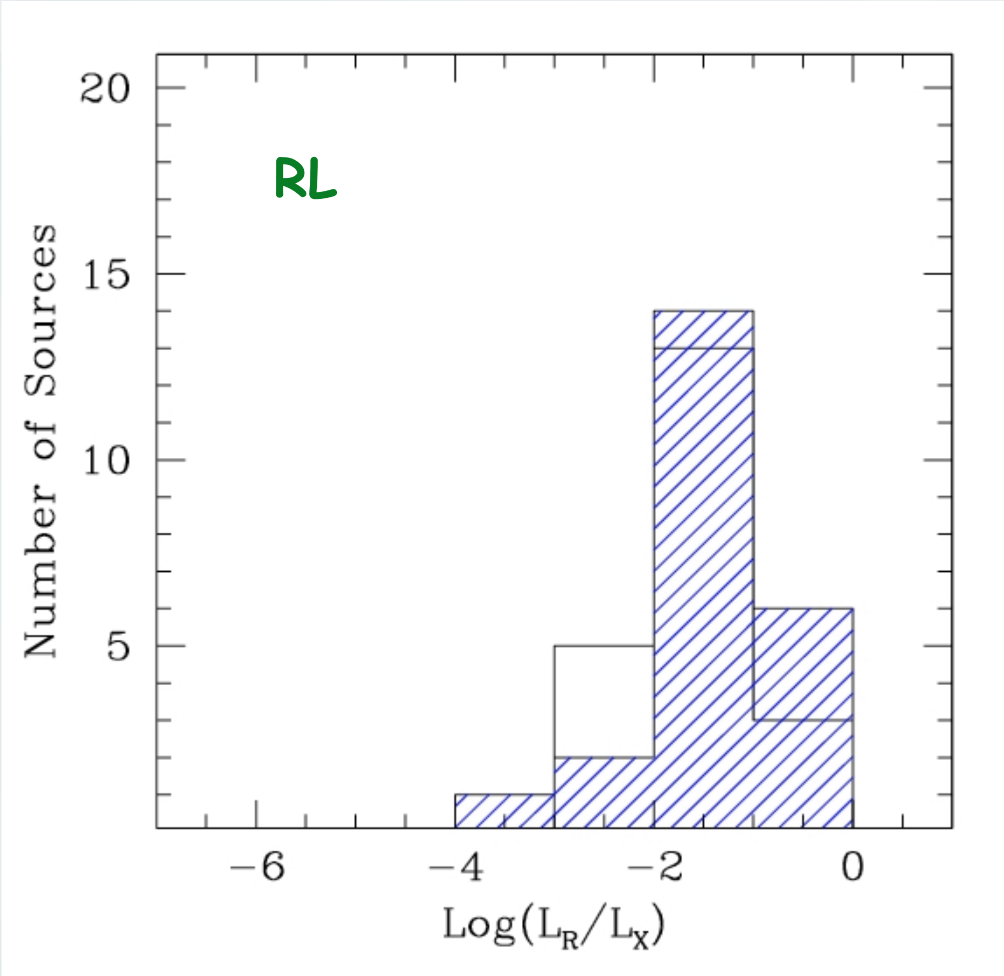
RQ = Some physical parameter that links the jet related power to the corona emission or radio and X-ray emission produced in outflow (Merloni et al. 2003, Ghisellini et al. 2004)

Corona at the base of the jet

Panessa et al in prep.

