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Letter to the Editor

Optically luminous QSOs observed with ROSAT

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Abstract. We present ROSAT PSPC observations of six luminous high-redshift (z = 2.15 to 3.2) QSOs. All were detected in X-rays. For four of them with $\gtrsim 200$ counts spectral fittings using power laws yield a photon index $\alpha_P = 2.25 \pm 0.2$ and hydrogen column densities N_H consistent with Galactic N_H values. There is no evidence for excess absorption due to intervening matter, in agreement with Bechtold et al.'s (1994) findings for radio quiet QSOs, who also found a similar spectral index. HE1104−1805 (z = 2.303), the recently discovered bright double QSO (Wisotzki et al., 1993) is particularly X-ray loud ($0.095\,\mathrm{cts\,s^{-1}}$) and radio quiet ($< 0.18\,mJy$ at 6 cm). Our observations support the view that the apparent excess absorption found in several radio-loud high redshift QSOs is intrinsic to the objects and distinguishes them from radio quiet QSOs and from most low-redshift AGN which have no intrinsic absorption.

Key words: X-rays: galaxies - quasars: general - quasars: individual: HE1104-1805, HS1700+6416

1. Introduction

The luminous QSO HS1700+6416 (z = 2.72, V = 16.1, Reimers, et al., 1992) is one of the few quasars observed at EUV restwavelengths. Its flux increases to shorter wavelengths as $f_\lambda \sim \lambda^{-1.25}$ to at least $\lambda_{\rm rest} = 310$ Å which cannot be explained by standard thin accretion disk models (cf. Störzer and Hauschildt, 1994). In order to extend our knowledge of the energy distribution of HS1700+6416, a deep pointed ROSAT observation was made in 1992, and HS1700+6416 was detected. To our surprise, the QSO appears "framed" by two X-ray clusters of galaxies close to and extending to the line of sight of HS1700+6416 (see Fig. 1). This to our knowledge unique case of an association of one of the most luminous QSOs known with two X-ray bright clusters led to the suspicion that the high luminosity of the QSO might be caused by cluster lensing. Bartelmann et al. (1994) have shown that there is a statistically significant correlation between high-redshift QSOs and foreground diffuse X-ray sources probably caused by magnification bias in the background source sample.

Subsequently we initiated a programme to search for further cases like HS1700+6416 by pointed ROSAT observations of a number of extremely luminous z > 2 QSOs, ($M_V < -30$) mostly from the Hamburg quasar surveys. In the end, 6 QSOs have been observed. The result was negative in so far as no further case of a QSO - X-ray cluster association has been found. However, all six QSOs observed have been detected as X-ray sources, and four of them are bright enough for a X-ray spectral analysis of ROSAT PSPC data. Since the sample of high-redshift QSO which are sufficiently X-ray bright for such an investigation is rather small (≤ 10 objects), we report here the results of the PSPC observations and compare our results with previous work.

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2. Observations

The pointed ROSAT (Trümper, 1983) observations were carried out in the "wobble" mode where the detector structure is smoothed out through moving the detector to and fro with a 400s period. All QSOs were detected with ROSAT, nevertheless for HS1425+6048 only less than 30 source photons could be gathered. For all objects we have got a good match between the X-ray position derived by the SASS (Voges, 1992) and the optical position. The objects were centered in the PSPC field to optimize the resolution and to minimize flux losses due to vignetting. However, in the case of HE1104−1805 an accident in the sending of the position placed the object 45' off center degrading significantly the spatial resolution of the QSO's X-ray image. Therefore for this object we cannot totally rule out the possibility that an unknown neighbouring X-ray source gives a contribution to the X-ray flux.

HS1700+6416 was observed twice. For each observation less than 300 counts were gathered. Because the two

Table 1. Observational parameters for the presented 6 QSOs

Name	R. A. (2000.0)	Declination	Dev.[1)] *arcsec*	z	V	M_V[2)]	Date	Reference
Q1101−264	11 03 25.9	−26 45 12	10	2.148	16.1	−30.5	1993 Dec 3	Osmer & Smith, 1977
HE1104−1805	11 06 33.1	−18 21 34	12	2.303	15.9[3)]	−30.6	1993 Jun 15-16	Wisotzki et al., 1993
HE1122−1649	11 24 42.8	−17 05 17	10	2.400	16.5	−30.1	1993 Jun 19	Reimers et al., 1994
HS1425+6039	14 26 56.4	+60 25 48	4	3.16	16.4[4)]	−31.2	1993 Nov 1-3	Stepanian et al. (1991)
Q1442+2931	14 44 53.3	+29 19 04	2	2.67	16.2	−30.9	1993 Jul 23-24	Sanduleak & Pesch, 1989
HS1700+6416	17 01 00.4	+64 12 09	4	2.72	16.1	−31.1	1992 Nov 13-14 1993 Jul 21-22	Reimers et al., 1988

1) Dev. is the deviation between the optical and ROSAT position
2) According to Véron-Cetty and Véron (1993)
3) Components A+B
4) From R = 16.1, with the assumption $V - R = 0.3$; V itself is not a measure of the continuum brightness due to the strong Ly-α. B = 16.98 from CCD photometry.

