ROSAT observations of radio-loud AGN

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Abstract. We have analysed the ROSAT soft X-ray spectra of a sample of radio loud AGN from the public archive. Based on the catalogues of Véron-Cetty & Véron (1993), Hewitt & Burbidge (1993), Stickel *et al.* (1994) and the NED database the sample was selected by the following criteria:

- radio loudness ($\alpha_{ro} > 0.4$),
- radio flux $S_{5\mathrm{GHz}} \geq 0.5$ Jy,
- position within 55' of the center of FOV in pointed ROSAT PSPC observations.

Our sample comprises 165 detected radio loud AGN (including 6 AGN without known redshift). It contains 98 FSQ (radio flat spectrum quasars with $\alpha_r < 0.5$), 35 SSQ (radio steep spectrum quasars with $\alpha_r > 0.5$) and 32 BL Lac objects.

We find that the FSQ have flatter spectra than the SSQ and BL Lacs in the ROSAT energy range (0.1 – 2.4 keV). No difference between these classes is found in α_{ro} and α_{ox}. The ROSAT spectra of radio loud and radio quiet quasars are steeper than the spectra measured at higher energies (> 1 keV) by EINSTEIN, EXOSAT or GINGA.

1. Data Analysis

The ROSAT data analysis was performed using the EXSAS software package (Zimmermann *et al.* 1994). Power-law spectral fits with absorption fixed at the Galactic column density of N_{H} (Stark *et al.* 1992, Elvis *et al.* 1986, 1989) were acceptable for most observations (135 of 165 sources have $\chi^2_\nu < 2.0$, 10 of the remaining 30 sources show indications that double power-law fits were preferable).

We have applied a maximum likelihood method to determine the mean $\langle\alpha_p\rangle$ and width σ_p of the distribution of spectral energy indices in our sample (see also Maccacaro *et al.* 1988 for a detailed description of the method). In the contour plot presented here, $\langle\alpha_p\rangle$ is displayed on the x-axis and σ_p on the y-axis. The contour lines are at 68% and 90% confidence level. In the following the errors given for $\langle\alpha_p\rangle$ only represent the 68% uncertainty of the mean value of the Gaussian distribution of α_p. σ_p is the dispersion (the width of the distribution) in α_p.

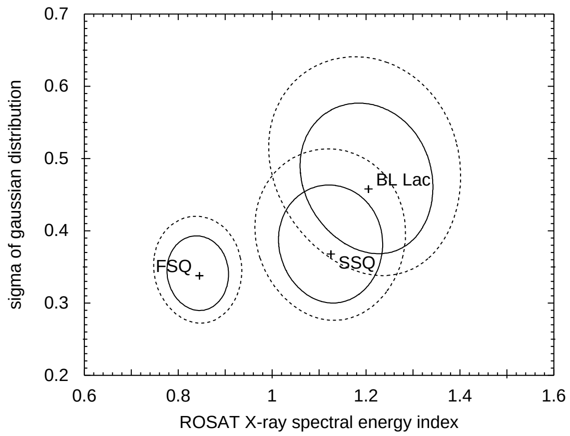

Fig. 1. α_x for FSQ, SSQ and BL Lacs.

2. Mean Spectral Indices

We find that the mean X-ray energy index of FSQ is flatter than those of SSQ and BL Lacs (Fig.1). The mean X-ray energy indices are $\alpha_x = 0.85 \pm 0.06$ for FSQ, 1.13 ± 0.10 for SSQ and 1.21 ± 0.15 for BL Lacs. The dispersion on α_x is between 0.4 and 0.5 for each of the classes. These results are in excellent agreement with the ROSAT results of Brunner *et al.* (1994) and Brinkmann & Siebert (1994). In contrast to these ROSAT results, previous results from EINSTEIN (Wilkes & Elvis 1987), EXOSAT (Lawson *et al.* 1992) and GINGA (Williams *et al.* 1992) show a zero or very low dispersion on α_x for radio loud quasars. However, it has to be considered that the objects observed by EINSTEIN, EXOSAT and GINGA are only low redshift quasars ($z < 1.0$).

We find neither in α_{ox} nor in α_{ro} a significant difference between the FSQ, SSQ and BL Lacs. The mean values for our sample are $\alpha_{ox} \simeq 1.35 \pm 0.06$ with a dispersion $\sigma_{ox} \simeq 0.13$ and $\alpha_{ro} \simeq 0.67 \pm 0.03$ with a dispersion $\sigma_{ro} \simeq 0.10$.

3. Redshift Dependence of X-ray Spectral Index

We have investigated the redshift (z) dependence of α_x for the different classes of objects (Fig.2). For each class we computed the weighted mean for redshift bins of width 0.4 using the 1σ errors of α_x.