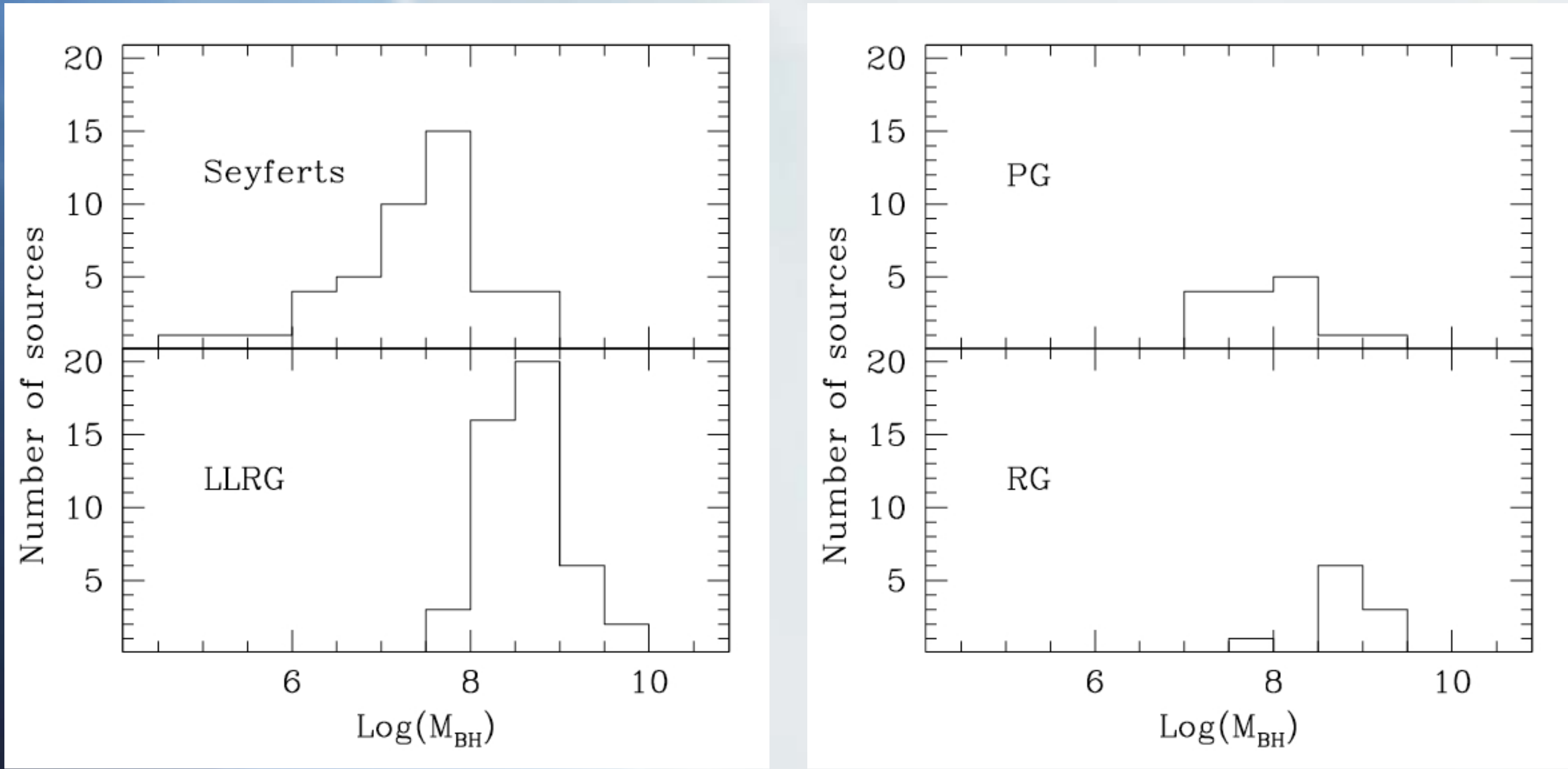
X-ray radio-loudness





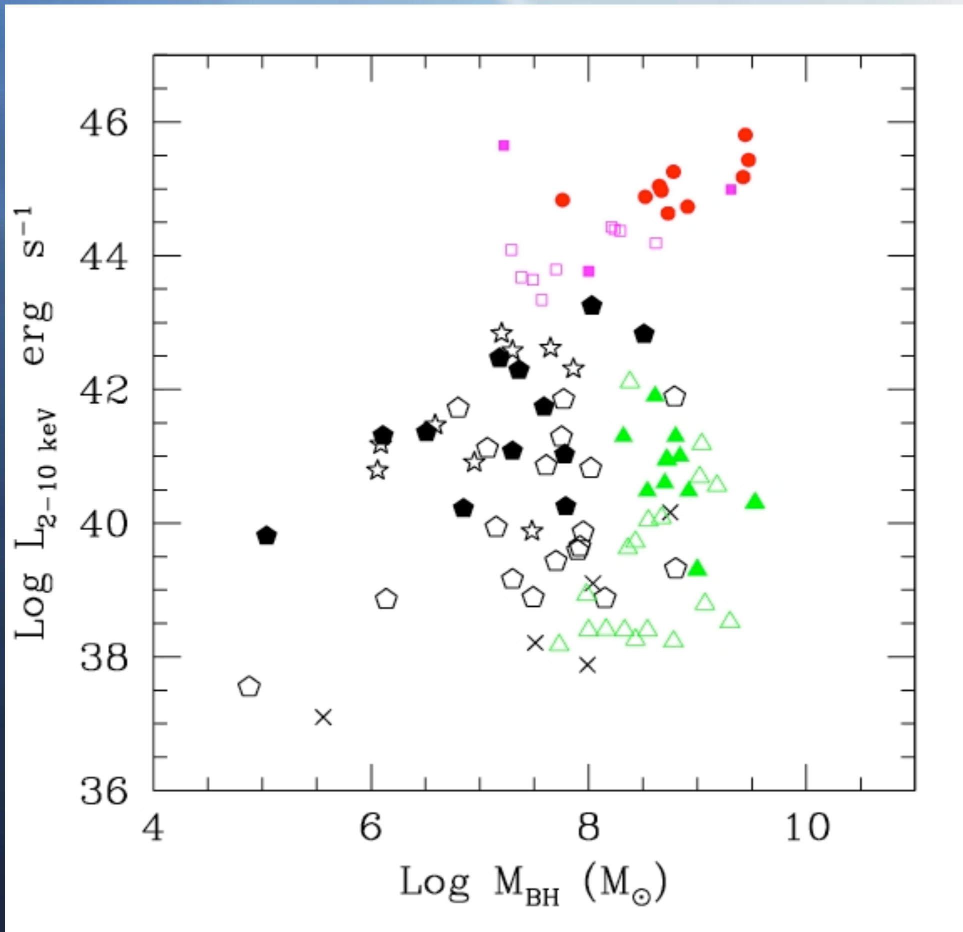
$R_X = L_R/L_X$

