The XBS AGN sample as a tool to study the spectral properties of the different kind of AGN

A. Corral, R. Della Ceca, A. Caccianiga, P. Severgnini
Osservatorio Astronomico di Brera (OAB-INAF, Milano)
On behalf of the XMM-Newton Survey Science Center

Active Galactic Nuclei 9, Ferrara, 25 Maggio 2010
The Sample(s): HBSS, BSS

- **BSS**: Selection band: 0.5-4.5 keV, 389 sources, spectroscopic identification rate: 93%.
- **HBSS**: Selection band: 4.5-7.5 keV, 67 sources, spectroscopic identification rate: 97%.

Flux limit: $\sim 7 \times 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}$, 56 sources in common $\rightarrow$ **305 AGN**

Elusive AGN: 35 sources which classification cannot be inferred solely from optical spectroscopy (Caccianiga et al. 2007).

<table>
<thead>
<tr>
<th>AGN Sample</th>
<th>Type 1 AGN</th>
<th>Type 2 AGN</th>
<th>BL Lacs</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBSS</td>
<td>42(41)</td>
<td>20(10)</td>
<td>0</td>
</tr>
<tr>
<td>BSS</td>
<td>270</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>271</td>
<td>29</td>
<td>5</td>
</tr>
</tbody>
</table>
The Sample(s): HBSS, BSS
The Sample(s): HBSS, BSS

Good X-ray spectral quality
Almost complete optical spectroscopic identification
# X-ray Spectral fitting

<table>
<thead>
<tr>
<th>Model</th>
<th>Type 1 AGN</th>
<th>Type 2 AGN</th>
<th>BL Lacs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Law</td>
<td>241</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>Scattered/Partial covering</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>PL+Thermal emission</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Power Law + Black Body</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ionized Absorption</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PL+Reflection</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PL+Edge</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Intrinsic absorption

Absorbed if $N_H > 4 \times 10^{21} \text{ cm}^{-2}$, Caccianiga et al (2008)

Type 1 AGN

Type 2 AGN

8/270 type 1 AGN are absorbed

6/29 type 2 AGN are unabsorbed
Hardness ratios

\[ HR_n = \frac{CR_{n+1} - CR_n}{CR_{n+1} + CR_n} \]

CR2: 0.5–1.0 keV, CR3: 1.0–2.0 keV
CR4: 2.0–4.5 keV, CR5: 4.5–12 keV

Unidentified sources
Hardness ratios

\[ HR_n = \frac{CR_{n+1} - CR_n}{CR_{n+1} + CR_n} \]

- CR2: 0.5-1.0 keV
- CR3: 1.0-2.0 keV
- CR4: 2.0-4.5 keV
- CR5: 4.5-12 keV

Unidentified sources

Partial covering/scattered component shape
Intrinsic absorption / hardness ratio

- Using computed $N_H > 4 \times 10^{21} \, \text{cm}^{-2}$
  \[
  \log(N_H) = 22.2(\pm0.2) + 1.2(\pm0.2)HR3
  \]
- Using computed $N_H$, upper limits and errors crossing $4 \times 10^{21} \, \text{cm}^{-2}$
  \[
  \log(N_H) = 22.00(\pm0.04) + 1.46(\pm0.10)HR3
  \]
Intrinsic absorption / hardness ratio

- Using computed $N_H > 4 \times 10^{21} \text{ cm}^{-2}$
  \[ \log(N_H) = 22.2(\pm 0.2) + 1.2(\pm 0.2)HR3 \]

- Using computed $N_H$, upper limits and errors crossing $4 \times 10^{21} \text{ cm}^{-2}$
  \[ \log(N_H) = 22.00(\pm 0.04) + 1.46(\pm 0.10)HR3 \]

Type 2 QSO, $z \sim 2$

Partial covering/scattered component shape
Photon Index – Type 1 AGN

- Maximum likelihood (Maccacaro et al 1988):
  **BSS**: $\Gamma = 2.05 \pm 0.03 \quad \sigma = 0.26 \pm 0.02$
  **HBSS**: $\Gamma = 1.98 \pm 0.08 \quad \sigma = 0.29 \pm 0.05$
Photon index – Type 1 AGN

Correlation between the photon index and redshift/luminosity.

Luminosity correlation the strongest one
Photon index – Luminosity bins

- Maximum likelihood (Maccacaro et al 1988):
  Low $L_X$: $\Gamma = 2.11 \pm 0.04 \quad \sigma = 0.29 \pm 0.03$
  High $L_X$: $\Gamma = 2.00 \pm 0.04 \quad \sigma = 0.20 \pm 0.03$
Soft excess

- PL+BB best-fit.
- PL+BB good fit, but not the best fit

- XBS: 5%
- BSS: 4%
- HBSS: 14% (data quality)

- $z < 0.5$:
  - XBS: 11%
  - BSS: 9%
  - HBSS: 20% (spectral fit)

- Different for absorbed (scattered or thermal component) and unabsorbed sources.

Correlation with luminosity?
Soft excess

- PL+BB best-fit.
- PL+BB good fit, but not the best fit

- XBS: 5%
- BSS: 4%
- HBSS: 14% (data quality)

- z < 0.5:
  - XBS: 11%
  - BSS: 9%
  - HBSS: 20% (spectral fit)

- Different for absorbed (scattered or thermal component) and unabsorbed sources.

Correlation with luminosity?
- Not enough statistics.
- Correlation disappears at z < 0.5
  - $<kT> \sim 0.1$
Average spectra absorbed/unabsorbed AGN

Unabsorbed AGN
PL+NLine(Fe Kα)+Reflection

\[ \Gamma = 2.07 \pm 0.03 \]
\[ R \sim 0.5 \]
\[ E = 6.40 \pm 0.05 \text{ keV} \]
\[ EW = 100 \pm 30 \text{ eV} \]
\[ EW(\text{broad}) < 230 \text{ eV} (3\sigma) \]

Absorbed AGN
PL+NLine(Fe Kα)+Reflection

\[ N_H \sim 10^{22} \text{ cm}^{-2} \]
\[ E = 6.45 \pm 0.08 \text{ keV} \]
\[ EW = 110 \pm 50 \text{ eV} \]
\[ R \sim 1.5 \]

Corral et al. (2008)
Average spectra absorbed/unabsorbed AGN

Unabsorbed AGN
PL+NLine(Fe Kα)+Reflection

Γ=2.07±0.03
R~0.5
E=6.40±0.05 keV
 EW=100±30 eV, EW(broad) < 230 eV (3σ)

Absorbed AGN
PL+NLine(Fe Kα)+Reflection

N_H ~ 10^{22} cm^{-2}
E=6.45±0.08 keV
EW=110±50 eV
R~1.5

Corral et al. (2008)
Luminosity bins

Low $L_X$:

Fe Kα EW = 130 ± 80 eV

R ~ 0.8

High $L_X$:

Fe Kα EW = 70 ± 30 eV

R ~ 0.3
Summary

- The most common deviation from a power law shape, apart from the intrinsic absorption, is soft-excess emission. No clear dependence with X-ray luminosity and different nature for absorbed and unabsorbed sources.
- Deviations from Unified models are more common among Type 2 AGN.
- Photon index anti-correlated with X-ray luminosity.
- **Average spectra:** difference between absorbed and unabsorbed sources are due to an increment in the amount of reflection, besides the intrinsic absorption.
- No significant relativistic broad Fe Kα emission line, EW < 230 eV at 3σ confidence level.
- Iwasawa-Taniguchi effect, likely present but not enough statistics.