The class of FSQ shows a significant flattening of the

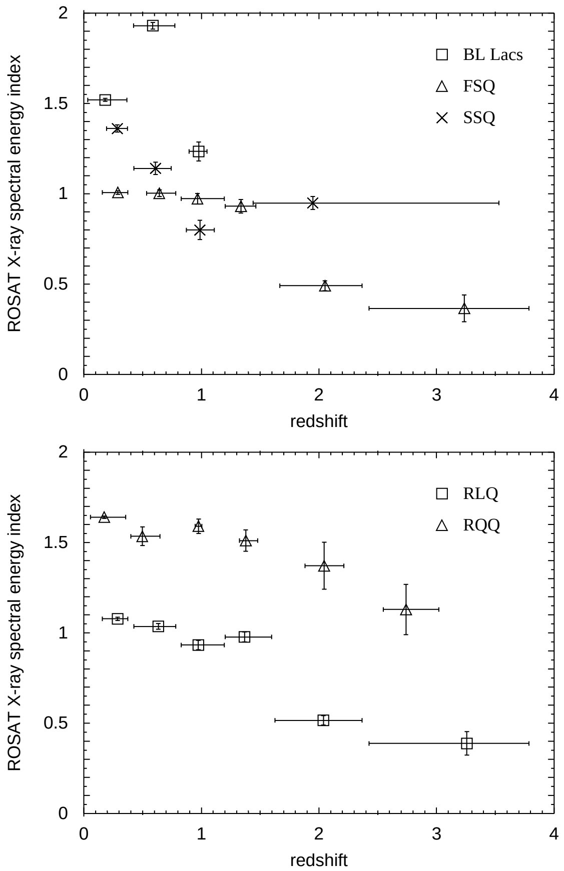

Fig. 2. top: α_x vs. z for FSQ, SSQ and BL Lacs. bottom: α_x vs. z for radio loud quasars RLQ and radio quiet quasars RQQ.

X-ray spectrum towards higher redshift ($\alpha_{x,z<0.4} = 1.00 \pm 0.01$, $\alpha_{x,z>2.4} = 0.36 \pm 0.08$). The class of SSQ follows that tendency ($\alpha_{x,z<0.4} = 1.36 \pm 0.02$, $\alpha_{x,z>1.6} = 0.95 \pm 0.04$). The BL Lacs show no dependence of α_x on z, however, there is no BL Lac beyond $z = 1.2$. These dependencies on the redshift remain the same if only the high luminosity sources are selected. EXOSAT spectra reveal a similar difference between FSQ ($\alpha_x = 0.62 \pm 0.07$) and SSQ ($\alpha_x = 0.87 \pm 0.17$) but are significantly flatter compared to our low redshift quasars.

A comparison between these radio loud quasars (RLQ: FSQ and SSQ) and a sample of 64 radio quiet quasars (RQQ, $\alpha_{ro} < 0.3$) from pointed ROSAT PSPC observations (Müller 1995) shows that the RQQ have a much steeper X-ray spectrum than the RLQ. This difference in α_x remains independent of redshift ($\Delta\alpha_x \simeq 0.6 - 0.7$). Spectral results from EINSTEIN, EXOSAT and GINGA show a similar difference in α_x between RLQ and RQQ, but the spectra are significantly flatter (RLQ: $\alpha_x \simeq 0.5 - 0.7$, RQQ: $\alpha_x \simeq 0.9 - 1.0$). Because all objects of these samples have a redshift $z < 1.0$ their spectra can only be compared with our low redshift objects.

4. Galactic $N_{\rm H}$ vs. Fitted $N_{\rm H}$

For those sources with a sufficiently large number of counts (> 200) we also performed power-law fits with $N_{\rm H}$ as a free parameter (108 of 116 sources have $\chi^2_\nu < 2.0$, the remaining 8 sources are double power-law candidates). We have analysed the redshift dependence of $\Delta N_{\rm H}$ ($= (N_{\rm H,gal} - N_{\rm H,fit})/N_{\rm H,gal}$) for our sample of radio loud AGN. For each redshift bin the weighted mean using the 1σ erros of $N_{\rm H,gal}$ and $N_{\rm H,fit}$ was computed.

In contrast to Elvis *et al.* (1994), we find no evidence that high-redshift quasars exhibit absorption in excess of the Galactic column densities (Fig.3). A significant dependence of $\Delta N_{\rm H}$ on z is not found.

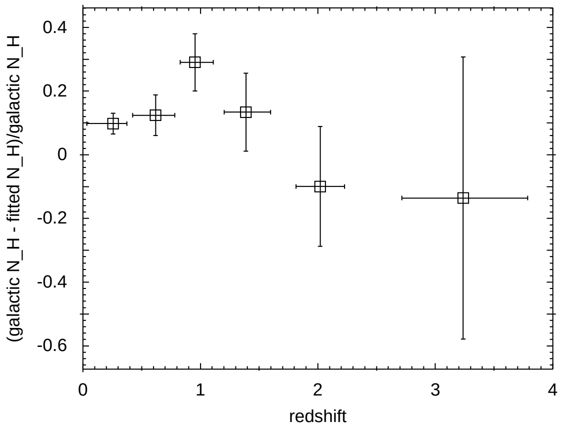

Fig. 3. $\Delta N_{\rm H}$ vs. z for our sample of radio loud AGN.

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