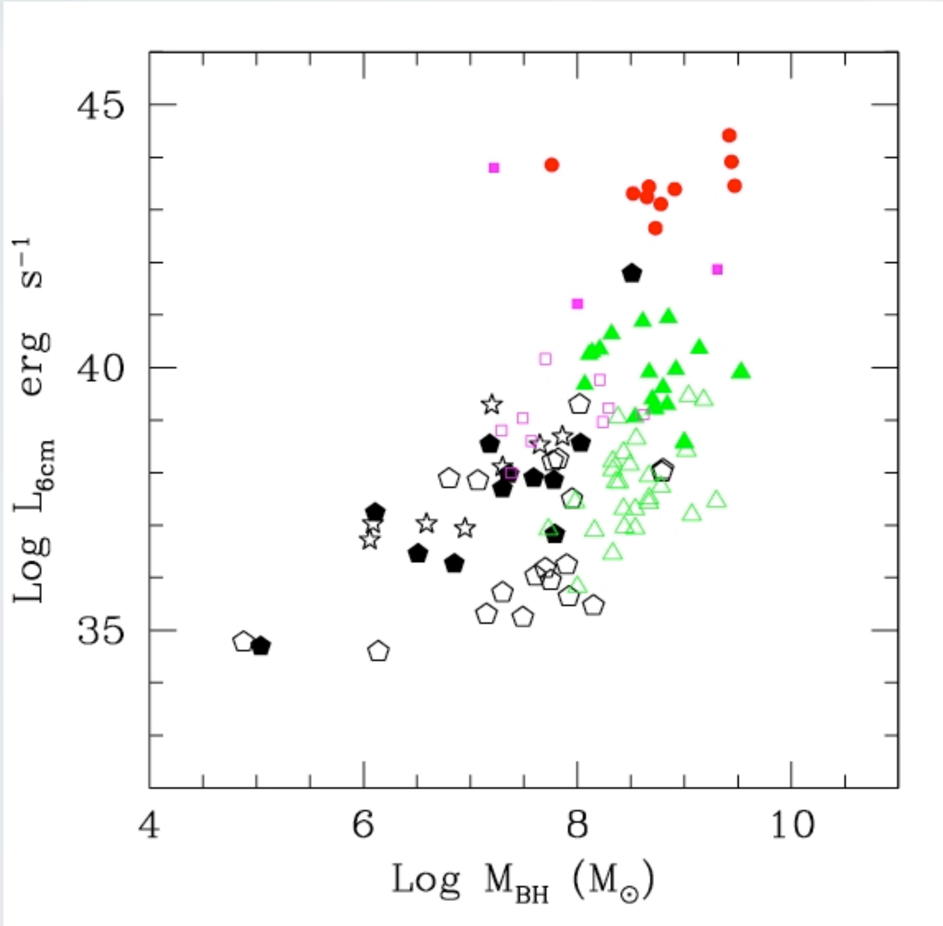
Black Hole Mass Distribution



→ **Distributions between RL and RQ different (KS=0.001) !!!**

L_X and L_R vs M(BH)

