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 ($L_{\text{Bol}}/L_{\text{Edd}} < 10^{-2}$)

Are LLAGN a scaled-down version of luminous AGN?
Observational properties of LLAGN

SPECTRAL ENERGY DISTRIBUTION:
- Lack of the 'big blue bump' feature
- Radio emission higher than RQ AGN

Ho 1999
Accretion theories for LLAGN

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

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

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

- **Others?**

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

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

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

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 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 candidates \(N_H \geq 10^{24} \text{ cm}^{-2}\)
(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 $L_{2-10\text{keV}}$ vs. $L_{\text{H} \alpha}$

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

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

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

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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
- Hα and [OIII] luminosities good tracer of AGN power

Tools to estimate the expected X-ray luminosity:

\[
\log L_{2-10\,\text{keV}} = (1.05 \pm 0.04) \times \log L_{\text{Halpha}} + (-0.89 \pm 1.82)
\]
\[
\log L_{2-10\,\text{keV}} = (1.21 \pm 0.06) \times \log L_{[\text{OIII}]} + (-7.25 \pm 2.55)
\]

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)
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 et al. 2003)
  - Chandra + HST (biased toward radio jet)
  - Flat Spectrum RL FSRL
  - Steep Spectrum RL SSRL
  - All are FRII - high power radio sources
L2-10 keV vs. L_{Radio}

The $L_X$ versus $L_R$ luminosities correlates:

- Two correlations founds $\Rightarrow$ 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

\[ R_X = \frac{L_R}{L_X} \]
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!

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**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
NO Transition between INEFFICIENT - EFFICIENT at $L_x/L_{\text{edd}} \leq 10^{-3}$ & $\geq 0.7$

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 $L = 10^{-6}L_{\text{edd}}$ (Park & Ostriker 2001)
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
- X-ray vs Radio correlation - RQ
- X-ray vs Radio correlation - RQ/RL
- M(BH) for RL & RQ different distribution
- No transition in Eddington ratios
- RL & RQ Fundamental planes

Similar to luminous AGN/QSO
Jet + X-ray source are strongly coupled
Slope different from 0.7 by Gallo et al. for XRBs--> Jet only model excluded (??)

Comparison with theoretical models is needed for complete samples!

!!! Many open questions !!!