New Constraints on the X-ray Spectral Properties of Type 1 AGN

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Motivation

- Largest sample of type 1 AGN with X-ray spectra

**Aim:** Characterize the typical shape

- So far, most information from individual, bright AGN
- Despite lower S/N spectra, samples show the allowed range in properties

**Recent sample studies:**
- Bianchi et al. 2009. CAIXA, 160 AGN, XMM targets, High S/N, but biased to low z
- Young et al. 2009. SDSS/XMM, ~300 sources used in analysis, no SE modelling
- Mateos et al. 2010. XWAS, 500 type 1 AGN
Sample Creation

Optical Data
- SDSS DR5 quasar catalogue (Schneider et al. 2007)
- 5740 deg$^2$
- 77,429 quasars
- $0.08 < z < 5.41$
- FWHM $> 1000$ kms$^{-1}$

X-ray Data
- XMM-Newton
- 2XMMi (Watson et al. 2009)
- 420 deg$^2$
- 290,000 detections $\rightarrow$ 220,000 unique sources

Cross-correlate using 10” matching radius
$\rightarrow$ 1281 unique objects
Sample Creation

• Required >75 total counts
• → 761 sources
  - z: 0.11 - 5.41, \( L_x: 10^{43} - 10^{46} \text{ ergs}^{-1} \)
  - CTS: ~50% > ~300 counts
Spectral Fitting

- XSPEC, 0.5-12.0 keV
- Assume power law fit unless additional components are required by an F-test at >99% significance

<table>
<thead>
<tr>
<th>Model</th>
<th>Number of sources best-fit with model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power law</td>
<td>672</td>
</tr>
<tr>
<td>Power law + intrinsic absorption</td>
<td>29</td>
</tr>
<tr>
<td>Power law + soft excess</td>
<td>55</td>
</tr>
<tr>
<td>Power law + intrinsic absorption + soft excess</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>761</td>
</tr>
</tbody>
</table>

761 100%
Gamma Distribution

- **Fit with Gaussian**
  - $\langle \Gamma \rangle = 1.99 \pm 0.01$
  - $\sigma = 0.30 \pm 0.01$
  - $\Delta \Gamma = 0.13$
  - Similar to previous results
  - $p = 0.34\%$
  - i.e. Not a good fit due to presence of extremes in wings
Trends of $\Gamma$ with $z$ and $L_X$

- $\Gamma$ vs $z$, $\sim 3\sigma$
- Higher $z$ sources have flatter $\Gamma$
- Not due to reflection

- $\Gamma$ vs $L_X$, $\sim 5\sigma$
- Higher $L_X$ sources have flatter $\Gamma$
Gamma vs Eddington Ratio

- Black Hole mass estimates from Shen et al. 2008
  - \( \sim 56,000 \, M_{\text{BH}} \) for DR5QSO
  - Virial Method
  - 79% of sample included

- Eddington Luminosity:
  \[
  L_{\text{Edd}} = \frac{4\pi G M_{\text{BH}} m_p c}{\sigma_T} \approx 1.3 \times 10^{38} \frac{M_{\text{BH}}}{M_{\odot}} \text{ergs}^{-1}
  \]

- Bolometric Luminosity: (Marconi et al. 2004)
  \[
  \log \left( \frac{L_{\text{bol}}}{L_X} \right) = 1.54 + 0.24\ell + 0.012\ell^2 - 0.0015\ell^3
  \]
  \[
  \ell = \log L_{\text{bol}} - 12
  \]
• $\Gamma$ vs Eddington Ratio
  - H$\beta$, $\rho = +0.26$, 2.8$\sigma$
• $\Gamma$ vs Eddington Ratio
  - MgII, no correlation
• $\Gamma$ vs Eddington Ratio
  - CIV, $\rho = -0.32, 2.9\sigma$
Radio Properties

- Radio Loudness, $R_L = \frac{F_R}{F_O}$, $R_L > 10$ is radio loud
  (Kellermann et al. 1989)

$F_R$ = flux at 5 GHz (from FIRST – Becker et al. 1995)
$F_O$ = flux at 4400Å (from SDSS)

→ 552 RQQ, 75 RLQ
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Absorbed Sources

- Type 1 not expected to be absorbed (Unified Model)
- Intrinsic absorption detected in 4% sample
- $N_H: 10^{21} - 10^{23}$ cm$^{-2}$
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- \( N_H: 10^{21} - 10^{23} \text{ cm}^{-2} \)
- No trend of \( N_H \) with \( z \) or \( L_X \)
- No significant variation in the percentage of absorbed sources

27/06/2011
Sources with a Soft Excess

- Soft Excess detected in 7% of sources
Sources with a Soft Excess

- Soft Excess detected in 7% of sources
- $<kT> = 0.17 \pm 0.09$ keV

68% of sources:

0.1 - 0.25 keV

i.e. Narrow range
Sources with a Soft Excess

![Graph showing the relationship between $kT$ (in keV) and $M_{BH}$ (in Solar Masses) with different line types representing different ionization stages: Hβ, MgII, and CIV. The graph includes error bars and a 3.0σ significance level.](image)

27/06/2011  
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Sources with a Soft Excess

\[ 4.4\sigma \]

\[ \log L_x \]

\[ kT (\text{keV}) \]
Sources with a Soft Excess

![Graph showing the relationship between blackbody luminosity and power law luminosity with error bars and lines at different luminosity levels.]

~8σ
Conclusions

• Studied the X-ray spectral properties of 761 type 1 AGN

• Characterize the typical shape:
  - \( <\Gamma> = 1.99 \pm 0.01, \sigma = 0.30 \pm 0.01 \)
  - SE found in 7% with values \( <kT> = 0.2 \pm 0.1 \) keV  Ubiquitous?

• Surprisingly, intrinsic cold absorption found in 4% with \( N_H = 10^{21} - 10^{23} \text{ cm}^{-2} \)

• Trends with \( \Gamma \):
  - Marginal trend between \( \Gamma \) and \( z \) (3\sigma)
  - Trend between \( \Gamma \) and \( L_X \) (5\sigma)
  - Trend between \( \Gamma \) and Eddington ratio depends on which broad line is used to measure the black hole mass.

  - \( \rightarrow \) arXiv: 1106.4904 (MNRAS accepted)