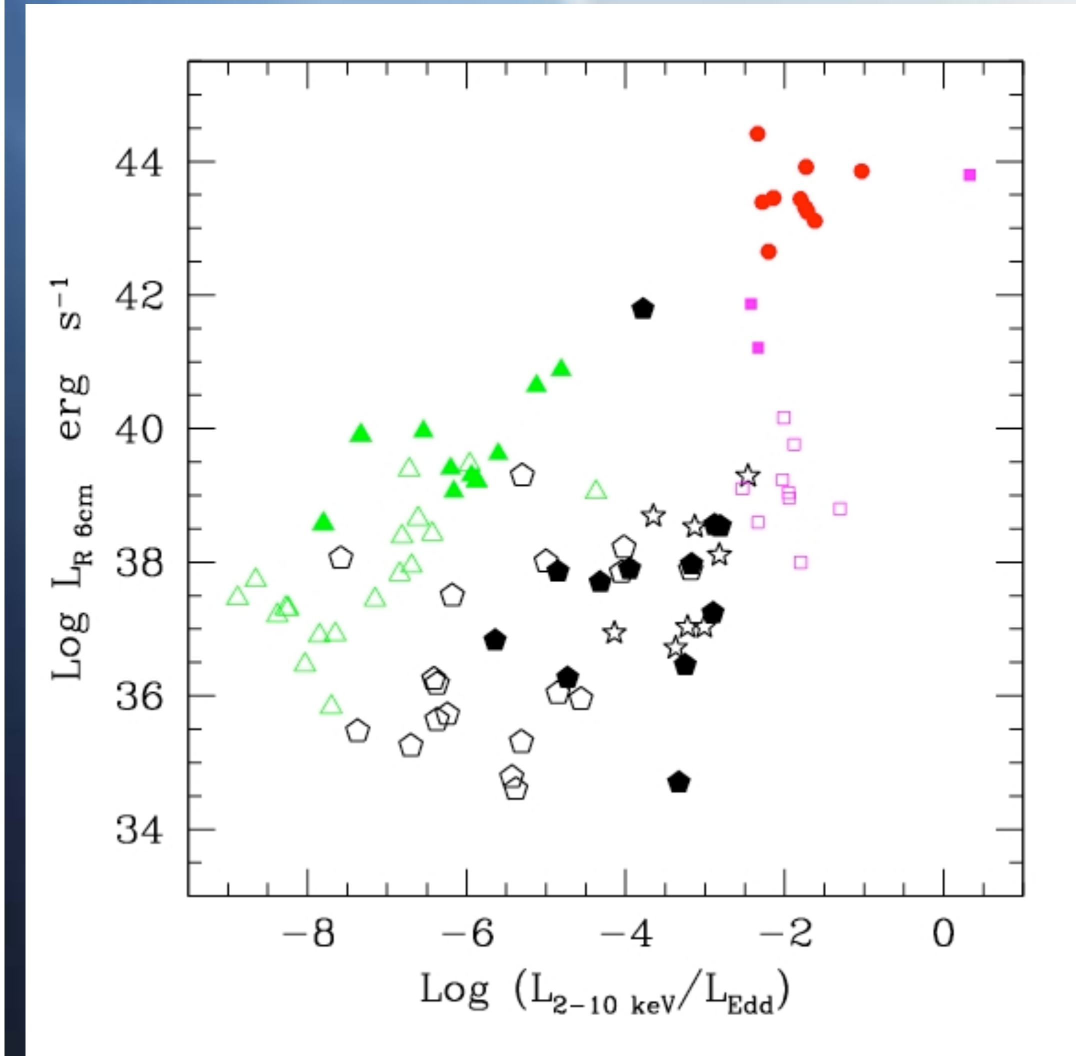




→ No correlation found, in agreement with Pellegrini 2005

→ Nagar et al. correlation found! Woo & Urry 2002 not found!