Table 2. Results from the ROSAT observations for the presented 6 QSOs

Name	Exposure [s]	$N_{H Gal}$ [10^{20}cm^{-2}]	Counts	Rate [s^{-1}]	$N_{H fit}$ [10^{20} cm^{-2}]	α_P	f_X [10^{-13} ergs cm^{-2} s^{-1}]
Q1101−264	5117	5.68	198	0.039	6.8 ± 4.4	2.23 ± 0.34	12.3 ± 10.8
HE1104−1805	13497	4.61	1282	0.095	5.2 ± 1.7	2.24 ± 0.16	26.8 ± 12.0
HE1122−1649	4781	4.29	232	0.048	3.3 ± 2.3	2.29 ± 0.21	10.7 ± 9.1
HS1425+6039	4296	1.54	30	0.007			0.9
Q1442+2931	4553	1.33	71	0.016			1.9
HS1700+6416	43486	2.46	464	0.011	2.9 ± 1.3	2.26 ± 0.58	2.13 ± 1.0

observations gave only negligible differences in count rate and hardness ratio we merged the photon event tables of the two observations and the following analysis depends on the merged dataset.

The X-ray spectrum of each QSO was obtained with the aid of EXSAS Version January 1994 (Zimmermann et al., 1993). The source and background photons were extracted in a radius of 150" around the source position. For HS1700+6416 we had to shrink the extraction radius to 60" because of the two neighbouring clusters (see Fig. 1 and Reimers et al., 1994, in prep.). It is known that such a small extraction radius is not sufficient to gather all soft X-ray photons ($E_P < 0.4$keV), therefore our X-ray spectrum should be harder than the real spectrum. For the background we choosed an area in the neighbourhood of the objects with no apparent sources.

The background-subtracted source counts were corrected for telescope vignetting and dead-time. The source counts were rebinned giving a minimum of 25 counts per channel. Channels 5-8 were ignored because the XRT response is not well understood in these channels. With the exception of HE1104−1805 the pulse height spectra have only low statistics. Therefore testing complex models with more than three free parameters is not possible. In accordance to the results for low redshift QSO with higher statistics (Walter and Fink, 1993) the spectra were fitted with a power law plus low energy absorption if $\gtrsim 200$ net counts were gathered. The spectra are shown in Fig. 2. In order to investigate the allowed parameter space of the two fitted parameters (α_P and N_H) we show contour plots of the interesting parameters in Fig. 3.

For the remaining two QSOs (HS1425+6039 and Q1442+2931) the amount of net counts was not sufficient for such a fit. But the gathered photons show no hint for a strong absorption since the photons are distributed over the whole ROSAT energy range. The given flux in Tab. 2 is calculated from a fit with the Galactic N_H.

2.1. Individual notes and related observations

HE1104−1805 was discovered in the Hamburg/ESO (HE-) Survey as a bright double QSO separated by 3.0" with B magnitudes of 16.70 and 18.74 (Wisotzki et al., 1993). It is regarded as an gravitational lens and was therefore observed as Target of Opportunity with the ROSAT PSPC. To probe the lens hypothesis we obtained an 6cm

