NLS1s and Sy1s: A comparison of ionized X-ray absorber properties

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Abstract

The first results from a systematic study of warm absorbers in NLS1s using BeppoSAX public archive data are presented here. We confirm ASCA results showing that a warm absorber, as modeled by two oxygen K-shell absorption edges, is less frequent in NLS1s than in broad line (BL) Sy1s (∼20% versus ∼50%). However, our study suggests that the ionization state of NLS1s is not lower than that of BLS1s, as opposed to the ASCA-based results.

The soft excess temperatures of our sample, when fitted with blackbody emission models, lie within a small range of values (∼0.02–0.15 keV in the rest frame) with no marked dependence on source luminosity. This is in agreement with ASCA-based findings for NLS1s and early results from IUE-ROSAT BL Sy1 observations.

Key words: AGN; NLS1; X-rays; absorption

The BeppoSAX NLS1 sample

The spectra of our sample were obtained with the LECS (平方公里), MECS (平方公里), HPGSPC (平方公里) and PDS (平方公里) instruments on-board BeppoSAX. Because of its good low-energy resolution and effective area down to 0.1 keV, BeppoSAX is very efficient for the study of the complex spectral features in the soft X-rays. The broad-band sensitivity of BeppoSAX also allows a much more accurate measurement of the underlying continuum than is possible with other X-ray observatories. Our sample is composed of all the publicly available BeppoSAX NLS1 spectra before December 1999, plus the proprietary data for one source (Mrk 335). Table 1 lists the sources with their X-ray luminosities and redshifts. The X-ray luminosities span more than 4 orders of magnitude, from the narrow-line QSO PKS 0558–504 down to NGC 4051 in its ultra-low state.

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Table 1
The exposure times are for the MECS. A value of $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ is assumed. The units for $N_H$, $t_{\text{exp}}$ and $L_{0.1-10}$ are $10^{20} \text{ cm}^{-2}$, $10^4 \text{ s}$ and $\text{erg s}^{-1}$ respectively.

| Source Name   | redshift | $N_H$ | date               | $t_{\text{exp}}$ | $L_{0.1-10}$ |
|---------------|----------|-------|--------------------|------------------|--------------|
| NGC 4051-low  | 0.00242  | 1.31  | 9-11 May 98        | 2.6              | $0.87 \times 10^{41}$ |
| NGC 4051-high | 0.04244  | 1.43  | 28-29 Jun 98       | 1.2              | $1.75 \times 10^{42}$ |
| RE J 1034+39  | 0.013    | 1.77  | 17-18 May 97       | 7.8              | $4.9 \times 10^{43}$  |
| Mrk 766       | 0.025    | 7.77  | 10-12 Dec 98       | 8.9              | $8.0 \times 10^{43}$  |
| Mrk 335       | 0.0667   | 1.43  | 29-30 Jan 98       | 2.2              | $15.9 \times 10^{43}$ |
| IRAS 13224−3809 | 0.062   | 4.39  | 18-19 Oct 98       | 6.4              | $4.4 \times 10^{43}$  |

The data were processed using the SAXDAS 2.0.0 data analysis package and the spectra were rebinned in order to allow the use of the $\chi^2$ statistic. Where available, data were selected in the energy ranges 0.1–4.0 keV (LECS), 1.8–10 keV (MECS), 8.0–34 keV (HPGSPC), and 15–100 keV (PDS). Because the spectra of IRAS 13224−3809 and the low state of NGC 4051 have a relatively low signal to noise ratio, only data below 10 keV were considered for these two objects.

**Fit results for the warm absorber**

All our fit models include Galactic absorption as well as factors to allow for flux normalization uncertainties between the instruments. These factors were constrained within their standard ranges (3). Uncertainties are quoted as 90% confidence intervals for one parameter of interest.

The single power-law model does not give a good fit to any of the spectra except PKS 0558−504, where the fit is marginally acceptable ($\chi^2 = 1.19$, 109 dof). A soft excess, in the form of either power-law or blackbody emission, gives significant improvement to the fit statistics of all spectra. In 4 spectra (IRAS 13224-3809, Mrk 335, Mrk 766, NGC 4051-high), the soft excess is slightly better fit by a blackbody component than by a power law. In the remaining 5 spectra, the opposite is true. We then tried adding a Fe Kα line and 2 K-shell absorption edges (Ovii and Oviii) to the power-law plus blackbody continuum. The edge energies are fixed at $E = 0.74$ and $0.87 \text{ keV}$ in the rest frame and the line at $E_{\text{rest}} = 6.4 \text{ keV}$ with $\sigma = 0.1 \text{ keV}$. The fit results are listed in Table 2. Only two spectra of our sample (Mrk 335 and Mrk 766) show significantly improved fits (confidence level > 95 %) with the addition of these three spectral features. Three others show a marginal improvement (TON S 180, NGC 4051-high and Ark 564). The remaining four spectra show no improvement in the fit statistics. In all 9 spectra, we obtain only upper limits for $\tau_{\text{O7}}$. Likewise, in 7 spectra there are upper limits for $\tau_{\text{O8}}$. Only two spectra (Mrk 335 and Mrk 766) have definite, albeit low, values for $\tau_{\text{O8}}$.