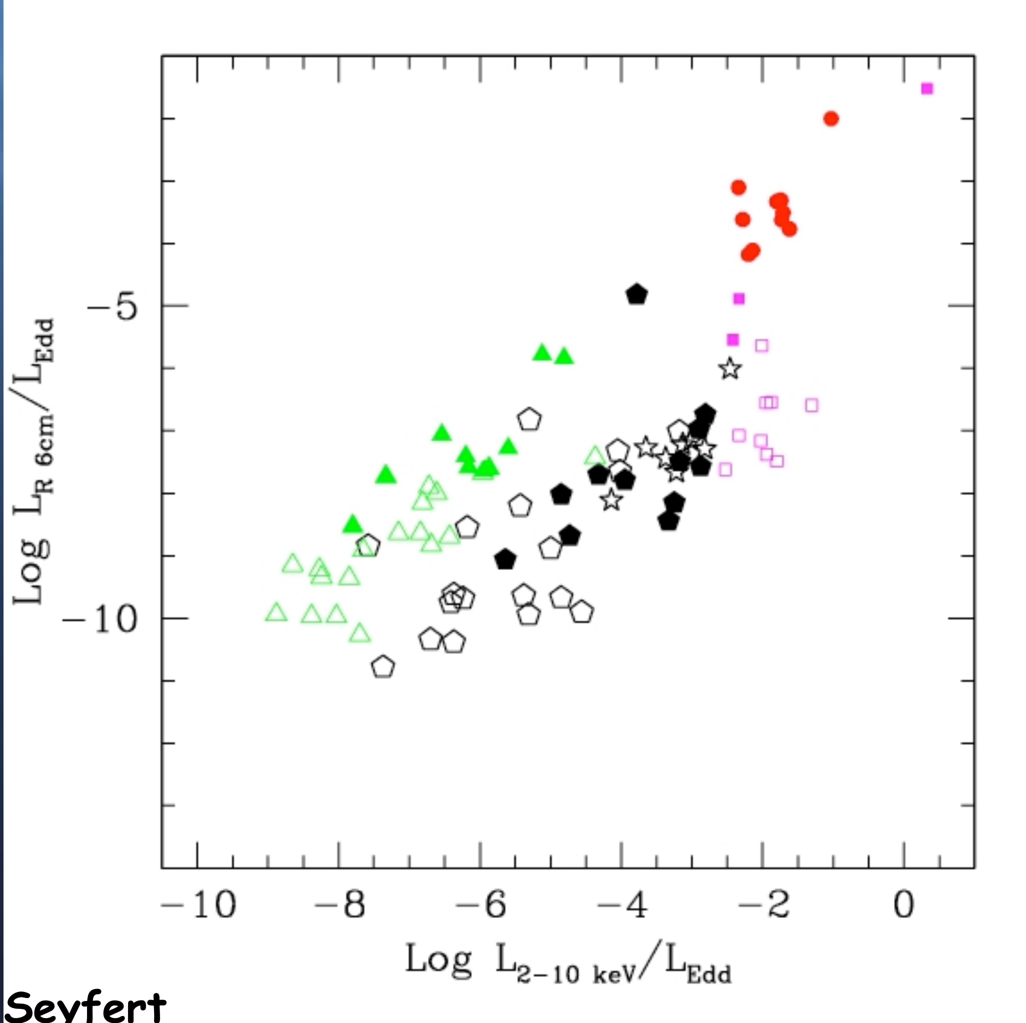
LRadio vs. Eddington ratio



- Large spread in Eddington ratios for a given L_R
- LLRG are accreting at very low Eddington ratios
- Type 1 ≠ Type 2 distribution (KS=0.01) --> if confirmed Nicastro '00 model