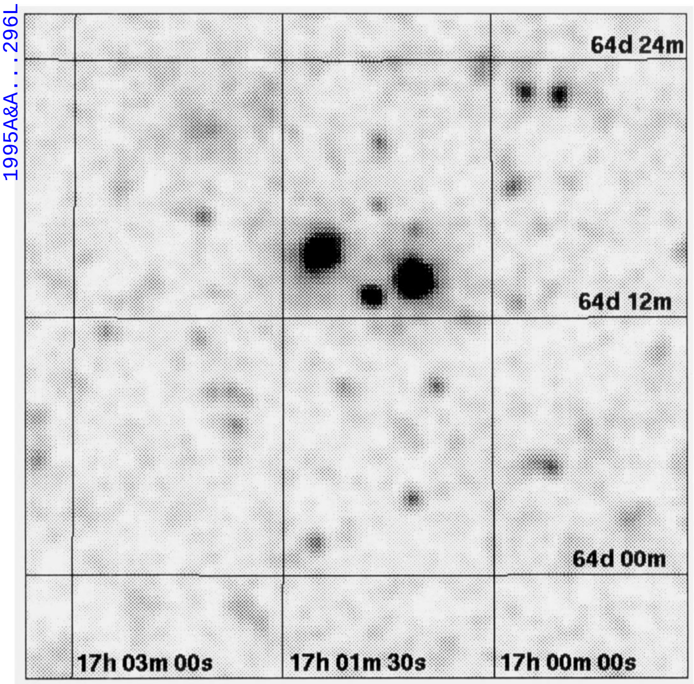

Fig. 1. Inner part of the PSPC image of HS1700+6416 in the hard ROSAT band (channel 51 – 201). The QSO is in the center of the image "framed" by two extended X-ray clusters.

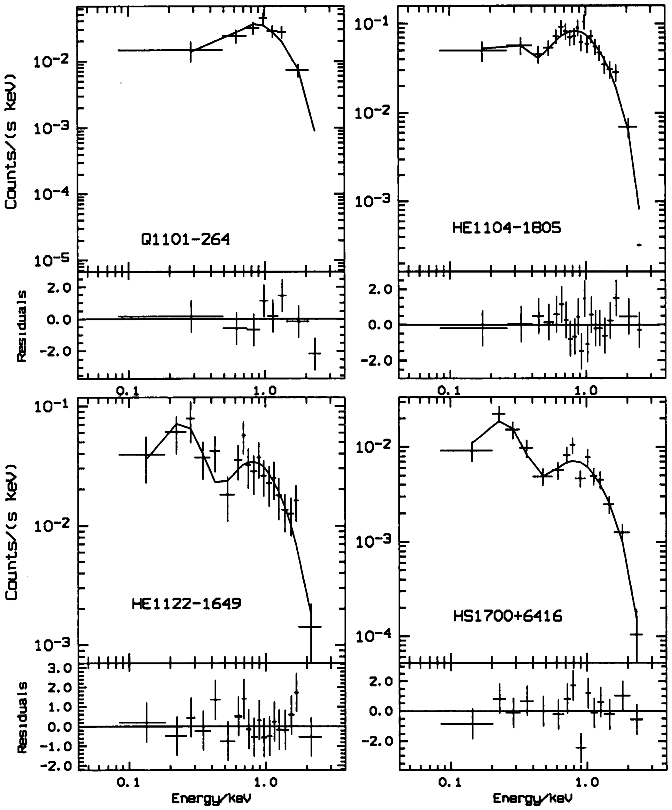

Fig. 2. ROSAT PSPC pulse height spectra for the four QSOs with $\gtrsim$ 200 counts. The upper panel shows the pulse height spectrum with power law plus low energy absorption model with the residuals of the fit in the lower panel.

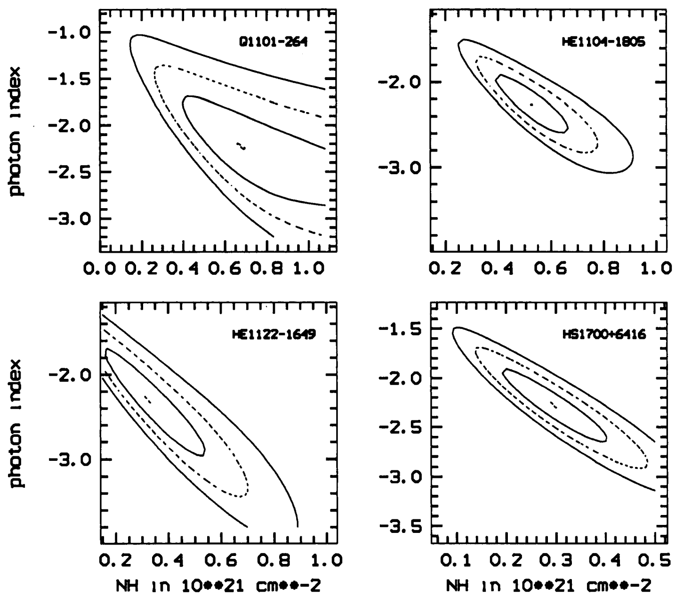

Fig. 3. Contours of the allowed values for the parameters α_P and N_H for the four X-ray brighter QSO. Contours are given for 68%, 95% and 99.7% confidence for the two parameters assuming absorption at z = 0.