We have also tried fitting a warm absorber model (absori in Xspec) instead...
Table 2
Two edge plus Fe Kα line fit results. NA = not available

| Source Name     | τ_{O7} | τ_{O8} | EW(Fe Kα) eV | χ^2/(dof) |
|-----------------|--------|--------|--------------|-----------|
| NGC 4051-low    | < 0.34 | NA     | NA           | 1.44 (30) |
| NGC 4051-high   | < 1.68 | < 1.65 | 208 ± 135    | 1.12 (147)|
| RE J 1034+39    | < 0.08 | < 0.10 | < 624        | 1.22 (124)|
| Mrk 766         | < 1.53 | 0.20 ± 0.16 | 102 ± 60 | 1.34 (158)|
| Mrk 335         | < 0.07 | 0.24±0.22  | 228 ± 82    | 1.43 (138)|
| IRAS 13224−3809 | < 1.08 | < 0.49  | < 813        | 1.48 (11) |
| Ark 564         | < 0.21 | < 0.08  | 299 ± 122    | 1.20 (156)|
| TON S 180       | < 0.12 | < 0.11  | 306 ± 214    | 1.30 (187)|
| PKS 0558−504    | < 0.09 | < 0.06  | < 104        | 1.03 (104)|

of the two O edges. In this case, 5 spectra out of 9 show a significant improvement in quality of fit over the 2-edge fits: Mrk 335, TON S 180, RE J 1034+39, Ark 563 and NGC 4051-low. For the first three in this list, the improvement in χ^2 has an F-statistic > 15. Among the remaining spectra, it is evident that PKS 0558−504 has no warm absorber, and that absor brings no significant improvement over the 2-edge fit for NGC 4051-low or Mrk 766. However, Mrk 766 most likely does have two O absorption edges. In the cases of NGC 4051-low and IRAS 13224−3809, the poor quality of the spectra does not allow one to conclude anything about the presence of soft X-ray features.

**Comparisons with ASCA NLS1 results and with BLS1s**

Recent studies based on ASCA data have shown that warm absorbers are a common spectral component of BL type 1 AGNs (10) (3). Reynolds (10) detected Ovii and Oviii K-shell absorption edges in 50% of his sample of 24, with >37% having optical depths greater than 0.2 for one or both edges. The average optical depths for Ovii and Oviii in the Reynolds sample are 0.29 ± 0.07 and 0.18 ± 0.06, respectively (9). These type 1 AGN results are in sharp contrast with the values from our BeppoSAX NLS1 sample (see Table 2), that has only 2 clear detections of O absorption edges in a total of 9 spectra, corresponding to ~20%. A similar low proportion of ~26% was found by Leighly (6) in her study of NLS1 ASCA spectra, where 6 spectra from 5 sources (out of 23) have significant O absorption edge detections. We note that all the sources of our sample are included in the larger ASCA sample (9), but only one of our two sources with significant edge detections (Mrk 766) is among Leighly’s five “warm-absorbed” NLS1.

The average optical depths for Ovii and Oviii in the ASCA sample (9) are 0.19±0.14 and 0.053±0.020, respectively (9). The low value of τ_{O8} suggests that the ionization state of NLS1s is lower than that of BLS1s (9). However, looking at Table 2 we see that the BeppoSAX results do not support this conclusion. The ASCA sample includes objects which may have dusty warm absorbers.

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2 The soft excess is modeled by a blackbody, as with our BeppoSAX sample.
(e.g. IRAS 13349+2438, IRAS 17020+4454 and IRAS 20181−2244). If the effects of the dust are not taken in to account correctly one can derive warm absorber ionization states which are too low ([4]). Furthermore, it is a common assumption that the central black holes of NLS1s accrete at very high rates. In this case, a high power output is expected that could cause the ionization state of the warm absorber to be correspondingly high.

ASCA-based studies of NLS1s ([7]) have shown that certain sources (e.g. Ark 564) have broad absorption features in the 1.1-1.4 keV range. We find that we can reproduce the BeppoSAX results on Ark 564 published by Comastri et al. ([2]), but not those of Vaughan et al. ([11]) based on ASCA data. In other words, a weak emission line or absorption edge may be present, but probably no absorption line as in ([11]). And when a warm absorber (absori) is included, the need for such a line is no longer very strong. We have not yet tested the other sources in our sample for such features, but it is clear that no large residuals are present between 1.1-1.4 keV in our absori fits.

The EWs of the Fe Kα line in our sample are low and, within the uncertainties, compatible with values expected in typical Sy 1 BLR conditions, i.e. column densities of $10^{22–23}$ cm$^{-2}$, leading to EWs of $\sim$50–150 keV. The soft excess temperatures of our sample, when fitted by blackbody emission, lie within a small range of values ($\sim$0.02–0.15 keV in the rest frame) with no marked dependency on source luminosity. This is in agreement with ASCA-based findings for NLS1s ([7]) ([11]) and also IUE-ROSAT BL Sy1 observations ([12]).

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