Seyfert
LL Radio-Loud
PG QSO
Radio-Loud QSO

LRadio vs. Eddington ratio



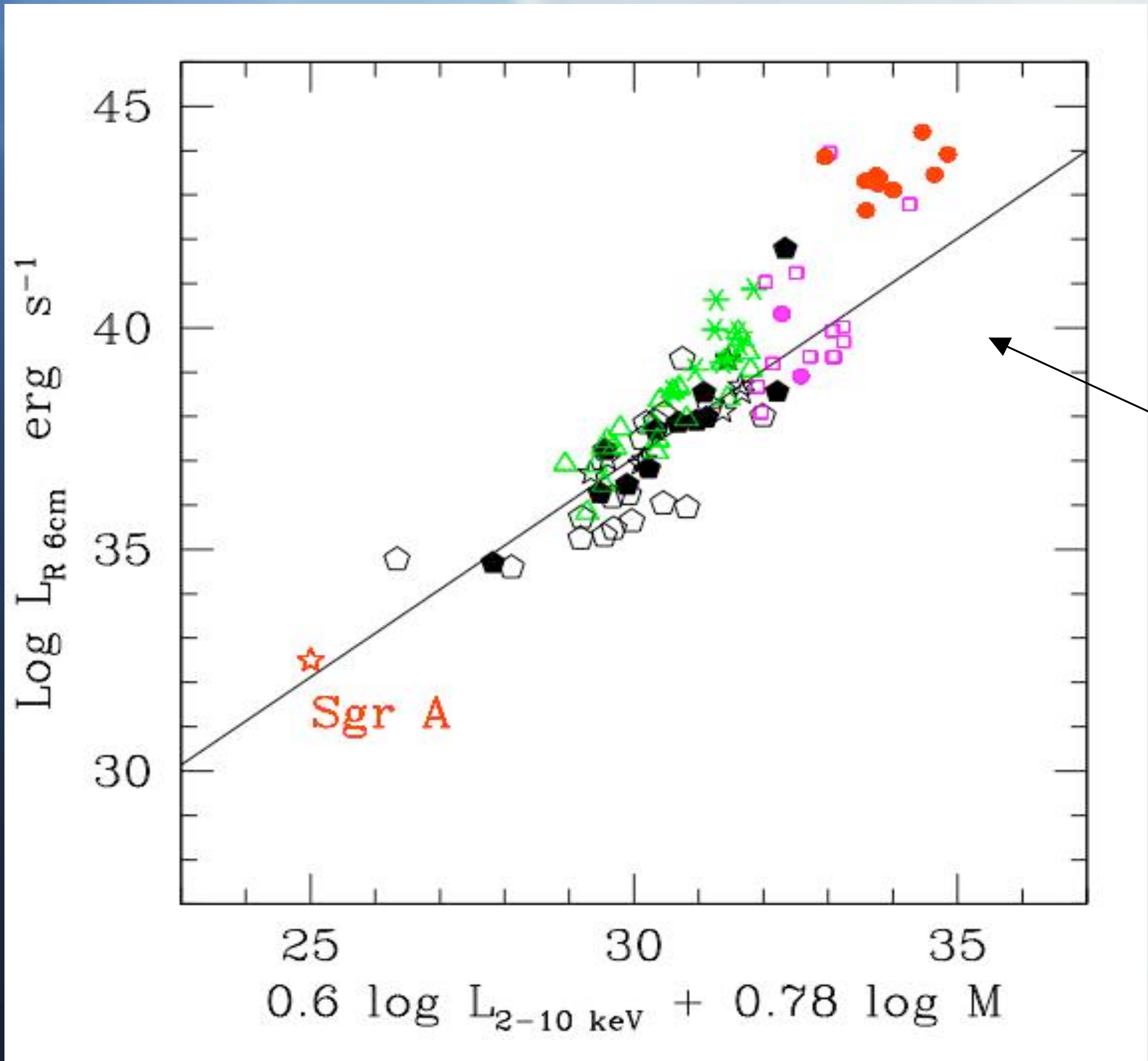
Seyfert
LL Radio-Loud
PG QSO
Radio-Loud QSO

- NO Transition between INEFFICIENT - EFFICIENT at $L_X/L_{EDD} \lesssim 10^{-3}$ & $\gtrsim 0.7$

- Radio Loud- Radio Quiet dichotomy caused by a switch of accretion mode appearing only at high accretion rates. At low luminosity no dichotomy expected (Nagar et al. 2002)

Radiatively efficient accretion disks are stable down to $L = 10^{-6}\ L_{EDD}$ (Park & Ostriker 2001)

Fundamental plane



- Radio-loud behave differently than radio-quiet!

Best fit =Merloni et al. 2003

Two fundamental planes??
Wang et al. 2006
Kording et al. 2006

SUMMARY

- X-ray spectral properties + X-ray vs Optical emission lines correlations — Similar to luminous AGN/QSO
- X-ray vs Radio correlation - RQ — Jet + X-ray source are strongly coupled
- X-ray vs Radio correlation - RQ/RL — Slope different from 0.7 by Gallo et al. for XRBs--> Jet only model excluded (??)
- M(BH) for RL & RQ different distribution
- No transition in Eddington ratios
- RL & RQ Fundamental planes

!!! Many open questions !!!

Comparison with theoretical models is needed for complete samples!