radio image using the VLA in its C-configuration. The observation was made in 1993, August 16 with an integration time of 30 min. No signal above 180 $\mu Jy (3\sigma)$ was found. This result marks HE1104−1805 as an exceptionally radio weak QSO (RL < −0.72 according to the definition of Bechtold et al. (1994)). For comparison the two QSOs with z > 2 in the BQS (Schmidt and Green, 1983) were found as radio sources by Kellermann et al. (1989) with fluxes above 1 mJy at 6 cm. The brighter A component has a damped Ly-α absorption cloud at z = 1.66 (Wisotzki et al., 1993) with column densities of $\sim 6 \cdot 10^{20}$ cm^{-2} (Smette et al., 1994) which, however, redshifted in wavelength by a factor of 2.66, has to compete with the Galactic absorption of $4.6 \cdot 10^{20}$ cm^{-2} and is therefore probably not detectable with ROSAT.

HE1122−1649 This new QSO has been found in the course of the Hamburg-ESO survey for bright QSOs. It is extremely UV bright, but has a Lyman limit system at z = 0.685 which absorbs the QSO flux below 1770 Å (Reimers et al., 1994). This QSO is with 147 ± 13 mJy (Griffith et al., 1994) at 6 cm and RL = 2.29 moderately radioloud.

HS1700+6416 is an optical luminous QSO with a transparent line of sight in the UV. It was therefore used for extensive absorption line studies in the UV with HST (Reimers et al., 1992, Vogel and Reimers, 1994). An outstanding result of the PSPC observations of this QSO is the finding of two new extended X-ray sources in the vicinity of the QSO which can be classified as distant clusters of galaxies (Reimers et al., 1994, in prep.).

HS1425+6048 was found in the HQS as an exceptionally luminous QSO. Its optical spectrum contains a damped Ly-α line and a corresponding Lyman cutoff at $\sim$ 3500Å. Photometry over 6 consecutive nights in January 1993 shows small amplitude variations on a timescale of days (Hopp & Kuhn, private communication). Its radio properties are unknown. It has been found independently by the SBS (Stepanian et al., 1991). The correct redshift is z = 3.16. This new QSO is somewhat less luminous than HS1946+7658 (Hagen et al., 1992).

3. Results and discussion

Spectra of the four X-ray brightest QSOs are shown in Fig. 2, together with power law spectral fits with low energy absorption where both α_P and N_H are free to vary. Contours of allowed values of α_P and N_H are displayed in Fig. 3. The comparison with Galactic N_H-values (Stark et al., 1992) shows that within the errors, X-ray spectra give the same galactic absorption column densities as radio measurements. There is no apparent need for additional absorption, provided that the intrinsic X-ray spectra of luminous QSOs can be approximated by a power law. The derived spectral indices for the four QSOs have a remarkably narrow range, namely $\alpha_P = 2.2 \pm 0.2$ which is in perfect agreement with what Bechtold et al. (1994) had found independently.

We also confirm the absence of apparent excess absorption in radio quiet QSOs (Bechtold et al., 1994), and HE1122−1649 confirms that excess absorption is not a general property of radio-loud QSOs. The origin of the apparent excess absorption in some radio loud QSOs is unknown. Probably it is intrinsic to some both radio- and X-ray loud QSOs. Recent ASCA observations (Serlemitsos et al., 1994) with higher energy resolution of the two apparently absorbed radio-loud z = 3 QSOs from the Elvis et al. (1994) sample show that the interpretation in terms of excess absorption is by no means unambiguous: While in one case absorption in intervening matter at low redshift appears to give the statistically best description, alternative explanations invoking intrinsic complex - non power law - spectra are also possible.

With HS1425+6039 we have found a further probably radio quiet $z > 3$ QSO with an X-ray brightness comparable to that of HS1946+7658 which is unabsorbed (Bechtold et al., 1994). We also notice that HE1104−1805, the brightest known double QSO (Wisotzki et al., 1993) is one of the X-ray brightest radio quiet QSOs.

For two QSOs, HS1700+6416 (Reimers et al., 1992, Vogel and Reimers, 1994) and HE1122−1649 (Reimers et al., 1994) the energy distribution has been observed in the UV with HST and IUE to EUV restwavelengths of 330 and 450Å, respectively. These QSOs show that the spectrum turnover (a break by a factor $\sim$ 10) between the UV and soft X-rays must occur somewhere in the unobservable EUV beyond 3 Rydbergs. This turnover is also observed in Seyfert 1 galaxies (Walter and Fink, 1993). Remarkably, the same basic features of AGN spectral energy distributions are observed over at least a factor of 10^3 in AGN luminosities.

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